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

U.S. DEPARTMENT OF TRANSPORTATION

RESEARCH, DEVELOPMENT, AND TECHNOLOGY STRATEGIC PLAN

FY 2017–2021

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Executive Summary

This U.S. Department of Transportation (U.S. DOT/Department) Research, Development, and Technology (RD&T) Strategic Plan presents U.S. DOT's research priorities for the next five years (Fiscal Years (FY) 2017–2021) and describes the activities taken by the Department to address those priorities. In doing so, the document provides a five-year action plan that responds to the trends affecting the current and future performance of the Nation's transportation system, as identified in U.S. DOT's *Beyond Traffic*–Trends and Choices 2045 document. The RD&T Strategic Plan meets the statutory requirements of the Fixing America's Surface Transportation (FAST) Act (Pub. L. 114-94), which requires the Secretary of Transportation to develop a five-year strategic plan to guide future Federal transportation research and development activities.

The Office of the Assistant Secretary for Research and Technology (OST-R) led the preparation of this RD&T Strategic Plan, relying heavily on input from the Department's Operating Administrations. The Strategic Plan also includes feedback from external stakeholders through a period of public comment in the spring of 2016 and a two-day workshop with transportation experts representing the various sectors and disciplines in the transportation research enterprise. Input from all of these sources has been incorporated into the development of this strategic plan.

U.S. DOT has defined four critical transportation topic areas that will be supported by U.S. DOT RD&T over the next five years:

Promoting Safety relates to safety issues affecting all modes and the development and deployment of countermeasures designed to address these issues. U.S. DOT's goal is to improve public health and safety by reducing transportation-related fatalities and injuries.

Improving Mobility refers to demographic, economic, geographic, cultural, and technological trends affecting travel demand, personal and commercial mobility across all transportation modes, and the effects of those trends on quality of life and access to economic and educational opportunities. U.S. DOT's goal is to improve the mobility of people and goods, reduce congestion, and increase access to opportunities for all.

Improving Infrastructure covers issues relating to the condition, costs, funding, and delivery of the transportation infrastructure, as well as the methods and technologies to increase its durability and resilience. U.S. DOT's goal is to improve the durability and extend the life of the transportation infrastructure, preserve the existing transportation system, and ensure that the U.S. proactively maintains the critical transportation infrastructure in a state of good repair.

Preserving the Environment covers the effects of transportation activities on climate change and the environment as a whole (including water, noise, and air pollution, and habitat degradation) and discusses approaches to avoid or mitigate those effects. U.S. DOT's goal is to advance environmentally sustainable policies and investments that reduce carbon and other harmful emissions from transportation sources.

This Strategic Plan describes the current and planned Research and Development (R&D) strategies used by the U.S. DOT Operating Administrations to address the research needs within each critical transportation topic area. Cross-modal research areas and collaborative initiatives are also highlighted.

The Strategic Plan also describes four overarching research themes, identified during the stakeholder engagement process, that cut across all of the critical transportation topic areas. These are Policy Research, Emerging Technology, Strengthening Research Coordination, and Big Data.

The Strategic Plan strongly emphasizes U.S. DOT efforts to promote the deployment and adoption of research results by integrating technology transfer throughout the Research and Development process. It describes how the Department's Technology Transfer Program and each Operating Administration's Technology Deployment strategies address the FAST Act requirement to specify how research findings will be used to improve the efficiency, effectiveness, and safety of transportation systems.

Implementation of the Strategic Plan will take place on two levels. First, there are a range of FAST Act requirements that dictate how the Strategic Plan will be used to guide and report the Department's RD&T activities over the next five years, including the submission of Annual Modal Research Plans by each Operating Administration for review by OST-R. Second, each Operating Administration is responsible for tracking and evaluating the performance of their RD&T strategies. These processes are described in the final chapter of this Strategic Plan.

As mandated in the FAST Act, the Strategic Plan also includes program-level information about expected Department research findings by the end of FY 2021, and the annual funding levels anticipated by each Operating Administration during the period covered by the Strategic Plan FY 2017–2021. This information is provided in Appendices A and B.

1 Introduction

1.1. Plan Purpose

This U.S. Department of Transportation (U.S. DOT/ Department) Research, Development, and Technology (RD&T) Strategic Plan presents U.S. DOT's transportation research priorities for the next five years (FY 2017–2021) and describes the activities to be undertaken by the Department to address these priorities. In doing so, the document provides a five-year action plan that responds to the trends affecting the current and future performance of our transportation system, as identified by *Beyond Traffic: Trends and Choices 2045 (Beyond Traffic)*; a 30-year outlook on the future of our Nation's transportation system. The Strategic Plan establishes a framework to guide the development of Annual Modal Research Plans by each Operating Administration[1] and describes the processes used for planning, reporting, conducting, and evaluating RD&T across the Department.

Section 6019 of the Fixing America's Surface Transportation (FAST) Act (Pub. L. 114-94) specifies that Federal transportation research planning should be coordinated by the Office of the Secretary and be multimodal in scope. The FAST Act also states that coordinating such a multimodal research portfolio within the Office of the Secretary should help identify opportunities in which research could be applied across modes and prevent duplication of efforts and waste of limited Federal resources. It requires the Department to increase the transparency of its research and development (R&D) efforts to build stakeholder confidence and improve research product implementation.

The RD&T Strategic Plan meets the statutory requirements of the FAST Act, which requires the Secretary of Transportation to develop a five-year strategic plan to guide future Federal transportation research and development activities.* It presents the Department's approach to addressing the six primary purposes of its transportation research and development program, which are defined in the FAST Act as follows:

- Improving mobility of people and goods;
- Reducing congestion;
- Promoting safety;
- Improving the durability and extending the life of transportation infrastructure;
- Preserving the environment; and
- Preserving the existing transportation system.

* Although the scope of the FAST Act is limited to research and development activities, the Department has historically included a "Technology" component in its reporting and budgeting. The Technology component represents the Departmental resources and activities allocated to the deployment of research and development outputs. The Department considers this to be an important part of its role, ensuring that research results are fully leveraged in the transportation system. Thus, this plan provides a section on "Technology Deployment" in addition to a section on Research and Development Strategies.

Visualizing connected vehicles utilizing intelligent transportation systems

1.2. Plan Organization

U.S. DOT has defined four critical transportation topic areas to be used as a framework for describing how its RD&T priorities and activities over the next five years will address the FAST Act primary purposes and *Beyond Traffic* trends. These critical transportation topic areas are defined as follows:

Promoting Safety relates to safety issues affecting all modes and the development and deployment of countermeasures designed to address these issues. U.S. DOT's goal is to improve public health and safety by reducing transportation-related fatalities and injuries.

Improving Mobility refers to demographic, economic, geographic, cultural, and technological trends affecting travel demand, personal and commercial mobility across all transportation modes, and the effects of those trends on quality of life and access to economic and educational opportunities. U.S. DOT's goal is to improve the mobility of people and goods, reduce congestion, and increase access to opportunities for all.

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Table 1 shows the alignment of these critical transportation topic areas to the primary purposes listed in the FAST Act.

Table 1. Crosswalk of FAST Act's Primary Purposes and Critical Transportation Topic Areas

	Critical Transportation Topic Areas			
FAST Act's Primary Purposes	Promoting Safety	Improving Mobility	Improving Infrastructure	Preserving the Environment
Improving mobility of people and goods		X		
Reducing congestion		X		
Promoting safety	X			
Improving infrastructure durability			X	
Preserving the environment				X
Preserving the transportation system			X	

The core purpose of this Strategic Plan is to describe how the R&D strategies used by the Department's Operating Administrations address the research needs within each of the four critical transportation topic areas. The remaining sections of the plan are summarized below:

- **Section 2** describes four overarching themes that cut across all the critical transportation topic areas; these must be considered if the long-term challenges identified in *Beyond Traffic* are to be addressed.
- **Section 3** provides an overview of each Operating Administration's approach to RD&T, including research missions, program structure and administration, and key stakeholder partnerships.
- **Section 4** describes the research needs within each critical transportation topic area, and the Research and Development strategies and activities to be used by each Operating Administration to address these needs.
- **Section 5** describes the Technology Deployment strategies that each Operating Administration will use to move the outputs of U.S. DOT R&D activities towards adoption by the transportation system.
- **Section 6** explains how this RD&T Strategic Plan will be implemented over the next five years, through subsequent Annual Modal Research Plan submissions and other FAST Act requirements, and how the Department's Operating Administrations intend to evaluate the performance of their RD&T strategies.
- **Appendix A** lists the primary RD&T activities (programs) that the Department intends to pursue and the research findings that the Department expects to discover within each program by the end of FY2021.
- **Appendix B** lists the annual funding levels anticipated by each Operating Administration for the period covered by the Strategic Plan (FY2017–21).

The Office of the Assistant Secretary for Research and Technology (OST-R), reporting to the Office of the Secretary, is primarily responsible for preparing this RD&T Strategic Plan, with input from all of the Department's Operating Administrations. The Plan also reflects input from internal and external stakeholders as part of the Department's outreach. This included a two-day workshop with transportation research experts from across the transportation enterprise. The Department also published a Request For Information in the Federal Register, soliciting comments from the public on U.S. DOT's RD&T priorities. OST-R also reviewed transportation research strategic planning documents from the Department's Operating Administrations and national stakeholder groups, such as the Transportation Research Board (TRB). OST-R has considered information and comments from all of these sources in developing this RD&T Strategic Plan.

Turner-Fairbank Highway Research Center (TFHRC) Highway Driving Simulator (HDS)

Overarching Themes

U.S. DOT identified four overarching themes based on stakeholder feedback when developing this Plan. These themes are present in all four critical transportation topic areas and are central to the success of the Department's R&D strategies.

Policy Research: Supporting the development of transportation policies and assessing the impacts of proposed and implemented policies.

Emerging Technology: Advancing the development and integration of new transportation technologies.

Strengthening Research Coordination: Strengthening research coordination across modes, jurisdictions, institutions, sectors, and international boundaries.

Big Data: Developing data systems to support data-driven technologies and decision making in real time.

The Boeing Fuel Cell Demonstrator powered by a hydrogen fuel cell

1.3. Strategic Context

Beyond Traffic: Trends and Choices 2045 reports on the current and future conditions of our transportation system. It identifies the long-term and emerging trends in passenger and freight travel and discusses the potential impacts of our transportation system of technological advances, climate change, and evolving governance institutions and funding sources. In identifying these trends, *Beyond Traffic* creates a framework for understanding the strategic context in which transportation policies and transportation research decisions are made. This framework defines six major trends:

- How We Move
- How We Move Things
- How We Move Better
- How We Adapt
- How We Grow Opportunity for All
- How We Align Decisions and Dollars

1.3.1. How We Move

The biggest drivers of transportation demand—our growing population and economy—will continue to increase demand for passenger travel and freight across nearly all modes. Over the next 30 years our population is expected to grow by nearly 70 million and our economy will nearly double. Population growth will likely be concentrated in sprawling metropolitan areas in the South and the West, fueling the growth of emerging "megaregions" that could absorb three quarters of our population. This growth is straining infrastructure across all transportation modes—roads, rails, aviation, ports, and pipelines. Inadequate investments to support such growth is resulting in increasing congestion, greater pollution, and a deteriorating infrastructure.

Demand for transportation is shifting in response to cultural and economic changes and technological advances. Cities are getting "smarter" and experiencing a resurgence, and Americans—young Americans especially—are increasingly likely to bike, walk, or take transit rather than drive to get where they are going. Overall, however, shifts to non-driving modes have had a relatively minor impact on overall travel patterns, for which auto use remains the dominant mode.

1.3.2. How We Move Things

Freight travel is growing and changing rapidly, straining our transportation system. Freight volumes are projected to increase by 45 percent over the next 30 years across all modes. The globalization of the economy means that ensuring capacity at our ports and the infrastructure connecting them with the rest of the Nation is critical. The spread of real-time tracking of vehicles, containers, and rail cars has permitted logistics companies to steadily improve the productivity and performance of their fleets. Americans are increasingly shopping online, increasing the importance of package delivery. Dramatic increases in domestic gas and oil production are causing tectonic shifts in fuel shipments as new production areas emerge, exports of oil and liquefied natural gas have begun, and flows of imported and competing fuels have diminished.

1.3.3. How We Adapt

Climate change is a rising threat. The challenges of adapting to growing and shifting transportation demand is compounded by an increasingly changing climate. Transportation accounts for 27 percent of our economy's greenhouse gas emissions. Reducing these emissions to mitigate climate change will require a long-term, multifaceted transformation of our transportation sector. Reducing transportation emissions will require improving the fuel efficiency of cars and trucks, supporting electric vehicle and low-carbon fuel research and infrastructure, and shifting demand away from congested roadways to more sustainable modes. We also need to recognize the potential impacts of climate change on travel and take steps to improve the resiliency of our transportation system. Many of our transportation facilities are vulnerable to damage caused by the severe storms, rising sea levels, drought, and extremes of temperature associated with climate change.

1.3.4. How We Move Better

Technological innovation in information technology, navigation systems, communications and mobile platforms, automated and connected vehicles, and clean energy hold the promise of making our future transportation system safer, more accessible and efficient, and more environmentally sustainable. Advances in data processing are enabling governments and private companies alike to improve transportation services and better target investments. Government is rewiring to become more supportive of these beneficial technologies, while ensuring that they are safe and secure.

1.3.5. How We Grow Opportunity

Our Nation faces a growing opportunity gap. The top 10 percent of income-earning families now earn as much as the remaining 90 percent combined. Adjusted for inflation, median incomes are virtually the same as they were 30 years ago. More than 46 million people live in poverty. There is growing recognition that transportation policy also has an important role to play in addressing rising economic inequality and segregation. There is no opportunity without transportation. Transportation connects Americans to the schools, jobs, and social services and networks that help them get ahead. Transportation policy and investments must empower Americans to connect to opportunity and to come together, not grow apart.

1.3.6. How We Align Decisions and Dollars

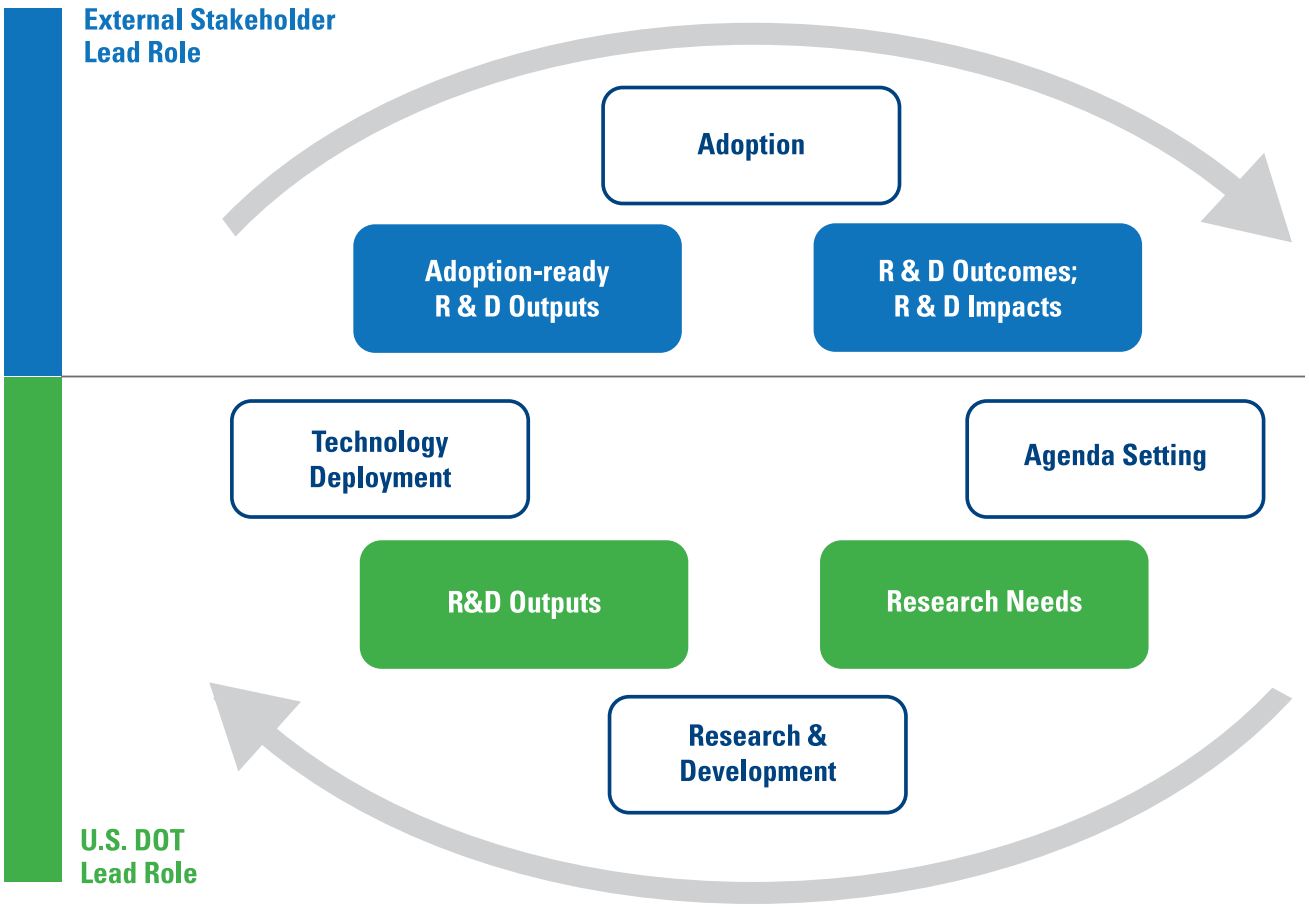
As the transportation system has grown and become more complex, transportation decision-making has become more difficult, transportation projects have become more costly, and revenue challenges have grown. Responsibilities for planning, financing, permitting, constructing, and operating infrastructure have become more and more fragmented and it has become increasingly difficult to reconcile local goals, while ensuring transportation investments are efficient at a regional level. Transportation investments have failed to keep pace with increasing needs and much of our infrastructure has fallen into disrepair. New policies are needed to generate sufficient revenues to meet the needs of our transportation system, prioritize funding to cost-effectively improve mobility, and incentivize efficiency and performance.

1.4. Defining Research, Development, and Technology

The RD&T deployment activities described in this Strategic Plan are components of a larger research lifecycle. This lifecycle, illustrated in Figure 1, represents the continual process of improving the transportation system through research and innovation. The process begins with setting a research agenda based on observed problems and issues in the transportation system, and then conducting R&D activities that address the identified research needs. R&D activities conclude with the production of new research products or technologies (R&D outputs), which are then moved through a Technology Deployment phase towards adoption into the transportation system. Any changes made to the transportation system, or the legislative and organizational frameworks that surround it, are defined as R&D outcomes. Once the R&D outputs have been adopted (and an adjustment period has elapsed), the effect of adoption on the transportation system can then be observed and evaluated (R&D impacts). Future research needs may then be considered. This process therefore represents an ongoing feedback loop that addresses problems and issues in the transportation system as they arise, incorporates new and emerging technologies, and continually optimizes the safety and efficiency of the system.

This Strategic Plan focuses on the U.S. DOT's Research and Development (R&D) strategies (described in Section 4) and the Department's Technology Deployment strategies (described in Section 5). These activities represent the two main areas where the Department takes a lead role, using its intramural and extramural research programs to develop the R&D outputs capable of addressing the research needs identified during the Agenda-Setting phase. Once it has been demonstrated that the R&D outputs are ready for adoption, the Department typically hands over the lead role to external stakeholders, such as State DOTs

Figure 1. Research Lifecycle



or municipal transit authorities, to lead the adoption process. However, the Department often plays a significant role in promoting the adoption of beneficial transportation technologies. In fact, the process of engaging adopters and other stakeholders throughout the research lifecycle is the central objective of the U.S. DOT's Technology Transfer (T2) program, described in more detail in Section 5 of this Plan. The Department uses its Research Hub database to track the research lifecycle. This database provides a project-level account of the Department's research portfolio and includes summary descriptions of the R&D outputs, outcomes, and impacts resulting from individual research projects.

Table 2. Research Lifecycle Terminology

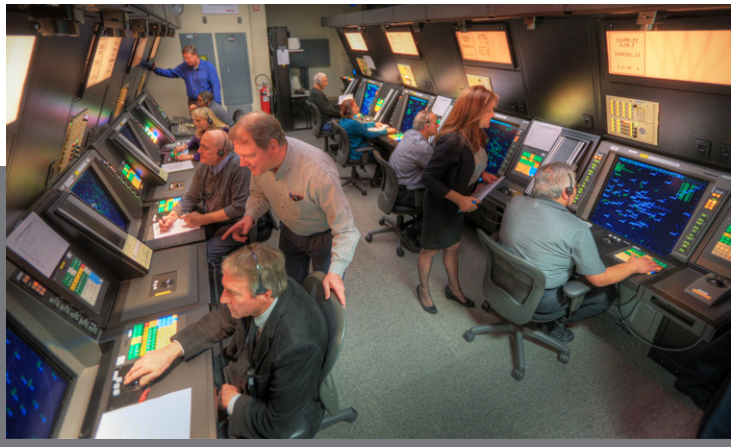
Term*	Definition
Agenda Setting	The act of evaluating the current and future state of the transportation system (including the impact of intentional changes to the system or to wider societal trends), identifying issues and problems that need to be addressed, and developing a research agenda based on clearly defined research needs.
Research Need	A detailed account of a problem or issue that requires R&D activities to be resolved.
Research and Development (R&D)	Research and Development (R&D) activities comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications (OMB Circular A-11).
R&D Output	Any new or improved process, practice, technology, software, training aid, or other tangible product resulting from R&D activities.
Technology Transfer**	Activities conducted to facilitate the adoption of R&D outputs. The Technology Transfer (T2) process runs in parallel with Agenda Setting and Research and Development activities. See Section 5.1 for more details.
Technology Deployment	Activities that demonstrate, pilot, or evaluate an R&D output, and/or facilitate the transfer of an R&D output to an adoption-ready state. Technology deployment is the final phase of the T2 process.
Adoption-Ready R&D Outputs	R&D outputs that are ready for full-scale operational use in the transportation system.
Adoption	The act of putting an adoption-ready R&D output into operational use in the transportation system.
R&D Outcome	Any changes made to the transportation system, or its regulatory, legislative, or policy framework, resulting from R&D outputs. Examples include the full-scale adoption of a new technology technique, or practice, or the passing of a new policy, regulation, rulemaking, or legislation.
R&D Impact	The impact of an R&D outcome on the transportation system, or society in general, such as reduced fatalities, decreased capital or operating costs, community impacts, or environmental benefits.

* The terms and definitions provided are intended for illustrative purposes only. Individual Operating Administrations may have terms and definitions that differ slightly from those provided here.

** This term is not specifically referenced in Figure 1, but is closely related to the other defined terms.

Aerial view of two new container vessels under construction

2 Overarching Themes



How do we get beyond traffic?

Essentially, three strategies need to be employed—all of which demand increased funding and new, more adaptive policymaking at the Federal, State and local levels. First, we have to take better care of our legacy transportation systems. We cannot cross bridges that have fallen apart or connect commerce to ports in disrepair. Second, we must build what is new and necessary, taking into account changes in living patterns and where products will move to and from. Third, we must use technologies and better design approaches that will allow us to maximize the use of our old and new transportation assets.

– Secretary Anthony R. Foxx, Beyond Traffic

Overview

Four overarching themes present in all four critical transportation topic areas were identified through the stakeholder outreach activities associated with the development of this Plan. They are:

- **Policy Research:** Supporting the development of transportation policies and assessing the impacts of proposed and implemented policies;
- **Emerging Technology:** Advancing the development and integration of new transportation technologies;
- **Strengthening Research Coordination:** Strengthening research coordination across modes, jurisdictions, institutions, sectors, and international boundaries; and
- **Big Data:** Developing data systems to support data-driven technologies and decision making in real time.

2.1. Policy Research

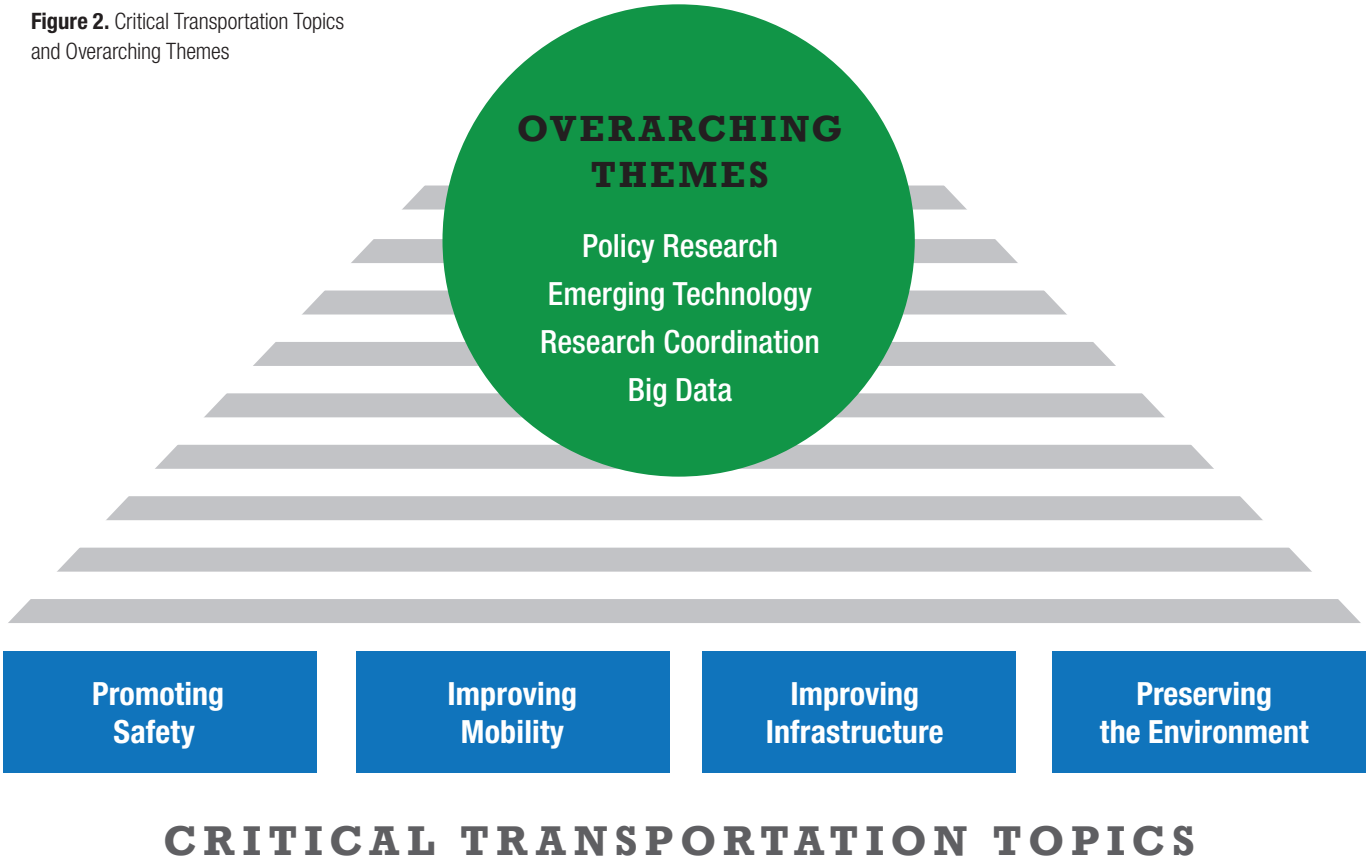
Policy research supports the development of transportation policies and assesses the impacts of proposed and implemented policies. Policy research provides the foundation for the development of new policies and legislative actions, assists decision makers in the evaluation and selection of policy options, and facilitates subsequent policy implementation.

By assessing the benefits and costs of proposed regulations and evaluating the performance of Federal programs, policy research helps policymakers determine the most cost-effective uses of Federal tax dollars. In today's fiscally constrained environment, U.S. DOT uses policy research to forecast revenues, analyze tax options, and identify more cost-effective approaches to achieving transportation policy objectives. Policy research is also critical for understanding the connection of investments in Federal programs to job creation and economic growth and competitiveness.

As priorities and technologies evolve, transportation policy research can help to ensure that Federal policies remain effective and address emerging challenges. For example, policy research is helping officials better understand the role transportation policy can play in addressing transportation equity and improving economic mobility. Research is also helping decision makers identify policy options that can leverage ride sourcing, bike sharing, and automated vehicles and other emerging technologies and business models to improve access to transportation assets and services for low-income households and people with disabilities.

Many issues that affect the daily lives of individuals cut across modes, disciplines, and jurisdictions and require coordinated, interdisciplinary policy research. By identifying policies that support the integration of land use issues into transportation planning and economic development practices, policy research is showing how planners and policymakers can foster the development of healthy, sustainable communities

Figure 2. Critical Transportation Topics and Overarching Themes



Wake turbulence created by commercial aircraft

and the preservation of natural and cultural resources. While emerging technologies promise to improve the efficiency of our transportation system, policy research is needed to ensure that agencies are positioned to take advantage of new technologies and put in place policies to mitigate the potential negative effects of new technologies. For example, as our Nation's population becomes increasingly urbanized and new technologies allow our world to become increasingly connected, policy research is helping local, regional, and Federal officials leverage technologies to improve access and mobility in cities. Smart cities policy research is identifying and promoting the deployment of policies, practices, and technologies to improve the sustainability, affordability, and overall performance of urban transportation systems. Similar policy research is exploring transportation strategies to enable more sustainable, affordable mobility and access for smaller and rural communities.

Federal Automated Vehicles Policy

On September 20, 2016, NHTSA announced a new Federal Automated Vehicles Policy to help facilitate the responsible introduction of automated vehicles to make transportation safer, more accessible, and more efficient. The primary focus of the policy is on highly automated vehicles (HAVs), or those in which the vehicle can take full control of the driving task in at least some circumstances. Components of the Policy include:

- Vehicle Performance Guidance for manufacturers, developers, and other organizations outlining a 15 point "Safety Assessment" for the safe design, development, testing, and deployment of highly automated vehicles.
- Model State Policy that clearly distinguishes Federal and State responsibilities and recommends policy areas for states to consider.
- Current Regulatory Tools that National Highway Traffic Safety Administration can use to aid the safe development of automated vehicles.
- New Regulatory Tools: This discussion identifies potential new regulatory tools and statutory authorities that may aid the safe and efficient deployment of new lifesaving technologies.

2.2. Emerging Technology

Transportation is evolving from a field focused on operational efficiency to one of the most innovative and rapidly changing areas of the economy. Emerging technology areas with the potential to significantly impact the transportation sector include unmanned aircraft systems, automated vehicles and other unmanned ground vehicles, the Internet of Things (IoT), and on-demand ride services. These, and other emerging technologies have the potential to advance the U.S. DOT's mission of providing safe, clean, accessible, and affordable transportation but they raise a number of new policy and technical issues. The Department is encouraging innovation using the following strategies, while ensuring that these emerging technologies are deployed safely and in a manner that provides opportunity to all citizens.

Bolster Fundamental Research Capabilities in the Department

Private sector innovators are invested heavily in many emerging transportation technology areas as they look to bring new systems to the market. To leverage these efforts for public benefit, the Department must proactively address regulatory demands while engaging with private and public partners to identify, research, and support areas that may not be sufficiently addressed by the private sector. As demonstrated by the rapid spread of unmanned aerial systems and the development of fully automated vehicles, the private sector can rapidly produce new regulatory demands. Without sufficient in-house expertise in these areas, it is unclear who can be trusted to provide unbiased technical advice to regulators and policymakers, and government response can lag the market's demand for clarity. Furthermore, policy becomes reactive to developments in the private sector instead of taking its place in guiding the development of future transportation. The U.S. DOT must ensure that it is in a position to rapidly respond to the regulatory challenges posed by emerging technologies so that the technologies are developed with safety in mind and that considerations such as affordability and accessibility for those with disabilities are considered in the development process. To respond to and guide the development of emerging technology requires that the Department bolster its research capabilities in these areas, particularly with regard to safety research and innovation, and maintain close connection to the larger research community.

Learn Quickly through Real-world Deployment of these Technologies

Demonstration or pilot projects provide a way to learn quickly about the performance and impacts of new technologies and enable alternatives to be tested in a safe environment before being opened up to broader use in the city, on the highway, or in the national airspace system. U.S. DOT has successfully demonstrated pilot deployment of Vehicle-to-Vehicle (V2V) communication technology on a city-wide scale. Such pilots create new laboratories for investigating opportunities and challenges across modes and across the full spectrum of issues from technical alternatives to policy choices.

Maintain and Improve Critical Infrastructure

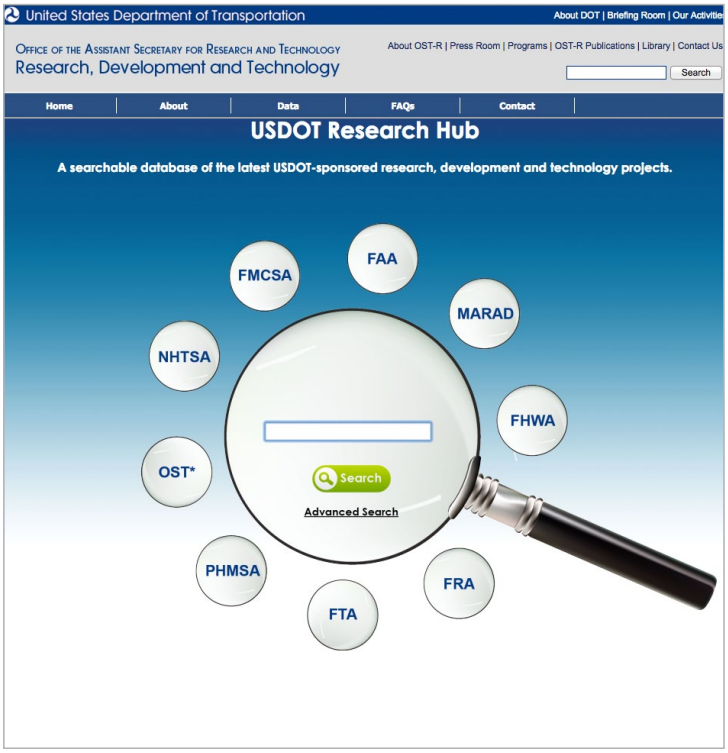
Emerging technologies will also place new demands on current infrastructure built, supported, or operated by the U.S. DOT. Automated vehicles operate on highways and bridges, drones must coexist in the National Airspace System, and a wide range of traveler services, V2V and V2I (Vehicle-to-Infrastructure) applications and on-demand mobility options require position and time information from the Global Positioning System. To support emerging technologies, physical infrastructure must be maintained; and the information and communication technology systems necessary to support them, such as GPS or DSRC; must be strengthened to ensure they are secure, robust, and resilient. Research that can identify and quantify the interaction between infrastructure and emerging technologies may greatly accelerate their deployment.

Share Experiences across Modes, Agencies, and Organizations

With all of these emerging technologies, research results must be developed quickly in order to be available to policymakers and other stakeholders when needed. This requires sharing information and experience across modes and stakeholders since many of these emerging technologies inherently cross modes. Mobility on demand concepts, for instance, blur the lines separating transit, motor carriers, and private ownership. These technologies often appear earlier in some modes giving the opportunity to learn from prior experience with sufficient communication and coordination. For example, automated highway vehicles raise issues of distraction and attention similar to those studied previously with pilots and aircraft automation. The lessons of automated ground vehicles and unmanned aircraft may, in turn, prove useful in examining the impact of automation on ships. Developing research results quickly also requires sharing data to make the best use of existing knowledge and experience across modes, Federal agencies, and outside stakeholders. Responding to the theme of emerging technologies also requires strengthening research coordination and leveraging Big Data.

2.3. Strengthening Research Coordination

Transportation research in the United States is highly fragmented, with multiple participants and layers, including several Federal agencies, numerous State and local transportation departments, metropolitan planning organizations (MPOs), local and regional transit agencies, and not-for-profit organizations, as well as a large and diverse private sector. Effective coordination with these entities, plus the vast array of overseas organizations, is essential to making the most efficient use of scarce research dollars, minimizing duplicative activities, and moving the country's transportation research forward in a cohesive fashion. Stakeholder feedback received during the development of this Plan indicated that the U.S. DOT, and the transportation research community in general, needs to strengthen research coordination across modes, jurisdictions, institutions, sectors, and international boundaries.



Screenshot of USDOT Research Hub

Enhancing Research Coordination within U.S. DOT

The FAST Act established a new vehicle for internal research coordination by requiring the submission of Annual Modal Research Plans (AMRP) by each modal administration and Joint Program Office for review and approval by the Office of the Secretary. The act of developing these plans by the modal administrations, which include details of coordination and collaboration with other U.S. DOT agencies and external stakeholders, and the subsequent review process conducted by OST-R, enhances the depth and coverage of existing Departmental coordination functions led by OST-R and provides additional safeguards against research duplication across the Department.

The FAST Act also requires a Consolidated Research Database that lists the research abstracts, activities, and outputs of U.S. DOT's research portfolio at the project level. The U.S. DOT intends to meet this requirement by building upon its Research Hub database and adding new content and functionality to provide the required comprehensive account of the Department's research. This "U.S. DOT Research Hub 2.0" will be used to identify opportunities for collaboration, conduct cross-modal research reviews, review budget allocations in different priority areas, and ensure that no duplication of activity occurs. The database will continue to be used to track the lifecycle of U.S. DOT research through to outputs, outcomes, and "real world" impacts, thus providing the ability to demonstrate and evaluate the value of the Department's research investment to the nation's transportation system.

Enhancing Research Coordination with Other Federal Agencies

Recognizing the fact that other Federal agencies outside U.S. DOT conduct transportation research, the Department will continue to identify and pursue opportunities to meet national research priorities through partnerships with other Federal agencies. For example, the research portfolios of U.S. DOT and U.S. Department of Energy (DOE) have become increasingly interrelated as transportation system and modal integration increases, prompting more formalized coordination. The two Departments signed a Memorandum of Understanding in 2016, and they are now developing a joint research action plan to cover topics like Smart Cities, connected and automated vehicles, and alternative fuels and electric vehicle research. Continuation of this and similar efforts can significantly leverage Federal investments and develop more robust, cross-cutting research findings.

