Motor vehicle crashes are the leading cause of death for Americans ages 4 to 34, according to the U.S. Centers for Disease Control and Prevention. Improving transportation safety is the top priority for the U.S. Department of Transportation (DOT). The Intelligent Transportation Systems Joint Program Office (ITS-JPO) of the Research and Innovative Technology Administration (RITA) is focusing on crash prevention through the Connected Vehicle Research Program.

The connected vehicle program pursues research and development into low-latency, wireless communications technology to enable motor vehicles to stream secure, private, real-time data about position, speed, and other information that is critical to improving roadway safety and management. The connected vehicle concept relies on a data-rich transportation network of vehicles virtually connected to each other and to infrastructure.

The connected vehicle technology platform supports collision-avoidance systems that can be highly effective at reducing many of the most deadly crashes that do not involve an impaired driver. Connected vehicles move beyond the protections of seatbelts and airbags, to expand roadway safety from crash survival to crash avoidance.

**Connected Vehicle Overview**

The mission of the ITS-JPO research program is to create an intelligent transportation system in which vehicles and infrastructure use 21st century technologies—such as the Global Positioning System, wireless broadband, and remote sensing—to enhance decision making and operations. To achieve...
this vision, the program is advancing major research initiatives, exploratory studies, and support for technology transfer, deployment, and training.

Connected vehicle technology emerged as the core focus for the ITS-JPO through cooperative research conducted by U.S. DOT, the academic community, and the automotive industry. The research results showed that connected vehicles can transform the way Americans travel by creating a safe, interoperable, wireless communications network of cars, buses, trucks, trains, traffic signals, cell phones, and other devices.

Connected vehicle technology has the potential to accomplish the following:

- Prevent crashes;
- Enable communication between vehicles and the infrastructure to realize benefits for safety, mobility, and the environment; and
- Enable communication among vehicles, infrastructure, and wireless devices to provide continuous, real-time connectivity for all system users.

Research results have encouraged a strategic shift toward developing and testing connected vehicle technologies and applications and assessing the potential benefits and costs. ITS-JPO is taking key steps to ensure that the applications are safe, reliable, and effective in a real-world environment. In addition, the efforts are building a technical, institutional, and policy framework for promoting commercialization and reducing the time to implementation.

Improving Safety

Connected vehicle safety applications reduce crashes through vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) data transmission. V2V and V2I transmissions enable vehicles to warn drivers about dangers on the roadway—including dangers that may not be visible—through a dynamic interface of in-vehicle displays, audible alerts, and even tactile prompts, such as seat vibration.

The interface can warn vehicle operators about imminent crash situations, such as a vehicle on the driver’s blind side during a lane change, or traffic ahead suddenly braking during a rainstorm. The safety benefits are not limited to dangerous situations that require immediate action, however; the interface can alert a driver approaching a school zone or road work area or a traffic signal about to change.

Connected vehicle safety applications enable safer and more responsive decision making by providing time-critical information and extending a driver’s awareness beyond the line of sight and any interfering elements.

Safety Pilot

U.S. DOT’s Safety Pilot Model Deployment was launched in summer 2012 in Ann Arbor, Michigan. The culmination of a decade of forward-thinking research and a strong commitment to new technologies for safer and improved transportation, the safety pilot is an unprecedented test of connected vehicle technology in real-world conditions and will continue through 2013.

Ann Arbor residents are driving nearly 2,800 specially equipped motor vehicles. The drivers’ experience and the vehicle data cannot be duplicated in a laboratory; the pilot represents a significant milestone in the development of connected vehicle technology.
In the first phase of the safety pilot, U.S. DOT conducted a series of six driver acceptance clinics to test V2V safety applications with ordinary drivers in controlled roadway situations. The data from the clinics revealed that 9 out of 10 drivers embraced the experience and wanted V2V safety features in their personal vehicles.

The University of Michigan Transportation Research Institute is conducting the second phase of the safety pilot, the model deployment. The vehicles are equipped with safety systems that use dedicated short-range communication (DSRC), a secure, wireless communications technology. DSRC allows the nearly instantaneous transmission of data between highly concentrated numbers of safety pilot test vehicles operating on public streets. The test vehicles can detect each other when in the same driving area.

