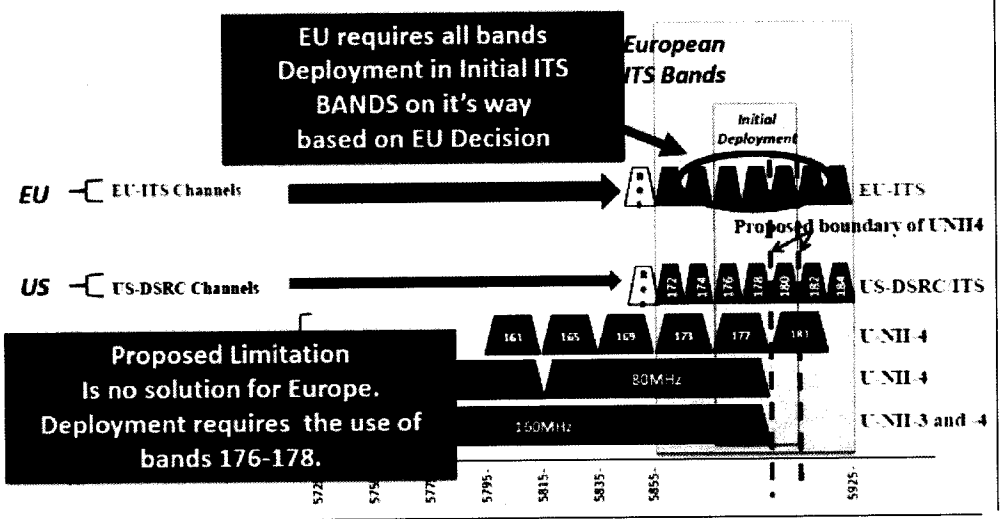
Proposal is US-Specific:

European Frequency Regulation (from 11-14-0550/r0)

ITS usage in band 5875-5925 MHz
In line with EU Decision 2008/671/EC



Proposal Stifles DSRC Innovation

- Communication technologies (e.g. Wi-Fi) typically undergo extensive evolution
- DSRC is in "early days" and can be expected to experience a similar evolution
- DSRC offers great potential for entrepreneurs and innovators
- For DSRC, 5.850-5.925 GHz is not "yet another" band. It is the only band where DSRC innovation can occur.
- The re-channelization proposal imposes significant constraints on how DSRC uses the band. This will tend to stifle the innovation that could unleash DSRC's full potential
- The Tiger Team should avoid approaches like the re-channelization proposal that stifle innovation

Review

- Proposal is inconsistent with ITS plans to use the entire band for safety-critical communication
- Proposal will delay DSRC deployment, with attendant costs
- Proposal calls for degraded DSRC performance
- Proposal is inconsistent with FCC NPRM
- Proposal offers no in-band protection
- Proposal is Wi-Fi specific
- Proposal is US-specific
- Proposal stifles DSRC innovation

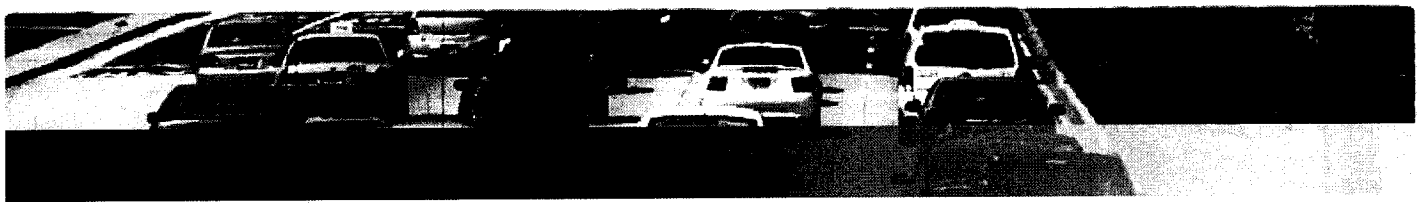
Conclusion

For the reasons cited here, the authors of this submission:

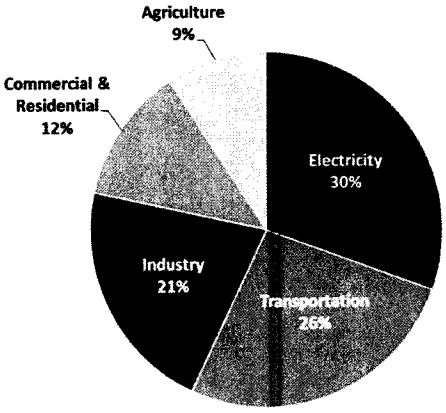
- consider the proposal in 11-13-1276/r1 and 11-14-0819/r0 ("the proposal") inconsistent with the DSRC mission for which the FCC allocated the 5.9 GHz band
- conclude that the proposal is not viable as a U-NII sharing technology that will protect DSRC services
- encourage the Tiger Team to focus resources on developing a proposal that has the potential to protect DSRC services and garner broad-based stakeholder support

Appendix VIII. EPA, *Sources of Greenhouse Gas Emissions.*

Greenhouse Gas Emissions: Transportation Sector Emissions | Climate Change



Total U.S. Greenhouse Gas Emissions by Economic Sector in 2014



Total Emissions in 2014 = 6,870 Million Metric Tons of CO2 equivalent

* Land Use, Land-Use Change, and Forestry in the United States is a net sink and offsets approximately 11% of these greenhouse gas emissions.

All emission estimates from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2014*

Related Links

The Transportation sector includes the movement of people and goods by cars, trucks, trains, ships, airplanes, and other vehicles. The majority of greenhouse gas emissions from transportation are CO2 emissions resulting from the combustion of petroleum-based products, like gasoline, in internal combustion engines. The largest sources of transportation-related greenhouse gas emissions include passenger cars and light-duty trucks, including sport utility vehicles, pickup trucks, and minivans. These sources account for over half of the emissions from the sector. The remainder of greenhouse gas emissions comes from other modes of transportation, including freight trucks, commercial aircraft, ships, boats, and trains as well as pipelines and lubricants.

Relatively small amounts of methane (CH4) and nitrous oxide (N2O) are emitted during fuel combustion. In addition, a small amount of hydrofluorocarbon (HFC) emissions are included in the Transportation sector. These emissions result from the use of mobile air conditioners and refrigerated transport.

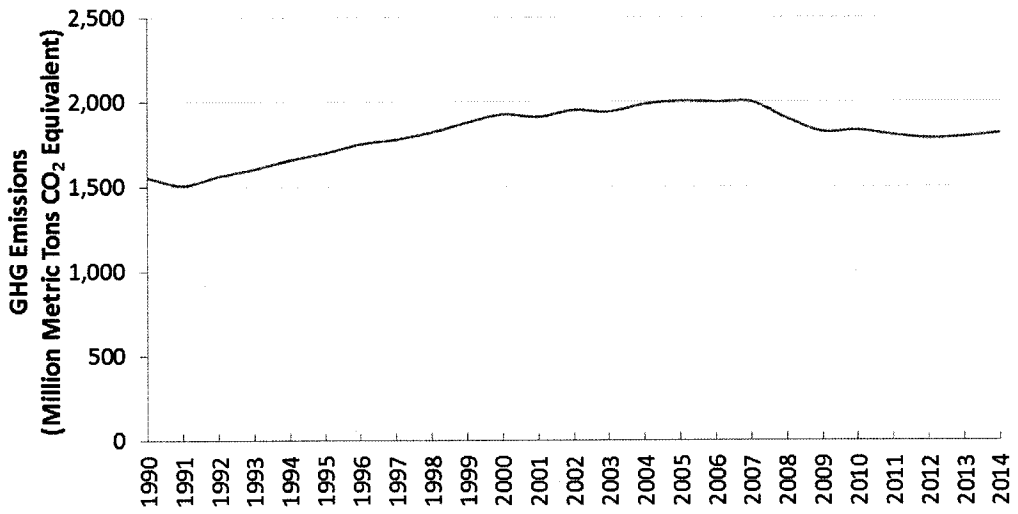
Emissions and Trends

In 2014, greenhouse gas emissions from transportation accounted for about 26% of total U.S. greenhouse gas emissions, making it the second largest contributor of U.S. greenhouse gas emissions after the Electricity sector. Greenhouse gas emissions from transportation have increased by about 17% since 1990. This historical increase is largely due to increased demand for travel and the limited gains in fuel efficiency across the U.S. vehicle fleet. The number of vehicle miles traveled by passenger cars and light-duty trucks increased 37% from 1990 to 2014. The

increase in travel miles is attributed to several factors, including population growth, economic growth, urban sprawl, and low fuel prices during the beginning of this period. Between 1990 and 2004, average fuel economy among new vehicles sold annually declined, as sales of light-duty trucks increased. However, new vehicle fuel economy began to improve in 2005, largely due to a lower light-duty truck market share and higher fuel economy standards.

Learn more about Greenhouse Gas Emissions from Transportation. To learn about projected greenhouse gas emissions to 2020, visit the *U.S. Climate Action Report 2014 (PDF)* (310 pp., 23.1 MB).

Greenhouse Gas Emissions from Transportation



Note: Emissions involved in the consumption of electricity for transportation activities are included above, but not shown separately (as was done for other sectors). These indirect emissions are negligible, accounting for less than 1% of the total emissions shown in the graph.
Note: All emission estimates from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2014*.

Reducing Emissions from Transportation

There are a variety of opportunities to reduce greenhouse gas emissions associated with transportation. The table shown below categorizes these opportunities and provides examples. For a more comprehensive list, see Chapter 5 of the *Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*.

EPA's vehicle greenhouse gas rules will save consumers $1.7 trillion at the pump by 2025, and eliminate six billion metric tons of GHG pollution.