RESEARCH COORDINATION — THE ROLE OF THE OFFICE OF THE SECRETARY FOR RESEARCH AND TECHNOLOGY (OST-R)

The Office of the Assistant Secretary for Research and Technology (OST-R) plays a lead role in research coordination within the Department. With a wide range of national and international stakeholders. OST-R focuses on three priority areas:

1. Coordinating Research Activities within the Department's Operating Administrations

Housed in the Office of the Secretary, OST-R is responsible for coordinating the RD&T activities of the Department's Operating Administrations. OST-R executes this task by:

- Collecting, synthesizing, and disseminating the information necessary for the Operating Administrations and the Department as a whole to make informed decisions on the allocation of research resources and management of research activities.
- Providing the organizational frameworks necessary for effective interaction between the Operating Administrations, including collaboration on cross-modal research topics.
- Promoting best practices for Departmental research management and technology transfer.

The primary vehicle to achieve this is the RD&T Planning Team, made up of the senior research directors from each of the Operating Administrations and chaired by the Director of OST-R's Office of RD&T. The Planning Team meets monthly to discuss and coordinate research activities underway around the Department. Operating Administration representatives provide regular updates on their agency's research activities to the group, facilitating research coordination and allowing potential opportunities for inter-agency collaboration to be identified.

As part of OST-R, the Volpe Center also plays a key role in facilitating research coordination and collaboration, partnering with the Department's Operating Administrations on a wide range of transportation research topics (see inset on next page for more information).

2. Aligning Departmental Research with other Secretarial Office Functions

OST-R's elevation to a Secretarial Office in 2014 facilitated a closer linkage between research and the Department's other Secretarial Office functions, such as policy development and budget development. OST-R's role is to represent Departmental research within the Office of the Secretary (OST) and act as the link between the Operating Administrations and the other Secretarial Offices. OST-R works with OST-Budget on research budget development, and works with OST-Policy and the staff of the Secretary and Deputy Secretary to ensure that the research portfolio is effectively aligned with the Department's Strategic Goals and Administration initiatives.

3. Engaging External Stakeholders

OST-R represents U.S. DOT research activities to governmental stakeholders like Congress, the White House, and other Federal agencies, and engages other transportation research stakeholders on behalf of the Department. This role includes coordinating external stakeholder requests that require a Department-level response, organizing and chairing briefings to members of Congressional Committees, formal reporting on Departmental research activities, and developing Departmental research policies in response to Executive Orders and legislative direction. This OST-R function supplements the extensive stakeholder engagement activities conducted by each of the Operating Administrations. Such activities allow the nation's transportation research enterprise to move forwards in a coherent fashion and optimizes the effective use of limited research resources.

Volpe: A cross-modal, cross-agency collaborator and a catalyst for transportation innovation

The Volpe Center works to maximize the linkages among U.S. DOT agencies and offices and the broader transportation community by maintaining a cross- and multimodal perspective in all work. Volpe is continuously seeking synergies among its projects and working to assure the transfer of best practices, lessons, findings, and technologies across U.S. DOT and beyond.

Global and Emerging Issues in Transportation

Volpe further supports U.S. DOT's strategic goals by anticipating future transportation issues, identifying transportation trends, and generating fresh approaches to emerging issues.

- Advancing Automation—driverless cars to unmanned aircraft systems
- Smart Cities/On-demand mobility
- Transportation System Resilience to natural and man-made disruption
- Future Freight and Logistics System
- Energy diversification and decentralization for transportation
- Transportation environmental impacts at a local level—including community health
- Evolving role of the human in the transportation system—including the future transportation workforce
- Financing and Public-Private Partnerships

U.S. DOT has also strengthened its ties with the Executive Office of the President (EOP) through peer exchanges and rotational assignments. For example, from October of 2014 through January of 2017, an OST-R staff member served the EOP component offices of the Office of Science and Technology Policy and the Council on Environmental Quality, and served as the transportation lead for the Detroit Federal Working Group to help lead the Administration's efforts in sustainable transportation and advanced mobility services. Not only has this assignment significantly enhanced the links between U.S. DOT, the White House, and other Federal agencies working in these research areas, it has also increased the visibility of the Department's contribution to climate change and alternative energy research.

Enhancing Research Coordination with National Stakeholders

To optimize the efficiency, relevance and deployment of transportation research, data and findings, U.S. DOT continuously seeks closer links with national stakeholder groups through innovative outreaches, including formal collaborations and partnerships. In 2017, the Department is planning to implement a newly-structured agreement with the Transportation Research Board, a unit of the National Academies of Sciences, Engineering, and Medicine, as enabled by the FAST Act . Such an agreement will enable a more strategic and agile working relationship between the long-standing partners, which will in turn provide greater opportunities for federal, state and local entities to align, coordinate and collaborate on transportation research initiatives of national and regional importance.

Infravation Program

The Infravation Program (Infravation means infrastructure plus innovation) is the first cooperative research initiative between FHWA and other national road administrations. It allows U.S. entities, such as academic institutions, state DOTs, and businesses, to participate in research, development, and technology deployment activities with entities from other countries. Infravation is an important complement to FHWA's national research agenda, and accelerates the consideration and development of innovations, especially in the areas of advanced systems, materials, and road infrastructure. Because FHWA is a funder, U.S. entities are eligible for research funding. Infravation program funding currently totals approximately $11 million for nine multi-year projects conducted by multinational research teams.

FHWA: The EU-US Research Project Twinning Initiative

FHWA and the European Commission have developed the concept of project "twinning," whereby two separately funded research projects with a similar scope, objectives, and timelines agree to work together for mutual benefit and efficient leveraging of resources. The concept has already been successfully applied on three separate FHWA research projects in the areas of urban freight, sustainable pavements, and warm-mix asphalt. This Twinning initiative has now been expanded to include all U.S. DOT agencies and a broader range of research areas, that includes ITS, road user safety, infrastructure resilience, and automation. The U.S. DOT foresees the twinning concept being widely applied over the next five years.

Enhancing International Research Coordination

The global nature of the challenges faced by the transportation systems across the world, and major advances achieved by countries outside the United States, make it increasingly important to achieve effective international research coordination. The U.S. DOT has already been successful in developing international partnerships with research programs in Europe, Asia, and elsewhere on topics such as intelligent transportation systems (ITS) and harmonization of Corporate Average Fuel Economy (CAFE) standards; as well as participating in international bodies, such as the Organization for Economic Cooperation and Development's Joint Transportation Research Centre of the International Transport Forum. In addition, the Department is pursuing new international research collaboration platforms, such as the Federal Highway Administration's Infravation Program and the EU-US Twinning Initiative, that offer new opportunities for improving the range and quality of future international research collaborations. The Department is committed to making international research initiatives a core component of its research portfolio over the next five years and beyond.

2.4. Big Data

As transportation and digital technologies increasingly converge, U.S. DOT must rethink how data produced and used by its research programs, including externally derived data, can be accessed by decision makers in real-time to help make accurate, informed decisions. To achieve this, it is critical that U.S. DOT conduct research into the technologies and techniques that can be applied to the big data[2] that will be generated in the future.

Bolster Research into Big Data Architectures and Management Techniques

It is important that the Department research how transportation agencies can leverage big data foundations, techniques, and technologies. An increasingly digital transportation system will be characterized by a highly distributed and heterogeneous data collection and sensor network. Research is also needed to develop techniques for managing these data streams as well as the computer system architectures for collecting, processing, analyzing, visualizing, and archiving these data. Furthermore, these architectures must facilitate the appropriate sharing of data, supporting the need to protect privacy, confidentiality, and operational security (e.g., for emergency and disaster response scenarios). The Department must leverage existing research into advanced privacy-protecting techniques and understand their application to big data from transportation.

The computer systems architectures that support big data are constantly evolving. Nevertheless, there are commonalities; including the application of cloud computing, the use of open source software, the application of dynamic access management, and the use of agile and iterative software development processes. U.S. DOT must research how transportation agencies can effectively implement these new computer systems architectures quickly and securely incorporate agile and iterative processes alongside traditional systems engineering management processes. Finally, the Department must continue its research into information management practices that should be applied to data captured and shared through big data systems, including governance and management of data analytics and algorithms.

What is Big Data?

Big data is a term for datasets that are so large or complex that traditional data processing applications are inadequate. Challenges include analysis, capture, data curation, search, sharing, storage, transfer, visualization, querying, and information privacy. The term often refers simply to the use of predictive analytics or certain other advanced methods to extract value from data; seldom to a particular size of dataset. Accuracy in big data may lead to more confident decision making in real time. Improved decisions can result in greater operational efficiency, cost reduction, and reduced risk.

Discover New Analytical Applications for Big Data

Big data presents significant opportunities as well as new challenges to analytics, especially as analysts begin mixing real-time streaming data with historical data. U.S. DOT must conduct research to ensure that big data analytics are conducted on trustworthy data generate valid, replicable, and reproducible results. The application of newer, innovative statistical approaches to big data generated from transportation and related sectors (e.g., energy, environment, health, law enforcement, and others) will be key to making the next breakthroughs in safety, access, operations, maintenance, and preservation as well as help inform policy choices and transportation investments.

Research into a wide range of potential analytical applications across transportation agency functions is also required. Coordinating research across planning, management, and operations disciplines will be key. Research into new analytical workflows that are enabled by bringing analytics to data, rather than running multiple copies and extracts of the same data set across transportation agencies, is important. In addition, research is needed into understanding how unstructured big data may be fused with surveys and other statistical data from transportation agencies to more accurately and quickly measure performance and management of the system.

Invest Strategically in Data Preservation and Use

One key to enabling the research, development, and deployment of big data tools and techniques in transportation is promoting the sharing and management of data. Strategic investment in the development of big data projects – including demonstration projects – can facilitate discovery, project evaluation, and secondary analysis, both within and beyond the transportation sector. Consistent with the Federal Open Data Policy[3] and the Department's Public Access Plan,[4] research investments should use best practices for applying metadata to facilitate discovery, use, and preservation of data. The Department may also consider strategic investments in archives and cloud-based architectures that facilitate efficient and secure access to big data.

Examples of current investments in long-term data research data sharing include the Long Term Pavement Performance Program, the Intelligent Transportation Systems Research Data Exchange and the Transportation Secure Data Center at the National Renewable Energy Laboratory. Each of these data archives contain large data sets that can be used to advance knowledge in their primary research fields, but they may also be rich data sets that can be used for secondary research purposes. The U.S. DOT will continue to expand data management across its entire research portfolio. In partnership with its internal and extramural researchers, the Department will invest in new research data preservation and sharing infrastructure as appropriate, and will also consider ways to advance secondary research activities on existing research data archives.

SHRP2 Naturalistic Driving Study

Under SHRP2, $70 million were devoted to produce a one-of-a-kind dataset that will be of value to highway practitioners and researchers from many fields in addition to safety. These one-of-a-kind data are referred to as the SHRP2 NDS Database and the SHRP2 Roadway Information Database (RID). The SHRP2 NDS data provides information on driver behavior, individual trip characteristics, events (crashes and near-crashes), non-events ('normal' driving), and vehicle characteristics. In total, 3500 volunteer-participants in 6 US locations (FL, IN, NC, NY, PA, WA) had their own vehicles outfitted with cameras, radar, GPS, and other sensors that collected data continuously. Data collection lasted 1–2 years resulting in a total of 5.4 million trips covering 30 million miles and a million hours of video and sensor data. The SHRP2 RID is a geospatial database that provides context for the SHRP2 NDS. Ultimately these data will provide decision makers with better information that will result in a more efficient, reliable, and inherently safer experience for road users.

RABIT™ bridge deck assessment tool inspecting road surface

3 U.S. DOT Research Programs

Overview

The U.S. DOT is the principal entity within the Federal Government tasked with supporting the Nation's transportation system. The Department performs research in support of its mission, which is to ensure "a fast, safe, efficient, accessible, and convenient transportation system that meets our vital national interests and enhances the quality of life of the American people, today and into the future."

The vast majority of U.S. DOT's research activities are conducted by the Department's Operating Administrations and Intelligent Transportation Systems Joint Program Office. Each agency has its own mission, statutory requirements, and funding sources through a range of Congressional committees. Individual Operating Administration research goals are therefore closely linked to the specific mission of the agency. Table 3 lists the mission statement for each of the Operating Administrations.

Table 3. U.S. DOT Operating Administrations' Mission Statements

U.S. DOT Operating Administration	Mission Statement
Federal Aviation Administration	To provide the safest, most efficient aerospace system in the world
Federal Highway Administration	To improve mobility on our Nation's highways through national leadership, innovation, and program delivery
Federal Motor Carrier Safety Administration	To reduce crashes, injuries and fatalities involving large trucks and buses
National Highway Traffic Safety Administration	To save lives, prevent injuries, and reduce economic costs due to road traffic crashes, through education, research, safety standards, and enforcement activity
Federal Transit Administration	To improve public transportation for America's communities
Federal Railroad Administration	To enable the safe, reliable, and efficient movement of people and goods by rail for a strong America, now and in the future
Pipeline and Hazardous Materials Safety Administration	To protect people and the environment by advancing the safe transportation of energy and other hazardous materials that are essential to our daily lives
Maritime Administration	To foster and promote the U.S. Merchant Marine and the American maritime industry to strengthen the maritime transportation system – including landside infrastructure, the shipbuilding and repair industry, and labor – to meet the economic and national security needs of our nation
Intelligent Transportation Systems – Joint Program Office	To conduct research, development, and capacity-building activities to facilitate the adoption of information and communication technology to enable society to move more safely and efficiently

Left-to-right: conceptual rendering of an automated vehicle dashboard; engineer conducting a jet engine test; FRA inspectors review a train's brake system

Table 4 illustrates the fact that the U.S. DOT's primary focus is maintaining and improving the safety of the transportation system. Several Operating Administrations focus on this critical topic area; other Operating Administrations, including FAA, FHWA, and FTA, and the ITS Joint Program Office, have a broader range of strategic goals, and therefore conduct research in multiple critical topic areas.

Table 4. Critical Transportation Topic Areas Addressed by each Operating Administration's R&D Strategies

	Promoting Safety	Improving Mobility	Improving Infrastructure	Preserving the Environment
Federal Aviation Administration	X	X	X	X
Federal Highway Administration	X	X	X	X
Federal Motor Carrier Safety Administration	X			
National Highway Traffic Safety Administration	X			
Federal Transit Administration	X	X	X	X
Federal Railroad Administration	X			
Pipeline and Hazardous Materials Safety Administration	X		X	X
Maritime Administration	X	X	X	X
Intelligent Transportation Systems – Joint Program Office	X	X	X	X

Table 5. RD&T Funding, FY 2015 – FY 2016

	FY 2015 Actual ($000)	FY 2016 Enacted ($000)	Annual Appropriation	Multi-Year Authorization	Combination
Federal Aviation Administration	256,558	392,943			X
Federal Highway Administration*	522,998	583,442		X	
Federal Motor Carrier Safety Administration	12,317	11,685		X	
National Highway Traffic Safety Administration	120,607	146,744			X
Federal Transit Administration	34,500	28,000			X
Federal Railroad Administration	39,776	40,127	X		
Pipeline and Hazardous Materials Safety Administration	21,219	21,479		X	
MARAD**	3,000	3,000			X
Total***	**1,010,975**	**1,227,420**			

* Includes ITS JPO funding of $100 million

** Maritime Environmental and Technical Assistance (META) funding is a line item within MARAD's Operations and Training budget and is provided pursuant to 46 USC 50307. Most, but not all, META funding is typically used for RD&T projects.

*** Funding for "R&D Facilities" is not included in this table in order to maintain consistency with subsequent Annual Modal Research Plan (AMRP) submissions and other formal R&D reporting requirements mandated by the FAST Act.

Total Departmental RD&T funding levels of around, or just over, $1 billion per annum have remained consistent over the last 10–15 years. Anticipated RD&T funding levels for the next five years are required by the FAST Act and are listed in Appendix B at the end of this Strategic Plan.

The following subsections describe RD&T programs for each Operating Administration, including research missions, program structure and administration, and key stakeholder partnerships.

3.1. Federal Highway Administration

The primary goal of FHWA's R&D programs is to sustain a research agenda for Federal policymakers and highway stakeholders that focuses on critical knowledge gaps, collaboration methods, and accelerated innovation to meet current and future highway transportation needs. The objective is to generate new solutions, provide better decision-making information and tools, and build more effective partnerships that will allow our Nation to make optimal investments in the transportation system. FHWA's R&D programs cover the entire innovation lifecycle; including agenda setting, research and development, technology testing and evaluation, and the deployment and evaluation of market-ready technologies and innovations. FHWA's R&D programs address six national highway challenges:

- Advancing highway safety
- Improving the mobility of people and goods
- Maintaining infrastructure integrity
- Enhancing system performance
- Promoting environmental sustainability
- Preparing for the future

FHWA looks at current issues and emerging challenges and provides information for policy decisions. Under the umbrella of its Highway Research and Development (HRD) program and Technology and Innovation Deployment Program (TIDP) FHWA conducts advanced and applied research, facilitates national and international coordination and collaboration, and develops and delivers solutions to address highway transportation needs. Within the U.S. highway community, FHWA is in a unique leadership position to identify and address highway issues that require high-risk, long-term research, and to sponsor research on emerging issues of national significance. FHWA builds effective partnerships to maximize the impacts of the Federal Government's total investment in highway-related research and technology.

Funding for R&D programs is authorized on a multiyear basis by annual appropriations. The Office of Research, Development, and Technology (RD&T) is located at the Turner-Fairbank Highway Research Center (TFHRC), a Federally-owned and operated national research facility in McLean, Virginia. Comprised of more than 20 laboratories and support facilities, the TFHRC administers the vast majority of FHWA's research and development activities in the areas of infrastructure, operations, and safety. FHWA offices located at U.S. DOT headquarters conduct or administer research into ITS, policy, innovative program delivery, planning, operations, and the environment. Appendix A and Appendix B list all of FHWA's R&D programs and funding levels.

Research product deployment is headed by the subject-area program offices at U.S. DOT headquarters, and through the headquarters-based Center for Accelerating Innovation, in cooperation with Technical Service Teams based in the FHWA Resource Center.

The FHWA's R&D programs are coordinated with R&D conducted through the University Transportation Center (UTC) research program (administered by OST-R), the Transportation Research Board's National Cooperative Highway Research Program (NCHRP), and State-based R&D initiatives. In addition, FHWA develops joint strategies to address U.S. DOT goals with other U.S. DOT Operating Administrations and has a long history of strong partnerships with the States, Federal agencies, academia, and private industry. FHWA leverages these partnerships to identify current and emerging highway transportation challenges, coordinate and collaborate on research, and deploy innovations.

University Transportation Centers (UTC) Program:

The UTC program is a congressionally mandated financial-assistance program that provides grants to universities to conduct research on critical transportation issues and to support education activities for the next generation transportation professionals. This program was funded through FY 2015 under the Moving Ahead for Progress in the 21st Century (MAP-21) Act, and has been recently renewed in the FAST Act, which authorized the Office of the Assistant Secretary for Research and Technology to award $72.5–$77.5 million in grants to UTCs annually through FY 2020. The program currently supports 35 multi-year university-based centers that conduct workforce development and basic and applied research, the products of which are judged by peers or other subject matter experts and are made available through technology transfer to the transportation industry.

With the passage of the FAST Act, U.S. DOT received authorization for the next round of UTC competition. The FAST Act authorized the competitive selection of up to 35 new centers to receive funding from FY 2016 through FY 2020 to conduct research activities that address the six primary purposes referenced in the FAST Act.

FHWA is committed to working collaboratively with its partners to identify research and technology initiatives needed to achieve results, especially since these partners may at times be responsible for implementing the technologies and innovations that were developed. To ensure stakeholder input, FHWA staff participate on highway-related committees and subcommittees of the American Association of State Highway and Transportation Officials (AASHTO) and TRB, in addition to other cross-cutting and inter-governmental research and transportation groups. In addition, FHWA has developed a collaboration website **(https://www.fhwa.dot.gov/research/fhwaresearch/agenda/)** that summarizes the RD&T program and requests stakeholder input.

Workers prepare to transport bridge components

3.2. Federal Aviation Administration

To maximize the opportunities provided by the aviation industry, the U.S. must maintain and continue to improve the National Airspace System (NAS) so that it continues to respond to the rapidly changing and growing transportation needs, yet ensures the highest level of safety. Increased mobility, higher productivity, reduced environmental impact, and greater efficiency are possible by introducing new technologies, procedures, innovative policies, and advanced management practices. Collaborative, needs-driven R&D is central to this process, as it enables the U.S. to be a world leader in its ability to move people and goods by air safely, securely, quickly, affordably, efficiently, and in an environmentally sound manner.

The FAA's mission is to provide the safest and most efficient aerospace system in the world. The corresponding R&D mission is to conduct, coordinate, and support domestic and international R&D of aviation-related products and services that will ensure a safe, efficient, and environmentally sound global air transportation system. The FAA supports a range of research activities, from materials and aeromedical research, to the development of new products, services, and procedures.

The FAA has defined five organizational values to better manage its R&D programs and achieve its R&D vision:

- **Goal driven—**The FAA uses R&D as a primary enabler to accomplish its goals and objectives.
- **World-class—**The FAA delivers R&D results that are high quality, relevant, and that improve the performance of the aviation system.
- **Collaborative—**The FAA partners with other government agencies, industry, and academia to capitalize on national R&D capabilities to transform the air transportation system.
- **Innovative—**The FAA empowers, inspires, and encourages our people to invent new aviation capabilities and create new ways of doing business to accelerate the introduction of R&D results into new and better aviation products and services.
- **Customer-focused—**The FAA R&D program delivers quality products and services to the customer, quickly and affordably.

By aggressively promoting these values, the FAA generates the maximum benefit from its R&D resources to help achieve its vision and the national vision of a transformed aviation system.

R&D programs support various operational mission areas across several lines of business and are funded through different appropriations. The complete R&D portfolio is described in an annual National Aviation Research Plan (NARP) that is submitted to Congress with FAA's annual budget request. Recognizing the diversity of mission objectives and research needs, elements of the R&D portfolio are organized and prepared by seven Program Planning Teams (PPT) before they are reviewed by the Research, Engineering, and Development Executive Board (REB). The PPTs are an organizing construct while the program is being developed and they also serve as the focal point representing progress status during review and execution. The PPTs and corresponding portfolio segments are listed below:

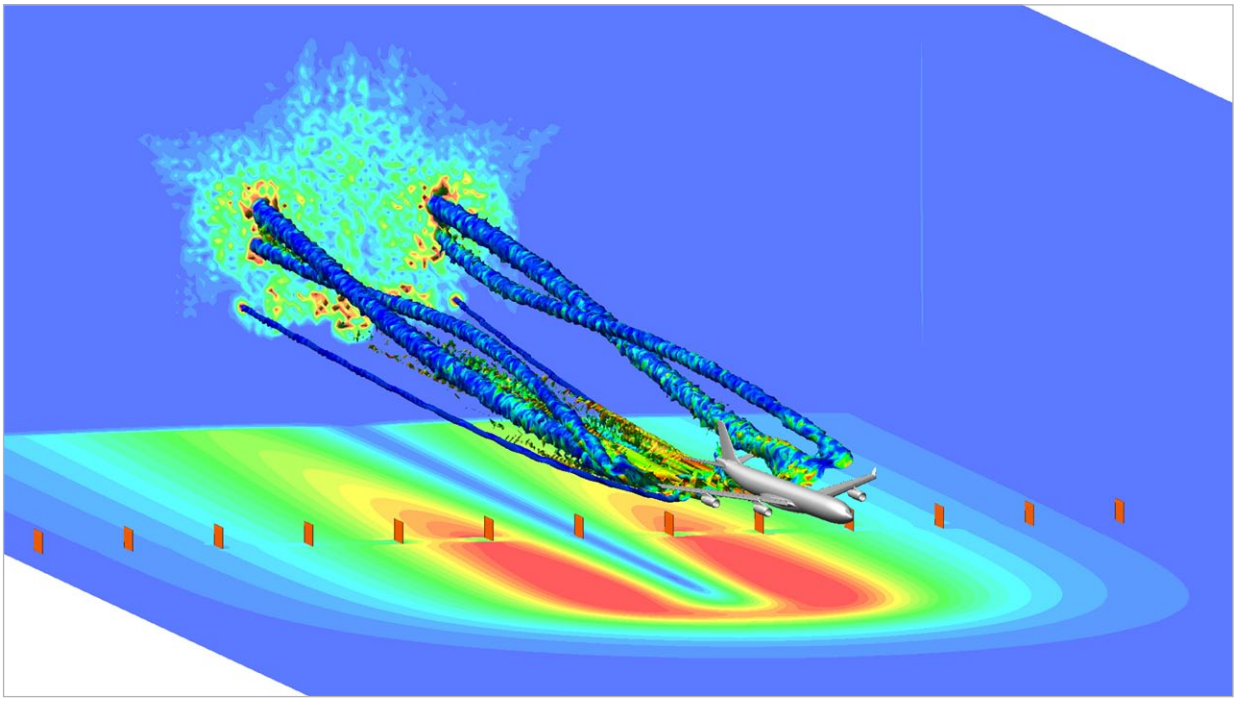
- Airports
- Aviation Safety
- Environment and Energy
- Human Factors
- Mission Support
- NAS Operations
- Weather

Each year the REB issues guidance to the PPTs on presenting programs within their segments of the portfolio during the budget formulation cycle. The PPTs conduct planning sessions following their processes for program prioritization and present the proposed program plan to the REB for review. The proposed R&D portfolio is then presented to an independent Research, Engineering and Development Advisory Committee (REDAC) for review, then feedback before the budgetary request is finalized and submitted. During execution, the program

review is conducted by performing program offices and sponsors, as well as external review bodies, as described in section 6.3. Appendix A and Appendix B list all of FAA's R&D programs and funding levels.

The FAA enhances and expands its R&D capabilities through partnerships with other government, industry, academic, and international organizations. By partnering with other organizations, the 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. Partnerships include:

- Other Federal Agencies, such as NASA, DOD, and the Transportation Security Administration (TSA);
- Industry, through mechanisms such as the Commercial Aviation Safety Team, the General Aviation Joint Steering Committee, the Aerospace Vehicle Systems Institute, and the Commercial Aviation Alternative Fuels Initiative; and
- The Nation's colleges and universities, through the Joint University Program, aviation research grants, and Air Transportation Centers of Excellence.



Computer graphic visualizing the wake turbulence created by commercial aircraft

3.3. Federal Transit Administration

The mission of the Federal Transit Administration (FTA) is to improve public transportation for America's communities so that America has a world-class public transportation system with access and mobility for all.

FTA projects meet public transportation innovation goals by:

- Enhancing equitable and accessible mobility for everyone;
- Encouraging public-private partnerships;
- Ensuring public transportation efficiency, safety, and reliability;
- Enabling seamless, effective integration across transportation modes and applications; and
- Expanding customer satisfaction and value.

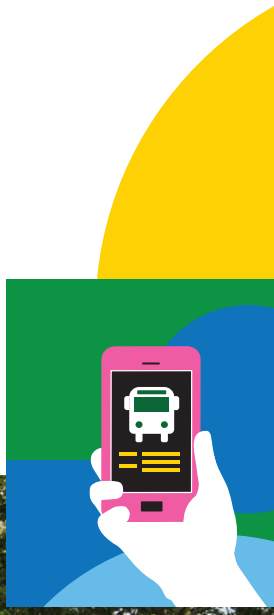
R&D activities are administered by the Office of Research, Demonstration, and Innovation (TRI). In addition, some of the projects funded by U.S. DOT's Small Business Innovation Research (SBIR) program help to stimulate new transit-related products and services from emerging businesses. Appendix A and Appendix B list all of FTA's R&D programs and funding levels.

The Transit Cooperative Research Program (TCRP), which operates through a cooperative agreement between the National Academy of Sciences, the American Public Transportation Association (APTA), and FTA, develops near-term research solutions to significant challenges facing public transportation. Original research and synthesis studies address cross-cutting innovation related to facilities, operations, policy and planning, human resources, safety, maintenance, and administrative practice. TCRP's mission is to promote, select, and conduct research; and disseminate findings to elevate the practice and the performance of public transportation consistent with FTA's strategic research goals for safety, mobility, asset management, and asset innovation.

TRI works with numerous stakeholders through interagency partnerships and collaborates closely with other modes within U.S. DOT. Key projects by modal partners are the Intelligent Transportation Systems Joint Program Office (ITS JPO) and the Accessible Transportation Technology Research Initiative (ATTRI), both of which operate within FHWA. Safety projects are coordinated closely with the FTA Office of Safety and NHTSA. Demonstration grantees often are State and local agencies that test out innovative approaches to public transportation capital investments, operational enhancements, rider mobility programs, and safety initiatives.

FTA also collaborates with other Federal laboratories, public transportation providers, private or non-profit organizations, and technical/community colleges to meet their research goals. Key partners include the U.S. DOT John A. Volpe National Transportation Systems Center (Volpe Center), the Center for Urban Transportation Research (CUTR) at the University of South Florida, the National Transit Institute (NTI) at Rutgers University, Portland State University, the National Renewable Energy Laboratory; and several groups within the National Academies, including TRB and the TCRP.

FTA also works collaboratively with other Federal Agencies, including the Environmental Protection Agency (EPA), Department of Energy (DOE), and the Department of Housing and Urban Development on projects ranging from fuel cell and electric drive initiatives to urban partnership efforts. The FTA's health and transportation initiative, Rides to Wellness, benefits from significant collaboration with the Department of Health and Human Services. In addition, FTA partners with national public transportation associations, especially APTA, the Community Transportation Association of America, and AASHTO.



Commuter bus times can now be conveyed to mobile devices

3.4. Federal Railroad Administration

The Federal Railroad Administration's R&D mission is to ensure the safe, efficient, and reliable movement of people and goods by rail through basic and applied research, and to develop innovative solutions. FRA's R&D program is separated into the following five areas:

- **Track Program —** reducing derailments due to track-related causes;
- **Rolling Stock Program —** reducing derailments due to equipment failures, minimizing the consequences of derailments, and minimizing hazardous material releases
- **Train Control and Communication —** reducing train-to-train collisions and train collisions with objects on the line and at grade crossings;
- **Human Factors Program —** reducing accidents caused by human error; and
- **Railroad System Issues Program —** prioritizing R&D projects on the basis of relevance to safety risk reduction and other DOT goals.

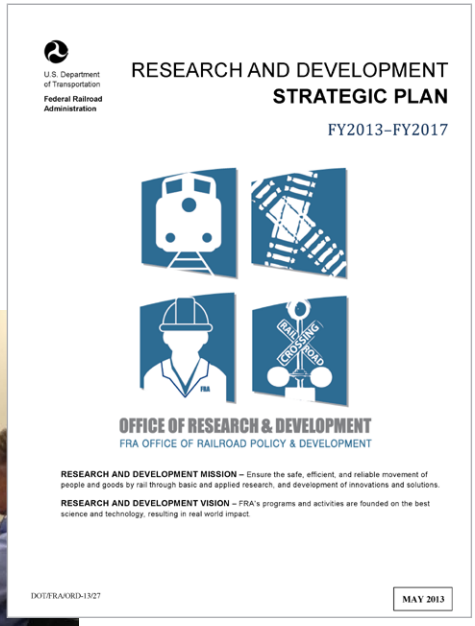
FRA's R&D program is administered by the Office of Research, Development, and Technology, part of FRA's Office of Railroad Policy and Development. Appendix A and Appendix B list all of FRA's R&D programs and funding levels.

Key research partners within FRA include the Office of Railroad Safety and the Office of Chief Counsel because much of the Program's efforts support developing and enforcing railroad safety regulations. The U.S. DOT's Volpe Center receives approximately one-quarter of the program's funds each year and has been a long-time partner.

External partners include the Association of American Railroads (AAR), which represents the private freight railroad companies in the United States. FRA's R&D program is coordinated with the AAR's Strategic Research Initiatives to avoid duplication and to co-sponsor research when appropriate. Transportation Technology Center, Inc., a wholly owned subsidiary of AAR, maintains and manages FRA's Transportation Technology Center in Pueblo, CO.

Academic partners include the rail-based UTCs, their member institutions, and several other universities with rail research programs. International partners include Transport Canada, the Rail Safety and Standards Board in the United Kingdom, the European Rail Agency, the Chinese National Rail Administration, and the Chinese Academy of Railway Science. FRA has also established the Global Railway Alliance for Suicide Prevention, which has several international members.

Since 1996, TRB has periodically evaluated FRA's R&D program. TRB's appointed expert committee reviews the program's activities and achievements, and then summarizes its findings in a letter report to FRA. The expert panel typically comprises representatives from the largest railroads, academia, States, and former senior-level government staff. FRA will continue to consider TRB inputs when setting R&D priorities and planning projects.



Left: FRA computer training session, a key aspect of FRA's Human Factors Program

Above: Cover of the FRA Research Development Strategic Plan

3.5. National Highway Traffic Safety Administration

NHTSA's mission is to save lives, prevent injuries, and reduce economic costs due to road traffic crashes, through education, research, safety standards, and enforcement. NHTSA's research activities to support this mission are divided between two different offices; Vehicle Safety Research and Behavioral Safety Research.

The Office of Vehicle Safety Research performs research and testing related to crashworthiness, human injury/biomechanics, crash avoidance, and electronic controls. These programs identify safety improvement opportunities and manage the facilities and research to address safety problems. Vehicle Safety Research programs support U.S. DOT's safety goals through conducting motor vehicle safety research and development into advanced vehicle safety technology, ways of improving vehicle crashworthiness and crash avoidance, and vehicle-based options for decreasing distracted driving and alcohol involvement in crashes. In addition, the Office conducts research into the reliability and security of complex safety-critical electronic control systems, vehicle cybersecurity, and new and emerging technologies that can help drivers avoid crashes. Other research areas include developing enhanced computer modeling tools; along with the expertise to quickly and efficiently identify vehicle fleet changes with potential safety ramifications, particularly in areas related to alternative fuel vehicles; advanced battery control modeling and analysis; assessment of crash notification technology and emergency response; and supporting NHTSA's other cross-cutting initiatives.

The Office of Behavioral Safety Research directly supports the Department and agency goals of reducing traffic crashes, fatalities, and injuries, such as those related to impaired, distracted and drowsy driving by providing the scientific basis for the development of effective behavioral countermeasures to reduce the occurrence of traffic crashes. The Office focuses on unsafe driving behaviors that contribute significantly to death and injury from crashes on the Nation's highways. Evaluation research documents the relative effectiveness of programs to reduce highway fatalities and injuries, and is critical to achieving further progress toward meeting national goals and performance targets. The Behavioral Safety Research program assesses existing and emerging highway safety problems. Results are distributed to the States to use in identifying effective traffic safety countermeasures for implementation through the highway safety formula grant (Section 402) funds and incentive grant funds (Section 405).

Appendix A and Appendix B list all of NHTSA's R&D programs and funding levels.

NHTSA partners with other DOT modal agencies, such as the Federal Highway Administration, the Volpe Center, universities, the Environmental Protection Agency (EPA) research contractors, safety advocates, and most automotive manufacturers and top-tier suppliers.

NHTSA crash test dummies prior to a vehicle test

3.6. Pipeline and Hazardous Materials Safety Administration

The Pipeline and Hazardous Materials Safety Administration (PHMSA) RD&T program supports the agency's mission to protect people and the environment by advancing the safe transportation of energy and other hazardous materials essential to our daily lives. To do this, PHMSA establishes national policy, sets and enforces standards, educates, and conducts research into preventing incidents. The agency also engages the public and first responders to ensure that these communities are prepared if an incident occurs.

Within PHMSA, the Office of Pipeline Safety regulates the pipelines that transport hazardous liquids and natural gas. The Office of Hazardous Materials Safety regulates the multimodal transportation of hazardous materials. Each of these two offices has an active RD&T program. Appendix A and Appendix B list all of PHMSA's R&D programs and funding levels.

Pipeline Safety

The mission of the Pipeline Safety RD&T program is to sponsor research and development that provides near-term solutions to improve the safety, reduce environmental impact, and enhance the reliability of the country's pipeline transportation system. The United States has the oldest and largest pipeline network in the world, with over 2 million miles of natural gas and hazardous liquid pipelines. Many of these pipelines are over a century old, are in deteriorating condition, are difficult to replace, and are located in environmentally sensitive or densely populated areas. Population encroachment, climate change, and lower public tolerance for pipeline accidents present very difficult risk management challenges. The RD&T program is a critical tool to provide solutions to address these many safety challenges.

New pipeline under construction

The Pipeline Safety RD&T program has the following objectives:

- **Develop Technology –** Accelerate and develop new technologies to improve pipeline safety.
- **Strengthen Industry Consensus Standards –** Identify and share new knowledge to advance industry safety standards and improving safety.
- **Promote Knowledge –** Generate and share pipeline safety information with decision makers.
- **Identify Emerging Risks –** Understand factors contributing to emerging safety risks.

The RD&T program falls under the Engineering and Research Division within the Office of Pipeline Safety. The program is managed by the Director of Engineering and Research and two research program managers. Individual project oversight is provided by trained and certified Contracting Officer's Representatives from the Office of Pipeline Safety headquarters, and field office staff provide individual project oversight.

PHMSA does not own any pipelines. This means the ability of partners to access pipelines and test new technologies is critical for the program's success. The pipeline research agenda is established every two years through a stakeholder-based, consensus-driven process. This includes a public R&D forum to obtain broad input from stakeholders from the public sector, academia, private industry and watchdog groups that the agency uses when prioritizing pipeline research topics. The proposed research agenda resulting from the forum is then reviewed and approved by PHMSA's leadership.

Hazardous Materials

The mission of the Hazardous Materials Safety RD&T program is to improve the safety of the multimodal transport of hazardous materials by providing the research, analysis, and technical information required to identify, mitigate, and understand the associated transportation risks.

