The Integrated Vehicle-Based Safety Systems Initiative

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ABSTRACT

This paper introduces the Integrated Vehicle-Based Safety Systems (IVBSS) initiative, a new safety research program sponsored by the U.S. Department of Transportation (U.S. DOT) aimed at accelerating the introduction of integrated crash warning systems in light vehicles and heavy commercial trucks. These systems will assist drivers and reduce the number and severity of injuries resulting from rear-end, roadway departure, and lane-change crashes. The U.S. DOT, in partnership with a private consortium led by the University of Michigan Transportation Research Institute (UMTRI), will carry out this initiative. This paper provides a program overview, describes the technologies of major subsystems, and discusses program activities, as well as the evaluation methodology.

KEYWORDS

Integrated vehicle-based safety systems, IVBSS, forward collision warning, roadway departure warning, lane-change/merge warning, curve speed warning.

TOPIC

Field Operational Tests – In-vehicle ITS – Collision avoidance – Advanced Driver Assistance Systems.

INTRODUCTION

In response to the growing economic loss due to traffic-related deaths, injuries and property damage on U.S. roadways, the U.S. DOT Intelligent Transportation Systems Joint Program Office (ITS JPO) has launched nine initiatives aimed at improving transportation safety, relieving congestion, and enhancing productivity. These initiatives reflect an ongoing recognition of the potential ITS technologies offer to enhance the operation of America's transportation systems. The nine initiatives include:

- Cooperative Intersection Collision Avoidance Systems
- Electronic Freight Management
- Emergency Transportation Operations
- Integrated Corridor Management Systems
- Integrated Vehicle Based Safety Systems
- Mobility Services for All Americans
- Nationwide Surface Transportation Weather Observing and Forecasting System
- Next Generation 9-1-1
- Vehicle Infrastructure Integration.

Initiatives were selected based on criteria that emphasized identifiable outcomes, performance schedules, private sector partnerships, and return on investment. Now in its second decade, the U.S. DOT ITS program is well positioned to build on accomplishments from previous research and field operational tests (FOTs). These new initiatives are an important step in the continuing evolution of the ITS program and will contribute to strengthening the role of ITS in transportation safety, mobility, and productivity.

TARGET CRASH PROBLEM

Based on the U.S. DOT General Estimates System (GES) crash database, there were approximately 6,318,000 police-reported crashes in the United States in 2003. About 96 percent or 6,060,000 of these crashes involved at least one light vehicle (e.g., passenger cars, minivans, sport utility vehicles, and light pickup trucks). Heavy commercial trucks (gross vehicle weight ratio greater than 4,545 Kg) were involved in about 362,000 police-reported crashes during the same period.

Rear-end, roadway departure, and lane-change crashes accounted for about 60 percent of all light vehicle and heavy commercial truck crashes, resulting in 1,550,000 and 69,000 injured persons, respectively. The U.S. DOT estimated that the economic costs of motor vehicle crashes in the United States totaled $230.6 billion in the year 2000 [1]. Included in these crash losses are lost productivity, medical costs, legal and court costs, emergency service costs, insurance administration costs, travel delay, property damage, and workplace losses. A U.S. DOT study also determined that 43 percent of the total economic costs were associated with roadway departure, rear-end, and lane-change/merge crashes [2].

Rear-end, roadway departure, and lane-change crashes account for approximately 50% of the 42,000 fatalities that occur in the United States each year. Preliminary analyses conducted by the U.S. DOT indicate that a substantial percentage of the fatal and non-fatal, police-reported target crashes could be prevented annually by a system that combined the three crash warning functions (rear-end collision warning, lane-change collision warning, and roadway departure warning) into a single, integrated warning system [3]-[5].

IVBSS PROGRAM OBJECTIVE

This paper introduces the IVBSS Initiative, a new U.S. DOT safety research program to build and field test an integrated crash warning system designed to prevent rear-end, lane-change, and roadway departure crashes for light vehicles and heavy commercial trucks. In November 2005, the U.S. DOT entered into a cooperative agreement with a program team led by the University of Michigan Transportation Research Institute (UMTRI). Team members include Visteon Corporation, Eaton Corporation, Honda Research & Development Americas, Cognex Corporation, and the Battelle Memorial Institute.

The IVBSS program team will develop and test prototype integrated crash warning systems in a fleet of 16 passenger cars and 10 heavy commercial trucks. UMTRI will serve as the primary contractor, coordinating the work of the private partnership and conducting the FOTs. The U.S. DOT will invest approximately $25 million in this program and the private partners will contribute an additional $6.6 million.

CRASH COUNTERMEASURE SYSTEMS

The integrated safety system for the light vehicle platform will include four crash countermeasure functions: forward collision warning (FCW), lane departure warning (LDW), lane-change warning (LCW), and curve speed warning (CSW). FCW alerts drivers when they are in danger of striking the rear of the vehicle in front of them traveling in the same direction. The FCW sensor suite will consist of long-range, forward-looking radar and a long-range, forward-looking camera, GPS and a map database, a short-range, forward-looking camera, and two short-range, forward-looking radars.

