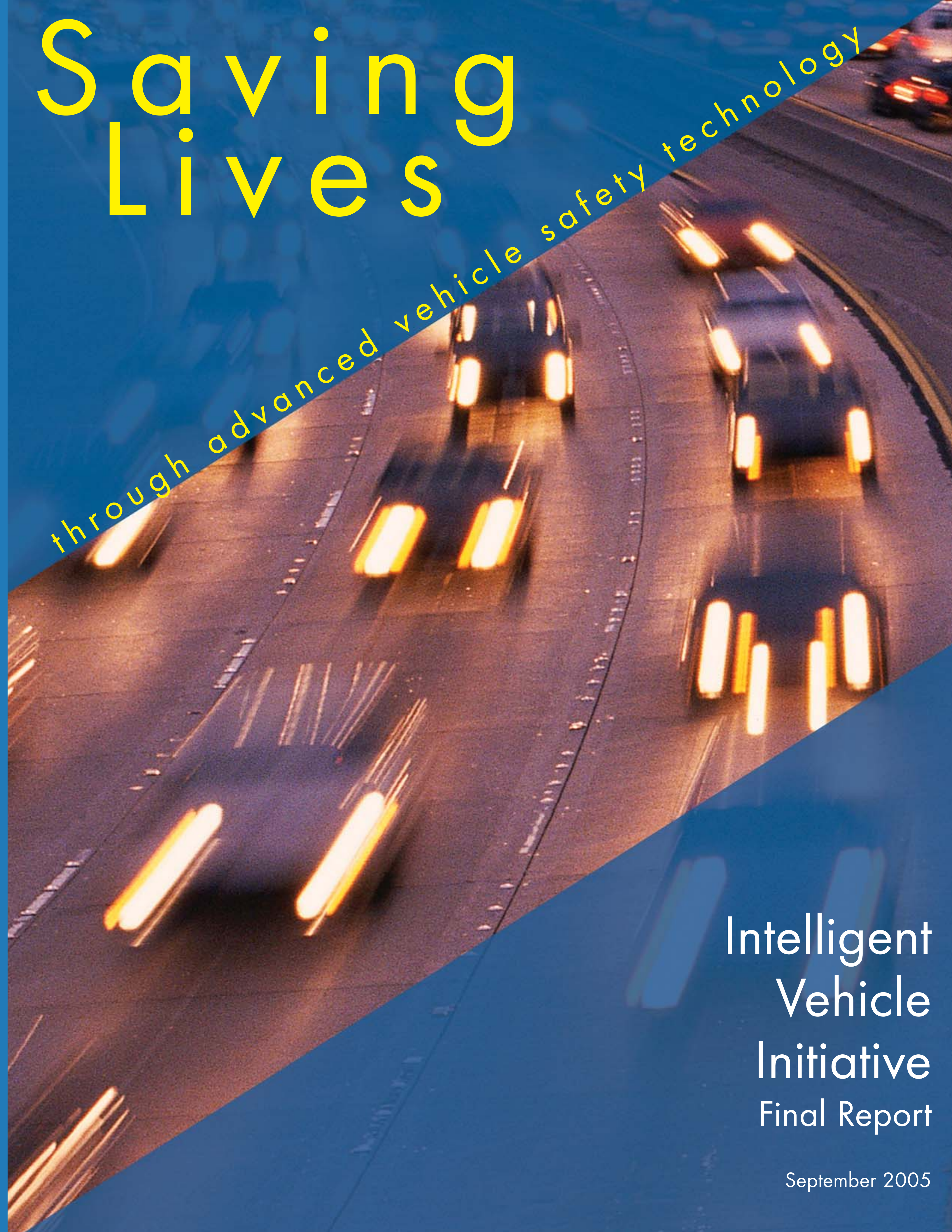
Saving Lives

through advanced vehicle safety technology



Intelligent Vehicle Initiative

Final Report

September 2005

IVI PROGRAM OVERVIEW

Introduced in 1997 and authorized in the 1998 Transportation Equity Act for the 21st Century (TEA-21), the Intelligent Vehicle Initiative (IVI) has been a revolutionary part of the U.S. DOT's Intelligent Transportation Systems (ITS) Program. As the initiative draws to a close this year, this Final Report provides an overview of the accomplishments over the life of the Program. This report presents the history of IVI and its successes, as well as how this initiative evolved over time. References are provided at the end of the document for those seeking detailed technical reports on the specific projects and topics discussed.

More than 6.3 million police-reported motor vehicle crashes occurred in the United States in 2003.

Each year, over six million crashes occur on U.S. highways. They kill more than 42,000 people, injure approximately three million others, and cost more than $230 billion per year. Driver error is the leading cause of highway crashes. The IVI Program was launched to help reduce the number and severity of these crashes.

Through innovation and technology, the IVI Program has focused on accelerating the development and commercialization of vehicle-based and infrastructure-cooperative driver assistance products that warn drivers of dangerous situations, recommend actions, and even assume partial control of vehicles to avoid collisions.