The Hazardous Materials Safety RD&T program has the following objectives:

- **Package Integrity –** Prevent and reduce hazardous material incidents resulting from package failures by improving standards related to manufacturing, testing, evaluating, and inspections.
- **Human Factors –** Improve the safety aspects of human involvement in hazardous materials transport.
- **Technical Analysis to Aid Risk Assessments –** Identify gaps and vulnerabilities in the Nation's transportation systems.
- **Risk Management and Mitigation –** Reduce the probability of hazardous material incidents within the Nation's transportation network and alleviate the adverse consequences of any such incidents.
- **Emerging Technologies –** Create or identify new materials and technologies to improve transport safety and minimize transport risks.

The RD&T program is in the initial stages of establishing a comprehensive program to address existing and emerging transportation systems and practices. Although contracting authorities differ between the Pipeline Safety and Hazardous Materials Safety programs, the Hazardous Materials RD&T program is using the Pipeline Safety research approach, which involves all stakeholders in identifying research needs, developing priorities, and evaluating research proposals.

Hazardous Materials Safety RD&T key partners and stakeholders include:

- The public
- Federal and State agencies
- Shippers and carriers of hazardous materials
- Hazardous materials trade organizations
- PHMSA-certified test and certification agencies
- Standards developing organizations
- Academics and researchers
- Technology service providers

Hazardous material transport on highway

3.7. Federal Motor Carrier Safety Administration

The mission of the Federal Motor Carrier Safety Administration's Office of Analysis, Research, and Technology is to reduce the number and severity of commercial motor vehicle (CMV) crashes and enhance the efficiency of CMV operations by:

- Providing data, producing statistics, and conducting high quality research studies directed toward fuller scientific discovery, knowledge, or understanding; and
- Identifying, testing, and supporting technology transfer activities and deployment of CMV safety technologies.

FMCSA's Research and Technology program is overseen and administered by the Associate Administrator for Research and Information Technology, and led by the Director of the Office of Analysis, Research, and Technology. Made up of three divisions, the Office of Analysis, Research, and Technology manages agency-wide research and data analysis programs and studies, and evaluates and deploys pilot or emerging CMV safety technologies. Appendix A and Appendix B list all of FMCSA's R&D programs and funding levels.

The Office of Analysis, Research, and Technology works with other program offices and external stakeholders (such as the Motor Carrier Safety Advisory Committee) to identify research, data analysis, and technology application needs. Research includes in-house, contract, congressionally-mandated, and joint-funded studies with other DOT elements, the private sector, and academia.

FMCSA's Research Executive Board periodically reviews proposed research and technology projects. The Board consists of representatives from FMCSA offices with research and technology interests. It is responsible for evaluating, prioritizing, and approving submitted research and technology proposals, and for ensuring that they are aligned with FMCSA's priorities and are consistent with budget objectives.

FMCSA's Research and Technology program coordinates motor carrier research, data analysis, and technology programs with other departmental offices, Federal agencies, academia and governmental entities; public and private transportation research organizations; and private industry, as appropriate. Internally, the agency works closely with NHTSA, FHWA, FRA, PHMSA, and the ITS JPO to align research and development goals. FMCSA works closely with a select number of external research-based organizations, such as the National Academy of Sciences, the Committee on National Statistics, the National Institute of Occupational Safety and Health, the National Institutes of Health, and the Center for Disease Control and Prevention. FMCSA partners with these organizations to:

- Conduct expert panel reviews of existing agency programs/research.
- Implement large-scale longitudinal studies on driver health and wellness.
- Develop educational outreach programs aimed at improving driver health and safety.
- Improve agency research methodologies and statistical approaches.

The agency has a longstanding partnership with TRB and participates in the TRB Annual Meeting, provides research support/guidance via standing committees and task forces, attends committee-sponsored conferences and workshops, and maintains and operates the Transportation Research Information System.

Officials converse with driver near his truck

Driver standing in front of her truck

3.8. Maritime Administration

The Maritime Administration (MARAD) is responsible for improving and strengthening the U.S. maritime transportation system—including the ships and mariners of the U.S. Merchant Marine, shipbuilding, and port operations—to meet the economic, environmental, and security needs of the Nation. MARAD contributes to technology applications within the U.S. maritime industry by identifying and focusing on specific industry research needs. The majority of resources in recent years have supported environmental sustainability, but other studies have addressed safety, economic competitiveness, and infrastructure issues.

Maritime Environmental and Technical Assistance (META) is MARAD's only funded RD&T program. META research activities are designed to enhance environmental stewardship, facilitate compliance, and reduce air and water quality degradation associated with maritime transportation, including ships, port operations, and waterways. Appendix A and Appendix B list all of MARAD's R&D programs and funding levels.

There are currently three research areas:

- Control of aquatic invasive species;
- Reduction of air emissions through improved control technologies and the use of less-polluting maritime fuels; and
- Alternative energy sources, efficiency, and conservation.

The META program is expected to result in improved technology and standards for testing and evaluating the effectiveness of ballast water management technologies, improved application of technologies that reduce air emissions, and expansion of alternative energy technologies and applications in the maritime industry.

New large shipping vessel under construction

MARAD has no formal coordinated program or authorized budget for RD&T activities; nevertheless, it works with other modes within U.S. DOT and its agencies, academia, industry partners, TRB's Marine Board, Federal maritime advisory committees, industry organizations, and maritime cooperative programs to initiate and complete RD&T activities that have a positive benefit on the maritime industry and the public. To promote synergy with the Federal family, MARAD periodically coordinates with other agencies interested in maritime technology and environmental protection; in particular the U.S. Coast Guard, EPA, U.S. Navy, National Oceanic and Atmospheric Administration, the U.S. Army Corps of Engineers, FHWA, and DOE.

The META program is built on public-private partnerships and collaboration with Federal, State and local government, academia, the maritime industry, and non-governmental organizations. Many META projects provide substantial cost sharing with other partners.

Students exiting a maritime safety training

3.9. Intelligent Transportation Systems – Joint Program Office

The ITS JPO conducts research, development, and capacity-building activities to facilitate the adoption of information and communication technologies that allow society to move more safely and efficiently. The R&D program addresses the following key goals:

- Enable Safer Vehicles and Roadways by developing better crash avoidance, performance measures, and other notification mechanisms; as well as mechanisms to protect consumer privacy, commercial motor vehicle safety considerations, and infrastructure-based and cooperative safety systems.
- Enhance Mobility by exploring methods and management strategies that increase system efficiency and improve individual mobility. This will be achieved through a variety of programs and applications; including improved traffic management, work zone and incident management, transit management, freight management, and road weather management.
- Limit Environmental Impacts by better managing traffic flow, speeds, and congestion and by using technology to address other vehicle and roadway operational practices. This will be achieved by assisting system users and operators with "green" transportation alternatives, and providing options such as avoiding congested routes, taking alternate routes, using public transit, or rescheduling a trip.
- Promote Innovation by fostering technological advancement and innovation across the ITS Program, continuously pursuing a visionary and exploratory research agenda, and aligning the pace of technology development, adoption, and deployment to meet future transportation needs.
- Support Transportation System Information-Sharing by developing standards and systems architecture, and applying advanced wireless technologies that enable communications among and between vehicles of all types, the infrastructure, and portable devices.

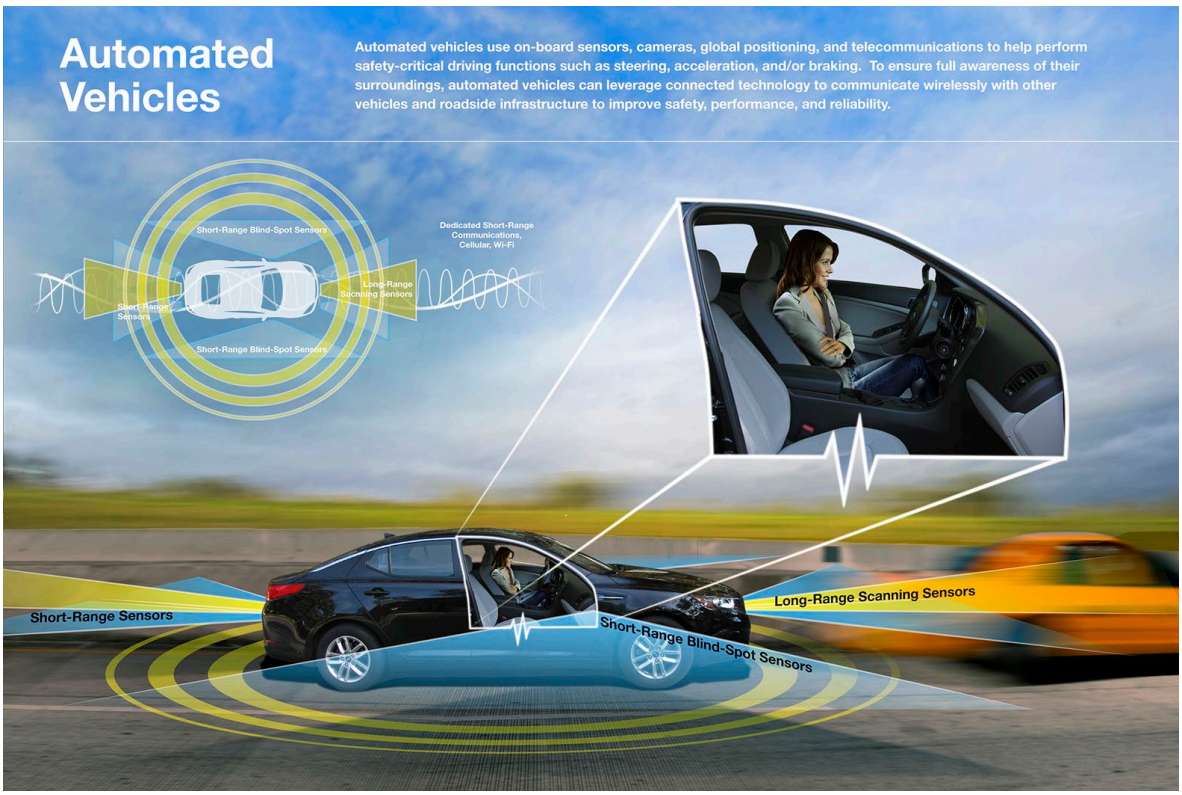
ITS research benefits from the multimodal planning and coordination process used by the ITS JPO. This includes participation of all surface modes through the modal Strategic Planning Group (modal associate administrators), with concurrence by the Management Council (all surface mode administrators and chaired by the Deputy Secretary) to coordinate ITS project funding. As a result research opportunities can be leveraged, duplication of effort eliminated, and ITS research integrated across the modes.

The ITS Strategic Plan for FY 2015–FY 2019 incorporated input from over 700 stakeholders. Additionally, ITS JPO research program managers and the staff responsible for professional capacity building

Cover of the ITS Strategic Plan 2015–2019

and communications routinely host a multitude of webinars, use social media, issue publications, and participate in conferences and events.

The ITS JPO routinely conducts evaluations to determine the effectiveness and benefits of deployed ITS and the value of ITS program investments. The Office has evaluated major ITS research initiatives, such as Integrated Corridor Management and the Urban Partnership Agreements. It is currently planning the future evaluation of two ongoing technology deployments; the Connected Vehicle Pilot Deployments and the Smart City Challenge. The ITS JPO also conducts the ITS Deployment Tracking Survey every three years to track and analyze the implementation of ITS solutions. The Office maintains the ITS Knowledge Resources database, which provides ITS stakeholders with convenient access to ITS costs and benefits data and lessons learned. Appendix A and Appendix B list all of ITS JPO's R&D programs and funding levels.



Graphic rendering of potential sensor placement on an automated vehicle

4 Research and Development Strategies

This section presents the U.S. DOT's research and development strategies for addressing the research needs within each critical transportation topic area. Each subsection begins with a summary of the critical topic area's research needs, then presents each Operating Administration's R&D strategies and activities to address these research needs.

4.1. Promoting Safety

Promoting Safety relates to safety issues affecting all modes and the development and deployment of countermeasures designed to address these issues. The U.S. DOT's goal is to improve public health and safety by reducing transportation-related fatalities and injuries.

Transportation safety is a critical societal issue and the U.S. DOT's top priority. Motor vehicle crashes are the leading cause of death in transportation; in 2015, they accounted for 35,092 fatalities.[5] Strategic investments in RD&T are necessary to maintain passenger and crew safety gains across all transportation modes. Advances in technology, engineering, and human-factors research are providing new insights into and solutions to long-term, persistent safety problems. Fatalities in commercial aviation have become exceedingly rare, while fatalities in rail and waterborne transportation have steadily declined.

Improving vehicle technologies, safer infrastructure, increased enforcement, and changing demographics and cultural norms have all contributed to these safety improvements. Technologies such as frontal and side air bags have helped to mitigate the consequences of vehicle crashes. At the same time, crash-avoidance technologies such as automatic emergency braking systems, lane-departure and forward-collision warning systems, and electronic stability control are helping drivers avoid crashes altogether. Advancements in connected and advanced driver assistance systems promise to improve driver situational awareness and automate an increasing share of driving functions, reducing the likelihood of crashes with other vehicles and road users.

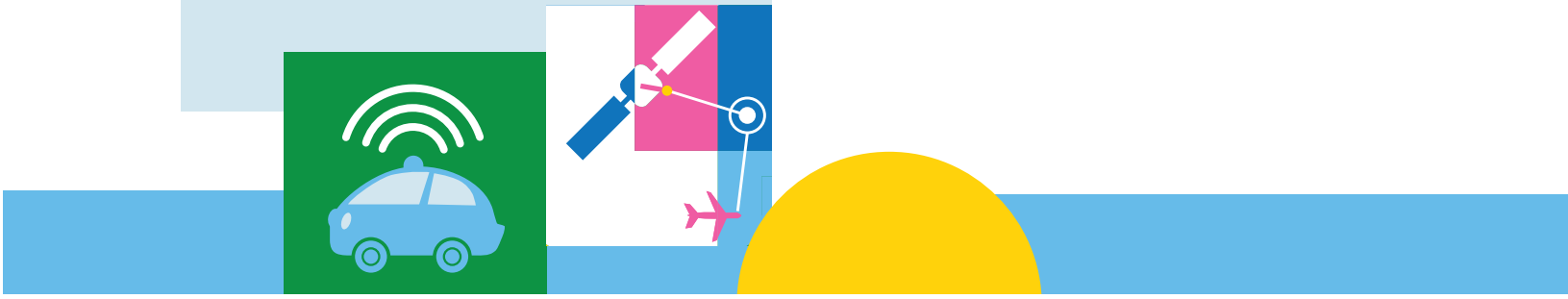
The deployment of NextGen promises to further improve the safety of the national airspace through the use of digital communication, satellite surveillance, and improved navigation technologies. The intent of NextGen is to improve flight and weather information, enhance communications among pilots and air traffic controllers, and introduce advanced platforms for the collection and analysis of safety information. Research investments can support

the development of new safety technologies, such as NextGen, and accelerate their deployment. Providing the mariner with enhanced real-time marine safety information will improve situational awareness and promote maritime safety, environmental protection, and operational efficiencies.

The U.S. DOT's publication and enforcement of regulations has made a significant contribution to improving safety over recent decades. Valid and appropriate regulations are built on a solid foundation of scientific and engineering research. Regulatory impact analyses—required to prove the benefits of proposed regulations—very often rely on tests, computer simulations, and other analyses by the research community. As transportation safety systems increasingly rely on frequently updated software, regulatory systems may need to adapt to accommodate and ensure the safety performance of such systems. Researchers at U.S. DOT also develop tools that help inspectors enforce safety regulations.

Improvements in the management and analysis of safety data are supporting better safety regulation and investments. For example, as part of FAA's safety management system, aviation stakeholders are systematically analyzing and learning from safety incidents. Increasingly the FAA is using data recording, collection, reporting, and analysis tools and techniques that enable early identification, assessment, and mitigation of safety risks. Automation of crash data collection, geolocation of crashes, and improved asset management data now support sophisticated data-driven decisions about highway safety investments. As safety data becomes more prevalent and important, research can help to establish methods for developing, applying, and evaluating performance-based safety standards; and support industry-wide adoption of safety management systems and safety culture practices.

Despite significant progress, serious safety challenges remain. The prevalence of impaired driving remains high, and seatbelt usage rates, while improving, are significantly less than the near-universal rates achieved in some countries in Europe. Driver distraction continues to be a major safety problem.[6] The importance of understanding and minimizing distraction will only increase as new in-vehicle technologies that require interaction, such as voice, touch, and gesture control, become more widespread. As the population ages, understanding the effects of aging and cognitive degeneration on driving, and the implications for safety and licensing policies, will grow in importance. Other emerging areas of operator impairment research include the effect of prescription, over-the-counter, and newly legalized drugs on operator performance and fatigue management. To address these issues, continued research will be needed on the causal role of human factors in safety issues.



Some areas of transportation safety research have not seen consistent progress. More than half of all traffic fatalities occur in rural areas, where fatality rates are 2.6 times higher than in urban areas. Increasing rates of walking and bicycling have coincided with a rising number of deaths among pedestrians and cyclists. Although there have been reductions in the number of rail worker fatalities and fatalities at grade crossings, trespassing fatalities remain high. Additional research is needed to better understand these issues and develop strategies to address them.

New transportation technologies have also introduced new types of safety risks. Operator overreliance on automation is increasingly contributing to aviation, rail, and maritime safety incidents. Greater complexity of transportation technology is creating regulatory challenges and introducing safety risks. For example, auto safety recalls have hit record levels in recent years.[7] Integrating unmanned aerial systems into the air traffic system also poses a major safety challenge. Understanding the risks inherent in the interaction of operators with advanced technology presents important challenges in all modes.

Increased connectivity of transportation technologies and infrastructure in aviation and surface transportation promises great potential benefits in many different areas, but these advances also introduce vulnerabilities that could lead to potentially catastrophic system disruptions. The safe operation of NextGen, Positive Train Control, connected vehicles, and other intelligent transportation systems all depend on secure, reliable digital communication infrastructure and systems. In theory, a transportation control system that is connected to the Internet could be attacked from anywhere in the world. Maintaining cybersecurity to prevent these types of attacks will be a major challenge for transportation agencies and companies.

There are also risks in a future where transportation services depend too heavily on access to GPS technologies for operations. Disruptions to service can be created by weather events, demand overload, jamming and spoofing by hackers, and excess system demand. The government agencies responsible for GPS, and the transportation firms and agencies that depend on that system, will need to consider ways to mitigate the risks of service disruptions. This may require making decisions on how best to maintain legacy navigation systems and capabilities, and building redundancy.

FHWA

Key R&D strategies for promoting safety include:

- Advancing the connected vehicle initiative;
- Fostering a culture of safety guided by the integrated "4E" principles of engineering, education, enforcement, and emergency medical services;
- Advancing the use of scientific methods and data-driven decision making to reduce traffic crashes, fatalities, and injuries;
- Promoting safer roadway design, by crafting advanced analyses that clearly identify behavioral and roadway feature crash risk, and by developing technologies and countermeasures that enhance the driver's capabilities to avoid crashes; and
- Advancing the DOT vision towards zero deaths and serious injuries.

The following subsections provide examples of FHWA research projects promoting safety.

SHRP2 Safety Data

FHWA develops data systems to support data-driven technologies and decision-making. For example, FHWA established the Safety Training and Analysis Center (STAC) in 2015 to help the research community and State DOTs use data from the second Strategic Highway Research Program's (SHRP2) Naturalistic Driving Study (NDS) and Roadway Information Database (RID) to define the next generation of safety countermeasures. The NDS is the largest data set of its kind to date, featuring over 1 million hours of video depicting driver responses to real world conditions. The RID provides high accuracy and high fidelity details about the NDS roadways to enable reliable analysis.

FHWA will use the STAC to analyze the data, conduct research, and develop tools to address high priority issues of national significance. The STAC will serve as an incubator of new ideas throughout the research community; providing sponsored opportunities for graduate and postdoctoral students, fellows, and other researchers to work with the data. The STAC will also continue to support U.S. DOT needs; by using SHRP2 safety data to conduct research on Department priority topics, and by developing tools that enhance data extraction and analytical capabilities.

CROSS-MODAL RESEARCH AREA: Human Factors in Transportation

The Secretary of Transportation established the Human Factors Coordinating Committee (HFCC) in 1991 to become the focal point for human factors and cross-modal issues within the Department. The HFCC now serves as a collaborative, multimodal team with Federal government-wide liaisons to address crosscutting human factors issues in transportation; such as human-systems interaction (including interaction with automated systems), the safety risks of operator impairment (including distraction, fatigue, substance impairment, aging operators), and other topics relevant to transportation safety.

The HFCC includes representatives from every DOT modal administration with a human factors program, including FAA, FHWA, FMCSA, FRA, FTA, MARAD, NHTSA, OST, and PHMSA. HFCC members have been designated as the human factors points of contact for their agency. In addition to DOT representatives, the HFCC maintains a network of affiliates from CDC, DHS, DOD, NASA, NTSB, TSA, and the U.S. Coast Guard. The Volpe Center within OST-R serves as the HFCC's Executive Agent, facilitating and reporting on monthly meetings and coordinating HFCC activities and programs. The participating modes effectively pool their resources to fund Volpe's participation using Interagency Agreements.

Since its inception 25 years ago, HFCC has influenced the implementation of human factors projects within and between modal administrations, provided a mechanism for exchanging human factors and related technical information among modal administrations, and encouraged synergy and continuity in implementing transportation human factors research. The HFCC has supported the DOT Safety Council, conducted workshops for TRB participants, held exhibitions and symposia to highlight the role of human factors in transportation, and engaged with UTCs on human factors research topics of specific interest to the U.S. DOT. HFCC members recently assembled a panel to present "The Evolving Role of Automation in Transportation: Human Factors Lessons Learned from the Different Modes" at the 2016 Human Factors and Ergonomics Society annual meeting.

Human Factors Assessment of Pedestrian Midblock Behavior

Midblock or non-intersection locations account for about half of the pedestrians injured in crashes. For fatal crashes, the situation is much worse. Approximately 75 percent of pedestrian fatalities occur at non-intersection locations. It is likely that a substantial proportion of these fatalities occur when the pedestrian is crossing the roadway outside the appropriate intersection crossings. Despite greater safety risks, many people will cross a road where it is most convenient. While it is not feasible to place crosswalks at all locations where pedestrians might choose to cross the roadway, it is possible to identify the environmental characteristics and cues that influence pedestrians to cross at risky locations. If there is a better understanding of midblock crossing affordances, modifications can be made to increase pedestrian safety through marked crossings or midblock crossing inhibitors.

To reduce pedestrian fatalities and injuries resulting from midblock crossings, this research project will apply human factors techniques and methodologies to identify pedestrian motivations to cross at midblock locations in urban and suburban areas, identify the environmental characteristics associated with different crossing behaviors, and develop effective and low-cost countermeasures; including roadway treatments or other safety strategies to improve pedestrian safety relating to midblock crossing. The goal of this research is to improve pedestrian safety at urban and suburban midblock crossing locations by identifying appropriate low- to mid-cost countermeasures.

Use of Digital Project Plans for Automated Machine Guidance

Use of digital project plans that are entered in construction equipment eliminates the need to stake projects during construction and reduces worker exposure to hazardous conditions on the jobsite. FHWA also operates a Work Zone Clearinghouse that is a resource of best practices not only for traffic control but also jobsite safety.

Impact of Vehicle-Based Technology on Roadway Departure Crashes

Connected and automated vehicle (CV/AV) technologies have the potential to enhance highway safety by providing drivers with precise vehicle control and maintaining appropriate driver attention to traffic and roadway conditions. Such technologies can have a tremendous impact on the reduction of roadway departure crashes (e.g., lane departure warning systems, which alert the driver when the vehicle drifts past the lane markings).

As the vehicle fleet transitions to a greater percentage of these vehicles, it is important to understand how the infrastructure and safety countermeasures need to adjust to accommodate the changes (e.g., rumble strips will become less important, while additional striping on more of the roadway may be needed). The objective of this project is to explore new and emerging technologies to determine which have the most potential benefits in reducing roadway departure crashes, how the roadway departure program can support the connected vehicles and vehicle-to-infrastructure programs, and how the roadway departure program focus may need to adjust to address these changes in the vehicles and infrastructure.

Pedestrian and Bicycle Assessments

U.S. DOT launched its Safer People, Safer Streets initiative in the fall of 2014, with the goal of improving pedestrian and bicycle safety across the country. The first element of the initiative was a call for the Department to convene a walk/bike safety assessment in every State. FHWA actively supported this initiative by leading 36 of the 52 pedestrian and bicycle safety assessments. A Pedestrian and Bicycle Safety Action Team, with representatives from several U.S. DOT modes (OST, FHWA, FTA, NHTSA, FMCSA, and FRA) coordinated the assessments and other initiative efforts.

The use of digital project plans can be input into construction equipment for automated machine guidance. This eliminates the need to stake projects during construction and reduces worker exposure to hazardous conditions on the jobsite. FHWA also operates a Work Zone Clearinghouse that is a resource of best practices not only for traffic control but also jobsite safety.

FAA

Continued research and development investment is critical to the safe and efficient evolution of an aviation system that addresses the emerging challenges of the industry and current critical transportation topics. New airspace user categories, advanced materials in aircraft design, the aging pilot population and changes in their health condition, and the environmental effects (e.g., noise and emissions) of aviation are some of the challenges that must be carefully considered to sustain continued operational improvement and growth in an aviation system that supports national transportation priorities.

Accommodating increased demand for passenger travel and freight movement requires continuous improvement in the management of the national airspace to increase its capacity and allow access by non-traditional new users, safely and efficiently. Over time increased system capacity will provide growth in aviation operations; this growth must be enabled and sustained in a way that preserves the environment and maintains the highest levels of safety. A coordinated R&D portfolio is essential to achieving optimal balance among these objectives. Several emerging and growing trends in the aviation industry present both challenges and opportunities to address the Nation's critical transportation issues and require continued research and development. Several examples are summarized below. Appendix A lists all FAA's current aviation RD&T programs.

Unmanned Aircraft Systems

Increased demand for airspace access for unmanned aircraft systems (UAS) operations raises new airspace management and operational safety questions that must be thoroughly explored. Which technologies or procedures are viable substitutes for the "see and avoid" capability and inherent safety margin presented by manned aircraft operations? What are the risks and fail-safe mechanisms to recover from the loss of the UAS command and control link? Which policies and guidelines should be issued to ensure UAS designs incorporate technologies that mitigate safety risks? Which standards and guidelines are required for UAS pilot control station design, operator training, and certification?

R&D activities will examine UAS-specific technical issues such as detect and avoid, datalink aircraft control and communications with air traffic control, and emergency response requirements. The program will generate technical information to support development of policies, guidance materials, and advisory circulars on using new or novel technologies to demonstrate regulatory compliance while operating UAS in the NAS.

Safety of Commercial Space Transportation

Like UAS operations, the commercial space industry is growing at a rapid pace and it is expected that the demand for civil airspace access to support commercial space operations will grow accordingly. Similarly, commercial space vehicles are a non-traditional new entrant with unique characteristics and operational dynamics that raise important questions about their integration in the NAS. The expansive airspace closures currently being implemented to ensure civil aviation safety during commercial space vehicle launch or reentry operations are a significant imposition on NAS operations. Improved airspace management procedures and decision-support tools would mitigate NAS operational impacts while continuing to ensure public safety during commercial space operations.

Advanced modeling concepts and analytical tools are required in areas such as whole atmospheric modeling, explosive debris generation, and dispersion and mitigation in the airspace; as well as uncertainty modeling. There is a need for continued research into aircraft vulnerability to space-vehicle-breakup debris; including model development and refinement to reduce overly conservative airspace 'keep out' areas to protect aircraft against a launch or reentry vehicle failure. Research is also needed to develop improved fragmentation models of structures—such as composite propellant tanks—to define appropriate public safety standoff distances. The Commercial Space Transportation Safety research program is designed to address these, as well as other challenges, generated by this growing industry.

Human Factors

Increased access to vast amounts of data is another emerging trend that offers both opportunities for operational improvement and constraints that are not well understood. For example, the role of the human in an increasingly complex and data rich environment raises a fundamental question—how can we leverage the operational improvement opportunities provided by increased access to a data-rich environment,

FAA: FIRE RESEARCH AND SAFETY: Underwriters Laboratories Adopts Microscale Combustion Calorimeter (MCC)

Underwriters Laboratories (UL) recently adopted the FAA-patented Microscale Combustion Calorimeter (MCC), developed by scientists in the Fire Safety Branch at FAA's William J. Hughes Technical Center to verify that manufactured materials are compliant with the UL 94 flammability test standard. Many components in building materials and consumer products must meet the UL 94 flammability standard. Material manufacturers must also demonstrate each lot is compliant. Rather than conducting a UL 94 flammability test, which requires a large sample bar, an MCC test requiring a very small sample—as small as several milligrams—may be used to demonstrate continued compliance of the manufactured material.

The benefit of using the MCC is reduced cost, time, and waste associated with molding plastic sample bars, and discarding the unused or unburned samples. The MCC also provides a more quantitative output—heat release rate signature—and significantly reduces the quantity of combustion products release during UL 94 testing. The MCC has become a common test method used by fire researchers. In recent years it has become a quality control tool, as shown by the recent UL adoption and previous use by the Boeing Company.

while recognizing the cognitive overload limitation of humans? Continued human factors research and analysis is required to address this risk/opportunity trade-off. The aviation research portfolio will continue to invest in human factors research to explore human/system integration issues and to develop guidelines to apply to the design of both ground-based and flight deck system operator interfaces.

More broadly, it is recognized that the human component of the aviation system is simultaneously the strongest and the weakest link in aerospace safety. Emerging human safety risk issues; such as those brought on by the aging pilot population and changes in their health condition, advances in pharmacology, therapeutic tools, and surgical procedures must be thoroughly explored and understood. FAA has developed an Aerospace Medical Research program for the aviation research portfolio to keep abreast of these issues, maximize the strengths of the human link, minimize inherent human weaknesses to prevent accidents, and improve human safety and health in commercial and general aviation operations. Aeromedical research output serves as the knowledge base for physicians, physiologists, human factors, and other engineers, psychologists, educators, and numerous other academia, industry, and government professionals in the United States and abroad who are concerned about the NAS and the safety of humans in world aerospace operations.

Advanced Materials and Structural Safety

Over the last decade, there has been a rapid expansion of the use of composites in increasingly larger structures. Dominating the rapid expansion is the use of reinforced composites to provide lighter, more fuel-efficient airframe and engine components, including full-fuselage barrels and wings. The current certification process for many advanced materials and structures was established for smaller, less critical components and service conditions. The difference in the structural characteristics and increased scale of these new components must be understood and incorporated into certification and operational plans to ensure safety. The Advanced Materials/Structural Safety research program investigates a broad spectrum of issues relating to the use of composite and advanced materials in aircraft structures. These include fatigue and damage tolerance from in-flight hail and ground vehicle collisions, environmental and aging effects, and bonded joints and repairs. Research findings enable development of safety awareness training, validation of dynamic test methods and procedures, and analysis to meet crashworthiness regulations, ensuring that new aircraft structures demonstrate levels of safety equivalent to existing aircraft structures when subjected to survivable crash conditions.

FTA

The goals of FTA's Safety Research Program are to improve public transportation safety, support the agency's regulatory role, and develop a safety oversight framework. Anticipated outcomes are improved public safety through reduced transit-related injuries and fatalities, and improved system reliability through fewer safety events.

Specific objectives for projects funded under this program include:

- Developing materials and technologies to reduce the number of transit-related fatalities and the severity of transit-related injuries, and improve the overall state of good repair of transit assets;
- Increasing knowledge about human/machine interface and reduce the potential for safety-related incidents;
- Improving the safety culture at transit agencies and enhance public confidence in transit, as well as support stakeholder coordination and outreach; and
- Supporting the development of transit safety standards, best practices, and lessons learned in safety operations.

The FTA Safety Research Program is broken down into five themes and associated subthemes, as shown in Table 6.

Human Behavior

The focus is human factors issues that impact transportation safety; including impaired driving, suicides, human/machine interface, and pedestrian/bicycle safety for both transit operators/employees and passengers/public that interact with transit services. Conflicts between pedestrians/bicycles and transit vehicles (buses and rail) are an important safety issue for FTA and the agency has invested a substantial amount of research effort.

Collisions

The focus is research relating to transit vehicle collisions and their causes and includes simulations developed to gain a better understanding of the physics of the crashes. Physical (non-human) aspects of crashes is highlighted; such as vehicle materials that can be improved to reduce impact damage, models built to simulate crashes, and actions taken to avoid future crashes by using automation and collision-avoidance technology.

Resiliency and Emergency Management

The focus is research to increase the resiliency of public transportation systems to natural disasters and other emergencies that result from external causes, improved communication with emergency responders in the event of disruptions or catastrophic failures of transit systems, and best practices and leveraging of existing technologies to restore transit services after an emergency.

Regulations and Standards

The focus is continued improvement of safety programs, policies, and regulations. Projects provide information on current industry conditions and support FTA leadership, the FTA Safety Oversight Office, and the transit industry, by providing relevant information to drive safety standards development and new safety legislation.

Data Analysis

The focus is high-level data analyses of U.S. transit system safety to identify critical issues and emerging issues and trends in different modes of public transportation. Projects include enhanced safety data collection and potential applications of big data to identify safety issues and enhance safety research.

Table 6. FTA Safety Research Program's Themes and Subthemes

Theme	Subthemes
Human Behavior	Impaired driving and suicide prevention Human/machine interface Pedestrian/bicycle safety
Collisions	Crashworthiness (vehicle seating and interior design) Crash energy management Collision avoidance technology Automation
Resiliency and Emergency Management	Nature (natural disasters, storms, earthquakes, etc.) State of good repair (asset reliability) Emergency management
Regulations and Standards	Policy and regulation Standards development
Data Analysis	Data collection and analysis Big data

FRA

FRA's R&D program focuses on the critical topic area of Promoting Safety. The goal for all projects is to improve safety in the rail industry. Often, projects will also contribute to benefits in other critical topic areas of this Strategic Plan. For example, technology that detects defective rails before the safety hazard occurs and there is a break in service can also be used to preserve the life of the rail asset.

FRA's strategic vision for improving rail safety is to work towards eliminating accidents and to minimize the consequences of accidents that do occur. FRA analyzes its rail accident and incident database to determine the highest safety risks. Findings drive R&D strategies in the following program areas.

Track Research

Broken rails continue to be the main cause of derailments. FRA will continue researching broken rail prevention using early detection of defects and preventative track maintenance. The agency also plans to increase the amount of data it captures on the condition of the Nation's railway infrastructure and use the data to predict critical safety conditions before they occur. This will require new analytical methods and ways of distributing information to intended users.

Rolling Stock Research

The amount of hazardous materials transported by rail is expected to grow in coming years. For example, several railroads are developing locomotives powered by natural gas. Liquefied natural gas is also starting to be shipped in bulk containers by rail. FRA will continue researching how to eliminate causes of train derailment and mitigate consequences when trains do derail.

FRA will also develop wayside and on-board monitoring systems to detect equipment failures before accidents occur. The agency will also continue researching ways of improving the survivability of railcar occupants when collisions, derailments, and fires occur.

Train Control and Communication Research

Pedestrians trespassing on railroad property result in half of all rail-related fatalities annually. Accidents at highway-rail grade crossings cause almost all of the remaining fatalities each year. FRA will research new methods of detection, warning, and prevention to address these problems.

Available radio spectrum for train communications is very limited and in some regions is inadequate to handle secure messages. To overcome this limitation, FRA will research software-defined radios and new modulation and compression techniques to help increase the efficiency and security of communication.

Human Factors Research

Human error is currently the cause of one-third of all railroad accidents and incidents. New automation, such as positive train control (PTC), is being introduced that will require research to ensure it can be implemented without introducing new hazards. One important area for study is human-machine interaction.

Improving safety at grade crossings continues to receive attention. Grade-crossing fatalities are the second largest cause of rail-related deaths. Although substantial engineering advances have improved the safety of grade crossings, FRA does not fully understand how motorists' behaviors and motivations contribute to these accidents. Further research into motorist behavior will help reduce these preventable accidents.

FRA will continue to expand its safety culture improvement programs. Pilot projects of confidential close-call reporting and peer-to-peer observations have been successful. Lessons learned will be applied to ensure success as pilot projects grow system-wide.

FRA: Test Bed for Positive Train Control

FRA developed and installed a PTC Test Bed at the Transportation Technology Center (TTC) in Pueblo, CO, to support the railroad industry in developing, implementing, and maintaining PTC. The PTC Test Bed replicates current PTC technologies used by the railroads and provides a controlled test environment for conducting functional testing, safety testing, interoperability testing, regression testing, performance evaluations, and development support for current and future PTC systems. The Test Bed integrates PTC and communications equipment with existing railroad and communications infrastructure at TTC, which provides a realistic operating environment independent of the revenue service operation of any railroad. This allows expedited research and testing without affecting regular railroad operation.

The PTC Test Bed has already been used by the industry to test on-board train management computers, radio communications, and braking algorithms for freight trains. It has also been used as a training ground for FRA inspectors.

Freight train moving across landscape

NHTSA

NHTSA's key R&D strategies are designed to serve the agency's mission of saving lives and preventing injuries and fall under the Promoting Safety topic.

Over the next five years, NHTSA will address automated vehicles, cybersecurity, vehicle-to-vehicle communications, alcohol impairment detection technology, and seat belt interlocks. In the Behavioral Safety Research program NHTSA will address priority issues including alcohol and drug-impaired driving, occupant protection (front and rear seat belt use and correct child safety seat use), and speeding behavior. Other crash-related factors (distraction, drowsy driving, the elevated crash risk of young and older drivers, enhancing motorcycle, pedestrian and bicycle safety, and mitigating the dangers of the rapid developments in technology use by drivers) will be addressed as needed.