**Devices and Messages**

The model deployment includes a mix of cars, trucks, and transit vehicles and is the largest test of connected vehicles in a real-world, multimodal operating environment. The model deployment is testing four types of DSRC electronic devices:

- **Integrated safety devices**, installed during vehicle production;
- **Aftermarket safety devices**, installed after initial vehicle manufacture;
- **Retrofit safety devices**, installed in a truck or bus by an authorized service provider after the vehicle’s manufacture; and
- **Vehicle awareness devices**, aftermarket devices installed in a vehicle without connection to the vehicle system.

Each of these devices broadcasts a basic safety message (BSM) about vehicle size, position, speed, heading, acceleration, and braking. The BSM is transmitted 10 times per second, forming the data stream that the vehicles and infrastructure can use to identify potential traffic or roadway dangers. The devices can detect an impending collision at an obscured intersection, a vehicle changing lanes in another vehicle’s blind spot, a potential rear collision with a vehicle stopped ahead, a vehicle traveling too fast to navigate a curve safely, and other hazardous conditions.

**Applications**

The BSM transmission identifies developing crash situations; the in-vehicle safety devices use the data to activate a series of time-critical safety alerts, such as the following:

- **Blind spot warning–lane change warning**, to alert drivers who are changing lanes that a car is in the blind spot or that a vehicle is about to overtake them;
- **Forward collision warning**, to alert and warn drivers who fail to brake when a vehicle ahead has stopped or is traveling slower;
- **Electronic emergency brake lights**, to notify drivers that a vehicle they cannot see ahead is braking hard;
- **Intersection movement assist**, to warn the driver that entering an intersection is not safe—for example, something is blocking the driver’s view of the opposing traffic; and
- **Do-not-pass warning**, to warn drivers attempting to change lanes and pass that a vehicle is in the opposing lane within the passing zone.

**Informing Decisions**

ITS-JPO is coordinating this research initiative in conjunction with several U.S. DOT agencies that are also supporting the model deployment: RITA, the National Highway Traffic Safety Administration (NHTSA), the Federal Highway Administration, the Federal Motor Carrier Safety Administration, and the Federal Transit Administration.
The model deployment research will produce data to support a major decision by NHTSA later this year about future V2V safety applications. Similar decisions are scheduled for 2014 on V2V and V2I safety technology in heavy vehicles.

**Integrated Truck Safety**

DSRC and similar wireless communications technologies also can yield significant benefits for truck safety and efficiency. U.S. DOT’s Integrated Truck Safety Program is incorporating DSRC technology into a commercial heavy-vehicle platform to develop research prototypes capable of testing crash avoidance safety applications. The applications support the transmission of interoperable safety messages across multiple vehicle platforms and models—specifically between commercial vehicles and cars—so that the safety benefits are harmonized for all types of vehicles on the road.

The safety pilot includes two clinics for truck drivers and has recruited a cross section of commercial vehicle drivers primarily from local fleets. The participants will operate the vehicles in a safe, highly controlled, closed course. Researchers will collect subjective driver acceptance data related to integrated safety systems and driver–vehicle interfaces, to guide the development of future applications.

**Improving Mobility**

Traffic congestion drains $100.9 billion from the U.S. economy every year, according to the Texas A&M Transportation Institute’s 2011 Urban Mobility Report; the cost reflects 4.8 billion hours of lost productivity and 1.9 billion gallons of wasted fuel.

Although the primary goal of connected vehicles is to improve safety, the technology also can ease traffic congestion and limit delays. Connected vehicles can help prevent disruptive incidents—such as crashes—and can generate a wealth of real-time data about traffic flows and travel conditions. Transportation agencies can use this information to optimize traffic signals, guide construction to eliminate bottlenecks, implement wireless roadside inspections, or help commercial vehicle drivers identify areas designated for extended parking.