The accomplishments of the IVI Program are intrinsically tied to the significant efforts made by each of the Program's public, private, and academic participants. Beside Federal transportation and safety agencies, the motor vehicle industry has been a key IVI partner, because ultimately it will be industry that develops and deploys IVI safety systems in standard vehicle product lines. Original equipment manufacturers (OEM), automotive suppliers, and private fleet operators have all actively participated in the IVI Program as well. Public sector partners, including state and local government agencies, public fleet operators, universities, and associations also were critical partners in the development and deployment of IVI services.

TEAMING PARTNERS

Private Sector Partners

- 3M Corporation
- AssistWare Technology, Inc.
- BMW of North America, LLC
- DaimlerChrysler Research and Technology North American, Inc.
- Delphi Delco Electronics Systems
- Ford Motor Company
- Freightliner Corporation
- General Motors Corporation
- Gillig Corporation
- Mack Trucks, Inc.
- McKenzie Tank Lines, Inc.
- Navigation Technologies Corporation
- Navistar International Transportation Corporation
- Nissan Technical Center North America, Inc.
- Praxair, Inc.
- Raytheon
- Toyota Technical Center USA, Inc.
- TRW
- US Xpress Leasing, Inc.
- Visteon Corporation
- Volkswagen of America, Inc.
- Volvo Trucks North America, Inc.
- X-Meritor-Webco

Public Sector Partners

- Ann Arbor Transportation Authority, Michigan
- California Department of Transportation
- City of Hutchinson, Minnesota
- McLeod County, Minnesota
- Minnesota State Patrol
- Minnesota Department of Transportation
- Pennsylvania Department of Transportation
- Port Authority of Allegany County
- San Mateo County Transit
- Virginia Department of Transportation

University Partners

- California PATH
- Carnegie Mellon University
- Johns Hopkins Applied Physics Laboratory
- University of Iowa
- University of Michigan Transportation Research Institute
- University of Minnesota
- Virgnia Tech Transportation Insitute

Association Partners

- American Trucking Association
- Intelligent Transportation Society of American (ITS America)

OBJECTIVES

Over the years, U.S. DOT's vehicle-based safety research programs have focused primarily on crash mitigation techniques. The IVI Program was unique in that it focused on crash prevention and included research on the implications of in-vehicle technologies on driver behavior.

The IVI mission was to prevent highway crashes and the fatalities and injuries they cause. The IVI objectives were developed in support of this overall mission. Objectives of the Program were to prevent driver distraction and to facilitate accelerated development and deployment of crash avoidance systems.

IVI Objectives

– Prevent driver distraction

– Facilitate accelerated deployment of crash avoidance systems

Prevent Driver Distraction

The highway environment is increasingly complex both inside and outside of the vehicle. In addition to dealing with highly congested roadways, more drivers use in-vehicle devices, most notably cellular phones. In-vehicle devices can be distracting because they can require drivers to engage manually, cognitively, or both in nondriving tasks for unsafe periods of time. Moreover, nondriving tasks, such as the ringing of a cellular phone, can interrupt drivers at unsafe periods of time.

Although distraction cannot be prevented entirely, work under the IVI Program significantly increased the understanding of why and when distraction is likely to occur. Numerous tools were developed to help minimize the consequences of distracted driving.

No one solution can solve the problem of driver distraction.

A significant portion of IVI studies consisted of evaluating the influence of in-vehicle information and communication systems on driver performance, including cellular telephones, in-vehicle computers, route guidance, and adaptive cruise control.

IVI Approach

Investigating driver distraction requires a comprehensive and programmatic effort. The Intelligent Vehicle Initiative used a myriad of tools to define the driver distraction problem and find solutions. Methods included expert working groups, public forums, focus groups, laboratory experiments, naturalistic driving studies on-the-road, and analyses of crash, injury, and fatality statistics.

Studies were conducted that examined the relationship between distraction and crashes or near-misses; research into practical ways of measuring distraction and driver workload; simulator studies assessing the effects of in-vehicle usage on distraction and safety; research into the willingness of drivers to engage in risky behavior; and the development of guidelines to optimize the interface of in-vehicle devices. And because problems associated with driver distraction cut across all vehicle types, the IVI research focused on both light and heavy vehicles. To compare results across different studies, the IVI also involved standardizing methods for objectively measuring driver distraction, workload, and performance.

In summary, the research approach included:

- Improving the understanding of the nature and extent of the driver distraction safety problem;
- Developing tools and methods that can measure and predict the potential for in-vehicle technologies to be distracting;
- Developing human factors guidelines to aid in equipment design; and
- Developing integrated approaches to reduce the distraction caused by in-vehicle devices.

Research Results: Summary of Findings and Accomplishments

The accomplishments from the following key IVI activities have helped minimize the consequences of distracted driving.