Automated Vehicles

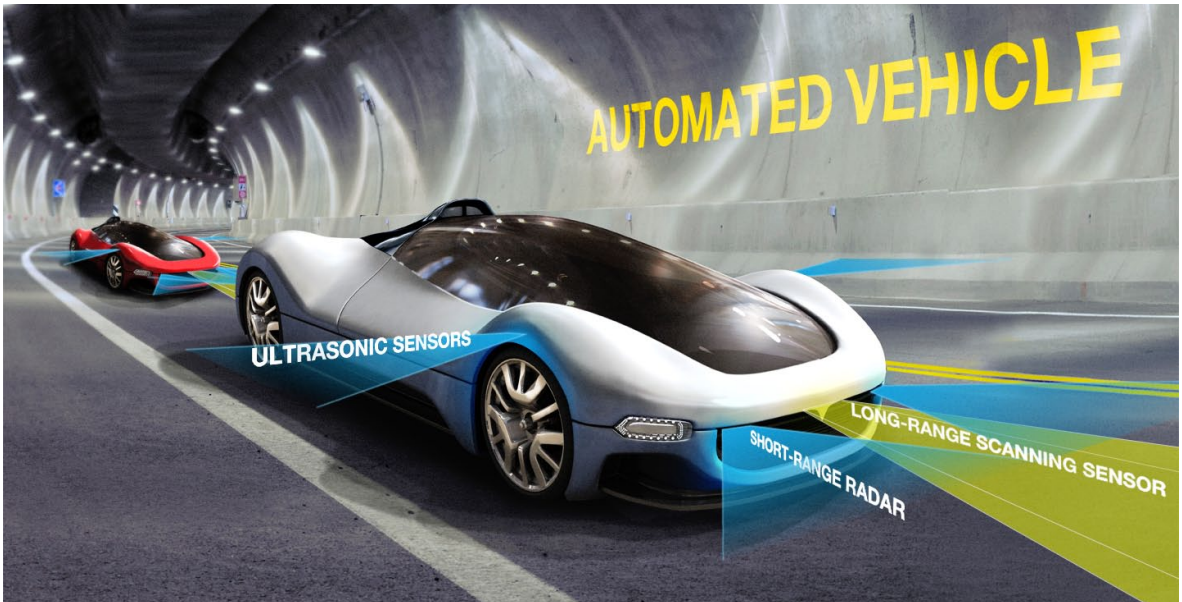
On September 20, 2016, the Department released the Federal Automated Vehicles Policy, an unprecedented, proactive measure to safely test and deploy automated vehicles without stifling innovation. The four-part policy was thoughtfully developed with extensive public input to engage as many stakeholders as possible as the policies governing automation innovations are developed. The components include Vehicle Performance Guidance for Automated Vehicles, Model State Policy, NHTSA's Current Regulatory Tools, and Modern Regulatory Tools. NHTSA is committed to routine stakeholder outreach and update of these policies for the nimble and flexible framework needed to keep pace with vehicle innovation.

NHTSA plans to carry out the next step action items identified in the Vehicle Performance Guidance policy to entities designing, testing, and planning to deploy highly automated vehicle systems. While few regulatory burdens stand in the way of full vehicle automation in the United States, entities still have the responsibility to demonstrate compliance with Federal Motor Vehicle Safety Standards (FMVSSs), and due care to provide countermeasures that will fully protect all occupants given any planned seating or interior configurations. Automated vehicle functions may not be covered by specific regulations, entities designing new automated vehicle systems are still required by the Motor Vehicle Safety Act to ensure their systems are free of unreasonable risks to motor vehicle safety (typically known as defects). Thus, while NHTSA executes its research program, the agency expects that entities planning to test and deploy highly automated vehicles will use the issued Vehicle Performance Guidance, industry best practices, and related internal processes and strategies to ensure that their systems will be reasonably safe under real world conditions.

The published Vehicle Performance Guidance is just a first step; however, it highlights important areas that entities designing automated vehicle systems should be following, as well as a number of analytical methods that should be considered as manufacturers weigh the safety implications of their design choices and develop methods to manage potential safety risks.

Automation promises not only to revolutionize how we drive, but also how we license, register, inspect, and train people to use such vehicles. To avoid a patchwork system of State policies that might impede interstate travel, NHTSA worked with stakeholders to develop nimble model State policy to assist States with their role in governing automated vehicles.

Graphic rendering of potential sensor placement on an automated vehicle



The Federal role in the safe deployment of automated vehicles must not stand in the way of innovation. NHTSA has, and continues to explore ways to use its current authorities—rulemaking, exemptions, and interpretations—in this area to develop a nimble, orderly process for deployment and oversight. Because NHTSA is focusing on the quickest way to accomplish this, it has been exploring ways to encourage the use of exemptions and interpretations, and will continue to improve its processes to provide rapid, robust responses to regulated entities.

Cybersecurity

Over the last few decades, our lives have been revolutionized by the rapid connectivity made possible by computers, the Internet, satellites, and other technologies. As these systems became integral to our daily lives, so too did the potential for attacks to those same systems. Cybersecurity emerged out of necessity to protect these vital systems and the information contained within them. Applied to vehicles, cybersecurity takes on an even more important role: systems and components that govern safety must be protected from malicious attacks, unauthorized access, damage, or anything else that might interfere with safety functions.

Cybersecurity is essential to the public acceptance of increasingly computerized vehicle systems, to the vehicle control systems they govern, and to the safety-enhancement potential they offer. NHTSA is pursuing an approach to vehicle cybersecurity that is based on sound research, proactive actions by industry, best practices, regulatory considerations, and enforcement. These activities support the goal of improving the cybersecurity posture of modern vehicles. NHTSA will research not only protection methods, but also intrusion detection techniques, rapid remediation strategies, and fast adoption of new lessons learned. The agency will steer the industry to make cybersecurity a priority by using a systematic and ongoing process to evaluate risks. These processes will give explicit considerations to privacy and cybersecurity risks through the entire life cycle of the vehicle. Furthermore, safety of vehicle occupants and other road users is a primary concern when assessing risks. NHTSA published a set of best practices for modern vehicles and will remain proactive in understanding how vehicle manufacturers are implementing vehicle design changes to address cybersecurity issues.

Cyber Security Research

The U.S. DOT's Safety Council is chaired by the Transportation Deputy Secretary and made up of the heads of each DOT modal administration, their senior safety officers, and senior officials from the Office of the Secretary (OST). The Safety Council has established the Cybersecurity Action Team, made up of representatives from OST and Operating Administrations across the Department. It meets monthly to share and coordinate cybersecurity initiatives throughout the Department. The Team is exploring opportunities to coordinate research efforts to improve the resilience of the transportation system to cybersecurity disruptions and to integrate cybersecurity considerations in the safety management system approach to safety adopted by the Department.

Vehicle-to-Vehicle (V2V) Communications

NHTSA has been researching V2V communication technology for more than a decade, in partnership with other U.S. DOT researchers, the automotive industry, and academic institutions. V2V is a crash avoidance technology, which relies on the communication of information between nearby vehicles to potentially warn drivers about dangerous situations that could lead to a crash. V2V can enable safety applications that are difficult to implement with conventional sensors such as radar or cameras. Unlike such "vehicle-resident" sensors, V2V is not restricted to line-of-sight sensing of other vehicles. There are two potential applications of V2V technology:

- Intersection Movement Assist warns the driver when it is not safe to enter an intersection because of an increased potential for collision with another vehicle.
- Left Turn Assist warns the driver when there is high probability of collision with an oncoming vehicle when making a left turn, even when the driver's line-of sight is blocked by a vehicle also making a left turn from the opposite direction.

Many more potential safety applications exist, but NHTSA estimates that these two applications alone will prevent up to 600,000 crashes, up to 270,000 injuries, and save over 1,000 lives each year when implemented across the entire fleet.

V2V technology can be integrated with other sensors (such as radar and camera) to improve the overall performance of several Advanced Drivers Assistance Systems (ADAS) by improving threat recognition and enhancing the reliability of driver warnings. Furthermore, our work with industry stakeholders suggests that V2V communications can help with improving the performance and safety of emerging automated vehicle (AV) technologies by allowing V2V equipped vehicles to have more precise 360 degree awareness of other vehicles in proximity.

Seat Belt Interlocks

Seat belt interlocks prevent a car being driven, or limit a car's operation, unless the seatbelts are fastened. NHTSA has developed a research program focusing on the effectiveness and acceptance of seat belt interlock systems. The agency has also developed performance specifications and assessed implications for vehicle crash safety. Since 2014, NHTSA has initiated four seat belt interlock system research projects:

- A field operation test to provide data on the functional approach, system effectiveness, consumer acceptance, any unintended consequences (e.g., avoidance strategies), and likely cost;
- A project to understand potential changes to restraints and the occupant compartment resulting from removing crash test requirements for unbelted occupants;
- An investigation of the design and development of a prototype seat belt interlock system that is resistant to misuse; and
- An update of a previous study to evaluate the effectiveness of existing Enhanced Seatbelt Reminder Systems.

Alcohol and Drug Impaired Driving

Approximately one-third of all fatalities involved impaired drivers. Although considerable progress has been made in reducing the harm caused by impaired driving, much remains to be accomplished. NHTSA has relied on an approach that includes strong laws and penalties and highly visible enforcement to deter drivers from driving while impaired. It has become increasingly difficult to achieve the level of law enforcement activity required to achieve further gains. Law enforcement has many competing priorities (e.g., homeland security) that impede more resources being expended on impaired driving. NHTSA plans to pursue alternative strategies for engaging law enforcement in this challenging area in the coming years. This will include encouraging a shift from periodic enforcement blitzes to strategies that can be sustained on a continuing basis.

States are increasingly interested in drug-impaired driving. NHTSA has been conducting research to better define the nature and scope of the drug-impaired driving problem. These efforts include studies of driver drug use over time (through periodic prevalence studies) and research on the crash risk that results from drug use by drivers (NHTSA recently completed a first of its kind case control study of the crash risk associated with drug use by drivers). These efforts will continue, and in some respects increase, as NHTSA gains a better understanding of the drug-impaired driving problem. NHTSA will soon be initiating another case control study of the crash risk of drug use by drivers that will focus on serious injury and fatal crash involved drivers (the previous study included police-reported crashes of all types).

NHTSA is also researching drug screening devices for use by law enforcement. This should make it more likely that law enforcement will increase the investigation of drug impairment by drivers. Current technology (involving blood draws that are sent to a forensic laboratory for analysis) inhibits police and prosecutor interest in charging drivers with drug-impaired driving. NHTSA intends to determine the reliability and accuracy of these newly-developed devices and the impact of law enforcement behavior.

Occupant Protection

Appropriate child safety seat use has been a challenge due to the complexity of the different types, makes, and models of car seats mixed with different makes, models, and types of vehicles into which they are secured. There is a new generation of parents facing this issue every year. NHTSA will continue to research why parents have difficulty properly restraining their children in child seats and installing child seats in their vehicles. The agency also plans to conduct future research on rear seat belt use, as the use rates for rear seat belts are considerably lower than the use rates for front seat belts.

Speeding

NHTSA research is designed to better understand the situations and circumstances under which speeding contributes to increased crash risk. This will allow law enforcement to focus their efforts at reducing speeding where it will have the most impact in reducing crashes. NHTSA is following a multifaceted approach that involves instrumented vehicles to capture information on driver speed choice, and uses existing naturalistic driving data and instrumented roadway segments to collect and analyze new data on speeding behavior under various conditions (roadway type, trip type, weather and lighting conditions, etc.), situations (e.g., traffic volume), and driver characteristics (age, gender, personality, etc.). The intent is to develop a better understanding of when and where risky speeding behavior is most likely to be exhibited.

PHMSA

PHMSA R&D strategies are divided into two programs: the Hazardous Materials Safety RD&T program and the Pipeline Safety RD&T program.

Hazardous Materials Safety RD&T

To improve public health and safety by reducing transportation of hazardous material-related fatalities and injuries, the Hazardous Materials Safety RD&T program addresses hazardous materials safety issues affecting all transportation modes and the development and deployment of countermeasures to address these issues. Maintaining a safe and effective program requires continuous evaluation, revitalization, and updating to address modern risks.

Future research objectives for promoting safety include:

- **Developing Packaging Technology and Materials –** Fostering the development of new technologies and materials to improve package performance in normal and accident transport scenarios;
- **Strengthening Industry Consensus Standards –** Developing domestic and international standards and incorporating new knowledge and trends into the revision process for existing standards;
- **Promoting Knowledge –** Generating and promoting general knowledge to decision makers; and
- **Identifying Emerging Risks –** Understanding modal, commodity and individual factors contributing to future safety risks.

Priority areas are:

- Prevent and reduce hazardous materials transportation incidents resulting from package failures by improving manufacturing, testing, evaluating, and inspections standards.
- Improve the safety aspects of human involvement in hazardous materials transport by enhancing programs involving human factors management.
- Identify gaps and vulnerabilities in the transport systems and improve safety, prevent fatalities, and minimize injuries by addressing these system and program weaknesses.
- Alleviate the adverse consequences of hazardous material transport incidents by reducing the probability of incidents within the transportation network.
- Identify and access past, existing, and emerging technologies to improve transport safety and minimize transport risks.

PHMSA: Hazardous Materials Automated Cargo Communications for Efficient and Safe Shipments (HM-ACCESS)

Federal hazardous materials regulations (HMR) require persons who transport hazardous materials to describe key hazard communication information on a shipping paper. Currently, the HMR requires a paper copy of the shipping paper to accompany hazardous materials in transport. After the hazardous material is no longer in transport, shippers and carriers must retain and make available the hard copy shipping paper or an electronic image for one year. For hazardous waste, the hard copy must be retained for three years after the material is accepted by the initial carrier. For all other hazardous materials, the shipping paper must be retained for two years after the material is accepted by the initial carrier. The use of electronic communication while hazardous materials are in transport is the next step in the evolution of hazard communication

Title III of the Moving Ahead for Progress in the 21st Century Act (MAP-21) authorized of pilot projects to evaluate the feasibility and effectiveness of paperless hazard communications systems. In support of this initiative, the Hazardous Materials Safety program conducted pilot projects in 2015 to test the feasibility and effectiveness of using paperless hazardous materials (e-HM) communication systems (E-Systems) to transmit hazardous materials shipping paper information while the hazardous materials was in transport.

Based on study findings and information collected , the Hazardous Materials Safety RD&T program determined E-Systems is a feasible and effective alternative to hard copy documentation for communicating shipping paper information during transport. If certain performance standards are met, E-Systems can provide at least an equivalent level of safety and security to that provided by hard copy shipping papers.

Repair and testing of pipeline infrastructure during a safety review

Pipeline Safety RD&T

The strategic vision of the Pipeline Safety RD&T program is to support the programs and DOT's mission by implementing integrity management protocols, risk-based analysis, and forward-looking guidance to increase the safety and protection of the infrastructure and the environment. Public notices, publications and enforcement of regulations have made significant safety contributions over recent decades.

Future research objectives for promoting safety are:

- **Developing Technology –** Fostering the development of new technologies so that pipeline operators can improve safety performance and more effectively address regulatory requirements;
- **Strengthening Industry Consensus Standards –** Targeting standards and feeding new knowledge into the process of keeping standards relevant to their purpose;
- **Promoting Knowledge –** Generating and promoting general knowledge to decision makers; and
- **Identifying Emerging Risks –** Understanding factors contributing to future safety risks.

Priority areas are:

- Prevent pipeline damage from excavation and identify critical pipeline defects before failure.
- Support remote condition assessment of pipeline defect severity.
- Investigate the role of human factors in incidents involving pipelines.
- Identify emerging technologies to improve hazardous material safety and minimize risks.

FMCSA

FMCSA's primary goals are to reduce the number and severity of CMV crashes and enhance the safety and efficiency of CMV operations. Research and technology projects primarily address the critical transportation topic of Promoting Safety. Some of FMCSA's research and technology projects overlap with other critical transportation topics, such as Freight Movement (e.g., research on automated CMVs and vehicle platooning) or Preserving the Environment (e.g., research on safety technologies that yield improved fuel efficiency in addition to safety benefits).

Strategic objectives for FMCSA's RD&T program are to:

- Produce safer drivers
- Improve safety of commercial motor vehicles
- Produce safer carriers
- Advance safety through information-based initiatives

Produce Safer Drivers

This strategic objective focuses on developing a better understanding of commercial driver behavior relating to safety, and an understanding of and addressing issues related to drivers' fitness for duty. Fitness-for-duty issues include alertness, health, training, and qualifications. Initiatives also focus on the enforcement of commercial credentials and driving rules and State practices for handling information about commercial drivers.

By completing targeted research, FMCSA will gain a better understanding of the causes and impacts of driver health and wellness issues and unsafe driving behaviors. New research on CMV driver fatigue will provide the agency with more detailed information on the causes of fatigue and the best methods for fatigue prevention. Research findings will: (1) equip the agency to develop effective tools for the promotion of driver wellness and the prevention of unsafe behaviors, and (2) help to shape future research efforts.

Improve Safety of CMVs

This strategic objective addresses large truck and motor coach safety through vehicle-based research and the deployment of CMV safety technologies. Initiatives under this objective focus on: (1) testing, evaluating, and deploying advanced intelligent vehicle safety technologies and other onboard safety technologies, and (2) developing new data and information to improve occupant protection and overall vehicle safety.

Through a variety of research and technology projects, the agency will gain a better understanding of the safety (and potential fuel efficiency/environmental) impacts associated with the adoption of cutting-edge CMV safety technologies (e.g., strengthened aerodynamic side guards designed to prevent pedestrian fatalities). FMCSA will also learn more about existing fleet management systems that link to truck parking applications. Through SBIR projects, there will also be continued progress in the development, testing, and potential commercialization of CMV safety technologies, such as a driver fatigue and distraction monitoring and warning systems.

Produce Safer Carriers

This strategic objective supports: (1) the agency's enforcement of carrier-related Federal Motor Carrier Safety Regulations, and (2) efforts to improve carrier safety, by applying principles of safety management science from other industries, compiling best management practices, and communicating these best practices to motor carrier managers. Initiatives focus on improving carrier compliance investigations, enabling better performance practices for carriers and shippers, continuing the development and deployment of the Commercial Vehicle Information Systems and Networks (CVISN)/Innovative Technology Deployment (ITD) Grant Program, and supporting carrier enforcement.

Research and technology projects conducted over the next several years will provide the agency with improved automated inspection tools (e.g., wireless roadside inspection) and a better understanding of the effectiveness of existing automated inspection tools (e.g., weigh station pre-clearance/e-screening systems). Furthermore, the agency will gain insights into the safety and potential regulatory impacts of automated CMVs.

Advance Safety through Information-Based Initiatives

Activities under this strategic objective focus on research that helps to support FMCSA rulemaking and enforcements: (1) evaluating existing research to highlight areas for additional investigation; (2) investigating the overall business, economic, and technical trends in the CMV industry to understand and respond to their impact on safety; and (3) exploring the feasibility and use of using multiple measures to calculate crash statistics and set safety goals.

Findings from research and technology projects will continue to inform and support FMCSA rulemaking and policy initiatives. Research projects to support FMCSA rulemakings will be conducted as needed.

The following areas will require more in-depth research over the next few years:

- Driver health and wellness
- Advanced CMV safety technologies
- Streamlined enforcement processes
- Regulatory-based research
- Studies required by the FAST Act

Driver Health and Wellness

FMCSA will research causes and impacts of driver health and wellness and unsafe driving behaviors. Using recently published recommendations from the National Academy of Sciences as a basis, FMCSA will tailor comprehensive research projects to better understand the causes and impacts of driver fatigue and the best methods for prevention. Research projects related to driver health and wellness will be coordinated with internal and external partners.

Advanced CMV Safety Technologies

Through a variety of planned research and technology projects, FMCSA will continue to investigate CMV safety technologies for improving CMV safety performance. Initiatives under this strategic objective will focus on: (1) testing, evaluating, and deploying advanced intelligent vehicle safety technologies and other onboard safety technologies, and (2) developing new data to improve occupant protection and overall vehicle safety.

Streamlined Enforcement Processes

FMCSA will improve carrier safety performance and enforcement by researching automated inspection technologies and the benefits and costs associated with fleet implementation of onboard safety systems, such as electronic logging devices. Initiatives under this objective will focus on improving carrier compliance investigations, enabling better performance practices for carriers and shippers, continuing the development and deployment of the CVISN/ITD Grant Program, and supporting carrier enforcement.

Regulatory-based Research

FMCSA will continue to conduct research to inform and support agency rulemakings and policy decisions. The end goal is to improve CMV driver and carrier safety on the highways. The agency will continue to work across program offices to ensure that research needs are identified and accounted for during the annual budget planning process. Development of these projects will be coordinated with other program offices as appropriate.

Fixing America's Surface Transportation Act

The FAST Act directed FMCSA to conduct a number of CMV and driver-related safety studies (Table 7). The FAST Act research studies vary by topic area and touch on all of the overarching research themes. For detailed information on each of the projects, visit the FMCSA website at **https://www.fmcsa.dot.gov/regulations/fixing-americas-surface-transportation-act-fast-act** or the U.S. DOT Research Hub at **http://ntlsearch.bts.gov/researchhub/index.do.**

Table 7. FMCSA Research Studies Required by the FAST Act

FAST Act Section	Project
Section 5221	Safety Measurement System Correlation Study
Section 5506	Commercial Driver's License Skills Test Delays
Section 5515	Study on CMV Driver Commuting
Section 5510	Safety Study Regarding Double-Decker Motorcoaches
Section 5517	Report on Motor Carrier Financial Responsibility

MARAD

Over the past century, maritime safety has progressively improved with a declining number of sinkings, groundings, shipboard fires, and port and shipyard safety incidents. Improved equipment on ships, in ports, and in shipyards, along with improved safety systems and procedures, have also contributed to safety improvements. Despite these many safety improvements, the lack of structured and standardized safety data makes it difficult to accurately measure progress and identify specific areas to improve maritime safety.

MARAD is implanting the following R&D strategies to promote maritime safety:

- Introducing processes, technologies, and innovations that reduce maritime-related fatalities, injuries, and accidents; and
- Developing and refining safety standards and terminology to promote the exchange of safety information for improved evaluation and analysis.

Open water safety training for maritime students

ITS JPO

There are numerous areas where the ITS JPO coordinates safety-promoting resources, projects, and activities among U.S. DOT's modes, including connected vehicles, cybersecurity, automation, and architectures and standards.

Connected Vehicles

Across the modes, U.S. DOT's first priority has always been to improve safety for all users of the transportation system. In keeping with this objective, the ITS JPO, in coordination with U.S. DOT's modal entities, and in collaboration with state officials, industry, car manufacturers, academia, and other organizations, created a technology-driven framework for CVs. The CV Program has become the hallmark of ITS JPO's research and engagement process and an excellent example of the Department's coordination of R&D activities. The ITS JPO has invested over $600 million across the department and industry, aligned with U.S. DOT's mission of advancing innovation in transportation and focused on transferring research results into real world application. The research towards state-of-the-art Wi-Fi technology supports NHTSA's V2V rule, FHWA V2I guidance, the development of a scalable operational Security Credential Management System (SCMS) to accommodate tens of millions of vehicles, and expansion of the deployment of both vehicles and infrastructure beyond the Southeast Michigan test site through the continued support of the CV pilots. The primary focus is to spur widespread adoption and deployment of the system nationwide, reducing collisions, injuries, and fatalities. This U.S. DOT program has the potential to reduce unimpaired collisions by 80 percent.

ITS Security by Design

The U.S. DOT has pursued a "security by design" approach to developing the connected vehicle environment—meaning that the entire CV system (vehicles, roadside components, and communications media) has been designed with the critical goal of cybersecurity in mind. The U.S. DOT has several research programs designed to develop a secure connected transportation environment:

- **Vehicle Cybersecurity –** Focuses on mitigating the safety impacts of potential cyber-attacks into vehicle systems and components;
- **Infrastructure Cybersecurity –** Focuses on protecting against threats and vulnerabilities to our Nation's roadside equipment, devices, data, and systems;

- **Dedicated Short-Range Communications (DSRC) Security –** Focuses on ensuring trusted communications between vehicles and between infrastructure and vehicles; and
- **Intelligent Transportation System (ITS) Architecture and Standards Security –** Focuses on the development of architecture and standards required to ensure security in the CV environment.

Vehicle Cybersecurity

Today's vehicles offer an amazing array of advanced technologies that enhance safety, improve efficiency, and reduce environmental impacts. These are accomplished through increased use of electronics and software in vehicle design and manufacture. However, the same capabilities also introduce new risks involving unauthorized access to vehicle systems to retrieve driver data or manipulate vehicle functionality.

As vehicle cybersecurity threats have emerged, the U.S. DOT has followed a layered approach, focusing on identifying solutions to harden the vehicle's electronic architecture against potential cyber-attacks and ensuring vehicle systems respond appropriately in the event of an attack. This layered approach reduces the probability of success for an attack and mitigates the potential ramifications of a successful intrusion.

Infrastructure Cybersecurity

The U.S. DOT is working on multiple fronts to improve the cybersecurity resilience of surface transportation infrastructures. Outreach and awareness efforts are underway in cooperation with the National Highway Institute, engineering organizations, and transportation agencies to demonstrate how cybersecurity risks can affect their operation. Tools are being created to help interested agencies improve their infrastructure, processes, and organizational structures to more effectively address risk to their cyber physical systems. ITS JPO is also working closely with FHWA and other modal partners to explore, assess, and mitigate additional risks that potentially could stem from increased connectivity between vehicles and infrastructure.

Security Certificate Management Systems (SCMS)

The ITS JPO and NHTSA have partnered with the automotive industry and industry security experts through the Crash Avoidance Metrics Partnership (CAMP) to design and develop a communications security solution for the CV environment—the Security Credential Management System (SCMS)—that can ensure trusted communications between vehicles and between vehicles and infrastructure. The proof-of-concept version of the SCMS is under development and is expected to be operational in the fall of 2016 to provide security credential materials to early deployments of CV technology, such as the CV Pilots and CV Test Beds.

ITS Architecture and Standards Security

The U.S. DOT's vision is to build uniform, end-to-end security into the system architecture to protect the integrity and privacy of the data traveling throughout the CV environment. This security approach ensures that vehicles exchanging data as they travel down a highway, vehicles receiving data from infrastructure at traffic signals or work zones, and all other components and participants in the CV system can rely on the integrity of the CV data received. The Department has supported and participated in the development of voluntary consensus standards critical to the trust/authentication model of security for CV environments. These foundational standards required for the Department's CV security solution have been published and are publicly available.

Automated Vehicles

The goal of JPO's automated vehicle research is to enable safe, efficient, and equitable integration of automation into the transportation system. The ITS JPO works in close coordination with the Department's modal partners on research to address key technical and policy challenges for automation. Safety topics include: high public expectations and limited understanding of the technology, human factors issues in system design and operation, data ownership, privacy, and cybersecurity; testing and certification complexity, and harmonizing state and local regulations.

This research program focuses on three areas:

- **Foundational policy research –** assess regulatory, institutional, and policy challenges facing safe and equitable adoption of automated vehicles;
- **Targeted technical research –** support future safety regulatory as well as technologies and applications with potential for strong societal benefits; and
- **Stakeholder coordination –** engage with stakeholders, both domestically and abroad, to educate and learn from core audiences and identify opportunities for data sharing and exchange of research results.

4.2. Improving Mobility

Improving Mobility refers to demographic, economic, geographic, cultural, and technological trends affecting travel demand, personal and commercial mobility across all transportation modes, and the effects of those trends on quality of life and access to economic and educational opportunities. The U.S. DOT's goal is to improve the mobility of people and goods, reduce congestion, and increase access to opportunities for all.

Many Americans lack access to affordable, reliable, and convenient transportation options. Poor households in suburban and rural areas are especially at risk, as they face major challenges accessing affordable transportation to get to the jobs and services needed to improve their economic conditions. Growing economic segregation and the decentralization of employment centers in metropolitan areas is increasing the distance between workers and employment opportunities. Rural populations in many parts of the country are aging and declining in number, reducing economic opportunities and increasing transportation challenges. As the American population ages, meeting the transportation needs of older Americans and Americans with disabilities, particularly those facing economic challenges, is a growing issue that transportation and social service providers must address.

One focus of U.S. DOT research investments is the development and deployment of tools and training to help transportation planners assess the effects of transportation programs, policies, and activities on minority populations and low-income populations to achieve an equitable distribution of benefits and burdens. Federal research can also play a role in identifying and disseminating effective policies and practices for creating jobs for local residents and small and disadvantaged businesses, connecting underserved communities to opportunities and social services, and revitalizing and restoring communities by attracting development. These activities relate directly to the Department's "Ladders of Opportunity" initiative, which connects Americans and communities to economic opportunity through three policy themes; Work, Connect, and Revitalize.

LADDERS OF OPPORTUNITY
— Work — Connect — Revitalize —
U.S. Department of Transportation

Multiple vehicle types for an urban car sharing service

The capacity of the U.S. transportation system has not kept up with rising demand for travel, resulting in recurring and nonrecurring congestion across all modes. In metropolitan regions, the average private vehicle spends an estimated 42 hours per year in traffic delays, at a cost to the economy of $160 billion annually.[8] Because much of the transportation system is at or near capacity, disruptions caused by accidents and weather events are more likely to cause more widespread and severe delays. To cost-effectively address capacity constraints, practitioners must apply technologies and operational strategies that optimize system performance and enhance connectivity between modes.

Major transportation infrastructure typically has an engineering lifespan of 50 to 70 years. To plan long-term investments in transportation capacity, transportation planners and policymakers need to be able to reasonably anticipate long-term travel demand. In recent years, changing economic conditions, demographics, and cultural norms, as well as the introduction of new technologies, have decreased confidence in long-term projections of demand for vehicle travel. A slowdown in the growth rate of vehicle travel has coincided with increasing use of passenger rail, walking, cycling, and telecommuting. Information and communication technologies have increasingly been used as substitutes to travel. Online shopping is steadily increasing and will soon account for 10 percent of all retail sales,[9] and changing business and workplace models, including an increase in freelance contract labor, flexible workplace schedules, and teleworking, are changing commuting patterns. As the American

Rail inspection training review with FRA officials

population ages, workforce participation is declining and non-commute travel is making up a higher portion of trips. Emerging transportation technologies and service models such as car-sharing, bike-sharing, and ride-sourcing services are rapidly changing urban travel by improving access to transportation assets and services and reducing the need for vehicle ownership. Research can help transportation planners and

policymakers understand the effects of changing technologies, business practices, and social attitudes on transportation demand so they can plan accordingly. It can also help planners and policymakers better understand how alternative multi-modal configurations affect transportation choices.

Growing international business and the increasing concentration of economic activity in metropolitan areas are also increasing the demand for international and intercity travel. Many metro regions are growing rapidly and these regions are becoming increasingly economically and culturally interdependent, forming megaregions. Yet, there is little data on long-distance travel patterns, and the institutional structures, planning processes, and funding policies to support mobility across megaregions are not well established.

Despite recent investments, the United States remains one of the few developed countries in the world without an extensive high-speed rail system. Discount motor coach services are experiencing rapid growth. Increasing demand for air travel, coupled with adverse weather, lead to increases in flight delays and cancellations. Approximately one in five flights in the U.S. is delayed or cancelled, resulting in estimated economic costs of $33 billion each year.[10] Research can accelerate the deployment of NextGen and high-performance rail technologies and reduce the national transportation system's vulnerability to service disruptions. As international business relationships grow increasingly important, research can also support the development and evaluation of policies and economic regulations to improve the safety and efficiency of international air travel.

Commuter rail at night in Massachusetts

Efficient freight movement is critical to the economic competitiveness of the United States, as well as to the health and welfare of all Americans. Today, increasing freight volumes, changing freight patterns, and the application of new technologies to the freight and logistics industries, present both major challenges and opportunities for those in government and industry looking to facilitate safe and efficient freight flows.

Over the next 30 years, the amount of freight hauled by truck and rail is expected to increase by more than 40 percent.[11] Continued growth in overall freight demand will increase pressure on freight bottlenecks and chokepoints throughout the country. Many of the worst freight bottlenecks are located in and around major urban areas, and at ports and border crossings where freight traffic and passenger traffic compete for capacity. Freight research can help to improve the understanding of safety and environmental risks associated with this expected growth, and help freight planners and operators identify and address key bottlenecks and chokepoints, streamline intermodal transfers, and improve the efficiency and reduce the negative impacts of urban freight shipments.

Energy products account for more than 30 percent of the domestic ton-miles of freight moved each year.[12] Domestic oil and gas production has increased rapidly in recent years, creating issues for the safe and efficient transportation of energy from production regions to refineries and consumer markets. Due to limited pipeline capacity in the relevant corridors, transportation of oil by rail has increased significantly.[13] Recent derailments of tank cars have highlighted the safety and environmental risks associated with using this mode to transport oil. Cross-modal risk assessments are needed to assess and mitigate the safety and environmental risks associated with the domestic movement of fuel by pipeline, rail and tanker ship.

Advances in robotics and information technologies are expected to transform the freight industry. Electronically connected, partially automated truck technologies could soon enable truck fleets to travel more closely together ("platooning") to improve fuel efficiency. At ports, the process of transferring containers from ships to docks, trucks, and trains is becoming more efficient through the application of new technologies. Within the next decade, remotely-piloted drone deliveries could be used to provide high-value and urgent cargo to remote and hard-to-reach locations. Delivery by UAS in more populated environments presents significantly greater security, safety, and privacy risks, and will likely take longer to develop. Research is needed to assess

and mitigate the risks associated with the adoption of emerging freight technologies and, when appropriate, accelerate their adoption.

Federal freight research has traditionally focused on the safety of freight movement. Operating Administrations with regulatory oversight of the safety of freight movements, such as FMCSA, FRA, and PHMSA, have made safety the primary subject of their research efforts. The private sector, which owns and operates a significant portion of freight-dedicated infrastructure, has generally taken a leadership role in research related to freight mobility. However, in recent years, recognizing the importance of freight movement to economic competitiveness and quality of life, the U.S. DOT has made research on freight mobility a larger priority

FHWA

Key R&D strategies for improving passenger travel and access to opportunity include:

- Advancing the connected vehicle initiative;
- Improving mobility through improving the reliability and operation of the highway system;
- Connecting and reconnecting communities; and
- Providing improved travel options and access to transportation for seniors, people with disabilities, and the economically disadvantaged.

The following subsections provide examples of FHWA research projects promoting mobility.

Performance Management and Data Support

The FHWA will develop, use, and maintain data sets and data analysis tools to help States and MPOs in carrying out performance management analyses, targeting operational and capital investments strategically, and implementing policies effectively in support of the national transportation system. A national-level Performance Management and Data Support program will provide an advanced level of capacity for decision-making to guide investments and policy efforts.

This could lead to significant cost savings to States and others by using data and analytics to define an optimal transportation system including pedestrian and bicycling elements. These efforts build on years of FHWA's development and use of per- formance measurement tools to create a robust, comprehensive, and high-quality data and analytical system for planning and decision-making.

Looking to the future, FHWA is assessing potential future transportation trends and options, including transportation needs for seniors, people with disabilities, and the economically disadvantaged, in the context of changing economic and demographic factors. This includes identifying potential data sources and analytical methods for better understanding trends in pedestrian and bicycle as well as personal and shared vehicular travel and modal choices. It also includes assessing the implications of these trends on transportation system design, investments, and financing, and their ability to enhance a broad range of federal, state, and local public policy goals and objectives.

Truck Platooning

FHWA's Exploratory Advanced Research (EAR) Program sponsors research on heavy truck cooperative cruise control. The first phase of the study looked at the commercial feasibility of driver assistive truck platooning. According to the research team the platooning study is looking at radar, vehicle-to-vehicle communications and video technology to decrease over-the-road truck headways and achieve better fuel economy without compromising safety. The team will conduct both test track and on-road pilot testing of the system. They will also monitor and assess a variety of human factors considerations, including driver satisfaction, driver training requirements, and driver operational experiences.

Equitable Access to the Benefits of Connected Vehicle (CV) Technology Deployments

FHWA RD&T programs support the development and integration of new transportation technologies, such as vehicle to infrastructure (V2I) technologies. For example, FHWA plans to develop a position on the equitable access to the benefits of connected vehicle technology deployments.

Since it is FHWA's policy to encourage V2I deployments, should it also ensure that all sectors of society benefit from and promote better public understanding of those benefits? This research effort will address this issue by incorporating the needs of all sectors in the Department's funding eligibility requirements; as well as in demonstration or pilot deployment selection criteria, research, and other CV and technology programs. FHWA will also better define the issue by

engaging internal and external non-traditional stakeholders and partners, developing a path to deploying CV applications with this broader perspective, and creating a "narrative" of how this technology provides widespread benefits.

Connected Automation Research

FHWA has identified opportunities and is conducting research in connected automation technologies that could significantly enhance the operation of the highway transportation system by improving mobility. This research suggests that significant public benefits in mobility, measured in both better reliability and reduced traffic congestion, can be achieved through the introduction of some partially automated (SAE Level 1) systems where drivers maintain control of the steering function while automated systems control the vehicle speed. For example, FHWA is conducting research to develop possible connected automation applications for speed harmonization, cooperative adaptive cruise control, and coordinated start at traffic signals that could significantly increase the practical capacity of freeways and arterials.

FHWA: Community Connections-Inventory, Innovations, and Financing

Secretary Foxx's Ladders of Opportunity Initiative creates awareness and direction on the need to reconnect communities. FHWA has responded through the numerous program office-led efforts that build on current priorities.

FHWA will work with States and MPOs to identify data and assessment tools to determine transportation connectivity gaps in communities and provide better access to essential services. A complementary toolkit will help with the conceptual design and alternatives scoping. Given the scale of retrofit/revitalization of existing urban infrastructure, there could be significant economies of scale by helping practitioners access state-of-the- practice information and providing a framework for building a repository of information. FHWA will compile case studies on financing and phasing information specific to reconnecting communities, and use forums such as Build America Transportation Investment Center to house and promote innovative financing. More information is available at: **https://www.transportation.gov/ opportunity**

Transportation Equity

Environmental justice (EJ) is grounded in the practice of making sure that both benefits and burdens of transportation investments are shared as equitably as possible among all affected communities. Historically, low-income and minority communities have borne many negative effects of transportation projects and have gained few direct benefits. As a result, efforts to promote EJ in transportation focus on engaging these communities in transportation planning and investment decisions. By promoting the principles of EJ in transportation decision-making, practitioners can better mitigate disproportionately high and adverse human health and environmental effects—including social and economic—on minority, low-income, and other populations.

