

Transforming Transportation through Connectivity



ITS Strategic Research Plan, 2010 – 2014 Progress Update 2012

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Executive Summary

Purpose of this Report

This report is a progress update for the United States Department of Transportation's (US DOT's) *ITS Strategic Research Plan – 2010–2014*. In 2010, the Department established a focused research agenda to prepare the next generation of intelligent transportation system (ITS) technologies for widespread deployment throughout the nation. This report describes the status of those research programs that are pursuing the most promising research for advancing transportation safety, mobility, and environmental performance.

Toward Implementing a Vision

Two and a half years ago, a "connected transportation environment" through vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications and applications was envisioned, based on a set of auspicious results. Previous ITS research¹ had culminated in the development of new, prototype, short-range wireless technologies and applications for safety that were successfully demonstrated in a highly mobile environment. These results were over five years in the making; the success of these engineering efforts led the Department and industry stakeholders to commit to continue efforts toward eventual nationwide implementation.

Through broad stakeholder discussions and rigorous internal analysis, a subsequent 2010–2014 research agenda was developed that focused on a set of critical research needs, including:

- ▶ The technological gaps and challenges associated with moving from research prototypes to deployment-ready vehicle and infrastructure technologies;
- ▶ The institutional and policy challenges associated with cooperative public-private implementation, particularly the establishment of security features to enable trustworthy yet anonymous transmission of safety-critical messages; and
- ▶ The institutional complexities associated with scaling a research prototype to a nationwide system.

The ongoing, rapid evolution of commercial wireless mobile data technologies presents challenges as well as opportunities. Since 2010, private industry has introduced technologies and applications that have established a highly connected world; similarly, the automotive industry is responding with ever increasing connectivity.

While options exist for achieving many connected transportation objectives, the need for vehicles to communicate with other vehicles in a safe, secure, and interoperable manner remains a critical capability that can only be delivered through dedicated short-range communications (DSRC). Thus, the Department's vision has evolved to incorporate an inclusive concept of connected vehicles and infrastructure using both DSRC and other mobile data communications technologies.

The Department remains resolute in its near-term commitment to finalizing initial V2V technologies and safety applications based on DSRC by late 2013; working with industry and government stakeholders on planning strategies and decisions; and researching and delivering a solid, analysis-based policy foundation for eventual implementation. The Department also affirms its commitment to leveraging other, existing communications media as a means of optimizing use of our nation's spectrum and for accelerating adoption and usage of connected-vehicle technologies and applications beyond V2V.

Summary of Progress

The ITS Strategic Research Program is on track and is a model of multimodal collaboration with the active participation of six US DOT administrations (the majority of the programs described in this report are inherently multimodal in scope and execution). The program has pursued active and consistent engagement with a broad stakeholder community. Based on strong program management principles, the research programs are on time and within budget.

¹ ITS Research Success Stories at: http://www.its.dot.gov/res_successes.htm.

In 2012, the research agenda is being performed at a time when the wireless world is still evolving rapidly but is vastly different from when this plan was originally written (for instance, smart phone ownership in the U.S. and other countries was approximately just over 20 percent in 2010; by 2012, it is closer, on average, to 50 percent with some age groups near 75 percent²). The ITS Program has kept abreast of these changes and has instituted frequent reviews with key decision makers to ensure that the research is in sync with emerging technology trends and market forces. Documenting the research agenda at this point offers an important resource for broader stakeholder review of program results and research progress.

Research and development efforts have advanced notably over the last two and a half years in four research areas: connected vehicle research; short-term intermodal research, including past research that is in demonstration stages; ITS exploratory research; and ITS cross-cutting support. The following presents key, significant advancements of the ITS Program.

Connected Vehicle Research Advancements

This area of research has produced the most significant accomplishments that support near-term decisions on the path toward implementation of a connected-vehicle environment. Results include:

In Safety

- ▶ **Advancement of the technical research for V2V/V2I safety technologies and applications to create prototypes for testing and demonstration.** This milestone includes development and testing of equipped-vehicle systems as well as retrofit and aftermarket devices (which were added to the research in 2010 to determine their technical viability and discern whether they might accelerate adoption). With the recognition that testing and demonstration are key to adoption, the ITS research agenda has evolved to include a new multimodal effort known as the Connected Vehicle Safety Pilot to test the technologies under real-world conditions. Results of *Safety Pilot* will support the National Highway Traffic Safety Administration's (NHTSA's) analysis of how safe and how transformative these technologies are, and will support agency decisions in 2013 for light vehicles and 2014 for heavy vehicles regarding the optimal path toward nationwide adoption.
- ▶ **The Department established the Connected Vehicle Safety Pilot as a means of demonstrating the readiness of DSRC-based connected vehicle safety applications for nationwide deployment.** Through this program, the US DOT will test connected vehicle safety applications in real-world driving scenarios in order to determine their effectiveness at reducing crashes and to ensure that the devices are safe and do not unnecessarily distract motorists or cause unintended consequences. A key objective of the *Safety Pilot* Program is to evaluate everyday drivers' reactions, both in a controlled environment through driver clinics and on actual roadways with other vehicles through the real-world model deployment. To date, an initial 24 cars have been built and tested through six *Safety Pilot* Driver Clinics, held in 2011, in Brooklyn, Michigan; Brainerd, Minnesota; Orlando, Florida; Blacksburg, Virginia; Fort Worth, Texas; and Alameda, California, during which 690 everyday drivers participated, generating over 20,000 miles of performance data. Progress is being made to prepare for the *Safety Pilot* Model Deployment which was awarded to the University of Michigan's Transportation Research Institute (UMTRI) and partners and will include up to 3,000 vehicles for testing including three integrated trucks, sixteen retrofitted commercial vehicles, and three buses.
- ▶ **Analysis of communications media options** has confirmed that DSRC continues to remain the most promising communications technology for V2V safety. However, the analysis has allowed the US DOT to expand its concept of "connectivity" and to embrace other forms of communications where appropriate. This is evidenced by development of the core system architecture that may open the platform while ensuring that communications remain secure and trusted.

² U.S. ownership estimates from 2010 located at: <http://money.cnn.com/2010/10/19/technology/smartphones/index.htm> and at <http://www.fiercemobilecontent.com/press-releases/smartphone-ownership-doubles-year-over-year-nearly-one-third-americans-says>. Changes from 2011–2012 cited from: <http://www.statista.com/statistics/194992/percentage-of-us-smartphone-owners-by-age-group>.



In Policy

- ▶ **Launch of research and analysis to create options for addressing the policy and institutional challenges associated with technology transfer, adoption, implementation, and use.** In collaboration with stakeholders, the policy team has identified three overarching, critical issues that impact public acceptance and transfer of the new technologies into use — a financially sustainable strategy for implementation, operations, and maintenance; a robust security system that preserves privacy at the highest levels; and a governance model that provides a voice to stakeholders. Further analysis on the implications of technical choices and legal issues is underway and will result in development of policy options that facilitate successful adoption.
- ▶ **Development of technical and institutional models for a security system** whose goals are to provide security in a highly mobile environment while leveraging existing organizational and operational entities and processes. At this date, a range of models have been produced and are being used to further explore risks, costs, and legal and implementation challenges. The Department also is consulting stakeholders about their concerns relating to risks, cost acceptability, and adoption. With feedback, the Department will further define these models and, in consultation with our stakeholders, engage in a comparative analysis in late 2012/early 2013. Importantly, the ability to deliver a viable security solution is critical to the goal of delivering V2V safety; an appropriate solution not only protects against risks but also ensures and provides users with assurance that the V2V messages are trusted. In the event of potential crash-avoidance situations, this capability is critical.

In Mobility, Environment, and Road Weather Management

Although the Department's ITS research agenda is focused predominantly on near-term results of V2V and V2I for safety, research has also advanced in the areas of mobility, environmental, and road weather-related applications. While the research time lines for these programs extend beyond the *Safety Pilot* demonstration and NHTSA decision, they build from the concepts and results, especially the policy and security foundation. Accomplishments include:

- ▶ **Data capture and management (DCM) research has highlighted the complexity of capturing and managing real-time data.** In 2010, a small, laboratory-grade prototype data environment was established to examine a range of key issues such as data quality and formatting, data integrity, timing, data standards, and others. With these results, a larger-scale prototype environment (referred to as the Research Data Exchange, or RDE) was launched in summer of 2012 to inform the technical requirements associated with real-time data capture and systems operations replete with a dynamic exchange capability.³ An expected, transformative result of these new technologies is the benefit of “collecting once and reusing data for multiple purposes,”⁴ providing greater cost savings to all system users. The RDE will also support the demonstration of the ability to synthesize data from multiple sources as the basis of more dynamic applications. An additional benefit to researchers and developers is that early connected vehicle data will be available for use in their research or development of new commercial applications.
- ▶ **New, dynamic mobility applications for managing the transportation system** have been defined in consultation with stakeholders.⁵ These applications reflect both critical needs as well as present new opportunities to synthesize multiple sources of data in real time for more dynamic applications. Research efforts are establishing Concepts of Operations that will result in a foundation for the Department to make future research and investment decisions. Research is also pursuing the development of metrics that define a desired end-state for system operations and performance.
- ▶ **New road weather-related applications** have been defined, based on an assessment of how connected vehicle data can support practical road weather solutions. These applications are designed to assess, forecast, and address the impacts that weather has on roads, vehicles, and travelers. The intent is to capitalize on the previous road weather research, which has delivered a network of road weather information by integrating existing data sources. Through additional research, technology development, and community

³ RDE is located at: <https://www.its-rde.net/>.

⁴ Real-Time Data Capture and Management Program is described at: http://www.its.dot.gov/data_capture/data_capture.htm.

⁵ The process for determining application and the resulting list of identified applications is located at: http://www.its.dot.gov/press/2011/mobility_app.htm.

outreach, Road Weather Connected Vehicle Applications research will develop greater specificity regarding the impact that weather has on roadways and will promote strategies and tools to mitigate those impacts.

- ▶ **Innovative research into the area of environmental performance has resulted in a vision for new applications for reducing environmental impacts.** The research focuses on how generating and acquiring environmentally relevant real-time data can create actionable information that supports and facilitates “green” transportation choices by transportation system users and operators. The research has resulted in a comprehensive understanding of the state-of-the-practice both nationally and internationally, and has generated candidate strategies from around the world⁶ and applications for modeling and testing. A key result has been the acknowledgement from around the world that this research is considered leading edge. Another key result is the formation of a joint effort with European counterparts to develop applications.
- ▶ **A Vehicle Data Translator (VDT)** is under development. It is an important technology for the connected vehicle environment that enables the translation and formatting of vehicle probe data as usable weather and road condition observations. Output data is then usable in decision-support tools and management systems to assist in proactive road weather management.

In Connected Vehicle Technology

- ▶ **A core system concept has been developed,** based on the understanding that there needs to be a basis for users to have a common capability for secure and interoperable exchange. Using input from a series of user workshops across the nation, a first, high-level Concept of Operations and Architecture have been developed. The underlying assumptions are being tested and refined through continuing technical and policy research and through *Safety Pilot* test bed development. These refinements will result in a more stable and detailed architecture and standards policy.
- ▶ **The Department has participated in the development of standards critical to the connected transportation environment.** These standards include the IEEE 802.11p (amendment to 802.11), the vehicle-centric IEEE 1609 series (known as 1609.x) that add wireless access in vehicular environments (WAVE) capability, and version 2 of the SAE J2735 DSRC message set standard.⁷
- ▶ **An additional accomplishment in the standards area is the recent international harmonization efforts that have resulted in a consortium** among the U.S. automotive industry, the European standards-setting body, European Telecommunication Standards Institute (ETSI), and the Car2Car European automotive industry. The consortium is working toward successful harmonization of a core safety message set which will enable common hardware to be developed for a global marketplace. To date, harmonization efforts have succeeded in addressing major challenges; now, only simple translation is required between the U.S. and candidate EU messages. Common hardware and software improves interoperability, reduces implementation costs for manufacturers, and facilitates more rapid deployment of ITS systems.

Short-Term Intermodal Research

Short-term intermodal research furthers the Department’s goal of leveraging technology to maximize safety, mobility, and environmental performance. A set of new, applied research initiatives were launched in 2010 – **Active Transportation and Demand Management (ATDM), Commercial Vehicle Information Systems and Networks (CVISN) Core and Expanded Deployment Program, and the Intelligent and Efficient Border Crossings** – to advance the integration of existing and available infrastructure, communications networks, and technological capabilities to more dynamically reduce freeway congestion, integrate commercial vehicle information networks and systems, and improve safety and mobility at our nation’s borders.

⁶ Description of the candidate strategies and the role they play is available from a presentation at a recent workshop. Slides are located at: http://www.its.dot.gov/aeris/pdf/AERIS_WorkshopII_march12.pdf.

⁷ Details available at: <http://www.its.dot.gov/standards.htm>.



In ATDM

- ▶ Research in ATDM seeks to understand how to evolve transportation management from current static and reactive methodologies to dynamic and pro-active strategies; and to study the role of ITS technologies as the basis of real-time management. Currently, a concept of operations is underway and includes a review of technologies and practices. The program also has identified gaps and implemented an analysis of shoulder lane use, operations, and safety of the ATDM technologies which will inform a cost-benefit analysis for deploying agencies.

In CVISN

- ▶ To date, all 50 states plus the District of Columbia are deploying Core CVISN functionality, providing the ability to effectively facilitate the seamless exchange of critical information in support of efficient and safe commercial vehicle operations (e.g., information on safety, credentials, and tax administration) through ITS technologies. Over the years, the ITS Program has supported Federal Motor Carrier Safety Administration (FMCSA) in efforts to ensure the deployment of Core and Expanded CVISN. With the next legislative authorization, CVISN will be mainstreamed into FMCSA's programs.

In Intelligent and Efficient Border Crossings

- ▶ A state-of-the-practice technology review has identified relevant technologies and institutional arrangements for supporting greater efficiencies at border crossings and with bi-national tolling projects. The identification of suitable technologies forms the basis for developing concepts of operations that are tailored to customer needs at both the north (Canada) and south (Mexico) borders of the U.S. The next step is to develop plans for field operational tests.

In Multi-Modal Research

In addition to these current efforts, previous research initiatives are producing significant results in the 2013 timeframe with the completion of two real-world demonstrations that integrate regionally-based ITS and other technologies to more effectively address mobility:

- ▶ The Integrated Corridor Management (ICM) initiative moves forward with the selection of two Pioneer Demonstration Sites: Dallas, Texas and San Diego, California. The sites are scheduled to go live in the spring of 2013. The program completed the evaluation framework and pre-deployment modeling for the demonstrations, and is now in the middle of final design. The program is also gearing up for technology transfer to the initial wave of early deployers by developing an Implementation Guide and an Analysis, Modeling and Simulation Guide.
- ▶ The Mobility Services for All Americans (MSAA) initiative is demonstrating plans for replicable and scalable travel management coordination centers for the transportation disadvantaged (low income, senior citizens, and individuals with disabilities). There are three full deployment sites – Aiken, South Carolina (went live August 2010); Paducah, Kentucky (went live March 2010); and Camden, New Jersey (scheduled to go live the fall of 2012) – and four partial deployment sites (Orlando, Florida; Fitchburg, Massachusetts; Louisville, Kentucky; and Kent, Ohio) which are at various stages of completion. The MSAA initiative is scheduled to run through the end of 2012. Final project reports for each site are scheduled to be completed by March 31, 2013.

In Road Weather Research

- ▶ The Clarus Initiative demonstrations are complete; Federal Highway Administration (FHWA) is working with the National Oceanic and Atmospheric Administration (NOAA) on the prospect of transitioning the system to operational status with NOAA. With 39 state DOT's, five local agencies, and four Canadian provinces connected, Clarus data is improving mobility and safety under adverse weather conditions by offering users the ability to translate data into actionable information.
- ▶ New research is underway with the cities of Chicago, Salt Lake, and New York to test and evaluate weather-sensitive traffic estimation and prediction systems for modeling the impacts of weather on transportation network demand and supply characteristics. The research involves calibrating and

modeling the cities' transportation networks for off-line and real-time traffic estimation and prediction under a variety of weather conditions and traffic management and intervention strategies. The models and results generated from this study can be used to guide the analysis, development, and implementation of weather-related, active transportation and demand management strategies and other dynamic mobility applications (e.g., speed harmonization, intelligent traffic signal system, real-time traveler information, dynamic routing, integrated corridor management) being explored under the Dynamic Mobility Applications Program. This study is scheduled for completion at the end of June 2012.

ITS Exploratory Research

Most ITS research is directly applied to real-world conditions. ITS exploratory research, by comparison, is intended to provide an avenue to explore emerging technologies that may complement or surpass current ITS solutions. Since 2010, the ITS Program has made progress in three areas:

- ▶ **A technology scan** in partnership with industry stakeholders was launched to examine new and fast-moving trends in navigation, computer vision, next-generation wireless, and telematics.
- ▶ A set of first-time outreach initiatives, based on the success of such programs as the Defense Advanced Research Project Agency (DARPA), were offered to explore whether the ITS Program could effectively **harness creative and innovative problem-solving** of a broad, public audience in relation to new uses for DSRC. In addition to wide range of idea submissions on DSRC, the Department received thoughtful solutions to the essential problem of imprecision in current GPS data. The ITS Program also received a set of videos highlighting the benefits of ITS deployments around the nation.
- ▶ **Exploratory research** is underway in support of developing future research initiatives. This research is examining the viability of emerging, next-generation technologies to determine whether it is appropriate for the Federal government to invest in these high-risk/high-reward opportunities and partner with industry to explore their application to transportation. Using results from the technology scans and challenges, the ITS Program has identified two emerging opportunities for future pursuit: automated vehicles and robotics and electric vehicles. Industry is moving forward in both of these areas. As a result of these trends, the US DOT anticipates a forthcoming set of roles in setting a research agenda: facilitating industry and academia in identifying gaps, best practices, and innovative opportunities; and providing oversight needed to ensure that the goals of safety and security are met.

ITS Cross-Cutting Support

The ITS Program has made important progress in the foundational, cross-cutting elements of implementation. Accomplishments from these programs include:

In National ITS Architecture

- ▶ **Version 7.0 of the National ITS Architecture** was published in 2012. It incorporates functionality and interfaces to align with the Connected Vehicle Environment, ATDM strategies, Electronic Freight Manifest research, and Integrated Corridor Management results; as well as other updates including ITS standards alignment. This version also incorporates CVISN Wireless Roadside Inspection and transportation planning features in addition to ITS standards developments and other updates. These updates, along with updates to the companion Turbo Architecture software, have proven useful to state and local stakeholders as they provide enhanced tools to leverage the results of US DOT research initiatives — alignment incorporates those features in their regional ITS architectures, thereby expanding the reach of these initiatives.
- ▶ The National ITS Architecture team updated the **US/Canadian Border Information Flow Architecture (BIFA)**, including support for the Border Wait Times (BWT), to maintain synchronization with both the U.S. National ITS Architecture and the ITS Architecture for Canada. With these accomplishments, regions along the U.S./Canadian border are updating their regional ITS architectures and deployment plans to include



cross-border systems and interfaces, allowing for increased collaboration and development of integrated solutions that are supported by common ITS architectures.

In Professional Capacity Building

- **The effort to educate the current and emerging transportation workforce about ITS technologies** has resulted in a new program agenda that promotes greater collaboration with external partners, innovative thinking, a customer-focused strategy, and a results-driven approach. Specific accomplishments include the development of a web portal that combines knowledge and resources in one area to accelerate technology transfer⁸; and the development of a new model for delivering a 21st century learning environment to build an ITS profession that leads the world in the innovative use of ITS technologies (documented in the recently released strategic plan, ITS Professional Capacity Building: Setting Strategic Direction 2010-2014⁹).

In Evaluation

- **A major achievement that allows the ITS Program to determine the effectiveness and benefits of deployed ITS and the value of ITS investments, is a deployment tracking database** that contains over fifteen years of deployment data. It is the only database of its kind that is able to display, longitudinally, the results from different policies and programs designed to support effective ITS deployment¹⁰. Results from analysis of the data provide insight into intervention levers that could be used to positively affect adoption and deployment of ITS technologies. This information can be used to inform future ITS strategic planning and decision making.¹¹

The ITS JPO Website Home Page at <http://www.its.dot.gov>

8 The new portal is located at: http://www.its.dot.gov/tech_transfer.htm.

9 The strategic plan is located at: http://www.pcb.its.dot.gov/strat_direction_plan.asp.

10 The database can be found at: <http://www.itsdeployment.its.dot.gov>.

11 Results of such analysis can be found at: <http://www.itsdeployment.its.dot.gov/Opinion.aspx?result=3>.

In Program Management and Communications

- The new ITS Program Management Office (PMO) provides ITS Program Managers the programmatic support needed to accomplish their work activities effectively and with high quality. The PMO provides technical and project management assistance and thought leadership in: identifying and defining programmatic research outcomes and measures; developing and implementing project management processes and documentation to enable uniform collection and analysis of performance data; and providing management recommendations based on the data collected. The PMO focuses on efforts that drive accountability, transparency, and alignment between work activities and the strategic goals of the Department.

Conclusion

The balance of this report describes in greater detail the progress in ITS research and the many achievements that serve to solidify the path toward a new Connected Vehicle Environment. These successes are the result of a focused multimodal partnership in collaboration with a broad stakeholder community. Recent feedback from stakeholders affirms that the community attributes success in advancing the program to the strong leadership of the Federal ITS Program.

Collectively, the accomplishments of the initial two and a half years of research under the 2010-2014 agenda have brought the transformative vision of a Connected Vehicle Environment closer to reality.

Although much remains to be completed in the next two and a half years, the rate of advancement since 2010 demonstrates that the next steps to achieving the vision are within reach.



Introduction



Connectivity

It is a concept that is rapidly changing our daily habits: real-time information gives us the power to make decisions and act on opportunities, provides us with details needed to understand our fast-paced world, and brings us greater awareness of how our systems work. The start of the 21st century introduced advanced wireless technologies to our lives, and already they are having a dramatic impact on our connections to family, friends, and the social and entertainment worlds. These technologies are proliferating throughout the business, political, and educational arenas, changing our relationship to information and creating an awareness of situations that previously would have gone unnoticed. They are redefining how we access knowledge. For the realm of transportation, this means unprecedented awareness about what is happening to and throughout the transportation system at all times.

Transportation Connectivity

The U.S. Department of Transportation's (US DOT's) Intelligent Transportation System (ITS) Program aims to bring connectivity to transportation through the application of advanced wireless technologies — powerful technologies that enable transformative change. Envision:

- ▶ A system in which highway crashes and their tragic consequences are rare because vehicles of all types can sense and communicate the events and hazards happening around them.
- ▶ A fully connected, information-rich environment within which travelers, transit riders, freight managers, system operators, and other users are aware of all aspects of the system's performance.
- ▶ Travelers who have comprehensive and accurate information on travel options — transit travel times, schedules, cost, and real-time locations; driving travel times, routes, and travel costs; parking costs, availability, and ability to reserve a space; and the environmental footprint of each trip.
- ▶ System operators who have full knowledge of the status of every transportation asset.
- ▶ Vehicles of all types that can communicate with roadway infrastructure and equipment to eliminate unnecessary stops and help people drive in a more fuel-efficient manner.
- ▶ Vehicles that can communicate the status of on-board systems and provide information that travelers and system operators can use to mitigate the vehicle's impact on the environment or make more informed choices about travel modes.

Enabling the Vision

The vision of the ITS Program for 2010 to 2014 is to provide the nation with a national, multimodal transportation system that delivers connectivity among vehicles of all types, the infrastructure, and portable devices — a Connected Vehicle Environment.

Through research into the systems, technologies, and applications that comprise a Connected Vehicle Environment, the ITS Program has the potential to serve the public good by leveraging technology to maximize and transform surface transportation safety, mobility, and environmental performance in our lifetimes.

To enable the vision, researchers; vehicle manufacturers (automotive, commercial vehicle, and bus); consumer electronics and telecommunications firms; and Federal, state, and local transportation officials have come together in the previous two years to further the critical, foundational research and to plan for technology transition into new markets. The planned outcomes of this research include a determination of the potential benefits of connected vehicle technologies and evaluation of driver acceptance of vehicle-based safety systems, as well as identification of any research gaps and the steps to address them. Other outcomes include factual evidence needed to support a 2013 National Highway Traffic Safety Administration (NHTSA) agency decision on the deployment of these technologies for light vehicles and a 2014 decision for heavy vehicles. In preparation for these decisions, the ITS Program has made significant progress (as reported in this

document) in moving the technologies from research into testing, developing a set of rigorous test procedures and evaluation metrics, and performing policy analysis – including identifying and comparing various alternatives – in support of policy development.

Why?

Highway safety is one of our nation's major public health challenges, responsible for 32,885 fatalities in 2010¹² and the leading cause of death for people between the ages of 4 and 34.¹³ NHTSA estimates the economic impact of motor vehicle crashes on U.S. roadways is \$230.6 billion a year, nearly 2.3 percent of the nation's gross domestic product, or an average of \$820 for every person living in the country. NHTSA has reported that the average roadway fatality has economic costs of \$977,000, while the costs associated with a critically injured crash survivor surpass \$2 million.¹⁴ Although these statistics reflect a recent decrease in the number of fatalities, they represent an unacceptably high loss of lives.

Traffic congestion is an \$87.2 billion annual drain on the U.S. economy – more than \$750 for every U.S. traveler. Americans waste 4.2 billion hours in traffic every year or nearly one full work (or vacation) week for every traveler.¹⁵

Vehicle fuel utilization and its tailpipe emissions are the single largest human-made source of carbon dioxide, nitrous oxide, and methane. These fumes cause pulmonary diseases and premature deaths. Children are particularly vulnerable, as poor air quality triggers asthma, which is the number-one cause of hospitalization among children and has a major impact on our schools, emergency rooms, and health care system.¹⁶ Additionally, vehicles that are stationary, idling, or traveling at reduced speeds due to congestion emit more than those in free-flow conditions. Therefore, technologies that reduce fuel consumption, idling, and vehicle miles traveled while reducing acute congestion could play a significant role in reducing greenhouse gas (GHG) emissions, particularly in major cities, around ports and freight hubs, and on major roads and corridors.

Why Now?

In 2010, a timely opportunity presented itself to the Department – to plan for the delivery of the next generation of ITS research. The planning process began in late 2008 with outreach to stakeholders and the public, input from modal decision makers and technical staff, and a trend analysis on the direction and rapid pace of technology evolution. A key result gained from this planning process was a vision of how significant and powerful the potential of wireless connectivity could be for transportation, given the growing use of new and dynamic technologies. For the DOT, the predominant research issue was (and is) how to safely harness wireless connectivity for transportation and to leverage the potential in ways that positively transform the transportation environment – in other words, putting 21st century technologies into use for a 21st century transportation system and opening doors to future opportunities.

In 2008, the opportunity was timely. In 2012, the opportunity is reality, as evidenced by the graphics on the next page that illustrate the growth of wireless technologies and the economic and personal dependencies that we have on our mobile and connected society.

"During the past 50 years, the research focus has been on surviving crashes; the next 50 years will be about avoiding crashes."

— Greg Winfree, Deputy Administrator, RITA

12 NHTSA Fact Sheet at: <http://www-nrd.nhtsa.dot.gov/Pubs/811583.pdf>.

13 NHTSA's National Center for Statistics and Analysis, Traffic Safety Facts: Research Note at: <http://www-nrd.nhtsa.dot.gov/Pubs/811226.pdf>.

14 Blincoe, A., Seay E., Zaloshina, T., et al. The Economic Impact of Motor Vehicle Crashes, 2000. May 2002. NHTSA Report No. DOT HS 809446.

15 Schrank, David; Lomax, Tim; Eisele, Bill, 2011 Urban Mobility Report, Texas Transportation Institute, Sept., 2011, at: <http://tti.tamu.edu/documents/mobility-report-2011.pdf>.

16 EPA and Centers for Disease Control Statistics at: <http://cfpub.epa.gov>; <https://www.cdc.gov>; <https://www.cdc.gov/mmwr/preview/mmwrhtml/ss5608a.htm>.



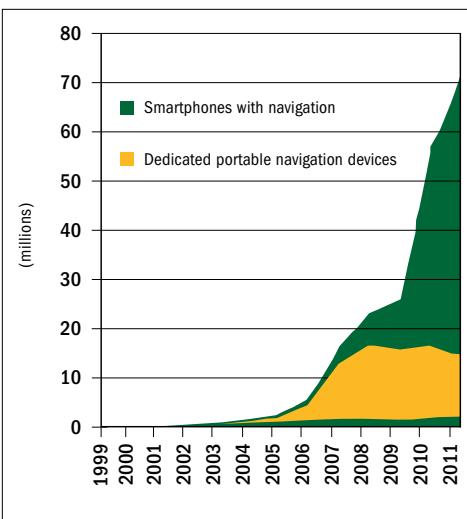


Figure 1. Illustration of the Growth in Portable Connectivity (Courtesy of Nokia)

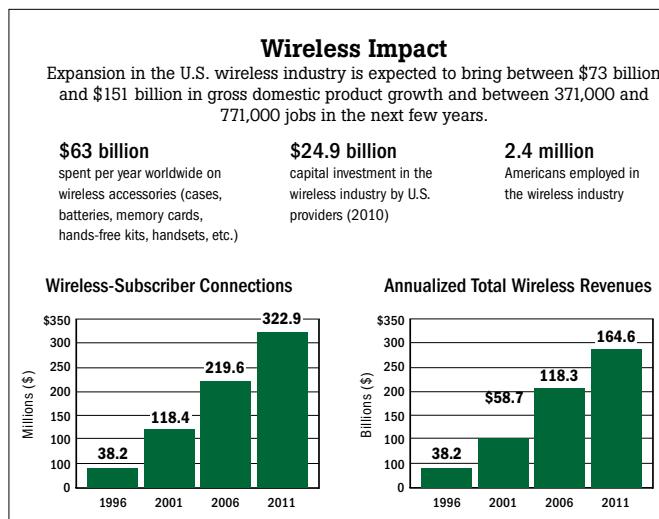


Figure 2. Impact of Wireless Communications on Society (Source: CTIA)

Notably, from 2010–2012, the vehicle manufacturing industry has worked to incorporate a range of wireless technologies into new vehicles, giving the nation its first generation of “connected vehicles” through the use of cellular communications. More and more vehicles are connected for purposes of real-time diagnostics, emergency response services, and passenger infotainment. In researching the architecture and capabilities of “cellular-connected vehicles” against the vision of DSRC-based connected vehicles, there are two pronounced differences:

- ▶ Cellular technologies do not yet provide the capabilities of latency, accuracy, and reliability needed to support safety-of-life applications, thus confirming the requirement that DSRC is needed for connected vehicle safety.
- ▶ The new cellular-based applications and technologies do not always provide an integrated set of interfaces that are proven not to distract drivers. DSRC-based technologies and applications on fully equipped vehicles offer an integrated and interoperable capability with interfaces that are being developed according to emerging NHTSA guidelines to ensure the safety of the driver.

The ITS Program proactively tracks such market innovations and looks to leverage their opportunities in ITS research. An important result is that the Department’s understanding of the uses for DSRC and cellular technologies in creating a connected transportation environment has changed over the past two years. Given the ubiquity of mobile, cellular technologies in use today, the Department recognizes that many of the connected vehicle technologies, applications and systems will be able to optimize use of communications media that are available; this is true for a wide range of mobility and environment applications, vehicle-to-infrastructure applications, security system functions, and others. However, research has confirmed that V2V commercial-grade safety applications will require DSRC. The textbox on the next page presents the Department’s rationale for and commitment to DSRC as it was described in 2010 and as it stands today.

With this as its foundation, the ITS Program will leverage the “connected vehicle” trend and guide it toward greater public benefit. As will be noted throughout this report, the confluence of these events has significantly influenced the direction of this ITS Strategic Research Plan. It has resulted in an evolution toward greater refinement of the program, with more targeted research in its objectives; it has grown more closely aligned with the opportunities of the marketplace and the direction of industry while maintaining an overarching focus on safety.

Use of Dedicated Short Range Communications (DSRC) Technology

The Department is committed to the use of the DSRC technologies for active safety for both vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) applications. The Department also reaffirms its intention to explore all wireless technologies for applicability to safety, mobility, and environmental applications.

In 2008, the ITS Program framed the definition of connectivity to include both DSRC and non-DSRC technologies as a means of providing a platform for a connected transportation environment. Such a framework has multiple benefits:

- ▶ It allows for the integration of a wider array of technologies and thus enables private industry to develop innovative technologies that may offer new or additional features.
- ▶ It allows the wireless traffic safety system architecture to adapt as technologies evolve over time, ensuring that the networks are able to incorporate innovative approaches and applications into their existing systems as they become available.
- ▶ It ensures that benefits are not limited only to drivers of vehicles equipped with connected ITS technologies.

The Department's commitment to DSRC highlights two critical points:

- ▶ Safety is the highest priority for the Department and will form the central focus for the research in support of a connected environment for transportation.
- ▶ Analysis illustrates that DSRC is the only available technology in the near-term that offers the latency, accuracy, and reliability needed for active safety.

Enacting the Vision

The *ITS Program's Strategic Research Plan* has been defined through a multimodal Departmental effort and informed through stakeholder input. The resulting research program is administered as a collaborative partnership between the Intelligent Transportation Systems Joint Program Office (ITS JPO), part of the Research and Innovative Technology Administration (RITA), and modal administrations that include:

- ▶ Federal Highway Administration (FHWA);
- ▶ Federal Motor Carrier Safety Administration (FMCSA);
- ▶ Federal Railroad Administration (FRA);
- ▶ Federal Transit Administration (FTA);
- ▶ Maritime Administration (MARAD); and
- ▶ National Highway Traffic Safety Administration (NHTSA).

To explore the potentially transformative capabilities of wireless technologies to make transportation safer, smarter, and greener and, ultimately, to enhance livability for Americans, the central focus of the ITS Program's Research Plan is on a connected environment for transportation – a cross-modal, research initiative that aims to create safe, interoperable connectivity among vehicles (automobiles, trucks, motor coaches, transit vehicles, and other fleets), infrastructure, and mobile devices.

The research is designed to achieve a deployable system. To do so, critical success factors were identified, each of which must be addressed and resolved for the research results to be implementable. These critical success factors define three distinct areas for research:

- ▶ **Applications:** Applications in safety, mobility, and environment are effective and validated.
- ▶ **Technology:** Technology is secure and interoperable.
- ▶ **Policy:** The system as a whole is sustainable. The system is publicly acceptable.

From these critical success factors, programmatic research questions were derived (summarized in the text box on the next page).



Critical Success Factors

Applications

- Are applications available and benefits validated?
- What technologies, applications, and data are needed to create the maximum benefit? How much, where, when, and what type?
- What is the degree of market penetration required for effectiveness?

Technology

- Is the technology stable, reliable, secure, and interoperable?
- Are domestic and international standards available to ensure interoperability?

Policy

- What policies, governance, and funding are required for sustainability?
- How to address public concerns for privacy and ensure that applications do not cause driver distraction?

All must be answered to be deployable.

Research programs were formed that are organized around and focused specifically on resolving these questions and other technical issues, as a means for achieving the goal of deployment.

The four major components of this ITS Strategic Research Plan, 2010–2014 are the following:

- ▶ **Connected Vehicle Research:** The section describes the applications, policy, and technology research programs that are structured to address the research questions.
- ▶ **Short-Term Intermodal ITS Research:** In close cooperation with modal partners, new ITS technologies, strategies, and systems have been defined as part of the next research agenda.
- ▶ **ITS Exploratory Research:** The ITS Program intends to provide an avenue to structure creative ideas for new technology options that deserve further attention. This section describes this new exploratory research.
- ▶ **ITS Cross-Cutting Support:** In addition to the research programs, the ITS Program hosts critical functions that provide support across the research programs. This section describes these cross-cutting functions, which include: standards, architecture, professional capacity building, evaluation, and outreach and communications.

Finally, this plan concludes by describing the expected benefits of delivering this next generation of ITS to the nation and by looking beyond 2014 to envision the opportunities for the future generation of ITS research.

Connected Vehicle Applications



Application of Connectivity

The following table depicts significant transportation challenges and identifies how the systems, technologies, and applications for a connected transportation environment are intended to address them.

Table 1. Transportation Challenges and Connected Vehicle Applications

Problem: Safety (numbers are for 2011)

- ▶ 32,885 deaths/year (US).¹⁷
- ▶ 5.8 million crashes/year (US).¹⁸
- ▶ Direct economic cost of \$230.6 billion.¹⁹
- ▶ Leading cause of death for ages 4 – 34.²⁰

Vision: Imagine –

- Your vehicle can “see” vehicles that you can’t see.
- Your vehicle informs you of roadway conditions and hazards that you can’t see.
- Your vehicle knows the speed and location of approaching vehicles.

Safety applications that support a connected environment for transportation are designed to increase situational awareness and reduce or eliminate crashes through V2V and V2I data transmission that supports driver advisories, driver warnings, and vehicle and/or infrastructure controls. With these applications, a connected transportation environment may potentially address up to 81 percent of crash scenarios with unimpaired drivers²¹, preventing tens of thousands of automobile crashes every year (further research will incorporate heavy-vehicle crashes, including buses, motor carriers, and rail).

Problem: Mobility

- ▶ Traffic congestion of \$100 billion an annual drain on U.S. economy.
- ▶ 4.8 billion lost hours.
- ▶ 1.9 billion gallons of wasted fuel.²²

Vision: Imagine –

- Managing the transportation system as if you knew where every vehicle (automobile, truck, motor coach, and transit vehicle) was in real time.
- Planning for growth patterns as if you could see complete traffic patterns around development.
- Planning travel as if you knew real-time options on all roads, transit, and parking along your route.

Mobility applications that support a connected environment for transportation provide data-rich travel opportunities. The network captures real-time data from equipment located on board vehicles (automobiles, trucks, and buses) and within the infrastructure. The data are transmitted wirelessly and are used by

17 NHTSA Fact Sheet at: <http://www-nrd.nhtsa.dot.gov/Pubs/811583.pdf>.

18 Ibid.

19 <http://www-nrd.nhtsa.dot.gov/Pubs/809446.pdf>.

20 NHTSA's National Center for Statistics and Analysis, Traffic Safety Facts: Research Note: <http://www-nrd.nhtsa.dot.gov/Pubs/811226.pdf>.

21 Analysis located in a report titled Frequency of Target Crashes for IntelliDrive Safety Systems, sponsored by the National Highway Traffic Administration, October 2010, DOT HS 811 381. Link located at: <http://www.nhtsa.gov/Research/Crash+Avoidance/Office+of+Crash+Avoidance+Research+Technical+Publications>.

22 Shrank, David and Lomax, Tim. 2011 Urban Mobility Report, Texas Transportation Institute, September 2011, <http://mobility.tamu.edu>.

transportation managers in a wide range of dynamic, multi-modal applications to manage the transportation system for optimum performance.

Problem: Environment

- ▶ 1.9 billion gallons of fuel wasted each year.
- ▶ 31 percent carbon dioxide (CO₂) emissions from vehicles.²³

Vision: Imagine –

- Managing your system for environmental and weather events as if you knew specific information about the road and vehicle.

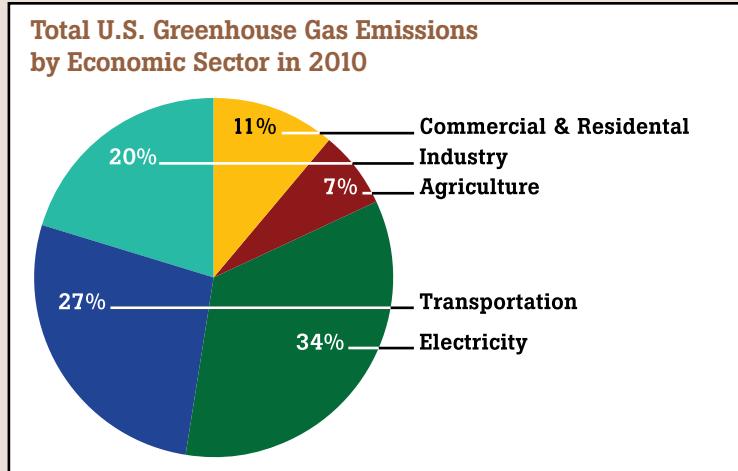


Figure 3. In 2010, greenhouse gas emissions from transportation accounted for about 27% of total U.S. greenhouse gas emissions, making it the second largest contributor of U.S. greenhouse gas emissions after the electricity sector. (Source: <http://www.epa.gov/climatechange/ghgemissions/sources/electricity.html>)

Environmental applications that support connected transportation systems both generate and capture environmentally relevant real-time transportation data and use this data to create actionable information to support and facilitate “green” transportation choices. They also assist system users and operators with “green” transportation alternatives or options, thus reducing the environmental impacts of each trip. For instance, informed travelers may decide to avoid congested routes, take alternate routes, use public transit, or reschedule their trip – all of which can make their trip more fuel-efficient and eco-friendly. Data generated from wireless communication among vehicles can also provide operators with detailed, real-time information on vehicle location, speed, and other operating conditions. This information can be used to improve system operation. Onboard equipment may also advise vehicle owners on how to optimize the vehicle’s operation and maintenance for maximum fuel efficiency.

As described in the following pages, connected vehicle technological and policy advances underpin the successful development and deployment of these applications by:

- ▶ Providing a platform for interoperability, security, and access that is based on a logical, systems approach;
- ▶ Distinguishing the appropriate boundaries that effectively leverage public-sector funding versus private-sector financing and market opportunities;
- ▶ Defining minimum governance requirements that use regulatory actions only when fact-based evidence (based on field testing and evaluation) points to its effectiveness;
- ▶ Identifying options for resolving institutional issues that enable successful deployment and sustainable market development and growth; and
- ▶ Providing a platform for effective technology and knowledge transfer.



© iStockphoto.com/Tim McCagh

²³ United States Environmental Protection Agency, Carbon Dioxide Emissions, <http://www.epa.gov/climatechange/ghgemissions/gases/co2.html>.



Pages 20 – 97 provide detail on the application research programs by describing their research plans, accomplishments, critical research insights, and next steps. The sections are divided by the four priority areas and include:

- ▶ Safety:
 - V2V Communications for Safety
 - V2I Communications for Safety
 - Connected Vehicle Safety for Rail
- ▶ Mobility:
 - Real-Time Data Capture and Management (DCM)
 - Dynamic Mobility Applications (DMA)
- ▶ Environment:
 - Applications for the Environment: Real-Time Information Synthesis (AERIS)
- ▶ Road Weather
 - Road Weather Applications

Safety



Vehicle-to-Vehicle (V2V) Communications for Safety ...

... is the wireless exchange of data among vehicles traveling in the same vicinity which offers opportunities for significant safety improvements.

The vision for V2V research is that each vehicle on the roadway (inclusive of automobiles, trucks, transit vehicles, and motorcycles) will be able to communicate with other vehicles, and that this rich set of data and communications will support a new generation of active safety applications and systems.

Research Plan

The objective of the V2V safety research program is four-fold:

1. Develop V2V active safety applications that address the most critical crash scenario;
2. Develop a rigorous estimation of safety benefits that will contribute to the assessment of a 2013 NHTSA agency decision;
3. Work with industry to enable market factors that will accelerate safety benefits through both in-vehicle technologies and through the use of aftermarket and/or retrofit options to ensure that the first V2V-equipped vehicle owners find value in their investment; and
4. Building from the results of earlier proof-of-concept tests, complete the development and testing of the V2V communications technologies and standards.

Success will be measured by progress on the following:

- ▶ Development of practical, DSRC-based, V2V active safety applications and supporting equipment and demonstration of their effectiveness;
- ▶ Completion of the DSRC standards and other standards that are needed for deployment of V2V, and development of solutions to security, scalability, positioning, and other technical issues (refer to the Connected Vehicle Technology section on page 106);
- ▶ Develop guidance for the driver-vehicle interface (DVI) to optimize effective warnings, while minimizing distraction and driver workload (refer to the Human Factors research program description on page 108);
- ▶ Acceleration of technology implementation into vehicles for generating the basic safety messages (BSMs); and
- ▶ Definition of security network requirements for V2V and its supporting systems (such as certification, security, or access procedures).

The ITS Program has defined a collaborative research process that will engage the appropriate parties to address the breadth of technical and non-technical V2V research needs:

- ▶ **Track 1:** Identify critical crash scenarios for V2V and develop benchmarks for safety application function, performance, and effectiveness.
- ▶ **Track 2:** Ensure interoperability and determine supporting network security and/or infrastructure needs for V2V deployment. Safety applications must work on all types of equipped vehicles and adhere to communication standards to ensure security and message integrity.

Research Goals:

- ▶ Employ advanced V2V wireless technologies to reduce, mitigate, or address approximately 80 percent of light vehicle crash scenarios involving unimpaired drivers.
- ▶ Establish robust DSRC standards for safety-critical applications.
- ▶ Accelerate in-vehicle technology to ensure value to the first V2V vehicles.

Research Outcomes:

The planned outcomes of this research are to document and validate the potential benefits of V2V technologies and to develop the factual evidence needed to support a 2013 NHTSA agency decision.



Transforming the nation's transportation system through V2V connectivity can provide significant safety benefits.
Image: © iStockPhoto.com/Deitschel

- ▶ **Track 3:** Develop rigorous estimates of safety benefits. The development of performance measures, objective test procedures, and an adaptation of Advanced Crash Avoidance Technologies (ACAT) will assist in validating safety benefits.
- ▶ **Track 4:** Develop prototype active safety applications that include control features and crash avoidance applications that address forward crashes and intersection crashes, and evaluate through objective tests. The evaluation process provides data for safety benefits calculations.
- ▶ **Track 5:** Develop guidelines for effective Driver Vehicle Interfaces (DVIs). Collision warning system effectiveness relies on the quality of its interface, which can affect the driver's performance.
- ▶ **Track 6:** Investigate policy issues and formulate regulatory decisions within the context of the broader program.
- ▶ **Track 7:** Develop and evaluate V2V safety applications that incorporate the unique needs and vehicle dynamics of commercial vehicles, large trucks, and motor coaches. NHTSA estimates V2V applications can address 71 percent of all heavy truck crashes involving unimpaired drivers.²⁴
- ▶ **Track 8:** Develop transit safety applications utilizing results from automobile safety applications and transitioning their applicability to transit vehicles.