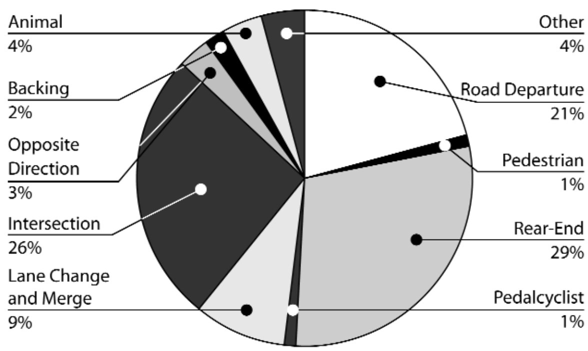
Driver Distraction Working Group and Internet Forum. Early in the IVI Program, the National Highway Traffic Safety Administration (NHTSA) sponsored a series of working meetings and an Internet forum to improve understanding of driver distraction and workload. The meetings, referred to as Driver Distraction Expert Working Group Meetings, were held in Washington, D.C. Attendees consisted of experts in driver behavior, experimental design, automotive safety, and traffic engineering. The Internet forum, called the Driver Distraction Internet Forum, provided the means for the public to access research papers, ask and receive answers to questions, and share experiences regarding the use of in-vehicle devices. The findings from this activity were used to shape related research conducted over the course of the IVI Program.

Workload Measures. Driver workload encompasses all activities being performed by a driver, including the necessary tasks to operate the vehicle plus other activities such as speaking on a cellular phone. Measuring driver workload is an important component to evaluating an in-vehicle information system, or IVIS. One IVI project, referred to as IVIS DEMAnD, produced a software package that measures workload; its purpose is to assist human factors designers and engineers in evaluating the demands placed on the driver's cognitive resource pool by in-vehicle devices. IVIS DEMAnD uses a behavioral model to evaluate the attention demand required to operate a given IVIS. The research used an extensive literature review, information from practitioners, and four on-road studies to determine the behavioral model and the software tool components.

Heavy Vehicle Workload. As driving tasks and workload in heavy vehicles vary considerably from the typical passenger car, the IVI included a separate analysis of heavy vehicle driver workload. The objective for this area was to determine if and how performing a secondary task alters the performance of a primary task. The results 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. Further investigations involved tracking where the driver is looking and for how long. Such visual measures were found to be especially sensitive and robust to evaluating driving conditions and requested tasks.

A simulator study and a field study on workload created by in-cab text messaging and cellular phone usage by heavy truck drivers found that text message reading can negatively impact lane-keeping behavior. Visual scanning was reduced almost 50 percent on average when drivers were engaged in a dialogue. The knowledge developed under these projects is a critical part of the basis for understanding acceptable levels of driver workload.

Crash-Type Distribution



CAMP Driver Metrics Workload. The U.S. DOT partnered with the Crash Avoidance Metrics Partnership (CAMP) to better understand driver workload when engaging in nondriving-related tasks such as tuning the radio or using a cell phone. Private sector partners participating in this partnership were GM, Ford, Nissan, and Toyota. Workload was investigated in three venues: laboratory, test track, and on-the-road. The main objective for the automotive industry was to provide an approach for measuring workload early in the development process. Findings indicate that workload is a multidimensional problem and requires different approaches for visual-manual tasks versus auditory-vocal (cognitive) tasks.

Facilitate Accelerated Deployment of Crash Avoidance Systems

The second fundamental objective of the IVI Program focused on facilitating the accelerated development and deployment of crash avoidance systems. This theme encompassed the bulk of the work performed under the IVI Program.

IVI Approach

The fundamental approach to this portion of the IVI Program encompassed a four-step process. Each step built upon the results of the previous one. This methodology proved effective in accomplishing the overall goal of accelerating the deployment of crash avoidance systems. The work steps included:

1. Defining the safety problem;
2. Developing performance guidelines, specifications, and standards;
3. Testing and evaluating promising technologies, applications, and configurations; and
4. Researching and evaluating benefits.

Defining the Safety Problem. Definition of the safety problem is necessary to understand the potential of advanced technologies to mitigate the consequences of vehicle collisions. The IVI research examined crash data to determine the causes of motor vehicle crashes. Various types of crashes were carefully studied to help determine what types of crash avoidance systems could be effectively deployed.

> **The greatest opportunity to improve safety exists in three driving conditions**
>
> **Normal Conditions–**
> In-vehicle communications systems that drivers can operate without distraction.
>
> **Degraded Conditions–**
> Driver warning systems related to reduced visibility or driver fatigue.
>
> **Imminent Crash Conditions–**
> - Rear-End
> - Road Departure
> - Lane Change
> - Intersection
> - Stability Control

The study of crash data analysis provided the basis for describing the driving environment in which specific crash types occur and in establishing the functional requirements for appropriate collision warning systems. The IVI Program addressed crashes related to rear-end, road departure, lane change, intersection, and vehicle stability.