Examples of Reduction Opportunities in the Transportation Sector

Type	How Emissions are Reduced	Examples
	Using fuels that emit less CO2 than fuels currently being used. Alternative sources can include biofuels; hydrogen;	• Using public buses that are fueled by compressed natural gas rather than gasoline or diesel. • Using electric or hybrid

Fuel Switching	electricity from renewable sources, such as wind and solar; or fossil fuels that are less CO2-intensive than the fuels that they replace. Learn more about Alternative and Renewable Fuels.	automobiles, provided that the energy is generated from lower-carbon or non-fossil fuels. • Using renewable fuels such as low-carbon biofuels.
Improving Fuel Efficiency with Advanced Design, Materials, and Technologies	Using advanced technologies, design, and materials to develop more fuel-efficient vehicles. Learn about EPA's vehicle greenhouse gas rules.	• Developing advanced vehicle technologies such as hybrid vehicles and electric vehicles, that can store energy from braking and use it for power later. • Reducing the weight of materials used to build vehicles. • Reducing the aerodynamic resistance of vehicles through better shape design.
Improving Operating Practices	Adopting practices that minimize fuel use. Improving driving practices and vehicle maintenance. Learn about how the freight transportation industry can reduce emissions through EPA's SmartWay Program.	• Reducing the average taxi time for aircraft. • Driving sensibly (avoiding rapid acceleration and braking, observing the speed limit). • Reducing engine-idling. • Improved voyage planning for ships, such as through improved weather routing, to increase fuel efficiency.
Reducing Travel Demand	Employing urban planning to reduce the number of miles that people drive each day. Learn about EPA's Smart Growth Program. Reducing the need for driving through travel efficiency measures such as commuter, biking, and pedestrian programs. See a list of links to state, local, regional travel-efficiency programs.	• Building public transportation, sidewalks, and bike paths to increase lower-emission transportation choices. • Zoning for mixed use areas, so that residences, schools, stores, and businesses are close together, reducing the need for driving.

Appendix IX. USDOT, *Transit Connected Vehicle Research Program.*

RITA - Intelligent Transportation Systems - Transit Connected Vehicle Research Program

Research Overview

Connected vehicles have the potential to transform the way Americans travel through the creation of a safe, interoperable wireless communications network that links cars, buses, trucks, trains, transportation infrastructure, and personal mobile devices.

The technology will change the transportation system paradigm by giving people the tools to avoid crashes, and make travel faster, easier, more accessible, and environmentally friendlier. The vision for transit connected vehicle research is to collaborate and leverage the evolving connected vehicle communications capability to achieve desirable transit safety, mobility, and environmental outcomes.

Why Connected Vehicle Technologies are Needed

Connected vehicle technologies aim to tackle some of the biggest challenges in the surface transportation industry —in the areas of safety, mobility, and environment.

- **Safety**: According to the Federal Transit Administration, there were more than 4,000 transit crashes reported in 2009, resulting in over 200 fatalities and more than 2,500 injuries. While transit is already one of the safest modes for travel, connected vehicle technologies will further empower transit drivers with the tools they need to anticipate potential crashes and significantly reduce the number of lives lost each year.
- **Mobility**: According to the Texas Transportation Institute, U.S. highway users waste 4.8 billion hours in 2010 stuck in traffic—nearly one full work week (or vacation week) for every traveler. Connected vehicle mobility applications will enable system operators and travelers to make informed decisions that reduce travel delay.
- **Environment**: According to the American Public Transportation Association, each year transit systems collectively reduce carbon dioxide emissions by 16.2 million metric tons by reducing private vehicle miles. Connected vehicle environmental applications will give all travelers the real-time information they need to make "green" transportation choices.

How Connected Vehicles Work

A system of connected vehicles is still in development, and plenty of research still needs to be done. Safety-related systems for connected vehicle technology will likely be based on dedicated short-range communications (DSRC), a technology similar to WiFi. DSRC is fast, secure, reliable, and is not vulnerable to interference.

Nonsafety applications may be based on different types of wireless technology. Cars, trucks, buses, and other vehicles will be able to "talk" to each other with in-vehicle or after market devices that continuously share important safety and mobility information. Connected vehicles can also use wireless communications to "talk" to the transportation infrastructure, such as traffic signals, toll equipment, and work and school zone warning systems. The vehicle information communicated does not identify the driver or vehicle, and technical controls have been put

in place to help prevent vehicle tracking and tampering with the system.

Connected Vehicle Research Promotes Transit Safety

Due to its unique characteristics and behaviors, such as vehicle size and frequent stops/starts, transit often faces safety challenges and priorities that are different from those for light and commercial vehicles. In collaboration with transit industry stakeholders, the U.S. Department of Transportation (USDOT) has identified several priority transit connected vehicle safety applications. Among these safety applications, two have been selected for near-term development and testing:

- **Pedestrian Warning Application for Transit Vehicles**: A bus driver receives an alert of the presence of a pedestrian near or in a crosswalk as the driver makes a turn at a signalized intersection. Signal phasing and timing information, including pedestrian detection data, is transmitted to the bus from roadside equipment.
- **Vehicle Turning Right in Front of a Transit Vehicle**: A bus driver receives an alert of a vehicle making a right turn in front of the bus as the bus driver pulls away from a bus stop. DSRC messages are transmitted to the bus and used to predict collisions between buses and other vehicles in this scenario.

Transit Connected Vehicle Research Enhances Mobility Choices

The overarching goal of the Transit Connected Vehicle for Mobility program is to improve public transportation by increasing transit productivity, efficiency, and accessibility; mitigating congestion in an integrated transportation environment; and providing travelers with better transportation information and transit services. Transit-oriented connected vehicle mobility applications support dynamic system operations and management, enable a convenient and quality travel experience, and provide an information-rich environment to meet the needs of travelers and system operators across all modes.

The following three mobility applications have been selected as high-priority applications and are collectively identified as the Integrated Dynamic Transit Operations (IDTO) "bundle":

- **Connection Protection (T-CONNECT):** Enables public transportation providers and travelers to communicate to improve the probability of successful transit transfers.
- **Dynamic Transit Operations (T-DISP)**: Advances the concept of demand-responsive transportation services utilizing the global positioning system (GPS) and mapping capabilities of personal mobile devices to enable a traveler to input a desired destination and time of departure tagged with their current location when requesting transit service.
- **Dynamic Ridesharing (D-RIDE)**: Makes use of in-vehicle and hand-held devices to allow dynamic ride-matching, thereby reducing congestion, pollution, and travel costs to the individual with a low initial investment.

A description of all the high-priority Connected Vehicle for Mobility applications and the process through which they were selected and grouped can be found at: www.its.dot.gov/ press/2011/mobility_app.htm.

Transit is a Key Element in Connected Vehicle Research to Improve the Environment

Mitigating greenhouse gas (GHG) contribution is everyone's responsibility. The transportation sector contributes roughly 28 percent of the country's GHG emissions, according to the Environmental Protection Agency's Inventory

of U.S. Greenhouse Gas Emissions and Sinks. Connected vehicle technologies will generate real-time data that drivers and transportation system managers can use to make green transportation choices.

Transit vehicles operate primarily on urban streets in heavily congested areas and thus offer a unique opportunity to study and assess the positive environmental impacts that could result from improved operations. By the very nature of their purpose Transit vehicles represent a unique vehicular operational profile, resulting in higher idle times and frequent mild acceleration/ deceleration into and out of traffic that impact the environment differently than other types of vehicles. Thus, transit vehicles and operators have different needs in relation to the development of environmental mitigation strategies from those for light duty and heavy duty vehicles. In the context of this research, transit vehicles are considered as both a source of pollutants as well as sources of data to measure and mitigate environmental impacts.

The U.S. Government's Role

The USDOT's Research and Innovative Technology Administration's Intelligent Transportation Systems (ITS) Joint Program Office fosters the development and future deployment of connected vehicle technologies. But connected vehicle research involves all agencies within the USDOT including the National Highway Traffic Safety Administration, Federal Highway Administration, Federal Motor Carrier Safety Administration, Federal Transit Administration, and Federal Railroad Administration. The USDOT and its public and private partners are working to address the technical, safety, and policy challenges and are helping to create the standards and the wireless architecture that will be the backbone of the system. Connected vehicle research will leverage the potentially transformative capabilities of wireless technology to make surface transportation safer, smarter, and greener. If successful, connected vehicles will ultimately enhance the mobility and quality of life of all Americans, while helping to reduce the environmental impact of surface transportation.

Contacts

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Appendix X. NHTSA, *Vehicle-to-Vehicle Communications: Readiness of V2V Technology for Application*, DOT HS 812 014 ("V2V Readiness ").

U.S. Department
of Transportation
**National Highway
Traffic Safety
Administration**

NHTSA
www.nhtsa.gov

DOT HS 812 014

August 2014

Vehicle-to-Vehicle Communications: Readiness of V2V Technology for Application

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16. Abstract

The purpose of this research report is to assess the readiness for application of vehicle-to-vehicle (V2V) communications, a system designed to transmit basic safety information between vehicles to facilitate warnings to drivers concerning impending crashes. The United States Department of Transportation and NHTSA have been conducting research on this technology for more than a decade. This report explores technical, legal, and policy issues relevant to V2V, analyzing the research conducted thus far, the technological solutions available for addressing the safety problems identified by the agency, the policy implications of those technological solutions, legal authority and legal issues such as liability and privacy. Using this report and other available information, decision-makers will determine how to proceed with additional activities involving vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), and vehicle-to-pedestrian (V2P) technologies.