The results achieved through the V2V safety research program will be indicators of an environment in which V2V can flourish. The Department and its modal partners will engage the automotive, truck, and bus manufacturers and suppliers, along with other partner groups, through working group participation. In addition, the Department will work with stakeholder groups to define effective technology transfer opportunities. Ultimately, this research will support a decision by NHTSA in 2013 for light vehicles and 2014 for heavy vehicles on whether a regulatory decision for deployment is warranted.

²⁴ See report at <http://www.nhtsa.gov/DOT/NHTSA/NVS/Crash%20Avoidance/Technical%20Publications/2010/811381.pdf>.

Potential V2V safety applications include safety warnings for drivers, such as:

- ▶ Emergency electronic brake lights warning
- ▶ Forward collision warning
- ▶ Intersection movement assist warning
- ▶ Blind spot warning
- ▶ Lane change warning
- ▶ Do not pass warning
- ▶ Control Loss Warning
- ▶ Bus Driver Warning – vehicle making a right-turn-in-front-of-bus



Image: US DOT

2012 SNAPSHOT OF PROGRESS

Track 1: Crash Scenario Framework

Research Accomplishments

- ☒ The statistical analysis on crashes is complete and forms the foundation for three important reports: *Description of Light Vehicle Pre-Crash Scenarios for Safety Applications Based on Vehicle-to-Vehicle Communications*, *Depiction of Priority Light Vehicle Pre-Crash Scenarios for Safety Applications Based on Vehicle-to-Vehicle Communications*, and *Light Vehicle Crash Avoidance Needs and Countermeasure Profiles for Safety Applications based on Vehicle-to-Vehicle Communications*.
- ☒ All of the reports are in the process of approval for publication and will be available on the V2V and NHTSA web pages in 2012.²⁵

²⁵ Located at: <http://www.its.dot.gov/research/v2v.htm> and <http://www.nhtsa.dot.gov/research/crash+avoidance/office+of+crash+avoidance+research+technical+publications>.



Critical Research Insights

- This critical research identified the priority pre-crash scenarios and the pre-crash scenario characteristics, and translated the pre-crash characteristics into V2V safety application requirements.

Next Steps

- ➔ With report publication approval, this research track is complete.

Track 2: Interoperability

Research Accomplishments

- Through collaborative DOT-industry research, the program developed and tested a set of minimum performance requirements for on-board equipment that ensures interoperability across all vehicles and devices. The research partners include the automotive industry and suppliers. The requirements address standards, non-hardware interface requirements, testing and access requirements, and hardware requirements.
- Scalability tests, conducted on test tracks in three stages, allowed for iterative software updates and revisions. Further testing will be conducted in real-world conditions during the *Safety Pilot Model Deployment* in 2012–2013.
- Completed test procedures for Aftermarket Safety Device safety applications.

Critical Research Insights

- Test results showed that with use of the standards, different devices are interoperable.
- Test results also informed revisions to the standards that are critical for security (IEEE 1609.2 and IEEE 1609.3) and the message standard (SAE J2735). The results are also forming the basis for development of the minimum performance requirements (e.g., the sending rate for BSMs, transmit power control, adaptive message rate control) for V2V safety standard (SAE J2945).

Next Steps

- ➔ Initial research for supporting the production of commercial grade prototype equipment that is integrated into test vehicles will be completed in October 2012. Follow-on research will address congestion management and misbehavior detection.

Track 3: Develop Estimates of Safety Benefits

Research Accomplishments

- Obtained NHTSA leadership approval concerning the safety benefit estimation approach. NHTSA leadership – representing research, crash statistics, and rulemaking – approved the approach that will support the 2013 agency decision.
- Completed draft performance requirements for 10 priority pre-crash scenarios.
- Completed and distributed the safety data requirements for data acquisition systems to *Safety Pilot* test conductor.

Critical Research Insights

- The research has resulted in a *Safety Pilot* Experimental plan which is based on a complex set of calculations that ensure a sufficient amount of interactions necessary to obtain enough data to calculate the safety benefit estimations.

Next Steps

- ➔ Conduct objective tests.
- ➔ Integrate results from *Safety Pilot* into benefits estimation process.

Track 4: Develop Safety Applications

Research Accomplishments

- In partnership with industry, completed six V2V safety applications.
- Identified the forward collision avoidance (FCA) as a safety application for development. Development has been launched by five original equipment manufacturers (OEMs). Each OEM will include control after warning as a means to avoid forward collision crashes. To date, FCA draft performance measures have been completed.
- Initiated work on a comprehensive V2V intersection application.

Critical Research Insights

Research has revealed that control applications may require a redundant sensor for reliability.

Next Steps

- ➔ Complete a draft of the FCA objective test procedures.
- ➔ Identify and agree on interoperability specifications that all OEMs and the US DOT will use as objective test procedures.
- ➔ Initiate development of Advanced Intersection Collision Avoidance applications.

Track 5: Develop Driver Vehicle Interfaces (DVIs)

Research Accomplishments

- Completed *Safety Pilot* DVI guidance.

Next Steps

- ➔ Finalize and provide the guidelines to industry to guide the development of their commercial systems.

Track 6: Investigate Policy Issues

Research Accomplishments

- In support of developing a research path for the US DOT's 2013 decision, identified the V2V policy and institutional issues in the areas of communications security, certification, governance, spectrum management, and benefit-cost analysis.²⁶
- Research is currently underway to investigate the organizational requirements for security, compare different business models for communications systems, define the need for spectrum management, develop governance models, and develop the benefit-cost basis for a US DOT decision in 2013 for light vehicles and in 2014 for heavy vehicles. Across all of these efforts, definition of the Federal interests and role is a priority focus.

²⁶ The Safety Policy roadmap is located at: http://www.its.dot.gov/connected_vehicle/pdf/Safety_PolicyPublicRoadmap_v6.pdf.



Critical Research Insights

- ◊ A preliminary analysis of the policy factors associated with communications for security including system network costs, governance, privacy, and safety, suggests that there is no easy option for funding/financing a system that is primarily focused on the public good.
- ◊ Preliminary analysis of communications technologies resulted in the selection of DSRC as the basis of communications for security for *Safety Pilot*. This decision has been expanded to also include testing using cellular technologies.

Track 7: Develop Commercial Vehicle Safety Applications

Research Accomplishments

- Completed the integration of V2V safety applications on four commercial vehicles. Additionally, two different types of retrofit safety devices are being developed for testing. One device builds from the knowledge gained in developing the fully-equipped, integrated trucks; the device includes all V2V applications developed for the integrated commercial vehicles. A second device is being developed following an open architecture design process to provide industry participants sufficient details to enable sooner involvement of other development teams. While this second device implements a limited set of V2V applications, it is expected to increase the opportunities for deployment.

Critical Research Insights

- ◊ Preliminary work is showing that truck applications can be developed using light vehicle application research. See the expanded details on Truck V2V research on the following pages (p. 26 – 27).

Next Steps

- ➔ Perform interoperability testing and integrate trucks into the *Safety Pilot* Model Deployment.

Track 8: Develop Transit Safety Applications

Research Accomplishments

- In September 2011, the Department launched research to retrofit transit vehicles with V2V technologies and applications. The retrofit contract has been awarded and two buses are under development. Three transit V2V applications are under development and will be demonstrated in *Safety Pilot*. One V2V application is transit specific – Vehicle Turning Right in Front of a Transit Vehicle Warning. The application is meant to provide warnings to bus drivers to alert them to other vehicles passing around and in front of the bus to turn right at an intersection at the same time that the bus pulls away from the bus stop. Two other applications are adaptations of light vehicle V2V applications and are being tailored for transit vehicles. These applications include the Emergency Electronic Brake Light Warning and the Forward Collision Warning applications.

Critical Research Insights

- ◊ Preliminary work is showing that transit applications can be adapted from light vehicle applications. See the expanded details on Transit V2V research on pages 28-29.

Next Steps

- ➔ Complete the retrofit and integrate transit into the *Safety Pilot* for testing.

Truck V2V Research ...

... is the application of wireless communications technology into a commercial vehicle platform to create research prototypes for crash-avoidance safety applications on commercial vehicles. The vision for Truck V2V research is to employ wireless communications to make trucking safer, smarter, and greener, ultimately enhancing livability for all Americans.

Research Plan

In support of Track 7 of the V2V safety research program, truck V2V research focuses on truck-specific opportunities, which are distinct from those of passenger vehicles. These efforts are supported by strong engagement with industry. The applications developed for truck platforms are being designed to be interoperable with all other vehicle platforms, so that drivers in light and heavy vehicles can be more aware of each other as they share our highways. Some of the trucking applications to be developed as part of the V2V safety program include:

- ▶ **Forward Collision Warning**—Warns drivers of an impending rear-end collision with a vehicle ahead in the same lane and direction of travel;
- ▶ **Blind Spot Warning/Lane Change Warning**—Helps drivers avoid or mitigate collisions with vehicles in or approaching a blind spot;
- ▶ **Intersection Movement Assist**—Warns drivers when it is unsafe to enter an intersection due to high-collision probability with other vehicles; and
- ▶ **Electronic Emergency Brake Light**—Helps drivers avoid or mitigate rear-end collisions with braking vehicles in the forward path of travel.

Truck V2V research and demonstration is closely aligned with the *Safety Pilot* time line, a key testing point for observing how connected vehicle technology can enable heavy trucks and light vehicles to share the road safely. To enable greater examination of the benefits and user acceptance of V2V technology in trucks, the *Safety Pilot* will include two driver clinics specific to truck V2V applications, with over 100 commercial vehicle drivers, in total, experiencing this new technology under controlled test conditions. The *Safety Pilot* model deployment will test six different truck platforms under real-world conditions.

Because of the substantial impact that V2V technology could have on safety, NHTSA believes that this technology warrants consideration for possible regulatory action. NHTSA has stated their intent to make an agency decision on V2V safety technology for heavy vehicles by 2014, following on the 2013 decision for light vehicles. The decision will be based on the projected benefits results from the *Safety Pilot Model Deployment* demonstration in Ann Arbor, Michigan; and driver clinics and objective performance testing of V2V applications by NHTSA at the Vehicle Research Test Center, East Liberty, Ohio and Alameda, California.



Truck V2V Research

Truck V2V for Safety: The Connected Commercial Safety Applications Development Project

Research Accomplishments

- The US DOT has awarded a contract to a diverse team of manufacturers, project managers, and researchers to integrate the connected vehicle technologies on a range of truck platforms. Additionally, the project focuses on refining the V2V safety applications and on-board systems for heavy vehicles. The project began in May 2011 and will result in testing three trucks during the *Safety Pilot* Model Deployment and one in the Smart Roadside Program.

Critical Research Insights

- ◊ The research has highlighted that the previously developed light vehicle technologies and applications can be leveraged for the truck platform with some refinements (i.e., accounting for vehicle length, among other features). Early observations have shown that the safety technologies and applications are applicable to the different problems of commercial vehicles, including the time-critical safety applications such as crash warnings and in-vehicle signage.

Next Steps

- ➔ Develop commercial vehicle retrofit safety devices for testing and participation in the *Safety Pilot*.



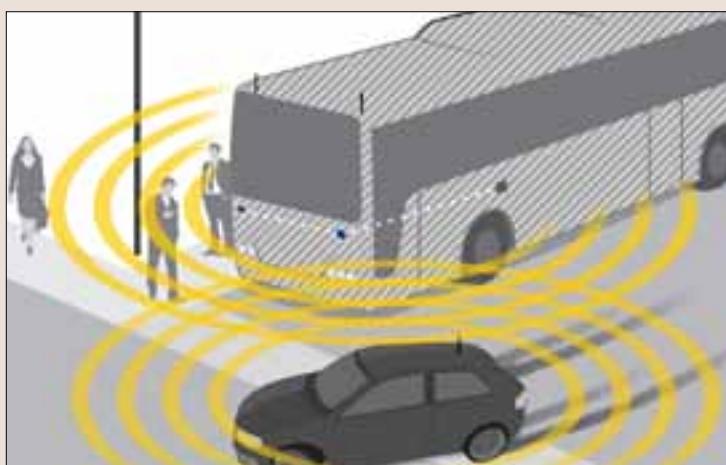
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Transit V2V Research ...

... is the research and application of the connected vehicle concept to transit to improve safety, mobility, and the environment while addressing the unique needs and properties of transit vehicles, operations, institutions, and travelers. The vision for Transit V2V research is to apply connected vehicle technologies to develop safety, mobility, and environmental applications that address transit needs and priorities while providing interoperability and coexistence with connected-vehicle equipped cars and trucks.

Research Plan

Transit V2V research supports Track 8 of the V2V research program with a focus on the needs and opportunities specific to transit. Similar to truck V2V research, transit will participate in the *Safety Pilot Model Deployment*. The transit team is working with industry to integrate wireless DSRC technology into transit vehicles and develop research prototypes of appropriate safety applications on these transit vehicles. These applications must be interoperable (e.g., share messages) with other vehicle platforms, specifically the light duty vehicles applications. The *Safety Pilot Model Deployment* will: 1) test overall compatibility and interoperability of transit vehicles with other light and heavy vehicles; and 2) inform future transit V2V and V2I research and development activities. Based on transit stakeholder input to explore new applications that can address transit's critical safety needs, a set of three high-priority applications were identified. They include the Vehicle Turning Right in Front of a Transit Vehicle Warning (see textbox and image below), the Emergency Electronic Brake Light Warning, and the Forward Collision Warning applications. Additional analysis is underway to study transit crash types which will lead to the identification of additional priority V2V and V2I applications for transit.



Transit vehicle warned of an unexpected automobile. © iStockPhoto.com/Alejandro Soto

Vehicle Turning Right in Front of a Transit Vehicle Warning

A critical safety application using V2V communications will provide a warning to a bus driver that another vehicle is passing around and in front of the bus and is planning to turn right at the intersection as the bus pulls away from a bus stop. If the bus is pulling away at the same time as the other vehicle is turning right, there is a strong potential for a collision.

2012 SNAPSHOT OF PROGRESS

Transit V2V for Safety

Research Accomplishments

- The US DOT awarded a series of contracts between October 2011 and January 2012 to research the most effective ways to incorporate transit into the Connected Vehicle Environment. The research includes:

- A contract to assess the applicability of the light vehicle safety applications to transit. Using the *NHTSA Safety Communications-Applications (VSC-A) Study*,²⁷ bus crash-types were matched to the capabilities of the applications. The full report will be available in the fall of 2012. A further study was launched in 2012 to develop additional detail on transit crash types. This analysis is expected to lead to additional priority V2V and V2I applications for transit. This follow-on study will be available in spring of 2013.
- A contract to assess the feasibility of modifying current transit bus driving simulations for connected vehicle research purposes including driver-vehicle interface testing; driver acceptance and training; transit applications evaluation; human factors analysis; cost-effectiveness; and resource requirements. This work includes a literature review and inventory of all driving simulators. Preliminary results will be available in the summer of 2012.
- A contract to develop a Transit Safety Retrofit Package (TRP) was awarded and work is underway to produce two retrofitted buses for demonstration during the Safety Pilot Model Deployment. The TRP also includes development of the transit V2V and V2I communications technologies and applications. In addition to the transit V2V applications described in the Research Plan, the TRP package includes two applications that make use of infrastructure capabilities — A Pedestrian Warning System for Bus Drivers and an adaptation of the Curve Speed Warning for transit vehicles. Further detail can be found on page 41.

Critical Research Insights

- Interim results are available from the assessment of bus crash-types to light vehicle applications. The research reveals that the applications can be leveraged for transit, but some constraints will need to be addressed. For instance, the results note that the BSM will need to include vehicle height and length as buses are moving in mixed traffic. Another important insight is that an articulated bus — made in two or more sections for easier turning — requires different application criteria than a conventional bus or light vehicle. In addition, buses accelerate and decelerate more slowly than other vehicles and require longer stopping distances. These modifications will be necessary to ensure that transit is a safe as well as an integrated part of the Connected Vehicle Environment.
- Another insight that has resulted from the initial exploration into the Vehicle Turning Right in Front of a Transit Vehicle warning application is the necessity of understanding the complexity of the movements of the bus and light vehicle to know when to trigger the warning.

Next Steps

- ➔ Begin developing the transit safety applications.



Image: US DOT

²⁷ Study located at: <http://www.nhtsa.gov/DOT/NHTSA/NVS/Crash%20Avoidance/Technical%20Publications/2011/811492A.pdf>.

Connected Vehicle Safety Pilot ...

... is a research program that demonstrates the readiness of DSRC-based connected vehicle safety applications for nationwide deployment.

The vision of the Connected Vehicle Safety Pilot program is to test connected vehicle safety applications in real-world driving scenarios in order to determine their effectiveness at reducing crashes and to ensure that the devices are safe and do not unnecessarily distract motorists or cause unintended consequences.

As a means of accelerating safety benefits, the V2V research efforts have expanded to include cooperative development of BSM devices with six vendors. The research team is also working with four suppliers to develop and test aftermarket safety devices.²⁸ With the completion of the critical research, the V2V technologies and applications will be tested under real-world conditions in the Connected Vehicle Safety Pilot Driver Clinics and Model Deployment. The *Safety Pilot* is a significant effort that was defined in 2010 and advanced in 2011. It comprises two sets of tests – driver clinics and a model deployment.

Research Plan

The objective of the *Safety Pilot* Program is to evaluate everyday drivers' reactions, both in a controlled environment through driver clinics and on actual roadways with other vehicles through the real-world model deployment.

Safety Pilot Driver Clinics: Clinics include six different sites in the United States with tests to assess user acceptance of the connected vehicle technology. At each driver clinic, approximately 100 drivers test in-vehicle wireless technology in a controlled environment, such as a race track. The goal is to determine how motorists respond to and benefit from in-vehicle alerts and warnings.

Safety Pilot Model Deployment: Approximately 3,000 vehicles will be equipped with wireless connected vehicle devices to test safety applications using DSRC between vehicles, while operating on public streets in an area highly concentrated with equipped vehicles. The model deployment is designed to determine the effectiveness of the technology at reducing crashes. Vehicles will be able to tell when another vehicle with connected vehicle technology has moved into the immediate driving area. The model deployment will include a mix of cars, trucks and transit vehicles; it will be the first test of this magnitude of connected vehicle technology in a real-world, multimodal operating environment. The University of Michigan Transportation Research Institute (UMTRI) will lead a diverse team of industry, public agencies, and academia in supporting this effort. The data generated from both the driver clinics and model deployment will be critical to supporting the 2013 NHTSA agency decision regarding connected vehicle communications for safety.



Image: US DOT

Research Goals:

- ▶ Support the 2013 NHTSA agency decision by obtaining empirical data on user acceptance and system effectiveness and technical readiness.
- ▶ Demonstrate real-world connected vehicle safety applications in a data-rich environment.
- ▶ Establish a real-world operating environment for additional safety, mobility, and environmental applications development.
- ▶ Archive data and make openly available for additional research purposes by government and industry.

Research Outcomes:

- ▶ Documentation and determination of the potential benefits of connected vehicle technologies and evaluation of driver acceptance of vehicle-based safety systems.
- ▶ Identification of any research gaps and the steps to address them.

²⁸ More information is available at: http://www.its.dot.gov/meetings/pdf/ITS_Update2011_world-congress.pdf.

Safety Pilot research tracks include:

Track 1: Vehicle Builds and Driver Clinics: This track features the building of integrated light vehicles, transit vehicles, and trucks for driver clinics and preparation for model deployment activities. This track also includes driver clinics and performance testing in a variety of geographically diverse environments using a variety of enabled connected vehicles.

Track 2: Device Development and Certification: This track will determine specifications for devices and integrated safety systems so that they work on all types of vehicles and adhere to communication standards to ensure security and message integrity. Developed devices that have met US DOT-defined specifications will be placed on a Qualified Product List and considered as potential devices for model deployment equipment needs. Devices include vehicle awareness devices, aftermarket safety devices, and roadside equipment.

Track 3: Real-World Testing: This track will establish the necessary exposure data to determine potential benefits. Through a one-year model deployment, the track will test the effectiveness of the V2V and V2I safety applications by creating a highly concentrated connected vehicle communications environment with approximately 3,000 vehicles "talking to each other." In addition to the US DOT-required safety applications, the model deployment will also consider showcasing other applications such as:

- ▶ Grade crossing warning
- ▶ Data utilization for transportation management and operations
- ▶ Smart work zone merge management
- ▶ Warning system for pedestrian crosswalk at mid-block locations
- ▶ Emergency vehicle pre-emption

- ▶ Factual evidence needed to support the 2013 NHTSA agency decision.

Safety Applications:

- ▶ Blind spot warning
- ▶ Do not pass warning
- ▶ Emergency electronic brake lights warning
- ▶ Forward collision warning
- ▶ Intersection movement assist warning
- ▶ Lane change warning
- ▶ Red light warning
- ▶ Curve speed warning
- ▶ Pedestrian and turning transit vehicle crash warning
- ▶ Right turn in front of transit vehicle crash warning



Safety Pilot Vehicles at the Orlando Test Track Images: US DOT

During the model deployment, US DOT will open this data-rich environment to the industry for use in testing their devices and applications.

Track 4: Independent Evaluation: This track will analyze data from testing and provide assessments of the performance and benefits of the technology and the safety applications.

2012 SNAPSHOT OF PROGRESS

Connected Vehicle Safety Pilot

Track 1: Vehicle Builds and Driver Clinics

Research Accomplishments

- The US DOT is working with the Crash Avoidance Metrics Partnership (CAMP), a pre-competitive research consortium consisting of 9 OEMs, to build integrated cars for testing during the *Safety Pilot*.
- An initial 24 cars have been built and tested through 6 *Safety Pilot* Driver Clinics, held in 2011, in Brooklyn, Michigan; Brainerd, Minnesota; Orlando, Florida; Blacksburg, Virginia; Fort Worth, Texas; and Alameda, California, during which 690 everyday drivers participated, generating over 20,000 miles of performance data. Results are being analyzed through May 2012.
- To prepare for the *Safety Pilot* Model Deployment, US DOT expects to have approximately 3,000 vehicles for testing. Preparations include:
 - Awarding contracts to vendors to build three integrated trucks and retrofit 16 commercial vehicles and three buses for testing;
 - Continuing to work with the OEMs to build 64 integrated vehicles; and
 - Developing up to 2,500 vehicle awareness devices (which will only broadcast the Basic Safety Message without providing any alerts or warnings to the drivers) that will be installed on volunteers' vehicles.

Critical Research Insights

- Feedback from clinic drivers was overwhelmingly positive. Approximately 90 percent of drivers expressed a desire for the demonstrated safety systems.

Next Steps

- ➔ Assess data from clinics and publish report.
- ➔ Finish vehicle builds (car, truck, and bus) for the model deployment.
- ➔ Conduct two driver clinics for trucks with integrated wireless crash warning devices in the summer of 2012. The clinics will include a cross-section of commercial vehicle drivers in two U.S. locations: East Liberty, Ohio, and Alameda, California.

Track 2: Device Development and Certification

Research Accomplishments

- The ITS Program awarded contracts for development of vehicle awareness devices, aftermarket safety devices, and roadside equipment for supporting model deployment requirements. Qualified Product Lists for each device type are currently being established.



- The ITS Program is working with a consortium of industry stakeholders to define device certification processes. A prototype process will be defined and used to certify devices for use in the model deployment.

Critical Research Insights

- Conducted multiple Vehicle Awareness Device certification events during which submitted devices were tested and detailed results were provided to suppliers with the goal of advancing the development and qualification of the devices for use in the *Safety Pilot* model deployment.

Next Steps

- ➔ Procure devices for use in the model deployment.
- ➔ Finalize prototype certification process and implement for the *Safety Pilot*.

Track 3: Real-World Testing

Research Accomplishments

- Awarded a contract to UMTRI to develop a real-world test site.
- Initiated planning phase of the project, which includes development of plans for various components, such as driver recruitment, experimental design, logistics, security, and infrastructure plans.

Critical Research Insights

- None to date.

Next Steps

- ➔ Complete the planning phase of the project and transition into the pre-model deployment phase.

Track 4: Independent Evaluation

Research Accomplishments

- Produced and finalized an evaluation framework detailing the scope and high-level approach to the *Safety Pilot* evaluation.
- Proposed a recruitment plan intended to maximize the number of interactions between test vehicles.
- Created a traffic simulation model of the Model Deployment test area, which will be used to validate and optimize the proposed recruitment plan.
- Developed data collection requirements for the Model Deployment test vehicles.
- Initiated a data coordination effort across vehicle platforms with the goal of moving toward common database structures and formats for all Model Deployment field-test data.

Critical Research Insights

- None to date.

Next Steps

- ➔ Analyze Driver Clinic subjective data.
- ➔ Develop detailed Model Deployment data analysis plans.

Distracted Driving Principles Guide Connected Vehicle Research

Since the inception of the connected vehicle research, an important principle has guided research – *to ensure that the use of connected vehicle technologies does not introduce unforeseen or unintended safety problems.*

Technology, in particular, has the propensity to generate signals or messages that take the driver's eyes off the road (visual distraction), the driver's mind off the driving task (cognitive distraction), and the driver's hands off the steering wheel (manual distraction). These include such distractions as texting, using a cell phone or smartphone, using a navigation system, watching a video, or adjusting a device. NHTSA reports that in 2010, 3,092 people were killed in distraction-affected crashes and an estimated 417,000 were injured. To help address this important and growing concern, NHTSA developed a comprehensive research plan, *Overview of the National Highway Traffic Safety Administration's Driver Distraction Program*,²⁹ published in 2010, to address all facets of the distraction issue.

A key product of the NHTSA Driver Distraction plan is a set of voluntary Driver Distraction Guidelines (NHTSA Guidelines) to promote safety by discouraging the introduction of excessively distracting devices in vehicles. The first phase of the NHTSA Driver Distraction Guidelines has been released for public comment. These NHTSA Guidelines cover original equipment in-vehicle device secondary tasks (communications, entertainment, information gathering, and navigation tasks not required to drive are considered secondary tasks) performed by the driver through visual-manual means (meaning the driver looking at a device, manipulating a device-related control with the driver's hand, and watching for visual feedback). The second phase will include portable and aftermarket devices. The third phase will expand the guidelines to include auditory-vocal interfaces.

All of these efforts show that the Federal research investment is a critical factor in developing a better understanding of driver distraction and developing techniques to mitigate driver distraction. The ability to establish the basic principles of attention and distraction within the context of advanced technologies used in vehicles is, however, a challenge whose outcomes will form the parameters for and guide consistent development of safer systems and interfaces for countless new applications across a wide and diverse set of manufacturers. The ultimate goal is to prevent distraction related to vehicle-to-vehicle communications devices as a contributing factor to crashes. To do so, the connected vehicle research is directed toward developing and implementing technology-based solutions that motivate drivers to avoid multitasking when possible, and reduce vehicular sources of distraction. The research objectives focus on the following:

- ▶ Lowering the frequency with which drivers multitask to reduce their exposure to risk;
- ▶ Reducing the complexity of distracting tasks to reduce their demands on driver attention;
- ▶ Managing the multitasking options that drivers can make when driving to avoid overloading them; and
- ▶ Assisting distracted drivers through in-vehicle technologies that monitor their attention status and provide feedback on unsafe behaviors and potential crashes.

The intent is to achieve these goals by working cooperatively with the vehicle industry (manufacturers and suppliers), fleet operators and the consumer electronics industry.

²⁹ http://www.nhtsa.gov/staticfiles/nti/distracted_driving/pdf/811299.pdf.



Vehicle-to-Infrastructure (V2I) Communications for Safety ...

... is the wireless exchange of critical safety and operational data between vehicles and highway infrastructure, intended primarily to avoid motor vehicle crashes and enable a wide range of other safety, mobility, and environmental benefits. Preliminary studies show that an additional 12 percent of potential crash scenarios could be addressed by V2I safety applications.

The vision for the V2I research is to enable safety applications that are designed to avoid or mitigate vehicle crashes (inclusive of automobiles, trucks, motor coaches, and transit vehicles), particularly for those crash scenarios not addressed by V2V research. It also focuses on creating national interoperability to support infrastructure and vehicle deployments; and facilitating interoperable, cost-effective infrastructure deployment.



Image: Thinkstock/US DOT

Research Plan

The objective of the technical V2I safety research program is four-fold:

1. Develop and evaluate a systems environment that allows transfer of information, particularly signal phase and timing (SPaT) data, between vehicles and infrastructure;
2. Establish guidelines and standards for the components and systems required for the functional transfer of information between vehicles and infrastructure;
3. Provide tools and guidance based on objective benefits that will guide investment decisions by public agencies on deploying, operating, and maintaining a V2I system; and
4. Ensure appropriate strategies are implemented for privacy, security and system certification, interoperability, scalability, oversight, and public acceptance. Ensure that policies result in a marketplace that is capable of effectively sustaining deployment of infrastructure components.

The program research will involve multiple transportation agencies and modes. It will concentrate on key FHWA, FTA, and FMCSA application areas of interest, including intersection safety, run-off-road prevention, speed management, transit communications and operations, and commercial vehicle enforcement and operations. In addition, exploratory research on V2I safety for commuter, freight, and heavy rail will investigate data interoperability and communications to support a variety of applications, including grade-crossing operations, track surveillance, and right-of-way (ROW) detection.

Due to the great variety of safety systems currently installed and forthcoming, the program also emphasizes the need for consistent, widely applicable standards and protocols. As part of this research, data and communications standards have been tested. Research results will inform revisions to standards, including the BSM in the SAE J2735 DSRC Message Set Dictionary standard, and a standard communications architecture/platform communicating in the 5.9 GHz band of radio spectrum.

Research Goals:

- To employ advanced V2I wireless technologies to reduce, mitigate, or prevent an additional 12 percent of crash scenarios not addressed by the V2V technologies.
- To develop signal warnings that support active safety.

Research Outcomes:

- Understand and plan for a minimum level of infrastructure needed to support V2V and V2I safety and operational efficiency applications.
- Document the stakeholder needs and impacts associated with developing policy guidance or recommendations, in support of deployment.
- Enable additional safety and mobility applications through the use of traffic Signal Phase and Timing (SPaT) data exchange.
- Enable and facilitate interoperable, cost-effective infrastructure deployment.

The key to success in V2I research is defining the minimum components needed to ensure maximum benefit from the safety applications. Success will be further measured by progress on:

- ▶ Development of practical, high-value V2I applications and supporting tools and guidance (including applications for specialty vehicles such as transit bus, rail, trams, and trucks);
- ▶ Development and assessment of a traffic signal system application to communicate SPaT information to the vehicle in support of delivering active safety advisories and warnings; and
- ▶ Testing and demonstrations of application effectiveness:
 - Identification of all critical interfaces and analysis of where standards are needed.
 - Research on the DVI to ensure effective approaches that enhance overall safety while minimizing distraction and driver workload (see Human Factors research on p. 114).

Through collaborative research, the ITS Program will engage appropriate parties in a multi-track approach that addresses the breadth of technical and policy related V2I research needs:

Track 1: Develop Enabling Technology that supports transfer of information between vehicles and the infrastructure. The objective of this track is to develop hardware, firmware, and software that enable selected infrastructure to interact in the Connected Vehicle Environment. The final goal is a definition of V2I enabling technology which includes the standards and specifications required to manufacture, install, operate and maintain Connected Vehicle infrastructure components and the interfaces that ensure interoperability of components. In addition, a V2I Infrastructure Reference Implementation will be completed for use in testing and evaluation of V2I applications and new infrastructure components.

Track 2: Select, Develop, and Evaluate Applications. A list of crash types that could potentially be addressed through V2I safety applications were developed based on an analysis of crash scenarios (see list of applications in the side text box). This list was refined and prioritized through discussions with AASHTO and other stakeholders. Concepts of Operation and Systems Requirements were developed for priority applications. Based on a review of potential benefits and technical feasibility, four or five of these applications will be proposed for application development. Additional mode-specific applications are being developed in partnership with FHWA, FTA, FMCSA, and FRA. The objective of this track is to develop and test a series of safety and safety related applications. The final goal is to define the effectiveness of these applications and develop societal and financial benefits assessments.

Track 3: Infrastructure Planning and Policy is intended to develop tools and guidelines that give practitioners the information required to make sound investment decisions regarding deployment, operation and maintenance of V2I systems.

The key to success of the V2I Communications for Safety program is defining the minimum components required for maximum national benefit from the safety applications. However, Tracks 1 and 3 also directly support Dynamic Mobility Applications (DMA), Data Capture and

Potential V2I Safety Applications
crash scenario mitigation
opportunities include:

- ▶ Intersection safety
- ▶ Roadway departure prevention
- ▶ Speed management
- ▶ Transit safety and operations
- ▶ Commercial vehicle enforcement and operations
- ▶ At-grade rail crossing operations
- ▶ Priority assignment for emergency vehicles



Image: US DOT

V2I applications can be designed to help improve critical safety situations.



Management (DCM), Applications for the Environment: Real-time Information Synthesis (AERIS), and Road Weather Management (RWM). Accordingly, development of Enabling Technology and Infrastructure Planning and Policy incorporate any special requirements for these program areas.

2012

SNAPSHOT
OF PROGRESS

Vehicle-to-Infrastructure (V2I) Communications for Safety

Track 1: Develop Enabling Technology

Research Accomplishments

- Development of enabling technology is underway:
 - Roadside equipment (RSE) from five manufacturers has been placed on a Research Qualified Products List. Two of the manufacturers will provide units for the *Safety Pilot*³⁰ Model Demonstration.
 - An interface has been defined to accept Signal Phase and Timing (SPaT) information from a traffic signal controller and format it for broadcast to mobile devices using existing standards (NTCIP 1202 and SAE J2735). One manufacturer has completed all required firmware upgrades to broadcast the SPaT message. A second manufacturer has indicated they will be ready to broadcast the SPaT message before the end of 2012.
 - A study titled *Roadway Geometry and Inventory Trade Study* (FHWA-HRT-10-073) was delivered in November 2010 and forms the basis for the mapping and positioning research that is ongoing. The report summarizes the findings of an investigation of existing and emerging sources of roadway geometry and inventory data (including public and commercial databases) as well as technologies and methods for collecting, maintaining, and updating roadway attribute information. These data sources are compared along several technical dimensions including geographic coverage, network connectivity, feature resolution, positional accuracy, included attributes, data format and size, and methods and frequency of updates and are evaluated relative to potential near term connected vehicle application data needs. The study also examines the workflow practices and business models of current data providers and their capacity for delivering the roadway data needed for future connected vehicle applications. Based on the findings from the trade study, current roadway geometry and inventory data gaps are identified. Recommendations are proposed for specific research activities and institutional and regulatory options to address data gaps.
 - Trade studies of positioning and communications technologies are complete. Phase II work has been awarded for unit testing of the top contenders at the Federal Highway Turner-Fairbank Highway Research Center (TFHRC).
- Initial mapping of the TFHRC test bed using Light Detection And Ranging (LIDAR) and optical cameras has been completed and data reduction is underway.
- Development of a SPaT interface device is complete. End-to-end transmission of SPaT messages, from signal controller to mobile device, has been successfully tested both in the laboratory and in the field.

Critical Research Insights

- Preliminary analysis into V2I has highlighted the importance of developing an

³⁰ List can be found here: http://www.its.dot.gov/safety_pilot/safety_pilot_qpl.htm.

integrated prototype that links the communications, positioning, and mapping technologies in order to assess their interactions. A V2I Reference Implementation is now part of the V2I roadmap. An initial version will be installed at TFHRC and, after testing, expanded to the Michigan test bed and other test beds.

- Network security from an infrastructure perspective has also been highlighted as a priority. Current work on investigating existing security approaches and identifying risks is underway. For the Connected Vehicle Environment, communications security will be addressed in a comprehensive, integrated manner (see the Connected Vehicle Core System Concept on page 119).

Next Steps

- ➔ Incorporate lessons learned from the *Safety Pilot Model Demonstration* to refresh infrastructure components, as necessary.
- ➔ Integrate the enabling technologies (communications, positioning, mapping, SPaT, RSE and security) to produce and field test a comprehensive V2I deployment that can be used to test and evaluate proposed applications and new infrastructure components.

Track 2: Select, Develop, and Evaluate Applications

Research Accomplishments

- Development of applications is underway:

- The Concept of Operations (ConOps) and Systems Requirements (SysReq) for three priority V2I Safety applications (Red Light Violation Warning (RLVW), Stop Sign Gap Assist (SSGA) and Curve Speed Warning (CSW)) are complete.
- The ConOps for additional V2I Safety applications are complete. The SysReq are under development.

Critical Research Insights

- Intersection safety application development has been able to draw from previous research under the Cooperative Intersection Collision Avoidance Systems research (CICAS) program conducted from 2005 to 2008.³¹ That initial research highlighted the gap in technology capability that the current connected vehicle efforts are addressing.
- Crash factors analysis and migration studies were conducted and provided a list of potential V2I application areas. Two reports have resulted and will be made publicly available in late 2012: *Crash Data Analyses for Vehicle-to-Infrastructure Communications for Safety Applications* (FHWA-HRT-11-040) and *Infrastructure-Based ITS Migration Study for V2I Safety Applications: Feasibility of Migrating Safety Countermeasures to a V2I Cooperative System*. These results were shared with the American Association of State and Highway Transportation Officials (AASHTO) to develop a prioritized list of high impact applications that are being evaluated under the ConOps.

Next Steps

- ➔ Down select to one or two additional V2I Safety applications and complete SysReq.
- ➔ Develop Performance Requirements and Test and Validation Procedures for the three priority V2I Safety applications and the additional selected applications.
- ➔ Award work to complete application development, simulation and validation. Refine applications as needed to permit Field Operational Testing (FOT).
- ➔ Conduct FOT for selected V2I Safety Applications.

³¹ See: ntl.bts.gov/lib/32000/32200/32231/14429_files/ch3.html.

Track 3: Infrastructure Planning and Policy

Research Accomplishments

- Initial analysis of what critical policy and institutional issues may challenge V2I implementation has been compiled as part of the Policy research efforts.

Critical Research Insights

- ◊ Discussion with stakeholders and initial analysis finds that the implementation of an infrastructure component for the connected vehicle program will face policy and workforce challenges:
 - The technology is significantly different from typical ITS applications and the installation and maintenance will require new workforce skills.
 - It is not clear whether V2I technologies will create new issues with regard to tort liability for State and local agencies or whether operating agencies are protected through similar immunities offered with the operation of traffic signals.
- ◊ Key risks for access management and control of the system enabling the safety applications have been identified for further evaluation and definition of effective installation guidelines.

Next Steps

- ➔ Further policy and institutional analysis is needed to develop options for addressing key implementation issues.
- ➔ Stakeholder input through meetings and workshops will further clarify existing and potential implementation and policy challenges.
- ➔ With the test and evaluation results, work can begin on developing guidance and a tool box for supporting V2I implementation.

Truck V2I Research ...

... the application of wireless communications technology into a commercial vehicle platform to create research prototypes for crash avoidance safety applications on commercial vehicles. The vision for Truck V2I research is to employ wireless communications to make trucking safer, smarter, and greener, ultimately enhancing livability for all Americans by transforming the way Americans travel.

Research Plan

Research results from 2010 to 2011 have revealed that the Smart Roadside research program is nearly synonymous with the desired outcomes of truck V2I research. Smart Roadside research focuses on developing a prototype that capitalizes on the identification, integration, documentation, and analysis of successful deployments of truck-specific roadside technologies. As a result, the Smart Roadside program is conducted closely with the V2I safety research to ensure alignment and reduce redundancy.

2012 SNAPSHOT OF PROGRESS

Truck V2I for Safety: The Smart Roadside Initiative

Research Accomplishments

- The US DOT has awarded a contract to a partnership of public and private sector and academic organizations to identify and integrate successful deployments of truck-specific roadside technologies. The focus of the effort is on developing a ConOps and testing prototypes of Smart Roadside applications.
- Outreach has been conducted with key stakeholders, which has formed the basis for identifying user needs.
- An assessment has been completed that reviewed and analyzed currently deployed systems on Smart Roadside applications.

Critical Research Insights

- The current commercial vehicle environment consists of numerous Federal, State, regional, and private sector programs that use a combination of manual, semi-automatic, and advanced technologies to support safety, mobility, and security. The effectiveness of these programs will be greatly improved by the Smart Roadside concept as relevant and appropriate data is shared among the current systems and they are integrated in a collaborative fashion.

Next Steps

- ➔ Complete the development of the ConOps, systems requirements, architecture, and prototype design process.
- ➔ Identify benefits and develop deployment plan.
- ➔ Frame an experimental test design.
- ➔ Conduct build up for test experimental design and conduct limited field test deployment.
- ➔ Document findings and generate an evaluation report.
- ➔ Integrate Smart Roadside into the overall V2I research program and planned regional pilots.



Transit V2I Research ...

... is the research and application of the connected vehicle concept to transit to improve safety, mobility, and the environment while addressing the unique needs and properties of transit vehicles, operations, institutions, and travelers. The vision for Transit V2I research is to apply connected vehicle technologies to develop safety, mobility, and environmental applications that address transit needs and priorities while providing interoperability and coexistence with connected-vehicle equipped cars and trucks.

Research Plan

Transit V2I research is an element of the Track 2 research conducted as part of the V2I program. It focuses on the needs and opportunities that are specific to transit. Two transit V2I applications are under development – a Pedestrian Warning System for Bus Drivers (see image and text box below) and an adaptation of Curve Speed Warning for transit vehicles.



Transit Connected Vehicle. Image: US DOT

A Pedestrian Warning System for Bus Drivers

This application would be operational at signalized intersections only, at least initially, using V2I communications. The research is investigating a number of methods for detecting the presence of pedestrians at signalized intersections (e.g., in crosswalks) in support of alerting bus drivers.

2012 SNAPSHOT OF PROGRESS

Transit V2I for Safety

Research Accomplishments

- Develop Transit Connected Vehicle ConOps.
- To date, transit stakeholders have identified the pedestrian warning for bus drivers application as a high-priority V2I application. It will be developed and demonstrated during the *Safety Pilot Model Deployment*. Another V2I safety application, Curve Speed Warning for transit, is also under development.

Critical Research Insights

- ⦿ Based on the work to develop a Transit Connected Vehicle ConOps, other transit safety applications may be identified and potentially developed as part of the V2I program with the plan to demonstrate them in one or more connected vehicle regional demonstrations.

Next Steps

- ➔ Develop other transit V2I applications and demonstrate them in a regional demonstration(s).

Connected Vehicle Safety for Rail ...

... is a research effort designed to support the Rail Safety Improvement Act of 2008, which mandates that certain classes of railroads that carry Toxic Inhalation or Poison Inhalation (TIH/PIH) cargo have categories of track instrumented with Positive Train Control, (PTC) by 2015. A further focus of the research is to develop a more precise understanding of the risks presented by the railroad Right of Way (ROW) and to determine how best to mitigate these risks through the application of ITS technologies.

The vision for the Connected Vehicle Safety for Rail is to research and demonstrate a prototype set of applications to advance the FRA's safety goal of a reduction in fatalities, injuries, and collisions, as well as to identify a cohesive approach to fulfilling other goals such as reduction of transportation congestion.

Research Plan

The objective of the Connected Vehicle Safety for Rail initiative is to undertake research and an exploratory design of connected vehicle applications to enhance the safety of trains and all vehicles at railroad grade crossings where rail intersects with other traffic. The research will focus on integrating DSRC hardware with existing railroad grade-crossing safety systems such that an alert is broadcast to approaching connected vehicles when a rail crossing safety system is active.

The ITS Program will use a multi-track approach to carry out the research effort:

Track 1: Engage Stakeholders for input across all phases from foundational analysis to focused demonstrations to ensure that requirements are well understood and addressed with the new technologies and applications.

Track 2: Develop a System ConOps that will describe how connected vehicle safety applications and strategies can be implemented to improve safety outcomes at railroad grade crossings. It should be noted that the scope of this research is limited to rail safety scenarios at grade crossings where interaction occurs between rail and other traffic, such as motor vehicles and pedestrians. Rail-to-rail safety scenarios are beyond the scope of this research. The ConOps development process includes the following elements:

- Establish a project steering committee consisting of representatives from all the stakeholders involved in or impacted by the project – owners, operators, maintainers, and users, among others;
- Capture a clear definition of the stakeholders' opportunities and constraints that will support system requirements development; and
- Develop operational scenarios for both normal and anomalous operations. This includes definitions of:
 - Operating characteristics or functions of the rail system;
 - The operational environment in which the system is expected to function;
 - System usage and its elements in the anticipated operating environment;
 - Scenarios of infrastructure and/or system control;

Research Goals:

- ▶ To stimulate research in the design of Connected Vehicle applications to enhance safety of commuter, heavy, and freight rail systems, specifically at railroad grade crossings where rail intersects with other traffic such as light, commercial, and transit vehicles and pedestrian/bicycle traffic.
- ▶ To address evaluation methodologies, visual and audio warnings, motor vehicle and train presence detection, crossing geometry, crossing gate and flashing light technologies, and human factors issues.
- ▶ To integrate Connected Vehicle and Highway Rail Interface (HRI) technologies to examine the potential for deployment of low-cost, innovative warning systems that could have greater effectiveness than passive warning devices.