Developing Performance Guidelines, Specifications, and Standards. The development of performance guidelines, specifications, and standards facilitate the accelerated deployment of crash avoidance systems. The definition of these requirements is based on the safety problem definition and has set the stage for future product development and deployment opportunities.

Evaluating Safety System Effectiveness. Research conducted under this area involved the testing and evaluation of promising technologies, applications, and configurations of safety systems.

Evaluating Benefits. The research and development projects conducted under IVI were aimed at creating a scientific knowledge base that could lead to the development of products aimed at the reduction of collisions, fatalities, collision severity, and injuries. Initial work to estimate safety benefits was based on real-world crash databases combined with analytical and simulation methods. Later benefits work made use of experimental work on the track or in driving simulators. The most sophisticated efforts to estimate safety benefits were the conduct of field operational tests using prototype systems.

Imminent Crash Research

The IVI Program addressed the feasibility of providing drivers with imminent crash warning advice to avoid several different crash types, including rear-end, road departure, lane change, and intersection collisions, and stability control for heavy vehicles. The following paragraphs summarize some of the major projects which concluded the research undertaken within each of these crash types. A complete discussion of the individual projects that covered the four IVI approach steps discussed above can be found in the key references and at the Internet web sites listed at the conclusion of this report.

- **Rear-End Collisions –** The most predominant crash type is a rear-end collision, as they account for approximately 28 percent of crashes annually. The study of this crash type was a high priority and research was initiated at the very beginning of the

IVI Program. Several studies examined the crash characteristics associated with rear-end collisions. These studies defined the causal factors and crash scenarios for rear-end collisions that could be used to define further work in identifying mitigation concepts. A series of studies were then undertaken to expand the scientific knowledge base related to sensor systems, warning algorithms, and driver-vehicle interfaces.

The study of rear-end collision avoidance within the IVI Program concluded with a field operational test (FOT) to evaluate the feasibility of collision warning systems. The project consisted of a five-year joint research program between the U.S. DOT and General Motors Corporation for an Automotive Collision Avoidance System (ACAS) FOT which was initiated in June of 1999. The ACAS FOT built on previous research to create prototype crash warning systems. The project assessed the performance of rear-end collision warning systems in combination with adaptive cruise control (ACC) systems in operational environments. The conduct of a FOT employing state-of-the-art rear-end collision warning systems and ACC systems has provided the basis for documenting system performance, effectiveness, potential safety benefits, and user acceptance. The ACAS integrated the rear-end collision warning system and adaptive cruise control. The rear-end collision warning system detects, assesses, and alerts the driver of a potential hazard in the forward region of the vehicle. The ACC provides automatic brake and throttle actuation in order to maintain speed and longitudinal headway control. The ACAS FOT was completed in 2004.

An evaluation of the results of the FOT indicated that, ACAS, as an integrated system of rear-end collision warning and ACC functions, has the potential to prevent about 10 percent of all rear-end crashes. ACAS also reduced the exposure to severe near crashes during the FOT by 10 to 20 percent. The evaluation also examined user acceptance of the two systems. The evaluation indicated that driver acceptance findings suggest interest and fairly positive regard of the rear-end collision avoidance system by FOT participants as a group. Its acceptance, an indicator of purchase likelihood, was estimated at 27 percent. In general, drivers viewed ACC positively despite expressing concerns about its ungainly acceleration and braking. The purchase likelihood of ACC was estimated at 44 percent. To assist with deployment and acceptance, the evaluation indicates that additional research must be conducted to reduce false and nuisance alerts and to enhance the timing of crash imminent alerts. The evaluation also discusses lessons learned from the FOT and contains suggestions for future work and FOTs.

A spectrum of vehicle types were considered during IVI research

Light Vehicles
Passenger vehicles, light trucks, vans, and SUVs.

Commercial Vehicles
Heavy trucks and interstate buses.

Transit Vehicles
Nonrail vehicles operated by transit agencies.

Specialty Vehicles
Emergency response and highway maintenance vehicles.

A FOT involving commercial vehicles also was conducted to evaluate the viability of rear-end collision warning systems. Volvo Trucks North America, Inc. and U.S. Xpress, Inc. partnered with U.S. DOT to conduct an FOT of a rear-end collision warning system that includes adaptive cruise control and advanced braking. The equipped tractors were used with various trailers from the U.S. Xpress fleet.

The Transit Forward Collision Warning (FCW) project ended in 2002 with the development of a FCW system and driver vehicle interface. This work was then merged with a side collision warning development project to create an integrated system. This warning system integration for transit vehicles is further discussed in the lane-change section.

- **Road Departure Collisions –** The road departure collision category is dominated by the single-vehicle crash – where the vehicle leaves the road first and not because of a collision with another vehicle. Road departure crashes typically are caused by driver inattention, fatigue, or excessive speed, particularly when maneuvering in complex road geometry (curves, ramps, etc.). In fact, one in five crashes is reported as a single-vehicle roadway departure. NHTSA estimates that road departure warning systems could apply to about 458,000 of the 1.2 million crashes each year.