FHWA plans to conduct research to:

- FHWA is evaluating the extent to which highway construction to date has impacted the socio-economic fabric of adjacent communities. FHWA will explore design features which appear to have the largest positive or negative impacts on adjacent communities.
- FHWA is exploring concepts for improving mobility with multi-modal right-of-way usage, boulevards and grids; as alternatives to larger highway infrastructures, which can restrict access and economic opportunity for adjacent communities. The analysis will include the potential to enhance transportation flow, reduce infrastructure investment costs from a nation-wide level, and an international benchmarking element.
- Develop tools, resources, and information to support the implementation of the U.S. DOT/FHWA EJ Order.
- Establish a strategic, collaborative approach for making walking and bicycling viable transportation options

Freight Operations R&D Plan

The Freight Operations R&D Plan was developed to establish a freight operations research agenda for FHWA and support more effective coordination on freight operations research within FHWA. The Plan reflects input from several FHWA offices, U.S. DOT modes, and over 60 stakeholders representing research, academic, public sector, and private freight industry perspectives. It identifies five key highway freight operations R&D topic areas for FHWA to address over a 5-year horizon (2015–2020). It also provides a framework for FHWA to assess its progress on addressing these topics and consider new R&D efforts under the key topic areas. These areas are: truck size and weight, freight infrastructure, network efficiency, connected and automated vehicles, and environmental considerations of freight operations.

Truck Size and Weight Research Plan

The Comprehensive Truck Size and Weight Limits Study identified numerous gaps in data and modeling that prevented a comprehensive analysis of the safety, bridge and pavement impacts, compliance, and modal shift effects of various truck configurations and truck weights. An independent peer review confirmed that better data or models did not exist at the time of the study. In an effort to understand how to fix this knowledge gap, FHWA will develop a Truck Size and Weight Research Plan. This Plan will identify the additional information to understand the range of effects of changes in size and weight laws and how to collect or develop it, identify which vehicle types would be most relevant, propose timeframes and cost estimates, and identify other aspects needed for an effective TSW research program. This Plan is not required by Congress but FHWA will develop it to anticipate future technical questions about truck size and weight.

Freight Analysis Framework (FAF)

Freight professionals need accurate, current, and comprehensive information to plan and make effective decisions. To address these needs, FHWA developed the Freight Analysis Framework (FAF), an inventory that compiles data from various sources to create a comprehensive picture of freight movement for all modes of transportation, within and between States and major metropolitan areas. FHWA continues to update FAF data in five-year cycles and to provide annual commodity and freight traffic forecast information based on the most recent base year FAF data. By using the FAF, freight stakeholders can better understand complex freight movements, and make cost-effective, timely decisions that improve freight flows and safety, reduce environmental impacts, and support better integration of freight into transportation system operations.

Freight Performance Measure Program (FPM)

The Freight Performance Measure Program (FPM) supports the collection and analysis of data to assist national, State, regional, and local transportation agencies in better measuring and managing highway transportation system performance. Unique among U.S. DOT efforts, the focus of the FPM is on major freight-significant corridors, intercity pairs along those corridors, and major United States-international land-border crossings. FPM data may be used in the future to inform investment decisions that produce benefits of regional and national significance. When combined with other sources, FPM data can provide a better understanding of travel time, reliability, congestion, and delay; which in turn assists decision makers in targeting infrastructure and operational improvements to maximize freight efficiency in the transportation system.

Europe Coordinated Research on Urban Freight

As cities around the world continue to grow in population, transportation agencies are grappling with how to manage the associated growth in the flow of goods. In 2014, FHWA entered into a "twinning" agreement with the European Commission to coordinate their respective research efforts on urban goods movement. This agreement stemmed from a 2013 international symposium on urban freight convened by the U.S. DOT, TRB, and the European Commission. Under the agreement, FHWA and the European Commission held an information-sharing session between U.S. and European researchers during TRB's Annual Meeting in 2016, and will do so again in 2017. In the fall of 2016, a small delegation of American freight practitioners traveled to Europe to meet with European researchers and policymakers and to visit demonstration sites. FHWA will host a larger peer exchange between American and European researchers in the fall of 2017 or the spring of 2018.

The European Commission has funded four urban logistics projects (approximately €106 million or $118 million in total) as part of EU Horizon 2020, its latest R&D program. These projects will involve pilot testing of urban freight strategies in up to 20 European cities. FHWA's Office of Freight Management and Operations is undertaking a set of research projects, collectively known as Innovative Solutions for Improving Freight Movements in Urban Areas. This research will produce three primary products for freight planners and policymakers:

- A primer on ways to enhance communication and coordination between the public and private sectors on freight issues;
- A primer on operations, logistics, and technological strategies for managing urban goods movements; and
- An update to a document produced by the Institute of Transportation Engineers (ITE) titled Designing Walkable Thoroughfares: An ITE Recommended Practice. As part of this update, freight considerations will be addressed.

FAA

Continually improved air traffic operational efficiency optimizes use of the navigable airspace and thus improves its capacity to accommodate growing demand for airspace operations. Such improvements in operational efficiency and system capacity ultimately yield reduced air travel delays as well as increased system access and predictability, thereby enhancing the passenger air travel experience.

Through its NextGen program the FAA conducts research to explore and mature new operational concepts with the potential to improve efficiency in airspace operations and increase system capacity, while maintaining the highest levels of operational safety. Within its Separation Management and Improved Multiple Runway Operations portfolios, the program explores, demonstrates, and validates new technologies and operational procedures to advance efficiency and capacity enhancement objectives.

NextGen Separation Management

Under its NextGen Separation Management portfolio the FAA conducts pre-implementation activities to reduce risk and implementation activities supporting the safe and efficient separation of aircraft and other vehicles in the National Airspace System (NAS). Risk reduction activities may include validation of concepts or technologies, demonstration and integration of operational capabilities, and an understanding of the role of the human through cognitive engineering experiments. Separation Management evaluates and matures concepts and capabilities that focus on the enhancement of separation assurance using both ground-based automation and aircraft technology enhancements. Improvements will provide air traffic controllers with tools and procedures to separate aircraft with different kinds of navigation equipment and wake performance capabilities. In general, capabilities in this portfolio will enhance aircraft separation assurance by safely reducing separation between aircraft; and, as a result, improving capacity, efficiency and safety in the National Airspace System.

NextGen Improved Multiple Runway Operations

The NextGen Improved Multiple Runway Operations (IMRO) portfolio conducts pre-implementation activities to reduce risk in multiple runway operations. The objective is to improve runway access using improved technology, updated standards, safety analysis, and modifications to air traffic monitoring tools and operating procedures, resulting in more arrival and departure operations. Improving runway access equates to reduced delays that occur now when demand exceeds the capability of the airport's runways.

Use of capabilities supported by Wake Turbulence Mitigation for Arrivals (WTMA), Closely Spaced Parallel Runway Operations (CSPO), and the Paired Approach Demonstration projects allows more runway operations per hour while maintaining safety, but without the major capital investment and time delay of building additional runways.

FTA

Mobility on Demand (MOD) Research Program

Mobility on Demand (MOD) is an innovative, user-focused research initiative with a transformative approach to travel; leveraging emerging mobility services, integrated transit networks and operations, real-time data, connected travelers, and cooperative ITS. The MOD concept allows for a more traveler-centric, transportation system-of-systems approach; providing improved mobility options to all travelers and users of the system. MOD will work to enable and leverage advancements in technology and operations to create an environment in which all travelers have safe mobility options; ensuring reliable, informed, and efficient travel in a multimodal network that prioritizes individual, on-demand mobility. The guiding principles of MOD are that it is traveler-centric and consumer driven, data-connected and platform-independent, and multimodal and mode-agnostic, incorporating the needs of all travelers and users of the transportation system.

In the early stages of the program, activities will focus on foundational research, data standards, and analytics to create a portfolio of MOD research areas. The

MOD research program hopes to partner with the research community and stakeholders to identify and further develop high-impact research areas and to define related concepts. FTA recently released a Notice of Funding Opportunity to fund MOD Sandbox demonstration projects that promote innovative business models to deliver high-quality, seamless, and equitable mobility options for all travelers. In later phases of the program, selected research areas will be identified for further development, benefits assessment, and potential prototyping, testing, and deployment of emerging technologies.

MOD research will investigate opportunities, emerging technologies, and new business models in which the individual traveler can experience high-quality mobility choices to complete point-to-point trips, regardless of their individual needs and choices. This includes personal, integrated trips to individual destinations in a seamless, multimodal environment. MOD will work to enable and leverage advancements in technology and operations to create an environment in which all travelers have safe mobility options; ensuring reliable, equitable, informed, and efficient travel in a multimodal network that prioritizes individual on-demand mobility. These projects complement DOT's Smart Cities initiative. They take into consideration the important tenets of Ladders of Opportunity as well as the socioeconomic, employment, equity, and accessibility impacts of large-scale transportation infrastructure investments. The integrated innovative technologies, and transportation investments are also consistent with the principles and practices of land-use planning to address environmental issues and concerns.

MARAD

As resources permit, MARAD will pursue opportunities with OST-R, other modes, and industry, to advance system design and integration for improving passenger travel and access to opportunity, and reducing congestion through collaborative research partnerships.

Possible opportunities include:

- Partnering with ITS JPO to explore contributions that maritime can make to the intelligent transportation network;
- Leveraging partnerships, opportunities, and resources when available in support of improved passenger travel and access to opportunity for U.S. citizens;
- Investigating and piloting technology based on efficient processes to reduce congestion and flows around maritime ports; and
- Promoting the use of maritime transportation as an option for moving heavy freight, and helping to reduce instances of conflict with freight and passenger movement on our highways.

ITS JPO

The ITS JPO has two primary strategic priorities: Realizing Connected Vehicle (CV) Implementation and Advancing Automation. The first priority builds on the substantial progress made in recent years around design, testing, and planning for CVs to be deployed across the nation. The second priority is research, development, and adoption of automation-related technologies as they emerge. They both reflect a sense of where transportation research and innovation is heading, but they are not exclusive of other technologies or research areas.

The ITS JPO has four additional strategic priorities that represent supplemental and interdependent activities critical to achieving the Program's vision: Emerging Technology, Enterprise Data, Interoperability, and Accelerating Deployment. All six strategic priorities are discussed below.

CROSS MODAL RESEARCH AREA: Accessible Transportation Technologies Research Initiative (ATTRI)

Transportation plays a critical role in enhancing access to education, jobs, and healthcare for people with disabilities, veterans with disabilities, and seniors. Launched in 2012, ATTRI is a joint, cross-modal U.S. DOT initiative co-led by FHWA and FTA with support from the ITS JPO and other Federal partners, including the National Institute on Disability, Independent Living and Rehabilitation Research (NIDILRR), and the Veterans Administration. ATTRI focuses on research and development to improve the mobility of travelers with disabilities through the use of ITS and other advanced technologies. The initiative aims to enhance the capability of travelers with disabilities to reliably, safely, and independently accomplish their unique travel plans.

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ACCESSIBLE TRANSPORTATION TECHNOLOGIES RESEARCH INITIATIVE

Connected Vehicles

The Connected Vehicle Program focuses on transferring research results into real world application. Program objectives are to:

- Advance knowledge of Connected Vehicle (CV) systems
- Evaluate high priority CV applications
- Support State and local, and transit agency integrating CV environment deployments

The Connected Vehicle program supports the following activities:

- NHTSA V2V rule;
- FHWA V2I guidance;
- Development of a scalable operational Security Credential Management System; and
- Continued support of connected vehicle pilots.

In response to Congress, this program will conduct research in using a Wi-Fi and Dedicated Short Range Communications (DSRC) spectrum for collision-avoidance technologies. In addition, the program will promote technology transfer of over 60 connected vehicle applications. Connected vehicle technology research and development will also be leveraged in the Department's Smart City Challenge efforts.

Research program outcomes include:

- Demonstrations of connected vehicle environments that fit into real-world environments of today.
- Real-time and real-world data to help with transportation planning and transportation system operations.
- Increases in safety, mobility, system efficiency, and access to resources for disadvantaged groups; and decreases in negative environmental impacts, such as vehicle emissions and the need for physical expansion and noise.
- Increased opportunities to partner with non-government groups, such as private industry and universities.
- Decreases in undesirable transportation impacts to the environment and society.
- Reduction of fatalities through weather-related safety, infrastructure-based, and other applications.

Automated Vehicles

The world is facing the emergence of automated vehicles. The focus of the Automated Vehicles program is to enable the U.S. DOT to keep up with industry's fast pace of technology development. Introduction of this technology presents both opportunities and risks for the safety, efficiency, and sustainability of the transportation system. U.S. leadership in this industry is not a foregone conclusion, and the U.S. DOT is lagging behind a number of government and private entities already focused on topics related to automated road-vehicle systems and related technologies. The development and adoption of safe vehicle automation through real-world pilot projects would enable the Department to catch up with other international activities. A key component of the Smart City Challenge includes investigating the impact of automated vehicle technology on mobility, safety, and sustainability. At current budget levels, participation will be more on the level of observation and planning preparation, rather than the extensive research needed to safely expedite the integration of these technologies into the U.S. transportation system.

Smart City Challenge

The U.S. DOT pledged up to $40 million to one city to help it define what it means to be a "Smart City "and become the country's first city to fully integrate innovative technologies—self-driving cars, connected vehicles, and smart sensors—into their transportation network. The vision of the Smart City Challenge was to demonstrate and evaluate a holistic, integrated approach to improving surface transportation performance within a city and integrate this approach with other smart city domains, such as public safety, public services, and energy. The Smart City Challenge generated enormous enthusiasm—78 cities submitted applications and 7 cities (Austin, Columbus, Denver, Kansas City, Pittsburgh, Portland, and San Francisco) were selected as finalists. These seven cities were able to leverage U.S. DOT's $40 million grant to raise approximately $500 million more in funding—with a vast majority from a diverse group of over 150 partners. On June 23, 2016, Secretary Foxx announced Columbus, Ohio as the winner.

The objectives of the ITS JPO's Automated Vehicles research are to:

- Define the core elements and the performance criteria for automation;
- Test automation components in the CV Pilots and the Smart City Challenge, as well as in other test situations; and
- Define the Federal role in facilitating and encouraging deployment of automated systems.

Expected research program outcomes are to:

- Provide guidance to State and local agencies to improve the understanding of the potential impacts of automated vehicles on the assets they manage;
- Expand the reach of transportation modes to disabled and older users and provide "last-mile" connectivity services for all users;
- Increase the efficiency and effectiveness of existing transportation systems;
- Reduce the number and severity of crashes caused by drivers or by other conditions (e.g. weather, pedestrians, and roadway conditions); and
- Reduce aggressive driving.

Emerging Technology

This program category scans the technology horizon for emerging technologies and trends with a focus on future generations of intermodal transportation systems. The ITS JPO will work with the winning city of U.S. DOT's Smart City Challenge to demonstrate how advanced data and ITS technologies and applications can be used to reduce congestion, keep travelers safe, use energy more efficiently, respond to climate change, connect underserved communities, and support economic vitality. ITS JPO is also working with the Saint Lawrence Seaway Development Corporation (SLSDC) and MARAD to implement emerging technologies in projects to enhance goods movement.

Graphic from the Smart City Challenge competition

The objectives of Emerging Technology research are to:

- Establish ways to use new technologies and decision-support tools for real-time needs, and to meet longer-term public policy objectives; and
- Integrate the operational characteristics of new technologies into CV and legacy systems and applications.

Expected research program outcomes include:

- Stronger relationships and partnerships with private industry and universities;
- Improved ability to accommodate new ITS technologies and
- Economic growth through innovation and technological leadership.

Enterprise Data

This program category will continue existing research into operational data capture from stationary sensors, mobile devices, and connected vehicles, and expansion into research activities to develop mechanisms for housing, sharing, analyzing, transporting, and applying the data for improved safety and mobility across all modes of travel. Ultimately, these efforts are at the root of developing the data underpinnings of the transportation sector for the Internet of Things and Smart Cities. They will enable agility, data sharing, and privacy protection throughout the future intelligent transportation system. Research relating to Smart Cities will focus on demonstrating how sharing data from connected and automated vehicles and combining it with other data sources can fuel innovative public and private transportation services, such as mobility on demand and urban freight and logistic services.

The objectives of Enterprise Data research are to:

- Integrate new and larger data sets in a scalable and replicable way
- Develop and test a model for data management and ownership; and
- Enable new business relationships between the public and private sectors and to ensure privacy protection.

Expected program outcomes include:

- Methods to share information efficiently while ensuring data privacy protection;
- Methods to manage and leverage big data;
- Performance monitoring and system agility;
- Innovation in new applications and research;
- New revenue opportunities and business models for sustaining data operations; and
- Improved quality (accuracy and timeliness) of data.

Interoperability

This program is essential to ensure effective connectivity between devices and systems. Interoperability focuses on enabling ITS elements in vehicles, devices, infrastructure, and applications to effectively communicate with other parts of the system as needed; regardless of where they are built and where or when they are used. Interoperability is critical to facilitating the implementation of CV systems and the introduction of automated transportation systems as system interdependencies increase, not only in number, but also in complexity. Standards, system architectures, and certification must continue to evolve to ensure that technological advancements are reflected, and the required backward compatibility and interoperability are maintained. In addition, technical research on cyber security, human factors, and regulatory decision-making testing ensure a sound industrial base. The goal of this research is to ensure effective connectivity from the device level to the transportation system level.

The objectives of Interoperability research are to:

- Develop and maintain a National ITS Architecture sufficient to ensure required nationwide interoperability while maximizing flexibilities;
- Develop and maintain an inventory of candidate interfaces for standardization and support of standards development efforts for interfaces where there is greatest public interest, including those required to support regulatory activity; and
- Develop international harmonization standards and architectures in line with the public interest; and facilitate availability of testing and certification processes and procedures to ensure required interoperability and regulatory compliance.

Expected program outcomes include:

- Nationwide interoperability for vehicles and other participants in ITS;

- Transportation solutions that resolve interoperability among developers, users, agencies, and modes to increase efficiencies, reduce costs, and provide real-time and effective information;
- Increased efficiency in communication and information sharing between transportation agencies and users;
- Increased efficiencies in the economic enterprise; and
- Maintenance of the forward and backward interoperability of ITS equipment and reduced need for re-investment over time.

Accelerating Deployment

This program category stimulates adoption of technology and helps stakeholders and localities deploy maturing ITS systems. It also provides knowledge transfer and supports technical assistance, training, outreach, program evaluation, and other stakeholder engagement to advance ITS from research to initial adoption to wider scale deployment, in coordination with other stakeholders at the Federal, State, regional, and local level.

The objectives of Accelerating Deployment research are to:

- Define collaboration and communication mechanisms and targets to encourage public and private investment;
- Develop comprehensive cost benefits and analytic tools that allow deployers to understand the financial and operational benefits of new technologies and systems; and
- Establish the tools that support the new user base.

Expected program outcomes are to:

- Provide deployment support by assisting with transition planning, training, transition plans, timelines and milestone development;
- Provide communication and education support to facilitate awareness, understanding, acceptance, adoption, and deployment of ITS technologies across all stakeholder groups;
- Ensure effective partnerships are fostered and developed at various levels—executive, program, and project; and
- Develop partnerships to encompass a wide range of public and private partners.

ITS JPO: Vehicle-to-Infrastructure Deployment Coalition

To strengthen research coordination across modes, jurisdictions, and institutions, FHWA is establishing a Vehicle-to-Infrastructure (V2I) Deployment Coalition. This coalition aims at fostering broader stakeholder participation, coordinating the current and upcoming CV deployment programs and initiatives, and disseminating educational and advisory information. The membership of this coalition will include representatives of government agencies, industry, and academia.

The activities for the coalition include comprehensive outreach to all transportation modes and system owner/operators to gather input and feedback on deployment issues. Outreach vehicles include such activities as webinars, workshops, and peer exchange forums; gap-filling research activities; and support in establishing establishment of guidelines, recommended practices, and standards relating to deployment initiatives. The V2I Deployment Coalition will maximize benefits through multi-faceted stakeholder participation, disseminate state-of-the-art information on ongoing efforts, and identify specific research needs.

Visualizing connected vehicles on the highway

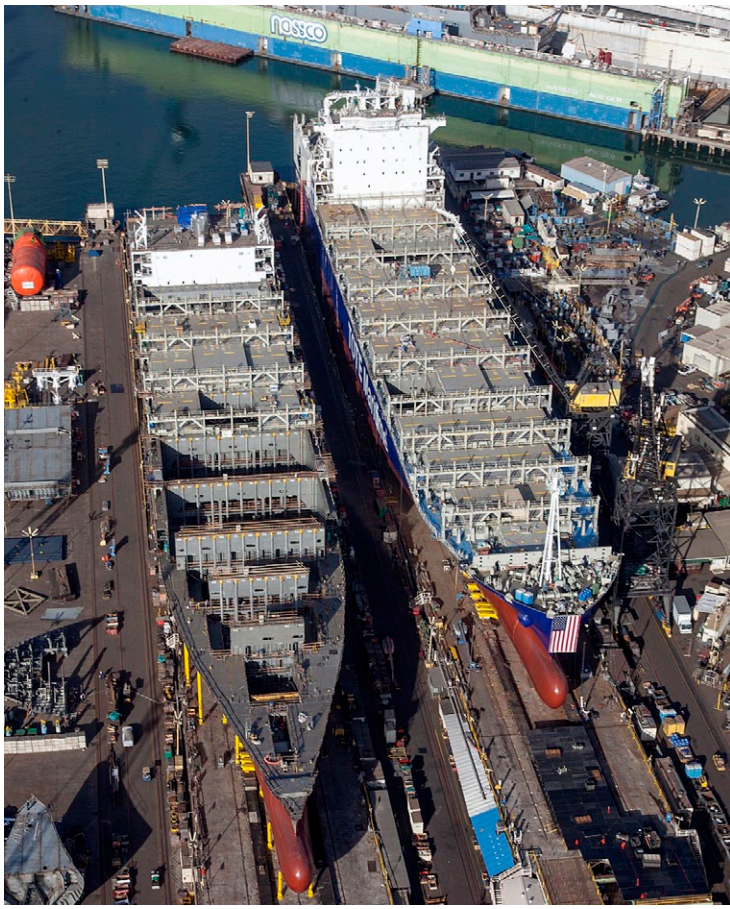
Port Performance Freight Statistics Program

Section 6018 of the FAST Act directed the Bureau of Transportation Statistics (BTS) to implement a Port Performance Freight Statistics Program (Program) on behalf of the U.S. Department of Transportation (U.S. DOT). As part of this Program, Section 6018 requires BTS to develop nationally consistent performance measures for, at minimum, the Nation's top 25 ports by tonnage, 20-foot equivalent unit (TEU), and dry bulk. Section 6018 also directs BTS to establish a Port Performance Freight Statistics Working Group to provide recommendations for specifications and data measurements for port performance measures, and for a process to collect them.

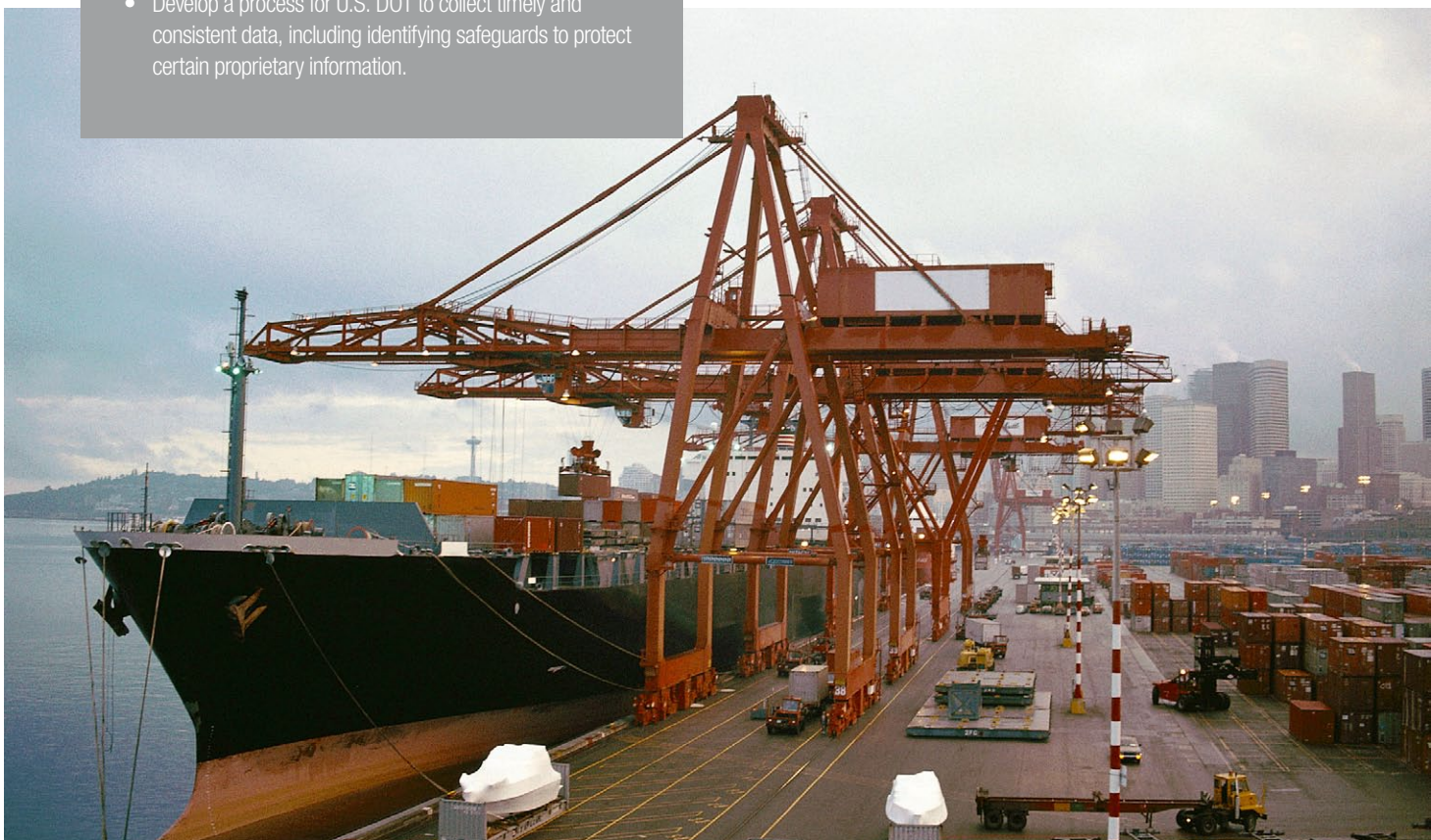
The Port Performance Freight Statistics Working Group, made up of representatives from the freight industry, labor groups, and the Transportation Research Board, is supporting the development of nationally consistent measures of performance at the nation's largest ports. The working group is supporting the BTS director to meet the following objectives:

- Identify a generally accepted industry standard for port data collection and reporting.
- Specify standards for collecting data and reporting port performance measures.
- Make recommendation for statistics on U.S. port capacity and throughput.
- Develop a process for U.S. DOT to collect timely and consistent data, including identifying safeguards to protect certain proprietary information.

Aerial view of large container ship yard with two vessels



Below: loading a large container vessel



4.3. Improving Infrastructure

Improving Infrastructure covers issues related to the condition, costs, funding, and delivery of the transportation infrastructure, as well as methods and technologies to increase its durability and resilience. The U.S. DOT's goal is to improve the durability and extend the life of the transportation infrastructure, preserve the existing transportation system, and ensure that the United States proactively maintains critical transportation infrastructure in a state of good repair.

Underinvestment in transportation infrastructure across every mode has created a massive maintenance backlog, which has increased maintenance costs and reduced transportation system performance. Of the 612,000 public road bridges in the transportation system, nearly one-tenth of them are structurally deficient. Poor pavement conditions cost the average motorist an estimated $516 annually in additional fuel and repair costs. Public transit systems in the United States face an estimated $86 billion backlog in preservation investments. As a result, users of many of the older systems are now experiencing more frequent service disruptions. Intercity passenger rail also faces a serious maintenance deficit—the Northeast rail corridor alone requires investments of nearly $1.5 billion per year over 15 years to bring it into a state of good repair and maintain that condition. The United States' largest ports association has projected that nearly $155 billion in investment from 2016 to 2020 will be needed to upgrade ports' waterside facilities to accommodate increasingly larger vessels. More than 60 percent of the navigation locks on inland waterways are over 50 years of age and require frequent repair, increasing congestion and the cost of transporting commodities. Finally, in addition to preserving structures, transportation agencies face growing challenges in preserving and updating information and communications technologies to keep pace with technological change and ensure continuity of operations.

Transportation research can support the development and application of advanced materials and technologies to improve durability, extend the life of the transportation infrastructure, and reduce maintenance needs. Advances in robotics, sensors, and navigation systems can improve the inspection, monitoring, and maintenance of infrastructure. Inspection tools such as ground-penetrating radar, electrical resistivity, and acoustic arrays can help to assess structural conditions. Development of advanced materials can enable new infrastructure designs, improve structural resilience to natural disasters, and accelerate construction and repair. Research into rapid reconstruction and repair methods can help to mitigate construction delays and work zone safety risks, and speed disaster recovery.

Deteriorating infrastructure conditions are a result of underinvestment and deferred maintenance. Many transportation agencies lack sufficient funding to maintain infrastructure in a state of good repair. Funding scarcity often forces transportation agencies to defer maintenance of assets; the ultimate costs associated with repair then increase, further worsening the problem. Adjusted for inflation, transportation spending at all levels of government fell by $29 billion, or 12 percent, between 2002 and 2012. Transportation user fee revenues are also not keeping up with the costs of maintaining, operating, and expanding infrastructure assets. In response, many State and local governments have found innovative ways to raise revenues and finance transportation projects. Some transportation agencies have used public-private partnerships to deliver privately financed highway, transit, and rail projects. Further research can help transportation agencies evaluate and use innovative sources of revenue, finance, and contracting to deliver transportation projects

The effects of climate change—warmer temperatures, rising sea levels, and increased frequency of severe weather—will damage the infrastructure and make travel conditions across all modes increasingly unreliable and ultimately more expensive. Higher temperatures may cause warping of railroad tracks, and increase evaporation of lakes and waterways used by cargo vessels. Increased frequency of severe weather will cause more frequent disruptions to travel and increase recovery costs. Sea-level rise, coupled with a higher frequency of severe weather, will make low-lying infrastructure increasingly vulnerable to flooding from storm surges. Governments may need to divert funds

to relocating infrastructure and completing weather-related repairs—inconveniencing the public with closures, detours, and disruptions. The regional impacts of climate change on infrastructure are not well understood and further research can assist decision makers with assessing vulnerabilities and planning the wide range of adaptation strategies that will be required.

There is opportunity for collaboration in the following areas:

- Transportation system research and analysis that assesses infrastructure investments and the impact of cargos on system assets.
- Facilitated research and studies that evaluate the potential for increased utilization of waterway transportation in an effort to increase the longevity of other surface transportation infrastructure.
- Research to better monitor the condition of the Nation's infrastructure and to integrate conditions and performance information to more efficiently manage our infrastructure assets.

FHWA

Key R&D strategies for improving the infrastructure include:

- Long Term Infrastructure (Pavement and Bridge) Performance Research
- Enable greater automation in highway construction and integration of data from design to construction to asset management

Testing bridge components at the Turner Fairbank Highway Research Center

- Improving the management of infrastructure assets; and
- Improving highway condition and performance through improvements in design, materials, construction and maintenance innovations.

Examples of FHWA's infrastructure research are highlighted below.

Future Interstate Study

The FHWA has entered into a cooperative agreement with TRB to conduct a Future Interstate System Study, as required by the FAST Act. The goal of this agreement is to plan, perform, and document a study that examines the actions needed to upgrade and restore the Interstate System as a premier system that meets the growing and shifting demands of the 21st Century. The study will contain specific recommendations about the features, standards, capacity needs, application of technologies, and intergovernmental roles to upgrade the Interstate System; including any revisions to law and regulations as appropriate.

Highway Tunnel Fire Suppression Systems

This topic was selected for the FY 2016 GBP and the study is in the early planning stage. The purpose of the study is to examine the state of technology in countries where fire suppression systems have been successfully deployed in highway tunnels. The goal is to understand effective practices and lessons learned and then bring this information to U.S. tunnel owners so that they can improve safety, streamline operations, and more effectively conduct tunnel research. The study is expected to accelerate the deployment of technology that will enhance safety in tunnels, produce long-term cost savings, and promote innovation that has been proven and accepted in other important industries.

Ultra-High Performance Concrete Connections for Prefabricated Bridge Elements

FHWA's pioneering research efforts in bridge construction technologies and advanced concretes has led to the development of the Ultra-High Performance Concrete (UHPC) Connections innovation that is transforming the way bridges are constructed. UHPC is the next generation of concrete, providing exceptional strength and resiliency. Bridge construction is embracing the use of prefabricated systems because of the high quality of the components and the ability to accelerate construction activities. However, wider adoption of precast bridge elements has been hindered by the lack

of commensurately performing connection solutions. UHPC connections address this Achilles' heel and thus facilitate broad adoption of prefabricated systems and the concurrent performance benefits that come from standardization and factory-controlled production of bridge components. Since the first US deployment of the UHPC connections technology in 2009, there have been more than 60 further deployments across more than a dozen States. Ongoing projects include interstate highway bridges, major river crossings, and miles-long viaducts. More than 40 States are working toward integrating this solution into their bridge programs with the ongoing support of the Every Day Counts program.

LTPP InfoPave™

Launched in 2014, LTPP InfoPave™ gives users the ability to easily tap into data, supporting documentation and findings derived from the LTPP Program. The LTPP Program was formally established by the U.S. Congress in the Surface Transportation and Uniform Relocation Assistance Act of 1987, as part of the first Strategic Highway Research Program.

LTPP InfoPave™ is an important part of FHWA's efforts to improving infrastructure durability and supporting open data. Understanding pavement performance and reliable performance predictions are fundamental to effective management of pavement assets. The LTPP Program has made significant contributions to improve performance prediction and understand how and why pavements behave as they do. Decades later, MAP-21 called for a data-driven performance management framework to be used by State highway agencies to guide pavement investment decisions. Data, information, and products offered through LTPP InfoPave™ will be instrumental in providing pavement performance information to help State agencies fulfill the performance requirements of MAP-21.

Civil Integrated Management

The rapid development of information technologies and technological advancement in heavy highway construction equipment and processes are dynamically changing the design, construction, and maintenance of a world class transportation system. Civil Integrated Management (CIM) is the collection, organization, managed accessibility, and use of accurate data and information throughout the life cycle of a transportation asset. It impacts a wide range of purposes including planning, environmental assessment, surveying, construction, maintenance, asset management, and risk assessment. FHWA is deploying the CIM related technologies and techniques of 3, 4, 5, xD modeling, intelligent compaction, and e-Construction. As a part of CIM, FHWA is also demonstrating how data from design and construction can be integrated with operations and maintenance. FHWA is working closely with partners (contractors, consultants, vendors, and owner agencies) to perform research, development and national deployment of the technology. In particular, FHWA is focusing on encouraging data interoperability and identifying technologies and

CROSS-MODAL RESEARCH AREA: Infrastructure Resilience

The ability to identify, assess, and mitigate threats to critical infrastructure is essential to maintaining secure and resilient systems capable of rapid recovery from hazards; including natural disasters, climate change, cyber-attacks, industrial accidents, pandemics, terrorism, sabotage, and destructive criminal activity. Understanding the behavior of infrastructure systems in the face of threats and vulnerabilities, and taking steps to make those systems more resilient, are critical to risk management and drive Federal R&D efforts.

The Transportation Systems Sector was identified as one of five National Priority Areas for R&D investment in the National Critical Infrastructure Security and Resilience (CISR) Research and Development (R&D) Plan (November 2015). The Office of the Secretary of Transportation's Office of Intelligence, Security and Emergency Response represents DOT as the co-Sector Specific Agency for the Transportation Systems Sector. The Sector in now implementing the CISR R&D Plan. Position, Navigation, and Timing (PNT) systems and high-performance materials are among the areas identified as priorities for cross-modal research.

The Department also recognizes the need to respond to the threats posed by climate change to our Nation's transportation infrastructure. Following the successful Gulf Coast Phase II study in Mobile, Alabama, which produced nationally-recognized vulnerability assessment tools, the Department is now working with local, State, and Federal stakeholders in Hampton Roads, Virginia, to develop tools and methodologies for quantifying the cost of adaptation to sea level rise, storm surge, and other climate change-related threats. Both studies were sponsored by U.S. DOT's Center for Climate Change and Environmental Forecasting and align with the Department's Climate Adaptation Plan–Ensuring Transportation Infrastructure and System Resilience, published in 2014.

techniques that leverage CIM data to improve our nation's highways safety, efficiency and effectiveness.

Infrastructure Resilience to Extreme Weather Events and Changes in Climate

This study was conducted in 2015 under the pilot Global Benchmarking Program. The purpose of the study was to identify innovative and best practices abroad that could help advance the development and implementation of transportation adaptation strategies in the United States. Based on information collected through a virtual international review, the study found that the Netherlands, Denmark, and Norway have moved beyond research and are actively constructing assets incorporating climate resilience.

FHWA is compiling findings from the study into a report that will be shared with the United States transportation community. Specific implementation actions will be followed to help transportation agencies effectively analyze climate impacts and adapt the way they build and maintain infrastructure. Preliminary actions include updating national guidelines and manuals based on key study findings, developing a National Highway Institute training course, and increasing cooperation on adaptation issues with other government agencies. Connections developed with counterparts in the countries visited are resulting in further information exchange and collaboration.