The LDW function provides alerts to drivers when a lateral drift toward or over lane edges is sensed without a turn signal indication. A short-range, forward-looking camera, four short-range radar sensors, and GPS with a map database will enable the LDW function.

LCW will increase a driver's situational awareness of vehicles in close proximity traveling in adjacent lanes in the same direction. The sensor suite of LCW includes four short-range radars distributed along the sides of the vehicle and two side-looking cameras.

The CSW function warns drivers when they are traveling too fast for an upcoming curve. The CSW function will be implemented using GPS and a map database and a short-range, forward-looking camera.

The integrated safety system for the heavy commercial truck platform will include the FCW, LDW, and LCW functions. FCW will be implemented using long-range, forward-looking radar, GPS and a dynamic map database, a short-range, forward-looking camera, and a gyroscope. LDW will use a short-range, forward-looking camera and GPS with a dynamic map database. The LCW function will be enabled by a suite of several side-looking and backward-looking, short-range radars. Table 1 lists the sensors used for each crash warning function by platform, and shows shared sensors across warning functions and platforms.

Table 1 – IVBSS Sensors across Warning Functions and Vehicle Platforms

	Crash Warning Functions			
Sensors	**FCW**	**LDW**	**LCW**	**CSW**
77 GHz, 200 meter Radar	LV & HT			
50 – 100 meter Vision	LV			
GPS/Map	LV & HT	LV & HT		LV
50 meter Vision	LV & HT	LV & HT		LV
24 GHz, 15 meter Radars	LV	LV	LV	
SL Vision			LV & HT	
5.8 GHz, 3 meter SL Radars			HT	
5.8 GHz, 10 meter BL Radars			HT	

SL: Side-Looking **LV: Light Vehicle**
BL: Backward-Looking **HT: Heavy Truck**

IVBSS PROGRAM OVERVIEW

The IVBSS program consists of five major activities, including preparatory analyses, system design, building and validation of prototype vehicles, field operational tests, and an independent evaluation (Figure 1). The program began with preparatory analyses in early 2004. In September 2004, a public meeting and workshop was held to solicit input from members of the automotive and heavy commercial vehicle industry and the vehicle safety research community. Feedback from the meeting was used to fine tune the IVBSS program plan.

Following industry and stakeholder input, high-level functional requirements based on target crashes and dynamic vehicle scenarios were established. This was followed by a technical review to assess the state-of-the-art of system and subsystem technology and identify relevant work from prior efforts. Research into different driver-vehicle interface (DVI) concepts was also reviewed and summarized. In addition, the business case and deployment potential for heavy commercial trucks were assessed through industry and stakeholder input and separate analyses.

At the conclusion of the preparatory analyses, the U.S. DOT prepared and issued a Request for Applications in June 2005. Following evaluation of the applications received, a cooperative agreement was awarded to the technical team lead by UMTRI in November 2005.

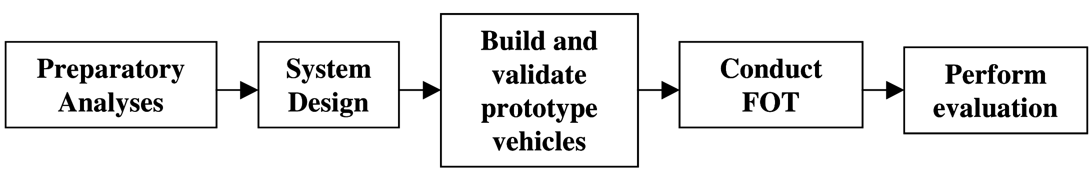

Figure 1 – IVBSS Program Activities

The IVBSS initiative is a four-year program consisting of two consecutive, non-overlapping phases. The program began in November 2005 and will continue through December 2009. During Phase I, the UMTRI team will carry out the system design and validation of the prototype vehicles. These activities will take place from December 2005 through December 2007. The system design work will define the system operational concepts and develop corresponding performance specifications and objective test procedures. UMTRI and its partners will design, build, and test sensor subsystems and develop threat assessment algorithms and driver interfaces.

The proposed DVI development approach combines sound human factors practice and data driven methods. Specifically, data from the warning literature and concepts from feedback control models, as well as psychophysics, will be used to answer design questions and make predictions about driver performance. Performance and subjective data from previous FOTs, along with lessons learned from DVI development in those studies, will be used as a guide to predict expected driver performance, as well as warning system characteristics that are acceptable for the application and vehicle platform.

The DVI will be designed using rapid prototyping and a series of driving simulator experiments, which will combine expert judgment with experimental data from the simulator experiments and driving on public roads. Formal driving simulator experiments will be performed to quantify performance with each of the warning candidates. Results from the simulator experiments and on-road testing will be used to select the most appropriate alternatives based on system effectiveness, driver acceptance, and practical integration into the light vehicle and heavy truck platforms.