Research Outcomes:

The outcome of the research will be an improvement in safety through the systematic examination of human performance in railroad operations and related activities.



- Critical system performance measures to force early consideration and agreement of how system performance and project success will be measured; and
- A preliminary system validation plan, incorporating system performance measures, to establish system success or completion.

Tracks 3 and 4 will be performed pending the review and results of Track 1 and 2.

Tracks 3: Develop System Requirements Specifications that transform stakeholder needs (identified in the ConOps) into verifiable performance and functional requirements.

Track 4: Develop a Preliminary Test Plan incorporating the following goals:

- Verifies that the connected vehicle system satisfies the high-level design, requirements, and verification plans and procedures;
- Confirms that all interfaces have been correctly defined; and
- Confirms that all requirements and constraints have been satisfied.

Tracks 5 and 6 will be based upon approval of system specifications and test plan.

Tracks 5: Develop and Demonstrate a Viable Connected Vehicle Rail Safety Prototype. Based on the candidate applications and technologies identified as a result of Tracks 2 and 3, a prototype system will be developed and the concept tested. The prototype will integrate rail operators and vendors to cooperate in the development process. A demonstration will be performed using the test plan developed in Track 4. At a minimum, the demonstration will characterize the warning time for driver reaction under a range of vehicle speeds.

Tracks 6: Develop a Test Report covering the deliverables from all tasks together with conclusions on the efficacy of this research.

Because operational scenarios differ among different rail operators, challenges exist in developing across-the-board, comprehensive scenarios. If these challenges are met, new opportunities may arise to apply the potential safety improvements to light rail operations and activities.



Houston, Texas, Metro, passenger train going through an intersection.

©iStockPhoto/Zellmer/US DOT

Connected Vehicle Safety for Rail

Connected Vehicle Safety for Rail

Research Accomplishments

FRA is leading research to develop a ConOps for connected vehicle safety for rail. The effort began in September 2011. To date, accomplishments include:

- Developed and completed a project management plan;
- Formed a DOT stakeholder group and held a formal DOT stakeholder group meeting; and
- ConOps work is nearly complete. ConOps is expected to be available in late 2012.

Critical Research Insights

- None to date.

Next Steps

- ➔ Complete the ConOps and develop a working prototype for testing.



© iStockPhoto.com/Rob Vomund



Mobility



Data Capture and Management (DCM) ...

... is the creation and expansion of access to high-quality, real-time, multimodal transportation data, captured from connected vehicles, mobile devices, and infrastructure. Data Capture and Management technologies collect real-time data from single sources and modes and either integrates the data across modes and sources or makes it available for users to incorporate according to their needs.

The vision of the DCM program is to enhance current operational practices and transform future transportation-systems management and traveler information through the active acquisition of integrated data from vehicles, travelers, mobile devices, and fixed sensors, provided to researchers, application developers, and system operators.

Research Plan

The objective of the Real-Time Data Capture and Management program is to develop data environments that support the collection, management, integration, and application of real-time transportation data.

Applications that use real-time data have the potential to increase highway safety and operational efficiency nationwide. The output of the applications will produce data to allow travelers to make better-informed travel decisions. Public- and private-sector data on all modes and roads can be used to transform surface transportation management.

Real-time data sets also have the potential to support a range of multimodal mobility applications. For example, real-time information on parking availability and transit schedules can enable smarter mode-choice decisions and yield time and fuel efficiencies for travelers. Updated freight-movement data helps commercial freight operators to optimize operations.

The results of the DCM program will reveal opportunities for achieving greater efficiencies within our transportation systems by providing multimodal data to developers and researchers. Some of the data types that can be captured and managed include situational safety; environmental conditions; congestion data; and cost information (derived from both traditional sources, such as traffic management centers and automated vehicle location systems; and nontraditional sources, such as vehicles, the infrastructure, mobile devices, and ITS applications). Data can also be collected from toll facilities, parking facilities, and transit stations.

Results that are key to success in this research area include:

- ▶ Establishment of one or more multisource data environments for the development and testing of safety, mobility, and environmental applications;
- ▶ Engagement of stakeholders to assist in defining the requirements for test-data environments and to encourage active use of prototypes and test beds;
- ▶ Identification of data-management processes, operational practices, standards, integration, and rules for data exchange and sharing, particularly across jurisdictions;

Research Goals:

- ▶ To systematically capture real-time, multimodal data from connected vehicles, devices, and infrastructure.
- ▶ To develop data environments that enable integration of high-quality data from multiple sources for transportation management and performance measurement.

Research Outcomes:

The results of this research program will be used to develop additional data environments and demonstrations that show the value of widespread real-time multimodal information.



Real-time data can be integrated across modes and made available to users.

Image: ©iStockPhoto.com

- ▶ Successful testing that validates assumptions about:
 - Data (availability and accessibility of sources, quality, reliability, consistency, timing, etc.);
 - Management and operational practices (how real-time data capture and use is managed); and
 - Benefits as demonstrated through testing of the applications.
- ▶ Success will be further measured by progress on:
 - Synthesis of foundational research to assess the state of the industry;
 - Development of a variety of large-scale data sets, using connected vehicles, mobile devices, and infrastructure, for testing transportation-management and performance-measurement applications; and
 - Demonstrations of multimodal and multistate real-time data capture and management to show the value of ubiquitous transportation information.

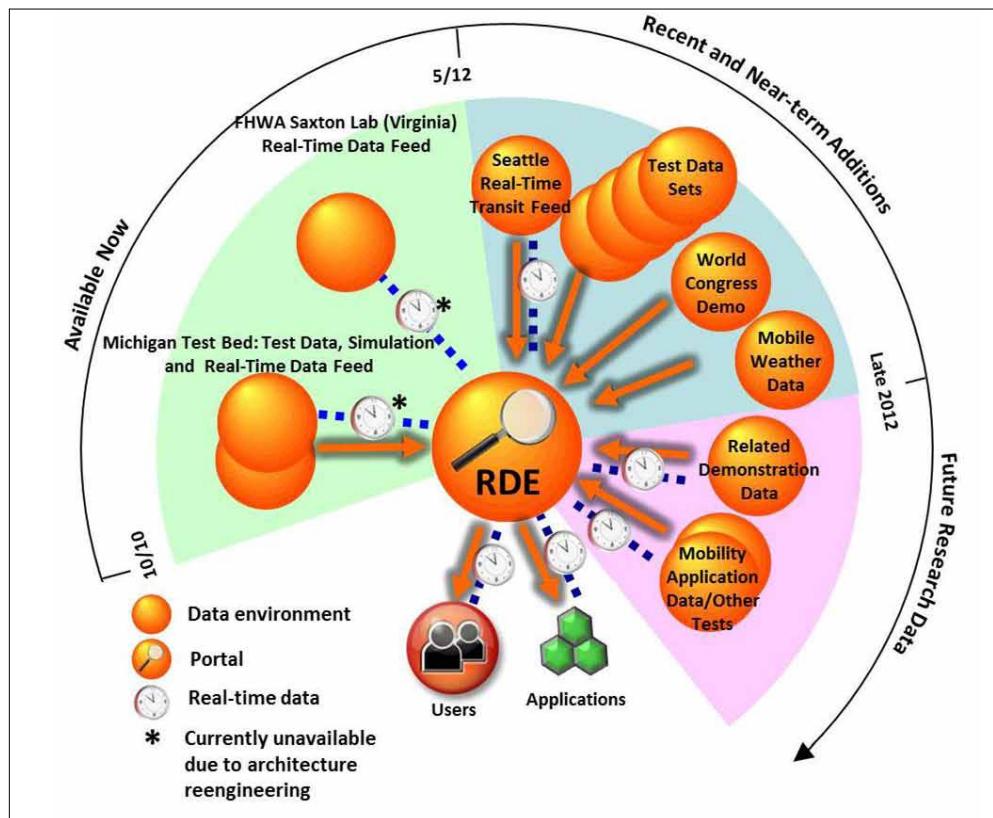


Figure 4. US DOT is developing a new Research Data Exchange Portal for collection and analysis of Connected Vehicle data. Source US DOT

The Real-Time DCM program includes the following tracks:

Track 1: Engage stakeholders for input from initial analysis to pilot deployment. Test data sets, data collection, and analysis methodologies will be shared with stakeholders, with information made available to the broader transportation community.

Track 2: Develop data environments to support transportation applications and address technical, institutional, and standards issues surrounding the collection and dissemination of data.

Track 3: Conduct proof-of-concept tests and testing of standards, procedures, tools, and protocols to provide implementation guidance for real-world deployment.

Track 4: Conduct pilot deployments and demonstrate the data capture and management techniques in an operational setting, while providing stakeholders with opportunities to develop systems that will extend beyond the life of the program.

Track 5: Develop evaluation and performance measures to assess benefits of the data environments.

Track 6: Share the program's findings and procedures with stakeholders and the broader transportation community through coordinated outreach activities and technology transfer.

The DCM research builds on the existing Real-Time Information Market Assessment and the Real-Time System Management Information program. It will provide open access to data to developers and researchers. Other US DOT ITS programs, such as the DMA and AERIS, have been helping to define data requirements, identify information gaps, and use the real-time data sets that are being developed under this program.

2012

SNAPSHOT
OF PROGRESS

Data Capture and Management (DCM)

Engage Stakeholders

Research Accomplishments

- In December 2010, the program engaged in a Mobility Workshop with over 150 attendees to identify and define the data-capture needs associated with new, dynamic mobility applications.
- In addition, the DCM program has participated in a number of joint stakeholder engagement events with the DMA program over the last 18 months with the Institute of Transportation Engineers (ITE), AASHTO, ITS America (ITSA), University Transportation Centers (UTCs), American Public Transportation Association (APTA), Transportation Research Board (TRB), National Science Foundation (NSF), I-95 Corridor Coalition, North American World Trade Group (NATWG), freight-industry stakeholders, and Transportation Safety Advisory Group (TSAG).
- A public stakeholder workshop to review progress and gather input was jointly hosted with the DMA program in May 2012.

Critical Research Insights

- Stakeholders strongly concur with the open-data concept and program direction of the DCM program.

Next Steps

- ➔ Engage the automotive industry to identify the types of data that can be captured.
- ➔ Form a Research Data Exchange Stakeholder Group.
- ➔ Continue engagement with established stakeholder groups.

Track 2: Develop Data Environments

Research Accomplishments

- In May 2010, a Prototype Data Environment (PDE) went live. The PDE documented and posted data from VII POC and NCAR tests.
- To organize the data, the DCM program developed meta-data guidelines in November 2011.
- In late fall of 2011, the DCM program completed a ConOps for a research data exchange (RDE) – an envisioned federated system of open-data environments sharing the results of connected vehicle research. The RDE will serve as a model for the private sector and academia on how to construct a data environment capable of capturing real-time data.³²
- In May 2012, the PDE was transitioned to the RDE as the first step in moving toward a federated exchange.
- The four probe vehicle/infrastructure/transit data sets are resident in the RDE. These data sets were procured for initial testing in January 2012. The data sets were scrubbed of existing personally-identifiable information (PII).

Critical Research Insights

- There has been consistent web traffic on the PDE, with users downloading and using shared, connected vehicle data for their own research and applications, highlighting the value of this emerging new data set. There have been 1,597 total visits and 615 unique visitors as of July 2011.

Next Steps

- ➔ Continue to populate the RDE with additional data sets, and build the research community.

Track 3: Conduct Proof-of-Concept Tests and Testing

Research Accomplishments

- In July, 2011, the DCM program established a real-time data feed from the V2I/V2V and TFHRC Saxton Laboratory field test bed.
- In November 2011, the DCM program completed an industry state-of-the-practice and innovation scan project that reviewed existing practices in data-capture technologies.

Critical Research Insights

- The establishment of the real-time data feed proved that real-time data-sharing from connected vehicles is possible and practical.
- The innovation scan highlighted that a range of industry best practices can support connected vehicle data capture, including cloud-based computing, crowdsourcing, data federation, virtual warehousing, and dynamic interrogative data exchange.

Next Steps

- ➔ Conduct a series of small-scale connected vehicle tests, using test beds, and share these data in 2012.
- ➔ Incorporate innovations and scan results in RDE build-out, (e.g., the RDE will be constructed with use of cloud-based computing, data federation, and virtual warehousing).

³² <http://www.its-rde.net>.

Track 4: Conduct Pilot Deployments

Research Accomplishments

- The Road Weather program has joined with the DCM program to demonstrate the ability to capture integrated mobile observations in real-time in the PDE.

Critical Research Insights

- The demonstration illustrated that there is a clear role for the DCM program to document and provide data from a variety of connected vehicle research efforts; the RDE is a critical component in assimilating multisource weather, transportation, and vehicle data from multiple research projects to enable the use of accurate, timely data for application testing and prototype development.

Next Steps

- ➔ Coordinate with completed, ongoing, and planned demonstrations, including the upcoming *Safety Pilot* Model Deployment (to begin in August 2012) to access connected vehicle data for mobility application research, prototype testing, and benefit assessment.

Track 5: Develop Evaluation and Performance Measures

Research Accomplishments

- In May 2011, the DCM program developed a draft evaluation framework for data sets, anticipated to be released through the RDE.
- The DCM program is in the process of establishing uniform metrics for measuring the impacts of data sets released through the DCM program; these impacts are related to both the number of users and the range of research conducted with use of the data sets.

Critical Research Insights

- Initial development of the RDE has validated the need for accurate data attributes and metrics to enable multisource open data to be accessible to enable mobility applications research, testing, and deployment.

Next Steps

- ➔ Integrate the evaluation framework concept into the RDE as it is built in summer/fall of 2012.
- ➔ Initiate an over-arching DCM program evaluation activity in the summer of 2012.

Track 6: Share the Program's Findings and Procedures

Research Accomplishments

- In the summer of 2011, the DCM program jointly hosted a webinar series that presented the Research Data Exchange Concept (July 2011) and Innovation Scan Findings (August 2011).

Critical Research Insights

- A strength demonstrated by the program outreach to date is the ability to connect with organizations that are interested in sharing research data around the world. A range of agencies from Japan, the European Union (EU), universities, and transit agencies have provided data and expressed interest in the PDE and upcoming RDE.

Next Steps

- ➔ Encourage use of data products posted to the RDE with universities.
- ➔ Issue data-related challenges (jointly with the DMA program) in the summer of 2012.
- ➔ An updated Program Fact Sheet is expected to be published in 2012.



Real-time data sources. Image: US DOT



Dynamic Mobility Applications (DMA) ...

... are the next generation of applications that are intended to support further transformations in mobility. They do so through the acquisition of new forms of real-time data that is captured, synthesized, and made accessible through a connected vehicle environment. This new data extends the geographic scope, nature, precision, and latency of control within the transportation system. These applications are focused on innovative methods for operating existing transportation systems, and on greater integration across modes (e.g., light vehicles, transit vehicles, and heavy commercial vehicles).

The vision of the DMA research program is to expedite the development, testing, commercialization, and deployment of innovative mobility applications. The research will fully leverage new technologies and Federal investment to transform transportation system management, maximize the productivity of the system, and enhance the accessibility of individuals within the system.

Research Plan

The objective of the DMA research program is to foster the release of high-value, open-source applications that use synthesized, multisource ITS data to transform surface transportation management and information. The research conducted in this program is also focused on developing the tools (for instance, an open source portal), metrics, and concepts that support application development.

The current applications were identified with broad stakeholder input. In 2010, the DMA program collected and considered stakeholder needs by hosting an open call for concepts between May and October 2010. With over 90 ideas, a December 2010 workshop brought stakeholders together to discuss priorities and whether application ideas could be consolidated or bundled. Discussion also focused on the applications concepts' potential impact on four environments – arterial, freeway, corridor, and regional operational.

Using this input as a basis, a multimodal DOT team performed further ranking, scoring, and identification of synergistic applications. The result is a set of six bundles of applications that not only reflect the vision of the DMA program to enable greater public sector, multimodal system management, and modal integration – but also reflect the criteria for high-risk and high-reward investment.

Each bundle contains a set of related applications that are focused on similar outcomes (i.e., more efficient signal prioritization and timing for mobility), but perform in different capacities (i.e., transit signal priority versus emergency preemption). Importantly, each application could not work as effectively without understanding the influence of the other applications – the timeframe that they have to operate (sometimes within seconds), and the nature of the impacts and need to sequence the impacts are highly related. Thus, by developing the applications together, synergistic relationships are embedded into the algorithms resulting in:

- ▶ Greater efficiencies – the same data and observations can be used across all of the applications as opposed to deriving such inputs separately or in varying formats
- ▶ Less stove-piping as the applications must effectively interact
- ▶ Greater safety and operational awareness of a broad range of impacts

The bundles and their applications include:

Research Goals:

- ▶ To identify transformative applications and innovative methods to manage and operate transportation systems based on the availability of new data sources and communications methods.
- ▶ To build an application data integration foundation that will transform the data into information that can provide travelers and systems operators with greater access to real-time information about the transportation system to enable better decision making.

Research Outcomes:

The results of this research will provide the foundation (the concepts, requirements, specifications, analyses, tests, and metrics) needed for development of dynamic mobility applications.



Real-time data and communication networks are critical to the development and deployment of new DMA applications. Image: US DOT

- ▶ Freight Advanced Traveler Information System (FRATIS)
 - Freight Dynamic Route Guidance (F-DRG)
 - Freight Real-Time Traveler Information with Performance Monitoring (F-ATIS)
 - Drayage Optimization (DR-OPT)
- ▶ Integrated Dynamic Transit Operations (IDTO)
 - Connection Protection (T-CONNECT)
 - Dynamic Transit Operations (T-DISP)
 - Dynamic Ridesharing (D-RIDE)
- ▶ Intelligent Network Flow Optimization (INFLO)
 - Dynamic Speed Harmonization (SPD-HARM)
 - Queue Warning (Q-WARN)
 - Cooperative Adaptive Cruise Control (CACC)
- ▶ Multi-Modal Intelligent Traffic Signal System (MMITSS)
 - Intelligent Traffic Signal Control (I-SIG) – the overarching optimization algorithm that manages and optimizes preemption and priorities.
 - Transit Signal Priority (TSP)
 - Mobile Accessible Pedestrian Signal System (PED-SIG)
 - Freight Signal Priority (FSP)
 - Emergency Vehicle Preemption (PREEMPT)
- ▶ Response, Emergency Staging and Communications, Uniform Management, and Evacuation (R.E.S.C.U.M.E.)
 - Incident Scene Pre-Arrival Staging Guidance for Emergency Responders (RESP-STG)
 - Incident Scene Work Zone Alerts for Drivers and Workers (INC-ZONE)
 - Emergency Communications and Evaluation (EVAC)
 - Advanced Automated Crash Notification Relay (AACN-RELAY)
- ▶ Enable Advanced Traveler Information System (EnableATIS) which is looking to develop a suite of capabilities to foster multisource data integration and delivery; promote development of dynamic, real-time multimodal traveler information and applications; improve transportation system mobility and safety; and advance research with new forms of data about traveler behavior and response to transportation operations. While no specific applications are being developed under EnableATIS, activities include expanding and exercising emerging data sets that merge multimodal data into potentially transformative traveler information, and exploring ways of increasing data collection as well as capturing traveler behavior through nomadic platforms.

A more detailed description of each bundle and the current progress in development appears on pages 59 – 75, following the snapshot of progress for the DMA program.



While focused on different elements of the transportation system, these applications contain similar characteristics. They:

- ▶ Use vehicle and infrastructure connectivity to enable dynamic decision making.
- ▶ Allow managers to anticipate problems, be proactive in addressing issues, and rapidly monitor impacts on and across multimodal transportation networks.
- ▶ Support emerging work in Decision Support Systems (DSS) – systems that can assimilate and analyze large volumes of detailed real-time and historic data to provide recommendations in formats that are most valuable to traffic managers or travelers.

In addition to application selection and development, the research is also focused on:

- ▶ Defining multimodal performance metrics that form the basis for DSS, tools, and models.
- ▶ Collecting real-time data for assessment (to include collaboration with the Real-Time DCM program).
- ▶ Assessing data from historical and real-time traffic and travel behavior perspectives to understand which types of multimodal data enable dynamic, proactive decision making.
- ▶ Identifying which public sector, multimodal dynamic applications might be of the highest value and use demonstrations to test the validity of those assumptions with stakeholders.

The DMA research program includes the following tracks:

- ▶ **Track 1: Engage stakeholders** for input across all phases, from foundational analysis to focused demonstrations.
- ▶ **Track 2: Conduct program planning and coordination** including fundamental research and development, institutional policy, and standards that will ultimately enable public and private sector applications development, and support application impact assessments while using communications across interoperable platforms.
- ▶ **Track 3: Conduct applications development and testing** for the standards, algorithms, tools, and protocols that will be needed for implementing the applications.
- ▶ **Track 4: Conduct focused demonstration and analysis** based on a partnership with the Real-Time DCM and AERIS programs to demonstrate applicability in a market-based environment and assess quantifiable benefits. This track includes conducting a near-term demonstration of market-ready technologies and applications.
- ▶ **Track 5: Develop evaluation and performance measures** that address the performance of the applications developed, as well as the program itself.
- ▶ **Track 6: Coordinate outreach and technology transfer** to inform the transportation community on the activities of the program, and share findings and procedures with stakeholders.



Dynamic Mobility Applications (DMA)

Track 1: Engage Stakeholders

Research Accomplishments

- With the DCM program, the DMA program conducted a Mobility Workshop in December 2010 with over 150 stakeholders. The workshop provided the DMA program with an initial list of proposed applications that were later prioritized for selection.
- The DMA program staff engaged OEM stakeholders through Vehicle Infrastructure Integration Consortium (VIIC) in February 2012. Collaboration with vehicle manufacturers is critical to understand what data is accessible from vehicles and in what format.
- A more recent workshop in May 2012 (again, in partnership with the DCM program) brought stakeholders together to learn about the progress, products, and plans of the two programs, and to seek input from stakeholders on the direction of the two programs.

Critical Research Insights

- Stakeholders have concurred that new forms of wireless data from mobile devices and vehicles can transform mobility applications. Stakeholders have also expressed interest in participating in the development of high-priority applications.

Next Steps

- ➔ Use structured stakeholder engagement in each of the high-priority application bundles to refine ConOps through summer of 2012.
- ➔ Continue to update stakeholders on progress and engage with them to understand the impacts and opportunities associated with the emerging applications.

Track 2: Conduct Fundamental Research and Development

Research Accomplishments

- The DMA program has completed a review of decision support systems to identify lessons learned. The program has also initiated an effort to identify analytical needs to support application-impacts assessment.
- The DMA technical teams have completed a ConOps for an Open Source Applications Development Portal (OS Portal), meant as an environment for academic, private-sector, and public-sector programmers to develop new mobility applications.

Critical Research Insights

- Initial policy analysis found that different applications have different levels of confidential and sensitive intellectual property, source code, and/or PII. The level of "open" development that is possible is still under assessment.

Next Steps

- ➔ Build and launch OS Portal in the fall of 2012.
- ➔ Launch analytical tool enhancement initiative in the fall of 2012.



Track 3: Develop and Test Applications

Research Accomplishments

- Working with stakeholders from Track 1, the DMA program staff defined 30 high-priority applications, grouped into six logical bundles.
- The program awarded six procurements to further develop these concepts with use of a systems engineering approach.
- The DMA program has issued request for task proposals for both the FRATIS and IDTO bundles and is seeking a variety of sites and approaches to inform development for a range of different real-world conditions.

Critical Research Insights

- Significant synergy has been observed in combining traveler, vehicle, and roadside infrastructure data in transformative application concepts.

Next Steps

- ➔ Complete ConOps development for each of the application bundles by the summer of 2012.
- ➔ Decide which applications should move forward into development with Federal funding.
- ➔ Initiate integrated research program of challenges, applications development, and testing by the fall of 2012.

Track 4: Demonstrate Applications

Research Accomplishments

- The DMA program has coordinated with the *Safety Pilot Model Deployment* test to ensure that mobility-related data elements are captured and utilized for applications development.

Critical Research Insights

- Opportunities to utilize ongoing demonstrations in other parts of the ITS program can be capitalized on with good advance planning.

Next Steps

- ➔ Coordinate with completed, ongoing, and planned demonstrations, including the upcoming *Safety Pilot Model Deployment* (begins in August 2012).

Track 5: Develop Evaluation and Performance Measures

Research Accomplishments

- The DMA program has worked to develop performance measurements for mobility and productivity assessment at the user and system levels.

Critical Research Insights

- Mobility can be defined by taking a traveler-centric view of system performance rather than a facility-centric view.

Next Steps

- ➔ Initiate a DMA application evaluation effort in the summer of 2012.
-

Track 6: Share the Program's Findings and Procedures

Research Accomplishments

- ☒ The DMA program hosted a summer webinar series in 2011. The series introduced the public to six prioritized mobility applications cross-cutting the areas of traveler information, freeway and arterial applications, transit, freight, and emergency response. Transportation stakeholder workshops were held in early 2012 that provided input to concept development in each of these areas.

Critical Research Insights

- ◊ Program strengths include the use of outreach methods to connect with potential developers of applications with an open-source approach.

Next Steps

- ➔ Encourage use of applications posted to the OS Portal.
- ➔ Issue data-related challenges (jointly with the DCM program) in the summer of 2012.



Freight Advanced Traveler Information System ...

... is a bundle of applications that provides freight-specific dynamic travel planning and performance information and optimizes drayage operations so that load movements are coordinated between freight facilities to reduce empty-load trips.

Research Plan

The FRATIS bundle of applications seeks to improve the efficiency of freight operations by using several levels of real-time information to guide adaptive and effective decisionmaking. Currently, freight routing, scheduling, and dispatch decisions are sometimes made in an ad-hoc fashion, with inadequate data to make fully informed decisions. This is particularly the case for small- to medium-sized firms (this category includes many drayage operators and over-the-road haulers) that may not be able to invest in information technologies and systems at the level of larger firms. While much data are already available, FRATIS seeks to integrate existing data sources in a manner and with a quality that is oriented toward freight's unique operational characteristics that require different data and methods/time frames for information delivery. Also, the applications will be developed in a manner that leverages new connected vehicle data.

Two applications comprise FRATIS:

- ▶ **Freight Specific Dynamic Travel Planning and Performance:** This application bundle seeks to include all of the traveler information, dynamic routing, and performance monitoring elements identified by users as needs. It is expected that this application will leverage existing data in the public domain, as well as emerging private sector applications, to provide benefits to both sectors. In addition to connected vehicle data, other data includes real-me freeway and key arterial speeds and volumes, incident information, road closure information, route restrictions, bridge heights, truck parking availability, cell phone and/or Bluetooth movement/speed data, weather data, and real-time speed data from fleet management systems.
- ▶ **Drayage Optimization (DR-OPT):** This application bundle seeks to combine container load matching and freight information exchange systems to fully optimize drayage operations, thereby minimizing bobtails/dry runs and wasted miles, as well as spreading out truck arrivals at intermodal terminals throughout the day. With this application, the US DOT and industry also have an opportunity to address some key industry gaps – to truly optimize a freight carrier's itinerary, extensive communication is required from a wide range of entities (including rail carriers, metropolitan planning organizations, traffic management centers, customers, and the freight carriers themselves) in a manner that assesses all of the variables and produces an optimized itinerary. This requires the development of a powerful set of algorithms that leverage data that exists in the "cloud." In addition to optimization, these improvements are expected to lead to benefits in terms of air quality and traffic congestion.

Figure 5 on the following page provides a graphic of the FRATIS high-level design concept.

Both bundles will consist of two application levels – a basic application, developed from open-source data and services and available in the public realm; and a "value-added" commercial application, targeted at existing, subscriber user groups. A set of foundational documents (including a ConOps and systems requirements document) will be available in the summer of 2012.

With the conclusion of the first phase of FRATIS research nearly complete, the DMA program has moved into the second phase which is focused on applications development and testing. A June 2012 request for task proposals resulted in a range of innovative ways to prototype and demonstrate a FRATIS application under real-world conditions and with strong public-private partnerships and participation from planning associations, freight forwarder associations, private sector owner/operators, port and inland port associations, and local DOT and planning agencies. The FRATIS prototypes will build from a previous research effort – the Cross-Town Improvement Project (C-TIP) – which was a 2009–2010 prototype of a system and algorithm that sought to demonstrate the benefits of travel demand management, dynamic routing, and drayage optimization for the Kansas City inland port. The FRATIS prototypes are expected to address the gaps identified in C-TIP.

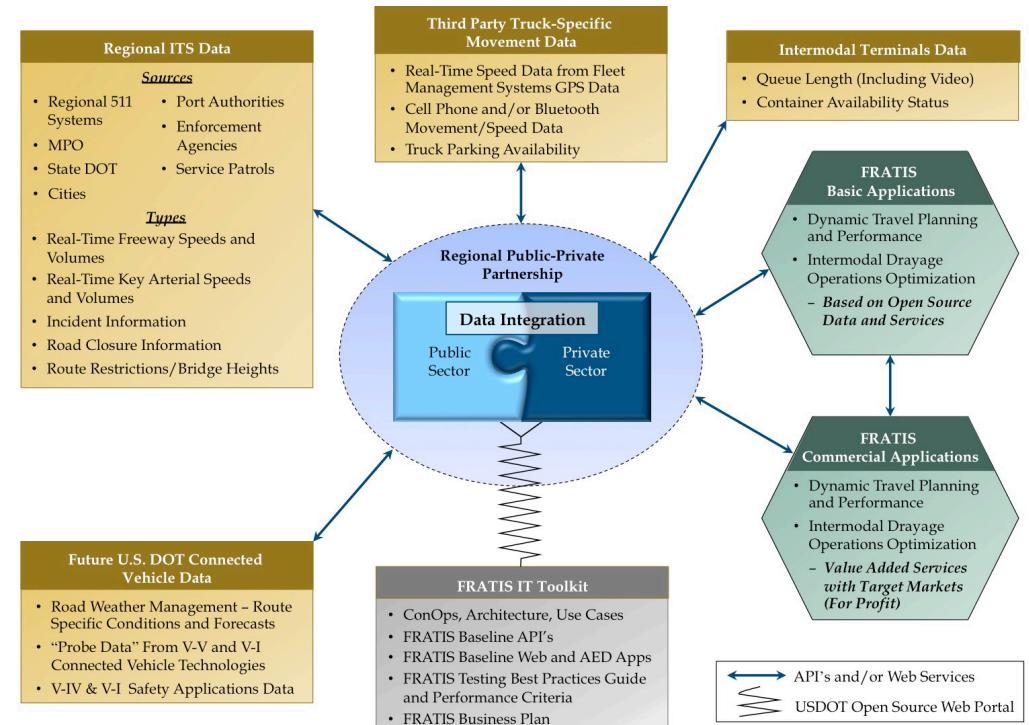


Figure 5. Proposed High-Level System Concept for FRATIS

The three sites chosen to demonstrate FRATIS will offer the following:

- ▶ The Los Angeles, California site will be developing the FRATIS applications to address the dynamic travel planning algorithm around the marine terminals and queues to move cargo out of the port more efficiently.
- ▶ The Dallas-Fort Worth, Texas site will be prototyping the FRATIS applications to incorporate the integrated corridor management capability along with size and weight permitting. This site is also testing the Connected Vehicle Basic Safety Message. It is additionally looking to optimize drayage opportunities in coordination with Burlington Northern Railroad and local truck drayage companies.
- ▶ The Miami, Florida site will be focused in a similar manner as the other sites, but will be adding an emergency response capability to FRATIS that would realign the purpose of freight transportation to bring in supplies during an emergency such as a hurricane.

All three areas will integrate existing data sets and identifying the new data sets that are needed to meet new performance metrics that FRATIS is expected to meet. These performance metrics include reductions in:

- ▶ The number of "bobtail" trips³³
- ▶ Terminal queue time
- ▶ Travel time
- ▶ Freight-involved incidents
- ▶ Fuel consumption
- ▶ Level of criteria pollutants and greenhouse gas equivalents

Phase 2 will begin with data collection to establish the existing baseline in each area. Software development will also proceed. Prototype demonstrations are expected to be launched in the summer of 2013 and run for approximately six months in order to collect evaluation data. Evaluation results are expected in 2014.

³³ A "bobtail" trip is a truck operating without a trailer. This is also referred to as operating the truck in a non-trucking capacity and is highly inefficient for the transportation system.

FRATIS

Research Accomplishments

- The foundational documents that describe FRATIS at a level appropriate for modeling and investment decisions will be made available in the summer of 2012. They include:
 - FRATIS ConOps
 - Assessment of Relevant Prior and Ongoing Research and Industry Practices
 - Test Readiness of FRATIS
 - FRATIS Functional (System) Requirements
- The DMA program has issued a request for task proposals for phase 2 research and has awarded three partnerships that bring a variety of sites and range of proposals for FRATIS application development under different real-world conditions.

Critical Research Insights

- An important Federal role that was recognized through C-TIP is the ability to facilitate entities coming together and to support development of a more powerful algorithm that forms the basis of the optimization program. Private entities cannot do this alone – it is truly the creation of a connected vehicle environment in which data is secure and trusted. Essentially, it is creating an “innovation ecosystem” that builds from each other’s inputs where each entity contributes information to make the results the most effective for everyone. The FRATIS drayage optimization application, in particular, can benefit from the emergence of open architecture devices and cloud computing to create an innovation ecosystem for freight carriers.
- With the results from C-TIP and other demonstrations, commercial entities have begun offering robust dynamic routing applications for freight. Device manufacturers have modified their products to open their architecture to better support emerging, dynamic applications that leverage virtual or cloud computing.

Next Steps

- ➔ Complete and release the foundational documents in the summer of 2012.
- ➔ Develop three prototypes of FRATIS under varying conditions and conduct small-scale demonstrations to evaluate the effectiveness.
- ➔ Develop a request for task proposal to perform an independent analysis of the impacts of the FRATIS prototypes and extrapolate the observations and findings into conclusions about the effectiveness and impact of FRATIS.



Truck Connected Vehicle. Image: US DOT

Integrated Dynamic Transit Operations ...

... are the next generation of applications that transform transit mobility, operations, and services through the availability of new data sources and communications.

Research Plan

Integrated transit operations will enable transit systems to provide better information to travelers and increase the quality of service. Improvements in the transit experience are expected to lead to increases in the use of public transit, allowing the FTA to meet goals for improving the environment and increasing mobility.

In selecting the IDTO applications, the US DOT sought opportunities to be transformative – these applications significantly alter existing transit services and result in substantial mobility improvements; are achievable in the near-term; and leverage the connected transportation environment data. While these applications exist at some level in today's world, the systems and communications upon which they rely can be fragmented, leading to insufficient protections, untimely information, and inconvenience for travelers. Further, some of the capabilities are operated by public sector agencies and some by private sector providers who may be unaffiliated and frequently employ different communications and technology systems. The IDTO applications look to resolve these gaps and evolve the current state to offer transformative impacts while minimizing risks.

The US DOT defines the IDTO bundle to include the following three applications:

- ▶ **T-CONNECT:** The goal of T-CONNECT is to improve rider satisfaction and reduce expected trip time for multimodal travelers by increasing the probability of automatic intermodal or intra-modal connections. T-CONNECT will protect transfers between both transit (e.g., bus, subway, and commuter rail) and non-transit (e.g., shared ride) modes, and will facilitate coordination between multiple agencies to accomplish the tasks. In certain situations, integration with other IDTO bundle applications (T-DISP and D-RIDE) may be required to coordinate connections between transit and non-transit modes.
- ▶ **T-DISP:** T-DISP seeks to expand transportation options by leveraging available services from multiple modes of transportation. Travelers would be able to request a trip via a handheld mobile device (or phone or personal computer) and have itineraries containing multiple transportation services (public transportation modes, private transportation services, shared-ride, walking and biking) sent to them via the same handheld device. T-DISP builds on existing technology systems such as computer-aided dispatch/automated vehicle location (CAD/AVL) systems and automated scheduling software. These systems will have to be expanded to incorporate business and organizational structures that aim to better coordinate transportation services in a region. A physical or virtual central system, such as a travel management coordination center (TMCC) would dynamically schedule and dispatch trips. T-DISP enhances communications with travelers and presents them with the broadest range of travel options when making a trip.
- ▶ **D-RIDE:** The Dynamic Ridesharing (D-RIDE) application is an approach to carpooling in which drivers and riders arrange trips within a relatively short time in advance of departure. Through the D-RIDE application, a person could arrange daily transportation to reach a variety of destinations, including those that are not serviced by transit. D-RIDE serves as a complement subsystem within the IDTO bundle by providing an alternative to transit when it is not a feasible mode of transport or unavailable within a certain geographic area. The D-RIDE system would usually be used on a one-time, trip-by-trip basis, and would provide drivers and riders with the flexibility of making real-time transportation decisions. The two main goals of the D-RIDE application are to increase the use of non-transit ride-sharing options including carpooling and vanpooling, and to improve the accuracy of vehicle capacity detection for occupancy enforcement and revenue collection on managed lanes. As a result of accomplishing these two goals, a myriad of other benefits could exist that benefit transit systems, including that D-RIDE could help reduce peak demand for public transit so the public transit system can be designed more affordably and can have greater customer satisfaction during spikes in ridership.

Figures 6 – 8 on the next page illustrate how the IDTO applications might work at a conceptual level.



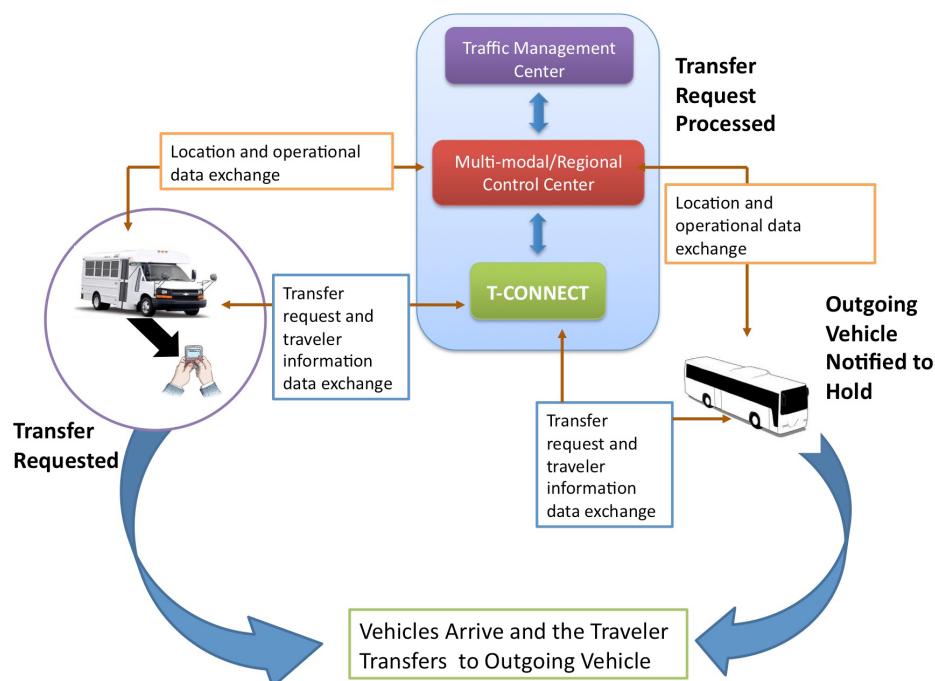


Figure 6. T-CONNECT Concept Overview

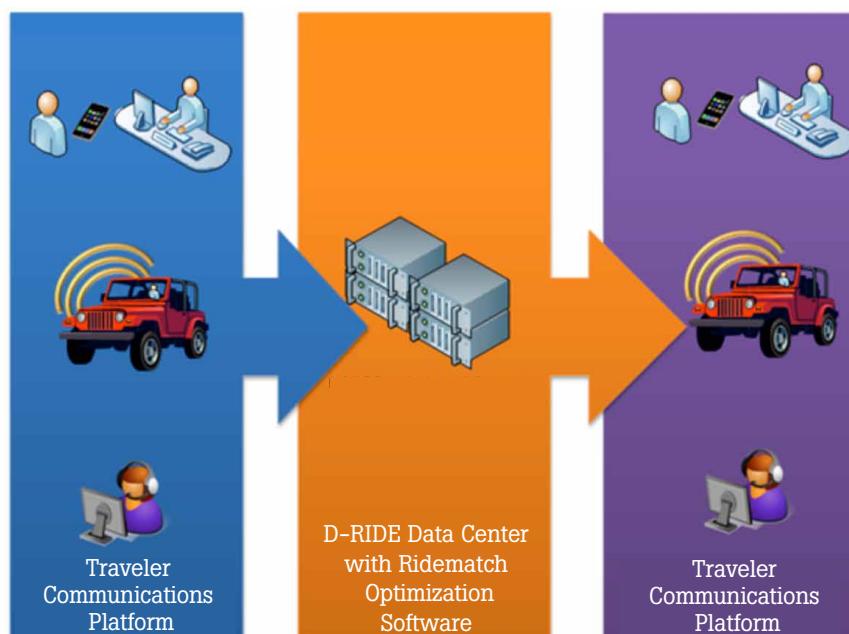


Figure 7. D-RIDE Communication Flow



Figure 8. T-DISP Concept Overview

Integrated Dynamic Transit Operations

Research Accomplishments

- The foundational documents that describe IDTO at a level appropriate for modeling and investment decisions will be made available in the summer of 2012. They include:
 - IDTO ConOps
 - Report on Assessment of Relevant Prior and Ongoing Research for the Concept Development and Needs Identification for Integrated Dynamic Transit Operations
 - Report on Functional and Performance Requirements, and High-Level Data and Communications Needs for Integrated Dynamic Transit Operations
- To develop the IDTO application concepts, public workshops were held in 2011 and early 2012 to establish goals and objectives for the IDTO applications, develop performance measures, and review the concepts.³⁴

Critical Research Insights

- Industry stakeholder input received during the webinars and meetings during 2011 and 2012 confirmed the significance of the three applications developed in the IDTO to enable transformative change in providing mobility. Other insights from the workshops included:
 - The importance of developing the program based upon diverse perspectives, which included public- and private-sector professionals, system developers, implementers, users and system managers, manufacturers, vendors, consultants, and researchers to allow for realistic definitions of performance measures since different elements in the industry have different definitions for the same term.
 - User needs were defined broadly and include travelers or riders using public and/or private transportation modes; drivers or passengers of private automobiles; software vendors; transit agencies and other transportation providers; and systems managers.
 - Participants expressed a strong interest in ensuring that each application that is developed is related to each other application in order to maximize the mode choice for travelers.
 - Conserving environment and energy use was determined to be a significant goal to maintain in developing the applications.

Next Steps

- ➔ Complete the IDTO functional and performance requirements and the Test Readiness Assessment summary by August 2012.
- ➔ Based on project results and outcomes (due December 2012), work with decision makers to determine whether the IDTO bundle will deliver enough benefits to support a Federal investment in its development.

³⁴ The agenda for the January 2012 workshop can be found at: http://www.its.dot.gov/meetings/idto_meeting.htm and the presentations can be found at: <http://www.its.dot.gov/meetings/pdf/StakeholdersWkspConOpsv2.pdf> and <http://www.its.dot.gov/meetings/pdf/IDTO%20Stakeholder%20Concept%20of%20Operations%20Workshop.pdf>.



Intelligent Network Flow Optimization ...

... is a collection of high-priority transformative applications that relate to improving roadway throughput and reducing crashes through the use of frequently collected and rapidly disseminated multisource data drawn from connected vehicles, travelers, and infrastructure.

Research Plan

Advancing applications for intelligent network flow optimization (INFLO) can offer important system-wide benefits to traffic flow and safety. The INFLO bundle consists of applications related to queue warning, speed harmonization, and cooperative, adaptive cruise control. Current practices for queue detection and warning and speed harmonization are fundamentally limited by their exclusive reliance upon infrastructure-based detection and alerting. This imposes a number of limitations on the system, impacting its ability to:



Image: US DOT

- ▶ Locate and distribute queue warnings sufficiently along a facility and ensure that generated warnings are received by drivers
- ▶ Obtain sufficient traffic and road weather data to be able to produce accurate warnings
- ▶ Operate for sufficient periods in the day to provide warnings whenever queues occur
- ▶ Target appropriate speed recommendations to specific portions of the facility and ensure that generated speed recommendations are received by drivers
- ▶ Obtain sufficient traffic and road weather data to be able to produce accurate speed recommendations
- ▶ Operate for sufficient periods in the day to provide speed guidance whenever the need may arise.

In addition, cooperative cruise control is reliant upon yet-to-be-deployed connected vehicle technologies.

A connected vehicle system is both vehicle- and infrastructure-based and has the potential to provide a broader and more dynamic set of data and data exchange that will support the INFLO applications in a manner that will addresses today's limitations.

The three applications that comprise INFLO include:

- ▶ **Queue Warning (Q-WARN):** The objective of Q-WARN is to provide a vehicle operator with sufficient warning of an impending queue backup in order to brake safely, change lanes, or modify the route such that secondary collisions can be minimized or even eliminated. It is distinct from collision warning, which pertains to events or conditions that require immediate or emergency actions. Queue warnings are provided in order to reduce the likelihood of the formation of such emergency events.

A queue backup can occur due to a number of conditions, including:

- Daily recurring congestion caused by bottlenecks
- Work zones, which typically cause bottlenecks
- Incidents, which, depending on traffic flow, lead to bottlenecks
- Weather conditions, including icing, low visibility, sun angles, and high wind
- Exit ramp spillovers onto freeways due to surface street traffic conditions

In all cases, queuing is a result of significant downstream speed reductions or stopped traffic and can occur with freeways, arterials, and rural roads. Queuing conditions present significant safety concerns; in particular, the increased potential for rear-end collisions. They also present disruptions to traffic

throughput by introducing shockwaves into the upstream traffic flow. A queue warning system will be successful at minimizing secondary collisions and the resulting traffic flow shockwaves by being able to: rapidly detect the location, duration, and length of a queue propagation; formulate an appropriate response plan for approaching vehicles; and disseminate such information to the approaching vehicles readily and in an actionable manner.