17. Key Words vehicle-to-vehicle communications, crash avoidance, connected vehicle, safety applications, model deployment, safety pilot, vehicle awareness device, integrated device, aftermarket safety device, communication security, security credential management system, V2V technology		18. Distribution Statement Document is available to the public from the National Technical Information Service www.ntis.gov	
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Acronyms

AAMVA	American Association of Motor Vehicle Administrators
ABS	antilock braking system
ACM	a la carte message set
ACN	automatic crash notification
AERIS	Applications for the Environment: Real-Time Information Synthesis
AHS	Automated Highway System Program
ANPRM	Advanced Notice of Proposed Rulemaking
ARIB	Association of Radio Industries and Businesses
ARINC	Aeronautical Radio Incorporated
ASD	aftermarket safety device
ASTM	American Society for Testing and Materials
ATM	automatic teller machine
ATMIA	ATM Industry Association
BAH	Booz Allen Hamilton
BSM	basic safety message
BSW	blind spot warning
CA	certificate authority
CAMP	Crash Avoidance Metrics Partnership
CAN	controller area network
CARS	Car Allowance Rebate System - "Cash for Clunkers"
CBP	channel busy percentage
CCH	control channel
CFR	Code of Federal Regulations
CICAS-V	Cooperative Intersection Collision Avoidance System-Violation
CLW	control loss warning
CME	certificate management entity
CP	certificate policy
CRL	certificate revocation list
CSR	common safety request (message set)
CSW	curve speed warning
CVE	Common Vulnerabilities and Exposures
CVSS	Common Vulnerability Scoring System
DAC	(V2V Light Vehicle) Driver Acceptance Clinics
DCM	device configuration manager
DE	data element
DF	data frame
DG CONNECT	European Commission Directorate General for Communication Networks, Content and Technology
DIACAP	DOD Information Assurance Certification and Accreditation Process
DNPW	do not pass warning

DOD	U.S. Department of Defense
DOT	U.S. Department of Transportation
DSRC	dedicated short-range communications
DSRCS	Dedicated Short Range Communications Systems
DVI	driver-vehicle interface
ECA	enrollment certificate authority
ECU	electronic control unit
EEBL	emergency electronic brake lights
EIA	Energy Information Administration
ELVS	End of Life Vehicle Consortium
EPA	Environmental Protection Agency
ESC	electronic stability control
ETSI	European Telecommunications Standards Institute
EU	European Union
EUR	European Union Region
FAA	Federal Aviation Administration
FARS	Fatality Analysis Reporting System
FCC	Federal Communication Commission
FCW	forward collision warning
FHWA	Federal Highway Administration
FIPS	Federal Information Processing Standards
FMVSS	Federal Motor Vehicle Safety Standard
FOT	field operational test
FSS	fixed satellite service
FTC	Federal Trade Commission
GDP	gross domestic product
GES	General Estimates System
GHz	gigahertz - frequency measurement
GPS	Global Positioning System
HIPAA	Health Insurance Portability and Accountability Act
HUD	heads-up display
HV	host vehicle
HW	hardware
ICA	intersection collision avoidance
ICANN	Internet Corporation for Assigned Names and Numbers
ID	identification
IEEE	Institute of Electrical and Electronics Engineers
IMA	Intersection Movement Assist
IPG	inter-packet gap
ISACA	Information Systems Audit and Control Association
ISM	Industrial, Scientific and Medical
ISTEA	Intermodal Surface Transportation Efficiency Act
ITIS	Integrated Taxonomic Information System
ITS	Intelligent Transportation System
IVBSS	Integrated Vehicle-Based Safety Systems

IVI	Intelligent Vehicle Initiative
JPO	Joint Program Office
LA	Linkage Authority
LCW	lane change warning
LDW	lane departure warning
LLC	logical link control
LOP	location obscurer proxy
LTA	left turn assist
LTAP/OD	left turn across path/opposite direction
LTV	Light-truck vehicle
LVD	lead vehicle decelerating
LVM	lead vehicle moving
LVS	lead vehicle stopped
MA	misbehavior authority
MAC (Section IV)	Message Authentication Code
MAC (Section VIII)	Medium Access Control
MAIS	Maximum Abbreviated Injury Scale
MLIT	Japanese Ministry of Land, Infrastructure, Transportation and Tourism
MOU	Memorandum of Understanding
MY	model year
NAS	National Academy of Sciences
NCAP	New Car Assessment Program
NHTSA	National Highway Traffic Safety Administration
NIST	National Institute of Standards and Technology
NPRM	Notice of Proposed Rulemaking
NTCIP	National Transportation Communications for Intelligent Transportation System Protocol
NTIA	National Telecommunications and Information Administration
NTTAA	National Technology Transfer and Advancement Act
OBE	on-board equipment
OBU	on board units
ODI	Office of Defects Investigations
OE	original equipment
OEM	original equipment manufacturer
OST-R	Department of Transportation Office of the Assistant Secretary for Research and Technology
OTA	Over the air
OVW	Oversize Vehicle Warning
PC	Passenger car
PCA	Pseudonym Certificate Authority
PCI DSS	Payment Card Industry Data Security Standard
PDO	property-damage-only
PER	packet error rate
PII	Personally-identifiable information
PKI	public key infrastructure

POC	proof of concept
PPP	public private partnership
PPS	pulse per second
PPSG	NTIA's Policy and Plans Steering Group
PRA	Paperwork Reduction Act
PSID	provider service identifier
PTE	position tracking error
RA	registration authority
RCVW	railroad crossing violation warning
RF	radio frequency
RLVW	red light violation warning
RSD	retrofit safety device
RSE	road-side equipment
RSU	road side unit
RSZW	reduced speed zone warning
RTCM	Radio Technical Commission for Maritime Services
RTK	right turn into path
RV	remote vehicle
SAE	Society of Automotive Engineers
SCH	service channel
SCMS	Security Credentials Management System
SCP	straight crossing path
SD	secure digital
SE	system engineering
SHRP2	Strategic Highway Research Program 2
SP	single point
SPaT	signal phase and timing
SSGA	stop sign gap assist
SSP	service specific priority
SSVW	stop sign violation warning
STD	Standard
SW	Software
SWIW	spot weather information warning
TEA-21	Transportation Equity Act for 21st Century
TESLA	Timed Efficient Stream Loss-Tolerant Authentication
UBI	usage based insurance
UDP	user datagram protocol
UMRA	Unfunded Mandates Reform Act
UMTRI	University of Michigan Transportation Institute
U-NII	Unlicensed-National Information Infrastructure
USDOT	U.S. Department of Transportation
UTC	Coordinated Universal Time
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
V2X	Vehicle to Other [pedestrian, bicycle, etc.]

VAD	vehicle awareness device
VII	vehicle infrastructure integration
VIIC	Vehicle-Infrastructure Integration – Consortium
VIN	Vehicle Identification Number
VMT	vehicle miles traveled
VSC	vehicle safety communications
VSL	value of statistical life
VTTI	Virginia Tech Transportation Institute
WAAS	Wide Area Augmentation System
WAVE	Wireless Access for Vehicular Environments
WLAN	wireless local area network
WRV	warning range variance
WSM	wave short message
XML	Extensible Markup Language

I. Executive Summary

The National Highway Traffic Safety Administration helps to reduce deaths, injuries, and economic losses resulting from motor vehicle crashes by setting and enforcing safety performance standards for motor vehicles and motor vehicle equipment. Vehicle manufacturers respond to NHTSA's standards by building safer vehicles. Combined with State and local government efforts, market effects, and driver behavior improvements, NHTSA's standards have contributed to a significant reduction in annual highway fatalities and injuries, from 52,627 fatalities in 1970,[1] to 32,479 fatalities in 2011.[2]

The purpose of this research report is to assess the readiness for application of vehicle-to-vehicle (V2V) communications, a system designed to transmit basic safety information between vehicles to facilitate warnings to drivers concerning impending crashes. The United States Department of Transportation and NHTSA have been conducting research on this technology for more than a decade.

Safety technology has developed rapidly since NHTSA began regulating the auto industry – vehicles protect occupants much better in the event of a crash due to advanced structural techniques propagated by more stringent crashworthiness standards, and some crash avoidance technologies are now standard equipment. Between existing crashworthiness and required standard crash avoidance technologies, motor vehicles are safer now than they have ever been.

However, a significant number of annual crashes remains that could potentially be addressed through expanded use of more advanced crash avoidance technologies. The agency estimates there are approximately five million annual vehicle crashes, with attendant property damage, injuries, and fatalities. While it may seem obvious, if technology can help drivers avoid crashes, the damage due to crashes simply never occurs.

The agency's push thus far for adoption of crash avoidance technologies, like electronic stability control, has helped *vehicles* react to crash-imminent situations, but has not yet been able to help the *driver* react ahead of time. To fill that gap, some of the most advanced crash

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[1] National Center for Health Statistics, HEW and State Accident Summaries (Adjusted to 30-Day Traffic Deaths by NHTSA).
[2] National Highway Traffic Safety Administration, Fatality Analysis Report System (FARS) final 2011 data. For more information, see: www.nhtsa.gov/FARS (last accessed Feb. 12, 2014).

avoidance technologies present on vehicles today include a host of on-board sensors, cameras, and radar applications. These technologies may warn drivers of impending danger so that the driver can take corrective action, or may even be able to intervene on the driver's behalf.

While these "vehicle-resident" crash avoidance technologies can be highly beneficial, V2V communications represent an additional step in helping to warn drivers about impending danger. V2V communications use on-board dedicated short-range radio communication devices to transmit messages about a vehicle's speed, heading, brake status, and other information to other vehicles and receive the same information from the messages, with range and "line-of-sight" capabilities that exceed current and near-term "vehicle-resident" systems -- in some cases, nearly twice the range. This longer detection distance and ability to "see" around corners or "through" other vehicles helps V2V-equipped vehicles perceive some threats sooner than sensors, cameras, or radar can, and warn their drivers accordingly. V2V technology can also be fused with those vehicle-resident technologies to provide even greater benefits than either approach alone. V2V can augment vehicle-resident systems by acting as a complete system, extending the ability of the overall safety system to address other crash scenarios not covered by V2V communications, such as lane and road departure. A fused system could also augment system accuracy, potentially leading to improved warning timing and reducing the number of false warnings. For a discussion of NHTSA's views as to how the various levels of vehicle automation will play an important role in reducing crashes and how on-board systems may someday work cooperatively with V2V technology, see NHTSA's Preliminary Statement of Policy on Vehicle Automation (May 2013).[3]

For several years, NHTSA has been working under a self-imposed goal of making an agency decision regarding light-duty V2V communication systems in 2013. NHTSA substantially completed the work necessary to reaching that decision by the end of 2013, and announced that decision in early 2014. "Agency decision," in this case, means the agency's choice of the best course of action with regard to exercise of its regulatory and research authority in the V2V context. Among the factors considered in making that decision were NHTSA's preliminary estimates of V2V technology's ability to reduce fatalities and injuries from motor vehicle crashes; the practicality of the technology from the perspectives of maturity, cost, reliability, and performance; and the existence of ways to test and measure V2V technology performance objectively.

The objective of this report is to analyze the research conducted thus far, the technological solutions available for addressing the safety problems identified by the agency, the policy implications of choosing those technological solutions, legal authority and legal issues

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[3] NHTSA's Preliminary Statement of Policy on Vehicle Automation (May 2013). See www.nhtsa.gov/staticfiles/rulemaking/pdf/Automated_Vehicles_Policy.pdf (last accessed Jan. 22, 2014).

such as liability and privacy. Using this report and other available information, decision-makers will determine how to proceed with additional activities involving V2V, V2I, and V2P technologies.