Climate Change Adaptation

To better understand the potential impacts of climate change on the transportation systems, and to develop methods and approaches to conduct assessments of risk and vulnerability, FHWA partnered with State DOTs, MPOs and Federal Lands Highway Divisions from around the country on 24 climate resilience pilot projects. In addition, FHWA has sponsored four cooperative projects in the Gulf Coast, Northeast, Southeast, and New Mexico. These combined 28 projects have collectively produced a huge body of knowledge; this has changed how the transportation profession approaches this important and critical topic. Lessons learned, tools and methodologies created, and techniques used from these pilots and projects will be used to update FHWA's key resource on the topic: Climate Change and Extreme Weather Vulnerability Assessment Framework. More information is available at: **http://www.fhwa.dot.gov/environment/climate_change/adaptation**

Big Data or Preserving Infrastructure: FHWA's Long-Term Bridge Performance (LTBP) Program's Bridge Portal

The Bridge Portal is a web based Data Management and Business Intelligence tool that was developed as part of FHWA's LTBP Program. The LTBP Bridge Portal has a two-fold purpose: (1) provide for storage, retrieval, dissemination, analysis and visualization of data collected through LTBP research efforts, and (2) provide users with the ability to holistically assess bridge performance. As the Bridge Portal becomes more fully developed and populated, the bridge-related data sources, along with the visualization and statistical tools in the Bridge Portal, will enable a more comprehensive understanding of how bridges perform from both a network and an individual project perspective.

FAA

Recognizing that weather accounts for the majority of air traffic delays and that a significant portion of those delays are potentially avoidable, the FAA continues to conduct R&D to mitigate the impact of weather on the National Airspace System. The NextGen NAS Infrastructure portfolio conducts pre-implementation activities to reduce risk for aviation weather-related and cross-cutting engineering issues. This portfolio provides the research, development, and analysis of portfolio capabilities such as validation activities, human system engineering, and demonstrations. It addresses aviation weather-related issues by supporting the improvement of: (1) air traffic management (ATM) decision-making during adverse weather conditions, (2) weather forecasting in the transformed NAS, and (3) existing weather infrastructure.

Airfield design is often a process that must balance safety, efficiency, capacity and other factors. Studies performed by the Federal Aviation Administration (FAA) over the last several years analyzed the role of taxiway and apron design coupled with operational procedures to reduce the probability of runway incursions. Airport Design and Operations Teams subjected the cumulative study results to a series of assessments at selected airports across the National Airspace System (NAS). The office of airports addressed a variety of airport-specific issues at different types of airports, including issues involving taxiway layout inherited from an older airfield runway configuration, issues associated with runway crossings, and discontinuing the practice of using a runway as a taxiway. All such findings are culminated into updates to airport circulars aimed to improve airfield infrastructure by design.

An important aspect of airfield design is maintaining a safe runway environment. A critical aspect of enhancing runway safety is to improve the runway safety area (RSA), as needed. RSAs create a buffer zone around a runway to provide a safe environment if the plane overruns, undershoots, or veers off the side of the runway. Such incidents are known as runway excursions. In the event of an excursion, RSAs provide a safe and clear area to protect property and people on board the plane, as well as in the surrounding area. When there is not enough land at the end of a runway to allow for a standard safety area, a type of mitigation, known as engineered materials arresting system (EMAS) is often installed. EMAS is a bed of crushable material, designed to safely decelerate an aircraft, in the event of an overrun beyond the runway. This happens by the material crushing under the weight of the aircraft.

The concept of EMAS began when NTSB issued a safety recommendation to initiate research on soft ground arresting systems, in wake of aircraft overruns. The FAA then launched a research and development program with this effort in 1986. In 1994, the FAA developed a cooperative research and development agreement with Engineered Arresting Systems Corporation (ESCO) of Zodiac Arresting Systems, to develop and test the first bed, and the first prototype was installed at New York's John F. Kennedy Airport (JFK) in 1996. To date, EMAS has safely arrested 11 aircraft, saving a total of 282 passengers on board.

FTA

Transit Asset Management and Innovation

With the Nation facing a backlog of transit infrastructure repairs that is approaching $100 billion and still growing, FTA has a goal of bringing transit infrastructure into a state of good repair. Statutorily referenced in 49 USC 5328 and Section 20019 of MAP-21, transit asset management will implement an approach for assessing needs and prioritizing investments for bringing the nation's public transit system into a state of good repair.

This program will provide research to transit industry for developing and demonstrating various asset management technology and tools, provide guidance and best practices to assist transit agencies to establish transit asset management plans, and implement a National Transit Asset Management System to measure asset condition.

Anticipated program activities include:

- Demonstration projects on innovative transit asset management practices, bus driver visibility, and crash energy management.
- Research and demonstration projects include bus operator protection, composite bus body, and platform edge doors.
- Training and technical support projects include implementation of asset management plans.
- Assessments of low- and no-emission vehicle components intended for use in transit buses.

Expected program outcomes include an improved state of good repair of transit infrastructure resulting from innovative asset improvement technologies (e.g., remote, auto, and condition-based assessment of rail-track conditions) and performance specifications and life cycle metrics for assets.

PHMSA

Hazardous Materials Safety RD&T

The Hazardous Materials Safety RD&T program plans to continue funding research in the area of preserving infrastructure. Hazardous materials research addresses issues related to the condition, costs, funding, and delivery of hazardous materials transportation infrastructure; as well as methods and technologies to increase its durability and resilience. The program

Workers near excavated pipeline

goal is to improve the durability and extend the life of hazardous materials transportation infrastructure, preserve the existing transportation system, and ensure that the U.S. proactively maintains critical transportation infrastructure in a state of good repair.

Hazardous materials transportation research can support the development and application of advanced materials and technologies to improve durability, extend the life of hazardous materials transportation infrastructure, and reduce maintenance needs. Advances in robotics, sensors, and navigation systems can improve the inspection, monitoring, and maintenance of infrastructure. Inspection tools such as ground-penetrating radar, electrical resistivity, and acoustic arrays can assist the assessment of structural conditions. The development of advanced materials could enable new infrastructure designs, improve structural resilience to natural disasters, and accelerate construction and repair. Research into rapid reconstruction and repair methods can help to mitigate the construction delays and work zone safety risks and speed recovery.

Pipeline Safety RD&T

The Pipeline Safety RD&T program research supports the development and application of advanced materials and technologies to improve durability, extend the life of pipeline transportation infrastructure, and reduce maintenance needs. Advances in robotics, sensors, and navigation systems can improve the inspection, monitoring, and maintenance of infrastructure. Pipeline inspection tools such as ground-penetrating radar, electrical resistivity, and acoustic arrays can help to assess structural conditions.

MARAD

Maritime transportation can significantly contribute to preserving existing surface transportation infrastructure and extending the service life of our future surface infrastructure by shifting heavy and/or destructive cargoes to our waterways, thereby reducing infrastructure construction and maintenance costs. Opportunity for collaborative research exists in the following areas:

- Transportation system research and analysis that assesses infrastructure investments and impact of cargos on system assets.
- Facilitate research and studies that evaluate the potential for increased utilization of waterway transportation in an effort to increase the longevity of other surface transportation infrastructure.
- Promote research to better monitor the condition of our infrastructure and integrate conditions and performance information for more efficient management of our infrastructure assets.

ITS JPO

The ITS JPO supports infrastructure deployment activities at 5 pilot locations, Southeast Michigan, New York City, Tampa Florida, Wyoming, and Columbus, Ohio. The JPO provides research, development and training to support infrastructure technical assistance, road side unit enhancements, infrastructure certification, architecture and standards. The ITS JPO supports knowledge and technology transfer in key areas with key stakeholders such as the FHWA's Vehicle to Infrastructure (V2I) Deployment Guidance as well as AASHTO, the Institute of Transportation Engineers (ITE), and ITS America (ITSA).

4.4. Preserving the Environment

Preserving the Environment covers the effects of transportation activities on climate change and the environment as a whole (including water, noise, and air pollution, and habitat degradation) and discusses approaches to avoid or mitigate those effects. The U.S. DOT's goal is to advance environmentally sustainable policies and investments that reduce carbon and other harmful emissions from transportation sources.

Transportation activities can have significant negative impacts on the natural environment and human health. They are a cause of air, water, and noise pollution and support land use patterns that divide and degrade habitats. They are also a major source of GHG emissions that contribute to climate change.

Although stricter regulation and technological advances in recent decades have helped to mitigate the impacts of transportation activities on the environment, continued transportation research can support the development of cost-effective mitigations. These include practices to reduce the impacts of storm water runoff and preserve wetlands; policies and technologies to minimize emissions of air pollutants, and technologies to prevent the introduction of aquatic invasive species via ballast water discharges from ships. Continued research can also develop better tools to evaluate the impact of transportation activities on wildlife, habitats, and natural resources.

Research can help to understand the relationship between transportation, development, and land use. Sprawling development patterns in Americans metropolitan areas have lengthened commutes and increased dependence on automobiles, leading to increased congestion and reducing access to affordable, convenient alternatives to automobile travel.[14, 15] The geographic expansion of metropolitan areas has also impacted the environment by contributing to air pollution and the loss of farmland and natural habitat. As metropolitan regions have increased in scale and complexity and become more interdependent, these issues have become increasingly regional; and traditional decision-making structures and institutions have been challenged to coordinate responses across jurisdictions. U.S. DOT research is improving our understanding of travel patterns in these growing megaregions and helping transportation decision makers develop strategies to facilitate freight and passenger movements while maintaining healthy, sustainable communities.

More research is also needed to understand how transportation conditions affect human health. For example, further research is needed on the effect of particulate matter emissions on human health and the effectiveness of policies and regulations designed to curtail emissions. Research is also needed to quantify aircraft noise and emissions and their environmental impacts, develop cost-beneficial impact mitigation options, and to develop ways for improving energy efficiency and alternate fuel sources.

In 2014, the transportation sector as a whole accounted for 26 percent of total U.S. GHG emissions.[16] Passenger cars and light and heavy trucks were the source of approximately 84 percent of these emissions. Other modes—maritime, rail, and aviation—account for the remaining 16 percent of emissions. Progress in stemming GHG emissions has been uneven across the transportation sector. Transportation GHG emissions grew by 14 percent between 1990 and 2014; however, emissions from heavy trucks increased by 75 percent over the same period.[17] Methane emissions associated with pipeline and storage leaks have been recognized as a significant contributor to greenhouse gas emissions.

The Paris Climate Accords, adopted in December 2015, have committed the United States and the global community to holding the increase in the global average temperature to well below 2°C above pre-industrial

levels. Consistent with the Paris Accord, the United States has announced its intention to reduce its GHG emissions by 26 to 28 percent below its 2005 level in 2025 and to make best efforts to reduce its emissions by 28 percent. Achieving these goals will require a long-term, multifaceted transformation of the transportation sector.

Strategies to reduce GHG emissions include: improving the fuel efficiency of vehicles, ships, and aircraft; supporting electric vehicle and low-carbon fuel technologies and infrastructure, and reducing congestion by improving operations and managing travel demand. This could also accelerate the development and adoption of alternative fuel and electric vehicle vessel and rail technologies and the infrastructure needed to support them. As automated, electric, and alternative fuel vehicles comprise a greater segment of the market for passenger vehicles, research will be needed to understand the implications for infrastructure and the environment.

FHWA

Key R&D strategies for preserving the environment include:

- Advancing the connected vehicle initiative;
- Minimizing the environmental impacts of transportation investments; and
- Streamlining the project delivery process.

Towards more Sustainable Highway Practices

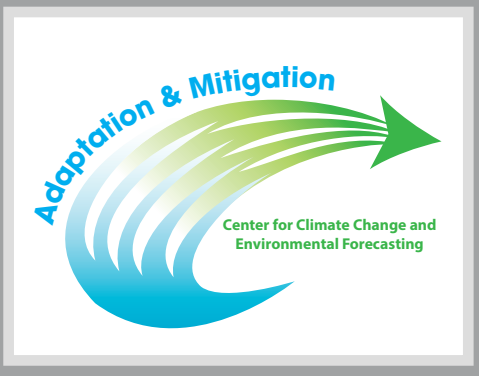
FHWA plans to improve its understanding of the effects of transportation activities on the natural and social environment. With this objective in mind, the agency developed the Infrastructure Voluntary Evaluation Sustainability Tool (INVEST) as a practical, web-based collection of voluntary best practices or criteria, designed to help transportation agencies integrate sustainability into their programs (policies, processes, procedures, and practices) and projects. Transportation agencies and their consultants are using INVEST to evaluate and help to integrate sustainability into their programs and projects. More information is available at:

www.sustainablehighways.dot.gov

CROSS MODAL RESEARCH AREA: Climate Change Mitigation

The Center for Climate Change and Environmental Forecasting (CCCEF) is the U.S. DOTs interagency group tasked with coordinating the Department's response to the challenges of climate change adaptation and mitigation. The Center's activities are funded through a "pooled fund" approach via contributions from Operating Administrations and directed by a Steering Committee composed of Operating Administration representatives. The Center funds research projects, develops policies, conducts short- and long-term strategic planning, and engages in a variety of outreach activities. The Center is drafting a Departmental Policy Statement on climate change mitigation and an accompanying Climate Change Mitigation Plan, which will set the agenda for the Department's goals in this area over the next five years and beyond.

U.S. DOT recognizes that developing alternative transportation fuel sources is key to achieving the aggressive GHG reduction targets set by the U.S. Government. The Department coordinates a range of cross-modal initiatives in this area. For example, in November 2016 the Depart- ment will designate national plug-in electric vehicle charging and hydrogen, propane, and natural gas fueling corridors in strategic locations along major highways to improve the mobility of alternative fuel vehicles. These corridors will be used to achieve the goal of strategic deployment of fueling infrastructure in the designated corridors by the end of 2020, which is consistent with the five-year time frame of this RD&T Strategic Plan.



Developing Pollinator-Friendly Practices for Sustainable Highway Roadsides

FHWA has developed best management practices and other resources for transportation agencies to implement pollinator-friendly practices in roadside design and maintenance. The tools provide information on how transportation agencies can reduce costs, increase long-term sustainability, and improve overall ecosystem health, while improving and protecting habitat for pollinators and other species. The FHWA pollinator program demonstrates cost savings through such pollinator-friendly practices as reducing mowing and how to improve sustainability through native plantings. More information is available at: **https://www.environment.fhwa.dot.gov/ecosystems/vegmgmt_pollinators.asp**

FAA

Despite the technological advancements achieved during the last 40 years, aircraft noise still affects people living near airports, and aircraft emissions continue to be an issue at local, regional, and global scales. While energy efficiency and local environmental issues have traditionally been the primary drivers of aeronautics innovation, the current and projected effects of aviation emissions on our global climate are a serious long-term environmental issue facing the aviation industry. Aside from their associated health and welfare impacts, noise and emissions are considerable and there are growing challenges from community acceptance of aviation activities. A more complete understanding of the complex interdependencies that exist among aircraft noise, fuel burn and emissions is required; as well as the impact on health and welfare. This knowledge must then be translated into an integrated environmental modeling framework and used to evaluate policy and technological options to mitigate the impact of aviation on the environment and energy use.

The FAA's Environment and Energy research program is studying the impacts of aviation—specifically from jet engines—on the environment, and is providing analysis to support the development of solutions to mitigate those impacts. The development of an interdisciplinary approach that considers the interdependencies among energy use, aircraft noise, and various air pollutant emissions is a key element. The core of the program is the development and use of an integrated aviation environmental tool suite. This tool suite is built upon a sound scientific understanding—which is also being developed as a part of this program—of aviation noise and emissions; as well as their environmental, health, and welfare impacts. The program is using these models and knowledge to inform decision-making on policies and technology development relating to aviation's energy use and environmental impacts.

Through the NextGen Environmental Research Aircraft Technologies and Alternative Jet Fuels program, the FAA is also accelerating the maturation of new aircraft and engine technologies using the Continuous Lower Emissions, Energy and Noise (CLEEN) Program and by developing sustainable alternative jet fuels through CLEEN, the ASCENT Center of Excellence, and CAAFI. These efforts are developing solutions that will reduce aviation noise and emissions

FAA: NextGen Alternative Fuels for General Aviation - Getting the Lead out of General Aviation Fuel

The Piston Aviation Fuels Initiative (PAFI), a government and industry partnership, is facilitating development and deployment of a new unleaded aviation fuel for use across the general aviation fleet. After Phase I PAFI testing concluded in December 2015, FAA assessed the candidate fuels; based on their impact on the existing fleet and the environment, the production and distribution infrastructure, toxicology, and the cost of aircraft operations.

Industry partners used Phase 1 PAFI test data to update their original feasibility assessments and evaluated the impact of their fuel on the current general aviation (GA) fleet of engines and aircraft (including the number and extent of any necessary aircraft modifications). The FAA reviewed the Phase 1 PAFI data, updated the feasibility assessments, and selected two fuels for further testing. Scheduled to begin in the summer of 2016, these tests will help the companies obtain an ASTM International Production Specification for their fuels, and allow the FAA to authorize the existing GA fleet to use the unleaded replacements. The PAFI goal is to have a new unleaded fuel that reduces lead emissions for GA by 2018.

FAA's Alternative Fuels Program staff works with aircraft and engine manufacturers, fuel producers, industry associations, and the U.S. EPA to overcome the technical and logistical challenges in using a new unleaded fuel. Approximately 167,000 of the Nation's general aviation aircraft currently rely on 100-octane, low-lead aviation gasolines for safe operation.

FTA

FTA's introduced the Low and No Emissions (LoNo) Program in 2013 to deploy clean technology transit buses that had completed most of the demonstrations and testing but had not been widely deployed in transit fleets. Zero-emission technology was given priority consideration. The Program was created as a bridge between research and commercial production of successful new bus models; helping manufacturers and suppliers reduce costs by increasing vehicle production, and helping transit agencies understand the demands of new bus technology. The Program also was set up to encourage applicants to partner with vendors, enabling manufacturers and their suppliers to know production demand as soon as the U.S. DOT announced project selections. Using this approach, the positive economic impact of LoNo was much more immediate. Manufacturers were able to obtain credit and borrow money based on the FTA selections and immediately begin hiring and setting up production for the new buses. There was no delay and continued uncertainty for manufacturers while grants were made to transit agencies and agencies went out for another round of competition and selection. This approach also enabled FTA to prioritize technology and eliminated the risk that a local preference could result in funding a vehicle type that was inconsistent with the Program's purpose.

As of 2016, the LoNo Program has built or put on order more than 100 zero-emission buses or buses with technology that supports zero-emission technology. Thirteen of these buses use fuel cell technology developed under the FTA's National Fuel Cell Bus Program; they represent the most advanced buses in service today, with reliability that exceeds diesel buses and flexibility and range that battery-electric buses cannot duplicate. The U.S. Department of Energy's National Renewable Energy Laboratory (NREL) has agreed to perform an independent evaluation of the LoNo Program for the Department.

PHMSA

Hazardous Materials Safety RD&T

The Hazardous Materials Safety RD&T program plans to continue funding research in the area of preserving the environment. The transportation of hazardous materials can have significant negative impacts on the natural environment and human health. They cause air, water, and noise pollution, and support land use patterns that divide and degrade habitats. They are also a major source of GHG emissions that contribute to climate change.

Although stricter hazardous materials regulation and technological advances in recent decades have helped to mitigate the impacts of transportation activities on the environment, continued hazardous materials transportation research can support the development of cost-effective mitigations. These include policies and technologies to minimize emissions of air pollutants, and tools to evaluate the impact of transportation activities on wildlife, habitats, and natural resources.

Additional research is needed to understand how transportation conditions affect human health. Research is also needed to quantify environmental impacts, develop cost-beneficial impact mitigation options, and develop ways for improving energy efficiency and alternate fuel sources.

The Hazardous Materials Safety RD&T program plans to continue funding research to preserve the environment. Current efforts address the effects of hazardous materials transportation activities on climate change and the environment as a whole (including water, noise and air pollution, and habitat degradation) and approaches to avoid or mitigate those effects. One of the goals of the Hazardous Materials Safety RD&T program is to advance environmentally sustainable policies and investments that reduce carbon and other harmful hazardous materials emissions within transportation sources.

Pipeline Safety RD&T

Although stricter pipeline regulations and technological advances in recent decades have helped to mitigate the impacts on the environment of products transported by pipelines, continued Pipeline Safety RD&T program research can support the development of cost-effective mitigations. These include policies and technologies to minimize emissions of air pollutants, and tools to evaluate the impact of pipeline transportation activities on wildlife, habitats, and natural resources.

Students undergoing maritime safety training

Additional research is needed to understand how pipelines transporting products could upset environmental conditions and affect human health. Research is also needed to quantify environmental impacts, develop cost-beneficial impact mitigation options, and develop ways for improving energy efficiency and alternate fuel sources

MARAD

To preserve the environment through maritime applications, MARAD applies the following R&D strategies:

- Help to develop and verify technologies and treatments that mitigate introductions of nonindigenous (aquatic) species.
- Investigate and demonstrate air emissions reduction technologies for marine vessels and ports.

- Determine viable alternative technologies and fuels that lead to emissions reductions on marine vessels and at ports.
- Investigate and model multi-sector modal emissions to determine maritime contributions as a baseline for improvements or efficiencies.
- Investigate other maritime environmental issues besides air emissions and invasive species, such as underwater noise.

Subject to funding availability, MARAD will continue to identify collaborative opportunities with other U.S. DOT Operating Administrations, Federal agencies, industry, academia, and organizations with an interest in maritime research, development, and technology initiatives.

MARAD: Ballast Water/Aquatic Invasive Species Initiative

MARAD's ballast water initiative began several years ago. The overall goal is to assist the maritime industry in addressing invasive species in ballast water. The initiative has become a multistate and multiagency cooperative effort that includes development of technical and scientific protocols for technology testing and verification, development of independent testing facilities to provide the needed data for ultimate certification of technologies to International Maritime Organization and U.S. Coast Guard standards, and technology testing.

Directed by Congress, MARAD has provided technical assistance on the current state of ballast water treatment system development, along with funding, and the necessary technical support to establish local facilities to conduct independent verification and certification of ballast water treatment systems meeting international and national standards.

The U.S. Coast Guard has certified three testing facilities supported by MARAD. Each year, the facilities have tested between four to eight ballast water treatment systems.

ITS JPO

Applications for the Environment: Real-Time Information Synthesis (AERIS)

Vehicular accelerations, decelerations, idling, and stopping at traffic signals results in increased congestion, fuel consumption, and emissions. To tackle this challenge, the ITS JPO and the FHWA's TFHRC are researching how connected and automated vehicle technologies can be used to improve a vehicle's performance as it approaches a signalized intersection. Together, the ITS JPO and FHWA developed the automated GlidePath prototype application—the Nation's first application of a cooperative adaptive cruise control (CACC) system that uses wireless communication between vehicles and traffic signals to enable eco-friendly driving.

Launched in 2012, the ITS JPO's Applications for the Environment: Real-Time Information Synthesis (AERIS) team conducted a field experiment at TFHRC to explore the potential to reduce idling and emissions at signalized intersections. The Eco-Approach and Departure at Signalized Intersections application provided speed recommendations to a driver through a driver-vehicle interface. The application calculated recommended speeds based on the vehicle's location and signal phase and timing (SPaT) messages collected from the traffic signal. By providing speed recommendations to the driver, the driver could adjust the speed of his/her vehicle to avoid stopping at the traffic signal or to approach the intersection in the most eco-friendly way.

Although results were promising, the 2012 experiment identified potential driver distraction issues associated with providing speed recommendations to the driver using an interface. In 2014, the AERIS team launched the GlidePath prototype application project—a first-of-its-kind prototype incorporating automated longitudinal control capabilities along with the Eco-Approach and Departure algorithm. By introducing automated technologies, driver distraction could be reduced and vehicle efficiencies could be improved.

ITS JPO staff coordinated with their partners to build the onboard application and control software. Using the application, the driver activated automated longitudinal control capabilities, allowing the software to take control

of the vehicle's accelerator and brakes to safely and smoothly drive through the intersection while obeying the traffic signal and local speed limit. As with any cruise control system, the human driver is always in control of the vehicle and can disengage the automation by stepping on the brake or turning the cruise control feature off. The application determines speed profiles to minimize fuel consumption by adjusting the speed of the vehicle either up or down to avoid coming to a full stop at the intersection, if possible. Alternatively, if the vehicle has to come to a stop, the speed profiles provide speeds that allow the vehicle to come to a stop in a way that reduces unnecessary accelerations and decelerations. The software works on any properly configured intersection broadcasting SPaT and other connected vehicle messages. The application also has many configurable parameters; some of which include cruise speed, roadway speed limit, decision-point distances, and acceleration limits.

TFHRC conducted a follow-on field experiment to test the efficacy of the application. The automated GlidePath prototype application was tested at a single fixed-timed intersection. Data collected in field experiments revealed that average fuel consumption improved in vehicles equipped with the application. Results showed a 7 percent fuel saving for drivers using the original 2012 driver-vehicle interface compared to drivers who were not provided with any information (i.e., uninformed drivers). Drivers of vehicles with partial automation and the GlidePath application saw 22 percent fuel saving compared to the uninformed driver. In addition, there was a 15 percent fuel improvement for drivers of vehicles with automated longitudinal control capabilities compared to drivers trying to follow speed recommendations from the driver-vehicle interface. In addition to the fuel savings, driver distraction was also reduced with the automated GlidePath prototype application.

This pioneering work has established a solid foundation for continued research and innovation involving automated and connected vehicle applications at signalized intersections. Future research is considering how the application would work at actuated traffic signals, at multiple intersections in a corridor, and in mixed traffic.

Smart City Challenge Electrification

The Columbus Smart City Demonstration will reduce the region's carbon and GHG emissions through electrification in transportation sectors. The Electrification Plan is designed to: (1) produce one of the largest regional GHG reductions; (2) address the Midwest's lagging position in electric vehicle (EV) deployment, rapidly accelerating the region to a leading position; (3) advance a replicable model of transportation electrification for mid-sized cities across the nation; and (4) produce data-rich, trackable metrics to demonstrate project successes and share best practices.

5

Technology Deployment

Overview

Technology deployment is the act of preparing and demonstrating the results of R&D so that they can be moved to an adoption-ready state.

This section describes the Department's overarching Technology Transfer program and then presents the Technology Deployment activities of individual Operating Administrations.

The U.S. DOT approach to T2 is diverse and unique to each mode of transportation. The Department accomplishes its mission through research partnerships with academia, industry, commercial, nonprofit, non-government, and government agencies; development and advancement of sound and implementable national transportation policies, promotion of safe transportation behaviors, and the delivery of training in transportation safety and efficiency practices. Each Operating Administration has tailored its T2 approach and activities to their specific technology deployment needs.

As shown in Figure 3, there are two parallel sets of activities that are essential to developing a new technology. One is the R&D process, where research activities are defined and conducted. The other is the technology transfer (T2) process, where potential adopters and other stakeholders are engaged so that (1) their needs can be incorporated into the R&D process, and (2) they can understand and use the results. Technology deployment is the final phase of the T2 process.

Technician with an Unmanned Aerial Vehicle (UAV) of the FAA

5.1 The U.S. DOT Technology Transfer Program

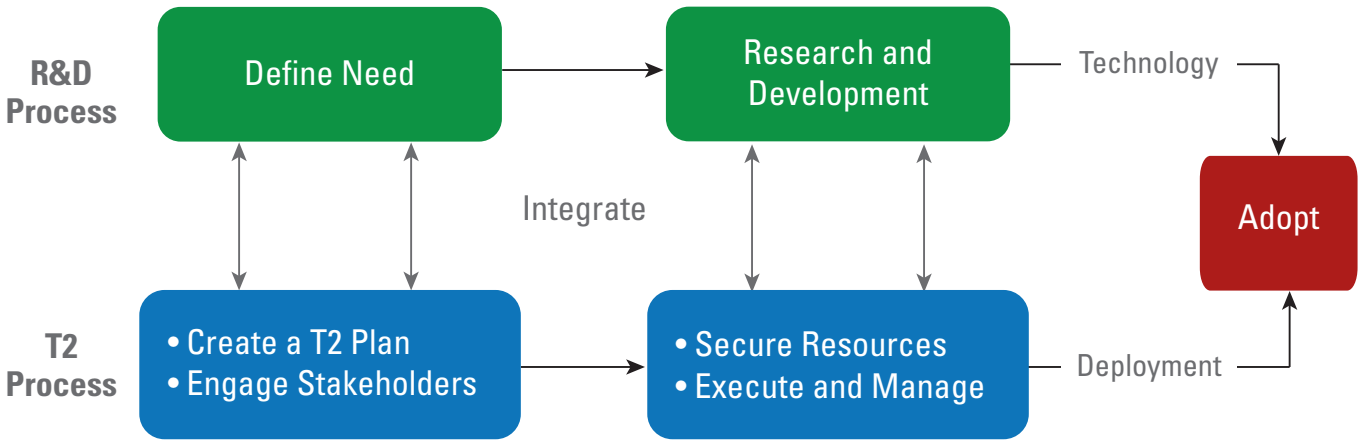
The U.S. DOT T2 Program, housed in the Office of the Assistant Secretary for Research and Technology, is responsible for coordinating, documenting, and supporting T2 activities across the Department. It accomplishes its goals by partnering with T2 and technology deployment experts within the Operating Administrations and by leveraging expertise and resources outside the Department.

The FAST Act requires the Operating Administrations to specify how they plan to disseminate and use their research findings to improve the efficiency, effectiveness, and safety of transportation systems. The T2 Program is working with the Operating Administrations to develop T2 Plans and practices that meet this FAST Act mandate.

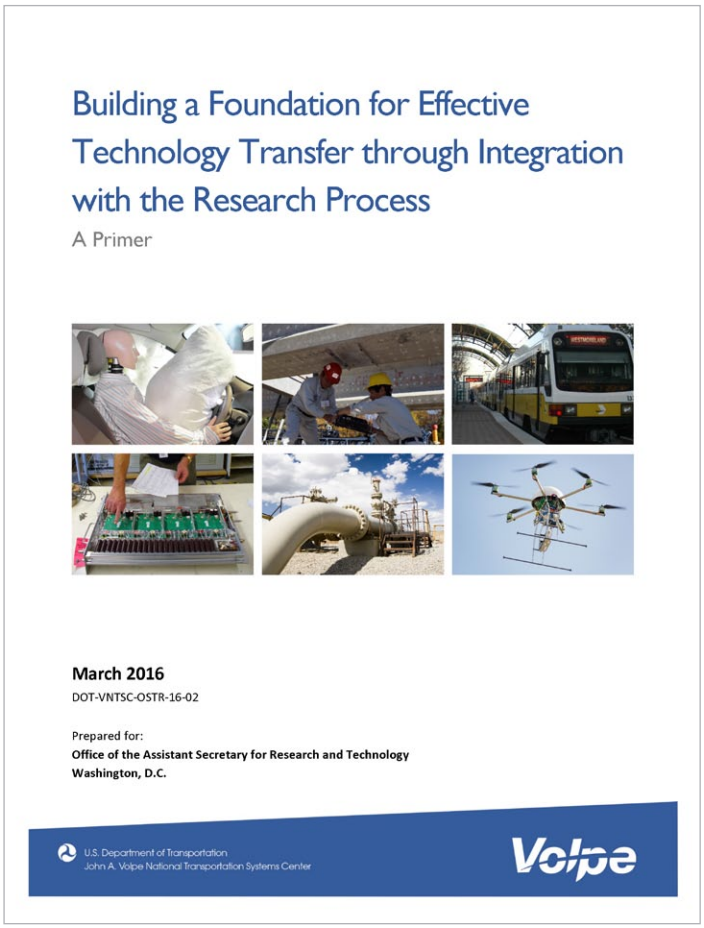
U.S. DOT's T2 activities focus upon research collaboration, knowledge transfer, information dissemination and the practical application of research. Specific coordination and collaborative efforts include:

- Coordinating U.S. DOT's annual contribution to the Department of Commerce's report on Federal Laboratory T2 Fiscal Year Summary Report to the

Figure 3. Integrating the R&D process with the Technology Transfer Process



Principles: Understand Adopter Needs, Address Barriers to Adoption, Understand the Technology, and Communicate Value



Cover of Building a Foundation for Effective Technology Transfer

President and the Congress in accordance with 15 USC 3710(g)(2), and summarizing the implementation of technology transfer authorities established by the Technology Transfer Commercialization Act of 2000 (Pub. L. 106-404) and other legislation.

- Coordinating the Department's response to Executive Orders and other T2 Administration mandates, such as *Accelerating Technology Transfer and Commercialization of Federal Research in Support of High-Growth Businesses,* October 2011.
- Developing training materials to help R&D personnel incorporate various technology transfer best practices into their research programs.[2]
- Collaborating with the Department's Senior Intellectual Property (IP) Counsel in developing an IP policy, which will streamline procedures for the submission and review of potential invention disclosures, and improve total effectiveness and reductions in cost.
- Preparing simplified model agreements for use or adoption by the Operating Administrations and the Department's Federal laboratories to reduce resources and time spent on negotiation.
- Implementing a new process for evaluating the Department's R&D outputs and providing resources to support high-priority outputs in their progress towards adoption in the transportation system.

The T2 Program also represents the Department's T2 interests in working with other outside organizations, including the Department of Commerce, Federal Laboratory Consortium for Technology Transfer, the White House, and AASHTO.

5.2. FHWA

The objectives of FHWA's Technology and Innovation Deployment program (TIDP) are to turn research products into proven technologies and demonstrated practices, identify the market forces that will influence successful technology and innovation deployment, and to plan and deliver effective communication strategies to promote rapid adoption of proven, market-ready technologies and innovations. After technologies have gone through the testing and evaluation processes and are successfully deployed, FHWA helps with the accelerated implementation and adoption as standard practices by State DOTs and other stakeholders. TIDP funding supports innovations through final analysis, pilots, demonstrations, marketing, communications, and promotional activities. TIDP funds are used for several initiatives, including Every Day Counts (EDC), accelerated innovation deployment demonstrations, and State Transportation Innovation Council (STIC) incentives.

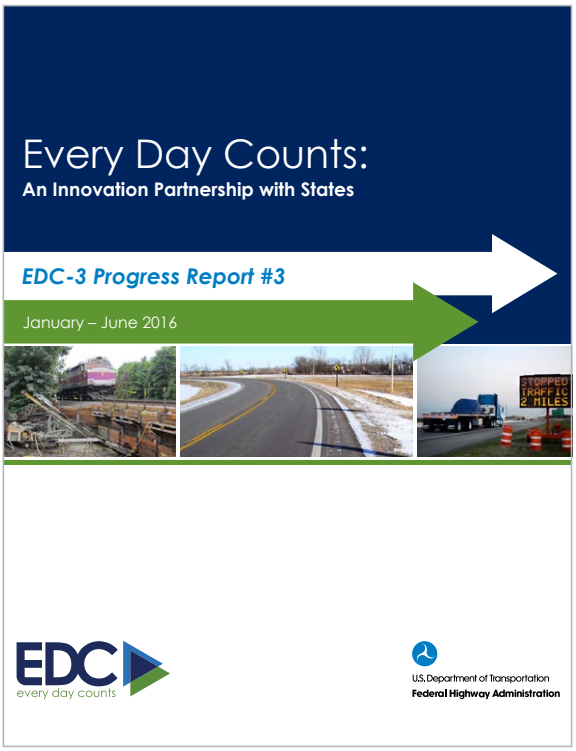
The goals of the TIDP program are to:

- Significantly accelerate the adoption of innovative technologies by the surface transportation community.
- Provide leadership and incentives to demonstrate and promote state-of-the-art technologies, elevated performance standards, and new business practices in highway construction processes that result in improved safety, faster construction, reduced congestion from construction, and improved quality and user satisfaction.
- Construct longer-lasting highways through the use of innovative technologies and practices that lead to faster construction of efficient and safe highways and bridges.
- Improve highway efficiency, safety, mobility, reliability, service life, environmental protection, and sustainability.
- Develop and deploy new tools, techniques, and practices to accelerate the adoption of innovation in all aspects of highway transportation.

FHWA uses a wide array of deployment strategies to target a variety of agencies that are implementing transportation innovations.

Every Day Counts Initiative

Every Day Counts (EDC) is a State-based initiative to identify and rapidly deploy proven-but-underutilized innovations to shorten the project delivery process, enhance roadway safety, reduce congestion, and improve environmental sustainability. Under EDC, technical assistance, training, and other resources are provided to State, local, and tribal transportation agencies to support the implementation and widespread adoption of the promoted innovations. In short, EDC identifies underutilized, market-ready technologies with high pay-offs and accelerates their deployment and acceptance throughout the nation. The FAST Act recognizes the success of the EDC initiative and adds it as a required program.



Cover of the Every Day Counts: Progress Report #3

Through the EDC model, FHWA works with transportation stakeholders to identify a new collection of innovations to champion every two years. FHWA first solicits suggestions for innovations to deploy through EDC. In collaboration with transportation stakeholders, FHWA then selects a set of innovations; taking into consideration market readiness, impacts, benefits and ease of adoption of each innovation. Transportation stakeholder input is obtained through

Test of truck platooning capabilities in California

formal correspondence (emails, letters, etc.); as well as an annual face-to-face meeting to discuss the EDC initiative. FHWA also holds annual meetings with each stakeholder group to discuss opportunities for further collaboration on deployment efforts. Stakeholders also regularly support and assist FHWA deployment teams with technology transfer activities. More information is available at: **http://www.fhwa.dot.gov/innovation/everydaycounts/**

State Transportation Innovation Council Incentives

The STIC Incentive program provides resources to help STICs foster a culture for innovation and make innovations standard practice in their States. Through this program, FHWA 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.

The STIC Incentive program supports the projects identified by STICs. STICs may use the funding to conduct internal assessments, build capacity, develop guidance, standards, and specifications; implement system process changes, organize peer exchanges, offset implementation costs, or conduct other activities the STIC identifies to foster a culture of innovation or to make an innovation a standard practice.

Accelerated Innovation Deployment Demonstrations

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 the maximum amount of $1 million, in areas such as planning, financing, operations, pavements, structures, materials, environment, and construction.

More information on awarded AID Demonstrations grant funding is available at: **http://www.fhwa.dot.gov/innovation/grants/.**

5.3 FAA

The FAA supports multiple pathways to deployment and operational transition of new technology and research results to advance aviation safety, efficiency, and environmental objectives. FAA's approach to research aligns with the varied operational roles and business models of the agency's lines of business. For example, aircraft system manufacturers and operators are responsible for safe, efficient, and environmentally sustainable design, manufacture, and operation of aircraft systems, while the FAA Aviation Safety line of business performs safety assurance oversight and regulatory functions. Similarly, while airport operators are responsible for the safe, efficient, and environmentally supportable design, construction, and operation of the Nation's airport infrastructure, the FAA Airports line of business performs oversight, and safety inspection and certification functions. In both cases, research outputs are in the form of scientific, technical, and engineering information products to inform oversight and regulatory guidance. In contrast, the FAA's Air Traffic Organization line of business is responsible for the acquisition, operation, and maintenance of the air traffic management system infrastructure. Supporting research output pathways are therefore different than those aimed at supporting oversight and regulatory functions.