Systems to avoid road departure collisions will warn the driver when his or her vehicle is likely to deviate from the lane of travel. These systems track the lane or road edge and warn drivers when they are likely to drift off the road or when they are traveling too fast for an upcoming curve. Future capabilities may integrate an ACC function to adjust vehicle speed for the shape of the road.

A FOT is presently being performed by a partnership among the University of Michigan Transportation Research Institute (UMTRI); Visteon, and Assistware Technologies. The Volpe National Transportation Systems Center (Volpe) is the independent evaluator for the field test. The purpose of this field test is to develop a driver warning system to indicate when the vehicle is about to drift off the road or that the vehicle is traveling too fast for an upcoming curve. These crash avoidance countermeasures will be fully integrated into field test vehicles so that the test vehicles have the look and feel of production cars, but are instrumented to collect data for system evaluation. The field test and analysis is scheduled to be completed in 2005.

- **Lane Change and Merge Collisions –** Collisions during lane changes and merges represent a major problem area, accounting for one in 25 of all crashes, with 90 percent caused by lane changes and 10 percent by merges. For transit bus collisions, these collisions represent more than half of all collisions. Primarily angle or sideswipe impacts, this problem requires in-vehicle technology to help detect and warn drivers of vehicles in adjacent lanes. These systems monitor the lane position and relative speed of other vehicles beside and behind the vehicle, and advise drivers of the potential for collision. It is estimated that these systems could help prevent up to 192,000 of the approximately 200,000 lane change/merge crashes each year.

In 1994-1997, TRW performed an extensive study to define the problem area for lane change/merge, including proposed performance specifications. This study included an on-road test of an advanced lane-change warning system using passenger cars. Early commercially available systems were then evaluated, paying particular attention to human factors issues. Battelle investigated alternative displays (human factors) for side collision warning systems in 1996.

Several field trials involving transit vehicles were conducted to determine the performance requirements of lane-change systems operating in the transit environment. Evaluation of a large test fleet of side collision warning systems on transit buses in Allegheny County, Pennsylvania (a.k.a. Pittsburgh) resulted in a side collision warning system specification (minimum performance requirements). Performance issues identified in the first phase of the test led to a more advanced system being developed and deployed in a second phase of the test. Specifically, the second generation system has a shorter detection range in order to reduce the instance of false alarms in congested conditions. Another transit field test used lane assist systems, which have sensors that "see" the road markings and warn bus drivers if they are too near the lane boundary.

Another project merged the performance specifications for a side collision system with the performance specifications for a forward collision warning system for transit buses, based on field trials results in Pennsylvania and California. This specification for an integrated transit warning system is particularly valuable guidance for transit agencies that are early deployers of these systems, due to particularly strong benefits for the cost.

- **Intersection Collisions –** More than a quarter of the nation's annual crashes occur at intersections when one vehicle crosses the path of another or strikes it front-to-side. Approximately 1.7 million crashes occurred at intersections in 1998, causing more than 6,700 fatalities.

Early in the IVI, Veridian Engineering developed several vehicle-based concepts to address the intersection crash problem. This work provided some of the initial research and experimentation in using advanced technologies for intersection collision avoidance work and provided a knowledge base for future work.

The Infrastructure Consortium was created to conduct research and development of infrastructure-only intersection collision avoidance systems. Members of the Consortium partnership include Minnesota, Virginia, and California Departments of Transportation (DOT), California PATH, the University of Minnesota, and the Virginia Polytechnic and State University. In order to demonstrate the concepts being developed by the Consortium, an intersection testbed was designed and built at the FHWA's Turner-Fairbank Highway Research Center. This facility demonstrated three early intersection collision avoidance concepts in June 2003 during the National IVI Meeting. The California team demonstrated a system which helps drivers judge when they should not make a permitted left turn at a signalized intersection due to potentially hidden traffic. Minnesota demonstrated a system designed to tell drivers trying to access major rural roads at a stop sign or unsignalized intersection when it is safe to enter the main roadway. Virginia's system demonstrated two systems – one infrastructure only and the other a cooperative system – that alert drivers of an imminent traffic signal violation.

Virginia Tech Transportation Institute (VTTI) created and demonstrated a vehicle-based signal and stop sign violation countermeasure with technology-independent performance specifications in a testbed vehicle. They also are developing objective tests to support a FOT of the system. The system is being designed to provide in-vehicle warnings if a driver is likely to violate a stop sign or red light at an intersection.

- **Vehicle Stability –** This problem area focuses on enhancing vehicle stability on the road. Efforts were focused on commercial vehicles, as their higher centers of gravity and coupling points make them more prone to jackknife or rollover. Most incidents of heavy vehicle instability are triggered either by braking or rapid steering movements. Because heavy vehicle instability often results in rollover, this problem is particularly serious in terms of its potential to cause loss of life, injuries, property damage, and traffic tie-ups.