In summary, based on the research and analysis conducted by NHTSA and its partners so far, it appears that:

- V2V devices installed in light vehicles as part of the Connected Vehicle Safety Pilot Model Deployment were able to transmit and receive messages from one another, with a security management system providing trusted and secure communications among the vehicles during the Model Deployment. This was accomplished with relatively few problems given the magnitude of this first-of-its-kind demonstration project. The V2V devices tested in the Model Deployment were originally developed based on existing communication protocols found in voluntary consensus standards from SAE and IEEE. NHTSA and others participating in the Model Deployment (e.g., its research partners and devices suppliers) found that the standards did not contain enough detail and left too much room for interpretation. They therefore developed additional protocols that enabled interoperability between devices participating in the study. The valuable interoperability information learned during the execution of Model Deployment is planned to be included in future versions of voluntary consensus standards that would support a larger, widespread technology roll-out.

- As tested in the Model Deployment, safety applications enabled by V2V, examples of which include IMA, FCW, and LTA, have proven effective in mitigating or preventing potential crashes, but the agency recognizes that additional refinement to the prototype safety applications used in the Model Deployment would be needed before minimum performance standards could be finalized and issued. Based on the agency's understanding of how these prototype safety applications operate, preliminary effectiveness estimates indicate substantial ability to mitigate crashes, injuries or fatalities in these crash scenarios. Also, some safety applications could be better tailored to the safety problem that they are intended to solve (e.g., LTA applications currently trigger only when the driver activates the turn signal, but many drivers do not always activate their turn signals in dedicated turn lanes). Finally, more research would help the agency develop objective performance tests that would ensure consistent operation that is helpful to drivers.

- The agency has the legal authority to mandate V2V (DSRC) devices in new light vehicles, and could also require them to be installed in commercial vehicles already in use on the road. The agency also has the authority to mandate safety applications that are V2V-based, and to work with an outside entity to develop the security and

communications infrastructures required to support deployment of V2V technologies in motor vehicles.

- Based on preliminary information, NHTSA currently estimates that the V2V equipment and supporting communications functions (including a security management system) would cost approximately $341 to $350 per vehicle in 2020. It is possible that the cost could decrease to approximately $209 to $227 by 2058, as manufacturers gain experience producing this equipment (the learning curve). These costs would also include an additional $9 to $18 per year in fuel costs due to added vehicle weight from the V2V system. Estimated costs for the security management system range from $1 to $6 per vehicle, and they will increase over time due to the need to support an increasing number of vehicles with the V2V technologies. The communications costs range from $3 to $13 per vehicle. Cost estimates are not expected to change significantly by the inclusion of V2V-based safety applications, since the applications themselves are software and their costs are negligible.

- Based on preliminary estimates, the total projected preliminary annual costs of the V2V system fluctuate year after year but generally show a declining trend. The estimated total annual costs range from $0.3 to $2.1 billion in 2020 with the specific costs being dependent upon the technology implementation scenarios and discount rates. The costs peak to $1.1 to $6.4 billion between 2022 and 2024, and then they gradually decrease to $1.1 to $4.6 billion.

- In terms of safety impacts, the agency estimates annually that just two of many possible V2V safety applications, IMA and LTA, would on an annual basis potentially prevent 25,000 to 592,000 crashes, save 49 to 1,083 lives, avoid 11,000 to 270,000 MAIS 1-5 injuries, and reduce 31,000 to 728,000 property-damage-only crashes by the time V2V technology had spread through the entire fleet. We chose those two applications for analysis at this stage because they are good illustrations of benefits that V2V can provide above and beyond the safety benefits of vehicle-resident cameras and sensors. Of course, the number of lives potentially saved would likely increase significantly with the implementation of additional V2V and V2I safety applications that would be enabled if vehicles were equipped with DSRC capability.

Even with the success of the Safety Pilot Model Deployment in proving that V2V technology can work in a real-world environment on actual roads with regular drivers, additional items need to be in place beyond having the authority to implement a V2V system, in order for a potential V2V system to be successful. These items include:

- Wireless spectrum: V2V communications transmit and receive messages at the 5.8-5.9 GHz frequency. The FCC is currently considering whether to allow "Unlicensed National Information Infrastructure" devices (that provide short-range, high-speed, unlicensed wireless connections for, among other applications, Wi-Fi-enabled radio local area networks, cordless telephones, and fixed outdoor broadband transceivers used by wireless Internet service providers) to operate in the same area of the wireless spectrum as V2V. Given that Wi-Fi use is growing exponentially, "opening" the 5.8-5.9 GHz part of the spectrum could result in many more devices transmitting and receiving information on the same or similar frequencies, which could potentially interfere with V2V communications in ways harmful to its safety intent. More research needs to be done on whether these Wi-Fi enabled devices can share the spectrum successfully with V2V, and if so, how.

- V2V device certification issues: V2V devices are different from other technologies regulated by NHTSA under the Federal Motor Vehicle Safety Standards, insofar as part of ensuring their successful operation (and thus, the safety benefits associated with them) requires ensuring that they are able to communicate with all other V2V devices participating in the system. This means that auto manufacturers (and V2V device manufacturers), attempting to comply with a potential V2V mandate, could have a significant testing obligation to guarantee interoperability among their own devices and devices produced by other manufacturers. It is an open question whether individual companies could meet such an obligation themselves, or whether independent testing facilities might need to be developed to perform this function. Based on the current security design, it also is likely that the entity or entities providing the security management system would require that device manufacturers comply with interoperability certification requirements to ensure the reliability of message content.

- Test procedures, performance requirements, and driver-vehicle interface issues: While existing test procedures, performance requirements, and driver-vehicle interfaces appear to be working well enough for purposes of the Model Deployment (as compared to a true production, real-world environment), additional research and development would be necessary to produce FMVSS-level test procedures for V2V inter-device communication and potential safety applications.

  NHTSA is currently engaged in research to examine the minimum performance measures for DSRC communication and system security. This research will include functional and performance requirements for the DSRC device and is intended to include how to address end-of-life issues on the DSRC components and security system.

  To eventually go forward with rulemaking involving safety applications, V2V and safety application standards need to be objective and practicable, meaning that technical

uncertainties are limited, that tests are repeatable, and so forth. Additionally, the agency has yet to determine whether standardization of DVIs would improve the effectiveness of safety applications, and whether some kind of standardization could have significant effects on costs and benefits.

- Standing up security and communications systems to support V2V: In order to function safely, a V2V system needs security and communications infrastructure to enable and ensure the trustworthiness of communication between vehicles. The source of each message needs to be trusted and message content needs to be protected from outside interference. In order to create the required environment of trust, a V2V system must include security infrastructure to credential each message, as well as a communications network to get security credentials and related information from vehicles to the entities providing system security (and vice versa). NHTSA currently anticipates that private entities will create, fund, and manage the security and communications components of a V2V system. While NHTSA has identified several potential types of entities, including some specific entities, which might be interested in participating in a V2V security system, private entities have not committed to doing so to date.

- Liability concerns from industry: Auto manufacturers repeatedly have expressed to the agency their concern that V2V technologies will increase their liability as compared with other safety technologies. In their view, a V2V system exposes them to more legal risk than on-board safety systems because V2V warning technologies rely on information received from other vehicles via communication systems that they themselves do not control. However, the decision options currently under consideration by NHTSA involve safety warning technologies -- not control technologies. NHTSA's legal analysis indicates that, from a products liability standpoint, V2V safety warning technologies, analytically, are quite similar to on-board safety warnings systems found in today's motor vehicles. For this reason, NHTSA does not view V2V warning technologies as creating new or unbounded liability exposure for the industry.

- Privacy: At the outset, readers should understand some very important points about the V2V system as currently contemplated by NHTSA. The system will not collect or store any data identifying individuals or individual vehicles, nor will it enable the government to do so. There is no data in the safety messages exchanged by vehicles or collected by the V2V system that could be used by law enforcement or private entities to personally identify a speeding or erratic driver. The system—operated by private entities—will not enable tracking through space and time of vehicles linked to specific owners or drivers. Third parties attempting to use the system to track a vehicle would find it extremely difficult to do so, particularly in light of far simpler and cheaper means available for that purpose. The system will not collect financial information, personal communications, or other information linked to individuals. The system will enroll V2V enabled vehicles

automatically, without collecting any information that identifies specific vehicles or owners. The system will not provide a "pipe" into the vehicle for extracting data. The system will enable NHTSA and motor vehicle manufacturers to find lots or production runs of potentially defective V2V equipment without use of VIN numbers or other information that could identify specific drivers or vehicles. Our research to date suggests that drivers may be concerned about the possibility that the government or a private entity could use V2V communications to track their daily activities and whereabouts. However, as designed, NHTSA is confident that the V2V system both achieves the agency's safety goals and protects consumer privacy appropriately.[4]

- Consumer acceptance: If consumers do not accept a required safety technology, the technology will not create the safety benefits that the agency expects. One potential issue with consumer acceptance is maintenance. If the security system is designed to require consumers to take action to obtain new security certificates – depending on the mechanism needed to obtain the certificates -- consumers may find the required action too onerous. For example, rather than return to a dealership periodically for a download of new certificates, consumers may choose instead to live with non-functioning V2V capabilities. The agency is exploring ways to make such downloads automatic, but more research is needed to understand this issue fully.

The above issues indicate that through the research conducted to date, the agency has a better understanding of the potential of V2V technology, but various aspects of the technology still need further investigation to support transition from a prototype-level to a deployment-level system. Further research to move toward deployment has been identified (and detailed in this report) and will be conducted to address the following:

- The impact of spectrum sharing with U-NII devices;
- Development of performance requirements for DSRC devices;
- Development of performance requirements for safety applications;
- The potential establishment of device certification and compliance procedures;
- The ability to mitigate V2V communication congestion:
- Incorporation of GPS positioning advancements to improve V2V relative positioning;
- Remedies to address false positive warnings from V2V safety applications;
- Driver-vehicle interface performance to enhance crash avoidance warning effectiveness;
- An appraisal of consumer acceptance of the technology;

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[4] NHTSA acknowledges that privacy and system security are current and relevant areas of discussion and that some may have concerns about the vulnerability of this system to malicious attack. We understand those concerns and intend to explore the risks and safeguards fully in our in-depth analysis of system security. Recently, for example, we have been in contact with DARPA about possible protections against software vulnerabilities.