New operational concepts and technologies resulting from research to transform the air traffic management system follow the FAA's Acquisition Management System (AMS) transition path. Under the FAA AMS, mission analyses are performed to quantify mission performance shortfalls, explore and mature new operational concepts, and develop alternatives for solution implementation. When appropriate, prototype design and demonstration projects are conducted

with industry partners to identify and measure critical performance parameters and evaluate the suitability of proposed operational concepts or new technology before committing to a system acquisition. Under this business model, research results transition through operational, performance, and system specifications that govern the design and implementation of new technology through an acquisition program. In this case the research investment matures proposed solutions to determine feasibility and potential operational effectiveness, and thereby reduces acquisition program uncertainty and risk.

Often helped by financial assistance grants through the FAA's Airport Improvement Program (AIP), airport operators design and implement capital improvements to their airport infrastructure to maintain and enhance safety and efficiency and to reduce environmental impacts on adjacent communities. The FAA also provides technical and engineering design guidance by issuing advisory circulars and engineering specifications. These guidance materials are the basis for new technology design, construction, and implementation standards, as well as compliance and certification inspections. Operational transition of airport technology research output is reflected in the engineering guidance and technical instructions contained in advisory circulars and the airport compliance inspections and certification procedures. Unlike other FAA line of business operational models, the Airport line of business can enable AIP grant eligibility for beneficial technologies resulting from airport technology research to facilitate operational transition. The AIP grant incentivizes operator adoption and implementation and thus serves as a research product deployment strategy.

The FAA incentivizes and facilitates operational transition of research products in several other ways. Through its Technology Transfer Program the FAA uses Cooperative Research and Development Agreements (CRDAs) to provide technical advice, review, facilities, and methods and assist industry proponents of particular technology solutions to address aviation needs. Research transition support is an important characteristic of CRDAs as they provide an initial validation of the operational suitability and potential effectiveness of a particular technology solution, and thus increase the likelihood of its eventual commercialization.

FAA: Wake Turbulence Recategorization

Air carriers are saving time and money through new FAA aircraft separation standards known as Wake Recategorization (Wake Recat). Wake turbulence, the swirling air generated from the wings of a flying aircraft, can create hazardous conditions for an aircraft flying behind it. Using Wake Recat air traffic controllers can safely reduce the spacing between consecutive departures from or arrivals to an airport. More aircraft can take off and land, reducing arrival delays and the time aircraft wait on taxiways and runways with their engines burning fuel. New standards are possible because of changing categories of aircraft, formerly based mainly on weight, to those based on wingspan, weight, and stability. The standards and categories are the result of more than a decade of research by various government agencies and industry partners.

An FAA performance assessment of Wake Recat impacts showed a noticeable reduction in time between successive flights that depart from or arrive to the same runway—resulting from shorter taxi-out times for departures and shorter time in terminal airspace for arrivals.

There are many examples of Wake Recat's positive impact. Air freight carriers understand the benefits. For example, FedEx reported that its Memphis operations gained 17 percent capacity while taxi-out time dropped by 3 minutes and approach time declined by 2.5 minutes. The company saved 10.7 million gallons of fuel and avoided releasing more than 100,000 metric tons of aircraft exhaust emissions into the atmosphere. UPS also experienced a difference at its Worldport hub in Louisville. The carrier reported between October 2013 and July 2015, its average taxi-out time dropped by 1.2 minutes, saving the company 257,647 gallons of fuel. Average hourly departures increased by 6, while arrivals rose by 5.

Since Wake Recat deployment through the end of fiscal year 2014, taxi-out time savings accumulated to more than 86,000 minutes in Atlanta, while the overall savings during peak periods accumulated to about 148,000 minutes at Memphis and 22,000 minutes at Louisville. Accumulated time saved in terminal airspace for the same period totaled almost 93,000 minutes in Atlanta, while the overall savings during peak periods accumulated to about 12,000 minutes at Memphis, 8,900 minutes at Louisville and 1,200 minutes at Cincinnati.

Testing new radar components

Through the Continuous Lower Energy, Emissions and Noise (CLEEN) program, the FAA is working with industry to accelerate development and commercial deployment of environmentally promising new aircraft and engine technologies, and sustainable alternative fuels. The companies in the CLEEN Consortium are developing technologies that reduce noise, emissions, and fuel burn and enable the aviation industry to expedite integration of these technologies into current and future aircraft. CLEEN helps these companies accelerate their technologies through a crucial phase in their maturation, culminating in full scale ground and flight test demonstrations and showing readiness for product implementation. At the conclusion of the development effort for a CLEEN technology, each company, having shared development costs with FAA, is invested in the technology's success and confident in its maturity to move into product development for entry into service. Once this occurs, the CLEEN technologies will realize their fuel burn, emissions, and noise benefits throughout the fleet for years to come.

5.4. FTA

FTA's Office of Research must ensure that public transportation innovation results from research investments. By using practice implementation models, FTA plans to stimulate adoption of research when findings demonstrate usefulness in addressing critical research topics. As national demographic and public transportation ridership trends show, demand for public transportation continues to increase, even while funding for infrastructure and technology is constrained. Research must be a force-multiplier to enable public transportation systems to meet this rising demand in the most cost-effective and high-quality manner possible.

FTA uses the following deployment and implementation strategies to translate research into practice:

- Knowledge transfer through training
- Industry diffusion
- Operational testing and demonstration
- Partnerships

- Standards development
- Formal dissemination
- Communities of practice and social network marketing

Going forward, FTA will refine and hone these models through additional collaboration and feedback during the development of a new five-year strategic research plan. This collaborative process will rely heavily on several cooperative agreement partnerships, cross-modal cooperation, and initiatives to gather broad industry feedback.

Knowledge Transfer through Training

The cooperative agreement between NTI and Rutgers University drives knowledge transfer through training for FTA's research program. The NTI also partners with the TCRP program to develop webinars that communicate the results of TCRP research. For example, NTI developed training courses on safety and asset management, and is currently developing training on key MOD intelligent transportation systems. Transit agencies rely on NTI training to keep their workforce current on key regulations, operational methods, and procurement rules. The NTI also translates research into training to enable transit agencies to implement promising practices.

Operational Testing/Demonstration and Industry Diffusion

FTA allocates more than 85 percent of its research budget to demonstration projects, enabling the industry to test innovative processes, products, and methods. These "real-world" demonstrations lay the groundwork for sustainability and replicability of advances, such as bus rapid transit, transit vehicle automation, low- and no-emission buses, and asset innovation. Once a transit agency or research institution finds economic, operational, or customer benefits from specific research demonstration activities, a natural diffusion begins to occur, and professional networking increases the pace of this natural diffusion. Transit agencies and researchers present their findings at transit conferences, such as those hosted by TRB, APTA, and the Community Transportation Association of America. Conference proceedings are documented and shared. Private-sector industry advances resulting from FTA joint public and private transit research investments, such as low- and no-emission vehicles, are promoted through exhibits at these conferences. In time, early innovations, such as bus rapid transit and buses powered by compressed natural gas, became mainstream. Many others will follow after research demonstrations have proven their usefulness. FTA expects that this process will result in similar systemic changes from the MOD initiative and commensurate shared services.

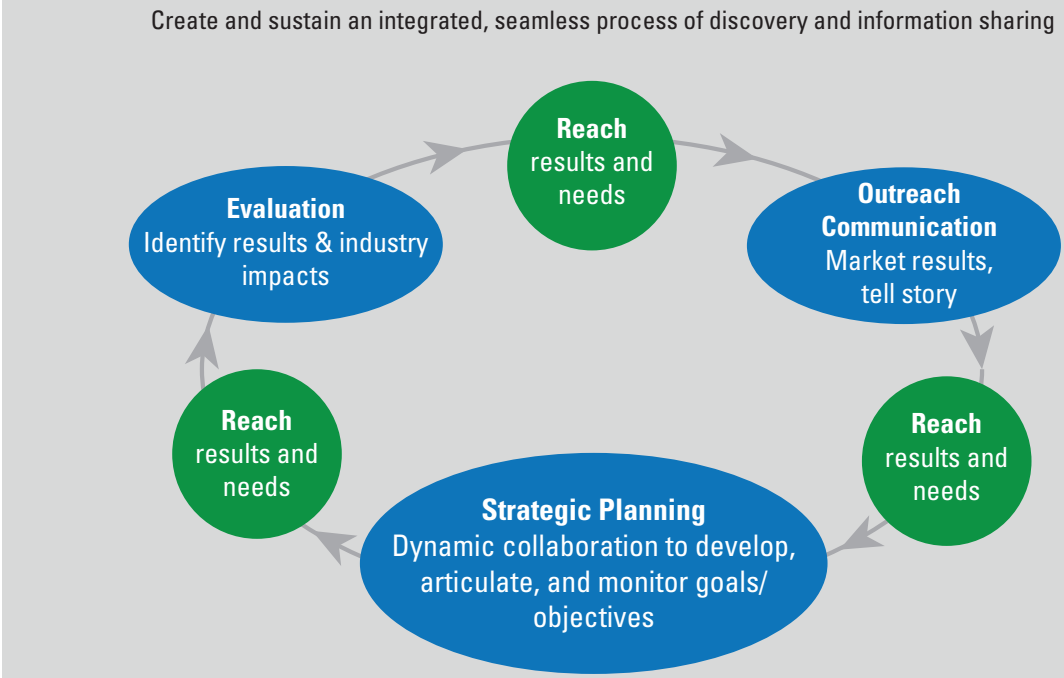
Partnerships and Standards Development

Broad partnerships with a number of key stakeholders assist with test and demonstration efficacy and help to deploy and disseminate research and develop standards. Key organizational partners include research institutions, training partners, non-profit partners, national transportation associations, university transportation centers, transit agencies, State agencies, technical assistance partners, and international partners. FTA's research includes collaboration with other modes including FHWA, NHTSA, and FMCSA on CV/AV related standards development. FTA also works with TRB to support various standards discussions, provide assistance with strategic planning input from advisory committees such as the Transportation Research Advisory Council, and generate outcomes from TCRP studies. The agency also provides funding to APTA for various industry standards development projects. Major research labs and academic institutions, including those running UTCs, promote research findings and provide input for standards development. Focus areas for standards development for the coming years are in MOD, safety management systems, and asset management systems.

Formal Dissemination and Use of Social Networks

A cooperative agreement between FTA and CUTR established the major formal dissemination arm for FTA's research findings. FTA's Office of Research works with CUTR to ensure that all research reports are published using a consistent format and posted on FTA's website. Going forward, FTA will expand the marketing and promotion of research findings through greater use of social networking and outreach. Media releases, blogs from FTA leadership, Facebook postings, online dialogues, podcasts, and other emerging social networking technologies will be a part of a new marketing and outreach plan developed by FTA's Office of Research as part of FTA's next five-year strategic plan.

Figure 4. FTA TRI Draft Integration Outreach, Planning and Evaluation Model



Resilience and All-Hazards Emergency Response and Recovery (SRER) Program

The goal of the SRER program is to support cutting-edge developments in mass transit using state-of-the-art technology to help transit agencies improve track worker and passenger safety, better withstand natural disasters, and respond more effectively to emergencies. After receiving 72 applications requesting $160 million in funding, FTA selected 12 organizations in 9 states to share $24 million in grant funding.

FTA expects that many of the prototypes and/or technologies will be introduced to the transit agencies as commercial products by the end of the demonstration program (others might require additional funding to further research and develop before commercialization). Examples include a suicide prevention and platform intrusion detection system, a crash energy management bumper for LRVs, a right-of-way worker protection system, a vehicle-to-vehicle and vehicle-to-infrastructure technology for transit buses to prevent collisions, use of hybrid buses as mobile power generators during emergencies, next generation (improve life cycle) concrete crossties and fastening system for transit rail systems, transit railcar wheels and rails interface monitoring to optimize condition-based maintenance of tracks and wheels, and development of an emergency asset management training course and decision support tools.

FRA: Test Bed for Positive Train Control

FRA developed and installed a PTC Test Bed at the Transportation Technology Center (TTC) in Pueblo, CO to support the railroad industry in developing, implementing, and maintaining PTC. The PTC Test Bed replicates current PTC technologies used by the railroads and provides a controlled test environment for conducting functional testing, safety testing, interoperability testing, regression testing, performance evaluations, and development support for current and future PTC systems. The Test Bed integrates PTC and communications equipment with existing railroad and communications infrastructure at TTC, which provides a realistic operating environment that is independent of the revenue service operation of any railroad. This allows expedited research and testing without affecting regular railroad operation.

The PTC Test Bed has already been used by the industry to test on-board train management computers, radio communications, and braking algorithms for freight trains. It has also been used as a training ground for FRA inspectors.

An important dissemination strategy for FTA is establishing and supporting communities of practice. Using its strategic planning process, FTA's Office of Research will help identify required communities of practice and how to establish or connect with existing communities of practice in identified areas.

FTA's Office of Research will also take a more programmatic approach to partnerships, including outreach to technical assistance centers funded both by FTA and other Operating Administrations, to ensure that promising research findings, evaluations, practices, and useful performance measures are promoted to further industry implementation and deployment actions.

The Office of Research will test and refine a draft integrated outreach, planning, and evaluation model as part of these formal dissemination activities. An important goal of dissemination is public transportation industry awareness of the short- and long-term benefits of implementing the findings of public transportation research. Figure 4 shows FTA's draft integrated outreach, planning, and evaluation model.

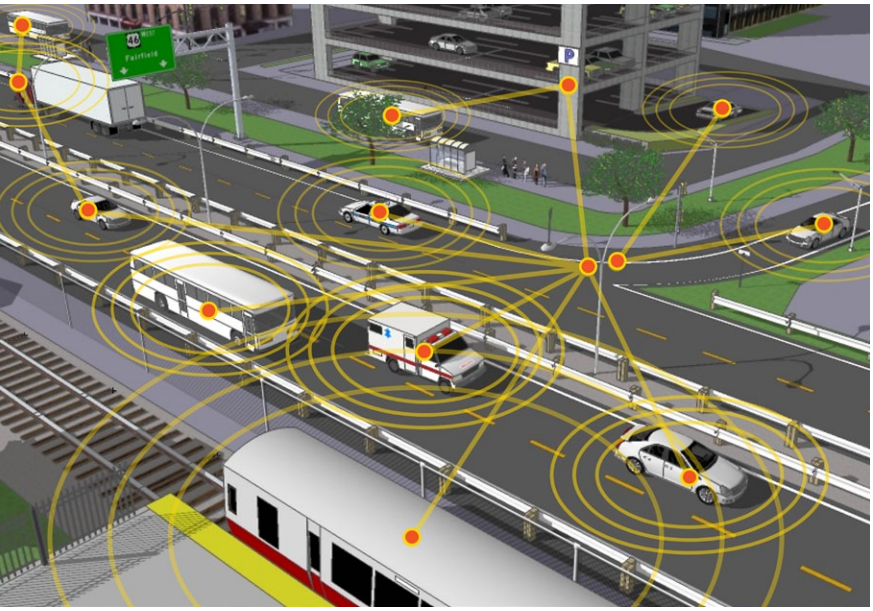
5.5. FRA

Much of FRA's basic research supports the agency's rulemaking responsibilities. FRA brings research results to its Rail Safety Advisory Committee; established in 1996 to develop new regulatory standards through a collaborative process involving all segments of the rail community. Research results are also used in regulatory impact analyses, which are cost-benefit analyses that are required for most rulemakings.

FRA develops technology that is used by FRA's inspectors to enforce 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 towards 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's Transportation Technology Center has 50 miles of test track and numerous test facilities for conducting R&D. The Center is shared with the rail industry. FRA encourages industry involvement in its R&D program and provides a path for early implementation of successful technologies.

FRA will continue to publish the results of its R&D in full technical reports and in shorter research summaries. These publications allow FRA to contribute to the international library of rail research and allow others to build on the advances the agency has made.



Visualizing connected vehicles and intelligent transportation systems

5.6. NHTSA

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. A recent example was the V2V Model Deployment in Ann Arbor, Michigan, where thousands of DSRC-equipped vehicles were deployed to test how well the V2V technology performed, supported safety applications, and was received by consumers. The findings from the deployment testbed have given NHTSA important data for supporting regulatory guidelines for V2V technology. NHTSA has already funded initial naturalistic driving studies with automated vehicles to see how drivers perform and accept the new technology. These studies provide detailed driver performance and behavior data when operating production and prototype technologies are deployed with real drivers. NHTSA's future plans include a limited naturalistic driving study for seat belt interlock prototype technologies and a substantial field operational test for DADSS technology.

Research Dissemination

In addition to publishing research reports on the NHTSA website and regulatory and guidelines products through the Federal Register, NHTSA has been a longtime sponsor of the Enhanced Safety of Vehicles (ESV) international conference held every other year. For more than 40 years, ESV has kept pace with technical innovation to identify new opportunities for advancing safety. A hallmark of the ESV Program continues to be the technical agenda where shared presentations are considered to be at the leading edge of vehicle safety research. As ESV approaches its fifth decade, the organizers, including NHTSA, continue to strive to present participants with the latest achievements in the field of motor vehicle safety. The 25th ESV Conference venue is Detroit, Michigan, June 5–8, 2017.

Stakeholder Engagement

NHTSA actively pursues information exchange with the automotive industry, as well as with the cutting-edge technology sectors that now have a stake in the transportation arena. By engaging the full spectrum of industry and safety advocacy stakeholders, NHTSA ensures that it continues to be at the forefront in knowing not only the industry's latest technology

Driver Alcohol Detection System for Safety (DADSS)

The DADSS effort is a multi-year program to develop and test prototypes that may be considered for vehicle integration. Its intent is to support a non-regulatory, market-based approach to prevent drunk driving. The program focuses on developing non-invasive, seamless technologies to measure drivers' blood alcohol content and reduce the incidence of drunk driving. The devices must be able to measure alcohol accurately, precisely, and reliably in a very short time so the sober driver is not inconvenienced. The devices are intended to prevent alcohol-impaired drivers (blood alcohol content ≥ 0.08 percent) from driving their vehicles.

The DADSS team is reducing the size and cost of the units; improving their speed, accuracy and precision; and conducting real world tests for reliability and durability. As the research continues, the team is focused on making sure the technology meets the strict performance specifications relating to precision, accuracy, and reliability. As part of the ongoing research, the breath-based and touch-based prototypes will be integrated into vehicles in a series of field tests that will thoroughly assess the systems in real-world scenarios. The first of these multi-vehicle field operational trials will begin in early 2017.

developments, but also the concerns of citizen advocates. In addition to internal meetings with various stakeholders, NHTSA has conducted several public meetings on specific topics related to the research strategies outlined above. 2016 public meetings on vehicle safety included:

- **Automated Vehicle Performance Guidelines:** input on planned vehicle performance for the safe deployment of automated vehicles (AV).
- **Driving Behavioral Change in Traffic Safety:** a call to action for highway safety practitioners and individuals interested in saving lives and stopping injuries and crashes on our Nation's roads. NHTSA is leading the charge with a new strategy on human choices.
- **Vehicle Cybersecurity Standards**: identifying actionable steps for stakeholder groups so that the vehicle manufacturing industry can address vehicle cybersecurity challenges effectively and expeditiously.
- **The New Car Assessment Program:** planned upgrades to the 5-Star Safety Ratings program will take the program into a new safety era and encourage automakers to produce cars with better crash protection and new technology innovations that will save more lives.

Consumer Education

NHTSA's 5-Star Safety Ratings, also known as the New Car Assessment Program, crash tests new vehicles every year and currently rates them on how well they protect occupants in frontal, side, and rollover crashes. Test results are compiled into a rating of 1 to 5 stars; more stars indicate a safer car. The vehicle safety ratings appear on window stickers of new cars, and searchable ratings are available on NHTSA's Safercar.gov website. The current program also includes a checklist of recommended advanced technology features, such as rear-visibility cameras, lane departure warning, and forward collision warning. This program provides invaluable information to consumers as they make important decisions about vehicle purchases. The program has been in place since 1978 and continues to be an important consumer education resource for NHTSA and the U.S. DOT. NHTSA is planning a major program upgrade.

5.7. PHMSA

Pipeline Safety

The Pipeline Safety RD&T program has wide-ranging partnerships during the early stages of technology development, as well as during later stages through the in-the-field technology demonstrations. This enables team diversity, consistent financial support, and use of pipeline operators' and service providers' knowledge, all to be brought to bear on various technological challenges. These partnerships have strengthened the commercialization success rate into the 20–30 percent range. The Pipeline Safety RD&T program investment supports job creation through the launch of new technological services from the pipeline services industry, and protects newly developed technology and intellectual property through U.S. patent applications.

PHMSA: MWM-Array Characterization of Mechanical Damage and Corrosion

Meandering Winding Magnetometer (MWM) array is a nondestructive examination technique used for detecting and characterizing corrosion and cracking using multiple inductive sensors. This research program enhanced the MWM array imaging capability to permit pipeline inspection without coating or insulation removal. The output was an MWM sensor able to operate at very low frequencies, and providing quantitative characterization of mechanical damage and corrosion through coatings and insulation, along with a higher-resolution capability with coatings removed. In addition to successfully delivering a practical field-deployable tool, the research team developed a process to detect cracks at damage sites.

The original commercialization plan involved an initial demonstration to inspect specific applications made available to customers. Some of this capability would take the form of available prototype inspection systems that can be purchased or leased. While these prototype systems were being used, the research team continued development and production of field-hardened instruments and scanners, refined measurement and training procedures, and incorporated feedback from customers and other stakeholders. Since the same basic system can be used for multiple inspection applications, typically with a different sensor array, ongoing research is focusing on defining product configurations and the remaining development requirements for the various applications. This will enable production of systems and services to reach commercially sustainable levels.

The tool is now available as fully-commercialized products, available for purchase and lease by service providers and end users. Additional Information on this successful research effort is available at: **https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=354**

Hazardous Materials Safety

Because the Hazardous Materials Safety RD&T program is still in its infancy, there are limited examples of successful technology deployments. However, the program intends to identify wide-ranging partnerships during this early stage of technology development and throughout the in-field demonstrations and development. This strategy will diversify teams and maximize the use of hazardous materials industry knowledge. The agreements and contracts developed during technology development and demonstration testing should improve the success rate of technology commercialization. The Hazardous Materials Safety RD&T investment supports job creation through the launch of new technological services from the hazardous materials packaging and transport industries, and protects innovation and intellectual property through U.S. patents applied for as a result of developing technology improvements.

The Hazardous Materials Safety RD&T program has signed research contracts that have enabled early and continued successes in developing regulatory and technology solutions for the growing number of hazardous material transport safety challenges. Program stakeholders and key partners agree that the regulator, the regulated, and the supporting service and vendor communities have mutual objectives that can be met by the continued development of regulations and technologies that address hazardous material transport vulnerabilities.

5.8. FMCSA

FMCSA's Research and Technology Program provides scientific safety research on driver behavior, carrier operations, and technology applications. These contributions have proven critical in supporting FMCSA's safety rulemakings, identifying enforcement priorities, and facilitating technology transfer to the marketplace. Program activities range from developing enhanced enforcement technologies, demonstrating the efficacy of CMV operators obtaining proper rest, evaluating the safety implications of automated and semi-automated vehicles, and understanding how CMVs can safely use alternative fuels. These projects provide the underpinnings for the agency's rulemaking and enforcement priorities. For example, recent research findings demonstrated the safety benefits of carriers' use of electronic logging devices to keep track of driver work hours.

FMCSA uses multiple vehicles to disseminate, deploy, and utilize research results, ranging from stakeholder engagement and training to demonstration projects and field operational tests. FMCSA will continue to test and deploy CMV safety technologies via:

- Partnership agreements with research institutions and State DOTs
- Technology demonstration projects and full-scale field operational tests.
- SBIR technology development and testing projects.
- Training for enforcement and inspection officials.
- Implementation of vetted technologies, such as wireless roadside inspection technology and the International Border Crossing e-Screening Application.
- Development of recommendations for updated North American Standards/out-of-service criteria/ FMCSRs for newer CMV types.

FMCSA continues to be an active participant in the Department's SBIR program and stimulate technology developments; such as driver fatigue monitoring, tractor-to-trailer communications, and using electronically-generated vehicle information to optimize routes that mitigate driver fatigue. The SBIR program has been particularly useful in developing niche technologies requiring specific expertise. FMCSA also participates in various technology consortia made up of industry, academia, and research organizations to identify and test technologies. Most recently, FMCSA supported the testing of an innovate rearview mirror product and a blind spot monitoring system.

5.9. MARAD

The majority of MARAD's research MARAD evaluates the effectiveness of technologies and concepts. Studies focus on the identification of problems and potential solutions, and/or forecasting the future direction and demands on the maritime industry. For the most part, 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 findings to the industry. Since MARAD is primarily a promotional agency, its influence on regulatory development is limited; however, its research program does support technological research and assessment that advances environmental compliance and transportation and environmental-related policy development. MARAD works closely with its industry, academic, and Federal partners through hosted workshops, cooperative programs meeting, and Federal advisory committees and partnerships.

5.10. ITS JPO

The foundation for the effective deployment and operation of the modern technology-based transportation system is interoperability. Interoperability focuses on enabling ITS elements in vehicles, devices, infrastructure, and applications to effectively communicate with other parts of the system as needed, regardless of where they are built and where or when they are used. Interoperability is critical to the Nation's transportation system since the implementation of connected vehicle systems and the introduction of automated transportation systems will cause system interdependencies to increase, not only in number, but also in complexity. System architectures, standards, and certification must continue to evolve to ensure that technological advancements are reflected, and backwards-compatibility and interoperability are maintained.

The MV Freedom Star, recently transferred to the USDOT as a training vessel

System architectures provide frameworks to guide planning and interoperable deployment of transportation technologies and to identify interfaces for standardization. Standards define interfaces with architectures to enable required interoperability and support efficient, non-proprietary implementations. Certification ensures that systems and components comply with standards and meet other critical requirements.

The U.S. DOT also considers cross-border interoperability to be a significant foundational element and leverages its international harmonization efforts to address this element. International harmonization is beneficial to leverage global resources and expertise to: (1) maximize commonality of technology deployments; (2) share labor resources; and (3) access best-available expertise in order to facilitate rapid, efficient, and interoperable technology; and broaden competitive markets or equipment and services. Cooperation with neighboring countries is essential to ensure technology deployments enable efficient cross-border commerce and interoperability across national transportation systems.

Professional Capacity Building (PCB) Program

The ITS Professional Capacity Building (PCB) Program is responsible for the design, development, and delivery of training and educational opportunities to facilitate the knowledge and technology transfer required to spur the deployment of ITS technologies. As research and deployment programs evolve, the training and educa-

State Trooper reviews safety procedures with truck driver

tion developed under the PCB program focuses on solutions that transfer the knowledge and technology to target the deployment communities. The lessons learned from demonstrations and deployment projects will help prepare the transportation workforce to successfully plan for, deploy, operate, maintain, and manage ITS transportation systems.

Accelerating successful ITS deployment across the Nation requires continued training and education, marketing and outreach, and knowledge and technology transfer under the PCB program. The ITS JPO will continue the strategies identified under the PCB program, along with its network of training and education partners; such as FHWA, FTA, the National Highway Institute (NHI), NTI, the Transportation Safety Institute (TSI), as well as external partner organizations, such as industry associations and academic institutions; to coordinate development and delivery of quality ITS learning experiences.

Technology Deployment Evaluation

The Connected Vehicle Pilot Deployment (CVPD) evaluation plans to assess four pilot locations—the three CVPD sites in New York City, Tampa, and Wyoming; and the Columbus, Ohio Smart City Challenge. Results will inform prospective deployers of connected vehicle-enabled applications of likely safety, mobility, environmental, and public agency efficiency impacts; quantify costs and identify practical institutional and financial models for long-term deployment. Additionally, these results will provide the U.S. DOT with valuable information about (1) the effectiveness of the pilot deployments in creating proven and transferable deployment concepts demonstrating measureable short-term impacts and longer-term transformational changes, (2) overcoming deployment challenges, (3) documenting lessons learned, and (4) accelerating deployment of successful and sustainable connected vehicle applications.

Students review results from a recent transportation research project.

6 Implementation

Overview

Implementation of this Strategic Plan will take place on two levels. First, there is a range of FAST Act requirements that dictate how the Strategic Plan will be used to guide and report the Department's RD&T activities over the next five years. These requirements are the responsibility of the Office of the Assistant Secretary for Research and Technology. Second, each Operating Administration is responsible for tracking and evaluating the performance of their RD&T strategies.

6.1. Aligning the Strategic Plan with other FAST Act Elements

This RD&T Strategic Plan is a core element of a range of measures inserted into the FAST Act to make the most effective use of the U.S. DOT's investment in R&D activities. These elements are discussed below, along with a description of how they will be aligned and coordinated with the Strategic Plan.

49 U.S.C. 6501 requires each Operating Administration to submit an AMRP for review and approval by the Office of the Secretary. The AMRP must be consistent with this Strategic Plan, beginning with the AMRPs submitted in May 2017. One of the primary functions of the OST review is to identify and eliminate duplicate research performed by the different Operating Administrations.

49 U.S.C. 6502 requires the U.S. DOT to provide a consolidated research database that lists the research abstracts, activities, funding, findings and outputs of the Department's research portfolio at the project level. This comprehensive database is required for several different reasons; (1) to identify and eliminate duplicate research activities, (2) to identify multimodal research areas and subsequent opportunities for interagency collaboration, (3) to document how research findings and outputs are used to improve the efficiency, effectiveness, and safety of transportation systems, and (4) to provide the necessary level of transparency for Department's research portfolio. The database must also list the AMRPs submitted each year and describe the public and stakeholder input into each AMRP. The Department intends to meet this requirement by adding new content and functionality to the existing U.S. DOT Research Hub database. RD&T programs listed in Appendix A will be updated each year in the Operating Administration's AMRPs and used as the baseline structure for the U.S. DOT Research Hub database.

49 U.S.C. 6502 requires a Department R&D funding report to be submitted in conjunction with the annual budget requests submitted by the President to Congress. The funding report will describe:

1. The amount spent in the last full fiscal year on transportation R&D with specific descriptions of projects funded at $5 million or more; and
2. The amount proposed in the current budget for transportation R&D with specific descriptions of projects funded at $5 million or more.

The contents of this funding report will follow the structure of this Strategic Plan, with the budget requests made by each Operating Administration categorized into Research, Development, and Technology line items.

49 U.S.C. 6502 also requires a new R&D section to be included within the Department's annual Performance Plan and Report submission to Congress. This submission must include:

1. A summary of the Department's transportation RD&T activities for the previous fiscal year in each topic area (Promoting Safety, Improving Mobility, Improving Infrastructure, Preserving the Environment);
2. The amount spent in each topic area;
3. A description of the extent to which the RD&T is meeting the expectations described in this Strategic Plan, and
4. Any amendments to this Strategic Plan.

The Department will use the four "critical transportation topic areas" defined in this Strategic Plan as the "topic areas" referenced above. The reporting of each Operating Administration's RD&T spending in the prior fiscal year will be categorized by these four critical topic areas. As required by the FAST Act, this annual submission will also include an appraisal of whether the Department's RD&T activities are meeting this Strategic Plan's expectations, and list any amendments made to the Strategic Plan.

Finally, 49 U.S.C. 6503 states that the Department must develop and publish on a public website an Interim Report that assesses this Strategic Plan and describes the extent to which the RD&T is or is not successfully meeting the FAST Act's requirements to assess both the Strategic Plan and the Department's R&D activities. The Office of the Secretary will prepare this report within the 2½ year timeframe specified in the FAST Act.

6.2. Monitoring and Evaluation of RD&T Programs

Each Operating Administration and Joint Program Office is responsible for monitoring and evaluating the performance of their RD&T strategies. Table 8 summarizes the processes used by each Operating Administration.

Operating Administration	Evaluation and Monitoring Activities
Federal Aviation Administration	The FAA's RD&T portfolio receives continuous internal and external reviews to ensure that it meets customer needs, high quality standards, and management excellence. Research review bodies include FAA's R&D Executive Board, the Joint Resource Council; the Research, Engineering, and Development Advisory Committee, and the Commercial Space Transportation Advisory Committee
Federal Highway Administration	The FHWA's R&T Evaluation Program, conducted under an interagency agreement with the U.S. DOT's Volpe Center, documents the short- and long-term value of FHWA-sponsored research. In moving to a performance-based system, FHWA is gathering data and information on outputs, outcomes, and program impacts; setting target accomplishments, and identifying cost-effective ways to deliver on program goals.
Federal Motor Carrier Safety Administration	FMCSA will evaluate its Research and Technology Program using a combination of output, outcome, and impact metrics. Together, these metrics will help demonstrate the extent to which the program is meeting its goals. FMCSA will identify a combination of measures for each strategic objective to manage and evaluate its Research and Technology Program. Performance metrics will be evaluated and refined periodically.
National Highway Traffic Safety Administration	NHTSA has several units that perform data analysis and evaluation. These groups work together for a data-driven, quantitative approach to identifying safety problems and evaluating potential remedies. The Office of Regulatory Analysis and Evaluation evaluates the effectiveness of vehicle safety regulations and technologies, and studies behavioral safety trends. Vehicle safety evaluations address crash avoidance, crashworthiness, compatibility, and recalls. Behavioral safety evaluations address impaired driving, occupant protection, child passenger safety, motorcycle safety, pedestrians, and emergency care (injury survivability).
Federal Transit Administration	FTA is developing a framework for multi-level program evaluation. It will assess key project and program goals and create logic models for each portfolio. Each demonstration program has an independent program evaluation to review the effectiveness and outcomes for demonstration and deployment projects.
Federal Railroad Administration	FRA is building its capacity for project evaluation, as described in its R&D Evaluation Implementation Plan. This Plan was released in 2013 as a foundation for guiding systematic, improvement-oriented evaluations and institutionalizing program evaluation throughout FRA's Office of R&D. The Plan calls for a pilot stage to test, refine, and mainstream the new evaluation approach. Each R&D division has selected one or more current projects for pilot evaluation.
Pipeline and Hazardous Materials Safety Administration	PHMSA has designed a systematic evaluation process for raising and validating program quality. The process follows research projects from their inception to result implementation. Each step of this systematic process ensures that project outcomes will be the highest quality, relevant to the mission of the program, and applied to the appropriate end users. In addition, annual peer reviews are conducted on all post-award or active research projects.
Maritime Administration	For MARAD and the maritime industry every research dollar is critical because funding is extremely limited, project costs are high and often span several years. MARAD understands that research funding when leveraged effectively can have significant positive impact on the industry and public for improving safety and our environmental footprint. In an effort to ensure public/private collaboration and cost sharing, MARAD consults with industry, regulatory and academic partners at least annually, and usually much more frequently to ensure that the activities/projects serve to address emerging marine transportation environmental issues and needs. The outreach also serves to provided program visibility, collect feedback and deliver research results to maritime stakeholders.
Intelligent Transportation Systems – Joint Program Office	The ITS JPO routinely conducts evaluations to determine the effectiveness and benefits of deployed ITS and the value of ITS program investments. The ITS JPO has evaluated major ITS research initiatives such as Integrated Corridor Management and the Urban Partnership Agreements. It is currently planning the future evaluation of two ongoing technology deployments; the Connected Vehicle Pilot Deployments and the Smart City Challenge

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APPENDIX A: R&D ACTIVITIES AND EXPECTED FINDINGS

As required by the FAST Act, this appendix lists the Department's primary proposed R&D activities (programs) and the expected research findings by the end of FY2021.

FAA

Current or Anticipated RD&T Program Title	Anticipated Research Findings
Fire Research and Safety	Introduction of enabling technologies to prevent accidents caused by fire in cargo and passenger aircraft. New technologies of interest to the aircraft manufacturers and operators will be enabled in a fire-safe manner or prohibited if warranted.
Advanced Materials/Structural Safety	Improvements to aviation safety through improved understanding of aerospace vehicle design, structure, and subsystems. Development of standards, policy, methodologies, and tools for certification.
Aeromedical Research	Improvements to aviation safety through improved understanding of factors influencing human physiology and performance in aerospace environments. Guidance and tools that enhance human safety, protection, and survival during civil aerospace operations.
Air Traffic Control/Technical Operations Human Factors	Improvements to aviation safety through improved knowledge of the human-system interface. Reduction in accidents and incidents through enhanced aerospace vehicle, air traffic, and technical operations that adapt to, compensate for, and augment human performance.
Aircraft Catastrophic Failure Prevention	Improvements to aviation safety through improved understanding of aerospace vehicle design, structures, and subsystems. Development of standards, policy, methodologies, and tools for certification.
Aircraft Icing/Digital System Safety	Improvements to aviation safety through improved understanding of aerospace vehicle design, structures, and subsystems. Development of standards, policy, methodologies, and tools for certification.
Commercial Space Transportation	**Improvements to aviation safety through:** **[1]** Safe and efficient integration of increased commercial space launch and re-entry activity into the NAS. **[2]** Improved vehicle safety and risk management, including knowledge of all safety-critical components and systems for space vehicles and their operations, to better identify potential hazards and apply and verify hazard controls. **[3]** Guidance and tools that enhance human safety, protection, and survival during space operations.
Continued Airworthiness	Improvements to aviation safety through improved understanding of aerospace vehicle design, structures, and subsystems. Development of standards, policy, methodologies, and tools for certification.