The U.S. DOT entered into a cooperative agreement with Freightliner and its partners to evaluate technology aimed at preventing rollover crashes in heavy trucks as part of a FOT. The technology evaluated was the Roll Advisor and Control (RA&C) system. The RA&C is designed to assist commercial vehicle drivers, especially drivers of tanker trucks, in avoiding rollover crashes. During the time of the FOT, Freightliner began offering the RA&C for sale.

The RA&C consists of two components. The first is the Roll Stability Advisor (RSA). The RSA will not prevent any particular crash through direct intervention. Instead, it advises a driver, after a maneuver is finished, that the lateral forces on the vehicle were higher than what might have been desirable. The second component is the Roll Stability Control (RSC). This system takes partial, momentary control of the vehicle if it deems that a serious rollover threat is developing.

The findings of the independent evaluator concluded that there was a slight reduction in the overall risk-taking behavior by FOT drivers that can be attributed to the educational function of the RA&C. Using the data from the FOT and data from U.S. DOT's General Estimates System and Fatality Analysis Reporting System, the following findings were reported:

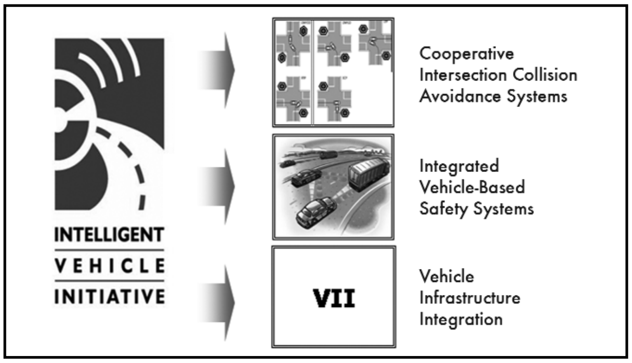
– Under conditions similar to those observed in the FOT, the RA&C is expected to prevent 20 percent of rollover crashes and 33 percent of single vehicle road departure crashes caused by excessive speed in a curve.

– For the national fleet of approximately 110,000 tanker trucks, it is estimated that the RA&C will prevent 34 crashes, 21 injuries, and two to three fatalities per year.

– On the test track, the RSC consistently triggered as the vehicle approached the limit of roll stability. In most of the test track experiments, the RSC prevented the outrigger (installed to prevent the experimental truck from actually rolling over) from touching the pavement.

FUTURE DIRECTION

Although the IVI Program has come to a close, it provides a strong base for further development of safety technologies. Research conducted under the IVI Program is now being used by industry to develop and deploy crash avoidance systems. There is more work to be done, and examples of continuing research are provided below.



Integrated Vehicle-Based Safety Systems (IVBSS)

Preventing Collisions the Smart Way. The widespread deployment of advanced integrated driver assistance systems has the potential to reduce rear-end, road departure, and lane-change collisions by 48 percent. Integrated systems will provide better hazard information from multiple sensors, enabling coordinated warnings to reduce driver distraction. The Integrated Vehicle-Based Safety Systems (IVBSS) initiative aims to equip all new vehicles with advanced driver assistance systems that would help drivers avoid the most common types of deadly crashes.

The IVBSS initiative will

- Develop information on how best to communicate an integrated warning to the driver;
- Develop objective tests and criteria for performance of systems that simultaneously address rear-end, road departure, and lane-change crashes; and
- Develop and field test integrated vehicle-based safety systems on the road with real drivers to understand the safety benefits of integrated systems.

This initiative, in partnership with the automotive industry, builds on completed and ongoing Intelligent Vehicle Initiative (IVI) field operational tests as well as results from naturalistic driving studies. It will involve projects and studies that include private passenger vehicles and freight-carrying trucks.

This initiative is the first attempt to fully integrate the individual solutions that address these three types of crashes. This research will combine existing research results and state-of-the-art commercial products and product performance for all systems related to this problem.

Cooperative Intersection Collision Avoidance Systems (CICAS)

Saving Lives and Preventing Injuries. Each year intersection-related crashes take a heavy toll on lives, productivity, and the economy. Intelligent intersection systems offer a significant opportunity to improve safety by enhancing driver decision-making at intersections that will help drivers avoid crashes.

Intersection collision avoidance systems use both vehicle- and infrastructure-based technologies to help drivers approaching an intersection understand the state of activities within that intersection. Cooperative intersection collision avoidance systems (CICAS) have the potential to warn drivers about likely violations of traffic control devices and to help them maneuver through cross traffic. Eventually, CICAS also may inform other drivers (i.e., potential victims) about impending violations as well as identify pedestrians and cyclists within an intersection.

CICAS consists of

- Vehicle-based technologies and systems – sensors, processors, and driver interfaces within each vehicle;
- Infrastructure-based technologies and systems – roadside sensors and processors to detect vehicles and identify hazards and signal systems, messaging signs, and/or other interfaces to communicate various warnings to drivers; and
- Communications systems – dedicated short-range communications (DSRC) to communicate warnings and data between the infrastructure and equipped vehicles.