- Evaluation of V2V system privacy risks; and
- An assessment of the security system to ensure a trusted and a safe V2V system.

The GAO report "Intelligent Transportation Systems, Vehicle-to-Vehicle Technologies Expected to Offer Safety Benefits, but a Variety of Deployment Challenges Exist"[5] confirms the appropriateness of the research identified. This research will facilitate a comprehensive representation of a deployment-ready V2V system. NHTSA, with the Intelligent Transportation System Joint Program Office, has positioned the resources needed to accomplish this research to support the possible deployment of V2V given any agency action.

[5] Intelligent Transportation Systems: Vehicle-to-Vehicle Technologies Expected to Offer Safety Benefits, but a Variety of Deployment Challenges Exist (Nov. 2013, GAO-14-13). See www.gao.gov/assets/660/658709.pdf (last accessed Feb. 12, 2014).

II. Introduction

A. Purpose of this report

For several years, NHTSA has indicated its intention to make an agency decision regarding light-duty V2V communication systems in 2013.[6] NHTSA substantially completed the work necessary to reaching that decision by the end of 2013, and announced that decision in early 2014. "Agency decision," in this case, referred to the agency's choice of the best course of action with regard to exercise of its regulatory and research authority in the V2V context. Among the factors considered in making that decision were V2V technology's ability to reduce fatalities and injuries from motor vehicle crashes; the practicality of the technology from the perspectives of maturity, cost, reliability, and performance; and the existence of ways to test and measure V2V technology performance objectively.

The objective of this report is to assess the readiness for application of V2V communications technology, by discussing the research conducted thus far, of the technological solutions available for addressing the safety problems identified by the agency, the policy implications of choosing those technological solutions, the agency's legal authority and related legal issues such as liability and privacy, and potential implementation options available to the agency for creating a national V2V system. Using this report and other available research, agency decision-makers determined how to proceed with additional activities involving vehicle-to-vehicle, vehicle-to-infrastructure, and vehicle-to-pedestrian technologies.

In September 2012, NHTSA's Senior Associate Administrator for Vehicle Safety formed the V2V Decision Team to examine these and other related issues and summarize the current state of knowledge on V2V. The team consisted of members from the NHTSA's offices of Vehicle Safety Research, Rulemaking, Enforcement, the NHTSA National Center for Statistical Analysis, and Chief Counsel and from the Federal Highway Administration, the Department of Transportation's Office of the Assistant Secretary for Research and Technology (OST-R), the DOT's John A. Volpe National Transportation Systems Center and the Intelligent Transportation System Joint Program Office (ITS-JPO).[7]

In particular, ITS-JPO, OST-R, and FHWA played a vital supporting role in the analysis by representing the broader interests of DOT's Intelligent Transportation Systems wide-ranging programs and assessing the potential impacts that an agency decision on V2V technology could

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[6] E.g., NHTSA Vehicle Safety Rulemaking and Research Priority Plan 2009-2011 (July 2009, Docket No. NHTSA-2009-0108-0001) and NHTSA Vehicle Safety and Fuel Economy Rulemaking and Research Priority Plan 2011-2013 (March 2011, Docket No. NHTSA-2009-0108-0032). See www.nhtsa.gov/Laws-Regs (last accessed Jan. 23, 2014).

[7] For more information on ITS-JPO, see www.its.dot.gov.

have. Additionally, ITS-JPO has been a supporting partner throughout the Connected Vehicle[8] Safety Pilot program,[9] working collaboratively with NHTSA's Vehicle Safety Research office to develop and execute the valuable information obtained by the program and used, in part, to inform the agency decision on V2V technology.

The Volpe Center played a vital role, as it does with many DOT programs, by providing critical expertise in the many specialized areas of both ITS and V2V. For example, Volpe Center experts developed and validated the Simulation Tool used for determining the preliminary V2V system benefits for this analysis. Additionally, the Volpe Center is contracted to operate as the Independent Evaluator of the data collected during the Safety Pilot Model Deployment.

This report was presented by the team to the SAA and constitutes analysis of the relevant issues and suggestions on various options before the agency. After full discussion of the report and the issues with the political leadership in NHTSA and DOT, the agency reached its decision on the future course of agency action.

The report breaks down the decision by describing and examining elements of the technology and the deployment of the technology using the results of available research. The sections of this report cover:

- how the technology addresses the safety need;
- an investigation of the legal and policy issues associated with the secure operation of the technology and the implications of these issues for privacy;
- a description of the technology, the different types of devices, the elements of the devices, and the security needed for trusted communications; and
- how much the technology may be expected to cost, in terms of both consumer and operational costs and potential effectiveness and benefits of the technology (based on preliminary data).

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[8] DOT has long used the term "connected vehicle" to refer to the vehicle-to-vehicle communication technology that supports crash avoidance applications. However, more recently the term has also been associated with vehicle telematics that connects vehicles to various information and "infotainment" applications through other forms of communication. There will be references in this report to "connected vehicle" and in the context of this report these references are intended to mean V2X technology.

[9] The Connected Vehicle Safety Pilot Program is a scientific research initiative that features a real-world implementation of connected vehicle safety technologies, applications, and systems using everyday drivers. The effort will test performance, evaluate human factors and usability, observe policies and processes, and collect empirical data to present a more accurate, detailed understanding of the potential safety benefits of these technologies. The Safety Pilot program includes two critical test efforts—the Safety Pilot Driver Clinics and the Safety Pilot Model Deployment. For more information, see www.its.dot.gov/safety_pilot/#sthash.LL2V6yT0.dpuf (last accessed Jan.23, 2014).

B. History of V2V communication research program

1. History of ITS

Before Intelligent Transportation Systems (ITS), the United States developed, planned, and built the interstate highway system. The interstate highway system has provided a high level of mobility for citizens as well as the efficient movement of goods. From the 1950s through the 1980s, the vision of highway transportation was focused on building roads. Yet issues began to emerge as the interstate system was being built: about traffic congestion, especially in our urban centers; about highway-related fatalities and injuries due to crashes; and about the impacts on energy consumption and air quality.

As early as 1986, a group of transportation professionals from academia, Federal agencies, State transportation agencies, and the private sector started to discuss the future of transportation in relation to the post-interstate era.[10] New transportation legislation needed to be developed, meaning that a new transportation paradigm needed to be invented that would use the current infrastructure, but also address the issues of safety, congestion, and environment.

The discussions culminated in a workshop held in Dallas, Texas, in 1990. During the workshop, participants invented the Intelligent Vehicle Highway Systems (IVHS) concept, which was later renamed to ITS.[11] The overall precept was that new transportation efficiencies could be found if current infrastructure could be married with advanced technology. New developments in computing, sensors, information systems, and advanced mathematical methods could be used to increase the operational capacity of the system, and achieve better overall transportation network operations.

The ITS concept became an integral part of the 1991 Intermodal Surface Transportation Efficiency Act (ISTEA). The Act allocated $660 million of funds for ITS research, development, and operational tests over six years. In addition, just before the Act was adopted, the Intelligent Vehicle Highway Society of America advisory organization was established; later renamed Intelligent Transportation Society of America. This advisory organization developed the first strategic plan for ITS in 1992. The plan called for the integrated operation of the system using technology to bring together information about modes and current conditions, and discussed how institutions can be organized to operate the total transportation network.[12]

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[10] Perspectives on Intelligent Transportation Systems (Sussman, 2005). See Docket No. NHTSA-2014-0022

[11] Sustainable Build Environment, Vol. II, Intelligent Transportation Systems (Williams). See www.eolss.net/Sample-Chapters/C15/E1-32-08-05.pdf (last accessed Jan. 23, 2014).

[12] The 1992 Strategic Plan by IVHS. See http://ntl.bts.gov/lib/jpodocs/repts_pr/1823.pdf (last accessed Jul. 12, 2013).

ITS covers many areas that have been adjusted and renamed over the years, but the basic tenets of safety, mobility, and environment have remained. The components of ITS have been characterized by various management systems (areas). The management systems cover information, traffic (signal systems and tolling), designated Advanced Traffic Management Systems, and Advanced Vehicle Control Systems. Over the years, the integration of transportation and technology has continued. Currently, Congress authorizes approximately $100 million a year for the continued research and development of ITS.[13]

There are a number of ITS program-developed applications deployed throughout the nation. These include both automated toll collection along with advanced traffic signal control systems and centers that monitor a region's transportation network to address network issues in real time.

Many involved with ITS research and development view the development of the capability to provide connectivity to the transportation system as the next frontier, in order to further improve safety, mobility, and the environment. Using DSRC in the mobile environment may support that connectivity for an array of transportation applications.[14]

Envisioning that vehicles communicating with other vehicles around them could identify potential crash situations and alert the drivers so that these situations could be avoided, DOT and the Crash Avoidance Metrics Partnership (CAMP) initiated the first V2V research in December 2006. DSRC, as a Wi-Fi-based technology, provides 360 degrees of coverage, whereas vehicle-based sensors can be more limited in terms of direction and distance at which they are able to detect a potential conflict. V2V systems predominantly apply to crashes with multiple vehicles, and these systems have the potential to address a large number of crashes.

2. History of V2V research program and its role in ITS

V2V communications research initially began under the Vehicle Infrastructure Integration Initiative in 2003, but its origins date back to the Automated Highway System (AHS) research of the 1990s.

The actual initiation of advanced technology research was mandated by the ISTEA.[15] The Act called for the development of an automated intelligent vehicle highway prototype that would use technology to make highway driving efficient, safe, and predictable. The effort was

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[13] Moving Ahead for Progress in the 21st Century Act (MAP-21) at sec. 51001(a)(4) (Pub.L.112-141; July 6, 2012). See www.gpo.gov/fdsys/pkg/PLAW-112publ141/pdf/PLAW-112publ141.pdf (last accessed Jan. 23, 2014)
[14] ITS Strategic Research Plan 2010-2014, Progress Update 2012 (FHWA-JPO-12-019). See www.its.dot.gov/strategicplan/pdf/ITS%20Strategic%20Plan%20Update%202012.pdf (last accessed Jan. 24, 2014).
[15] For more information, see the Automated Highway System, Public Roads (Summer 1994, Vol. 58, No. 1, Nita Congress) at www.fhwa.dot.gov/publications/publicroads/94summer/p94su1.cfm (last accessed Jan. 24, 2014).

designated the "Automated Highway System Program." The goal of the effort was to have a fully automated roadway or test track in operation by 1997.