The INFLO Q-WARN application concept aims to minimize the occurrence and impact of traffic queues by utilizing connected vehicle technologies, including vehicle-to-infrastructure (V2I) and vehicle-to-vehicle (V2V) communications, to enable vehicles within the queue event to automatically broadcast their queued status information (e.g., rapid deceleration, disabled status, lane location) to nearby upstream vehicles and to infrastructure-based central entities (such as the TMC). The conceptual Q-WARN application performs two essential tasks: queue determination (detection and/or prediction) and queue information dissemination. In order to perform these tasks, Q-WARN solutions can be vehicle-based or infrastructure-based or utilize a combination of each.

It is important to note that the Q-WARN application concept is not intended to operate as a crash avoidance system (e.g., like the forward collision warning [FCW] safety application). In contrast to such systems, Q-WARN will engage well in advance of any potential crash situation, providing messages and information to the driver in order to minimize the likelihood of his needing to take crash avoidance or mitigation actions later. As such, Q-WARN-related driver communication will always give priority to crash avoidance/mitigation safety applications when such applications determine that a safety-related alert is necessary.

- ▶ **Dynamic Speed Harmonization (SPD-HARM):** The objective of SPD-HARM is to dynamically adjust and coordinate maximum appropriate vehicle speeds in response to downstream congestion, incidents, and weather or road conditions in order to maximize traffic throughput and reduce crashes. A dynamic SPD-HARM system will be successful at managing upstream traffic flow by being able to: reliably detect the location, type, and intensity of downstream congestion (or other relevant) conditions; formulate an appropriate response plan (i.e., vehicle speed and/or lane recommendations) for approaching vehicles; and disseminate such information to upstream vehicles readily and in a manner which achieves an effective rate of compliance. Improved safety results, in terms of reduced crash rates and less severe crashes, have shown to be the most significant and consistent achievements across deployments that exist today at some level. In addition, SPD-HARM techniques promote reduced vehicle speeds and speed variance, especially in unsafe driving conditions; support modest improvements in throughput; and have a moderately positive impact on travel time reliability. There are three key factors that contribute to the operation of an effective speed harmonization system. The first factor is the availability of information on the prevailing condition on the field. The second factor is the existence of a reliable strategy for the speed limit selection. The last factor is the flow of information from the field to decision making center and vice versa.

Research and experimental evidence has consistently demonstrated that by reducing speed variability among vehicles, especially in near-onset flow breakdown conditions, traffic throughput is improved, flow breakdown formation is delayed or even eliminated, and collisions and severity of collisions are reduced. The INFLO SPD-HARM application concept aims to realize these benefits by utilizing connected vehicle V2V and V2I communication to detect the precipitating roadway or congestion conditions that might necessitate speed harmonization, to generate the appropriate response plans and speed recommendation strategies for upstream traffic, and to broadcast such recommendations to the affected vehicles.

- ▶ **Cooperative Adaptive Cruise Control (CACC):** The objective of CACC is to dynamically and automatically coordinate cruise control speeds among platooning vehicles in order to significantly increase traffic throughput. By tightly coordinating in-platoon vehicle movements, headways among vehicles can be significantly reduced, resulting in a smoothing of traffic flow and an improvement in traffic flow stability. Additionally, by reducing drag, shorter headways can result in improved fuel economy providing the environmental benefits of lowered energy consumption and reduced greenhouse gas emissions.

The CACC operational concept represents an evolutionary advancement of conventional cruise control (CCC) systems and adaptive cruise control (ACC) systems by utilizing V2V and V2I communication to automatically synchronize the movements of many vehicles within a platoon. As with SPD-HARM and Q-WARN, CACC-related driver communication will always give priority to crash avoidance/mitigation safety applications when such applications determine that a safety-related alert is necessary.



Because the INFLO applications are so closely linked, the effectiveness of each can be improved by taking advantage of the benefits to traffic flow and safety that the others provide. In fact, research-to-date has shown that the most successful implementations have been those that combine multiple different freeway management control applications. For example, SPD-HARM benefits Q-WARN by slowing and managing upstream traffic, thus reducing the risk of secondary collisions. CACC benefits SPD-HARM by providing a mechanism for harmonizing traffic flow and reducing or mitigating acceleration variability. Q-WARN benefits CACC by providing the platoon sufficient notification of an impending queue to effectively manage a response. Figure 9 illustrates how all three applications used in conjunction can help minimize the impact of a freeway incident on traffic flow.

In addition to the benefits of deploying the three bundled INFLO mobility applications in concert, the applications would also benefit from integrating with other applications, including safety systems like electronic stability control (ESC) systems, night vision systems, curve speed warning systems, lane departure warning systems, alcohol monitoring systems, brake assist systems, steering assist systems, forward collision warning (FCW) systems, and pre-crash sensing systems. Coordination with ramp metering systems would also help provide the INFLO applications a better connection with the overall transportation network. Finally, integrating the INFLO applications with Advanced Traveler Information Systems (ATIS) would provide road users enhanced information about the state of the transportation system, pre-trip planning, route-making, and incident avoidance.

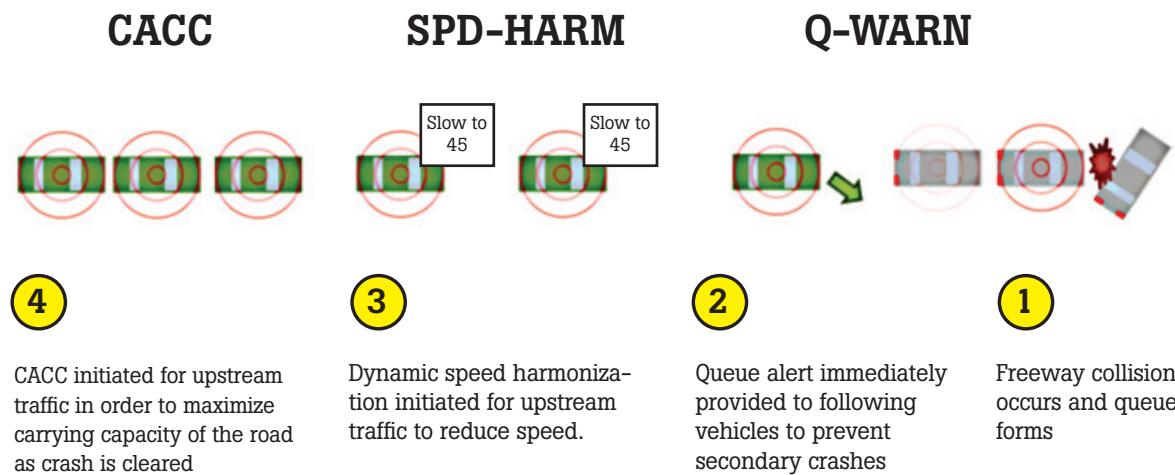


Figure 9. Combined Q-WARN/SPD-HARM/CACC Illustration

INFLO

Research Accomplishments

- The foundational documents that describe INFLO at a level appropriate for modeling and investment decisions will be made available in the summer of 2012. They include:
 - Concept Development and Needs Identification for Intelligent Network Flow Optimization (INFLO): Concept of Operations
 - Report on Assessment of Relevant Prior and Ongoing Research for the Concept Development and Needs Identification for Intelligent Network Flow Optimization
- To develop the INFLO operational concept, stakeholder workshops were held in February and April 2012.³⁵

Critical Research Insights

- Research and experimental evidence have consistently demonstrated that by reducing speed variability among vehicles, especially in near-onset flow breakdown conditions, traffic throughput is improved, flow breakdown formation is delayed or even eliminated, and collisions and severity of collisions are reduced.
- From an operational perspective, the introduction of any or all of the INFLO applications are likely to have the following major impacts:
 - Increased demands on data collection and storage capabilities – New data sources will be crucial to populating historical databases required for optimized speed selection and long-term planning. This data will be mostly vehicle-based rather than link-based.
 - Increased reliability of traffic control systems will be needed
 - Revised operational procedures and interfaces – In order to accommodate connected vehicle data sources and communications methodologies, operational procedures and interfaces will have to be revised. Updated training of system operators will also be required.
 - Increased focus on information security – Due to the reliance on private vehicle data and wireless communications, there will necessarily be an increased dedication of resources and technologies to ensure data and network security.
 - Compliance of speed, gap, and other INFLO-based targets and recommendations is critical to realizing the full benefit of the system. One approach to maximizing compliance is through automated enforcement, although this presents many challenges relating to data privacy concerns, data ownership, obtaining industry support, legal authority questions, and user acceptance.

Next Steps

➔ The following reports will be completed in the fall 2012:

- Report on Functional and Performance Requirements, and High-Level Data and Communications Needs for Intelligent Network Flow Optimization
- Report on Test-Readiness for Intelligent Network Flow Optimization

³⁵ Presentation slides can be found at: http://www.its.dot.gov/meetings/pdf/INFLO_StakeholderConOpsWorkshop.pdf.



Enabling Advanced Traveler Information Services (EnableATIS) ...

... represents a framework around a desired end state for a future traveler information network, with a focus on multimodal integration, facilitated sharing of data, end-to-end trip perspectives, use of analytics and logic to generate predictive information specific to users, and enhanced delivery mechanisms that reduce driver distraction. As the traveler information marketplace continues to evolve, EnableATIS seeks to facilitate, support, and enable those advancements and innovations to provide transformative traveler information.

Research Plan

EnableATIS is looking ahead to a future operational environment that will support and enable an advanced, transformational traveler information services framework. This future framework is envisioned to be enabled with a much more robust pool of real-time data through connected vehicles, public and private systems, and user-generated content. This Operational Concept does not define specific future applications, but rather seeks to formalize a framework whereby multiple activities are envisioned to interact to support a diverse traveler information environment. Two operational scenarios are possible – one is a laissez-faire approach to an incremental build out and enhancement of traveler information services over time and with limited influence on the market from US DOT; the second represents a desired end-state of a robust, multimodal, multisource traveler information environment that leverages new data sources and generates transformative uses of that information to benefit travelers as well as system operations and management by agencies.

EnableATIS has the potential to transform how traveler information is gathered and shared, how agencies are able to use information to better manage and balance the transportation networks, as well as transform how users obtain information about every detail of their trip. New forms of data will unlock the potential for a highly personalized, intuitive, and predictive suite of traveler information services well beyond what is experienced today.

Research for EnableATIS is identifying the gaps in the existing marketplace, and in coordination with other Dynamic Mobility Applications and Real-Time Data Capture and Management efforts, is providing strategic directions and investment decisions that will help shape the environment for unique public/private partnerships for the next generation of enabling traveler information services. To guide the ATIS community toward achieving the vision set forth for EnableATIS, the following goals have been established:

- ▶ **Goal #1:** EnableATIS will transform the user experience on the transportation network. Future traveler information systems will intuitively provide users with trip, location, and mode specific information to empower real-time decision making.
- ▶ **Goal #2:** As a result of EnableATIS, the transportation networks will experience measurable gains in performance, including mobility, safety, and efficiency.
- ▶ **Goal #3:** A more robust traveler information suite of capabilities will be enabled through a rich and multisource data environment that leverages public sector system and operations data, transportation network operations, and user data from privately operated systems.

EnableATIS

Research Accomplishments

- The foundational documents that describe EnableATIS at a level appropriate for modeling and investment decisions will be made available in the summer of 2012. They include:
 - *Vision and Operational Concept for Enabling Advanced Traveler Information Services: Market Readiness Assessment*
 - *Vision and Operational Concept for Enabling Advanced Traveler Information Services: Concept of Operations*
- An introductory stakeholder webinar was held in October 2011. A follow-on stakeholder workshop was also held in October 2011 to solicit feedback on the operational concept.³⁶

Critical Research Insights

- A more transformative environment for traveler information requires data providers, data collectors, and data disseminators to shift to potentially new and uncharted roles in the marketplace. There are a number of factors that may inhibit or promote the ability for partners to do so. Furthermore, there are market dynamics that are evolving rapidly, and adoption of new technologies by users will greatly shape the near-term technology focus of the private sector traveler information market.
- An overarching motivation for seeking out new and innovative ways to gather and disseminate traveler information is the growing need to address increasing congestion in many areas around the country. The emphasis on improved operations at a system-wide level as a means of maximizing available transportation system capacity necessitates new ways and approaches to delivering important alert information to travelers. Other factors include the increasing availability of data; advancements in consumer technology and social media; and increasing constraints and limitations on agency resources and business operations.
- Challenges and gaps include:
 - Data coverage and availability of data on all roads in both cities and rural areas remains a significant gap. In some areas, data is available but not typically shared.
 - How data is managed by an organization in terms of its availability, usability, integrity, and security is inconsistent across organizations, leading to hesitancy in making the data available because of concerns over quality.
 - The existing ATIS community needs a well-established group that can convene the disparate entities – agencies, technology developers, the automotive industry, equipment manufacturers, researchers, and others – to further the next-generation traveler information dialogue and advance critical goals collectively. This includes support for greater adoption of standard data formats and open data standards.

³⁶ Slides can be found at: <http://www.its.dot.gov/presentations/pdf/Enable%20ATIS%20Intro%20Webinar%20v2.pdf>.
Workshop slides can be found at: http://www.its.dot.gov/presentations/pdf/EnableATIS_DMA.pdf and
http://www.its.dot.gov/presentations/pdf/EnableATIS_Workshop_webcast.pdf.



Next Steps

- ➔ Explore ways to prepare and energize the application development community to embrace emerging forms of multimodal data for transformative traveler information services.
- ➔ Coordinate with Real-Time Data Capture and Management efforts to expand collection and processing of data derived from mobile sources into decision-level traveler information.
- ➔ Research potential methods for capturing traveler behavior based on the use and reaction to traveler information.

Response, Emergency Staging and Communications, Uniform Management, and Evacuation ...

... are the next generation of applications that transform the response, emergency staging and communications, uniform management, and evacuation (R.E.S.C.U.M.E.) process associated with incidents.

The vision for R.E.S.C.U.M.E. is to leverage wireless connectivity, center-to-center communications, and center-to-field communications to solve problems faced by emergency management agencies, emergency medical services (EMS), public agencies, and emergency care givers, as well as persons requiring assistance.

Research Plan

The R.E.S.C.U.M.E. bundle of applications seeks to leverage new information that helps to quickly detect and assess incidents and their effects on traffic flow, model the evacuation flow, push information to evacuees, and help responders identify the best available resources and ways to allocate them in the timeliest manner. Government officials who conduct evacuations will have a better common operational picture, enhanced by greater communication with vehicles and roadside equipment, public safety personnel in the field, and the public itself. Public safety personnel in the field who are increasingly using portable communications devices (such as tablets and smartphones to supplement radios, cell phones, and mobile data terminals) will be able to provide real-time information to operations centers and traffic management centers which will improve traffic and route guidance during incidents and evacuations.



Image: US DOT

Some of the key gaps that R.E.S.C.U.M.E. applications seek to address include:

- ▶ Lack of shared situational awareness among first responders and other managers
- ▶ Lack of interoperability among communications systems
- ▶ Need for more timely warnings and notifications to the general public
- ▶ Inadequate notification to incident scene work zone personnel and vehicles approaching the zones
- ▶ Insufficient information available on special needs populations to facilitate their evacuation and need for relocation

The US DOT defines the R.E.S.C.U.M.E. bundle to be the following five applications:

- ▶ **Incident Scene Pre-Arrival Staging Guidance for Emergency Responders (RESP-STG):** Provides situational awareness information to public safety responders while en route to an incident. This application can also help establish incident work zones that are safe for responders, travelers, and crash victims by providing input regarding routing, staging, and secondary dispatch decisions; staging plans; satellite imagery; GIS data; current weather data; and real-time modeling outputs. This new information is expected to provide more accurate and detailed information to support decisions and actions made by responders and dispatchers.
- ▶ **Incident Scene Work Zone Alerts for Drivers and Workers (INC-ZONE):** This application bundle has two components, one that warns drivers that are approaching temporary work zones at unsafe speeds, and or



trajectory; and another that warns public safety personnel and other officials working in the zone through an audible warning system.

► **Emergency Communications and Evacuation (EVAC):** This application bundle addresses the needs of two different evacuee groups:

- For those using their own transportation, EVAC provides dynamic route guidance information, current traffic and road conditions, location of available lodging , and location of fuel, food, water, cash machines, and other necessities.
- For those requiring assistance, EVAC provides information to identify and locate people who are more likely to require guidance and assistance, and information to identify existing service providers and other available resources.

► **Advanced Automated Crash Notification Relay (AACN – RELAY):** These applications are anticipated to help transmit a range of data to other vehicles and roadside hot spots that can help to enhance incident response. This information can then be forwarded to a public safety answering point. Some of the data elements that have been discussed are:

- Those generated through in-vehicle systems that can assist responders. Examples of this type of data include vehicle location, number of passengers, seat belt usage, airbag status, point of impact, risks inherent with the type of vehicle (alternate fuel), air-bag deployment, delta velocity of vehicle involved in crash, likelihood of injury, the vehicle's final resting position (e.g., overturned), exact vehicle location (immediately adjacent to waterway), and infrastructure damage (e.g., bridge support);
- Relevant medical information and patient history used to expedite lifesaving care; and
- Electronic manifest data collected from commercial vehicles that are involved in incidents to identify load contents and hazmat risks.

2012 SNAPSHOT OF PROGRESS

R.E.S.C.U.M.E

Research Accomplishments

- ☒ Project management and systems engineering plans have been developed to guide the scoping and development of the R.E.S.C.U.M.E. bundle of applications.
- ☒ Public safety stakeholders were engaged in the development and refinement of the concept of operations.

Critical Research Insights

- None to date.

Next Steps

- ➔ Finalize the ConOps in the summer of 2012
- ➔ Develop functional requirements and high-level data and communications needs report in the fall/winter of 2012
- ➔ Assess the readiness of the technologies and data associated with R.E.S.C.U.M.E. in the fall/winter of 2012

Multi-Modal Intelligent Traffic Signal System ...

... is the next generation of traffic signal systems that seeks to provide a comprehensive traffic information framework to service all modes of transportation, including general vehicles, transit, emergency vehicles, freight fleets, and pedestrians and bicyclists in a connected vehicle environment.

The vision for the Multi-Modal Intelligent Traffic Signal System (MMITSS) application is to provide overarching system optimization that accommodates transit and freight signal priority, preemption for emergency vehicles, and pedestrian movements while maximizing overall arterial network performance.

Research Plan

Traffic signal control has experienced very few fundamental improvements in the past 50 years. While tools and methods have been developed to enable traffic engineers' better use of traffic signal control, the fundamental logic and operations of the controller have not changed. Further, most systems today depend on loop detectors or video-based systems that are located at fixed locations in space to call and extend signal control phases. These detection systems provide basic information such as vehicle count, occupancy, and/or presence/passage information. This limits the use of advanced logic that can potentially be built into modern day traffic signal controllers.

Modern traffic control management systems provide the ability to monitor signal operations, change signal control plans by time of day or in a traffic responsive manner, and some provide adaptive signal timing where the signal timing parameters are adjusted based on traditional vehicle detector data. Traffic management systems provide a traffic engineer the ability to manipulate signals from a central traffic control center, but have limited strategic control capability and rely heavily on the innovation and skill of the traffic signal engineer user.

The advances in Connected Vehicle technologies provide the first real opportunity for transforming traffic signal control in terms of the traffic signal controller logic, operations, and performance. The advent of DSRC in vehicular communication provides a critical component that, when coupled with meaningful messages (SAE J2735), has the potential to provide detailed information required for intelligent traffic signal control. DSRC can be leveraged to provide real-time knowledge of vehicle class (passenger, transit, emergency, commercial), position, speed, and acceleration on each approach. The widespread availability of other wireless communications media, such as WiFi, 3G/4G, and Bluetooth enabled Smartphones, provide coverage for other users, including pedestrians and cyclists. The potential for safer and more efficient multimodal traffic signal operations is finally possible.³⁷

To realize these new opportunities, the MMITSS applications bundle has been conceived. It incorporates, at a minimum, the following arterial traffic signal applications:

- ▶ **Intelligent Traffic Signal System (ISIG):** Using high-fidelity data collected from vehicles through V2V and V2I wireless communications, this proposed application seeks to control signals and maximize flows in real time. The ISIG application also plays the role of an overarching system optimization application, accommodating transit or freight signal priority, preemption, and pedestrian movements to maximize overall network performance.
- ▶ **Transit Signal Priority (TSP):** This proposed application allows transit agencies to manage bus service by adding the capability to grant buses priority based on a number of factors. The proposed application provides the ability for transit vehicles to communicate passenger count data, service type, scheduled and actual arrival time, and heading information to roadside equipment via an on-board device.
- ▶ **Mobile Accessible Pedestrian Signal System (PED-SIG):** This application integrates information from roadside or intersection sensors and new forms of data from pedestrian-carried mobile devices. Such systems will be used to inform visually impaired pedestrians when to cross and how to remain aligned

³⁷ Multi-Modal Intelligent Traffic Signal System: Development of Concept of Operations, System Requirements, System -- Design and a Test Plan, Project Plan, located at: https://www.transportationresearch.gov/dotrc/cv/Lists/Researches/Attachments/12/PFS_MMITSS01_Summary.pdf.

with the crosswalk. This application may also support the accommodation of safe and efficient pedestrian movement of a more general nature.

- ▶ **Emergency Vehicle Preemption (PREEMPT):** This proposed application, while similar to existing technologies, will integrate with V2V and V2I communication systems. The application would account for non-linear effects of multiple emergency responses through the same traffic network.
- ▶ **Freight Signal Priority (FSP):** This application provides signal priority near freight facilities based on current and projected freight movements. The goal is to reduce delays and increase travel time reliability for freight traffic, while enhancing safety at key intersections.

The interaction of these applications, as part of the connected vehicle environment, provides a transformational opportunity to change the fundamentals of traffic signal control. The final goal is to field test or demonstrate MMITSS.

2012 SNAPSHOT OF PROGRESS

MMITSS

Research Accomplishments

- Foundational research has been launched and a roadmap for implementation of MMITSS will be made available in the fall of 2012. This research includes the following:
 - Assessment of Relevant Prior and Ongoing Research
 - Solicitation of Stakeholder Input on Transformative Goals, Performance Measures, and User Needs
 - ConOps

Critical Research Insights

- None to date.

Next Steps

- ➔ Complete and release the draft ConOps in the fall of 2012.
- ➔ Develop and release system requirements and design documents.
- ➔ Develop field test plan and deploy pilot systems in Maricopa County, AZ and El Camino Real, CA.

Environment



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

... is the "green" research component of the multimodal research initiative of the ITS JPO within RITA. The vision for AERIS research is to generate, capture, and analyze data to create actionable information that allows system users and operators to make "green" transportation choices. Through research, the AERIS program intends to assess how the suite of V2V and V2I connectivity and communications options and data may contribute to air quality improvements, and greenhouse gas reductions, and then evaluate and quantify the magnitude of these improvements.

Research Plan

The AERIS research program will be executed over the next 5 years. The first step has been to comprehensively review the state-of-the practice to:

- ▶ Determine the limits of current technology and available environmental data sets;
- ▶ Identify the limits and challenges of monitoring and analysis, including a review of existing models and algorithms;
- ▶ Examine and evaluate where ITS technologies and data can be more effective and contribute maximum value to addressing environmental impacts; and
- ▶ Review existing models of traveler behavior and existing traffic simulation models to determine how the effectiveness of improvement strategies can be gauged.

As the research baseline is developed and understood, the next step will be to identify candidate strategies and applications that appear to improve environmental decisions by both public agencies and travelers, and then profile, characterize and screen them by making an initial assessment of their effectiveness.

Based on initial results, a select group of applications that show the most promise will then undergo a more rigorous analysis. The ITS JPO team will begin a process of identifying, and modifying appropriate evaluation tools and building a robust evaluation and modeling process using program data sets. Further research may substantiate prototyping and testing applications using the test beds. Finally, the team will investigate how the data sets might help improve and validate environmental and other models (e.g., the Environmental Protection Agency's Motor Vehicle Emission Simulator "MOVES" model).

As this research is underway, there will be a parallel effort to conduct more policy-oriented research, designed to ensure that the technical research will provide results that can be deployed and provide value within the institutional and social environment. There will also be a concentrated, ongoing effort to engage and interact with stakeholders throughout the program's progress; the goal is to create champions for this research, both within the United States and internationally.

At the end of this research program, the ITS JPO expects to be able to recommend a number of applications for further research investment, testing, and deployment.

What is an AERIS Transformative Concept?

AERIS transformative concepts are intended to change the way that transportation systems operate. They are combinations of applications that provide environmental benefits to surface transportation networks in unique and different ways. The six transformative concepts defined to date include:

- ▶ Eco-Signal Operations
- ▶ Eco-Lanes
- ▶ Low-Emission Zones
- ▶ Support of Alternative Fuel Vehicle Operations
- ▶ Eco-Traveler Information
- ▶ Eco-Integrated Corridor Management (Eco-ICM)



The research will be comprised of five major tracks:

Track 1: Survey and build knowledge by comprehensively reviewing the state-of-the-practice to:

- ▶ Determine the limits of current technology and available data sets;
- ▶ Identify the limits and challenges of monitoring and analysis, including a review of existing models and algorithms;
- ▶ Examine and evaluate where ITS technologies and data can be more effective and contribute maximum value to addressing environmental impacts; and
- ▶ Use existing travel models to explore traveler behavior and use existing traffic simulation models to explore the effectiveness of improvement strategies.

Track 2: Identify candidate strategies and applications that appear to improve environmental decisions by public agencies and travelers (including an assessment of the technology and data needs and cost-benefit analysis).

Track 3: Analyze and evaluate candidate strategies and applications that make sense for further development and evaluation based on the expectations of their potential contributions.

Track 4: Demonstrate and test strategies and applications within a V2V and V2I technology test bed.

Track 5: Develop the facts and evidence needed to inform any future policy and regulatory decisions. This analysis will include an exploration of the relationships between traveler behavior and incentives; progress in private-sector application development, commercialization, and development of sustainable markets; the evolution of alternative energy vehicles and their role in mitigating environmental impact; and the ongoing analysis of carbon cap policies, trade policies, and worldwide environmental agreements.

The AERIS program will closely coordinate research with other ITS research programs such as the US DOT's Road-Weather Research program, the DMA research program, and the Real Time DCM research program.



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

Track 1: Survey and Build Knowledge

Research Accomplishments

As a relatively new research area, the AERIS program focused first on building a knowledge base for understanding how ITS might mitigate environmental impacts. It examined examples and best practices from around the world. The first set of research activities resulted in:

- Five state-of-the-practice reports that explored ITS technologies for the environment, evaluation techniques, activity-based modeling, environmental modeling, and data-acquisition techniques.
- Seven small-scale research projects that examined the ability of ITS applications to improve environmental performance and the ability to leverage the use and management of real-time data with environmental application and performance measurement. The reports have been completed³⁸ and include:
 - **ECO-ITS:** Recommends data-collection methods; environmental analysis methods; and integration of simulation and environmental modeling tools; and makes suggestions for environmental ITS applications and strategies.
 - **Developing Eco-Adaptive Signalized Intersection Algorithms:** Identifies an innovative application for eco-adaptive signal control, using traffic simulation tools.
 - **Engaging the International Community:** Identifies ways to collaborate with the international community through direct interactions and support to the US DOT.
 - **Research on ITS Applications to Improve Environmental Performance:** Examines extraction of environmentally relevant real-time data from vehicles and calculation of performance measures, based partly on previous research projects.
 - **Developing and Evaluating Intelligent Eco-Drive Applications:** Examines the network-wide impacts of Eco-Automated Cruise Control systems for different levels of market penetration and network configurations. Various simulation tests will be conducted to investigate how these systems will operate within a transportation network while interacting with other vehicles that are not equipped with such systems.
 - **An Evaluation of Likely Environmental Benefits of Lowest Fuel Consumption Route Guidance in the Buffalo-Niagara Metropolitan Area:** Models the likely environmental benefits of a new application for an environmentally optimized route guidance system for a medium-sized metropolitan area.
 - **Assessment, Fusion, and Modeling of Commercial Vehicle Engine Control Unit Data – Research on ITS Applications to Improve Environmental Performance:** Examines the use of real-time, on-vehicle data to calculate environmental performance measures, based partly on the team's Combined Network Equilibrium Model.

³⁸ Reports located at: <http://www.its.dot.gov/aeris/index.htm>.

Critical Research Insights

- ◊ By leveraging existing research, the AERIS program has quickly advanced its understanding about what critical research gaps remain, identified the most effective ways to collaborate with international partners, established a base of knowledge that is new and highly useful to the ITS and environmental community of practice, and revealed critical possible roadblocks to modeling efforts and missing data sources.

Next Steps

- ➔ Complete the remaining reports and use the initial research results to inform future analytical requirements.

Track 2: Identify Candidate Strategies and Applications

Research Accomplishments

- ☒ On the basis of the results of Track 1, the AERIS team has proposed six transformative concepts. During a public workshop in July, 2011, stakeholders helped to refine these concepts and confirmed that they saw them as viable scenarios for modeling the benefits and costs of connected vehicle technologies to support environmental goals.
- ☒ To introduce the concepts to a wider audience, the AERIS program held a webinar series in the fall of 2011³⁹ and participated in the Sustainability Village at the ITS World Congress in Orlando, Florida, in October 2011.⁴⁰

Critical Research Insights

- ◊ By bringing the stakeholder community together, the AERIS program has promoted the creative, expansive examination of ways in which the connected vehicle paradigm can transform the operation of our transportation system, advancing the effort to achieve the maximum environmental benefit while balancing the mobility and efficiency needs of the public and the system.

Next Steps

- ➔ Develop a detailed ConOps for each transformative concept, describing data and systems engineering requirements, communications strategies, and other technical and policy issues.

Track 3: Analyze and Evaluate Candidate Strategies and Applications

Research Accomplishments

- ☒ In conjunction with the developing the ConOps for each transformative concept, the AERIS program has initiated modeling that will support development of the ConOps and the systems requirements and that will form the baseline for future analysis and evaluation.

Critical Research Insights

- ◊ None to date.

39 Archived presentations at: <http://www.its.dot.gov/presentations.htm>.

40 Materials located at http://www.its.dot.gov/aeris/aeris_worldcongress.htm.



What Are AERIS Transformative Concepts?

The AERIS transformative concepts are integrated, operational concepts that use V2V and/or V2I data and communications in innovative ways to allow surface transportation networks to operate in ways that reduce environmental impacts resulting from transportation-related emissions and fuel consumption. They are intended to change the way transportation systems operate, facilitating greater emphasis on combining applications to provide significant environmental benefits to surface transportation networks. Transformative concepts also consider regulatory, policy, and educational tools.

The AERIS program has developed the following six transformative concepts:



Eco-Signal Operations

A foundational component of this concept is to dynamically leverage the wireless data communications among enabled vehicles and roadside infrastructure, including broadcasting signal phase and timing (SPaT) data and a vehicle's acceleration as it departs from a signalized intersection. Upon receiving this information, the applications are envisioned to perform calculations that provide speed advice to the driver of the vehicle, allowing the driver to adapt the vehicle's speed to pass the next signal on green or to decelerate to a stop in the most eco-friendly manner.

This Transformative Concept also considers Eco-Traffic Signal Timing applications. These applications are similar to current adaptive traffic signal systems; however the application's objective would be to optimize traffic signals for the environment using connected vehicle data. These applications collect data from vehicles, such as vehicle location, speed, GHG and other emissions data using connected vehicle technologies to determine the optimal operation of the traffic signal system based on the data.

Eco-Traffic Signal Priority applications are also included as part of this Transformative Concept. These applications allow either transit or freight vehicles approaching a signalized intersection to request signal priority. These applications consider the vehicle's location, speed, vehicle type (e.g., Alternative Fuel Vehicles) and associated GHG and other emissions to determine if priority should be granted. Other information, such as a transit vehicle's adherence to its schedule or number of passenger, may also be considered in granting priority.

Finally, Connected Eco-Driving Applications provide customized real-time driving advice to drivers so that they can adjust their driving behavior to save fuel and reduce emissions while driving on arterials. This advice includes recommended driving speeds, optimal acceleration, and optimal decelerations profiles based on prevailing traffic conditions and interactions with nearby vehicles. This application would also help optimize vehicle trajectories at non-signalized intersections such as stop signs and yield signs.

The Eco-Signal Operations include the following applications:

- ▶ **Eco-Approach and Departure at a Signalized Intersections:** The Eco-Approach and Departure at a Signalized Intersections application uses wireless data communications sent from roadside equipment (RSE) unit to connected vehicles to encourage "green" approaches to signalized intersections. This includes broadcasting signal phase and timing (SPaT) and Geographic Information Description (GID). Vehicle status messages, sent from nearby vehicles using vehicle-to-vehicle (V2V) communications, are also considered by the application. Upon receiving this information, on-board equipment (OBE) units perform calculations to provide speed advice to the driver of the vehicle allowing the driver to adapt the vehicle's speed to pass the next traffic signal on green or to decelerate to a stop in the most eco-friendly manner. This application also considers a vehicle's acceleration as it departs from a signalized intersection.
- ▶ **Eco-Traffic Signal Timing:** The Eco-Traffic Signal Timing application is similar to current adaptive traffic signal systems; however the application's objective is to optimize traffic signals for the environment. The application collects data from vehicles, such as vehicle location, speed, GHG and other emissions data using connected vehicle technologies. It then processes these data to develop operational strategies at signalized intersections focused on reducing fuel consumption and overall emissions at the intersection, along a

corridor, or for a region. The application evaluates traffic and environmental parameters at each intersection in real-time and adapts so the traffic network is optimized using available green time to serve the actual traffic demands while minimizing the environmental impact.

- ▶ **Eco-Transit Signal Priority:** The Eco-Transit Signal Priority application allows a transit vehicle approaching a signalized intersection to request signal priority. These applications consider the vehicle's location, speed, vehicle type (e.g., Alternative Fuel Vehicles) and associated GHG and other emissions to determine whether signal priority should be granted. Information collected from other vehicles approaching the intersection, a transit vehicle's adherence to its schedule, or the number of passengers on the transit vehicle may also be considered in granting priority. If priority is granted, the traffic signal would hold the green on the approach until the transit vehicle clears the intersection. This application does not consider signal preemption, which is reserved for emergency response vehicles.
- ▶ **Eco-Freight Signal Priority:** The Eco-Freight Signal Priority application allows freight vehicles approaching a signalized intersection to request signal priority in order to reduce emissions resulting from the vehicle stopping. The application considers the freight vehicle's location, speed, size, vehicle class (e.g., alternative fuel vehicles), load, schedule status, HAZMAT status, and associated GHGs and other emissions to determine if signal priority should be granted. If priority is granted, the traffic signal would hold the green on the approach until the freight vehicle clears the intersection. Granting of freight signal priority is based on multiple variables with the objective of producing the least amount of emissions at the signalized intersection, corridor, or network. This application does not consider signal preemption, which is reserved for emergency response vehicles.
- ▶ **Connected Eco-Driving:** The Connected Eco-Driving application provides customized real-time driving advice to drivers so that they can adjust their driving behavior to save fuel and reduce emissions. This advice includes recommended driving speeds, optimal acceleration, and optimal decelerations profiles based on prevailing traffic conditions and interactions with nearby vehicles. The application also provides feedback to drivers on their driving behavior to encourage drivers to drive in a more environmentally efficient manner. Finally, the application may also consider vehicle-assisted strategies where the vehicle automatically implements the eco-driving strategy (e.g., changes gears, switches power sources, or reduces its speed in an eco-friendly manner as the vehicle approaches a traffic signal).

Dynamic Eco-Lanes

At the heart of this Transformative Concept is an administrative application that supports the operation of Dynamic Eco-Lanes including establishing criteria for entering the lanes and defining or geo-fencing the Eco-Lanes boundaries. This allows the lanes to be dynamic. Eco-Lanes criteria may include the types of vehicles allowed in the Eco-Lanes, emissions criteria for entering the Eco-Lanes, number of lanes, and the start and end of the Eco-Lanes.

Dynamic Eco-Lanes are envisioned to leverage operational strategies implemented by the operating entity (e.g., Traffic Management Center) to reduce vehicle emissions in the lanes. This includes operational strategies such as eco-speed harmonization and eco-ramp metering. Once in the Eco-Lanes, drivers would be provided with speeds limits optimized for the environment. These eco-speed limits would be implemented to help to reduce unnecessary vehicle stops and starts by maintaining consistent speeds, thus reducing GHG and other emissions. Eco-Ramp Metering applications determine the most environmentally efficient operation of traffic signals at freeway on-ramps to manage the rate of vehicles entering the freeway.

Eco-Cooperative Adaptive Cruise Control is a concept that allows individual drivers to opt-into cruise control capabilities that are designed to minimize vehicle accelerations and decelerations for the benefit of reducing fuel consumption and vehicle emissions. These applications consider terrain, roadway geometry, and vehicle interactions to determine a driving speed for a given vehicle that uses the momentum of the vehicle, when suitable, to avoid unnecessary accelerations and reduce emissions. Connected Vehicle Platooning is also considered as part of this application.

Finally, Connected Eco-Driving Applications is envisioned to provide customized real-time driving advice to drivers so that they can adjust their driving behavior to save fuel and reduce emissions while driving on



freeway. This advice includes recommended driving speeds, optimal acceleration, and optimal decelerations profiles based on prevailing traffic conditions and interactions with nearby vehicles.

The Dynamic Eco-Lanes applications include:

- ▶ **Dynamic Eco-Lanes:** Dynamic Eco-Lanes are similar to current high-occupancy vehicle (HOV) lanes; however they would be optimized for the environment and encourage use by low emission, high occupancy, freight, transit, and alternative fuel or regular vehicles operating in eco-friendly ways (i.e., eco-speed limits, vehicle platooning). The Eco-Lanes application supports the operation of Dynamic Eco-Lanes including establishing Eco-Lanes criteria and defining or geo-fencing the Eco-Lanes boundaries. Eco-Lanes criteria may include the types of vehicles allowed in the Eco-Lanes, emissions criteria for entering the Eco-Lanes, number of lanes, and the start and end of the Eco-Lanes. The application also conveys pre-trip and en-route traveler information about Dynamic Eco-Lanes to travelers. This includes information about criteria for vehicles to enter the Eco-Lanes, current and predictive traffic conditions in the Eco-Lanes, and geographic boundaries of the Eco-Lanes.
- ▶ **Eco-Speed Harmonization:** The Eco-Speed Harmonization application determines eco-speed limits for a roadway based traffic conditions, weather information, and GHG and criteria pollutant information collected from roadside equipment and vehicles using connected vehicle technologies. The purpose of speed harmonization is to dynamically change speed limits approaching areas of traffic congestion, bottlenecks, incidents, special events, and other conditions that impact flow. Speed harmonization assists in maintaining flow, reducing unnecessary stops and starts and maintaining consistent speeds, thus reducing fuel consumption, GHGs, and other emissions on the roadway. Eco-speed limits may be broadcast and received by on-board equipment (OBE) units or displayed on variable speed limit (VSL) signs located along the roadway. This application is similar to current VSL applications; however the speed recommendations seek to minimize emissions and fuel consumption along the roadway.
- ▶ **Eco-Cooperative Adaptive Cruise Control:** The Eco-Cooperative Adaptive Cruise Control application automatically controls the speed of a vehicle leveraging connected vehicle technologies. The application uses vehicle-to-vehicle communications to transmit a vehicle's current speed and acceleration to a following vehicle. This allows the following vehicle to use adaptive cruise control (ACC) aimed at relieving a driver from manually adjusting their speed to maintain a constant speed and a safe distance from the lead vehicle. The Eco-Cooperative Cruise Control would also incorporate other information such as road grade, roadway geometry, and road weather information to determine the most environmentally efficient trajectory for the following vehicle. In the long term, the application may also consider vehicle platoons where two or more vehicles travel with small gaps, reducing aerodynamic drag. Platooning relies on V2V communication that allows vehicles to accelerate or brake with minimal lag to maintain the platoon with the lead vehicle. The reduction of drag results in reduced fuel consumption, greater fuel efficiency, and less pollution for vehicles. This application is applicable to all vehicle classes.
- ▶ **Eco-Ramp Metering:** The Eco-Ramp Metering application determines the most environmentally efficient operation of traffic signals at freeway on-ramps to manage the rate of automobiles entering the freeway. This application collects traffic and environmental data from vehicles and roadside equipment. This includes traffic and environmental conditions on the ramp, on the freeway upstream and downstream of the ramp. Using this information, the application determines a timing plan based for the ramp meter based on current and predictive traffic and environmental conditions. The objective for this application is to produce timing plans that reduce overall emissions. This includes reducing emissions from bottlenecks forming on the freeway as well as emissions from vehicles on the ramp.
- ▶ **Connected Eco-Driving:** The Connected Eco-Driving application provides customized real-time driving advice to drivers so that they can adjust their driving behavior to save fuel and reduce emissions. This advice includes recommended driving speeds, optimal acceleration, and optimal decelerations profiles based on prevailing traffic conditions and interactions with nearby vehicles. The application also provides feedback to drivers on their driving behavior to encourage drivers to drive in a more environmentally efficient manner. Finally, the application may also consider vehicle-assisted strategies where the vehicle automatically implements the eco-driving strategy (i.e., change gears, switch power sources, or reduce speed in an eco-friendly manner as the vehicle approaches a traffic signal).

- ▶ **Multi-Modal Traveler Information:** The Multi-Modal Traveler Information application provides pre-trip and en-route multi-modal traveler information to encourage environmentally friendly transportation choices. The application collects traffic and environmental data from connected vehicles and other sources and uses this data to determine real-time or predictive traffic conditions which are then provided to travelers. Traffic conditions include information about roadway speeds and travel times and predicted traffic conditions. This information may be used by travelers to adjust their departure time or to select an alternate route. Another key component of this application is providing travelers with transit options to encourage mode shift. This includes information about transit schedules and real-time transit vehicle arrival and departure times.



Figure 10. Eco-lane Concept Image: US DOT

Dynamic Low Emissions Zones

At the heart of this Transformative Concept is a Dynamic Emissions Pricing application. This application leverages connected vehicle technologies to dynamically determine fees for vehicles entering the Low Emissions Zone. These fees may be based on the vehicle's engine emissions standard or emissions data collected directly from the vehicle using vehicle-to-infrastructure (V2I) communications. To encourage travelers entering the zone to use public transportation, policy could be in place to waive fees for transit vehicles entering the Low Emissions Zone.

This Transformative Concept also provides the capability for the Low Emissions Zone to be dynamic or allowing the operating entity to change the location or time of the Low Emissions Zone. For example, this would allow the Dynamic Low Emissions Zone to pop-up based on various criteria including atmospheric conditions, weather conditions, or special events.

Pre-trip and en-route traveler information is also a critical component of this Transformative Concept. This includes information about criteria for vehicles to enter the Low Emissions Zone, expected fees and incentives for their trip, current and predictive traffic conditions, and the geographic boundaries of the Low Emissions Zone. Finally, Connected Eco-Driving applications are encouraged inside the Low Emissions Zone. Once inside the Low Emissions Zone, if real-time data from the vehicle shows that it is being driven in a manner that reduces emissions (i.e., practicing eco-driving tactics), the driver could be given an economic reward.

The Dynamic Low Emissions Zone applications include:

- ▶ **Dynamic Emissions Pricing:** The Dynamic Emissions Pricing application supports the operation of dynamic Low Emissions Zones based on traffic and environmental data collected from vehicles using connected vehicle technologies and roadside equipment. Low Emission Zones are similar to current cordon pricing strategies; however they would be scalable and moveable (e.g., pop-up for a day, removable,

flexible) and less dependent on conventional ITS infrastructure. Low emissions zone criteria may include the types of vehicles allowed in zone, exemptions for transit vehicles, emissions criteria for entering the Eco-Lanes, fees or incentives for vehicles based on emissions data collected from the vehicle, and geo-fenced boundaries for the Low Emissions Zone. Electronic toll collection functions that support payments of fees or tolls by electronically debiting the accounts of registered vehicle using connected vehicle technologies are also considered. Finally, this application also conveys pre-trip and en-route traveler information about the Low Emissions Zone to travelers. This includes information about criteria for vehicles to enter the Low Emissions Zone, expected fees and incentives for their trip, current and predictive traffic conditions, and geographic boundaries of the Low Emissions Zone.

- ▶ **Connected Eco-Driving:** The Connected Eco-Driving application provides customized real-time driving advice to drivers so that they can adjust their driving behavior to save fuel and reduce emissions. This advice includes recommended driving speeds, optimal acceleration and deceleration profiles based on prevailing traffic conditions and interactions with nearby vehicles. The application also provides feedback to drivers on their driving behavior to encourage drivers to drive in a more environmentally efficient manner. Finally, the application may also consider vehicle-assisted strategies where the vehicle automatically implements the eco-driving strategy (i.e., change gears, switch power sources, or reduce speed in an eco-friendly manner as the vehicle approaches a traffic signal).
- ▶ **Multi-Modal Traveler Information:** The Multi-Modal Traveler Information application provides pre-trip and en-route multi-modal traveler information to encourage environmentally friendly transportation choices. The application collects traffic and environmental data from connected vehicles and other sources and uses this data to determine real-time or predictive traffic conditions which are then provided to travelers. Traffic conditions include information about roadway speeds and travel times and the forecasting of traffic conditions. This information may be used by travelers to adjust their departure time or to select an alternate route. Another key component of this application is providing travelers with transit options to encourage mode shift. This includes information about transit schedules and real-time transit vehicle arrival and departure times.