The same continuously updated, anonymous data, accessible via a new generation of mobile applications, can empower travelers with route planning and other services to inform decision making. For example, applications could locate parking spaces, connect travelers between modes—for example, from a park-and-ride facility to a bus or train—or help a visually impaired pedestrian cross a busy intersection.

Data from connected vehicles can enhance current transportation management tools and can lead to new tools to address service gaps. U.S. DOT is conducting research on dynamic mobility applications that capitalize on V2V and V2I connectivity, such as real-time data from in-vehicle devices and other sources, to improve the efficiency and mobility of the transportation system. The program identifies high-value applications for research and develops the concepts, tools, metrics, and best practices for future
applications—prioritizing development for public agencies and other organizations not adequately served by commercial solutions.

**Environmental Benefits**

The transportation sector accounted for approximately 27 percent of total U.S. greenhouse gas (GHG) emissions in 2009 and is the second-largest source of carbon dioxide emissions in the United States, according to the Environmental Protection Agency’s *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2009*. Vehicles that are stationary, idling, and traveling in a stop-and-go pattern because of system inefficiencies, such as congestion, produce more GHGs than vehicles that are able to move freely and to adjust effectively to changing conditions.

A University of Michigan study released in 2012 found that U.S. DOT action has helped improve the average fuel economy of new vehicles sold in the United States since October 2007 by 4 miles per gallon. Continuing to find reasonable approaches to reduce fossil fuel consumption by vehicles would be a tremendous step forward in reducing GHG emissions and managing climate change.

The real-time transportation data generated by connected vehicles include information useful for environmental applications. The data can support and facilitate more environmentally sustainable transportation choices, operations, and planning.

The ability of a vehicle to communicate with traffic signals can help drivers and transit operators eliminate unnecessary stops and optimize fuel efficiency. Real-time information about travel conditions can help travelers avoid congestion by taking alternative routes, riding public transit, or rescheduling a trip. Applications help drivers mitigate their carbon footprint and manage vehicle operation and maintenance for maximum fuel efficiency.

The data-rich connected vehicle network provides transportation managers with accurate information about traffic and travel conditions—along with new tools to address congestion and other inefficiencies. Traffic signal phase and timing, electronic tolling, and dynamic message signs are among the innovative transportation management applications supported by connected vehicle technology.

The potential environmental benefits of connected vehicles derive from the aggregate impact of access to information about travel conditions by the transportation system users, operators, managers, and planners, enabling better travel decisions. For example, Eco-Signal Operations uses connected vehicle technologies to decrease fuel consumption and GHG and criteria air pollutant emissions by reducing idling, the number of stops, and unnecessary accelerations and decelerations; the application also can improve traffic flow at signalized intersections.

**Green Research**

Applications for the Environment: Real-Time Information Synthesis (AERIS) is an ITS-JPO initiative to develop “green,” or environment-friendly, connected vehicle applications. AERIS will explore the potential for V2V and V2I technology to produce data that can be used to reduce GHG and other pollutant emissions from motor vehicle travel. The initiative also will explore how this capability can evaluate and quantify related air quality and climate change outcomes.

AERIS research will identify, collect, and analyze the most promising data sets and will develop actionable information for transportation users and managers. Possible applications include advising motorists about alternative routes, optimal speeds, and other measures to reduce GHG output during a trip or enabling managers to adjust traffic signals dynamically or to notify travelers about air quality alerts.

In addition, AERIS conducts webinars and public meetings to engage stakeholders and researchers from the transportation and environmental communities. The focus is on promoting environmentally sustainable decisions, so that people and goods can travel in a way that can reduce GHG emissions in the long term and the number of poor air quality days annually.

**Core Systems**

A new architecture underpins the connected vehicle program’s safety, mobility, and environmental applications and links the core system to these functions. The vision is to combine the applications, services, and systems for safety, mobility, and environmental benefits through the exchange of data between transportation users:
Applications that provide the functionality for safety, mobility, and environmental benefits;
Communications that facilitate data exchange; and
A core system that enables data exchanges between mobile and fixed transportation users.