FAA *(continued)*

Current or Anticipated RD&T Program Title	Anticipated Research Findings
Flight Deck/Maintenance System Integration Human Factors	Improvements to aviation safety through improved knowledge of the human-system interface. Reduction in accidents and incidents through enhanced aerospace vehicle, air traffic, and technical operations that adapt to, compensate for, and augment the performance of the human.
NextGen Alternative Fuels for General Aviation	Reduced environmental impact of aviation operation through data and methodologies to support certification of alternative fuels for general aviation aircraft.
Propulsion and Fuel Systems	Enhanced aviation safety through improved understanding of aerospace vehicle design, structures, and subsystems. Development of standards, policy, methodologies, and tools for certification.
System Safety Management	Improvements to aviation safety through improved system-wide access and sharing of aviation safety data and analysis tools within the aviation community,
Unmanned Aircraft Systems	Improvements to aviation safety through improved understanding of aerospace vehicle design, structures, and subsystems. Development of standards, policy, methodologies, and tools for certification.
Weather Program	**Improvements to aviation safety through:** **[1]** Requirements and standards for improving the quality, quantity, and availability of meteorological information to safely implement NextGen operational improvements. **[2]** Improved accuracy and accessibility of observed and forecast weather information to reduce the number of accidents and incidents attributed to hazardous weather.
NextGen Wake Turbulence	Improvements to wake turbulence efficiency through improved aircraft separation processes associated with generalized and static air navigation service provider wake turbulence mitigation separation standards.
NextGen Air Ground Integration Human Factors	Improvements to human-system integration. Increased ATC efficiency through improved connectivity between cockpit technology and air traffic workstations, enhancing controller-pilot coordination in cooperatively managing traffic loads.
NextGen Weather Technology in the Cockpit	**Efficiency improvements through:** **[1]** Requirements and standards for improving the quality, quantity, and availability of meteorological information to reduce impacts of adverse weather on rerouting, NAS capacity, and NextGen operational procedures. **[2]** Improved accuracy and accessibility of observed and forecast weather information to improve NAS efficiency (e.g., reduced delays and cancellations, increased capacity in high traffic areas).

FAA *(continued)*

Current or Anticipated RD&T Program Title	Anticipated Research Findings
NextGen Information Security	Improved cyber resiliency for the NAS system of systems to deter adversaries who persistently attack the NAS.
Environment and Energy	**Reduced environmental impacts of aviation through:** **[1]** Reduced noise impacts on communities. **[2]** Reduced impact of aviation emissions on air quality and global climate. **[3]** Improved energy efficiency and assured availability of sustainable alternative jet fuels.
NextGen Environmental Research Aircraft Technologies	**[1]** Reduced environmental impacts of aviation through: **[2]** Reduced significant community noise impacts in absolute terms. **[3]** Reduced impact of aviation emissions on air quality and global climate.
System Planning and Resource Management	Timely and effective planning, formulation, coordination, and management of FAA's R&D portfolio, leading to a more effective research program, benefiting the public by making aviation safer and smarter, and enhancing U.S. global leadership in aviation.
William J. Hughes Technical Center Laboratory Facility	A capable and ready integrated laboratory platform to support R&D project performance in demonstrating operational procedures, defining human and system performance requirements, full-mission demonstrations integrating NextGen air and ground capabilities for pilot separation responsibility and controller efficiencies, and analysis, evaluation, and validation of R&D milestones.
Advanced Technology Development and Prototyping	**The Runway Incursion Reduction Program:** **[1]** Aviation safety improvements by ensuring there are no fatal accidents on certificated airports as a result of airport design, runway incursions or excursions, or wildlife strikes. **[2]** Continued development of safety technologies at large airports, and small-to-medium sized airports with commercial service throughout the NAS with a recent uptick in the rate of runway incursions. **The Operations Concept Validation and Major Airspace Redesign Programs:** Efficiency improvements through feasible procedures, operational methods, and technologically-advanced systems that can decrease workload and increase efficiency of the NAS. **The Operational Concept Validation Program:** Early concept research for advanced operational concepts to ensure they are well-understood and based on valid assumptions. Airspace redesign projects are projected to deliver benefits through the reduction of restrictions, shorter flight distances, more fuel efficient routes, and reduced delays.
NextGen Separation Management Portfolio	Project efficiency improvements through: **1]** Improved methods and/or capabilities that enable safe reduction in separation standards, increase in airspace capacity, and/or efficient management of aircraft trajectories (OTTM). **[2]** Improved aircraft separation processes associated with current generalized and static air navigation service provider wake turbulence mitigation separation standards (Wake RECAT).

FAA *(continued)*

Current or Anticipated RD&T Program Title	Anticipated Research Findings
NextGen Improved Surface Portfolio	Efficiency improvements through improved methods, technologies, and capabilities that result in increased surface traffic movement efficiency.
NextGen On-Demand NAS Information	**Advanced Methods project:** Efficiency improvements through feasible procedures, operational methods, and technologically advanced systems that can decrease workload and increase efficiency of the NAS.
NextGen Improved Multiple Runway Operations	Efficiency improvements by safely reducing separation standards for approaches to closely spaced parallel runways, allowing increased airport capacity.
NextGen NAS Infrastructure	**Weather Observation Improvements project:** **[1]** Implementation of requirements and standards for improving the quality, quantity, and availability of meteorological information to reduce the impacts of adverse weather on rerouting, NAS capacity, and NextGen operational procedures. **[2]** Improved accuracy and accessibility of observed and forecast weather information to improve NAS efficiency (e.g., reduced delays and cancellations, increased capacity in high traffic areas).
NextGen Laboratory Support Portfolio	Efficiency improvements through concept engineering and evaluation activities that reduce the risk of successful implementation of ATM concepts and capabilities that improve NAS operational efficiency.
Center for Advanced Aviation System Development (CAASD)	Critical products that directly impact the successful development of the mid-term and long-term NAS. The work executed by CAASD supports a multitude of programs across all FAA lines of business. The support provided by CAASD is essential for major FAA programs to continue activities to satisfy operational requirements, and area shortcomings.
Airport Technology Research Program	**[1]** No fatal accidents on certificated airports as a result of airport planning, airport design, runway incursions or excursions, Foreign Object Debris, Aircraft Rescue and Firefighting, or wildlife strikes. **[2]** Availability of existing airport facilities protected and used as efficiently as possible, while making strategic investments in new facilities consistent with evolving aviation needs and **[3]** Established requirements, policies, procedures, and resources to allow airports in the United States to become environmentally friendly neighbors.
Airport Cooperative Research Program (ACRP)	The ACRP advances state of the knowledge and practice to the airport operator community and other industry stakeholders across a broad range of topics. Specific outcomes depend on the particular research proposals awarded in a given year.

FHWA

Current or Anticipated RD&T Program Title	Anticipated Research Findings
Bridges and Structures	Improved safety and durability of infrastructure as a result of greater resilience to natural and human-induced hazards, effective bridge construction, and improved highway performance.
Pavement and Materials	Enhanced pavement designs, more durable and sustainable materials, and improved test methods to meet the needs of highway agencies.
Construction and Program Administration	Accelerated construction and improved infrastructure quality. Effective investment of Federal funds and resources in program stewardship and oversight.
Transportation Performance Management (TPM)	Increased adherence to new regulatory requirements by State DOTs and MPOs. Enhanced understanding of infrastructure performance, improved goal-oriented investment decision making, and increased transparency regarding the performance of Federal-aid funding.
Safety	Improved safety for pedestrians, bicyclists, and drivers due to data-driven safety analyses.
Freight and Operations	Improved safety and efficiency of freight transportation and decreased highway congestion.
Planning and Environment	Improved sustainability of highways and enhanced knowledge of the environmental impacts of highway transportation.
Policy	Improved policy and decision making through enhanced access to knowledge and data, international collaboration, expedited information delivery, and better guidance for State agencies.
Innovative Program Delivery	Improved knowledge and awareness of opportunities and challenges relating to public-private partnerships (P3s); and an improved statutory and policy framework that enables and supports P3s. Medium- to long-term outcomes include an integration of P3 use and improved decision making capabilities within States.
Exploratory Advanced Research	Breakthrough solutions in all aspects of highways, such as durability, efficiency, environmental impact, productivity, and safety.
Performance Management and Data Support	Improved decision making as a result of enhanced data systems, improved data collection, and new methods of data analysis.

FHWA *(continued)*

Current or Anticipated RD&T Program Title	Anticipated Research Findings
Surface Transportation Funding Alternatives (STSFA)	Improved functionality of user-based alternative revenue mechanisms. Increased awareness of the need for alternative funding sources for surface transportation programs.
Corporate and Communications	Coordinated, comprehensive research and technology program, and improved planning and communication of research and technology activities.
Every Day Counts	Accelerated deployment of innovations and decreased project development and delivery times. Enhanced safety, sustainability, and infrastructure integrity.
State Transportation Innovation Council (STIC) Incentive	Enhanced acceptance of an innovation culture within the States and the adoption of proven innovation practices and technologies as standard practices.
Accelerated Innovation Deployment (AID) Demonstrations	Increased deployment and adoption of innovations and enhanced technology transfer.
Accelerating Market Readiness	Accelerated market readiness of promising innovations for future promotion and deployment by FHWA.
Accelerated Development of Pavement Technologies	Increased pavement durability and enhanced pavement design and construction.
Advanced Transportation and Congestion Management Program	Demonstration of how emerging transportation technologies, data, and their applications can be effectively deployed and integrated with existing systems to address transportation challenges.
Small Business Innovation Research (SBIR)	Increased participation of small businesses in SBIR. Increased private-sector commercialization of innovations created using Federal R&D funding.

FMCSA

Current or Anticipated RD&T Program Title	Anticipated Research Findings
Produce Safer Drivers	Better understanding of the causes and impacts of driver health and wellness issues and unsafe driving behaviors. Develop effective tools to promote driver wellness and to prevent unsafe behaviors.
Improve Safety of CMVs	Better understanding of the safety impacts associated with the adoption/use of cutting edge CMV safety technologies. Through Small Business Innovation Research projects, development, testing, and potential commercialization of CMV safety technologies.
Produce Safer Carriers	Improved enforcement and inspection tools. Improved understanding of the effectiveness of existing CMV safety technologies and safety impacts of newly developed CMV technologies. Motor carrier guidance to make informed decisions in implementing various CMV safety technologies.
Advance Safety through Information-Based Initiatives	Resource for FMCSA's rulemaking, policy, and enforcement initiatives. Areas of focus to be determined based on FMCSA's needs.
Enable and Motivate Internal Excellence	Support management for the Research and Technology Program and internal partnerships/achievement of U.S. DOT's goals.

NHTSA

Current or Anticipated RD&T Program Title	Anticipated Research Findings
Crashworthiness/ Biomechanics	Enhancements in frontal and side crash safety, occupant containment, child passenger safety, and advanced occupant restraint performance. NCAP implementation of Test Device for Human Occupant Restraint (THOR) and Worldwide Harmonized Side Impact Dummy (WorldSID) front and side impact adult test dummies and associated new injury criteria, development of advanced child dummies. Detailed field data collection of serious injury cases and publication of cases by NHTSA's Crash Injury Research and Engineering Network (CIREN). Injury mechanisms/tolerances for vulnerable populations. Development and application of advanced mathematical models of human occupants and pedestrians.
Post-Crash Safety	Test procedure for and injury severity prediction and potential benefits associated with Advanced Automatic Collision Notification (AACN).
Crash Avoidance	Emerging driver assistance technologies focus on developing objective test procedures, assessing effectiveness, driver acceptance, system performance and reliability, costs and benefits of leading-edge crash avoidance technologies. Technologies and systems include collision imminent braking and dynamic brake support, pedestrian detection, warning and auto-braking, lane keeping assist and blind spot monitoring, lane departure warning, and other innovative crash avoidance technologies. Methodology is "real world" field studies; measurement of performance under controlled test track conditions; modeling, simulation and hardware-in-the-loop testing platforms. Technical support from academic research partners, vehicle OEMs, safety system suppliers, and support contractors and consultants. Continued evaluation and testing of connected vehicle technology using vehicle-to-vehicle (V2V) communications for leading-edge crash avoidance applications; such as intersection movement assist, left-hand turn assist, and other crash scenarios that may benefit from V2V.
Alternative Fuels	Development of new test procedures and performance measures for safe operation, charging, and emergency response for lithium ion battery vehicles and other emerging high voltage traction vehicles. Refinement of test procedures, and performance measure for the safe operation, filling, and disposal of high pressure container vessels for hydrogen and natural gas powered vehicles. Continued introduction of new requirements to address unique safety considerations for evolving vehicle types.

NHTSA *(continued)*

Current or Anticipated RD&T Program Title	Anticipated Research Findings
Vehicle Electronic and Emerging Technology	Safe operation and deployment of highly automated vehicles Cybersecurity issues resulting from increased connectivity of advanced technology vehicles. Identification of new hazards that may arise in emerging vehicle electronics before they are in production. Identification of potential defects in electronics and software, and assistance with recall or other consumer complaint issues.
Highway Safety Research	The results of NHTSA's Highway Safety Research program are used to develop guidance for State and local highway safety programs. The research develops the data that help States and others prioritize their efforts toward the larger contributors to traffic crashes and identifies new trends they should be aware of. Although we make publicly available at no charge research reports for most individual research and program evaluation projects, this information is summarized bi-annually in a guidance document titled Countermeasures That Work: A Highway Safety Countermeasure Guide for State Highway Safety Offices.
Vehicle Research and Test Center—Ohio	The Vehicle Research and Test Center (VRTC) is NHTSA's in-house research, development, test and evaluation facility located in East Liberty, Ohio. Activities conducted at VRTC support agency programs including safety defect investigations, updates to Federal Motor Vehicle Safety Standards, test procedure development for new regulatory actions and agency consumer information programs, test dummy development, injury criteria development, advanced research into cutting edge technologies, and safety issues that require quick reaction. The full range of testing and research capabilities available to NHTSA at VRTC allows the agency to address emerging technologies and safety issues and access to world class testing facilities similar to those used by automotive suppliers and manufacturers.
Autonomous Vehicle Development	Automation technologies have enormous potential to save lives, reduce travel times, and conserve fuel. They need to be incorporated quickly and safely into our transportation networks by developing interoperable standards that keep all users safe, staying ahead of cybersecurity threats, and ensuring safety standards can adjust to the speed of innovation. Large-scale deployment tests of connected and highly automated vehicles and expedited safe deployment of life-saving technologies will build consumer confidence and ensure that the United States retains its leadership position in the development of automated vehicle technology.

FTA

Current or Anticipated RD&T Program Title	Anticipated Research Findings
Mobility	Transportation efficiency by promoting an agile, responsive, accessible, and seamless multimodal service, inclusive of transit, through enabling technologies and innovative partnerships. Increased transportation effectiveness by ensuring that transit is fully integrated and a vital element of a regional transport network, providing consistent, reliable, and accessible service to every traveler. Enhanced customer experience by providing each individual with equitable, accessible, traveler-centric service leveraging public transportation's long-standing capability and traditional role in this regard.
Safety	Demonstrated feasibility of innovative solutions and technologies to improve transit operations safety. FTA expects agencies to share Program successes with the rest of the transit industry. i.e., the reduction of crashes, fatalities, and injuries. A comprehensive review of public transportation safety standards and creation of Federal minimum public transportation safety standards, including standards in other areas, such as connected vehicle, automation, electric vehicles, charging infrastructure, etc. Identification and adoption of standards that improve new transit bus visibility. Adoption of employee safety reporting systems nationwide and using data to improve transit agency safety policies and practices.
Asset Management and Asset Innovation	Ability of transit agencies to continuously monitor, assess, and determine track condition trends rather than wait for results from high-rail inspection vehicles or track geometry vehicles (normally twice a year). Reduction in left-turning crashes and corresponding fatalities and injuries involving transit buses and a reduction in transit agency liability claims. Performance specifications and life cycle metrics for components.
Transportation Cooperative Research Program	Enhanced transit customer travel experience by identifying ways to increase customer satisfaction, improve access to transportation options, expand service time/geography, and connect to life activities. Improved ability of transit agencies to integrate affordable and sustainable technology solutions that improve transit service quality for mobility, accessibility, operations, and community access. Increased effectiveness and efficiency of public transportation, through identifying processes and methods that support continuous improvement in public transportation industry services, safety, asset management, and operations.

FRA

Current or Anticipated RD&T Program Title	Anticipated Research Findings
Track Research	Fewer train derailments due to poor track conditions, broken rails, track buckles, landslides and washouts. Improved procedures for qualifying vehicles to operate on mixed use track. Improved facilities for conducting track research.
Rolling Stock Research	Fewer train derailments due to rolling stock equipment failures, improved protection for passengers and train crews in accidents, and reduced release of hazardous materials.
Train Control and Communication Research	Fewer train-to-train collisions and train collisions with objects on the line and at grade crossings.
Human Factors Research	Fewer accidents and incidents caused by human error. Improved safety culture in the railroad industry.
Railroad Systems Issues Research	Improved allocation of R&D funds and support to other programs in improving railroad safety.

PHMSA Hazardous Materials Safety Administration RD&T Program

Current or Anticipated RD&T Program Title	Anticipated Research Findings
Preventing Pipeline Damage	Damage to pipe by excavation and outside force continues to be a leading cause of pipeline failure. Develop new or improved tools and technology for preventing or reducing damage to pipelines, which will in turn prevent or lessen releases into the environment.
Improving Leak Detection Systems	Leak detection continues to present a challenge, especially in pipelines with very small liquid leaks. Develop new or improved tools and technology solutions for reducing the volume of product released into the environment and for identifying leaks before they lead to catastrophic ruptures.
Improving Anomaly Detection & Characterization	Detecting and characterizing anomalies in pipelines require solutions having people, processes, and technology as part of a comprehensive program. Develop new or improved tools, technology, and assessment processes for identifying and locating critical pipeline defects and identifying their severity.
Investigating the Impact of Alternative Fuels and Other National Challenges	Identify and remove technical issues preventing the safe transportation of alternative fuels in pipelines and address other emerging technological or policy issues of a national scale.

PHMSA

Pipeline Safety RD&T Program

Current or Anticipated RD&T Program Title	Anticipated Research Findings
Risk Management and Communication	Risk management methods for assessing hazardous materials transport; both regulatory operations and impacts, and transport operations and systems. Communication tools and best practices to ensure results are communicated to the transport industry.
Emerging Technology	Analysis of emerging energy products including various grades of crude oil; liquefied natural gas; ethanol and hydrogen. Analysis of new packaging materials and technologies. Analysis of transportation systems and operations.
Packaging Integrity	Testing and evaluation of existing packaging materials and packaging technologies. Analysis, evaluation and performance evaluations of emerging packaging materials and methods. Testing and evaluation of materials whose composition is included as part of the overall combination packaging.
Technical Analysis of Risks	Analysis of individual hazardous materials incidents and accidents to determine root cause. Analysis of all hazardous materials transport incidents and accidents to determine patterns or anomalies within packagings or systems. New inspection and test methods to classify materials and to certify packagings.

MARAD

Current or Anticipated RD&T Program Title	Anticipated Research Findings
Maritime Environmental and Technical Assistance (META)	Improved technology and standards for testing and evaluating the effectiveness of ballast water management technologies. Improved application of technologies that reduce air emissions. Expanded use of alternative energy technologies in the maritime industry.

ITS JPO

Current or Anticipated RD&T Program Title	Anticipated Research Findings
Connected Vehicles	Demonstrations of CV environments that fit into real-world environments of today. Real-time and real-world data to help with transportation planning and transportation system operations. Increased safety, mobility, system efficiency, and access to resources for disadvantaged groups. Decrease in negative environmental impacts, such as vehicle emissions, the need for physical expansion, and noise. Increased opportunities to partner with non-government groups, such as private industry and universities. Decrease in undesirable transportation impacts to the environment and society. Reduction of fatalities through weather-related safety, infrastructure-based, and other applications.
Automated Vehicles	Guidance to State and local agencies to help the understanding of impacts of automated vehicles on the assets they manage. Expanded reach of transportation modes to disabled and older users and "last mile" connectivity services for all users. Increased efficiency and effectiveness of existing transportation systems. Decrease in number and severity of crashes caused by drivers or by other conditions (e.g. weather, pedestrians, and roadway conditions). Decrease in aggressive driving.
Emerging Technologies (includes Smart Cities Challenge)	Stronger relationships and partnerships with private industry and universities. Increased ability to adapt existing or upcoming program to accommodate new ITS technologies. Stimulated economic growth through innovation and technological leadership.
Enterprise Data	Methods to share information efficiently while ensuring data privacy protection. Methods to manage and leverage big data. Performance monitoring and system agility. Innovation in new applications and research. New revenue opportunities/business models for sustaining data operations. Improved quality (accuracy and timeliness) of data.

ITS JPO *(continued)*

Current or Anticipated RD&T Program Title	Anticipated Research Findings
Interoperability	Nationwide interoperability for vehicles and other participants in the ITS system. Transportation solutions that resolve interoperability among developers, users, agencies, and modes to increase efficiencies, reduce costs, and provide real-time and effective information. Increased efficiency in communication and information sharing between transportation agencies and users. Greater adoption rates with reduced anxiety over obsolescence. Increased efficiencies in the economic enterprise. Maintenance of the forward and backward interoperability of ITS equipment and reduce need for re-investment over time.
Accelerating Deployment	Deployment support by assisting with transition planning, training, transition plans, timelines, and milestone development. Communication and education support to facilitate awareness, understanding, acceptance, adoption, and deployment of ITS technologies across all stakeholder groups. Effective partnerships at various levels – executive, program, and project. Partnerships that encompass a wide range of public and private partners.
Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD)	Model technology deployments showing how emerging transportation technologies, data, and their applications can be effectively deployed and integrated with existing systems to address transportation challenges.
SBIR	Increased participation in innovation and entrepreneurship by small businesses and socially and economically disadvantaged persons; and Increased private sector commercialization of innovations derived from Federal R&D funding.

APPENDIX B – ANTICIPATED FUNDING LEVELS

As required by the FAST Act, this appendix provides the annual funding levels anticipated by each Operating Administration for the period covered by the U. S. DOT RD&T Strategic Plan (FY 2017– 2021). The FAST Act only goes through the end of FY 2020, FY 2021 is based on the same distribution and total authorizations, with a redistribution across the other programs of the funds that had in earlier years been designated for the expected sunset of programs.

The FY 2017 column are FY 2017 President Budget funding levels. If the Operating Administration is authorized by the FAST Act, the FY 2018 through FY 2021 are FAST Act authorized funding levels. If the Operating Administration is not authorized by the FAST Act, they are inflated at a 2% policy growth rate. Funding levels other than the FAST Act authorized levels or a 2% policy growth rate are identified via footnotes in the following tables.

FAA

Current or Anticipated RD&T Program Title	Funding FY17 $000	Funding FY18 $000	Funding FY19 $000	Funding FY20 $000	Funding FY21 $000
Fire Research and Safety	7,925	8,084	8,245	8,410	8,578
Advanced Materials/Structural Safety	4,113	4,195	4,279	4,365	4,452
Aeromedical Research	9,538	9,729	9,923	10,122	10,324
Air Traffic Control/Technical Operations Human Factors	6,165	6,288	6,414	6,542	6,673
Aircraft Catastrophic Failure Prevention	1,528	1,559	1,590	1,622	1,654
Aircraft Icing /Digital System Safety	5,102	5,204	5,308	5,414	5,523
Commercial Space Transportation	2,953	3,012	3,072	3,134	3,196
Continued Airworthiness	10,269	10,474	10,684	10,898	11,115
Flight Deck/Maintenance System Integration Human Factors	8,513	8,683	8,857	9,034	9,215
NextGen Alternative Fuels for GA	5,792	5,908	6,026	6,147	6,269
Propulsion and Fuel Systems	2,574	2,625	2,678	2,732	2,786
System Safety Management	7,000	7,140	7,283	7,428	7,577
Unmanned Aircraft Systems	8,422	8,590	8,762	8,937	9,116
Weather Program	17,976	18,336	18,702	19,076	19,458
NextGen Wake Turbulence	8,609	8,781	8,957	9,136	9,319
NextGen Air Ground Integration Human Factors	8,575	8,747	8,921	9,100	9,282
NextGen Weather Technology in the Cockpit	4,059	4,140	4,223	4,307	4,394
NextGen Information Security	1,000	1,020	1,040	1,061	1,082
Environment and Energy	15,013	15,313	15,620	15,932	16,251
NextGen Environmental Research Aircraft Technologies	26,174	26,697	27,231	27,776	28,332
System Planning and Resource Management	2,788	2,844	2,901	2,959	3,018
William J. Hughes Technical Center Laboratory Facility	3,412	3,480	3,550	3,621	3,693

FAA *(continued)*

Current or Anticipated RD&T Program Title	Funding FY17 $000	Funding FY18 $000	Funding FY19 $000	Funding FY20 $000	Funding FY21 $000
Advanced Technology Development & Prototyping	24,800	25,296	25,802	26,318	26,844
NextGen Separation Management Portfolio	25,800	26,316	26,842	27,379	27,927
NextGen Improved Surface Portfolio	2,000	2,040	2,081	2,122	2,165
NextGen On-Demand NAS Information	8,500	8,670	8,843	9,020	9,201
NextGen Improved Multiple Runway Operations	6,500	6,630	6,763	6,898	7,036
NextGen NAS Infrastructure	17,660	18,013	18,373	18,741	19,116
NextGen Laboratory Support	12,000	12,240	12,485	12,734	12,989
Center for Advanced Aviation System Development	60,000	61,200	62,424	63,672	64,946
Airport Technology Research Program	31,375	32,003	32,643	33,295	33,961
Airport Cooperative Research Program	15,000	15,300	15,606	15,918	16,236
Total	**371,135**	**378,558**	**386,129**	**393,851**	**401,728**

FHWA

Current or Anticipated RD&T Program Title	Funding FY17 $000	Funding FY18 $000	Funding FY19 $000	Funding FY20 $000	Funding FY21 $000
Bridges and Structures	6,000	6,000	6,000	6,000	8,500
Pavement and Materials	11,000	11,000	11,000	11,000	16,000
Construction and Program Administration	3,000	3,000	3,000	3,000	4,500
Transportation Performance Management	15,000	15,000	15,000	15,000	21,500
Safety	13,500	13,500	13,500	13,500	19,500
Freight and Operations	14,000	14,000	14,000	14,000	20,000
Planning and Environment	12,500	12,500	12,500	12,500	18,000
Policy	8,000	8,000	8,000	8,000	11,500
Innovative Program Delivery	2,500	2,500	2,500	2,500	3,500
Exploratory Advanced Research	6,000	6,000	6,000	6,000	8,500
Performance Management Data Support	5,000	5,000	5,000	5,000	7,000

FHWA *(continued)*

Current or Anticipated RD&T Program Title	Funding FY17 $000	Funding FY18 $000	Funding FY19 $000	Funding FY20 $000	Funding FY21 $000
Surface Transportation Funding Alternatives	20,000	20,000	20,000	20,000	0
Corporate and Communications	7,500	7,500	7,500	7,500	11,500
Every Day Counts	8,000	8,000	8,000	8,000	11,500
State Transportation Innovation Council (STIC) Incentives	6,000	6,000	6,000	6,000	6,000
Accelerated Deployment Innovation Deployment (AID) Demonstrations	12,000	12,000	12,000	12,000	20,000
Accelerating Market Readiness	1,500	1,500	1,500	1,500	2,000
Accelerated Deployment of Pavement Technologies (ADPT)*	[12,000]	[12,000]	[12,000]	[12,000]	[12,000]
Advanced Transportation and Congestion Management Program (ATCMTD)	39,000	39,000	39,000	39,000	0
Small Business Innovation Research (SBIR)	2,000	2,000	2,000	2,000	3,000
Total	**192,500**	**192,500**	**192,500**	**192,500**	**192,500**

*The ADPT designation is funded out of the Pavement and Materials program and the AID Demos program.

FMCSA

Current or Anticipated RD&T Program Title	Funding FY17 $000	Funding FY18 $000	Funding FY19 $000	Funding FY20 $000	Funding FY21 $000
Produce Safer Drivers	3,720	3,720	3,720	3,720	3,720
Improve Safety of CMVs	3,420	3,420	3,420	3,420	3,420
Produce Safer Carriers	1,240	1,240	1,240	1,240	1,240
Advance Safety through Information-Based Initiatives	1,340	1,340	1,340	1,340	1,340
Enable and Motivate Internal Excellence	960	960	960	960	960
Total	**10,680**	**10,680**	**10,680**	**10,680**	**10,680**

NHTSA

Current or Anticipated RD&T Program Title	Funding FY17 $000	Funding FY18 $000	Funding FY19 $000	Funding FY20 $000	Funding FY21 $000
Crashworthiness	16,800	17,300	17,300	17,300	17,300
Crash Avoidance	12,300	15,400	15,400	15,400	10,400
Alternative Fuels	1,400	1,900	1,900	1,900	1,900
Vehicle Electronic and Emerging Technology	54,850	63,600	63,600	63,600	63,600
Vehicle Test Center— Ohio	500	20,000	20,000	20,000	20,000
Highway Safety Research	11,521	11,763	12,010	12,262	12,520
Autonomous Vehicle Development*	200,000	400,000	600,000	600,000	600,000
Total	**297,371**	**529,963**	**730,210**	**730,462**	**725,720**

* The Autonomous Vehicle funding reflects the breakout for five years of the $3.9 billion that is in NHTSA's FY 2017 Congressional Justification. The $3.9 billion is to be spent over 10 years. The amounts in the table above provide the breakout for the first five of those 10 years.

FTA

Current or Anticipated RD&T Program Title	Funding FY17 $000	Funding FY18 $000	Funding FY19 $000	Funding FY20 $000	Funding FY21 $000
Mobility	9,000	9,000	9,000	9,000	9,000
Safety	6,000	6,000	6,000	6,000	6,000
Asset Innovation & Asset Management	8,000	8,000	8,000	8,000	8,000
Transportation Cooperative Research Board	5,000	5,000	5,000	5,000	5,000
Total	**28,000**	**28,000**	**28,000**	**28,000**	**28,000**

FRA

Current or Anticipated RD&T Program Title	Funding FY17 $000	Funding FY18 $000	Funding FY19 $000	Funding FY20 $000	Funding FY21 $000
Track	11,429	11,658	11,891	12,129	12,371
Rolling Stock*	24,722	10,322	10,322	10,322	10,322
Train Control & Communication	8,086	8,248	8,413	8,581	8,753
Human Factors	5,542	5,653	5,766	5,881	5,999
Railroad Systems Issues	3,721	3,795	3,871	3,949	4,028
Total	**53,500**	**39,676**	**40,263**	**40,861**	**41,472**

* The Rolling Stock number received an increase in the FY 2017 budget for a one-time initiative, hence why the FY 2018 through FY 2021 levels are lower.

PHMSA

Current or Anticipated RD&T Program Title	Funding FY17 $000	Funding FY18 $000	Funding FY19 $000	Funding FY20 $000	Funding FY21 $000
Pipeline Safety RD&T Program*	13,916	13,946	14,225	14,510	14,800
Hazardous Materials Safety RD&T Program **	9,792	9,988	10,188	10,391	10,599
Total	**23,708**	**23,934**	**24,413**	**24,901**	**25,399**

* PHMSA's Pipeline Safety program was reauthorized in the PIPES Act from 2016 through 2019. FY 2018–2021 RD&T amounts reflect a MAX 2% policy growth rate.

** PHMSA's Hazardous Materials Safety program was reauthorized in the FAST Act. The FAST Act did not include specific RD&T amounts for this program. Hazardous Materials Safety's RD&T levels are determined in the annual Appropriations Act. FY 2018–2021 RD&T amounts reflect a MAX 2% policy growth rate.

MARAD

Table 17. Anticipated MARAD RD&T Funding

Current or Anticipated RD&T Program Title	Funding FY17 $000	Funding FY18 $000	Funding FY19 $000	Funding FY20 $000	Funding FY21 $000
Maritime Environmental and Technical Assistance*	3,000	3,060	3,121	3,184	3,247

* Maritime Environmental and Technical Assistance (META) funding is a line item within MARAD's Operations and Training budget and is provided pursuant to 46 USC 50307. Most, but not all, META funding is used for R&D projects. For FY2017, MARAD estimates that $2.7M of the requested $3.0M will be used for RD&T projects.

ITS JPO

Table 18. Anticipated ITS JPO RD&T Funding

Current or Anticipated RD&T Program Title	Funding FY17** $000	Funding FY18 $000	Funding FY19 $000	Funding FY20 $000	Funding FY21 $000
Connected Vehicles	30,275	30,000	30,000	30,000	12,000
Automated Vehicles	3,950	4,000	4,000	4,000	30,000
Emerging Technologies	18,025	18,000	18,000	18,000	10,000
Enterprise Data	3,400	3,400	3,400	3,400	15,400
Interoperability	6,050	6,300	6,300	6,300	10,300
Accelerating Deployment	15,300	15,300	15,300	15,300	20,300
Advanced Transportation and Congestion Management Technologies Deployment	21,000	21,000	21,000	21,000	0*
SBIR	2,000	2,000	2,000	2,000	2,000
Total	**100,000**	**100,000**	**100,000**	**100,000**	**100,000**

* Funds are not set aside in 2021 for ATCMTD (Sec.6004). Funding is as anticipated across programs.

** Funding total is as Authorized in FAST Act (Title VI Innovation) Sec. 6002(a)(4)

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LIST OF ACRONYMS

AAR	Association of American Railroads
AASHTO	American Association of State Highway and Transportation Officials
ACRP	Airport Cooperative Research Program
ADTP	Accelerated Deployment of Pavement Technologies
AERIS	Applications for the Environment: Real-Time Information Synthesis
AGA	American Gas Association
AID	Accelerated Innovation Deployment
AMS	Acquisition Management System
AMRP	Annual Modal Research Plan
APTA	American Public Transportation Association
ATCMTD	Advanced Transportation and Congestion Management Program
ATTRI	Accessible Transportation Technologies Research Initiative
AV	Automated Vehicle
BTS	Bureau of Transportation Statistics
CAAFI	Commercial Aviation Alternative Fuels Initiative
CAASD	Center for Advanced Aviation System Development
CACC	Cooperative Adaptive Cruise Control
CAFÉ	Corporate Average Fuel Economy
CAMP	Crash Avoidance Metrics Partnership
CCCEF	Center for Climate Change and Environmental Forecasting
CDC	Center for Disease Control
CISR	Critical Infrastructure Security and Resilience
CLEEN	Continuous Lower Emissions, Energy and Noise
CMV	Commercial Motor Vehicle
CNG	Compressed Natural Gas
COMSTAC	Commercial Space Transportation Advisory Committee
CRDA	Cooperative Research and Development Agreement
CSPO	Closely Spaced Parallel Runway Operations
CUTR	Center for Urban Transportation Research
CV	Connected vehicle
CVISN	Commercial Vehicle Information Systems and Networks
CVPD	Connected Vehicle Pilot Deployment
DADSS	Driver Alcohol Detection System for Safety
DOD	Department of Defense
DOE	Department of Energy
DOT	Department of Transportation
DSRC	Dedicated Short-Range Communication
EAR	Exploratory Advanced Research
EDC	Every Day Counts
EJ	Environmental Justice
EV	Electric Vehicle
EMAT	Electromagnetic Acoustic Transducer
EPA	Environmental Protection Agency
ESV	Enhanced Safety of Vehicles
FAA	Federal Aviation Administration
FAF	Freight Analysis Framework
FAST Act	Fixing America's Surface Transportation Act
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FMVSS	Federal Motor Vehicle Safety Standards
FPM	Freight Performance Measure Program
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
FY	Fiscal Year
GA	General Aviation
GHG	Greenhouse Gas
GIS	Geographic information systems
GBP	Global Benchmarking Program
GPS	Global Positioning System
HFCC	Human Factors Coordinating Committee (
HRD	Highway Research and Development Program
IoT	Internet of Things
IMRO	Improved Multiple Runway Operations
INVEST	Infrastructure Voluntary Evaluation Sustainability Tool
IP	Intellectual Property
ITD	Innovative Technology Deployment grant program
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation Systems
ITSA	ITS America
JPO	Joint Program Office
LoNo	Low and No Emissions
LTBP	Long-Term Bridge Performance
LTPP	Long Term Pavement Performance
MAP-21	Moving Ahead for Progress in the 21st Century
MARAD	Maritime Administration
MCC	Microscale Combustion Calorimeter
META	Maritime Environmental and Technical Assistance
MOD	Mobility on demand
MPO	Metropolitan Planning Organization
MWM	Meandering Winding Magnetometer

NARP	National Aviation Research Plan
NAS	National Airspace System
NCAP	New Car Assessment Program
NCHRP	National Cooperative Highway Research Program
NDS	Naturalistic Driving Study
NextGen	Next Generation Air Transportation System
NHTSA	National Highway Traffic Safety Administration
NIDILRR	National Institute on Disability, Independent Living and Rehabilitation Research
NSF	National Science Foundation
NTI	National Transit Institute
OST	Office of the Secretary
OST-R	Office of the Assistant Secretary for Research and Technology
P3	Public-Private Partnership
PAFI	Piston Aviation Fuels Initiative
PHMSA	Pipeline and Hazardous Materials Safety Administration
PNT	Position, Navigation, and Timing
PPT	Program Planning Team
PTC	Positive Train Control
Pub. L.	Public Law
RD&T	Research, Development, and Technology
R&D	Research and development
R&T	Research and technology
REB	Research, Engineering, and Development Executive Board
REDAC	Research, Engineering, and Development Advisory Committee
RID	Roadway Information Database
SBIR	Small Business Innovation Research
SCBA	Self-Contained Breathing Apparatus
SPaT	Signal Phase And Timing
SCMS	Security Credential Management System
SHRP2	Second Strategic Highway Research Program
STAC	Safety Training and Analysis Center
STIC	State Transportation Innovation Council
STSFA	Surface Transportation Funding Alternatives
T2	Technology transfer
TCRP	Transit Cooperative Research Program
TEU	Tonnage Equivalent Unit
TFHRC	Turner-Fairbank Highway Research Center
THOR	Test Device for Human Occupant Restraint
TIDP	Technology and Innovation Deployment Program
TPM	Transportation Performance Management
TRB	Transportation Research Board
TRI	FTA Office of Research, Demonstration, and Innovation
TSA	Transportation Security Administration
TTC	Transportation Technology Center
UAS	Unmanned aircraft system
UL	Underwriters Laboratories
UPHC	Ultra-High Performance Concrete
USC	United States Code
U.S. DOT	United State Department of Transportation
UTC	University Transportation Center
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
WorldSID	Worldwide Harmonized Side Impact Dummy
WTMA	Wake Turbulence Mitigation for Arrivals

ENDNOTES

[1] The terms “Operating Administration” and “Modal Administration” are used interchangeably in this document.

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