Support Alternative Fuel Vehicle Operations

This Transformative Concept includes two applications: (1) Engine Performance Optimization and (2) AFV Charging / Fueling. Engine Performance Optimization applications seek to enhance the performance of a vehicle's engine in real-time based on connected vehicle data. The concept is to collect pertinent environmental data and adjust engine operations to optimize both fuel economy and emissions performance. Information about prevailing traffic conditions, weather conditions, or road grade may also be used as input for optimizing the engines performance. For example, engine adjustments would be made in real-time on the vehicle to reduce emissions during high ozone alert days or during extremely hot or cold temperatures.

AFV Charging/Fueling applications provide travelers with information about the locations of AFV charging/fueling stations including inductive charging infrastructure. Users are provided with information about the availability of charging infrastructure at the stations and are supported in making reservations at charging/fueling stations through electronic payment systems that are a part of the connected vehicle technologies. It is also envisioned that AFV-specific information is transmitted as part of MAYDAY messages when a vehicle is in an incident or requires emergency assistance.

Inductive charging for electric vehicles is also considered as part of this Transformative Concept. This includes roadside infrastructure deployed along the roadway that uses magnetic fields to wirelessly transmit large electric currents between metal coils placed several feet apart. This infrastructure enables inductive charging of electric vehicles including cars, trucks, and buses. Roadside charging infrastructure supports static charging capable of transferring electric power to a vehicle parked in a garage or on the street and vehicles stopped at a traffic light or a stop sign. It also supports charging vehicles moving at highway speeds.

The applications include:

- ▶ **Engine Performance Optimization:** The Engine Performance Optimization application resides on individual vehicles and adapts that vehicle's engine performance to minimize emissions in real-time based on information collected from the vehicle's diagnostic systems, from nearby vehicles using connected vehicle technologies, or from connected vehicle roadside information. The application collects pertinent

environmental data and adjusts engine operations to optimize both fuel economy and emissions performance. Information about prevailing traffic conditions, weather conditions, or road grade may also be used as input for optimizing the engines performance. For example, engine adjustments would be made in real-time on the vehicle to reduce emissions during high ozone alert days or during extremely hot or cold temperatures.

- ▶ **AFV Charging /Fueling:** The AFV Charging/Fueling Information application provides travelers with information about the locations of AFV charging/fueling stations and inductive charging infrastructure. The application also provides users with information about the availability of charging infrastructure at the stations and provides the ability to make reservations. In addition to providing travelers with information about charging stations, this application also supports connection to the Smart Grid to facilitate payment at charging stations. This application also includes connection to the Smart Grid to support vehicle interactions with roadside infrastructure that uses magnetic fields to wirelessly transmit large electric currents between metal coils placed several feet apart. This infrastructure enables inductive charging of electric vehicles including cars, trucks, and buses. Inductive charging Infrastructure supports static charging capable of transferring electric power to a vehicle parked in a garage or on the street and vehicles stopped at a traffic light. It also supports charging electric vehicles moving at highway speeds. Electronic payment for inductive charging is also included in this application.

Eco-Traveler Information

The vision for this Transformative Concept is the provision of integrated, multi-source, multi-modal data intended to engage researchers and the private sector to spur innovation and environmental applications. These applications may include:

- ▶ **Dynamic Eco-Routing:** The Dynamic Eco-Routing application is an eco-routing navigation system that determines the most eco-friendly route, in terms of minimum fuel consumption or emissions, between a trip origin and a destination for individual travelers. The application uses historical, real-time, and predictive traffic and environmental data collected from vehicles using connected vehicle technologies to determine the vehicle's optimal eco-route between its origin and destination. This application is similar to current navigation systems which determine the route based on shortest path; however this application recommends the route that produces the least amount of emissions or reduces fuel consumption.
- ▶ **Dynamic Eco-Transit Routing:** The Dynamic Eco-Transit Routing application is similar to the Dynamic Eco-Routing application, but is focused on providing guidance on the most eco-friendly route that minimizes fuel consumptions or emissions for transit vehicles along their routes. This application considers both fixed transit routes and paratransit. Because transit vehicles may need to adhere to fixed routes, they may not be as flexible in altering their routes as personal vehicles. The application uses historical, real-time, and predictive traffic and environmental data collected from vehicles using connected vehicle technologies to determine the vehicle's eco-route between its origin and destination.
- ▶ **Dynamic Eco-Freight Routing:** The Dynamic Eco-Freight Routing application is similar to the Dynamic Eco-Routing application, but is focused on providing guidance on the most eco-friendly route that minimizes fuel consumptions or emissions for freight vehicles. The application uses historical, real-time, and predictive traffic and environmental data collected from vehicles using connected vehicle technologies to determine the vehicle's eco-route between its origin and destination. Information about the freight vehicle's deliveries and schedule may also be included in determining the eco-route.
- ▶ **Eco-Smart Parking:** The Eco-Smart Parking application provides users with real-time parking information including information about the location, availability, type (e.g., AFV only, street parking, garage parking) and price of parking. The application reduces time required for drivers to search for a parking space thereby reducing emissions and also provides incentives to use AFVs. The application also supports dynamic pricing of parking based on emissions, vehicle type, and demand. Finally, this application allows travelers to reserve parking spaces.
- ▶ **Connected Eco-Driving:** The Connected Eco-Driving application provides customized real-time driving advice to drivers so that they can adjust their driving behavior to save fuel and reduce emissions. This advice includes recommended driving speeds, optimal acceleration, and optimal decelerations profiles based on prevailing traffic conditions and interactions with nearby vehicles. The application also provides



feedback to drivers on their driving behavior to encourage drivers to drive in a more environmentally efficient manner. Finally, the application may also consider vehicle-assisted strategies where the vehicle automatically implements the eco-driving strategy (i.e., change gears, switch power sources, or reduce speed in an eco-friendly manner as the vehicle approaches a traffic signal).

- ▶ **Multi-Modal Traveler Information:** The Multi-Modal Traveler Information application provides pre-trip and en-route multi-modal traveler information to encourage environmentally friendly transportation choices. The application collects traffic and environmental data from connected vehicles and other sources and uses this data to determine real-time or predicted traffic conditions which are then provided to travelers. Traffic conditions include information about roadway speeds and travel times and the forecasting of traffic conditions. This information may be used by travelers to adjust their departure time or to select an alternate route. Another key component of this application is providing travelers with transit options to encourage mode shift. This includes information about transit schedules and real-time transit vehicle arrival and departure times.

Eco-Integrated Corridor Management (Eco-ICM)

At the heart of this Transformative Concept is a real-time data fusion and decision support system using multi-source, real-time V2I data on arterials, freeways, and transit systems to determine which operational decisions have the greatest environmental benefit to the corridor. The vision is to combine multi-modal applications defined in the other Transformative Concepts that together provide an overall environmental benefit to the corridor. At this time, this Transformative Concept includes one application but will be further defined after analyses of the other Transformative Concepts are complete. The current application is:

- ▶ **Eco-Integrated Corridor Management Decision Support System:** The Eco-ICM Decision Support System application involves using multisource, real-time data on arterials, freeways, and transit systems to determine operational decisions that are environmentally beneficial to the corridor. The Eco-Integrated Corridor Management Decision Support System is a real-time data fusion system that collects information from various multi-modal systems. Data from these systems are then used to determine operational strategies for arterials, freeways, and transit that would minimize the environment impact of the corridor. For example, on a Code Red Air Quality Day the Eco-Integrated Corridor Management Decisions Support System may recommend eco-signal timing plans, eco-ramp metering strategies, criteria for Eco-Lanes including eco-speed limits, and recommendations for increased transit service.

Each TC is currently being profiled and modeled to make an initial assessment of its effectiveness. The assessment includes identifying, and modifying appropriate evaluation tools to use to conduct a robust evaluation and modeling process using program data sets. Further research may substantiate prototyping and testing applications using the test beds. Finally, the team will investigate how the data sets might help improve and validate environmental and other models (e.g., the Environmental Protection Agency's Motor Vehicle Emission Simulator "MOVES" model).

As this research is underway, there will be a parallel effort to conduct more policy-oriented research, designed to ensure that the technical research will provide results that can be deployed and provide value within the institutional and social environment. There will also be a concentrated, ongoing effort to engage and interact with stakeholders throughout the program's progress; the goal is to create champions for this research, both within the United States and internationally. At the end of this research program, the AERIS program expects to be able to recommend a number of applications for further research investment, testing, and deployment.

Road Weather



Road Weather Connected Vehicle Applications ...

... are the next generation of applications and services that assess, forecast, and address the impacts that weather has on roads, vehicles, and travelers. These applications and services are intended to capitalize on the previous Clarus Initiative research, which has delivered a network of road weather information by integrating existing data sources. Through additional research, technology development, and community outreach, Road Weather Connected Vehicle Applications research will develop greater specificity regarding the impact that weather has on roadways and will promote strategies and tools to mitigate those impacts.

In close coordination with and cutting across efforts of other connected vehicle research programs, the vision for the Road Weather Connected Vehicle Applications research is to broaden the foundation of road weather data to include mobile sources and to focus the analysis on improving the ability to detect and forecast road weather and pavement conditions by specific roadway links.

Research Plan

An important responsibility of traffic managers and maintenance personnel is to implement operational strategies that optimize system performance and mitigate the effects of weather on the roadways. Starting in 2003, the Clarus Initiative – a research effort to integrate transportation and weather data – created access to high-quality weather data for improved measuring and monitoring of road-weather conditions. Access to this data has allowed the US DOT's Road Weather Management (RWM) Program to pursue research on advanced technologies that deliver advisory, control, and treatment strategies in response to rain, snow, ice, fog, high winds, flooding, tornadoes, hurricanes, and avalanches. This research has resulted in important gains for the traffic management, road operations, and weather communities with the development of new technologies that use the combined road weather data. These technologies include:

- ▶ Management tools and decision support systems such as the Winter Maintenance Decision Support System (MDSS).
- ▶ Weather-responsive traffic management strategies for traveler information systems and traffic signal management.
- ▶ Traffic estimation and prediction systems that determine how pre-trip and en-route weather information affects travel demand.

Connected vehicle data offer the next opportunity to transform road weather management by dramatically expanding the amount and geographic scope of the data (due to mobile observations of moving vehicles) as well as the specificity of road-segment information. To date, most road-weather observations are still somewhat regional in nature. Connected Vehicle data provide the opportunity to pinpoint where and how weather is affecting the roadways, thus leading to greater understanding of the scope of road treatments and mitigation strategies during inclement weather, greater quality of the information provided to drivers and travelers, and greater details for producing more targeted traffic management strategies.

Six high-priority connected vehicle road weather applications, technologies, and systems have been identified for further research. They are:

Research Goals:

- ▶ Identify the range of sources for collecting robust data that will support road weather and pavement condition forecasting, specifically focusing on the incorporation of mobile data information and data from public sector mobile sources such as fleets.
- ▶ Develop algorithms and capabilities to translate mobile data into usable weather and road condition observations.
- ▶ Incorporate these observations into effective applications, management systems, and weather-responsive traffic management and advanced decision support tools.



Image: US DOT/PennDOT

- ▶ **Enhanced Maintenance Decision Support.** These systems will provide the existing federal prototype MDSS with expanded data acquisition from connected vehicles. Snow plows, other agency fleet vehicles, and other vehicles operated by the general public will provide road-weather connected vehicle data to the Enhanced-MDSS, which will use this data to generate improved plans and recommendations to maintenance personnel. In turn, enhanced treatment plans and recommendations will be provided back to the snow plow operators and drivers of agency maintenance vehicles.
- ▶ **Information for Maintenance and Fleet Management Systems.** In this concept, connected vehicle information is more concerned with non-road-weather data. The data collected may include powertrain diagnostic information from maintenance and specialty vehicles, the status of vehicle components, the current location of maintenance vehicles and other equipment, and the types and amounts of materials onboard maintenance vehicles, and will be used to automate the inputs to Maintenance and Fleet Management Systems on a year-round basis. In addition, desirable synergies can be achieved if selected data relating to winter maintenance activities, such as the location and status of snow plows or the location and availability of deicing chemicals, can be passed to an Enhanced-MDSS to refine the recommended winter weather response plans and treatment strategies.
- ▶ **Traffic Signal Control and Variable Speed Limits for Weather-Responsive Traffic Management.** Connected vehicle systems provide opportunities to enhance the operation of traffic control systems including VSL and dramatically improve traffic safety during severe weather events. Additional road weather information can be gathered from connected vehicles and used in algorithms to refine the signal settings or posted speed limits to reflect prevailing weather and road conditions.
- ▶ **Motorist Advisories and Warnings.** Information on segment-specific (e.g., one mile) weather and road conditions is not broadly available, even though operational tests and driver surveys demonstrate that this information is considered to be important to travelers. The ability to gather road-weather information from connected vehicles will dramatically change this situation via significant improvements in abilities to measure and predict weather and road conditions at high spatial resolution. Information on deteriorating road and weather conditions on specific roadway segments can be pushed to travelers through a variety of means as alerts and advisories within a few minutes. In combination with observations and forecasts from other sources and with additional processing, medium-term advisories of the next 2 –12 hours to long-term advisories for more than 12 hours into the future can also be provided to motorists.
- ▶ **Information for Freight Carriers.** The ability to gather road-weather information from connected vehicles will significantly improve the ability of freight shippers to plan and respond to the impacts of severe weather events and poor road conditions. Information on deteriorating road and weather conditions on specific roadway segments can be pushed to both truck drivers and their dispatchers. In combination with observations and forecasts from other sources and with additional processing, medium- to long-term advisories can also be provided to dispatchers to support routing and scheduling decisions. Since these decisions must consider a variety of other factors, such as highway and bridge restrictions, hours-of-service limitations, parking availability, delivery schedules, and, in some instances, the permits held by the vehicle, it is envisioned that the motor carrier firms or their commercial service providers will develop and operate the systems that use the road-weather information generated through this concept.
- ▶ **Information and Routing Support for Emergency Responders.** Emergency responders, including ambulance operators, paramedics, and fire and rescue companies, have a compelling need for short-, medium-, and long-time horizon road-weather alerts and warnings. This information can help drivers safely operate their vehicles during severe weather events and under deteriorating road conditions. Emergency responders also have a particular need for information that affects their dispatching and routing decisions. Information on weather-impacted travel routes, especially road or lane closures due to snow, flooding, and wind-blown debris, is particularly important. Low latency road-weather information from connected vehicles for specific roadway segments, together with information from other surface weather

Research Outcomes:

Reducing the adverse impacts that weather conditions have on the safety and operation of the Nation's roads is possible. The RWM program will do so by:

- ▶ Providing the technology platforms, information tools, and resources that can help surface transportation users and managers respond to weather events with effective strategies and programs.
- ▶ Serving as a catalyst for the development of new products and services.



observation systems, such as flooding and high winds, will be used to determine response routes, calculate response times, and influence decisions to hand-off an emergency call from one responder to another responder in a different location. This information will also provide situational awareness to better prepare for the conditions the drivers will endure (i.e., when alternate routing is not an option).

Road Weather Connected Vehicle Applications are uniquely cross-cutting as weather is a critical input to many of the safety and mobility applications and environmental transformative concepts; weather also has the ability to impact the outcome of these applications. Notably, road weather information is sourced from fixed sources (such as traditional ITS sensing stations, loop detectors, etc.) as well as mobile sources such as connected vehicles or fleets. Because of the reliance on mobile observations, the Road Weather research team is taking the lead on demonstrating how weather, road condition, and related vehicle data can be collected, transmitted, processed, and used for decision making through the Integrated Mobile Observations (IMO) project. In this project, the National Center for Atmospheric Research (NCAR) is partnering with the Minnesota and Nevada Departments of Transportation to obtain vehicle data from heavy vehicles, including snow plows, and light-duty vehicles as they carry on routine maintenance functions across their states. In addition, they are leading the research on a vehicle data translator (VDT) which is designed to process vehicle probe data and turn it into useable weather and road condition observations. Both of these research efforts are expected to produce new technologies that will be used with the mobility and environment applications.

The research plan for 2010-2014 has a two-fold focus:

- ▶ The program will continue to invest in high-impact applied research to expand the breadth and capabilities of road weather data sources, technologies, traffic management and decision support tools, and information.
- ▶ The program will coordinate research with the DCM, DMA, V2V and V2I Safety, and the AERIS programs to determine how existing road weather technologies can be optimized by incorporation into the resulting applications from these programs.

The program uses a multi-track approach to address the range of activities required for research:

Track 1: RWM and Connected Vehicle Technology Research

- ▶ Identify and integrate new and expanded road weather data sources (in particular, mobile sources and state and local DOT fleets) that enhance roadway safety, capacity, and efficiency while minimizing environmental impacts.
- ▶ Analyze the capability of existing vehicle sensors to collect road weather data.
- ▶ Research the characteristics and quality of the data that can be retrieved from vehicles.
- ▶ Integrate existing observational networks and data management systems with evolving connected vehicle road weather data capturing capabilities, to establish a road weather research data environment.
- ▶ Develop algorithms and capabilities to translate mobile data into useable weather and road condition observations.
- ▶ Assess whether existing standards for data collection need to be modified for collecting weather data.
- ▶ Refine weather forecasting and transportation models that take advantage of these rich new data sources.

Track 2: Road Weather Connected Vehicle Applications Development

- ▶ Develop next generation connected vehicle-enabled road weather management applications and services (the six application areas are described previously on pages 90 – 91).
- ▶ Investigate the use of existing and connected vehicle road weather technologies and information to enhance safety, mobility, and environmental applications.
- ▶ Incorporate recent advances in weather-responsive traffic management and decision support tools into operations.

- ▶ Refine weather forecasting and transportation models by taking advantage of the rich new data sources and next generation applications.

Track 3: Stakeholder Engagement

- ▶ Maintain and expand the unique partnership that has been developed among the public, private, and academic sectors; the transportation and weather communities; and operations, maintenance, and research personnel. This partnership allows the program to engage in a multidisciplinary approach to solving road weather related problems.
- ▶ Engage with the private sector to develop and promote new services leveraging the data platforms and applications that result from the road weather connected vehicle research.
- ▶ Continue to collaborate with the National Weather Service to maximize the benefits of road weather connected vehicle research, for operational use in the weather community.
- ▶ Enhance mechanisms for communicating road weather information to users, including transportation officials and the public.

Track 4: Cross-Cutting Activities

- ▶ Enable technology transfer of effective road weather scientific and technological advances into the commercial marketplace.
- ▶ Improve education and training of road weather information users, such as state and local transportation officials and private sector transportation contractors.
- ▶ Coordinate with transportation weather research programs in other modes, such as aviation.

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Track 1: RWM and Connected Vehicle Technology Research

Data Capture and Management

Research Accomplishments

- ☒ The RWM program is currently developing a VDT,⁴¹ which processes vehicle probe data and turns it into useable weather and road condition observations.
- ☒ Output data from the vehicles, whether directly or via VDT, is being incorporated into a variety of weather-related decision support tools and management systems.
- ☒ The RWM program is partnering with the DOTs of Minnesota and Nevada to incorporate data collected from their mobile fleets into the VDT and Clarus, and ultimately into one of these advanced decision support and/or management systems.

Critical Research Insights

- In Minnesota, approximately 180 state DOT snowplows are collecting information from onboard sensors and incorporating it into their management system. This information is used to generate an end-of-shift Report that summarizes such variables as the amount and type of materials dispensed by the snowplows as well as where and when the vehicles traveled.

⁴¹ Report is located at: http://ntl.bts.gov/lib/43000/43200/43279/FHWA-JPO-11-127_Final.pdf.



- In Nevada, the mobile data (engine fault codes) will eventually be integrated into the fleet maintenance management system to generate reports that flag potential problems with the vehicles while they are on the road and alert the appropriate personnel to take necessary measures. The intent is to prevent costly vehicle breakdowns.

Next Steps

- ➔ An enhanced version of the VDT (VDT 4.0) with improved algorithms will be completed in April 2014.
- ➔ The RWM program plans to expand its work on the VDT and weather-related applications, perhaps working with other states and datasets.

The Clarus Initiative

Research Accomplishments

- ☒ *Clarus* is an ITS research and development initiative, aimed at improving the accuracy and timeliness of road weather information made available to road users and operators, and at building the road weather observational database that supports the development of “anytime, anywhere road weather information.” Thirty-nine state DOTs, five local agencies, and four Canadian provinces have connected 2,437 environmental sensor stations (ESS) to *Clarus*, for a total of 54,251 individual sensors.

Critical Research Insights

- Findings confirmed the value of ESS observations in road weather forecast systems and the benefits of DSS that use these forecasts over standard atmospheric forecasts.
- Funding was also provided to eight additional projects that made use of the *Clarus* data in innovative ways. These projects have been completed and reports on outcomes are being compiled.

Road Weather Management Best Practices

Research Accomplishments

- ☒ The database is undergoing an update to reflect the latest advancements in RWM.
- ☒ The effort is documenting solutions deployed by state DOTs, capturing a range of advisory, control, and treatment actions, which will help to improve roadway operations under inclement weather conditions.

Critical Research Insights

- Approximately 30 states have been interviewed regarding their RWM best practices. New information has been appropriately documented.

Next Steps

- ➔ The remaining state DOTs will be invited to participate in the update.
- ➔ Once the update is complete, the older information will be archived or updated as applicable, and the new report will be published.

Weather and Traffic Analysis: Incorporating Weather Impacts in Traffic Estimation and Prediction Systems (TrEPS)

Research Accomplishments

- ☒ The RWM program has developed new models to determine how pre-trip and en-route weather information affects travel demands and traffic flows, and is incorporating this knowledge into dynamic traffic assignment and prediction models, such as the leading-edge DynaSMART and DynaMIT models.
- ☒ Research is completed to test and evaluate weather-responsive TrEPS in Salt Lake City, New York City, and Chicago.

- Transportation networks in Salt Lake City, New York City, and Chicago were calibrated for the TrEPS model. Site visits were made and the model was tested and evaluated for various weather-responsive traffic management strategies.

Critical Research Insights

- Existing TrEPS models (both offline and real-time) do not account for varying traffic conditions due to weather and cannot evaluate the effectiveness of traffic management strategies designed to alleviate weather impacts. Calibration of transportation networks for weather-sensitive dynamic traffic assignment, however, creates the ability for weather impacts to be incorporated in the DynaSMART traffic estimation and prediction system models.
- Implementation and evaluation of the TrEPS model demonstrated not only the ability to improve traffic estimation and prediction during weather events but also the applicability of these models in day-to-day traffic operations. An important conclusion is that the availability of real-time weather and traffic data is widely needed to make this happen.

Next Steps

- ➔ Deploy the weather-sensitive TrEPS models in those areas that would benefit from it.

Developments in Weather-Responsive Traffic Management Strategies

Research Accomplishments

- The RWM program has documented the state-of-the-practice in weather-responsive traffic management (WRTM) and identified improvements to WRTM strategies. These operational improvements include such traffic management staples as active traffic and demand management, traffic signal management, and traveler information.
- A contract is initiated to design, develop, implement, and evaluate advanced WRTM strategies. The potential sites are currently being evaluated.
- Completed three webinars on advanced WRTM strategies as follows:⁴²
 - Active Traffic Management (ATM) for Weather Responsive Traffic Management
 - Using Social Media Effectively During Weather Events
 - Weather-Responsive Traffic Signal Management

Critical Research Insights

- Research has revealed the best ways to execute WRTM strategies under adverse weather conditions.

Next Steps

- ➔ Select sites for advanced WRTM implementation, refine concepts of operations, develop requirements, and design the systems.

Weather and Traffic Analysis: Human Factors

Research Accomplishments

- The RWM program has conducted research to examine the human factors involved in road weather advisory and control information. Given the amount of available weather information and the methods of dissemination, the study looked at the content and methods for presenting the information to travelers in a way that is useful to them.

42 The webinar archives can be found in http://www.ntctalks.com/web_casts_archive.php.



- Preliminary Guidelines for Disseminating Road Weather Advisory and Control Information were developed, tested, and evaluated in various locations throughout the country. The revised messaging guidelines are completed and will be published shortly.

Critical Research Insights

- Guidelines were developed for length of messages, message structure, and message wording, resulting in safer strategies for providing weather information to travelers.

Next Steps

- ➔ Promote and deploy the revised Road Weather Messaging Guidelines.

Road Weather Technology Deployment Data Mining and Analysis

Research Accomplishments

- The 2010 ITS Deployment Survey gathered information about the extent of ITS technology deployment for RWM across different transportation agencies.
- The survey was divided into seven agency types, two of which were selected for analysis: the Arterial Management Survey and the Freeway Management Survey.

Critical Research Insights

- The analysis revealed that RWM strategies vary on the basis of the functions of the transportation agency; this will help to identify ways to frame future programs that promote the use of ITS technology for RWM as well as areas for additional data collection.

Next Steps

- ➔ No further steps are planned.

Track 2: Road Weather Connected Vehicle Applications

Research Accomplishments

- A ConOps has been completed and is under review. The ConOps describes the six priority applications. The ConOps contains a number of scenarios that are based on stakeholder input. These scenarios assist with the identification of technical and institutional constraints as well as potential operational impacts. With these descriptions, a set of functional and data requirements will be developed. The ConOps is expected to be available in late summer of 2012, after it is presented at the Road Weather Management stakeholder meeting.

Critical Research Insights

- The ConOps has identified six critical weather-related applications and clearly states the benefits and risks for transportation agencies to implement any one (or more) of those applications.

Next Steps

- ➔ Development of functional and data requirements, due in the fall of 2012.
- ➔ Outreach to vehicle and device manufacturers to analyze whether the data sets can be made available.
- ➔ Outreach to implementing stakeholders to confirm and vet the scenarios.

Track 3: Stakeholder Engagement

Aurora and Clear Roads Pooled-Fund Studies

Research Accomplishments

- The Aurora and Clear Roads pooled-fund studies, led by several cutting-edge state DOTs, continue to do excellent work in the areas of road weather and winter maintenance, respectively. Please visit their websites to get the latest information.
- A Knowledge-Based Tool (Wiki) has been developed by the consortium members and is being populated. The tool focuses on maintenance management best practices.

Critical Research Insights

- Numerous studies have been completed, and many recommendations have been implemented as a result.
- State and local agencies continue to need research support in resolving critical road-weather transportation problems. Many states are willing to partner with the Federal government in conducting the research and are willing to be lead-adopters of new technologies.

Next Steps

- ➔ Continue to prioritize research needs statements for funding as well as to conduct technology-transfer efforts within the stakeholder community.
- ➔ Continue to populate the Wiki webpage.
- ➔ Continue to pursue interchangeability and interoperability of winter maintenance sensors and ancillary equipment ("plug and play").

Stakeholder Outreach

Research Accomplishments

- To publicize the research results and engage stakeholders, the RWM program held the first national workshop and stakeholder meeting on WRTM on October 6 and 7, 2011, in Portland, Oregon. Participants included representatives from FHWA, 26 state DOTs, 2 city agencies, and 1 turnpike authority, along with several private contractors and researchers.⁴³

Critical Research Insights

- The stakeholder meeting identified several action items pertaining to WRTM that the RWM program needs to focus on in the near and long term. These include best practices information, performance evaluation, peer exchange, and guidance materials.

Next Steps

- ➔ Implement the action items and plan for the next stakeholder meeting in 2013.

⁴³ To review the workshop presentations and the summary report, go to: <http://tti.tamu.edu/group/sysreliability/wrtm>.



Track 4: Cross-Cutting Activities

Web-Based Training Course on Weather-Responsive Traffic Management

Research Accomplishments

- A blended web-based course on WRTM is being developed through the University of Maryland CITE (Consortium for ITS Training and Education) program. The course materials were developed and conversion to web-based modules is underway.

Critical Research Insights

- The course will help traffic managers and practitioners to identify and implement proactive WRTM strategies and evaluate their effectiveness.

Next Steps

- ➔ Complete the web-based course and conduct the pilot.

Policy



Connected Vehicle Policy and Institutional Issues ...

... is research and analysis into critical policy and institutional issues that may limit or challenge successful deployment of connected vehicle technologies. The research supports the development and comparison of effective policy options; the analysis results in structured recommendations for policy and decision makers.

The vision for the Connected Vehicle Policy research is one of a collaborative effort among the Department, key industry stakeholders, vehicle manufacturers, state and local governments, representative associations, citizens, and others. After consultation with and with input from all stakeholders, the Department will structure and conduct a research agenda that weighs the benefits and risks and results in strong policy foundation for the successful deployment of connected vehicle technologies and applications.

Research Plan

The objective of the Connected Vehicle Policy and Institutional Issues research program is to identify critical issues that may hinder or present challenges to successful deployment of V2V and V2I technologies, applications, and systems. An overarching focus of the program's efforts is the creation of policy and institutional models associated with successful technology transfer, adoption, implementation, and use.

In collaboration with stakeholders, the policy team has identified the priority challenges that impact public acceptance and adoption:

- ▶ **A financially sustainable strategy** for implementation, operations, and maintenance;
- ▶ **A robust security system** that preserves privacy at the highest levels (inherent in this issue are the costs of the security network – the hardware, software, and facilities that support the high volume of certificate issuance which renders this security system unique); and
- ▶ **A governance model that gives a voice to all stakeholders.** In addition, there are a broad range of policy implications to the technical choices that are made; legal issues that require analysis; and development of strategies to guide implementation.

Policy research and analysis is divided into four tracks:

Track 1: Implementation Policy: Research and analysis efforts include: analysis and development of a range of viable options for financial and investment strategies; development of a security policy and the modeling of certificate management entity (CME) operational and operational models as a basis for how security will be institutionally delivered; identification of potential governance and oversight models; and analysis in support of the Department's 2013 decision which includes cost-benefit, value propositions, and market penetration analyses.

Track 2: Technical Policy: Research and analysis efforts include: comparison of a range of communications media to understand which ones most effectively support the technical and policy requirements of the Connected Vehicle Environment, including security but also extensible to other types of data delivery, and development of financially sustainable models; analysis of communications needs to support applications and

Research Goals:

The research is focused in part on the following policy questions:

- ▶ What options are available to successfully launch and sustain connected vehicle technologies?
- ▶ Are the options publicly acceptable?
- ▶ What entities will potentially fund, own, and govern connected vehicle systems, components, and data?

Research Outcomes:

Enable successful and sustainable ITS V2V/V2I implementation by identifying and analyzing policy and institutional issues and developing options for a solid ITS policy and institutional foundation.

development of supporting institutional options; analysis of the policy implications of the Core System and risks associated with access and control of the interfaces; development of policies on the use of certification and standards; and analysis of spectrum management needs as it moves from research to commercial operations.

Track 3: Legal Policy: Research and analysis efforts include: development of policies and practices to appropriately protect privacy and comply with applicable privacy laws; research and analysis of the Department's authority as it relates to the Connected Vehicle Environment; analysis of stakeholders' potential legal risks and liability for purposes of providing recommendations about whether the Federal government should consider a risk-sharing regime; assessment of intellectual property/data ownership issues that might hinder adoption of connected vehicle technologies; and, identification of legal parameters and considerations relative to governance, funding and other aspects of implementation.

The research and analysis from these first three tracks results in a final track:

Track 4: Implementation Strategies: With the final set of decisions within each area, the most viable options will be combined into implementation scenarios and a further comparative analysis will be conducted. Stakeholder will have the opportunity to collaborate. The analysis will result in guidance for implementing entities that will need to understand the resources needed for implementation, operations, and maintenance including the knowledge, skills, and ability of personnel.

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Track 1: Implementation Policy Analysis

Development of Financial/Business Model Options

Research Accomplishments

- Established a set of "System Principles"⁴⁴ for the Connected Vehicle Environment that identify the US DOT priorities for implementation with an emphasis on safety, national coverage, high levels of security, and appropriate privacy controls.
- Identified a need for innovative financing and partnership models to provide funds for capital investment and/or leveraging of existing systems as well as sustainable operations and maintenance.
- Developed a range of potential scenarios that describe how partners, agreements, and incentives might come together to finance the network. These scenarios will be refined using inputs from other research efforts (such as the costs associated with the security models, the costs and benefits associated with the core system, or the costs associated with implementation, among other inputs).

Critical Research Insights

- Research into innovative financing and partnership models is analyzing innovative financing options, including public-private hybrids and wholly private options.

Next Steps

- ➔ Market assessment of the potential value that would attract investors and partners.
- ➔ Vetting of research results with stakeholders.

⁴⁴ Available at: http://www.its.dot.gov/connected_vehicle/pdf/ConnectedVehiclePrinciples_final4-18-2012.pdf.



Development of Certificate Management Entity (CME) Organizational/Operational Models

Research Accomplishments

- Identified the elements that comprise a CME and have also identified a set of options that differ in their structure and operational processes for providing security and certificate management.
- Developed approaches for credentialing users of the network which impact how personal information will be collected and used. Current options range from no personal information collected to the formation of a new collection system (all of which present varying implications for security).
- Working with security experts to define a "baseline" of security needs. This identifies acceptable levels of risk and vulnerability to the network and its users.
- Held a stakeholder workshop in April 2012 to review preliminary models and receive input.

Critical Research Insights

- Research to date has revealed that security system requirements for a Connected Vehicle Environment are unique and complex. Existing security systems tend not to be based on such rigorous requirements for safety or privacy protection, nor do they address such a large set of users on a national scale. While the program has been able to draw lessons from existing industry examples, the connected vehicle security models will need to incorporate new and innovative processes.
- Research has also resulted in an understanding that CME organizational and operational options vary by levels of complexity, cost, and other technical considerations, but not necessarily effectiveness (all provide a similar level of security/privacy).
- Initial cost model research has exposed the trade-off between the very high volume of digital certificates and costs – the greater number of certificates, the higher the level of requirements for hardware, software, and computing power needed to sustain the security system, but the greater the level of privacy protection.

Next Steps

- ➔ Completion of the model options and analysis of whether existing entities can be leveraged for providing institutional operations and administration.

Governance/ External System Oversight Models

Research Accomplishments

- Conducted a governance roundtable, where experts from academia and industry congregated to discuss key governance issues facing Connected Vehicle implementation.
- Experts discussed 'lessons learned' from relevant examples in other industries that provide a model for oversight and governance (e.g., health information management, internet, Smart Grid).⁴⁵

Critical Research Insights

- The program has also learned that decisions regarding "who will finance" and "who will own and operate" are critical to developing viable governance models.
- Research results reveal that the Connected Vehicle Environment will likely require multiple governance structures – there will be a need for internal governance structures for each of the systems; and external, oversight governance structures to support conflict resolution and decision making at the level of the Connected Vehicle Environment. Further research is needed to understand the appropriate role of the Federal government.

Next Steps

- ➔ Pursue the completion of research on financing, ownership, and operations as an input to governance.
- ➔ Identify appropriate Federal roles.
- ➔ Develop a set of governance model options for stakeholder analysis.

⁴⁵ Workshop proceedings can be found at: http://ntl.bts.gov/lib/43100/43129/GovRoundTableProceedingsFINAL_9_22_11_v4.pdf.

Benefit-Cost Analysis

Research Accomplishments

- Developed vehicle fleet model analyzing technology deployment and adoption rates.
- Developed initial cost estimates for major organizational components of the security network, for example—hardware, software, and facilities for certificate management.
- Developed stakeholder analysis evaluating the financial impacts of adopting Connected Vehicle technologies for the trucking industry.
- Evaluated direct financial impacts of adopting Connected Vehicle technologies for the trucking industry.
Updated fleet models; examined retrofit scenarios.

Critical Research Insights

- The research identified that financial savings in crash costs from using V2V collision avoidance technologies is significant and beneficially impacts a firm's bottom line.

Next Steps

- ➔ Continue development of cost models that will support cost-benefit analysis.

Track 2: Technical Policy Analysis

Communications Data Delivery System Analysis (Communications Network Analysis)

Research Accomplishments

- Evaluated various wireless communications platforms for their functionality in supporting Connected Vehicle communications.

Critical Research Insights

- Research examined the potential of various communication types, including DSRC, cellular, WiFi, satellite, WiMax, and high definition radio, to support the needs for data delivery within a V2V and V2I network. DSRC, cellular, and WiFi were deemed as the most appropriate for supporting the needs, with each media having strengths and weaknesses; there is not one perfect solution.
- The next phase of research will look at combinations of these technologies through hybrid approaches to meet the needs. It will also look at availability of sustainable funding and/or leveraging of existing facilities to support operations of the communications network.
- Research is also emphasizing the need for DSRC communications for safety applications due to its low latency.

Next Steps

- ➔ Communications network analysis will be completed in late summer 2012.

Infrastructure Needs Analysis

Research Accomplishments

- In coordination with AASHTO, surveyed multiple state and local agencies in order to prioritize applications for this stakeholder community.



Critical Research Insights

- Research determined that safety applications such as those that reduce collisions at intersections and reduce lane-change crashes were important to agencies. Other types of applications that enhance mobility, facilitate electronic payment, and improve agency operational performance were also significant.
- Identified potential deployment scenarios and strategies for state and local agencies. Research emphasized strategies that can help agencies meet operational objectives by using agency vehicles, such as maintenance vehicles, transit vehicles, emergency vehicles, and public safety vehicles.

Next Steps

- ➔ Work with State and local agencies to build on this preliminary analysis to identify implementation needs.
- ➔ Work with transit and trucking agencies to identify their priorities and needs.

Core System Architecture and Interface Analysis in Support of Developing Policies for the Core System, Certification, and Standards

Research Accomplishments

- In process of defining policy implications of the connected vehicle core system concept.

Critical Research Insights

- Analyzing the core system architecture and developing user-based scenarios will uncover the policy and institutional issues associated with the need for an underlying core system for the Connected Vehicle Environment.
- Analysis of core system concept will lead to an understanding of how and where standards and certification are most effectively employed as part of system access and control policies.

Next Steps

- ➔ Develop a set of user-oriented case studies that guide implementers in using the Core System Architecture documents to implement a Core System or access services of a Core System. Case studies will include an analysis of impacts to institutions and organizations.
- ➔ Work with ITS Standards team to inventory interfaces as a basis for identifying the role for standards, certification, and other policies.

Standards and Certification Policies

Research Accomplishments

- Coordinated with the ITS Standards team to develop a plan for research and analysis of interfaces.

Critical Research Insights

- Preliminary insights provide an understanding of how requirements for standards and certification play a dual role — they facilitate interoperability and thus create an equitable set of opportunities for all interested parties to participate in the Connected Vehicle Environment; and they help control and mitigate some of the significant risks to the system by ensuring that inappropriate devices, equipment, and message formats cannot gain access to the system.

Next Steps

- ➔ Work with the ITS Standards team to implement analysis. Results expected in spring of 2013.
- ➔ Develop draft standards and certification policies in collaboration with stakeholders.
- ➔ Determine the extent to which certification standards or policies will be pre-empted by a potential NHTSA connected vehicle rulemaking.

Spectrum Management Policies

Research Accomplishments

- Identified the research that is needed in support of developing a spectrum management policy in support of commercial operations of the spectrum.

Critical Research Insights

- ⌚ Initial research highlights the difference in managing the spectrum in a research mode versus managing the spectrum in an operational mode. New research is describing the processes and describing the new roles and responsibilities that will be necessary after the transition.
- ⌚ With the planned transition to operational mode, research is needed to ensure non-interference with users at each end of the bandwidth.

Next Steps

- ➔ Perform research on non-interference.

Track 3: Legal Policy Analysis

Legal Analysis

Research Accomplishments

- Established a legal framework for conducting research across the modes on privacy, authority, intellectual property/data ownership, liability and shared-risk policies, and other legal policy issues relevant to the Connected Vehicle Environment.
- Performed a comprehensive analysis of the legal authority of the Department and each modal administration as it relates to the Connected Vehicle Environment, which will be synthesized into an overarching policy foundation for the program.

Critical Research Insights

- ⌚ Current research describes the basis for US DOT's legal authority to support implementation of many critical aspects of a Connected Vehicle Environment including authority to: regulate, fund, build, operate, oversee, and otherwise influence equipment, infrastructure, technologies, organizations, regulations, standards, certifications, and protocols required for V2V/V2I communications.

Next Steps

- ➔ Continue legal research on stakeholder liability and develop policies on whether the Department should support a shared-risk regime.
- ➔ Identify and analyze intellectual property/data ownership issues that present potential road blocks to regulation or deployment of connected vehicle technologies.
- ➔ Continue to develop a privacy program/policies for a Connected Vehicle Environment.

Track 4: Implementation Strategies

Research Accomplishments

- The US DOT has developed a critical decisions timeline to track progress across research and analytical efforts that result in policy and institutional options.
- The US DOT has formed a Senior Policy Task Force that formulates directions for research; reviews results against the US DOT system principles; and creates a basis for decision making.

- The US DOT has been engaging stakeholders with each set of results to elicit their feedback on potential impacts and to gather input on how they might play a role in implementation.

Critical Research Insights

- Development of draft policies and strategies in consultation with stakeholders. Comparisons against existing institutional and legal arrangements will reveal where leverage is possible and will also reveal where connected vehicle policies might conflict with existing policies and/or laws.
- Stakeholders have launched their own efforts to develop implementation plans. These early plans help identify where policy gaps remain.

Next Steps

- ➔ With the completion of research and analysis into each area, the results will form an implementation strategy that will be further examined to understand:
 - Impact to the workforce and existing institutional policies and laws;
 - Requirements for consistency in rules of operations; and
 - Roles of stakeholders who will lead implementation, operations, and maintenance.
- ➔ This implementation strategy will align with and support the US DOT decision in 2013.

Connected Vehicle Technology



Connected Vehicle Technology

The development and deployment of a fully connected transportation system that makes the most of multi-modal, transformational applications requires a robust, underlying technological platform. The platform consists of well-defined technologies, interfaces, and processes that combine to ensure safe, stable, interoperable, reliable system operations, thereby minimizing risk and maximizing opportunities.

A successful platform will be developed through a process of thorough and considered research while meeting a set of rigorous criteria:

- ▶ The platform will allow for growth, expandability, and incorporation of newly evolving technologies;
- ▶ By knowing the architectural configuration and definition of interfaces, creative private-sector firms will be able to develop new applications that are not yet envisioned; and
- ▶ The platform will be developed on the basis of the complexity and range of human behaviors that will interact with and impact the system.

For the ITS Program and its partners to deliver such a platform, further research is needed in the creation of standards for interoperability; system security, strategies that address the complexity of human behavior and risks associated with the driver's workload, and processes that define how travelers and equipment become a certified part of the system. Other technical research will also be pursued to identify and resolve technological limitations with positioning, scalability, and other technical issues.

The following represent some, but not all, of the critical research efforts over the next 5 years that will address the underlying technological platform for a connected transportation environment:

- ▶ Connected Vehicle Standards and International Harmonization of Standards around the Vehicle Platform
- ▶ Connected Vehicle Human Factors Research
- ▶ Connected Vehicle Core Systems
- ▶ Connected Vehicle Certification
- ▶ Connected Vehicle Test Beds

The following pages describe these research efforts.



Image: US DOT

Connected Vehicle Standards ...

... are rules that provide the software programming codes, definitions, and formats needed to create interoperable, consistent, and seamless communications exchange among shared information systems and devices. To accelerate the deployment and adoption of connected vehicle systems, and to preclude redundancy and reduce costs and complexity, the US DOT seeks to harmonize ITS standards through a process that includes stakeholders, including vehicle and equipment manufacturers, standards organizations, and governments, who work together to agree on harmonized standards across multiple regions.

The vision for the ITS Standards program is to enable interoperable connected vehicle and ITS services within a complex, multimodal, connected transportation network, including both vehicles and infrastructure. To do so, the ITS Standards Program will participate in and facilitate the development of standards and protocols that establish the rules for how ITS (and, specifically, connected vehicle) devices, vehicles, and operations centers communicate with one another and exchange information. And, further, the program will partner with NHTSA and other interested modal administrations, to participate in international standards harmonization activities for standards.



Research Plan

From 2010 to 2014, the primary focus of the ITS Standards Program will continue to be the development of high quality standards that directly support the ITS Program's goals for an interoperable, connected, and standards-based transportation environment. Specifically, the predominant focus for the program is in two areas:⁴⁶

- ▶ Development of cooperative vehicle system standards, an effort that is informed by:
 - Results of ongoing connected vehicle technical and policy research activities, findings from field testing, and other global technological developments;
 - Adaptation of existing standards, where relevant; and
 - Harmonization through joint international efforts.
- ▶ Maintenance and upgrades to existing ITS infrastructure standards and identification of new standards as needed.

To enact this strategy, the ITS Standards Program will conduct research and activities in five tracks:

Track 1: Revise and Field Test Connected Vehicle Standards: A critical step in the completion of the connected vehicle standards is the ability to prototype and test new and revised standards in the connected vehicle test bed. While recommended changes may address problems detected during connected vehicle proof-of-concept tests changes may or may not work effectively in the field and ensure the successful operation of smart communications between vehicles. Therefore, the ITS Program intends to test implementations of the revised standards based on standards test plans and procedures that will verify that: (1) the prototype implementations conform to the appropriate standard; and (2) the standards support the capability needed to advance smart communications between vehicles toward deployment.

⁴⁶ A recently released strategic plan details this research agenda and describes other activities. It is located at: http://www.its.dot.gov/standards_strategic_plan/index.htm.

Research Goals:

- ▶ To globally harmonize connected vehicle technologies by taking an active role in developing and harmonizing standards and architectures around the vehicle platform.
- ▶ To provide the standardization necessary for vehicles and infrastructure to communicate, using widely available, affordable, and interoperable technologies that maximize safety and efficiency.

Research Outcomes:

Vehicle connectivity through harmonization of standards and architectures will reduce costs to industry and consumers in that hardware and/or software development costs will be spread over a larger user base, resulting in reduced unit costs. Differences between vehicles manufactured for different markets will also be minimized, allowing private-sector markets to have a greater set of global opportunities.