Prototype vehicles that integrate the individual warning functions and driver interface will be constructed and used to verify system functionality and ensure conformance with the integrated system performance specifications. This activity will also include the design and fabrication of a data acquisition system to collect the data needed to verify the performance of the integrated systems. The verification activity consists of a series of objective test procedures conducted on a test track and pre-defined routes on public roads. The results of these tests will help refine the design of the integrated safety systems prior to the field operational test. The National Institute for Standards and Technology (NIST) will lead the efforts to develop objective test procedures in cooperation with members of the UMTRI team.

During Phase II, the UMTRI team will conduct field operational tests for the light vehicle and heavy commercial truck platforms. Data will be collected on driver performance with, and without, the assistance of the integrated safety system installed on the respective test fleets. This activity will involve definition of field test concepts, recruitment of subjects and a truck fleet, building the vehicle fleets, and conduct of pilot tests prior to the full-scale field trials. The light vehicle and heavy commercial truck field operational tests will be carried out over a 12-month period beginning in July 2008.

Approximately 108 subjects will be recruited to participate in the light vehicle field operational test. Test participants will drive an IVBSS-equipped 2007 Honda Accord sedan as their own personal vehicle for a period of six weeks. Their use of the vehicle will be unsupervised and unrestricted. During the first two weeks of the test period, the functions of the integrated safety system will be disabled and baseline driving data will be collected. During weeks three through six, the integrated safety system functions will be enabled. Test participants will receive training prior to their use of the test vehicle.

A trucking company will be selected to participate in the heavy commercial truck field operational test. A fleet of ten IVBSS-equipped tractors will be driven by a pool of 15-20 professional drivers over a period of ten months. Truck field test participants will begin with a five-month extended baseline period during which the integrated safety system will be disabled and normative driving data will be collected. During months six through ten, the integrated safety system functions will be enabled. Customized training will be provided to drivers, mechanics and fleet management personnel involved in the field test.

The Volpe National Transportation Systems Center, an agency within the U.S. DOT, will carry out an independent evaluation program in parallel with IVBSS program design, development and field test activities. The independent evaluation will include estimation of potential safety benefits, driver and fleet acceptance, and characterization of the integrated system capability.

Independent evaluation planning and evaluation concept definition began in January 2006 and will continue through the end of December 2007 with the development of an evaluation plan, a data analysis framework and a set of data mining algorithms, and evaluation tools. Evaluation of the field data will begin in November 2008 and continue through March 2010. The independent evaluation report will be published in June 2010 after all data analysis has been completed.

BENEFITS ESTIMATION METHODOLOGY

Benefits that would accrue from widespread deployment of the integrated safety systems being developed will be estimated as part of field trials carried out during Phase II of the IVBSS program. Safety benefits are measured by estimating the number of crashes that might be avoided due to full deployment of the integrated system. The benefits estimation methodology that will be used was developed by the Volpe National Transportation Systems Center. This approach has been used extensively in several U.S. DOT sponsored field operational tests (Automotive Collision Avoidance System Field Operational Test (1999-2005) [6], Roadway Departure Collision Warning Field Operational Test (2001-2006) [7], and the Drowsy Driver Warning System Field Operational Test (2002-2006) [8]).

Ideally, safety benefits are measured using actual crash data; however, it is not possible to collect this data during the conduct of a field test since wide exposure is required to ensure that adequate crash data are collected. Field operational tests are typically conducted for a year and involve only a few instrumented vehicles driven by volunteers. To extend the results of the field operational tests, the benefits estimation methodology will use non-crash performance data from driving conflicts and near-crashes that occur during the field tests with, and without, the assistance of the integrated system. A more complete description and discussion of the benefits estimation methodology is given in [9] and an application of the methodology can be found in [10].

SUMMARY

This paper introduced the IVBSS Initiative, a new U.S. DOT safety research program to build and field test an integrated crash warning system designed to prevent rear-end, lane-change, and roadway departure crashes for light vehicles and heavy commercial trucks. The goal of this program is to accelerate the deployment of integrated crash warning technologies by providing government and industry stakeholders with relevant information regarding system performance specifications, objective test procedures, potential safety benefits, and driver acceptance.

Over the next two years, the IVBSS program will produce integrated system functional requirements, performance specifications and objective test procedures. There will be a key milestone at the end of the prototype vehicle verification in Phase I (November 2007), and a decision point on whether or not to continue with Phase II and the field operational test based on the results of verification tests (December 2007). If results from the prototype vehicle verification phase are positive, the option to execute Phase II (January 2008 through December 2009) will be exercised.

In Phase II, a fleet of passenger cars and heavy commercial trucks will be outfitted with the integrated system in preparation for the field operational test. At the completion of the field operational test, a large database characterizing driver-vehicle performance on public roads with, and without, assistance of the integrated safety system will be created. This database will be mined to estimate potential safety benefits, driver and truck fleet acceptance, system capability, and maturity of the technologies.

Interim and final program results will be published in public reports that will be available in electronic form on the NHTSA website, http://www.nhtsa.dot.gov and the ITS JPO Electronic Document Library, http://www.its.dot.gov/library.htm. Program documents and up-to-date information on the IVBSS program may be found on the IVBSS website, http://www.its.dot.gov/ivbss/index.htm.

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