The core system includes the enabling technologies and services that support a distributed, diverse set of wireless and hardwired transportation applications. Open, standardized interface specifications govern all interactions between users, so that devices, agencies, or vendors do not define the boundaries of the core system. The system must be secure from hackers, signal interference, and other elements that can disrupt its safety and reliability.

The integrity of the core system and of the entire connected vehicle environment relies on the trust of the communicating parties that their data will be protected from misuse or disclosure. Maintaining the privacy of participants is a complex task that is crucial to the connected vehicle initiative. The core system will be designed to ensure anonymity in the exchange of data and will define the processes for establishing trust among participants.

Harmonization of Standards
For connected vehicles, standards development and harmonization provides a framework for sharing data and information among public agencies and private organizations and for fostering interoperability. The ITS-JPO has teamed with leading standard-setting organizations and public agencies to accelerate the development of standards for open, non-proprietary communications interfaces that support ITS application development and deployment.

These standards establish the way that ITS systems and components interconnect and exchange information for the delivery of services within a multimodal transportation network. Standards ensure that all motor vehicle fleets will be able to communicate with each other. Reducing the barriers to standardization and achieving a broad agreement on harmonization can reduce the time to deployment by reducing industry risk and cost as connected vehicle technology enters the commercial market.

The United States has cooperative relationships with the international ITS community, both at the policy level and at the technical level, and continues to work with international counterparts on research activities and standardization processes. Because transportation—especially vehicle manufacturing—is a global industry, harmonized standards are necessary to enable the use of common hardware and to reduce the cost and time to reach the marketplace. Sharing data and knowledge on safety, mobility, and environmental applications, as well as on the spectrum of transmission frequencies and other key policy issues, collectively can get the most out of investments made independently.

Policy Implications
The ITS-JPO Policy and Institutional Issues program researches, analyzes, and presents policy options to advance the implementation of connected vehicle technology. The program also identifies critical issues that may hinder or challenge successful implementation.

Of particular interest and focus are social and institutional frameworks most likely to support the transition from the research phase to implementation. Privacy and security, along with a variety of potential
institutional issues, are also of paramount importance. U.S. DOT has reached out to key stakeholders to help guide policy research and to ensure sound, real-world applications of the new technologies.

Successful implementation requires that complex policy and technical issues are addressed in a coordinated, balanced way. The two components are inextricably linked. To address the challenge, U.S. DOT has held meetings and discussions involving the automotive industry, state DOTs, and others to consider such issues as

- Options for security networks;
- The governance of security certificates;
- Privacy provisions, which have been a key part of the program; and
- Business modeling to ensure sustainable funding for implementation, operations, and maintenance.

**Looking Ahead**

The ITS-JPO is soliciting intensive input from stakeholders in the development of the next four-year strategic research plan, from drafting themes to determining the focused concepts that identify research initiatives. ITS-JPO program managers are using webinars, as well as engaging stakeholders through public meetings in Washington, D.C., and other locations.

Transportation agencies, organizations, and industry leaders are encouraged to share their perspectives for the next plan. The Ideascle website has opened a dialogue and published a discussion document on the following broad themes for the next strategic research plan:

- Maturing connected vehicle systems;
- Piloting and deployment readiness; and
- Integrating with the broader environment.

Many state and local agencies are proactive about ITS and are evaluating V2I applications and capabilities. Transportation agencies and their organizations can ask questions and help set the goals for a connected vehicle environment.

In addition, the program has active partners in the automobile industry, as evidenced by the safety pilot. The industry sees the promise of the technology and is devoting resources to its development. Industry's ability to offer consumers added value through ITS technology will help introduce the technology to cities and communities.

Connected vehicle communication systems can revolutionize roadway safety. In addition, connected vehicles can improve the mobility and the environmental impact of the U.S. transportation system. Like the Internet, which provides information connectivity through open standards, connected vehicle technology can provide a starting point for transportation connectivity that will enable countless applications and spawn new industries.

To learn more about the connected vehicle program, visit the ITS-JPO website, [www.its.dot.gov](http://www.its.dot.gov/).