Track 2: Update and Test Support Standards: These standards include infrastructure, vehicle, transit, motor carrier, and other ITS technologies.

Track 3: Apply Life-Cycle Management Principles to Standards Development Efforts: The program will work to improve standards quality and ensure that they are complete and correct.

Track 4: Harmonize Connected Vehicle Standards: Where appropriate and in the public interest, the program will also work to ensure that the connected vehicle standards are internationally harmonized (see text box below).

Track 5: Establish Outreach and Training in Partnership with the ITS Professional Capacity Building (PCB) Program: The program will design and develop a standards training program to assist deployers in acquiring and testing ITS systems that use ITS Standards.

International Harmonization of Standards Around the Vehicle Platform

The objective of the Standards Harmonization Program is to cooperate with the *international standards community and foreign governmental entities to harmonize standards and architecture* in order to increase commonality of connected vehicle technologies across multiple regions. Harmonization facilitates interoperability between products and systems, and it can allow the same hardware and/or software to be used in vehicles and products for multiple regions, significantly lowering both initial and life-cycle costs and accelerating deployment. Such harmonization further expands the overall marketplace, increasing both competition and opportunities while avoiding the inefficiencies of development and the deployment of redundant standards; this benefits transportation management agencies, vehicle manufacturers, equipment vendors, and others. By overcoming institutional and financial barriers to technology harmonization, stakeholders could realize lower life-cycle costs for the acquisition and maintenance of systems, along with faster deployment.

Considerable global interest has been expressed in cooperative ITS research and standards harmonization (see page 162 for further details on other joint international research activities). In support of that interest, efforts under this research program include collaboration with standards development organizations (SDOs), vehicle and equipment manufacturers, and other stakeholders, to seek agreements to harmonize standards, provide appropriate incentives, and execute harmonization activities. Research over the past two years has identified harmonization benefits to include:

- ▶ Improved interoperability and interchangeability of ITS across jurisdictional operational boundaries;
- ▶ Reduced development and deployment costs for manufacturers that improve affordability for consumers and speed deployment;
- ▶ Greater accessibility to international markets for manufacturers of connectivity equipment;
- ▶ Increased competition and innovation among manufacturers, which can help lower costs and expand service for consumers;
- ▶ The potential for a more rapid deployment of ITS; and
- ▶ Leveraging international expertise and reducing redundant efforts.

Connected Vehicle Standards

Track 1: Revise and Field Test Connected Vehicle Standards

Research Accomplishments

- The US DOT supported the completion of the IEEE 802.11p amendment to the IEEE 802.11 standard along with the connected vehicle-centric IEEE 1609 series of standards to add wireless access in vehicular environments (WAVE) capability. 802.11p permits the fast link setup critical to enable many connected vehicle technologies.
- The US DOT supported completion of version 2 of the SAE J2735 DSRC Message Set standard.
- The US DOT initiated a program to develop the next version of the SAE J2735 DSRC Message Set standard using a systems engineering (SE) approach. Stakeholders from the US DOT (FHWA, FTA, and NHTSA), OEMs, VIIC and CAMP are providing input for the user needs development.

Critical Research Insights

- IEEE 802.11p is a published standard.
- IEEE 1609.x is available in final draft and published forms depending upon section.
- SAE J2735 version 2 is a published standard.

Next Steps

- ➔ Complete the draft J2735 systems engineering requirements and design detail.
- ➔ Initiate contractual task with SAE to finalize, adopt, and publish J2735 as version 3 of the standard.

Track 2: Update and Test Support Standards

Research Accomplishments

- Support update of the Institute of Transportation Engineers (ITE) Traffic Management Data Dictionary, version 3 of the standard.

Critical Research Insights

- In cooperation with the standards development organizations (SDOs), identified high priority candidate infrastructure standards development activities for 2012.

Next Steps

- ➔ Contract with SDOs to execute high priority standards development activities.

Track 3: Apply Life-Cycle Management Principles to Standards Development Efforts

Research Accomplishments

- Require the SE approach to standards development in newly initiated projects.



- Developed a software tool, Test Procedure Generator (TPG), to evaluate the completeness and correctness of ITS Standards. The tool is also capable of developing test procedures for ITS Standards containing system engineering content (user needs and requirements).

Critical Research Insights

- Provided SDOs and working groups with feedback on errors found in two standards after evaluating the standards using the TPG tool. The tool provides analysis in a matter of minutes vs. the previously used multi-day activity of manual traceability analysis.

Next Steps

- ➔ Establish a beta test of the TPG tool with a SDO developing a new standard in 2012.

Track 4: Harmonize Connected Vehicle Standards

Research Accomplishments

Developed and successfully negotiated a Harmonization Action Plan with the EU which was adopted on June 30, 2011.⁴⁷ This plan provides greater detail on executing a key element of the November 2009 *Joint Declaration of Intent on Research Cooperation in Cooperative Systems with the European Union*. To move forward with harmonization, the ITS Standards Program has facilitated activities in launching the harmonization efforts; establishing relevant relationships with appropriate US and international entities, and reaching out to new entities. Accomplishments to date include:

- **Harmonization Efforts:** At the technical level, established five Harmonization Task Groups (HTGs) to jointly execute activities:
 - HTG #1: Service and security management to support joint applications.
 - HTG #2: Harmonization of the core safety message set.
 - HTG #3: Joint protocols for safety and sustainability services.
 - HTG #4: Harmonization of broader message sets and data dictionaries.
 - HTG #5: Harmonization of the SPaT standards.
 - HTG #1 and #3 have established schedules to meet and complete work items in 2012.
- **Establishing Relationships:** At the agency level, facilitated and/or established key relationships that help reduce barriers and support adoption. Efforts included:
 - Established a relationship between SDOs and industry to support further international harmonization of ITS standards.
 - Established a relationship between the U.S. automotive industry and the European standards-setting body, European Telecommunications Standards Institute (ETSI), and the Car2Car European auto industry consortium to support successful harmonization of the core safety message set contained in SAE J2735 version 2. Further, negotiated a Memorandum of Cooperation with the ETSI to recognize common objectives of contributing to the establishment of a global information infrastructure.
 - Established a US DOT working group, including representatives from ITS JPO, NHTSA, and FHWA Office of Operations, to work with the U.S. automotive industry in identifying common goals and objectives for international harmonization in support of a global marketplace.
 - Strengthened the relationship between the International Organization for Standardization (ISO) and the European Committee for Standardization (CEN), the other key European SDO working on connected vehicle standards.

⁴⁷ Published on the web at: <http://www.standards.its.dot.gov/hap.asp>.

- Initiated a discussion between the US DOT and the International Telecommunications Union (ITU), a global SDO, regarding potential cooperation on harmonization activities.
- Established cooperation with the National Institute of Standards and Technology's (NIST) Standards in Trade pre-program to support broadened market opportunities for U.S. equipment suppliers.
- **Outreach:** There is a need to substantially broaden cooperation with other regions. The well-publicized agreements with the EU and Japan, along with frequently reinforced openness to additional partners, remains important to broaden knowledge of harmonization benefits and the potential scope of harmonization partners. Building on previous efforts, further outreach includes:
 - Established a U.S.-EU and U.S.-Japan agreement to support development of globally open standards and coordinate standardization activities. A Memorandum of Cooperation was signed on October 20, 2010 and has resulted in Japan's participation in some of the US-EU research activities.
 - Initiated development of a response to an expression of interest from Korea with the intent of establishing a cooperative agreement similar to the one with Japan.

Critical Research Insights

- Successful harmonization of the core safety message set enables common hardware and mostly common software to be developed such that now only simple translation is required between U.S. and candidate EU messages. Common hardware and software improves interoperability, reduces implementation costs for manufacturers, and facilitates more rapid deployment of ITS systems.
- The US DOT has learned that even small gains in harmonizing vehicle standards that result in small unit-cost reductions can have large economic benefits due to large production volumes.
- Technical and policy analyses have confirmed the importance of harmonization and have noted that, without them, the costs of implementing these technologies may remain higher for U.S. consumers.

Next Steps

➔ **Harmonization Activities:**

- In cooperation with EU, complete HTG #1 & HTG #3 program of work by late 2012. (HTG #2 has largely been satisfied.)
- In cooperation with EU, finalize Work Item Descriptions (WIDs) for HTG #4 and HTG #5 and ensure that sufficient resources are available to execute programs of work.
- Continue to work within the US DOT to maintain appropriate representation within the US DOT working group.
- Support broader engagement of U.S. industry representatives and continue to work with them to understand requirements and jointly advocate enhanced cooperation on harmonization.

➔ **Relationships:**

- Continue to seek to strengthen existing relationships with the EU and Japan to increase cooperation.

➔ **Outreach:**

- Further strengthen cooperation with Japan and other interested partners.
- Continue to be open to multiple bilateral or trilateral agreements and/or countries interested in observation.



Track 5: Establish Outreach and Training in Partnership with the ITS PCB Program

Research Accomplishment

- In partnership with the ITS PCB program and ITE, developed a standards training program. Eighteen training modules now exist to train the ITS community on acquiring and testing ITS technologies using ITS standards. As of January 2012, all sessions are recorded and are available for free viewing via the ITS PCB website⁴⁸ and the ITE website.⁴⁹

Critical Research Insight

- In partnership with the PCB program and ITE, 18 webinar training sessions are developed.
- The next set of training modules is defined and ITE is under contract to complete the training development in 2012.

Next Steps

- ➔ Complete the development of the next set of training modules.

48 <http://www.pcb.its.dot.gov/standardstraining/>.

49 <http://www.ite.org/education/clearinghouse/search.asp?StartRec=1>.

Connected Vehicle Human Factors Research ...

... is research that is focused on understanding, assessing, planning for, and counteracting the effects of signals or system-generated messages that take the driver's eyes off the road (visual distraction), the driver's mind off the driving task (cognitive distraction), and the driver's hands off the steering wheel (manual distraction).

The vision for the Human Factors for Connected Vehicles research program is to address the number of new, competing visual and audible stimuli that create increasing demands for the driver's attention and a comparatively greater driver workload in order to ensure that wireless traffic safety applications and technologies are not distracting.

Research Plan

Operating the radio, eating, passenger noise, and fatigue are among a variety of distractions that drivers have always encountered. With the recent growth in technologies and portable devices used in vehicles, drivers now face an increasing number of distractions, further highlighting the need for human factors research.

The objective of the research program in human factors for wireless traffic safety systems is to assess, counteract, and ultimately eliminate possible driver distraction from technologies that enable wireless communication between vehicles. The program aims to research and implement technology-based solutions that could deter drivers from multitasking and reduce vehicular sources of distraction.

Using a cooperative and cost-sharing approach, the program will work with NHTSA and other DOT agencies and vehicle manufacturers, operators, and equipment suppliers. This collaborative effort will raise public awareness about the distracted driving problem and encourage vehicle and equipment manufacturers to design interfaces with minimal demands on driver workload. The program goals outlined below will guide the overall research. Success factors include the ability to:

- ▶ Lower the frequency with which drivers multitask to reduce their exposure to risk;
- ▶ Reduce the complexity of distracting tasks and reduce demands on driver attention;
- ▶ Manage the multitasking options that drivers can make to avoid overloading them; and
- ▶ Assist distracted drivers through in-vehicle technologies that monitor their attention status and provide feedback on unsafe behaviors and potential crashes.

Similar to the other research programs, the Human Factors Research program will use a multi-track approach:

Track 1: Define the problem by identifying the types of distractions that contribute to crashes. Distraction is anything that diverts the driver's attention from navigating the vehicle, and it often fits into more than one category. For example, eating is visual and manual, while using a navigation system is visual, manual, and cognitive.



Image: US DOT

Research Goals:

- ▶ To provide drivers with safe advisories, alerts, and warnings through advanced vehicle technologies, both built into the original equipment and brought into the vehicle (portable or nomadic technologies), that increase highway safety and offer drivers and passengers the promise of enhanced safety, comfort, security, and convenience.
- ▶ To control and mitigate the ever-present and growing threat to safety represented by driver distraction, which is a factor in many crashes.
- ▶ To evaluate driver distractions and other human factors related to ITS, leveraging the convergent findings of epidemiological studies, experimental studies, and analyses of crash data.



Track 2: Develop and evaluate performance metrics for distraction mitigation. By monitoring new technology interfaces and developing best practices, objective test procedures can be developed to assess distraction and usability of production vehicles and nomadic technologies.

Track 3: Produce an integration strategy that allows nomadic systems to be functionally integrated with vehicle-based systems to optimize the driver/vehicle interface. Integration reduces interface complexity and multitasking. In addition, real-time distraction monitoring systems that provide distraction alerts or messages are potential areas of integration research.

Track 4: Develop longer-term exposure testing through field operational experiments to determine the safety impacts of crash warning technologies and their effects on long-term driver behavior that could affect the safety of distracted drivers.

Track 5: Perform strategic outreach with stakeholders to identify requirements, information needs, and usability issues, so that the program and its results are publicly acceptable.

The Human Factors Research program is a highly collaborative effort that addresses the effectiveness of safety applications by evaluating any potential issues around driver distraction. The program will work toward mitigating any distracting by products from using In-Vehicle Information Systems (IVIS) and develop technology-based solutions.

Research Outcomes:

The outcomes are intended to eliminate distractions related to vehicle-based wireless communication devices as a contributing factor to crashes.

2012 SNAPSHOT OF PROGRESS

Track 1: Define Problems by Identifying Types of Distractions

Research Accomplishments

- ☒ Analyzed 2005 to 2007 data from the National Motor Vehicle Crash Causation Survey (NMVCCS) database, which consists of on-scene, in-depth multidisciplinary investigations of crashes. This approach provided more details than typical police reports about driver, vehicle, and traffic characteristics associated with distraction-related crashes.
- ☒ Completed a naturalistic study, conducted by Virginia Tech Transportation Institute, in which 100 cars in Northern Virginia were instrumented.
- ☒ Completed an assessment of international best practices in data collection methods and improvements in police reporting to reduce the variability (due to poor recall, avoiding self-incrimination or admission of fault) in reporting on distraction. Assessment relates improved reporting to the level of training and reporting requirements.

Critical Research Insights

- The NMVCCS data indicate that distractions internal to the vehicle were a critical reason in about 11 percent of crashes studied. An analysis of the types of internal distractions found that about 0.2 percent of drivers were dialing or hanging up phones, about 0.9 percent were adjusting radios/CDs or other controls, and about 12 percent were conversing with passengers or on cell phones. Drivers 16 to 25 years old had the highest rate (6.6 percent) of being engaged in at least one interior non-driving activity.

- Analyses of the 100-Car Study-recorded video data allowed researchers to determine whether the drivers were distracted in the moments leading up to the crashes or near-crashes. The researchers also analyzed video clips in which the drivers were engaging in secondary tasks. Comparing distractions during normal driving to distractions during crashes and near-crashes, estimates were made of the relative risk of drivers when distracted. Due to the success of this method, the Transportation Research Board, under its Strategic Highway Research Program 2 (SHRP2), has initiated a much larger naturalistic driving study with a wider sample of drivers, which is expected to be more representative of the general driving public.
- Improved training and standards for coding distraction on police accident reports would help NHTSA and the states to better estimate distracted-driving-related events and to monitor any new trends and the effects of countermeasures.

Next Steps

- ➔ The NMVCCS analysis has helped to define the distraction problem; with completion of this task, results are informing Track 2 activities on defining current and best practices.
- ➔ The SHRP2 analysis also helped to define the distraction problem; and have also informed Track 2 activities, which will ultimately be used to support the Human Factors for Connected Vehicles guidelines related to distraction, specifically identifying countermeasures, such as standards to lock out distracting device operation, and recommendations restricting driver use of distracting devices.
- ➔ This is an ongoing project. The first step, which involves communicating the variables that are available in all states, is complete. The second step, calling for improving those variables, will be completed by late 2012.

Track 2: Develop and Evaluate Performance Metrics for Distraction Mitigation

Research Accomplishments

- ☒ The US DOT has identified the state-of-the-industry in distraction mitigation. Analysis has resulted in preliminary recommendations on best practices for performance metrics. A NHTSA report is under review. This set of preliminary recommendations will form the basis for future efforts to develop design guidance and assessment tools.
- ☒ The US DOT has also developed preliminary guidelines for measuring driver distraction.

Critical Research Insights

- A long-standing challenge in human factors research is how to measure driver distraction. Distraction is significantly correlated to driver behavior, which is difficult to measure. To address this challenge, a wide and inconsistent range of definitions and different measurement techniques have been developed by researchers, academia, and industry.
- In reviewing and identifying best practices, NHTSA is on the leading edge of codifying a set of consistent practices for measuring and assessing



driver distraction. These practices will be instrumental in producing a set of connected vehicle distracted driver guidelines, which will be consistent with NHTSA's overarching policies and guidelines on distracted driving.

Next Steps

- ➔ Develop DVI design guidance and distraction assessment tools. This effort was initiated in November 2011 and seeks to gather key researchers to discuss current and future performance metrics for distraction mitigation.
- ➔ Develop DVI guidance with a focus on non-safety applications and connectivity issues. This activity will focus on design guidance gaps for DVIs associated with light vehicles, heavy vehicles, and transit operators; all age groups; and V2I interfaces.

Track 3: Produce an Integration Strategy

Research Accomplishments

- The US DOT completed DVI Design Criteria in March 2011. These criteria were delivered to the *Safety Pilot* developers and will be used as a starting point for further DVI design research, which will ultimately inform the final HFCV Guidelines.
- To develop an integration strategy, the US DOT has finalized a *Requirements Definition Final Report* and a *Guidelines Framework* (both completed in June 2011).
- The US DOT is currently developing an integrated ConOps and an overall "Metric Toolbox" for evaluating multiple, integrated DVI-based connected vehicle systems and applications, including safety and non-safety applications, validation efforts, light vehicles, heavy vehicles, transit operators, all age groups, and V2I issues.

Critical Research Insights

- Research has highlighted the criticality of producing further data and insights as a means of helping to define how multiple DVIs can be integrated so that the driver perceives a single system rather than being bombarded with various messages without coordination. The results suggest that integrating and coordinating information from multiple sources is important to driving performance with respect to the volume and rate of information, the type and complexity of the information, the priority of the information, and physical characteristics of the information displays.

Next Steps

- ➔ Finalize the research and develop Human Factors Guidelines for the integration of connected vehicle information, how to prioritize that information, and how to best present the information to the driver without distraction or unintended consequences. These guidelines are the principal product of this program.
- ➔ Develop a predictive DVI evaluation tool for validation and refinement. This is a software tool for designers to be able to estimate distraction potential or workload issues for their DVI and system configurations.

Track 4: Develop Longer-Term Exposure Testing

Research Accomplishments

- NHTSA has developed an experimental design, implementation plan, and test requirements for launching a field operational experiment that will test instrumented vehicles with advanced collision warning systems and measure driver behavior over time. This first test will deliver insights into how drivers change their behavior or responses to safety devices and will assess longer-term impacts over time. The test is being conducted on forward collision warning applications. An initial statement of work, released in 2011, did not result in an award due to critical questions by industry. With further clarification, a second statement of work is expected to be released in the spring of 2012.

Critical Research Insights

- None to date.

Next Steps

- ➔ Award a 2-year contract and initiate the study. Results are expected in 2014.
-

Track 5: Perform Strategic Outreach with Stakeholders

Research Accomplishments

- ☒ The US DOT hosted a public meeting to give an overview of research under the Human Factors for Connected Vehicles Program, including V2V and V2I communication, heavy-truck-related research, and environmental research related to connected vehicles. DOT representatives led a discussion to facilitate the exchange of ideas with stakeholders.

Critical Research Insights

- Stakeholders confirmed that the US DOT is addressing the right issues for connected vehicles. Input helped to further define gaps that need to be addressed and which inform the current program and future projects.

Next Steps

- ➔ NHTSA is planning to hold another workshop in 2012 to present results and receive additional stakeholder feedback on the preliminary DVI framework and guidelines and the data from Phase 1 studies.



Connected Vehicle Core Systems ...

... is a system that provides the functionality needed to enable trust relationships and data exchanges between and among mobile and fixed transportation users.

The vision for the Core System concept is to facilitate trusted applications transactions — requests for data, exchange of data, and synthesis of data for dynamic safety, mobility, and environment applications from multiple sources simultaneously — for both mobile and non-mobile users. In addition to providing trusted exchanges, the Core System will work with external systems to support and provide secure communications.

Research Plan

The objective of the Core System research program is to establish a system architecture for a trusted and secure data exchange system. The path to developing the architecture is based on proven systems engineering concepts — the first activity is to develop a stakeholder-based ConOps that describes how users expect to use the system, which evolves into a set of system requirements. Using requirements that stakeholders (in particular, future implementers) have reviewed and confirmed, a system architecture is developed that identifies:

- ▶ System components, their functions, and appropriate performance measures for the system;
- ▶ System interfaces, which are analyzed for their levels of risk and opportunities to determine the appropriate level of control or openness. Additionally, identifying system interfaces allows for:
 - Determination of the sufficiency of current standards and/or the need to develop new or modify existing standards;
 - Identification of where standards might be optional; and
 - Identification of where and how certification requirements will apply to devices, applications, or equipment to help mitigate risk.

The purpose in implementing a Core System is to support a distributed and diverse set of applications that operate using both wireless and wireline communications. The applications data exchange is expected to occur with and between mobile elements of all types including vehicles, pedestrians, cyclists, and other transportation users as well as between mobile elements and field infrastructure and with back office processing centers (typically commercial in nature) and transportation management centers.

A critical factor driving how the Core System and the entire Connected Vehicle Environment are developed is the level of trustworthiness between communicating parties. A complicating factor is the need to maintain the privacy of participants.

From a deployment perspective, the connected vehicle program is expected to include locally- and regionally-oriented Core System implementations that are flexible enough to grow organically to support the changing needs of its user base. Core Systems are expected to follow national standards to ensure that the essential capabilities are compatible across regions (the basis for interoperability).

It is important to note that the Core System is not meant to mandate or change existing transportation equipment, technology, or transportation centers. The Core System provides mechanisms for efficiently collecting and distributing transportation data, and may offer enhanced capabilities or options in substitution to existing data collection and data distribution functions.

To develop the foundation for a Connected Vehicle Core System, a multi-track systems engineering process was used. In using the systems engineering approach, the ITS Program is assured that the final products are comprehensive and thorough.

Critical Value of a Core System



Image: US DOT

A core system creates an efficiency that is needed for realizing a widespread, connected, multimodal transportation environment. Users who have no previously established relationship to one another can request and accept data, knowing that the source and the data are trusted. A core system supports the transport and synthesis of data from multiple sources simultaneously.

Current technologies and proprietary networks offer only piecemeal and inefficient solutions that hinder widespread adoption and use of cooperative, dynamic applications. A core system creates an efficiency that is needed for realizing a widespread, connected, multimodal transportation environment.

Track 1: Develop the Foundation of a Connected Vehicle Core System: Solicitation of stakeholder requirements is a critical first step in developing the ConOps and supporting documentation:

- **A Core System ConOps** defines user needs and different scenarios under which a core system might operate and provide value. In addition to stakeholder inputs, the ConOps developers will consider ongoing efforts in Europe and Asia; and
- Analysis and development of **a set of system requirements for the Core System**. These requirements define how applications will gain access to the core system's capabilities and services and define how the core system will operate and perform.
- **A system architecture** that describes:
 - The physical architecture that identifies all system components;
 - The security architecture that describes how security and privacy will be handled, as well as the consideration of alternative implementations of the *anonymity by design* approach; and
 - A functional architecture that identifies all major functions performed by the core system and allocates those functions to system components.

Track 2: Analysis and Testing: A second critical task is to assess the core system concept, system requirements, and architecture against requirements for implementation. A prototype core system will be developed as part of the *Safety Pilot Model Deployment*. Testing will provide answers to whether the initial configuration is sound and delivers the expected performance and whether the architecture is scalable to larger regions. Modeling and simulation may be included to assess the feasibility and trade-offs and to examine performance options related to different technical solutions.

Track 3: Policy Analysis: Policy analysis on the emerging core system configuration allows for the identification of whether the expected benefits of the system are aligned with the costs, acceptable levels of security and safety, privacy, and the ability to fund and finance the implementation of core systems. A policy



analysis will result in an understanding of the organizational and operational requirements for implementing a core system, and identify new requirements for the transportation workforce and cost-benefit impact to institutions looking to deploy.

Track 4: Final Core System Guidance: With testing results and policy analysis, the final task will be to revise the foundational documentation and develop guidance on implementation.

2012 SNAPSHOT OF PROGRESS

Track 1: Develop the Foundation of a Core System

Research Accomplishments

- Representatives from industry⁵⁰ and the public participated in a series of workshops in 2010 and 2011 that formed the basis for the iterative development of a set of critical engineering documents. With this input, the US DOT established a set of draft documents for the Core System ConOps, system requirements, and system architecture, which were completed in November, 2011.⁵¹
- With the foundation of a core system established, US DOT is conducting risk assessments and analyzing which standards are needed.
- The foundational research identified different technical architectures, allowing for analysis of the most effective architecture.

Critical Research Insights

- An important finding to date is that the security function is most effectively implemented outside of the Core System, with key core system functions operating in a supporting role. This allows for greater consistency of security and reduces the complexity of implementing a core system.

Next Steps

- ➔ Develop and test a core system architecture during the Safety Pilot Model Deployment.
- ➔ Develop a reference implementation of a core system.
- ➔ Complete the risk analysis, interface inventory, and standards identification. Results will be used to determine policy on devices, applications, and system certification.

Track 2: Analysis and Testing

Research Accomplishments

- A review is underway by an outside organization to independently verify and validate the draft core system architecture and risk assessment. This assessment will help in formulating the criteria for testing the prototype.
- The US DOT has awarded a contract to an engineering firm that will develop the prototype.

⁵⁰ Representatives included those from the automotive, transportation management, traffic signal controller, and telecommunications industries; the commercial vehicle operators (CVOs); vehicle aftermarket and retrofit providers; and transit and rail operators.

⁵¹ High-level presentation materials are available at: <http://www.its.dot.gov/presentations.htm>.

Critical Research Insights

- None to date.

Next Steps

- ➔ Development of the prototype and of criteria for testing it.
-

Track 3: Policy Analysis

Research Accomplishments

- A preliminary policy analysis has highlighted the issues that will need to be resolved in order to provide an institutional foundation for operating a core system.

Critical Research Insights

- Many policy issues associated with the Core System are similar to those faced by the other connected vehicle technologies, applications, and systems. They include governance, funding and financing, policy positions on use of standards and certification, and data ownership.
- A key policy issue will be to determine what constitutes a core system and what level of flexibility can be allowed for implementers without compromising interoperability, security, privacy, and safety. This analysis will guide the decision regarding whether core systems themselves will need to be certified, determine the criteria for certifying a core system, and provide options for who/what entity is authorized to provide such certification.

Next Steps

- ➔ Finalize the analysis and develop draft policies for the Core System.
-

Track 4: Final Core System Guidance

Research Accomplishments

- Not yet launched.



Connected Vehicle Certification ...

... is the process of ensuring that system components, manufactured according to connected vehicle interoperability requirements, to perform as intended. Certification ensures that users can trust that the components will work within the system.

The vision for the certification research is to work in close cooperation with public and private partners to establish appropriate certification requirements for equipment, applications, devices, and systems.

Research Plan

Successful implementation of a connected transportation system must address the inherent risks to consumer safety, security, and privacy. With national interoperability comes the opportunity to establish national standards and criteria for certification of individual products that have access to the system, system processes, and operational procedures. Since this is a new high-risk industry without an established consumer base, the US DOT will work with industry to develop certification processes and procedures independently. The ultimate form that a certifying entity would take, and the potential role of the Federal Government in oversight and enforcement of requirements, is yet to be determined and will be investigated as part of both the technical and policy research programs.

Certification research will primarily be focused on understanding the interoperability needs for device compliance, systems security, and privacy. The US DOT will conduct the following research activities in support of certification:

Track 1: Policy Research Related to Certification – The US DOT will establish a forum for solving policy-related issues, including a determination of what is to be certified, the entity that will be responsible for certification, and the parties that will need to obtain certification. The Policy and Institutional Issues research program will involve industry and Federal, State, and local government stakeholders to provide input.

Track 2: Technical Requirements for Certification – The level of components within devices, or which interfaces need to be certified will be defined. Additionally, how this certification is to be accomplished will be determined. It is envisioned that the responsibility for work in this area will be shared by Government and industry. However, Government will have a primary role in funding development prior to the emergence of a consumer market for certified products. In that sense, the Government will serve as an enabler and coordinator of this function.

Track 3: Implementation Support and Oversight – A third party entity is expected to conduct implementation of the planned certification process. The implementation process will include development of test tools and methods. The Federal Government may have a role in assisting with start-up, and in overseeing operation and adherence to standards. This implies an ongoing operational role for the Federal Government beyond the scope of this research.

It is critical that certification research milestones match related milestones in the other program roadmaps. For instance, a 2013 milestone for potential rulemaking on equipment requirements in vehicles must be matched by a similar milestone to have certification requirements and processes established in time for implementation of the rule.

Research Goals:

- To work with industry to define certification needs and to develop supporting test methods and tools.
- To develop a future plan that will make certification activities self-sustaining through fees for testing; development of new requirements and test methods will be shaped by the organizations seeking those requirements.

Research Outcomes:

- Nationwide interoperability of system components.
- Reduction of inherent risks to consumer safety, security, and privacy in the event of a whole or partial system breakdown.
- Establishment of an oversight structure (governance structure) that will provide the processes and procedures for system access as well as system enforcement.



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Connected Vehicle Certification

Track 1: Policy Research Related to Certification

Research Accomplishments

- The US DOT has worked with industry stakeholders to identify the need for and scope of certification policies.

Critical Research Insights

- Preliminary research has identified the basis for certification policies. This basis is grounded in the assumption that core system interfaces may require greater controls, management, and oversight due to higher risks.

Next Steps

- ➔ Work with the ITS Standards team to launch analysis in summer of 2012 that will result in an interface inventory in spring of 2013.
- ➔ Results will be used to inform the development of draft certification policies for the Connected Vehicle Environment.

Track 2: Technical Requirements for Certification

Research Accomplishments

- The US DOT and industry stakeholders have defined an initial process that will be applied to devices and applications for the *Safety Pilot Model Deployment*. The results of those implementations will identify gaps and guide the definition of any further technical research that may be needed.

Critical Research Insights

- All levels of the system need to be included in certification processes from the physical aspects of the communication media to the applications that rely on the communications.
- Appropriate organizations need to be involved in the certification process. Different skills are needed at the different levels of the system.

Next Steps

- ➔ Analyze results of the *Safety Pilot* implementation.

Track 3: Implementation Support and Oversight

Research Accomplishments

- Not yet launched.



Connected Vehicle Test Beds ...

... are real-world, operational test beds that offer the supporting vehicles, infrastructure, and equipment to serve the needs of public- and private-sector testing and certification activities.

The vision for the test environment research is to establish a minimum of one test bed that can support continued research, testing, and demonstration of connected transportation system concepts, standards, applications, and innovative products. Test environments will also serve as a precursor or foundation for state and local deployments of wireless communication between vehicles. They are expected to generate sustainable markets for the private sector, as the test environment will enable products and applications that will deliver benefits to state and local consumers who purchase them.

Research Plan

A critical result of the previous ITS research agenda (2005-2009)⁵² was the establishment of a test environment to conduct a set of proof-of-concept tests using field (roadside) installations in Michigan and California and a network control center located in a Herndon, Virginia facility. Those test results were instrumental in forming the foundation of this current research agenda, and its recommendations are reflected in the structure of the technology, applications, and policy research programs that support a connected transportation environment.⁵³

Since 2008, the Department has upgraded this major investment and made it widely available for use in testing applications, services, and components. The test bed is located in Oakland County, Michigan, centered in the cities of Novi, Farmington, and Farmington Hills with recent expansion into Southfield. At this location, the test bed offers RSE, back office servers and support, on-board equipment, as well as SPaT and GID applications. It also uses the latest technology standards and architecture and is based on the systems engineering principles discussed in the Core Systems section on p. 95. An additional test bed was established by the US DOT for the 2011 ITS World Congress in Orlando, Florida. Older California and New York sites that were developed for Vehicle-Infrastructure Integration (VII) tests are now upgraded and connected so that multiple sites function as one system. When operational, the Safety Pilot Model Deployment site will be connected as part of this system as well. (See image on the following page for locations.)

To continue the evolution of these test beds, current and future research activities are pursued under four tracks:

Track 1: Establish multiple locations, as part of a one connected system that can support continued research, testing, and demonstration of connected vehicle concepts, standards, applications, and innovative products;

Track 2: Establish accessible Connected Vehicle Test Beds for the public and private sectors to pursue research, testing, and demonstrations;

Track 3: Enhance and/or modify the existing test bed and establish it as model for the next generation of test beds, regional pilots, and/or real-world implementation; and

Research Goals:

- To operate, manage, and maintain the existing Connected Vehicle Test Bed for use by organizations and researchers in both the public and the private sectors, inclusive of the ITS Program's testing of connected vehicle standards and safety-, mobility-, and environment-related connected vehicle applications.
- To enhance and/or modify the existing Test Bed and establish it as a model for other test beds.
- To research, develop, and prototype a set of generic management processes, equipment, and back-end services.

Research Outcomes:

The outcome of this research will result in the establishment of an accessible vehicle-to-vehicle and vehicle-to-infrastructure technology test bed in Michigan for the public and private sectors to pursue research, testing, and demonstrations on innovative, next generation ITS technologies. The test bed will help establish requirements for future test beds that will provide the State and local foundation for deployment of wireless communication between vehicles.

52 Located at: http://ntl.bts.gov/lib/jpodocs/repts_te/14289/14289.pdf.

53 Test results found at: http://ntl.bts.gov/lib/30000/30800/30867/ITS_Research_Results_ITS_Program_Plan_2008_-_ITS_Report.pdf.

Track 4: Develop Generic Management Processes, Equipment, and Back-end Services. Research, develop, and prototype a set of generic management processes, equipment, and back-end services as a model for the next generation of test beds, regional pilots, and or real-world implementation.



Figure 11. Connected Vehicle Test Bed and Affiliated Interoperable Test Beds Image Source: US DOT

2012 SNAPSHOT OF PROGRESS

Connected Vehicle Test Beds

Track 1: Establish Multiple Locations

Research Accomplishments

- The Connected Vehicle Test Bed in Michigan and affiliated interoperable test beds have helped establish requirements for future test beds that will provide the state and local foundation for connected vehicle deployment.
- The design of the Michigan test bed was influential in the installation of the Florida affiliated interoperable test bed in Orlando, deployed to support the 2011 ITS World Congress connected vehicle demonstration showcase.

Critical Research Insights

- The Connected Vehicle Test Bed is equipped with 55 RSEs installed along an interstate, a divided highway, and arterial roadways within a typical suburban area near Detroit, as well as 22 RSEs enabled with SPaT and GID along Telegraph Road.
- The Florida Test Bed is equipped with an additional 27 RSEs, 11 of which are enabled with SPaT.

Next Steps

- ➔ Over the next 12 to 18 months, the US DOT will work towards enhancing and building the next generation of test beds, including deployments in Northern California and New York.
- ➔ The Department will upgrade equipment, which will feature a common design architecture, interoperable components and shared back office services, and working security processes.



Track 2: Establish Accessible Connected Vehicle Test Beds

Research Accomplishments

- Michigan's test bed was publicized in Automotive Engineering Online.⁵⁴
- The test bed was also featured in Thinking Highways magazine.⁵⁵

Critical Research Insights

- ⦿ Through outreach efforts, over 1,000 researchers and developers from over 400 organizations have expressed interests in learning more about testing opportunities at the Connected Vehicle Test Bed.
- ⦿ Over 25 groups of researchers and developers have toured the test bed, and over half of these groups have scheduled testing to be conducted in pursuit of their individual research efforts.

Next Steps

- ➔ A stakeholder user needs workshop/webinar will be held in early 2012 to determine any additional features or capabilities that researchers and developers may be seeking in order to conduct testing at the Connected Vehicle Test Bed.
- ➔ Feedback from the user needs workshop/webinar will be used to develop a list of additional features for the test bed to add to the planned enhancements happening over the next 12 to 18 months as part of building the next-generation test bed.

Track 3: Enhance and/or Modify the Existing Test Bed

Research Accomplishments

- The Connected Vehicle Test Bed in Michigan's SPaT testing capability was used as a model for the Florida Test Bed SPaT installation in Orlando.
- Michigan model operations and maintenance processes provided for an accelerated and more efficient delivery of both the Florida and Saxton Transportation Operations Laboratory at TFHRC in Mclean, Virginia.

Critical Research Insights

- ⦿ The Florida Test Bed provided a testing mechanism at which ITS World Congress Demonstrators could showcase their technologies in Orlando for the 2011 ITS World Congress.
- ⦿ The Saxton Transportation Operations Laboratory is a closed-circuit test bed deployment that is providing next-generation equipment testing, validation and system verification support, including the testing of vehicle awareness devices and next generation RSEs.

Next Steps

- ➔ Test bed expansion planned for Northern California and New York in the next 12 to 18 months will include the installation of upgraded equipment and software, in addition to specific capabilities that will be exclusive to each geographic site.
- ➔ New and improved security features will be developed at the Michigan test bed and deployed at affiliated test beds once testing and validation is complete.

⁵⁴ This article can be found at: <http://www.sae.org/mags/AEI/9682>.

⁵⁵ Article is located at: <http://thinkinghighways.com/Pages/View-issue/Magazine.aspx?id=6ad9bace-622a-43bd-bb11-a335f862bfae&issue=e3b8e560-5c07-4d07-85af-60a31ca36134>.

Track 4: Develop Generic Management Processes, Equipment, and Back-end Services

Research Accomplishments

- A training manual and seminar was developed for Florida deploying agencies' management, operators, and technicians to explain operations and maintenance processes, equipment, and communications processes.
- The Connected Vehicle Test Bed's Enterprise Network Operations Center (ENOC) Service Delivery Node (SDN) provides the information exchange service necessary to receive requests to post in-vehicle messages from other applications and transmit those messages to the appropriate RSE, both to the Michigan and Florida test beds.

Critical Research Insights

- After deploying the Florida Test Bed, a summary of lessons learned was produced for use in compiling a future set of deployment guidelines to be used by agencies interested in early deployment.
- To improve system operations and develop better guidelines for easier performance monitoring, new network monitoring software was installed at the Michigan Test Bed and will be used to develop improved guidelines on system monitoring and performance.

Next Steps

- ➔ As enhancements and upgrades to the Connected Vehicle Test Bed are made, improved operations and management protocols will be documented and compiled to add to the future deployment guidelines being developed.
- ➔ The new security features being deployed at the Michigan test bed will lead to additional protocols to be added to the future deployment guidelines being developed.



Image: US DOT



ITS Short-Term, Intermodal Research



ITS Short-Term, Intermodal Research

Although research in support of a connected transportation environment is a central part of the ITS Program, additional ITS research will be conducted that reinforces the overall vision of ITS. Specifically, a set of short-term intermodal research programs are expected to further the Department's goal of leveraging technology to maximize safety, mobility, and environmental performance. Three key short-term, intermodal ITS research programs include **Active Traffic Demand Management, Intelligent and Efficient Border Crossings, and Commercial Vehicle Information Systems and Technologies (CVISN)**.

This area of the ITS research agenda has changed since the publication of this Strategic Plan in January 2010. Changes include:

- ▶ **Smart Roadside** research has evolved into a key component of the Truck V2I Safety research (See page 40 for Truck V2I). The Smart Roadside technologies offer important V2I opportunities to share information for safety purposes that are crucial to the mission of the Department;
- ▶ **Two research initiatives are under review:**
 - **The Multimodal Integrated Payment Systems (MMIPS):** In 2010, in the early stages of launching the MMIPS research, the US DOT program managers and other stakeholders realized that private industry was investing in new business models aimed at delivering an integrated payment world. Over the last 2 years, the telecommunications, mobile device, and financial systems industries have been developing prototype systems, applications, and standards necessary to realizing the vision, and have been conducting small-scale field operational tests. For example, the establishment of technologies that use Near-Field Communications (NFC) has allowed industry to move forward on mobile phone-enabled payments as early as 2010. To date, testing has identified some of the gaps that need to be addressed in the areas of privacy, security, and agreements on how to divide transaction fees among the many players. As of early 2012, a number of major credit card firms, retail sellers, and other firms are supporting this type of payment system.

As the US DOT model for high-risk/high-reward research investments is grounded in pursuing those beneficial applications that private industry is unlikely to support, the US DOT has assessed that MMIPS no longer fit these criteria. The US DOT will, however, continue to monitor and examine how the industry results satisfy transportation needs for multimodal, integrated systems. If the resulting private-sector business models ultimately do not meet the goals set forth in the 2010–2014 Strategic Plan, the US DOT will reassess whether to pursue further research and investment in this area.

- **The ITS Maritime Research Initiative:** Since the 9/11 terrorist attacks, the United States has learned that it faces a growing number of security threats in many distant parts of the globe, as well as at home. For the Marine Transportation System today, defense mobilization still equates to having a strong industrial base, as well as sufficient U.S. commercial ships and civilian crews available to meet defense sealift requirements. It also now includes the shore-side equipment and infrastructure necessary to keep the intermodal system moving. The U.S. marine transportation industry has established itself as an indispensable and effective tool for projecting and sustaining military operations, no matter where they may be.

In light of the current Maritime Administration's necessary focus on national security, the opportunity to apply ITS technologies to intermodal freight transfers between ports, marine highway, truck and rail was not available during this research period. However, because of the serious issues related to port-roadway congestion, there still remains a need to address the potential for ITS technologies to provide greater operational efficiencies within the maritime environment. Within the 2014 research timeframe, MARAD and the ITS Program will continue the assessment regarding the potential ways in which effective application of ITS technologies can lead to greater maritime resource efficiencies and increased system performance. The US DOT recognizes that a successful demonstration of a Connected Vehicle Environment may provide MARAD with a powerful stepping-stone for envisioning how ITS can address the complex issues relative to port and roadway congestion. Thus, with the completion of the *Safety Pilot Model Deployment*, lessons learned will be examined from a port operations perspective.

Active Transportation and Demand Management (ATDM) ...

...is the dynamic management, control, and influence of travel demand, traffic demand, and traffic flow of transportation facilities.

The vision for Active Transportation and Demand Management research is to allow transportation agencies to improve trip reliability, system productivity, and safety.

Research Plan

Under a pro-active approach, the transportation system is continuously monitored. Using archived data and/or predictive methods, actions are performed in real-time to achieve or maintain system performance. Active management of transportation and demand can include multiple approaches spanning demand management, traffic management, parking management, and efficient utilization of other transportation modes. An agency can deploy a single ATDM approach in order to capitalize on a specific benefit or can deploy multiple active strategies to gain additional benefits across the entire transportation system.

ATDM represents an evolution of transportation management, from current static and reactive traffic management to dynamic and pro-active management. It is a philosophy of system management more than a specific technology and considers the real-time management of both supply and demand to prevent, delay, or minimize facility breakdown when travel demand exceeds system capacity.

ATDM offers significant potential for reducing freeway congestion without the need for building additional lanes or infrastructure. By using real-time information and technologies, transportation managers can optimize available capacity, increase traffic flow, improve travel time reliability, decrease primary/secondary incidents, and improve the uniformity of driver behavior. Simply put, more can be done with technology and existing assets and programs by making a strategic commitment to actively managing the transportation system. Active management is a tactical approach to operating systems, programs, and technologies differently; it is focused on applying a more "hands on" and dynamic approach through real-time and predictive analyses. ATDM creates an environment where the occurrence and effects of problems can be reduced.

Research Approach

ATDM research is focused on identifying benefits and operating criteria to allow agencies to truly, in real-time, manipulate traffic flow, capacity, and demand throughout the transportation network. This foundational research will result in a true, real-time test-bed simulation framework – an environment that will emulate real-time operational scenarios and conditions to allow for the development of strategies, data needs, and algorithms. The ATDM foundational research and test-bed will support identification of additional simulation operational tests and select field operational tests. The scope of this field operational test will be developed in year 1 with deployment in year 2 and evaluation in year 3. This operational test is expected to contribute to and validate the efforts of the overarching ATDM research effort.

Research Goals:

- ▶ Define the benefits and costs of active management.
- ▶ Improve analysis, modeling, and simulation of active management for planning and real-time operations.

Research Outcomes:

The ATDM research program will assist transportation agencies in moving from monitoring and responding to congestion problems to an operational strategy that influences traffic flow rates, capacity, and demand throughout the transportation network. The Concept of Operations for this program will lead to the development of performance criteria and traffic management techniques that safely optimize the flow of traffic.

By deploying market-ready technologies and strategies, an agency can evolve from monitoring and responding to congestion problems to an operational strategy that manipulates flow rates, capacity, and demand throughout the network.



The program builds upon existing research projects and provides a cohesive effort to bring the results together to provide actionable guidance and support to advance the adoption of ATDM. The program is pursuing research along several tracks:

Track 1: Develop an ATDM Operational Concept.

Track 2: Identify operational requirements for ATDM:

- ▶ **Develop algorithms, rules, and processing software for ATDM.** Preliminary results indicate that current technological research in algorithms, decision support systems, real-time modeling, data needs, and performance metrics for ATDM is still limited.
- ▶ **Identify real-time data needs for ATDM,** which include identifying the necessary fidelity and granularity. Examine data from various sources, including fixed and mobile sensing technologies.