The CICAS initiative builds on research and operational tests previously conducted under the U.S. DOT’s Intelligent Vehicle Initiative. It is being closely coordinated with the Vehicle Infrastructure Integration and the Intelligent Vehicle-Based Safety Systems initiatives. The CICAS initiative working group is being formed from partnerships with automotive manufacturers, State and local departments of transportation, and university research centers throughout America.

Through additional research, system integration activities, and demonstrations, the CICAS initiative will produce a system prototype that addresses both control violations and gap acceptance crash problems. The initiative will culminate in a series of coordinated field operational tests to help achieve a solid understanding of safety benefits and user acceptance.

Vehicle Infrastructure Integration (VII)

Crash Prevention and Congestion Relief Through Vehicle-to-Vehicle and Vehicle-to-Roadside Communication. About half of the deaths that occur each year on U.S. highways result from vehicles leaving the road or traveling unsafely through intersections. Traffic delays continue to increase, wasting more than a 40-hour workweek for peak-time travelers. A significant reduction in these numbers could be achieved through coordinated development of a nationwide wireless communication infrastructure that would allow communication between vehicles and between the vehicle and the roadside.

The VII vision is that every car manufactured in the United States would be equipped with a communications device and a GPS unit so that data could be exchanged with a nationwide, instrumented roadway system. Realization of this vision could mean a significant reduction in highway fatalities, while at the same time offering dramatic improvements in transportation mobility.

The VII initiative will build on the availability of advanced vehicle safety systems developed under the Intelligent Vehicle Initiative (IVI) and on the results of related research and operational tests.

The fundamental building blocks of the VII concept are coordinated deployments of communication technologies

- In all vehicles by the automotive industry; and
- On all major U.S. roadways by the transportation public sector.

Secure data transmitted from the roadside to the vehicle could warn a driver that it is not safe to enter an intersection or that the vehicle is dangerously close to running off the road. Vehicles serving as data collectors could anonymously transmit traffic and road condition information from every major road within the transportation network, giving transportation agencies the information needed to take action to relieve traffic congestion.

Protection of privacy is paramount. The intent is that general data collected by the public sector would be anonymous and used only for safety purposes and for efficient management of transportation operations. It is expected that this technology will facilitate a number of uses that drivers may choose such as electronic toll collection or telematics services for which some private information might be required. For those services, the intent is that the owner or driver would have to "opt in" and give permission for that information to be shared.

A VII consortium has been established to determine feasibility of widespread deployment and to establish an implementation strategy. Current membership includes U.S. DOT, AASHTO, 10 State DOTs, and several light vehicle manufacturers.

KEY REFERENCES

Technical Reports can be found on the following U.S. Department of Transportation (U.S. DOT) web sites:

- Intelligent Transportation Systems (ITS) Joint Program Office: *http://www.its.dot.gov/welcome.htm*
- Intelligent Vehicle Initiative (IVI): *http://www.its.dot.gov/ivi/ivi.htm*
- IVI Human Factors: *http://www.its.dot.gov/ivi/ivihf/reports.html*
- National Highway Traffic Safety Administration (NHTSA): *http://www-nrd.nhtsa.dot.gov/departments/nrd-12/pubs_rev.html*
- Federal Transit Administration (FTA): *http://www.fta.dot.gov/*
- Federal Motor Carrier Safety Administration (FMCSA): *http://www.fmcsa.dot.gov/*
- Federal Highway Administration (FHWA): *http://www.fhwa.dot.gov/*

The following are some of the key background reports available for download:

Program Overview

- 2000 IVI Business Plan: *http://www.its.dot.gov/ivi/docs/BP701.pdf*
- IVI Problem Areas Description: Motor Vehicle Crashes – Data Analyses And IVI Program Emphasis: *http://www.itsdocs.fhwa.dot.gov/\JPODOCS\REPTS_TE/9@101!.PDF*

Crash Data Analysis and Benefits

- Preliminary Assessment of Crash Avoidance Systems Benefits: *http://www.itsdocs.fhwa.dot.gov//JPODOCS/REPTS_TE/3V01!.PDF*
- Analysis of Light Vehicle Crashes and Pre-Crash Scenarios Based on the 2000 General Estimates System: *http://www-nrd.nhtsa.dot.gov/pdf/nrd-12/DOTHS809573.pdf*
- Synthesis Report: Examination of Target Vehicular Crashes and Potential ITS Countermeasures: *http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/1b@01!.pdf*
- Rear-End Crashes: Problem Size Assessment And Statistical Description: *http://www.itsdocs.fhwa.dot.gov/\JPODOCS\REPTS_TE/44F01!.PDF*
- The Role Of Driver Inattention In Crashes; New Statistics From The 1995 Crashworthiness Data System: *http://www.itsdocs.fhwa.dot.gov/\JPODOCS\REPTS_TE/LL01!.PDF*
- Intelligent Vehicle Initiative (IVI) Needs Assessment: *http://www.itsdocs.fhwa.dot.gov/\JPODOCS\REPTS_TE/96301!.PDF*
- Examination of Crash Contributing Factors Using National Crash Databases: *http://www-nrd.nhtsa.dot.gov/pdf/nrd-12/HS809664.pdf*
- Analysis of Lane Change Crashes: *http://www-nrd.nhtsa.dot.gov/pdf/nrd-12/DOTHS809571.pdf*
- Development of Test Scenarios for Off-Roadway Crash Countermeasures based on Crash Statistics: *http://www.itsdocs.fhwa.dot.gov//JPODOCS/REPTS_TE//13759.pdf*
- Analysis of Crossing Path Crashes: *http://www-nrd.nhtsa.dot.gov/pdf/nrd-12/DOTHS809423.pdf*
- Analysis of Fatal Crashes Due to Signal and Stop Sign Violations: *http://www-nrd.nhtsa.dot.gov/departments/nrd-12/809-779/index.html*