The AHS Program started in 1992 as part of DOT's ITS initiative that fell within the Advanced Vehicle Control Systems Area. Research activities looked into 16 different precursor areas to support the design of a prototype automated highway. The basic concept was that sensors in the roadway would communicate with sensors on the vehicle, to enable "hands-off" and "feet-off" but not "mind-off" driving. For the first time, the roadway and the vehicle would actually be connected.

The AHS concept required dedicated lanes that would contain magnetic nails that the vehicle sensors would recognize and use to guide the vehicle down the intelligent lane. The benefits of AHS would theoretically be derived from decreasing the amount of driver error; increasing the capacity of the highway; facilitating reduced fuel consumption and tailpipe emissions; and providing more efficient commercial and transit operations.

The research culminated in a 1997 demonstration conducted on I-15 in San Diego, California, with more than 20 AHS-equipped vehicles demonstrating hands- and feet-off driving. However, the idea that AHS needed dedicated lanes for the equipped vehicles posed a problem of where to put those lanes and how to finance them. AHS provided a glimpse of one possible future, but priorities changed in 1998 and the emphasis in relation to highway automation was refocused on developing technology that could address near-term safety.[16]

After AHS, DOT introduced the Intelligent Vehicle Initiative (IVI) in 1997, which was authorized in the 1998 Transportation Equity Act for 21st Century (TEA-21). The objectives of IVI were to: (1) prevent driver distraction, and (2) facilitate accelerated deployment of crash avoidance systems.[17] Intelligent vehicle technology included development of vehicle-based and infrastructure-cooperative assistance products that would help drivers operate more safely and effectively. The premise of the IVI program was "to develop and deploy intelligent vehicle systems that completely consider the driver's capabilities and limitations, rather than focus on developing highway infrastructure technology."[18]

In relation to the prevention of driver distraction, studies were conducted that examined the relationship between distraction and crashes; ways to measure distraction and driver

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[16] Traffic Technology International, Whatever Happened to Automated Highway Systems (AHS)? (August-September 2001). See http://faculty.washington.edu/jbs/itrans/bishopahs.htm (last accessed Jan. 24, 2014).
[17] Saving Lives Through Advanced Vehicle Safety Technology, Intelligent Vehicle Initiative, Final Report, (September 2005, FHWA-JPO-05-057). See http://ntl.bts.gov/lib/jpodocs/repts_pr/14153_files/ivi.pdf (last accessed Jan. 24, 2014).
[18] An Overview of Automated Highway Systems (AHS) and the Social and Institutional Challenges they Face (Cheon). See www.uctc.net/papers/624.pdf (last accessed Jan. 24, 2014).

workload; and ways to assess the impact of in-vehicle information on distraction and safety.[19] The results of the driver distraction research suggested that the chaotic nature of crashes precluded the possibility of developing and validating a quantitative model to predict crashes as a function of workload measures.

IVI also developed prototype crash avoidance systems using vehicle-based and infrastructure cooperative technology. The initiative sought to identify the safety problem; develop the performance requirements and specifications for prototypes that would address the safety problem; and, using promising technologies, to prototype and test those avoidance systems. Prototypes that were developed and tested addressed rear-end, road departure, vehicle stability (heavy truck), and intersection crashes. The results of the tests and field operational tests of the prototype systems provided a foundation, e.g., requirements such as the range needed for radar sensors and camera object-detection performance, for further research and private development of crash avoidance safety technologies.

As the IVI research was concluding, new developments in telecommunications prompted a new direction in relation to the interaction of vehicles and infrastructure. The Vehicle Infrastructure Integration (VII) Initiative brought together the results of the IVI, the need for improved traffic operations, and the new developments in telecommunication technology. The focus of the VII initiative was to prove the concept that communications technology could be used to send information among vehicles and between vehicles and the infrastructure.[20]

At the 10th Intelligent Transportation Systems World Congress in Madrid, Spain, in November 2003, DOT announced the initiation of the VII initiative. This was made possible by the FCC allocating 75 MHz of spectrum at 5.9 GHz (where DSRC operates) for research purposes for improving transportation safety and use for other non-safety applications to improve transportation mobility.[21]

Using the spectrum and the foundation of crash avoidance research from past efforts, the vision for the VII initiative was to establish a small-scale implementation to test and evaluate the VII concept of operations. The basic VII concept of operations was that vehicle-to-vehicle and vehicle-to- infrastructure communication could support safety and mobility applications. To prove the concept, research and development needed to be conducted to establish the characteristics of the VII system (e.g., requirements and design specifications for vehicle and

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[19] *See supra* note 17.
[20] Final Report: Vehicle Infrastructure Integration Proof of Concept Executive Summary–Vehicle (May 19, 2009). See http://ntl.bts.gov/lib/31000/31100/31135/14477.htm (last accessed Jan. 24, 2014).
[21] See http://apps.fcc.gov/ecfs/document/view;jsessionid=zJy8QddC2zQpvYt2fTQdJTp1qLL3rTmmVZvxb13HPtzwtfMphskN!-856245186!973241960?id=6009850553 (last accessed Jan. 24, 2014).

infrastructure communications devices, network communication, and security and privacy protocols). In December 2006, the DOT entered into a cooperative agreement with five automotive original equipment manufacturers to investigate whether DSRC, in combination with GPS relative positioning, could improve performance of autonomous onboard crash warning systems or enable new communication-based safety applications.[22]

The concept was broken down by two distinct components of the system: the roadside network and the on-board vehicle equipment (OBE). The roadside network supported the communication of information between the system through the road-side equipment (RSE) to the OBE and from the OBE back to the system. The VII research tested the communication on both sides of the RSE. The network connected the RSEs via the system. To prove the concept, prototypes of the roadside network (including RSEs) and the OBEs needed to be developed. Besides equipment, message protocols needed to be established that allowed time-constrained communications between OBEs and RSEs. The mobile communications would not have time to have devices establish a communication link between them in the way that current computers do with a wireless network, but messages still needed to be sent and received.

Laboratory and track tests were completed and the system was refined for an on-road proof of concept test. Data was collected to support analysis and the evaluation of the various components, including communications, the RSE, the network, and the OBEs. Key findings indicated that the VII concept was technically feasible; however, there were areas where the concept could be improved. Key areas that required more research included: (1) antenna placement for both OBEs and RSEs; (2) GPS positioning; (3) security for over the air communications; and (4) security systems operations.[23]

The VII Proof of Concept began with the vision that new telecommunication capabilities could be applied to transportation. It established DSRC as a means to connect vehicles and infrastructure via wireless communications. This foundation provided the information necessary to develop and plan the V2V Safety Application Research Plan and Safety Pilot. In addition, the success of the Proof of Concept provided the catalyst to create the Connected Vehicles Initiative.

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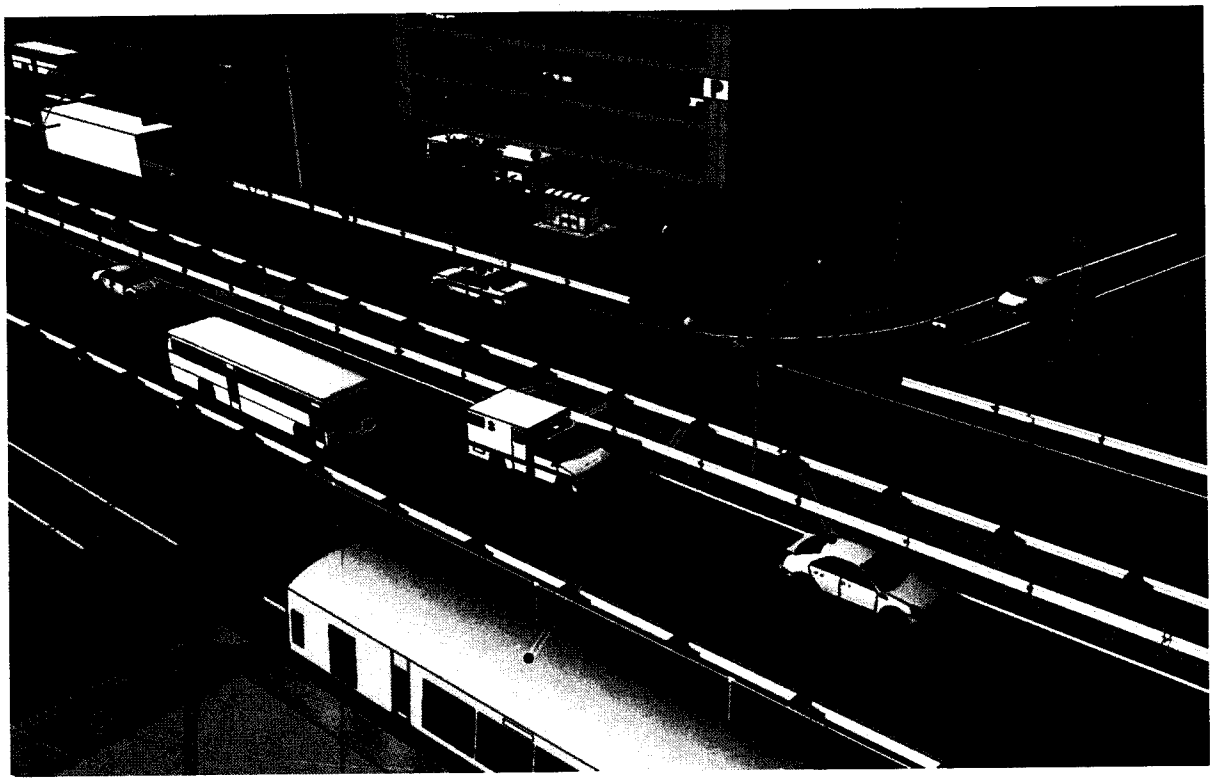
[22] Crash Avoidance Metrics Partnership (CAMP), Vehicle Safety Communications–Applications (VSC-A), Final Report at xi (September 2011, Report No. DOT HS 811 492A). See www.nhtsa.gov/Research/Crash+Avoidance/Office+of+Crash+Avoidance+Research+Technical+Publications (last accessed Jan. 24, 2014).
[23] Id.