Track 3: Plan for and develop an ATDM Analysis, Modeling, and Simulation (AMS) Test Bed:

- ▶ **Test Bed Planning:** Develop test bed methodology and test bed requirements that the developer will use as guidelines in designing a test bed. Also develop an evaluation plan that will describe how the benefits, challenges, and lessons learned from the test bed(s) will be analyzed and documented.
- ▶ **Test Bed Development:** Develop 2-3 fully-functional test beds. The ideal test bed team will be a partnership between a public agency (e.g., a State DOT or MPO) and developers such as a university or consultant team; a metro region where AMS tools already exist that can be leveraged and incorporated into the AMS test bed and where ATDM approaches are already applied (e.g., a site with variable speed limits, dynamic ridesharing, or adaptive ramp metering).

Track 4: Conduct ATDM Operational Tests:

- ▶ **Field Operational Tests:** Fully scope an operational test and evaluate the benefits of combining different approaches and technologies as part of promising ATDM strategies.
- ▶ **Simulation Operational Tests:**
 - **Demonstration and Evaluation:** The purpose of this effort is to demonstrate and evaluate various ATDM scenarios, plans, and combinations of strategies to quantify the benefits of ATDM. The evaluation will focus on the dynamic nature of all strategy combinations.
 - **Simulation:** The purpose of this effort is to demonstrate and evaluate various ATDM scenarios, plans, and combinations of strategies to quantify the benefits of ATDM. The evaluation will focus on the dynamic nature of all strategy combinations.



Track 1: Develop an ATDM Operational Concept

Research Accomplishments

- Initial foundational research started in October of 2010 and has established a high-level Concept of Operations and requirements.
- With these results, an initial stakeholder workshop was held in Virginia in April 2011.
- A final draft of an Operational Concept was submitted to the US DOT in December 2011.
- A final stakeholder review of the Operational Concept was conducted in February 2012 in conjunction with the stakeholder review for the DMA INFLO research.

Critical Research Insights

- None to date.

Next Steps

- ➔ The US DOT is reviewing the Operational Concept.

Track 2: Identify ATDM Operational Requirements

Research Accomplishments

- ATDM methodologies for the Highway Capacity Manual (HCM) have been drafted.
- Three stakeholder workshops have been conducted to review HCM proposed changes. The workshops were held in Washington DC, Chicago, Illinois, and San Francisco, California.
- Data collection for safety impacts of shoulder use is underway.
- Input has been provided to the Office of Operations Planning. These inputs include benefit-cost guidance and Designing for Operations guidance.

Next Steps

- ➔ Conduct analysis, modeling, and simulation of shoulder use.
- ➔ Develop decision support requirements for varying degrees of ATDM.

Track 3: ATDM Analysis, Modeling, and Simulation Test Bed Development

Research Accomplishments

- In support of the modeling and simulation efforts, twelve bundles have been developed.

Next Steps

- ➔ Develop a draft ATDM AMS framework and methodology
- ➔ Perform test bed planning
- ➔ Once test beds are operational, conduct demonstrations and evaluations

Track 4: Operational Tests

Research Accomplishments

- Not yet launched.



Commercial Vehicle Information Systems and Networks (CVISN) Core and Expanded Deployment Program ...

... is a collection of information systems and communications networks that are owned and operated by governments, motor carriers, and other stakeholders that support commercial vehicle operations (CVO).

The vision for this program is to implement Core CVISN and Expanded CVISN to improve the safety and productivity of motor carriers and their drivers and reduce regulatory and administrative costs for public- and private-sector stakeholders through improved data sharing, electronic credentialing, and targeted automated screenings and enforcement of high-risk carriers at the roadside.

Research Plan

Led by the FMCSA, CVISN is a framework or “architecture” that assists transportation agencies, motor carrier organizations, and other stakeholders in planning and deploying integrated networks and systems. Use of the CVISN Architecture for planning and deployment enables agencies and the motor carrier industry to integrate systems to share data. Working together in this manner greatly leverages the capability of the individual systems, allowing agencies and firms to accomplish more than they could independently in a more cost-effective and timely manner.

As a flexible framework, CVISN allows FMCSA the ability to ensure that technological advances, updates to the National ITS Architecture, and other research that might impact motor carriers are considered and incorporated. There are two levels of CVISN functionality for states and motor carrier firms:

- ▶ Core CVISN functionality provides specific capabilities in three areas:
 - Safety information exchange
 - Electronic credentialing
 - Electronic screening
- ▶ Expanded CVISN leverages the functionality of the Core CVISN systems to provide further capabilities for:
 - Driver information sharing
 - Enhanced safety information sharing and data quality
 - Smart roadside
 - Expanded electronic credentialing.

The objective of this research program is to support FMCSA in continuing the grant funding and oversight that has facilitated progress in deploying CVISN applications in 50 states and the District of Columbia. This partnership between the ITS JPO and FMCSA to fund and coordinate CVISN with the National ITS Architecture was established in previous legislation. Although the program is well on its way to meeting its stated goals, the funding will be continued through the new authorization when it is anticipated that the funding responsibility for the CVISN Architecture

Research Goals:

To effectively facilitate the seamless exchange of critical information in support of efficient commercial vehicle operations (e.g., information on safety, credentials, and tax administration).

Research Outcomes:

To ensure deployment of Core and Expanded CVISN in support of the Smart Roadside program and a host of other information exchanges that improve motor carrier safety, identify inspection priorities, and create operational efficiencies that enable carriers to save time and money and can assure more timely delivery of cargo.

will be ceded to FMCSA. Until that transition, the key elements of this effort will include:

- ▶ Support for deployment of Core and Expanded CVISN capabilities;
- ▶ Support for the ITS/CVO CVISN Program; and
- ▶ Technical support for ITS/CVO training and CVISN Deployment Workshops.

2012 SNAPSHOT OF PROGRESS

CVISN Core Deployment Status

Research Accomplishments

- 50 states plus the District of Columbia (DC) are deploying Core CVISN Functionality.
- 28 states have achieved certification toward Core CVISN Compliance.
- Safety Information Exchange Deployment:
 - 50 states plus DC have deployed FMCSA's Aspen inspection software or equivalent
 - 33 states are uploading data via FMCSA's Safety and Electronic Fitness Records (SAFER) system
 - 33 states are using Commercial Vehicle Information Exchange Window (CVIEW) or equivalent to upload/download data
- Credentials Administration Deployment:
 - 41 states are uploading International Registration Plan (IRP) data
 - 48 states are participating in the IRP Clearinghouse
 - 37 states are uploading International Fuel Tax Agreement (IFTA) data
 - 48 states are participating in the IFTA Clearinghouse
- Electronic Screening Deployment:
 - 40 states have implemented E-Screening

Critical Research Insights

- ⊗ It is highly beneficial for planning and deployment agencies and the motor carrier industry to integrate systems to share data; working together in this manner greatly leverages the capabilities of the individual systems.

Next Steps

- ➔ Continue to provide CVISN grant funding and support to assist all states to reach Core CVISN Compliance by FY 2015.



Intelligent and Efficient Border Crossings ...

... are ITS applications that use variable toll pricing, advanced traveler information systems, electronic screening, and other technologies to improve safety and mobility, reduce emissions, and improve security at our nation's borders.

The vision for the research on Intelligent and Efficient Border Crossings is to enable the implementation of innovative ITS solutions for a bi-national border system that ultimately improve safety and mobility, reduce emissions, and facilitate trade and travel without compromising the vital mission of securing America's borders.

Research Plan

The Intelligent and Efficient Border Crossings project is a joint modal initiative between the ITS JPO, FHWA, and FMCSA that focuses on using ITS to create safer, less congested, and more environmentally-sustainable border crossings. It encompasses the International Border Program.

The research under this initiative is two-fold, with emphasis on both Southern and Northern Borders:

- At a U.S.-Mexican border site, the Department will collaborate on and support the development of a plan for a tolling system that can accommodate dynamic pricing at the border. Currently, Caltrans, the San Diego Association of Governments (SANDAG), and Mexican agencies are planning a third border crossing to reduce delays caused by traffic congestion, better accommodate projected trade and travel demand, and increase economic growth and job opportunities on both sides of the border without sacrificing border safety and security. This opportunity allows all parties involved to plan a holistic approach to ITS at the new border crossing that enables a "Clean, Green, and Smart Border." The ITS components/areas included in this research are: electronic toll collection systems, border wait-time monitoring systems, variable pricing of tolls to reduce wait times, enhanced border security systems, and advanced traveler information systems. It will be the first North American international land border crossing

Research Goals:

To implement and evaluate bi-national systems at border crossings.

Research Outcomes:

The deliverables and results of the research will contribute to the overall ITS-driven model for safer, smarter, and more environmentally friendly border crossing systems.



Image: ©StockPhoto.com/Trevor Smith

project that proposes the use of non-traditional transportation project financing to improve capacity and operation of an international land border crossing.

A key aspect of this research initiative is to examine and develop marketing strategies such as discounting for lower emission trucks (promoting a green border); advance toll payment (pre-payment discounting); and guaranteed usage, as well as to determine what ITS and technology are needed to implement these strategies. If this research is not undertaken, no model will exist to encourage other border crossing regions to consider innovative financing and solutions to border infrastructure and operations issues.

The initiative, referred to as the "ITS Pre-deployment Strategy for the tolled Otay Mesa East (OME) New Border Crossing" started in October 2011. One of the most necessary components, a strong bi-national approach with our partners in Mexico, has been established. Four project research tasks have been completed and reports are available.

- At a U.S.-Canadian border site, the US DOT will support the development of a detailed plan for implementing the International Border Crossing - Electronic Screening System (IBC E-Screening) for trucks, motor coaches, and buses. IBC E-Screening is an alert-based system expediting the safe and legal flow of freight and passengers across northern and southern U.S. borders while targeting unsafe operations.

The IBC E-Screening component of this project leverages investment in the FMCSA Query Central-to-Customs and Border Protection's Automated Commercial Environment/ International Trade Data System (QC-ACE/ITDS) to provide an automated, data-driven approach to selection of vehicles for inspection at the border.

This system enables uniform and consistent application of policies and procedures related to safety and compliance assurance of cross-border commercial traffic. The data will be augmented to include verification of more than 20 additional screening factors, and enable identification and full safety/compliance verification of carriers, trucks, trailers, and drivers electronically, within three seconds or less of a truck's presentation at the processing point rather than the current 15 minute manual process. Additionally, at this second site, research will center on the implementation of IBC E-Screening to assess the feasibility of reducing large truck crashes using an automated tool. This tool has several functions:

- Electronically identifies the carrier, truck, trailer and driver data associated with commercial truck trips entering the U.S. at land ports through the use of radio frequency identification (RFID) which exists on approximately 90 percent of trucks;
- Electronically screens each trip component for factors of interest to state and FMCSA inspectors, providing for full safety and compliance verification of carriers, trucks, trailers, and drivers, each time they enter the U.S.;
- Displays screening results to state and FMCSA enforcement officers and inspectors to assist them in making more informed inspection selection decisions in fixed and mobile operations, and mainline and ramp settings, significantly increasing the efficiency and effectiveness of their operations; and
- Enables data monitoring/reporting by states and FMCSA to better position each organization to fulfill its mission.

At both sites, FHWA and FMCSA will research the use of DSRC (5.9 GHz) technologies and determine how implementation might maximize opportunities to work with Canada and Mexico on the potential to improve safety and operations in border regions. Although these two projects are managed separately, the research is pursued along similar tracks:

Track 1: State of the Practice Technology Review: This track is examining different practices around the world to identify which are most effective. Analysis will produce recommendations regarding deployment and selection of technologies and applications.



Track 2: Market Assessment: Research is being conducted to understand customer perspectives and institutional issues to ensure coordinated and interoperable deployment that meets the needs of all entities involved.

Track 3: Operational Concepts: Based on customer requirements, a set of operational frameworks will be developed and offered for public review and feedback from customers. The resulting operational concepts will guide deployment.

Track 4: Applying Technology Solutions at the Border: With operational concepts developed, research will be done to establish performance requirements and conduct field operational tests.

2012 SNAPSHOT OF PROGRESS

State of the Practice Technology Review

Research Accomplishments

- Analyzed practices, relevant technologies and institutional arrangements for border crossing and bi-national tolling projects. Scan Report generated.
- Examined specific project elements in Mexico that will need to interface with the Otay Mesa East Point of Entry.

Critical Research Insights

- ◊ Matched possible ITS and border system applications with suitable technologies for the new Points of Entry.
- ◊ Developed recommendations regarding ITS deployment and selection of technology for specific applications and ITS goals aligned with the goals of the project.
- ◊ Developed a series of seven potential ITS applications for introduction to key Point of Entry stakeholders including Customs And Border Protection (CBP) and General Services Administration (GSA).

Next Steps

- ➔ Development of the ConOps, detailed design, and implementation of ITS components and functions.

Market Assessment

Research Accomplishments

- Identified potential customer profiles of the Otay Mesa East Point of Entry and how they may use this new POE in conjunction with the existing San Diego-Tijuana Points of Entry.
- Conducted interviews with potential future users of the Otay Mesa East Point of Entry to gain an initial understanding of customers' perspectives.
- Engaged commercial goods movement groups and existing border crossing interests to better understand existing concerns and introduce the concept of the new Points of Entry.
- Coordinated customer interviews and profile development with parallel Traffic and Revenue Team to ensure consistency.

Critical Research Insights

- Developed a high-level overview of border operational characteristics, goods movement, socioeconomic, industry and other trends impacting future Points of Entry in the San Diego-Tijuana region.

Next Steps

- ➔ Proposed goals and plan for the "Envisioning the Border" Stakeholder Workshop will be developed.

Operational Concepts

Research Accomplishments

- Developed Initial System Concept and Preliminary Business Objectives as a starting point for broader input from the entire group of project stakeholders.
- Established an initial tolling concept that addresses different approaches to methods of payment, pricing strategy, institutional arrangements, toll points, and enforcement.
- Introduced seven ITS concepts to regional CBP stakeholders including methods for: wait time detection, enhanced traffic management, enhanced lane management, border traveler information, border crossing data enhancement options for resource prediction, etc.

Critical Research Insights

- Introduced five preliminary operational frameworks which were narrowed to three and then one preferred framework. This preferred framework includes toll locations, pricing considerations, institutional assumptions, and ITS options. The framework received direct input and feedback to gain consensus with Mexico's Secretariat for Communications and Transportation.
- Incorporated valuable feedback from stakeholders into preliminary operational concepts.

Next Steps

- ➔ Continue to use the preferred operational framework as the "placeholder" for on-going operations discussions and decisions.
- ➔ Develop the ConOps.
- ➔ Establish business rules between project stakeholders.

Applying Technology Solutions at the Border

Research Accomplishments

- Field operations test of technology to improve safety and efficiency for FMCSA and state safety inspectors at the border.
- Deliverables planned:
 - E-screening system deployed at three border crossing sites (Ysleta, Texas; Nogales, Arizona; and New York State).
 - Technical documents, software, system performance data.
 - Final report summarizing system operations and effectiveness.

Critical Research Insights

- Kick-off meeting and project work plan completed.



Next Steps

- ➔ Develop the ConOps, establish performance requirements, and install equipment for a field operational test.
- ➔ Conduct field operations test in late fall 2013.
- ➔ Prepare final report for June 2014.

ITS Exploratory Research



ITS Exploratory Research ...

... is intended to provide an avenue to solicit creative ideas for new technology options that warrant further attention and that further the ITS Strategic Research Plan goals for the next 5 years.

The ITS Program recognizes that technology evolves rapidly and that the community is filled with new, creative ideas for approaches to connectivity, safety, mobility, and environmental mitigation. While the research programs described in this document will lead to solid benefits, these are not the only areas of research with potential.

Research Plan

The vision of ITS Exploratory Research is to leverage new ideas and incorporate the new "Challenge" concept to get citizens interested in finding innovative options and solutions for government. From 2010 to 2012, four activities have comprised the Exploratory Research portfolio:

The vision of ITS Exploratory Research is to harness the creativity of a broad public audience and leverage those capabilities to find innovative options and solutions for government. Three activities comprise the Exploratory Research portfolio:

- ▶ **Technology Scan**
- ▶ **Innovation Challenges**
 - Connected Vehicle Technology Challenge 2011
 - Video Challenge 2011
- ▶ **Exploratory Research on Future Initiatives**

Technology Scan

With partners in industry, the ITS JPO is exploring a number of emerging trends that will impact the future of connected vehicle development and deployment. For instance, electric vehicles are gaining in popularity because of motorists' growing recognition of the negative effects of GHGs and pollution, and the cost of petroleum based fuels. In addition, automated cars have the potential to become an important part of the nation's automobile inventory in the future because of the Defense Advanced Research Projects Agency's (DARPA) success in advancing technology vehicles and other recent advancements.⁵⁶

In 2011, the ITS JPO partnered with ITS America to develop a series of forward-thinking research papers called the *Technology Scan*. This scan takes an in-depth look at evolving technologies that have the potential to impact the development of connected vehicles. The Technology Scan is examining trends such as:

- ▶ **Navigation, ranging, and computer vision-based object detection sensors:** Along with innovations such as sensor fusion and processing algorithms, this technology will exploit a wealth of information that may support future connected vehicle collision avoidance or mobility applications.
- ▶ **Computer vision:** This technology has been used in highway infrastructure for many years, and it could become as common as GPS as a data acquisition platform on vehicles.
- ▶ **Fourth-Generation (4G) wireless networks:** 4G will likely become "application-aware," intelligently supporting critical "off-board" or "cloud-based" ITS applications such as automated collision notification. Future, advanced 4G systems may be able to establish and manage communication sessions that hop between many wireless nodes (e.g., 4G, WiFi, DSRC) in a coordinated fashion. This concept is known as heterogeneous or "vertical" roaming, operating based on application needs such as coverage availability and cost.

⁵⁶ For instance, like the Google self-driving car. See article at http://news.cnet.com/8301-11386_3-57406639-76/google-self-driving-car-chauffeurs-legally-blind-man.

- ▶ **Telematics:** Often referred to as machine-to-machine applications, this technology may evolve to enable pooling of resources, allowing any sensor to be securely addressable and accessible to any ITS application service.

In addition, the *Technology Scan* will highlight particular risks or uncertainties that are broadly understood to impact a number of sectors, not just transportation. They include global innovations in computing, the design of secure systems, and the development of the "smart grid" and leveraging that system to improve vehicle safety, mobility, and environmental sustainability.

Innovation Challenges

The objective of RITA in initiating the use of challenges was to engage a third party or parties in identifying innovative solutions for improving safety and efficiency on roads and highways. Challenges range from fairly simple ideas and suggestions, and creation of logos, videos, digital games and mobile applications to proofs of concept, designs, or finished products. In his September 2009 Strategy for American Innovation, President Obama called on agencies to increase their ability to promote innovation by using tools such as prizes and challenges to solve tough problems. Through its challenges, the US DOT will endeavor to develop innovative, actionable ideas and to connect inventors with potential partners – businesses and investors – that might help bring new ideas to life.

From 2010–2012, RITA and the ITS Joint Program Office hosted two challenges:

- ▶ The Connected Vehicle Technology Challenge to explore new ideas for DSRC; and
- ▶ The ITS Video Challenge to promote the benefits of proven ITS deployments.

The next two pages describe the results of these two challenges.

Connected Vehicle Technology Challenge – 2011

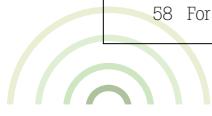
In January 2011, the ITS JPO initiated a competition that provided an opportunity for the public to identify creative uses for DSRC, an advanced wireless technology. The first of its kind, the ITS JPO hosted the Connected Vehicle Technology Challenge (CVTC), which was an exploratory research initiative aimed at finding realistic ways to use DSRC⁵⁷ technology to improve transportation safety, mobility, and environmental benefits. Problem solvers were asked to share their ideas about the potential uses of dedicated short-range wireless communications. The main goal of the challenge was to engage entrepreneurs, citizens, and students in finding innovative methods for improving and accelerating the adoption of DSRC by industry and the traveling public.

The challenge solicited short descriptions of innovative, implementable ideas for products or approaches that use DSRC to provide benefits to travelers and the general public. A total of 76 submissions were received, of which 58 met the criteria to be fully evaluated. A US DOT panel selected five entries, while the sixth winning entry received the most votes from registrants on the competition website.⁵⁸ On August 1, 2011, RITA announced the six winners which included research into the following:

- ▶ **Robust GPS: Enhancing Accuracy and Security Using DSRC.** Using DSRC signals on board vehicles to improve weakened positioning information and to correct illegally "jammed" GPS signals. This enables DSRC-equipped vehicles to automatically correct the GPS positioning of other similarly equipped vehicles.
- ▶ **Using DSRC Signals for Improving Vehicle Position Estimates.** A position-estimating system that blends inputs from GPS and DSRC links to roadways to improve location measurements. A GPS-equipped vehicle would be able to determine its location to within 1 meter by communicating with devices embedded in the roads.
- ▶ **Emergency Response Application of DSRC Technology.** A real-time accident awareness system that accelerates emergency response and assists with traffic management. Vehicles in accidents automatically inform emergency responders and traffic management centers.

⁵⁷ For information about DSRC, please visit: http://www.standards.its.dot.gov/Documents/advisories/dsrc_advisory.pdf and <http://connectedvehicle.challenge.gov/details/understanding-dsrc>.

⁵⁸ For additional information, please visit: <http://connectedvehicle.challenge.gov/>.



- ▶ **Connected Vehicle Proactive Driving.** A driver guidance system that collects and uses accident locations and types to help drivers choose safer routes. For example, a driver is alerted to an upcoming intersection with frequent rear-end accidents and has the option of choosing an alternate route.
- ▶ **Pollution Credit Trading in Vehicle Ad Hoc Networks.** An automated system for trading pollution credits among vehicles in which the level of pollution allowed per vehicle is capped and credits are given to less-polluting vehicles. A low emissions vehicle can accumulate credits that it automatically sells to a higher emissions vehicle.
- ▶ **Integrated Intelligent Transportation Platform.** A system that enables a vehicle to help with trip and day scheduling, from choosing a route to reserving a parking space.

Notably, two of these entries also present thoughtful solutions to the essential problem of imprecision in current GPS data, such data being the foundation of many connected vehicle applications.

ITS Video Challenge – 2011

The ITS Video Challenge was an initiative of the US DOT/RITA, FHWA, and FTA that was intended to highlight the deployment and benefits of proven ITS technologies around the country through videos produced and submitted by individuals, teams of individuals, corporations, and nonprofit organizations.

For this challenge, RITA solicited original videos of ITS technologies being implemented by state and local governments, transit agencies, private firms, and students that highlighted smart technologies. As part of the requirements, each video had to demonstrate the benefits of ITS technology in a local community. Each video was also required to feature an example of ITS deployment in the transportation field, which could include applications for motorists, pedestrians, bicyclists, transit, and freight vehicles, or any combination.

Twenty-four entries were considered from 19 different state DOTs, local transportation agencies, universities, and private firms. The submitted videos ranged from pedestrian and bicycle safety, traffic signal coordination, traveler information, teen driver safety dynamic curve warnings, and ITS careers, among others. The winning video submission came from a team of ITS professionals at the Charlotte, North Carolina Department of Transportation, and was titled *Bicycle Detection at Signalized Intersections*.⁵⁹ The team's video was featured at the 18th Annual World Congress on Intelligent Transportation Systems in Orlando, Florida in October 2011.

Exploratory Research on Future Initiatives

Technologies and systems will continue to evolve. The emergence of each next generation of innovations brings the potential for safer, more optimal and effective, vehicle-based systems. The role of the ITS Program is to provide leadership in researching these new opportunities with the objective of analyzing which offer the most viable potential for improving safety, above all else, as well as mobility, environmental performance, and other functions that are a priority for the US DOT. Inherent in this research is the challenge to boldly envision the future and identify the new high-risk/high-reward research concepts that present greater opportunities to transform our world for the better.

Using results from the technology scans and challenges, the ITS Program has identified two emerging opportunities for future pursuit: automated vehicles and robotics and electric vehicles.

Automated Vehicles and Robotics: An important trend on the horizon is the introduction of automated vehicles using robotics that are not yet proven within a transportation environment. It is estimated that each automotive manufacturer is developing its own version of a self-driving vehicle in partnership with leading technology and academic laboratories.⁶⁰

59 To view the winning video submission, please visit: http://www.youtube.com/watch?v=iF3J6Z_oXyU.

60 As noted in article, "Let the Robot Drive: The Autonomous Car of the Future is Here," in *Wired Magazine*, February 2012, pp. 86 – 124, by Tom Vanderbilt.

As industry is leading the research to address the technical challenges, the US DOT will need to keep pace with providing the regulatory and policy frameworks that can accommodate the safe and beneficial introduction of these new innovations. Recent incidents associated with unintended acceleration reveal the growing complexity associated with computer-based, advanced technologies and the human capacity to understand and employ them safely. These insights provide a critical understanding that successful automated systems and technologies⁶¹ require an optimal balance in decision making and control between humans and machines. While human-to-machine and machine-to-machine systems and robotics are providing new capabilities in complex decision making, the challenge for transportation in capturing these benefits requires exploring whether these new technology concepts can deliver safer and more effective driver decisions without distraction (similar to the systems used by aviation), or whether there exist any effective points at which transitioning the human from decision making and control makes sense.

Other newsworthy items note the growing capability for cyber-attacks and other security vulnerabilities to potentially open the vehicle to new threats. Additionally, cost will be a critical issue — while automated vehicles have the ability to address additional crash-scenarios beyond the connected vehicle capability, these functions are accomplished using a breadth of sophisticated new systems that integrate radar, stereo-vision systems, cameras, powerful algorithms, and other components.

As a result of these trends, the US DOT anticipates a forthcoming set of roles in setting a research agenda, facilitating industry and academia to identify best practices and innovation solutions, and to provide oversight needed to ensure that the goals of safety and security are met. To launch research in this area, near-term efforts for the ITS Program and its modal partners will include:

- ▶ Identifying and addressing the key policy and technical implementation issues such as fail-safe strategies and driver override concepts; or infrastructure modifications that will be necessary to support various levels of automation. Equally as critical will be the economic, regulatory, liability, and institutional and legal issues that impact the potential successful deployment of increasingly automated vehicles.
- ▶ Transferring lessons learned from connected vehicle research that provide critical insight into the types of opportunities and challenges that will be faced when applying automation concepts to transportation. Connected vehicle research has illuminated the critical gaps in reliability, standards, security, and human factors that will be needed when pursuing automated technologies.

Electric Vehicles: New vehicle designs that incorporate circuit boards and modular components are emerging on the market through the development of electric vehicles. The result is a vehicle design that more elegantly supports the data needs of connected vehicle technologies and applications and produces higher quality vehicle data. To launch research in this area, the ITS Program and its modal partners will:

- ▶ Study and exploit the synergies between connected vehicle research and electric vehicles; and
- ▶ Leverage AERIS research results on how real-time data and sensing capabilities might transform the manner in which the vehicle utilizes energy and fuel.

⁶¹ Note the recent, fully automated vehicle introduced by private industry in 2011. See references such as: <http://blogs.wsg.com/speak-easy/2010/10/12/googles-robot-cars-a-coming-out-for-automated-vehicles/> or <http://googleblog.blogspot.com/2010/10/what-were-driving-at.html>.



Collaboration with Small Business Innovation Research (SBIR) Program

In 2011–2012, the ITS Program has had the opportunity to collaborate on concept research. This research is exploring the provision of information and/or alerts to pedestrians and cyclists to mitigate certain crash events. Known as the "Smartphone Signal Alert Status," the purpose of this research is to develop applications that can operate on a variety of platforms (e.g., iPhone, Android, or Blackberry, among others), enabling pedestrians and cyclists to receive information about traffic signal status for intersections that the user is anticipated to enter.

This research will build upon commercial technology that is capable of detecting the traffic signal status and placing that information on the Internet. To do so, the smartphone application will need to be capable of determining a user's position, know the signal phase that the user will encounter upon reaching the intersection, and understand the geometric design of the intersection that the user will enter.

This research is moving forward with the concept development phase completed and a prototype development phase under consideration.*

* More information available at: <http://www.volpe.dot.gov/sbir/sol11/topicsfull.html#111-fh1>.

ITS Cross-Cutting Support



ITS Cross-Cutting Support

The ITS Program's Cross-Cutting Support are those functions that ensure the effective and successful implementation and use of ITS. These programs are the mechanism through which the ITS Program directly gathers and assesses the data on ITS needs; they are also the ITS Program's mechanisms for ensuring that implementers understand both the value of ITS and the uses for ITS technologies, systems, models, and strategies that are produced through the research initiatives. From 2010 to 2014, the ITS Program is providing five cross-cutting programs in support of ITS modal research:

- ▶ National ITS Architecture.
- ▶ ITS Professional Capacity Building.
- ▶ ITS Evaluation.
- ▶ International Collaboration on ITS Research.
- ▶ ITS Outreach and Communications.

National ITS Architecture ...

... provides a definitive and consistent framework to guide the planning and deployment of ITS. The program facilitates the ability of jurisdictions to operate collaboratively and to harness the benefits of a regional approach to transportation challenges.

The vision for the National ITS Architecture program is to continue the evolution of the architecture to incorporate technological developments and evolving user needs with a particular focus on connected vehicle requirements. The program will also provide deployment support for public agencies to assist with development, maintenance, and improvement of their regional ITS architectures along with compliance with applicable FHWA regulations.

Program Management Plan

From 2010 to 2014, the primary focus of the National ITS Architecture program is on the following efforts:

Track 1: Maintenance of the National ITS Architecture: This track is focused on activities to:

- ▶ Support and manage the evolution of the National ITS Architecture (including changes due to deployment experiences, changes in requirements, and changes due to results from public and private sector ITS research programs);
- ▶ Assist the US DOT policy makers in defining policy consistent with the National ITS Architecture, existing legislation (currently, SAFETEA-LU), and application regulations, including the "Architecture Rule" (23 CFR part 940);
- ▶ Maintain and upgrade the Turbo Architecture tool; and
- ▶ Support mapping of the ITS standards to the National ITS Architecture and participate in international ITS standards and architecture harmonization activities.

Track 2: Deployment Support: Activities in this track are focused on providing ITS deployment support during the transportation planning processes at the State, regional, and metropolitan planning organization (MPO) levels (and, on occasion, at the local level); provide technical support and training in the architecture and systems engineering process; and promote and facilitate the use of the National ITS Architecture among Federal, State, local, and private sector planners, implementers, integrators, and manufacturers.

Track 3: Border Architecture Coordination: This track focuses on continued technical support to ITS architecture activities along the United States and Canada border and, to the extent possible, future ITS architecture activities along the United States and Mexico border.

Track 4: Development of a V2V and V2I (V2X) Cooperative Systems Architecture: Activities in this track focus on the development of the V2X cooperative systems architecture using a systems engineering process. Activities also include integrating this architecture with the existing National ITS Architecture and maintaining, upgrading, and enhancing the functionality of this new section over time, as well as participating in international harmonization of V2X architectures in Europe, Japan, and other countries, as appropriate.



National ITS Architecture

Track 1: Maintenance of the National ITS Architecture

Research Accomplishments

- Published Version 7.0 of the National ITS Architecture, which incorporated functionality and interfaces to align with the Connected Vehicle Environment, ATDM strategies, Electronic Freight Manifest, and Integrated Corridor Management as well as other updates including ITS standards alignment. This version also incorporates CVISN Wireless Roadside Inspection and transportation planning features in addition to ITS standards developments and other updates.
- Developed and released two updates to the Turbo Architecture software tool (versions 5.0 and 7.0). Turbo is a software application that supports development of regional and project ITS architectures using the National ITS Architecture as a reference. The updates included the addition of features to directly link a region's ITS architecture to their transportation planning objectives, strategies, and needs, thereby aligning the regional ITS architecture with the planning process. The updates also include features that make it easier to produce user-friendly documentation and web pages.

Critical Research Insights

- ⦿ Alignment of the National ITS Architecture definition with current US DOT initiatives and research outcomes relates these activities more directly to the interests of state and local stakeholders for incorporation into ITS planning.
- ⦿ Regional stakeholders are able to leverage the results of US DOT initiatives by incorporating those features in their regional ITS architectures, thereby expanding the reach of these initiatives.

Next Steps

- ➔ Expand linkages and support for the use of ITS architecture among transportation planners.

Track 2: Deployment Support

Research Accomplishments

- Provided technical assistance to State, regional, and local stakeholders in the areas of ITS architecture development, implementation, and systems engineering.
- Conducted 23 workshops and process reviews for state and regional stakeholders including Regional Architecture and Systems Engineering Process Improvement Reviews, and ITS Architecture Use and Maintenance Workshops throughout the country to assist regional agencies with the incorporation of ITS architecture and systems engineering in their transportation project planning and development processes.
- Developed a new ITS Architecture "Quick-Start" workshop for regions that are initiating an update to an older regional ITS architecture to maximize their update efficiency. Eight "Quick Start" workshops have been conducted.
- Developed a web-based version of the Turbo Architecture software training course to make it available to more stakeholders and improve course delivery efficiency.

Critical Research Insights

- Supported an increasing number of regional ITS architecture updates to better reflect the evolving needs of the regional stakeholders regarding ITS development/deployment.
- Continued evolution of regional stakeholders' attitudes to looking at their regional ITS architectures less as a requirement from Rule 940.09 and more as a tool to assist with ITS planning and project development.
- Expanded the number of agencies reexamining their transportation planning and project development processes to better consider ITS projects and how they are best integrated into transportation systems.

Next Steps

- ➔ Promote, support, and develop tools and capabilities for using regional ITS architectures during the project scoping and project programming/transportation improvement program development.
- ➔ Expand support to transportation planners to assist with their application of ITS architecture in their planning activities and to better link transportation operations to transportation planning.
- ➔ Update Regional ITS Architecture and Systems Engineering guidance documents to reflect the latest developments and practices in ITS project planning and development.
- ➔ Develop additional web-based training materials to support Use and Maintenance of ITS Architectures and Systems Engineering.

Track 3: Border Architecture Coordination

Research Accomplishments

- ☒ Updated U.S./Canadian Border Information Flow Architecture (BIFA) to maintain synchronization with both the U.S. National ITS Architecture and the ITS Architecture for Canada.
- ☒ Supported FHWA's Border Wait Times project in developing a project ITS architecture to identify key interfaces among border agencies.

Critical Research Insights

- Regions along the U.S./Canadian border are updating their regional ITS architectures and deployment plans to include cross-border systems and interfaces defined in the Border Information Flow Architecture.
- Increased interest among all border regions to find ways to collaborate and develop integrated solutions supported by common ITS architectures.

Next Steps

- ➔ Provide ITS architecture and systems engineering support for ITS project definition along the Canadian and Mexican borders including project and regional support for land, marine, and air entry points.
- ➔ Develop and conduct a series of workshops with border stakeholders to support border ITS projects and the modification or development of ITS architectures at those sites to support the deployment of cross-border systems.
- ➔ Identify common data schemas for interfaces related to the sharing of border information.



Track 4: Development of a V2X Cooperative Systems Architecture

Research Accomplishments

- Defined the ConOps, System Requirements, and Architecture for the Core System required to support the connected vehicle program that supports V2X cooperative systems. This systems architecture encapsulates the enterprise, functional, connectivity, communications, and information viewpoints that describe the security services and data sharing services necessary to support the overall Connected Vehicle Environment (see pages 119–122).

Critical Research Insights

- Stakeholders in both public and private sectors are considering the Core System concepts in developing and testing interoperable systems and in defining the governance structures needed to foster deployment.

Next Steps

- ➔ Adaptation of National ITS Architecture and Turbo Architecture software to support V2X Cooperative Systems.
- ➔ Development of outreach and guidance materials to promote deployment of integrated, secure V2X Cooperative Systems.
- ➔ Development of a reference interface architecture to support identification and prioritization of candidate interfaces for standardization and/or international harmonization.

ITS Professional Capacity Building (PCB) ...

... is the US DOT's primary vehicle for educating the current and emerging transportation workforce about ITS technologies. The PCB program connects ITS practitioners and decision makers with researchers, educators and trainers, and peers to advance the state of ITS practice.

The vision of the ITS PCB program is to develop an ITS profession that leads the world in the innovative use of ITS technologies. This vision is comprised of four core components: collaboration, innovative thinking, a customer-focused strategy, and a results-driven approach.

Program Management Plan

From 2010 to 2014, the primary focus of the ITS PCB program is on building ITS professional capacity and developing the future ITS workforce. The program seeks to leverage the most engaging and effective learning platforms to deliver the latest in best practices in ITS research results to targeted audiences. The program supports activities that deliver multimodal ITS learning opportunities to the ITS community by:

- ▶ Promoting knowledge sharing of best practices;
- ▶ Providing technical assistance to ITS deployers through ITS Peer-to- Peer (P2P) and Talking Technology and Transportation (T3) webinar programs; and
- ▶ Delivering ITS training through partners.

A set of core components provide a basis for the program's four interrelated goal areas:

1. Professional Development, which seeks to equip current and emerging ITS professionals with the knowledge, skills, and abilities to plan, design, deploy, operate, and maintain ITS Technologies;
2. Leadership Outreach which includes the development of a network of champions who promote the value of ITS;
3. Knowledge Exchange to facilitate the exchange of knowledge through innovative PCB solutions; and
4. Technology Transfer to accelerate technology transfer to bring ITS research and proven solutions to the user community.

Put into action, the four components and goal areas support a strategic approach for program delivery that seeks to connect partners, accelerate the adoption of ITS technologies, deliver learning in the most effective and engaging manner, and continuously evaluate the program for maximum impact.



ITS Professional Capacity Building

Goal 1: Professional Development

Research Accomplishments

- From 2010 to 2012, the ITS PCB program delivered professional development by:
 - Analyzing audience needs to better target specific groups of ITS practitioners and decision makers.
 - Delivering and archiving T3 webinars.⁶²
 - Sponsoring peer exchanges and partnering with professional associations to provide local in-person training and interactive online training courses.
 - Developing online ITS Standards Training modules (18 are available as of January 2012).
- Over 2,500 transportation professionals were reached in 2011.
- Delivered 6 training sessions to state chapter meetings of ITS America.
- Delivered briefings to the ITS World Congress.
- Conducted webinar to train end users on the updated resources.

Critical Research Insights

- Professional development activities continue to remain an important element of the PCB program. Feedback from the ITS community has identified that easily accessible, online training is a priority.

Next Steps

- ➔ Further develop University Strategy, with the goal of piloting one to two programs to facilitate ITS teaching in the academic environment in 2012.
- ➔ Expand ITS Standards Training; 19 additional modules to be available by January 2013.
- ➔ New course development underway.

Goal 2: Leadership Outreach

Research Accomplishments

- The US DOT promoted greater stakeholder engagement via the following:
 - ITS PCB Program Strategic Visioning Session, held July 7, 2010, with leaders of the program and representatives from key stakeholder groups.
 - Four user workshops, held summer/fall 2010, with multimodal practitioners and decision makers from the public and private sector, professional associations, and others. Special session held for university instructors and researchers.
- Obtained consensus about the need to develop P2P network of model users to build the capacity of future leaders.

⁶² A list of current and future webinars is located at: <http://www.pcb.its.dot.gov>. This site also contains archived presentations.

- Partnered with National Transportation Operations Coalition to provide workshops for potential model users.
- Collaborated on first-ever student day at 2011 ITS World Congress, where students met with ITS leaders.

Critical Research Insights

- ⦿ Stakeholder outreach has resulted in a critical dialogue regarding the most effective means of delivering learning and transferring technologies to the ITS community. Through these efforts, it has been recognized that highly successful ITS deployment is typically led by a local champion who has both the vision and knowledge to facilitate local efforts. Based on this understanding, new PCB efforts are being developed to better develop and support champions.

Next Steps

- ➔ Identify 5 to 6 ITS champions for pilot videos to be produced in 2012 to 2013.
- ➔ Continue to provide student leadership opportunities.

Goal 3: Knowledge Exchange

Research Accomplishments

- Began a dialogue on the future of the PCB program through public comment on the strategic plan, *ITS Professional Capacity Building: Setting Strategic Direction 2010–2014*.⁶³
- Undertook redesign of the website with the goal of providing an ITS learning portal for one-stop shopping for courses, technical assistance, technology transfer, and P2P events. This effort included an improved search capability of the T3 Archives and the addition of an ITS for Students section.
- Planned for *ITS ePrimer*, an online handbook incorporating multimedia examples that provide information about currently deployed ITS technologies and connected vehicles (available in 2013).
- Proposed PCB Video Library to expand knowledge of existing and emerging ITS technologies in an engaging format.
- Integrated T3 Archive with the *ITS Knowledge Resources Databases*. Databases offer a unique collection of reports, studies, technical documents, and instructional guides for planning, procuring, and deploying ITS.

Critical Research Insights

- ⦿ New learning technologies offer new and innovation solutions for providing on-the-job learning and learning-as-needed. The ITS PCB program is working with the ITS community to identify how to leverage existing programs, such as the T3 archive, while adding new solutions such as the ePrimer or Video Library.

Next Steps

- ➔ Continue redesign of ITS PCB website to develop into learning portal.
- ➔ Oversee development of ITS ePrimer.
- ➔ Start building video library; choose 5 to 6 pilots for 2012.

⁶³ Plan located at: http://www.pcb.its.dot.gov/strat_direction_plan.asp.



Goal 4: Technology Transfer

Research Accomplishments

- Developed and maintain technology transfer portal that combines knowledge and resources in one area.
- Produced a leading-edge study that provides the ITS JPO with approaches and recommendations, based upon analysis of technology transfer in other industries.⁶⁴
- Developed baseline of current ITS Program technology transfer process.
- Working with ITS Test Beds, ICM, and ADTM to incorporate technology transfer principles in their Knowledge and Technology Transfer plans.

Critical Research Insights

- ◊ A recent study on technology transfer highlighted that the ITS Program is responsible for one of the largest research programs in the US DOT. However, technology transfer is a significant challenge because the program's research is not directly tied to an implementation program.
- ◊ The report on technology transfer has helped highlight the many other innovative mechanisms to technology transfer that are being utilized by other government agencies, national laboratories, universities, and industry. The PCB program will work to identify whether these different efforts can enhance the existing approaches in effective and beneficial ways.

Next Steps

- ➔ Analyze technology transfer report's recommendations to identify whether new solutions can be implemented in the near term to address current challenges in ITS operations and deployment.
- ➔ Engage with industry stakeholders regarding expectations for technology transfer.

⁶⁴ Study located at: http://ntl.bts.gov/lib/42000/42100/42107/FHWA-JPO-11-085_Key_Findings_Recommendations_for_Tech_Transfer_atITS_JPO_PDF_508.pdf.

ITS Evaluation ...

... is designed to determine the effectiveness and benefits of deployed ITS and the value of ITS investments.

The vision for the ITS Evaluation program is to ensure progress toward the vision of integrated ITS, achieving ITS deployment goals, as well as understanding the value, effectiveness, and impact of National ITS Program activities and allow for the program's continual refinement.

Program Management Plan

The objective of the ITS evaluation program is to determine the effectiveness and benefits of deployed ITS and the value of ITS program investments. Evaluations are critical to ensuring progress toward the vision of integrated intelligent transportation systems and achieving ITS deployment goals. Evaluations are also critical to an understanding of the value, effectiveness, and impacts of the ITS Program activities and to allow for the continual refinement of the ITS Program's strategy. To carry out these efforts, the ITS Evaluation Program has activities in six tracks:

Track 1: ITS Research Evaluation: Efforts in this track seek to establish a common point of reference for evaluation and comparing different research activities. Oversight is provided to ensure that methodologies are aligned with Federal government guidelines.

Track 2: ITS Deployment Tracking Surveys: This is a continuing effort to track and analyze results of surveys provided every three years to deploying agencies. These efforts have established a one-of-a-kind database that supports important longitudinal analysis to gather insights into direct and indirect effects of decisions, incentives, and other types of support.

Track 3: ITS Deployment Evaluation: This effort uses the databases developed with the ITS survey results to perform analysis for the ITS Program and modal partners. The results assist the ITS Program in making targeted program investments that more effectively support deployment.

Track 4: ITS Program Evaluation: Activities in this track are focused on providing evaluations for major ITS research initiatives such as the Integrated Corridor Management or the Urban Partnership Agreements. Current efforts including developing a plan for evaluation of the Connected Vehicle initiatives, including coordination with the *Safety Pilot Model Deployment* test plans.

Track 5: Knowledge Management: The wealth of insights and results from surveys and evaluations forms a broad and deep knowledge base to support current and future ITS deployments. Efforts in this track turn these resources into databases and other, easily accessible materials that are used in decision making, training, and providing assistance.

Track 6: Knowledge Transfer: Efforts in this track seek to link the knowledge management resources to training and decision making.

- In 2010, the ITS Evaluation program made a significant update to the existing ITS Evaluation Guidelines, a legislative requirement. The revisions incorporate the Net Present Value (NPV) calculation of research, applying principles of the Office of Management and Budget (OMB) Circular A-94, bringing the ITS Program into conformity with government-wide practices for evaluating research.

- The guidelines were also revised to ensure that contractors involved in evaluating deployment successes or lessons learned are not also engaged in deployment teams.

Critical Research Insights

- The shift to incorporate the OMB principles results in a common point of reference for comparing different research activities by their NPV. As a result, ITS research initiatives, and the potential for high-risk/high-reward results, can be viewed on equal footing with other research initiatives across the Department.
- The change in contractor qualifications eliminates a potential conflict of interest.

Next Steps

- ➔ Implement a framework that describes the value derived from research while in progress.

Track 2: ITS Deployment Tracking Surveys

Research Accomplishments

- The ITS Evaluation program continued its work with deployment tracking surveys with analysis of the results from the 2010 survey being presented throughout the 2011 year. Both the website and summary reports were released in 2011.⁶⁵ Analysis and other materials include:
- *Deployment Tracking Survey Results*.⁶⁶ The full 2010 survey database is available for download for other types of analysis.
 - *Deployment of ITS: A Summary of the 2010 National Survey Results*, August 2011.⁶⁷
 - Presentations from the 2011 ITS World Congress.⁶⁸

Critical Research Insights

- The ITS Evaluation Program has collected over 15 years of deployment data. It is the only database of its kind that is able to view, longitudinally, the results from different policies and programs designed to support effective ITS deployment.
- Rigorous analysis in 2011 offered the first opportunity to use historical data to understand how ITS implementation occurs. The results will be used to inform and support investment decisions for connected vehicle implementation.