Performance Specifications

- Development of Performance Specifications for Collisions Avoidance Systems for Lane Change Crashes: *http://www-nrd.nhtsa.dot.gov/pdf/nrd-12/Dev.OfPerf.Spec.CompleteBk.pdf*
- Development and Validation of Functional Definitions and Evaluation Procedures for Collision Warning/Avoidance System: *http://www-nrd.nhtsa.dot.gov/pdf/nrd-12/acas/HS808964_Report-1999-08.pdf*
- Run-Off-Road Collision Avoidance Using IVHS Countermeasures – Final Report: *http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/@@m01!.pdf*
- Intersection Collision Avoidance Using ITS Countermeasures: *http://itsdocs.fhwa.dot.gov/jpodocs/repts_te/@@l01!.PDF*
- Vehicle-Based Countermeasures for Signal and Stop Sign Violation: *http://www-nrd.nhtsa.dot.gov/departments/nrd-12/809-716/index.html*
- Preliminary Human Factors for the Intelligent Vehicle Initiative (IVI): *http://www.itsdocs.fhwa.dot.gov/edldocs/7363/index.html*
- Compendium of Human Factors Projects Supporting the Intelligent Vehicle Initiative: *http://www.itsdocs.fhwa.dot.gov/jpodocs/rept_mis/9@201!.PDF*
- Third Annual Report of the Crash Avoidance Metrics Partnership: *http://www-nrd.nhtsa.dot.gov/pdf/nrd-12/CAMP3/pages/index.html*

Field Operational Tests, On-Road Experiments, and Independent Evaluations

- Evaluation of the Intelligent Cruise Control System Volume I – Study Results: *http://www.itsdocs.fhwa.dot.gov//JPODOCS/REPTS_TE/94Z01!.PDF*
- Automotive Collision Avoidance System Field Operational Test Final Program Report: *http://www-nrd.nhtsa.dot.gov/pdf/nrd-12/acas/ACAS%20FOT%20Final%20Program%20Report%20DOT%20HS%20809%20886.pdf*
- Evaluation of the Freightliner Intelligent Vehicle Initiative Field Operational Test: *http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/13609_files/13871.html*
- A Comprehensive Examination of Naturalistic Lane-Changes: *http://www-nrd.nhtsa.dot.gov/departments/nrd-12/LaneChange/index.html*
- Interim Report on Road Departure Crash Warning Subsystems: *http://www-nrd.nhtsa.dot.gov/pdf/nrd-12/FINALINTER9-03.pdf*

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16. Abstract

This Final Report provides an overview of the Intelligent Vehicle Initiative's (IVI) progress and accomplishments. Authorized in the 1998 Transportation Equity Act for the 21st Century (TEA-21) as part of the U.S. DOT's Intelligent Transportation Systems (ITS) Program, IVI's mission was to prevent highway crashes and their resulting fatalities and injuries. In support of this mission, the objectives of the program were to prevent driver distraction and facilitate development and deployment of crash avoidance systems.

Safety systems researched, developed, and deployed under the IVI Program provide information to drivers, warn of dangerous situations, recommend actions, and/or assume partial control of vehicles to avoid collisions. Research conducted under the IVI Program has catalyzed new initiatives, including the Integrated Vehicle-Based Safety Systems (IVBSS), Cooperative Intersection Collision Avoidance Systems (CICAS), and Vehicle Infrastructure Integration (VII).

The accomplishments of the IVI Program are tied to the efforts made by Federal transportation and safety agencies as well as the program's public, private, and academic partners.

17. Key Word Intelligent Vehicle Initiative (IVI), Integrated Vehicle Based Safety Systems (IVBSS), Cooperative Intersection Collision Avoidance Systems (CICAS), Vehicle Infrastructure Integration (VII), driver distraction, crash avoidance system, collision, vehicle stability, safety, advanced vehicle safety technology	18. Distribution Statement No restriction. This document is available to the public through the National Technical Information Service, Springfield, VA 22161

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