3. The Connected Vehicle Safety Pilot Program

a) Introduction

The Connected Vehicle Safety Pilot Program is part of a major scientific research program run jointly by the DOT and its research and development partners in private industry. The program supports the development of safety applications based on V2V and V2I communications systems, using DSRC technology. The Safety Pilot Model Deployment was designed to inform the effectiveness estimates of these safety applications at reducing crashes and to show how real-world drivers respond to these safety applications in their vehicles. The test includes many vehicles with vehicle awareness devices, others with integrated safety systems, and others that use aftermarket safety devices to communicate with surrounding vehicles. All of these technologies are DSRC-based. The pilot includes multiple vehicle types—cars, trucks, and transit vehicles. The Safety Pilot has concluded for purposes of gathering information on light-duty vehicles, but it has been extended for additional data collection through late 2014.

Figure II-1 Visual Representation of V2V Communication



Note: Vehicles "talk" to each other exchanging information such as vehicle size, position, speed, heading, lateral/longitudinal acceleration, yaw rate, throttle position, brake status, steering angle, wiper status, turn signal status, enabling safety and mobility applications.

While the ITS-JPO within the OST-R is leading this research initiative, several agencies within DOT are supporting the Safety Pilot, including NHTSA, FHWA, Federal Motor Carrier Safety Administration, and Federal Transit Administration.

b) Research vision

The vision of the Safety Pilot Model Deployment was to test V2V safety applications in real-world driving scenarios to support estimation of their effectiveness at reducing crashes, and to ensure that the devices are safe and do not unnecessarily distract motorists or cause unintended consequences. The Model Deployment is evaluating everyday drivers' reactions, both in a controlled environment through driver clinics, and on actual roadways with other vehicles through the real-world model deployment.

c) Research plan

The two fundamental components of the Safety Pilot are:

Safety Pilot Driver Clinics: Driver clinics were conducted at six sites across the United States to assess user acceptance of the V2V technology. At each driver clinic, approximately 100 drivers tested in-vehicle wireless technology in a controlled environment, such as a race track. The goal was to determine how motorists responded to and benefitted from in-vehicle alerts and warnings. The driver clinics were conducted from August 2011 through January 2012.

Safety Pilot Model Deployment: The Model Deployment is being conducted in the Ann Arbor, Michigan, and ran from August 2012 to February 2014. Sponsored by DOT and conducted by the University of Michigan Transportation Research Institute, the experiment was designed to support estimation of the effectiveness of V2V technology at reducing crashes. Approximately 2,800 vehicles – a mix of cars, trucks, and transit vehicles operating on public streets within a highly concentrated area – are equipped with integrated in-vehicle safety systems, aftermarket safety devices, or vehicle awareness devices, all using DSRC to emit wireless signals of vehicle position and heading information. Vehicles equipped with integrated in-vehicle or aftermarket safety devices have the additional design functionality of being able to warn drivers of an impending crash situation involving another equipped vehicle.

The Safety Pilot Model Deployment, with 27 roadside units covering 75 miles of roadway, is also designed to test V2I applications, including:

- Signal priority for transit and emergency vehicles,
- Roadway maintenance,
- Density of pedestrian traffic, and
- Traffic signal timing.

Data from the model deployment is being archived and made available to researchers for evaluation and testing of applications beyond the testing period. The model deployment is the first test of this magnitude of V2V technology in a real-world, multimodal operating environment. UMTRI is leading a diverse team of industry, public agencies, and academia in supporting this effort.

d) Research goals

The goals of the Safety Pilot were to:

- Support the NHTSA agency decision by obtaining empirical data on user acceptance and system effectiveness;
- Demonstrate real-world connected vehicle applications in a data-rich environment;
- Establish a real-world operating environment for additional safety, mobility, and environmental applications development;
- Archive data for additional research purposes; and
- Identify prototype system characteristics that can be improved or that need to be corrected.

e) Research results

The planned outcomes of this research are:

- A determination of whether the system as designed, or somewhat modified, is viable
- Documentation of information helpful in estimating the potential benefits of connected vehicle technologies and evaluation of driver acceptance of vehicle-based safety systems
- Identification of any research needs and the steps to address them
- Analysis of Model Deployment data to support making the agency decision on how to proceed.

4. Studies related to V2V light-vehicle research

As this report focuses on the basis and potential of applying V2V technology to light vehicles, it important to note the agency is also heavily involved in V2V research related to heavy vehicles, pedestrians, and motorcycles.

a) Heavy vehicles

The agency intends to make a decision concerning the disposition of V2V technology concerning heavy vehicles in 2014. The heavy vehicle research is in parallel with the light vehicle research. The interoperability, security, and safety application research associated with light vehicles directly supports the heavy vehicle research. Interoperable devices (both integrated

and retrofit) were installed on heavy trucks and run during the Safety Pilot Model Deployment. Heavy vehicle driver clinics were conducted to obtain feedback from professional drivers about V2V crash avoidance systems for heavy vehicles. Data collected during the Safety Pilot Model Deployment will be used to support an evaluation of the V2V technology, but meanwhile, the agency continues to conduct research to better understand the operational contrasts for these vehicles in terms of V2V technology and safety applications.

b) Pedestrians

Past investigation concerning preventing crashes with pedestrians has focused on vehicle-based sensors. The Pedestrian Crash Avoidance and Mitigation project studied the effectiveness of vehicle-based systems to detect a pedestrian in a possible crash situation with a vehicle and warn the driver. With V2V technology, pedestrians can carry devices (such as mobile phones) that can send out a safety signal using DSRC and communicate with DSRC devices that would be used in vehicles. We envision that both the driver and the pedestrian could both be warned if a possible conflict arises. However, there are many issues to be resolved concerning V2P safety applications. The agency is developing a research plan that will investigate issues relating to V2P communication, safety applications, and human factors, among other things. The initial research will identify the pre-crash scenarios involving pedestrians that can be addressed by V2P technology. That analysis will also provide information concerning the dynamics of each pre-crash scenario that will facilitate the prototyping of V2P safety applications.

c) Motorcycles

Motorcycle fatalities represent approximately 11 percent of all highway fatalities each year, and 80 percent of reported motorcycle crashes result in injury or death.[24] A small group of motorcycles were outfitted with Vehicle Awareness Devices and participated in the Safety Pilot Model Deployment. Using VADs on motorcycles enables the motorcycles to be "seen" by other V2V-equipped vehicles, enabling alerts to the driver if a motorcycle and the equipped vehicle are in a possible crash situation. Subsequent analysis of the Safety Pilot Model Deployment data will provide information that will assist in the development of a V2V motorcycle research program. V2V motorcycle research will likely entail investigating how to adapt safety applications to be used by motorcycles and addressing how to warn a motorcyclist of a possible crash situation, among other things.

5. Vehicle-to-infrastructure (V2I)

The same wireless technology that supports V2V safety applications (5.9 GHz DSRC) will also enable a broader set of safety and mobility applications when combined with

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[24] Motorcycle Safety (Report No. DOT HS 807 709, revised December 2007). See www.nhtsa.gov/people/injury/pedbimot/motorcycle/motosafety.html (last accessed Jan. 9, 2014).

compatible roadway infrastructure; therefore V2V serves as the gateway for the broader intelligent transportation system program. The Connected Vehicle Core System Architecture[25] describes the overall anticipated system, including V2V and V2I capabilities. DSRC-based V2I communications are also being developed that involve the wireless exchange of critical safety and operational data between vehicles (including brought-in devices) and highway infrastructure, intended primarily to avoid motor vehicle crashes while enabling a wide range of mobility and environmental benefits. The program is funding V2V and V2I communications research within the Dynamic Mobility Applications (real-time traffic information to enhance mobility), Road Weather, Applications for the Environment: Real-Time Information Synthesis (AERIS), and V2I Safety programs.[26] V2I applications under development include applications for commercial freight operators and transit agencies. V2I applications complement the V2V safety applications by addressing crash scenarios that the V2V program cannot address or that could be addressed more efficiently with low levels of penetration of DSRC-equipped light vehicles. The following is a list of V2I potential safety applications:

- Red Light Violation Warning,
- Curve Speed Warning,
- Stop Sign Gap Assist,
- Reduced Speed Zone Warning,
- Spot Weather Information Warning,
- Stop Sign Violation Warning,
- Railroad Crossing Violation Warning, and
- Oversize Vehicle Warning.

Additional mode-specific applications are being developed in partnership with FHWA, FTA, FMCSA, and the Federal Railroad Administration.

The V2I safety research program also focuses on creating national interoperability to support infrastructure and vehicle deployments and facilitating cost-effective infrastructure deployment. DOT and State and local agencies are implementing test beds in Michigan, California, Arizona, Florida, New York, Virginia, and Minnesota to analyze V2I and V2V communications systems. The ITS-JPO created a group[27] for these entities to coordinate lessons learned, in particular related to the implementation of DSRC-based infrastructure.

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[25] See www.its.dot.gov/research/systems_engineering.htm (last accessed Jan. 9, 2014).
[26] For detailed information on these programs, see www.its.dot.gov.
[27] For information about the affiliation of Connected Vehicle Test Beds, see www.its.dot.gov/testbed.htm (last accessed Jan. 24, 2014).

The ITS-JPO also awarded a contract with the American Association of State Highway and Transportation Officials to conduct a "National Connected Vehicle Field Infrastructure Footprint Analysis." This analysis was conducted to engage State and local departments of transportation in the development of concepts and scenarios for deployment of V2I systems that will be owned and operated by State and local DOTs. A final report, due later this year, will estimate costs for deployment and operations and maintenance of V2I. In addition to developing a concept for early deployments and a growing National Footprint for V2I systems, the analysis will serve as input to guidance that FHWA is preparing to release in late 2015. The FHWA Public Agency Guidance, currently under development, will initially focus on Federal-aid eligibility, use of right-of-way and infrastructure, innovative financing, procurement processes, and interoperability issues. This initial guidance is intended to address the needs of early demonstration site deployments, and to assist in planning for future investments and deployment of V2I systems. It is envisioned that deployment guidance will evolve as specific applications enter service.