Next Steps

- ➔ Design the 2013 Deployment Tracking Surveys.
- ➔ Provide the 2010 survey database on <http://www.data.gov>.

Track 3: ITS Deployment Evaluation

Research Accomplishments

- The US DOT published *ITS Technology Adoption and Observed Market Trends from ITS Deployment Tracking*, which compiled statistical evidence on what influences ITS adoption and deployment.⁶⁹
- A second report, *An Analysis of the Factors Influencing ITS Technology Adoption and Deployment*, looked at how decisions are made through historical adoption patterns, and examined the maturity of different ITS markets.⁷⁰

⁶⁵ Materials can be found at: <http://www.itsdeployment.its.dot.gov/FM.aspx>.

⁶⁶ Available at: <http://www.itsdeployment.its.dot.gov>.

⁶⁷ Available at: <http://www.itsdeployment.its.dot.gov/documents/nationalreport.pdf>.

⁶⁸ Presentation can be found at: <http://www.itsworldcongress.org/>.

⁶⁹ Report can be found at http://ntl.bts.gov/lib/34000/34991/ITS_Deployment_Tracking_FINAL_508C_101210.pdf.

⁷⁰ Report can be found at http://ntl.bts.gov/lib/44000/44100/44189/FHWA-JPO-12-002_Deployment_Tracking_Task_2_2_FINAL_2_9_2012.pdf.

Critical Research Insights

- With the 2011 ITS survey results, the program was able to perform analysis on the patterns of ITS adoption to understand how external factors, and in particular, those that are policy related, may affect ITS diffusion. Results from this analysis provide insight into intervention levers that could be used to positively affect adoption and deployment. This information can be used to inform future ITS strategic planning and decision making. Important insights include:
 - Since the late 1990s, there has been a relatively steady increase in the adoption and deployment of ITS technologies. The data reveal that most adopters are "imitators" – those who make the decisions to deploy ITS after the technologies have been proven successful at other sites.
 - Data and analysis proves that earmarks are not effective at encouraging ITS technology adoption. Instead, the results observe that budget, regional architecture involvement, and the effect of peer behavior are among the key factors affecting ITS adoption and implementation.
 - Analysis also revealed that developing or updating a regional architecture is a cost-effective way to increase adoption of ITS technologies.

Next Steps

- ➔ The report represented the final step in this track. A new project in 2012 will attempt to gather more detailed empirical data on technology diffusion.

Track 4: ITS Program Evaluation

Research Accomplishments

- ☒ The SafeTrip-21 evaluation was completed in 2011.⁷¹
- ☒ A number of upcoming evaluations are in different stages of moving forward:
 - The Urban Partnership Agreement (UPA) Evaluation Plans and Test Plans were submitted for Seattle, Minneapolis-Saint Paul, Atlanta, and Los Angeles.
 - A UPA evaluation was completed for Miami.
 - ICM Evaluation Plans were submitted for Dallas and San Diego and an overall ICM evaluation framework is being developed.

Critical Research Insights

- To gain a more accurate analysis of the impact of deployment and to help isolate the various factors affecting deployment outcomes, the program stresses analyses of factors beyond transportation, including employment and economic indicators, to accurately state the impact of ITS research deployments with precision.
- Test plans and evaluation plans are looking at the effectiveness of strategies consisting of combinations of tolling, transit, telecommuting/transportation demand management, and technology.
- The Miami UPA results reveal that conversion from High Occupancy Vehicle (HOV) to High Occupancy Tolling (HOT) lanes improved travel times and on-time performance for transit express bus service. The HOT lanes also encouraged the shift from driving in cars to taking transit.
- Total person throughput on all modes increased 42 percent for AM/PM peak periods.

Next Steps

- ➔ Complete UPA and ICM evaluations.
- ➔ Advise on the structure for evaluation of the *Safety Pilot*.

⁷¹ Report can be found at http://ntl.bts.gov/lib/38000/38500/38510/Safetrip_CRF.pdf.



Track 5: Knowledge Management

Research Accomplishments

- The ITS Evaluation program continued to update and maintain three knowledge management resources that are critical to decision making about deploying ITS. Over 10,000 monthly users refer to these resources for information. Significant new resources have been added since 2008. The databases include:
 - ITS Benefits Database
 - ITS Costs Database
 - ITS Lessons Learned Database⁷²
- The ITS Evaluation program revised the web presence of the databases by creating a new website with more graphics, ensuring the look is more consistent with the ITS website, and providing a new geographic component (a beta version of a mapping application helps to locate sites with their benefits information).
- The program has added a new online feature, "Rate this Benefit," that allows end users to express the value of the information received. End users now have a simplified mechanism to supply self-developed evaluation reports.

Critical Research Insights

- The knowledge management resources are easier to use. Users have been pleased, particularly with the mechanism to weigh in on the ITS evaluation results.
- Users respond to the website with their own analysis of the evaluation results or they request more information.

Next Steps

- ➔ Keep databases populated, seek out reports; evaluations include those benefits costs, and lessons learned data in our database.

Track 6: Knowledge Transfer

Research Accomplishments

- Collaborated on linking knowledge resources into PCB training materials.

Critical Research Insights

- Stakeholder engagement has improved website usage.
- Collaborating with ITS PCB program on opportunities from deployment tracking analysis and evaluations.
- Launched Longitudinal Study to analyze the factors that motivate deployment community.

Next Steps

- ➔ Developing evaluation methodologies that describe value of research in progress and that also considers impact of stakeholder development on deployment stability.

⁷² The databases can be accessed at:

- ITS Benefits Database at: http://www.itsknowledgeresources.its.dot.gov/its/benecost_nsf/BenefitsHome.
- ITS Costs Database at: <http://www.itscosts.its.dot.gov/>.
- ITS Lessons Learned Database at: <http://www.itsknowledgeresources.its.dot.gov/its/benefits.nsf/LessonHome>.

International Collaboration on ITS Research ...

... is the Department's effort to foster cooperative international research on ITS.

The vision in conducting coordinated research is to increase the value of each region's research by creating a joint framework for field operational tests and evaluation tools, collaborating on cooperative vehicle safety applications, and working to internationally harmonize standards. The purpose is also to support and accelerate the deployment and adoption of connected vehicle systems by facilitating a global marketplace through harmonization of standards.

Program Plan

In seeking to establish a coordinated, global market for connected vehicle systems, the ITS Program has reached out to nations around the world to establish a basis for joint research and exchange. Two important efforts have resulted in formal agreements:

- ▶ In January 2009, RITA and the European Commission Directorate General for Information Society and Media (DG INFSO) signed an Implementing Arrangement to develop coordinated research programs specifically focusing on cooperative vehicle systems. The commitment was further affirmed in an *EU-US Joint Declaration of Intent on Research Cooperation in Cooperative Systems*, signed in November 2009. The goals of this declaration are:
 - Support, wherever possible, global open standards to ensure interoperability of cooperative systems worldwide and to preclude the development and adoption of redundant standards;
 - Identify research areas that would benefit from a harmonized approach and that could be addressed by coordinated or joint research; and
 - Avoid duplication of research efforts.
- ▶ In 2010, RITA and the Road Bureau of the Ministry of Land, Infrastructure, Transport, and Tourism (MLIT) of Japan signed an Implementing Arrangement to cooperate in transportation science and technology. The arrangement formalizes and advances the existing technical cooperation and information exchange on ITS that exists between the two nations.



International Collaboration on ITS Research

European Union Collaboration

Research Accomplishments

- The US and EU have established a Joint ITS Technical Task Force as well as Working Groups that are co-led and staffed by representatives of the US DOT and the EU. The working groups include:
 - **Safety Applications Working Group:** Focuses on supporting the development of cooperative safety applications by defining a common agreement among car manufacturers on specific standards/parameters to harmonize between the regions.
 - **Sustainability Applications Working Group:** Focuses on identifying, researching, quantifying, and evaluating the environmental benefits of an ITS application or scenario that would improve the operation and performance of an environmentally optimized transportation network.
 - **Standards Harmonization Working Group:** Focuses on encouraging and fostering the development and adoption of globally harmonized open standards for ITS cooperative systems.
 - **Assessment Tools Working Group:** Focuses on establishing a fundamental foundation to facilitate a common level of analysis capabilities, comparison of field operational tests, and exchange of data and information regarding test and evaluation of cooperative systems.
 - **Driver Distraction and Human-Machine Interaction Working Group:** Focuses on identifying opportunities for research collaboration, aligning research, and identifying differences in the area of driver distraction and human-machine interaction.
 - **European Technical Roadmap Working Group:** Focuses on producing a document to review the current state of the development of cooperative systems in Europe and plans for future development and deployment.
 - **Glossary Working Group:** Focuses on establishing and publishing the common working definitions for the key terms and concepts to facilitate mutual understanding in ongoing discussions within the EU-US Task Force.
- The revised planned contents of the EU Cooperative Awareness Message (CAM) have been harmonized with the contents of the US Basic Safety Message (BSM).

Critical Research Insights

- ◊ Cooperation between the EU and US industry, governments, and standards communities has resulted in a substantially harmonized core safety message set. While the CAM and the BSM are not identical, they are now sufficiently harmonized such that only simple translation is required for systems to utilize both message sets nearly interchangeably. From an industry perspective, this will enable usage of substantially common hardware and software for products destined for both regions, reducing cost and complexity.

Next Steps

- ➔ The EU and U.S. will create a showcase to share the joint work with the global ITS community at the ITS World Congress in Vienna, Austria in 2012. The showcase will highlight their efforts to harmonize the CAM and BSM.
- ➔ The harmonized content of the CAM and BSM is expected to be incorporated into the final version of the CAM standard via the European Telecommunications Standardization Institute's (ETSI) processes with adoption expected in the near future. This harmonized content will also be featured as part of the Car2Car Communication Consortium vehicle demonstration at the ITS World Congress in Vienna.

Japan-US Technical Cooperation and Information Exchange

Research Accomplishments

- RITA and Japan's Ministry of Land, Infrastructure and Transport and Tourism (MLIT) have collaborated on:
 - Identifying research and development areas that would benefit from joint development as well as sharing information on ongoing research and development projects, estimated benefits, research outcomes, and results of field demonstrations. Progress has been made in three areas in particular:
 - **Information Exchange on Evaluation Methods:** The MLIT and the ITS Program have been exchanging information on data collection methodologies and evaluation approaches. In data collection, the exchange has focused on defining the purposes, collection procedures, use, and modeling of data to inform evaluation of projects and systems. On evaluation approaches, the MLIT and the ITS Program are seeking to harmonize approaches in order to have consistent and comparable methods for evaluation. The outcome of this effort is that it expands the amount of data for analysis with similar field tests.
 - **Probe Data Exchange:** The MLIT has provided RITA with probe data to support the research into consistency of data elements and attributes. Japan has a significant amount of traffic probes – cameras and in-vehicle devices – allowing the MLIT to gather much more precise probe data for managing congestion as well as for improving safety.
 - **Standards:** Supporting development of globally open standards that ensure interoperability (for more details, see pages 108–113).
 - The MLIT has joined the EU and US in several working areas.

Critical Research Insights

- ◊ The ability to establish consistent metrics for probe data is expected to result in a global market for mobility applications, devices, and information service providers.

Next Steps

- ➔ Define an evaluation framework with MLIT and develop a program plan in 2012.
- ➔ Begin review of the probe data and joint development of metrics in 2012–2013.



ITS Outreach and Communications ...

... is a function of the ITS Program that works to ensure that stakeholders are actively informed and engaged during the development of the connected vehicle research program. Communications and outreach not only include stakeholder engagement but also media relations, online and print communications, social media, and public meeting planning.

Management Plan

The objective of the ITS Outreach and Communications program is to effectively manage four tracks of outreach and communications. The tracks include:

Track 1: Website Development: Create a premier website that educates the public about the potential benefits of connected vehicles.

Track 2: Stakeholder Outreach: Significantly expand the channels that the ITS Program uses to communicate with its stakeholders and the public.

Track 3: Stakeholder Community Diversification: Diversify the number and variety of stakeholder organizations that interact regularly with the ITS Program.

Track 4: Communications and Outreach Strategy: Develop and implement an effective communications and outreach strategy for the *Safety Pilot* research initiative.

2012 SNAPSHOT OF PROGRESS

Track 1: Website Development

Research Accomplishments

- ☒ A newly redesigned website for the ITS Program was unveiled at the Transportation Research Board annual meeting in January 2011.
- ☒ The website includes new sections with video, fact sheets, and an image library.
- ☒ The website now contains online sections featuring technology transfer, the *Safety Pilot*, procurement opportunities, and public meetings.

Critical Research Insights

- ✿ Content on the website has helped to generate a significant increase in traffic to the site.

Next Steps

- ➔ Continue to increase the number and variety of fact sheets on the site.
- ➔ Add new animation section that illustrates how connected vehicles will work in the future.
- ➔ Expand the press room section of the website to accommodate increasing media interest in the *Safety Pilot* Program.

Track 2: Stakeholder Outreach

Research Accomplishments

- Added Twitter, Facebook, and LinkedIn as new ways to communicate with industry stakeholders.
- Significantly increased the number of email subscribers to the ITS Program website.
- Held summer webinar series to showcase various aspects of the connected vehicle mobility program.
- Held two annual Connected Vehicle Safety and Policy Meetings.
- Released the Connected Vehicle Technology Challenge (CVTC) and the ITS Video Challenge to solicit innovative ideas from ITS stakeholders.

Critical Research Insights

- ◊ The ITS Program's Twitter account has more than 500 followers, and more than 500 stakeholders have signed up for regular e-mail alerts. More than 200 tweets and email alerts have been sent out since January 2010.
- ◊ More than 125 stakeholders submitted ideas for the ITS Video Challenge and the CVTC.
- ◊ Electronic communications through online media such as email, Twitter, Facebook, and LinkedIn have become the leading ways that stakeholders learn about ITS Program public meetings and other stakeholder opportunities.
- ◊ The number of public meetings hosted by the ITS Program increased from 9 in 2010 to 19 in 2011.

Next Steps

- ➔ Increase the use of stakeholder social media outlets such as association Facebook pages and LinkedIn groups.

Track 3: Stakeholder Community Diversification

Research Accomplishments

- Produced the first stakeholder engagement plan, which featured an inventory of related stakeholder groups.
- Developed new stakeholder relationships with a number of groups outside of the traditional ITS community including Lifesavers, the Consumer Electronics Association, the American Public Works Association, and others.
- Hosted a demonstration of connected vehicle technology for members of Congress, Congressional staff, and a number of non-traditional stakeholders in the Washington, DC area.
- Hosted "Demonstration Days" to expose local stakeholders to connected vehicle technology. The demonstrations took place in Michigan, Minnesota, Florida, Texas, and California.

Critical Research Insights

- ◊ The number of stakeholder groups in the ITS Program database has increased dramatically.
- ◊ The number of invitations for the ITS Program to speak at industry conferences continues to rise.



Next Steps

- ➔ Develop fact sheets about the connected vehicle program and other ITS-related subjects that are tailored for individual stakeholder groups.

Track 4: Communications and Outreach Strategy Development

Research Accomplishments

- The US DOT hosted a media event to showcase connected vehicle technology during the ITS World Congress in October 2011.
- The ITS Program created a *Safety Pilot* background section on its website.
- The ITS Program has developed easy-to-understand fact sheets about how connected vehicles can improve safety, mobility, and the environment.
- Videos and graphics available on the ITS Program website have helped to illustrate how connected vehicle technology works.

Critical Research Insights

- ◊ Media coverage of the connected vehicle research program has increased, particularly in top-tier media outlets. Appendix C provides a list of media sources that have covered the connected vehicle program over the last two years.
- ◊ The US DOT has developed a communications strategy with UMTRI to educate the public and the ITS industry about the upcoming *Safety Pilot* Model Deployment. UMTRI is the test conductor for the model deployment.

Next Steps

- ➔ In the summer of 2012, the US DOT and UMTRI began the *Safety Pilot* Model Deployment. The demonstration will run from August 2012 to September 2013. This will be an important media and communications opportunity for the US DOT.

Conclusion

Conclusion

Collectively, the accomplishments of the initial two and a half years of research under the 2010–2014 research agenda have advanced the vision of a Connected Vehicle Environment and brought the nation closer to its reality. These accomplishments were possible because of the commitment by the Department to support this multimodal initiative with dedicated staff, and because of continued stakeholder efforts to identify and overcome challenges in a manner that provides a solid foundation for successful deployment. Accomplishments and results are also due to the incorporation of strong program management principles which has resulted in the individual research programs being on time and within budget.

Consistent with this administration’s commitment to open government, the ITS Program has been and will continue to implement processes that assure:

- ▶ Transparency that provides citizens with information about what the ITS Program is doing so that it can be held accountable.
- ▶ Participation from a broad audience inside and outside of government and from other industries so that the resulting policies and technical accomplishments benefit from the best expert analysis and information that this nation can provide.
- ▶ Collaboration that results in agencies working together with one another and with citizens as part of the efforts involved with solving national problems.

This report is an important communications tool that, at a high-level, sets a targeted and strategic direction; and at a deeper-level, provides the details necessary for stakeholders and interested members of the public to track progress, recognize research gaps, and identify opportunities for working together. It does so by describing each research effort and how it has evolved since inception; summarizing the major accomplishments from 2010–2012; offering the critical insights gained from conducting the research; and listing next steps and actions toward the completion of this research agenda.

In summary, the notable accomplishments, advancements, and critical insights include the following:

In Connected Vehicle Research

- ▶ **Safety research** has advanced to the level of producing prototypes for testing and demonstration in real-world conditions with novice drivers. The tests conducted as part of the *Safety Pilot* initiative will produce the data needed to analyze the level of safety and the transformative capability provided by these wireless technologies and applications. In combination with policy analysis, these results will inform an agency decision regarding the optimal path toward nationwide adoption.
- ▶ **Policy research** has identified the most critical institutional, technical, financial, and legal challenges associated with adoption, implementation, and use of connected vehicle technologies and applications. Three issues, in particular, impact the viability of implementation – whether a financially sustainable strategy for implementation, operations, and maintenance is possible; whether a robust, security system that preserves privacy at the highest levels is feasible; and whether a governance model that gives stakeholders a voice can be established. Research is underway to analyze these issues and produce policy options.
- ▶ **Mobility, Environment, and Road Weather Management research** is advancing the state-of-the-knowledge in methods for capturing and managing real-time data streaming, which is the basis for agencies to gain access to higher quality data sources. Working with stakeholders, new, dynamic mobility application concepts are being defined through ConOps; and new transformative concepts for environmental applications are being modeled. These results will support the Department’s decision about whether to invest in future development of these applications or whether there are innovative partnership opportunities to bring these applications to market. Additionally, both the mobility and environment research efforts are informed by the real-world road weather research. With demonstrations and evaluations underway in three cities, the results of testing estimation and prediction systems that model impacts of weather and changing conditions on transportation demand will guide analysis and development of new mobility and environmental applications.

- ▶ **Connected Vehicle Technology research** is resulting in an interoperable platform for supporting connected vehicle implementation. The critical standards have been developed and published and efforts are underway to harmonize them at an international level across multiple regions. To support trusted and secure message exchange, a core system concept has been developed which will inform the expansion of the National ITS Architecture to include connected vehicle technologies.

In Short-Term Intermodal Research:

The Department's research investments into mode-specific and regionally integrated systems is resulting in new, active, and efficient solutions for transportation problems in areas such as traffic management, border crossings, multimodal operations, and commercial vehicle operations. Most of this research is moving into field operational tests and demonstrations that will provide data and insights on performance as well as impacts to safety, operations, and efficiency. These public demonstrations are also an important element in promoting adoption and facilitating technology transfer. Results are expected in the 2014 time period.

In ITS Exploratory Research:

Using a variety of techniques that include scans, innovation challenges, and exploratory research, the Department is identifying important opportunities in which leadership in research is needed. Two areas in particular – automated vehicles and robotics; and electric vehicles – hold the promise of greater transformations in safety and in fuel efficiency and reduction of transportation's impact on the environment. However, both of these opportunities pose significant complexity in addressing the technical gaps and policy challenges.

In Cross-Cutting Support:

The cross-cutting programs have continued to provide the tools and knowledge necessary to support ITS adoption and deployment decisions:

- ▶ The **National ITS Architecture** remains current and offers a critical tool in State and local planning, coordination, and interoperability;
- ▶ The **Professional Capacity Building** program is making new investments in establishing partnerships that broaden and optimize the capability to reach greater numbers of transportation professionals with critical ITS training and education;
- ▶ A focused outreach effort has resulted in important **agreements with key international agencies to conduct joint research and harmonize standards and approaches**. Expected results include the establishment of a global marketplace for vendors with a corresponding reduction in costs for consumers and reduction in the complexities associated with worldwide manufacturing; as well as the opportunity to leverage knowledge and expertise from around the world and reduce redundancy in research efforts; and
- ▶ The **Outreach and Communications** program has significantly increased the awareness of ITS and connected vehicle technologies by engaging with a wide and varied set of new media outlets to produce articles, television and web-based stories, and online informational pieces. As a result, around the nation, the connected vehicle concept is gaining in public awareness and interest.

Accomplishing this progress and realizing key milestones over the last two years has been a substantial effort that has resulted in a heightened sense of anticipation and excitement within the connected vehicle stakeholder community. In compiling the results of the 2010–2012 research efforts, two outcomes in particular stand out:

- ▶ **The opportunity to safely harness the powerful potential of wireless communications and applications to bring new transportation benefits to the nation is upon us**, powered by a well-structured and measurable research agenda and supported by the energy and collaborative efforts of committed stakeholders. The *Safety Pilot* test and demonstrations will reveal whether there are any remaining technical or policy challenges to address; and the results will support the Department's establishment of a future policy direction; and
- ▶ **There is a closer alignment of research opportunities with commercial potential** – robust wireless technologies and applications are no longer emerging but, instead, are commonplace. Consumers continue



to demand more – more real-time, more data, more dynamic exchange of data, and more sophisticated applications. By studying and leveraging these trends, the ITS Program is now more closely aligned with market evolutions and has integrated these new concepts into the connected transportation vision where and when it is both safe and optimal.

Looking Forward

Building from the successes and using results from technology scans and innovative ideas from experts and the public, the ITS Program expects to evolve this current research agenda over the next two years into a new strategic direction. The focus will be three-fold as the program advances into the future:

- ▶ Definition and scoping of a high risk/high-reward exploratory research agenda that focuses on emerging, complex technologies with significant technical gaps and policy issues;
- ▶ Leveraging and integration of market-available technologies for transformative purposes; and
- ▶ Facilitation of greater ITS adoption.

1. High Risk/High Reward Exploratory Research

As with connected vehicles, the US DOT is positioned to boldly envision the future and provide leadership into new high-risk/high-reward research concepts that present transformative opportunities. Two areas, in particular, are experiencing rapid industry movement, resulting in the anticipation of a forthcoming set of US DOT roles in setting a research agenda, facilitating industry and academia to identify best practices and innovative solutions, and, most importantly, providing oversight needed to ensure that the goals of safety and security are met with the introduction of new technologies. The high-risk/high reward research areas are:

- ▶ **Automated Vehicles and Robotics:** The introduction of automated vehicles using robotics that are not yet proven within a transportation environment is a critical shift within the industry. It is estimated that each automotive manufacturer is developing its own version of a self-driving vehicle in partnership with leading technology and academic laboratories. As industry is leading the research to address the technical challenges, the US DOT will need to keep pace with providing the regulatory and policy frameworks that can accommodate the safe and beneficial introduction of these new and complex innovations. Exploratory research efforts are expected to include:
 - Identifying and addressing the key policy and technical implementation issues such as fail safe strategies and driver over-ride concepts; or infrastructure modifications that will be necessary to support various levels of automation. Equally critical will be the economic, regulatory, liability, and institutional and legal issues that impact the potential successful deployment of increasingly automated vehicles.
 - Transferring lessons from connected vehicle research on such issues and gaps as performance standards for reliability, interoperability, security, and human factors that will be needed when pursuing automated technologies.
- ▶ **Electric Vehicles:** New vehicle designs that incorporate circuit boards and modular components more elegantly support the data needs of connected vehicle technologies and applications and produce higher quality vehicle data. Exploratory research efforts are expected to include:
 - Research into how to exploit the synergies between connected vehicle research and electric vehicles.
 - Application of AERIS research results on how real-time data and sensing capabilities might transform the manner in which the vehicle utilizes energy and fuel.

2. Market-Available Technologies

The rapid pace of evolution of market technologies and the corresponding impact on in-progress research results was a critical insight learned from the Vehicle-Infrastructure Integration research that has helped shaped the Department's requirement to stay abreast of industry trends. A continuing element of the research agenda will be the examination of incorporating next generation market-available technologies as a means of providing accessible and leading-edge technology solutions for consumers and deploying agencies. Looking forward, the Department recognizes important changes that will have a significant effect on current and

near-term ITS systems, technologies, and applications. With these insights, the Department perceives a need to, at a minimum:

- ▶ Track opportunities with the newly emerging fourth generation of communications (or LTE) and the emerging Version 6 of Internet Protocols (IPv6) and guide deploying agencies in decisions regarding when and how to incorporate changes without creating great disruptions to operations or services.
- ▶ Observe and evaluate the changes in the wireless “ecosystem” and identify how or whether the ITS Program should adopt or change to take advantage of these trends.

3. ITS Adoption

A recent longitudinal and economic analysis of 17 years of ITS deployment tracking data has shed light on the market dynamics and benefits associated with the deployment and diffusion of ITS technologies. With this report, the Department has a deeper insight into the key events that have influenced the trends in deployment and factors that may play an important role in shaping the market’s future direction. An important insight is the recognition that ITS is an important tool for system operators; adoption of key technologies has grown steadily over the last twenty years.⁷³ The knowledge and insight gained as a result of this analysis can be used to inform strategic planning efforts and guide investments in deployment of ITS at regional and local levels. These insights also focus the ITS Program’s efforts to facilitate greater adoption through more targeted strategies that provide technology transfer, training, technical exchanges, and outreach where the need is greatest and the results are likely to be significant.

Next Steps, 2012–2014

It is the nature of research that, as answers emerge for these and other questions, new and potentially more questions will arise. Therefore, this research plan will remain flexible; the ITS Program leadership is committed to tracking progress against milestones and providing programmatic reviews in order to adjust to new needs and changing directions in policy, technology, and the marketplace.

In conclusion, through 2014, the ITS Program is committed to the following steps:

- ▶ Finalize the connected vehicle research agenda for safety and, specifically, demonstrate and evaluate the transformative nature of a connected environment for transportation. The results will provide the US DOT with a sound analysis for making a 2013/2014 decisions on whether all new vehicles should have these technologies integrated during the manufacturing process;
- ▶ Establish targeted transfer technology processes to move state-of-the-art in connected vehicle technologies into the marketplace to accelerate progress on the US DOT’s highest priority – safety;
- ▶ Pursue a similar path for mobility and environmental technologies and applications – finalizing the research agenda, contemplating regional pilot deployments for demonstrating capabilities in the 2015–2016 timeframe, and facilitating technology transfer;
- ▶ Continue to engage stakeholders throughout the process to ensure that research results are aligned with expected benefits to users as well as aligned with emerging business models so that transfer of technologies generates successful market opportunities;
- ▶ Begin the exploration of needs and interests of the ITS stakeholder community with regard to emerging concepts and opportunities; and
- ▶ Strategically establish the next research agenda that assures that the Federal government is, once again, positioned in a relevant leadership role to facilitate the most pressing high-risk/high-reward transportation research needed by the nation.

⁷³ <http://www.itsdeployment.its.dot.gov/FM.aspx>.



Appendices



Appendix A

Acronyms and Abbreviations

4G	4th Generation Wireless
AASHTO	American Association of State Highway and Transportation Officials
ASE	Automated Speed Enforcement
ATRI	Alliance for Transportation Research Institute
AERIS	Applications for the Environment: Real-Time Information Synthesis
ACAT	Advanced Crash Avoidance Technologies
APTA	American Public Transportation Association
ARINC	Aeronautical Radio, Inc.
ASE	Automated Speed Enforcement
ATA	American Trucking Associations
ATM	Active Traffic Management
ATDM	Active Transportation and Demand Management
BIFA	Border Information Flow Architecture
CAMP	Crash Avoidance Metrics Partnership
CBP	Customs And Border Protection
CEN	European Committee for Standardization
ConOps	Concept of Operations
CO2	Carbon Dioxide
CV	Connected Vehicle
CVISN	Commercial Vehicle Information Systems and Networks
CVO	Commercial Vehicle Operators
CVSA	Commercial Vehicle Safety Alliance
CVTC	Connected Vehicle Technology Challenge
CWIM	Crash Warning Interface Metrics
DARPA	Defense Advanced Research Projects Agency
DCM	Data Capture and Management
DMA	Dynamic Mobility Applications
DSRC	Dedicated Short Range Communications
DVI	Driver Vehicle Interface
DynaSMART	Prediction Model
DynaMIT	Prediction Model
ENOC	Enterprise Network Operations Center
EPA	Environmental Protection Agency
ESS	Environmental Sensor Stations

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EU	European Union
FCA	Forward Collision Avoidance
FCW	Forward Collision Warning
FCC	Federal Communications Commission
FOE	Field Operational Experiment
FOT	Field Operational Test
FRATIS	Freight Advanced Traveler Information
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
FMCSA	Federal Motor Carrier Systems Administration
FRA	Federal Railroad Administration
GID	Geometric Intersection Description
GHG	Greenhouse Gas
GPS	Global Positioning System
GSA	General Services Administration
HAP	Harmonization Action Plan
HCM	Highway Capacity Manual
HRI	Highway-Rail Intersection
HTG	Harmonization Task Groups
IDTO	Integrated Dynamic Transit Operations
IEEE	Institute of Electrical And Electronics Engineers
IMO	Integrated Mobile Observations
ISO	International Standardisation Organization
ITE	Institute of Transportation Engineers
ITDS	International Trade Data System
ITS	Intelligent Transportation Systems
ITU	International Telecommunications Union
JPO	Joint Programs Office
LIDAR	Light Detection And Ranging
LTE	Long Term Evolution, also the 4th Generation of Wireless Communications
MARAD	Maritime Administration
MDSS	Maintenance Decision Support System
MMIPS	Multimodal Integrated Payment Systems
MOVES	Motor Vehicle Emission Simulator



Appendix A

NARL	North America Research Laboratory
NATWG	North American World Trade Group
NCAR	National Center for Atmospheric Research
NFC	Near-Field Communications
NHTSA	National Highway Traffic Safety Administration
NIST	National Institute of Standards and Technology
NMVCC	National Motor Vehicle Crash Causation Survey
NOAA	National Oceanic and Atmospheric Administration
OEMs	Original Equipment Manufacturer
OME	Otay Mesa East
OS Portal	Open Source Portal
P2P	Peer-to-Peer
PCB	Professional Capacity Building
PDE	Prototype Data Environment
PKI	Public Key Infrastructure
POC	Point of Concept
POE	Point of Entry
QC-ACE/ITDS	Query Central-to-Customs and Border Protection's Automated Commercial Environment/International Trade Data Systems
RDE	Research Data Exchange
RITA	Research and Innovative Technology Administration
ROW	Right of Way
RSD	Retrofit Safety Device
RSE	Roadside Equipment
RWM	Road Weather Management
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
SDN	Service Delivery Node
SDO	Standards Development Organizations
SHRP	Strategic Highway Research Program
SPaT	Signal Phase and Timing
T3	Talking Technology and Transportation Webinar Programs
T-CONNECT	Connection Protection
T-DISP	Dynamic Transit Operations

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TIMTC	Trucking Industry Mobility and Technology Coalition
TPG	Test Procedure Generator
TRB	Transportation Research Board
TrEPS	In Traffic Estimation and Prediction Systems
TSAG	Telecommunication Standardization Advisory Group
UGPTI	Upper Great Plains Transportation Institute
US DOT	United States Department of Transportation
UMTRI	University of Michigan Transportation Research Institute
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
VDT	Vehicle Data Translator
VIIC	Vehicle Infrastructure Integration Consortium
VSL	Variable Speed Limits
WRTM	Weather-Responsive Traffic Management



Appendix B

Important Changes in the ITS Strategic Plan

With the evolution of the ITS Program since 2010, two research initiatives have moved out of the research portfolio – Multimodal Integrated Payment Systems (MMIPS), and ITS Maritime Applications. The original text has been moved to this Appendix and the following status updates describe the evolution that has taken place:

Multimodal Integrated Payment Systems (MMIPS)

In 2010, in the early stages of launching the MMIPS research, US DOT program managers and other stakeholders realized that private industry was investing in new business models aimed at delivering an integrated payment world. Over the last two years, the telecommunications, mobile device, and financial systems industries have been developing prototype systems, applications, and standards necessary to realizing the vision, and have been conducting small-scale field operational tests. For example, the establishment of technologies that use Near-Field Communications (NFC) has allowed industry to move forward on mobile phone-enable payments as early as 2010. To date, testing has identified some of the gaps that need to be addressed in areas of privacy, security, and agreements on how to divide transaction fees among the many players. As of early 2012, a number of major credit card firms, retail sellers, and other firms are supporting this type of payment system.

As the US DOT model for high-risk/high-reward research investments is grounded in pursuing those beneficial applications that private industry is unlikely to support, the US DOT has assessed that MMIPS no longer fit these criteria. The US DOT will, however, continue to monitor and examine how the industry results satisfy transportation needs for multimodal, integrated systems. If the resulting private-sector business models ultimately do not meet the goals set forth in the 2010-2014 Strategic Plan, the US DOT will reassess whether to pursue further research and investment in this area.

ITS Maritime

Since the 9/11 terrorist attacks, the United States has learned that it faces a growing number of security threats in many distant parts of the globe, as well as at home. For the Marine Transportation System today, defense mobilization still equates to having a strong industrial base, as well as sufficient U.S. commercial ships and civilian crews available to meet defense sealift requirements. It also now includes the shore-side equipment and infrastructure necessary to keep the intermodal system moving. The U.S. marine transportation industry has established itself as an indispensable and effective tool for projecting and sustaining military operations, no matter where they may be.

In light of the current Maritime Administration's necessary focus on national security, the opportunity to apply ITS technologies to intermodal freight transfers between ports, marine highway, truck, and rail was not available during this research period. However, because of the serious issues related to port-roadway congestion, there still remains a need to address the potential for ITS technologies to provide greater operational efficiencies within the maritime environment. Within the 2014 research timeframe, MARAD and the ITS Program will continue the assessment regarding the potential ways in which effective application of ITS technologies can lead to greater maritime resource efficiencies and increased system performance. The US DOT recognizes that a successful demonstration of a Connected Vehicle Environment may provide MARAD with a powerful stepping-stone for envisioning how ITS can address the complex issues relative to port and roadway congestion.

Multimodal Integrated Payment Systems ...

... are integrated, interoperable electronic fare payment systems that can be utilized by all modes at all times.

The vision for the Multimodal Integrated Payment Systems research is to deliver to travelers the ease of use and convenience that comes from one payment system that can be used across modes. Transportation agencies will benefit from simplified transactions, streamlined revenue collection, improved efficiency, and lower transaction costs.

Research Plan

This research program assesses the impediments to deploying multimodal, integrated payment systems (MMIPS) and identifies whether there are opportunities for markets and business models that would lead to sustainable markets for these technologies. While the private sector has done much to develop and deploy electronic payment technologies for transit and tolling systems, further research is needed to extend these systems across all modes by addressing interoperability.

The FTA and the FHWA will cooperatively investigate the potential for multimodal, integrated payment systems. In partnership, they will build upon previous research into electronic fare payment systems, tolling systems, parking reservation and payment systems, standards, and back-end financial transaction models that currently support transit and highway systems. New research will begin with a feasibility assessment of integrated systems, including analysis of new and emerging technologies and models for operations, financial transactions, and consumer electronics capabilities. This first phase will assess the platform of various electronic payment techniques and technologies, such as smart cards, bank-owned cards, cell phones, personal digital devices (e.g., BlackBerry, iPod), and transponders.

Further research will be conducted to determine the ITS standards needed to create an open architecture environment. Research will also be done to evaluate the technological capabilities and flexibility for identifying and assigning fees based on usage of the system. Finally, research will be conducted to identify benefits and costs.

If it is determined that an integrated, multimodal system is technologically feasible, non-technical research will address institutional issues and customer acceptance, assess market opportunities, analyze back-office clearinghouse operations, and develop one or more business models for consideration in developing policy options. The research is expected to result in the demonstration and evaluation of an integrated system comprised of transit bus service, parking, and tolls.

Research Goals:

- ▶ To research the national policy requirements and investigate technological options for an interoperable, multimodal payment platform.
- ▶ To identify target markets of early adopters that demonstrate the greatest sustained value in having integrated electronic payment formats.

Research Outcomes:

The outcome of the research will result in the facilitation and expedition of multimodal, commercially available, regionally integrated, next-generation electronic payment systems that accept multiple payment media and are cost effective.



ITS Maritime Applications ...

... are transportation technologies applied within intermodal freight transfers between port, marine highway, truck, and rail. More than 90 percent of the nation's imported and exported goods move by water and over one billion tons of domestic freight travels annually on America's Marine Highways.

The vision for the ITS Maritime Applications research is to investigate the range of ITS applications that can provide greater operational efficiencies within the maritime environment.

Research Plan

Using waterborne transportation for moving freight can help mitigate landside congestion, reduce greenhouse gas emissions, and conserve energy. Despite these benefits, inefficiencies within the first and last travel legs of freight delivery can make waterborne transportation cost prohibitive.

Effective application of ITS technologies can lead to greater resource efficiencies and increased system performance. Some examples of ITS applications include:

- ▶ Optimized scheduling for waterborne freight arrival and transit, which increases system capacity and reduces fuel consumption by minimizing delays;
- ▶ Providing real-time weather information to improve safety operations for vessels; and
- ▶ Coordinating truck and container move scheduling to reduce wasted trips and unnecessary empty containers moves.

The ITS maritime technology research will be conducted in two phases:

- ▶ The first phase will begin with a series of stakeholder workshops that focus on two outcomes: (1) identifying opportunities for increased efficiency and lowering the cost of intermodal maritime services, and (2) determining the most appropriate ITS application(s) to meet the objectives.

The results of this first phase of research are expected to result in:

- ▶ Identification of ITS applications that are specific to Marine Highway services and that will minimize waste and optimize resource utilization in the intermodal transfer during the first and last leg of freight deliveries;
- ▶ Describe performance measures for evaluating the applications' efficiencies and public benefit; and
- ▶ Quantify public benefits of increased Marine Highway utilization.

Phase two research will focus on deploying selected pilot projects. The research will establish a baseline for service and determine potential efficiencies and cost savings. Performance measurement evaluations will be conducted to test and validate the efficiencies and benefits produced from these applications. Upon project completion, the Maritime Administration and the ITS Program will determine whether to deploy additional ITS deployments and develop best practices for fleet-wide dissemination.

Research Goals:

- ▶ To identify effective ITS applications for the maritime transportation environment.
- ▶ To pilot and evaluate a range of maritime ITS applications and capture their benefits.

Research Outcomes:

To develop definitive insight into whether ITS applications can provide increased efficiencies and lower costs for waterborne freight arrival and transit.



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Appendix C

Media Outlets and Links to Featured News

From 2010 to 2012, the ITS Program has significantly expanded its outreach to media outlets as a way to create greater awareness of the Connected Vehicle research, the research progress, and the potential benefits. The following is a sample of some of the articles and radio and television coverage.

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"Safety Experiment: Cars That 'Talk' to Each Other," Matthew Larotonda, May 23, 2012

<http://abcnews.go.com/blogs/technology/2012/05/safety-experiment-cars-that-talk-to-each-other/>



"Will Drivers Cede Safety to Computers? Feds Finding Out," David Sedgwick, August 1, 2011

<http://www.autonews.com/apps/pbcs.dll/article?AID=/20110801/OEM01/308019973/1018>



"The Connected Vehicle" video, Bob Petrancosta, Vice President, Safety, Con-way Freight

<http://www.bigtrucktv.com/video/connected-vehicle>



"Someday 'Talking Cars' May Save Lives," January 26, 2011 8:25 AM

<http://www.cbsnews.com/stories/2011/01/25/business/main7282906.shtml>



"Coming soon: vehicles that talk to one another," Liza Barth, Feb 21, 2012 6:00 AM

<http://news.consumerreports.org/cars/2012/02/coming-soon-vehicles-that-talk-to-one-another.html>



"Look! No hands! The driverless future of driving is here," Doug Gross, CNN, Feb., 22, 2012

<http://whatsnext.blogs.cnn.com/2012/02/22/the-sci-fi-future-of-driving-its-already-here/?iref=allsearch>



"Feds Test Car-to-Car Communication," David Shepardson, Detroit News Washington Bureau, April 27, 2012

<http://www.detroitnews.com/article/20120427/AUTO01/204270334>

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"Connected Vehicles: The Future of Transportation Safety,"
Peter Appel, Administrator, US DOT's Research and Innovative
Technology Administration (rita), Spring 2011, Vol. 13, No. 1

http://www.ghsa.org/html/publications/directions/2011/spring_k-rita.html



"The Traffic Problems That Will Disappear When Vehicles Can Talk To Each Other," Ariel Schwartz

<http://www.fastcompany.com/1770893>



"Car Talk," Julie Halpert

<http://www.hemispheresmagazine.com/2011/01/01/car-talk/>



"Need for harmonisation in ITS standards,"

<http://www.itsinternational.com/sections/comment-interview/interviews/need-for-harmonisation-in-its-standards/?locale=en>



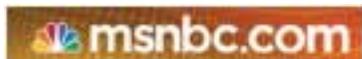
"Unlocking Hidden Capacity," William B. Cassidy, Sep 12, 2011,

<http://www.joc.com/trucking/unlocking-hidden-capacity>



"Taking advantage of urbanization," Martin Kruse, March 19, 2012,

http://www.koreatimes.co.kr/www/news/nation/2012/03/370_107241.html



"Connected cars: 'Knight Rider' meets George Jetson," Rob Lovitt, August 1, 2011

http://overheadbin.msnbc.msn.com/_news/2011/08/01/7199291-connected-cars-knight-rider-meets-george-jetson



"What Have We Done for You Lately?" July, 2011

<http://www.nema.org/about/upload/whatHaveWeDoneLately.pdf>

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"Take A Ride In A Car Of The Future," Talk of the Nation, November 21, 2008,

<http://www.npr.org/templates/story/story.php?storyId=97303396>



"Cars that 'talk' to one another not far off," Dan Tracy,
August 7, 2011

<http://www.orlandosentinel.com/features/consumer/os-smart-cars-technology-20110731,0,6275542.story>



"Integrated Corridor Management," Brian Cronin, Steve Mortensen, Robert Sheehan, and Dale Thompson, Publication Number: FHWA-HRT-11-001, November/December 2010, Vol. 74 · No. 3.

<http://www.fhwa.dot.gov/publications/publicroads/10novdec/02.cfm>



"Connected Vehicle Technology, Is it Time?" Pete Goldin, Fall, 2011

http://pulse.wavetronix.com/assets/pulse_5-2.pdf



"CONGESTION MANAGEMENT: Moving in the city," Angela Jacobs and Carol A. Zimmerman, May 5, 2011

<http://www.roadsbridges.com/CONGESTION-MANAGEMENT-Moving-in-the-city-article12755>



"Car-to-Car Communication System to Get a Massive Road Test," Julie Halpert, September 7, 2011

<http://www.technologyreview.com/communications/38525/#.TmjMBeW4Ffo.email>



"Crash Survival Systems + Car-to-Car Communication = A Next Gen Crash Avoidance System," Alan Pierce, December 2011

http://www.its.dot.gov/press/pdf/Car_to_Car_Communication.pdf



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"Welcome to the Wireless World," Vol. 6, No. 1

<http://thinkinghighways.com/Pages/View-issue/Magazine.aspx?id=6ad9bace-622a-43bd-bb11-a335f862bfae&issue=e3b8e560-5c07-4d07-85af-60a31ca36134>



"Now that Cars Can Talk to Each Other What Should They Say?" Alex Goldmark, August 1, 2011

<http://transportationnation.org/2011/08/01/now-that-cars-can-talk-to-each-other-what-should-they-say/>

The Washington Post

"The not-too-distant future of driving: When cars can talk, crashes may be avoided" Ashley Halsey III, April 10, 2012

http://www.washingtonpost.com/local/trafficandcommuting/the-not-too-distant-future-of-driving-when-cars-can-talk-crashes-may-be-avoided/2012/04/10/gIQAGCbA9S_story.html; and

"Talking' cars may someday warn of crashes and save lives," Peter Whoriskey, Jan., 25, 2011 <http://www.washingtonpost.com/wp-dyn/content/article/2011/01/25/AR2011012506232.html>



Roundtable Informs Wireless Innovation for Transportation, Posted by Aneesh Chopra, Peter Appel, and David Strickland on May 27, 2011

<http://www.whitehouse.gov/blog/2011/05/27/roundtable-informs-wireless-innovation-transportation>

WIRED

"Feds To Begin Testing Connected Vehicles," Keith Barry, Aug., 23, 2011

<http://www.wired.com/autopia/2011/08/nhtsa-begins-connected-vehicle-testing>; and

"Talking Cars are Coming Soon to Keep Us Safe," Chuck Squatriglia, Jan., 31, 2011

<http://www.wired.com/autopia/2011/01/talking-cars-are-coming-soon-to-keep-us-safe>

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