The Basic Safety Message is the primary message set proposed to send data between vehicles and between vehicles and the infrastructure. While the BSM is mainly developed for safety applications, the data in the message may also be used by other connected vehicle applications, such as mobility, weather, and AERIS programs. Additional messages from vehicles or from the infrastructure may also be developed in the future. Some of the applications can also deliver significant safety benefits once implemented. Currently, DOT is developing the applications and planning for field testing, evaluation, and modeling analysis of the benefits.

Also, mobility, weather, and environment applications will benefit from vehicles storing certain limited types of data and, possibly, transmitting and receiving information over multiple communication media, such as DSRC and cellular. The NHTSA decision and market forces may have a role in encouraging vehicle manufacturers to provide storage and cellular capabilities that could facilitate mobility, weather, and environment applications. The following example describes why these capabilities are needed. DOT anticipates that few DSRC RSE units will be installed initially. In order to enable these applications, vehicles would need either to store data gathered along a trip and download it when reaching an RSE unit, or to transmit the information at regular intervals using cellular communications. Data may be used by the public sector to predict travel times along routes, as well as to identify incident locations or areas that may need salt treatments, in order to inform drivers about changes in traffic and road conditions. It will be important for vehicles to be able to receive V2I messages (e.g., Signal Phase and Timing, traveler information messages).

Enabling these capabilities could likely require additional elements in the BSM and could also cause more data to be broadcast to and processed by devices, potentially leading to communication congestion. It is critical that safety messaging not be compromised due to broadcasting more data for V2I. Fortunately, it is likely that mobility, AERIS and weather applications will not need data transmitted 10 times per second. It is expected that the DOT's

ITS-JPO will conduct additional channel congestion analysis to understand the implication of communicating V2I data in addition to V2V data. The ITS-JPO will fund more V2I and V2V modeling and field testing, to be completed within 24 months after a NHTSA decision. The ITS-JPO plans to perform the modeling and field tests and go through a peer review process with NHTSA to validate credibility of the methodology and results.

III. Safety Need

NHTSA was established by the Highway Safety Act of 1970, as the successor to the National Highway Safety Bureau, to carry out safety programs under the National Traffic and Motor Vehicle Safety Act of 1966 and the Highway Safety Act of 1966.[28] Among other things, NHTSA helps to reduce deaths, injuries and economic losses resulting from motor vehicle crashes by setting and enforcing safety performance standards for motor vehicles and motor vehicle equipment, and through grants to State and local governments to enable them to conduct effective local highway safety programs. Vehicle manufacturers respond to NHTSA's standards by building safer vehicles, and safety technology has developed rapidly since the 1970s – not only are air bags and ESC standard equipment now, but vehicles protect occupants better in the event of a crash due to advanced structural techniques propagated by more stringent crashworthiness standards. Combined with State and local government efforts, market effects, and driver behavior improvements, NHTSA's standards have contributed to a significant reduction in highway fatalities and injuries - from 52,627 fatalities in 1970,[29] to 32,479 fatalities in 2011.[30] Between existing crashworthiness and crash avoidance technologies, motor vehicles are safer than they have ever been.

Nevertheless, crashes continue to occur, with attendant property damage, injuries, and fatalities. Although continued improvements in vehicle crashworthiness will still help reduce fatalities and injuries, NHTSA believes the greatest gains in highway safety in coming years will result from broad-scale application of crash avoidance technologies.[31] Fortunately, the pace of technological development is picking up rapidly as advances in computers and electronics enable new crash avoidance technologies that may not only mitigate the remaining occurring crashes but avoid them entirely. By warning drivers of impending crash situations, V2V technology may be able to reduce the number and severity of motor vehicle crashes, thereby minimizing the costs to society that would have resulted from these crashes.

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[28] NHTSA also carries out consumer programs established by the Motor Vehicle Information and Cost Savings Act of 1972.

[29] National Center for Health Statistics, HEW and State Accident Summaries (Adjusted to 30-Day Traffic Deaths by NHTSA).

[30] National Highway Traffic Safety Administration, Fatality Analysis Report System (FARS) final 2011 data. For more information, see www.nhtsa.gov/FARS (last accessed Feb. 12, 2014).

[31] For more information, see the agency policy statement on automated vehicles at www.nhtsa.gov/staticfiles/rulemaking/pdf/Automated_Vehicles_Policy.pdf (last accessed Jan. 24, 2014).

A. Crashes potentially addressed by V2V technology

Calculating the target potential crashes that V2V-based safety applications could address helps provide a starting point for estimating the magnitude of the problem in terms of the number and severity of crashes and injuries, the number of fatalities, and the societal cost of vehicle crashes. Dividing up the potential target crashes by pre-crash scenario also helps us understand how different V2V-based safety applications can address different kinds of safety problems.

DOT conducted a preliminary analysis in 2009 of the annual number of crashes that could be addressed by V2V technology.[32] The identified applicable crashes are based on the DOT-[33]developed pre-crash scenario typology as shown in Table III-1, which is in turn primarily based on pre-crash variables recorded in the GES and Crashworthiness Data System.

Table III-1 37 Pre-Crash Scenario Typology

	Crash Scenario		Crash Scenario
1	Vehicle Failure	21	Vehicle(s) Not Making a Maneuver – Opposite Direction
2	Control Loss with Prior Vehicle Action	22	Following Vehicle Making a Maneuver
3	Control Loss without Prior Vehicle Action	23	Lead Vehicle Accelerating
4	Running Red Light	24	Lead Vehicle Moving at Lower Constant Speed
5	Running Stop Sign	25	Lead Vehicle Decelerating
6	Road Edge Departure with Prior Vehicle Maneuver	26	Lead Vehicle Stopped
7	Road Edge Departure without Prior Vehicle Maneuver	27	Left Turn Across Path from Opposite Directions at Signalized Junctions
8	Road Edge Departure While Backing Up	28	Vehicle Turning Right at Signalized Junctions
9	Animal Crash with Prior Vehicle Maneuver	29	Left Turn Across Path from Opposite Directions at Non-Signalized Junctions
10	Animal Crash without Prior Vehicle Maneuver	30	Straight Crossing Paths at Non-Signalized Junctions
11	Pedestrian Crash with Prior Vehicle Maneuver	31	Vehicle(s) Turning at Non-Signalized Junctions
12	Pedestrian Crash without Prior Vehicle Maneuver	32	Evasive Action with Prior Vehicle Maneuver
13	Pedalcyclist Crash with Prior Vehicle Maneuver	33	Evasive Action without Prior Vehicle Maneuver
14	Pedalcyclist Crash without Prior Vehicle Maneuver	34	Non-Collision Incident
15	Backing Up into Another Vehicle	35	Object Crash with Prior Vehicle Maneuver
16	Vehicle(s) Turning – Same Direction	36	Object Crash without Prior Vehicle Maneuver

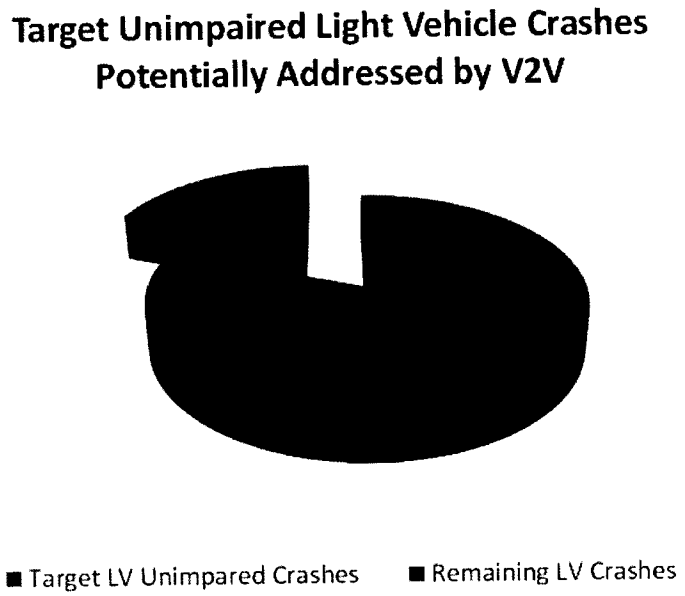
[32] Frequency of Target Crashes for Intellidrive Safety Systems (Najm, Koopman, Smith, and Brewer, October 2010, Report No. DOT HS 811 381). See www.nhtsa.gov/Research/Crash+Avoidance/ci.Office+of+Crash+Avoidance+Research+Technical+Publications.print (last accessed Jan. 30, 2014).

[33] Analysis of Light Vehicle Crashes and Pre-Crash Scenarios Based on the 2000 General Estimates System (Najm, Sen, Smith, and Campbell, Nov. 2002, Report No. DOT HS 809 573). See www.nhtsa.gov/Research/Crash+Avoidance/ci.Office+of+Crash+Avoidance+Research+Technical+Publications.print (last accessed Jan. 9, 2014).

17	Vehicle(s) Parking – Same Direction	37	Other
18	Vehicle(s) Changing Lanes – Same Direction		
19	Vehicle(s) Drifting – Same Direction		
20	Vehicle(s) Making a Maneuver – Opposite Direction		
Vehicle Action refers to a vehicle decelerating, accelerating, starting, passing, parking, turning, backing up, changing lanes, merging, or successful corrective action to a previous critical event.			
Vehicle Maneuver denotes passing, parking, turning, changing lanes, merging, or successful corrective action to a previous critical event.			

Of these 37 pre-crash scenarios, DOT determined that 15 represented either single vehicle crashes or crashes that would need to be addressed by V2I. That left 22 pre-crash scenarios remaining that could potentially be addressed by V2V technology. The 22 remaining crash scenarios, if the crashes they represent could be prevented, could address 81 percent of unimpaired light vehicle crashes, Figure III-1.

Figure III-1 Target Unimpaired Light Vehicle Crashes Potentially Addressed by V2V



Using 2004-2008 crash data, the approximate average number of fatalities, injuries, and property damage per year caused by these 22 target light-vehicle pre-crash scenarios are 27,000; 1,800,000; and 7,300,000, respectively, as illustrated in Figure III-2 below.