OBJECTIVE TEST SCENARIOS FOR INTEGRATED VEHICLE-BASED SAFETY SYSTEMS

John J. Ference
National Highway Traffic Safety Administration
Sandor Szabo
National Institute of Standards and Technology
Wassim G. Najm
Volpe National Transportation Systems Center
United States
Paper Number 07-0183

ABSTRACT

This paper presents a set of crash-imminent test scenarios to objectively verify the performance of integrated vehicle-based safety systems designed to address rear-end, lane change, and run-off-road crashes for light vehicles and heavy trucks. National crash databases are analyzed to identify applicable pre-crash scenarios and guide development of track-based test procedures that can be safely and efficiently carried out. Requirements for an independent measurement system to verify the crash warning system performance are also discussed.

INTRODUCTION

In November 2005, the U.S. Department of Transportation (U.S. DOT) entered into a cooperative research agreement with a private consortium led by the University of Michigan Transportation Research Institute (UMTRI) to build and field test an integrated vehicle-based safety system designed to prevent rear-end, lane change and run-off-road crashes [1]. This four-year, two-phase program being carried out under this agreement is known as the Integrated Vehicle-Based Safety Systems (IVBSS) program within the U.S. DOT.

The IVBSS prototypes being developed will provide forward collision warning (FCW), lane departure warning (LDW), lane change warning (LCW), and curve speed warning (CSW) functions.

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 LDW function provides alerts to drivers when a lateral drift toward or over lane edges is sensed without a turn signal indication.

LCW will increase a driver's situational awareness of vehicles in close proximity traveling in adjacent lanes in the same direction. The CSW function warns drivers when they are traveling too fast for an upcoming curve.

The integrated safety system for the light vehicle platform will include the FCW, LDW, LCW and CSW functions; the heavy commercial truck platform will include the FCW, LDW, and LCW functions only.

During the first two years of the IVBSS program, the industry team will design, build, and verify integrated safety system prototypes for use on passenger cars and heavy trucks. The prototype vehicles will undergo a series of closed-course track tests aimed at ensuring that the integrated system meets the performance requirements and is safe for use by unescorted volunteer drivers during a planned field operational test.

Following successful prototype vehicle testing, the industry team will develop field test concepts and build a vehicle fleet of 16 passenger cars and 10 heavy trucks for use in the field test.

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 six weeks. A trucking company will be selected to participate in the heavy truck field operational test. A fleet of ten equipped trucks will be driven by a pool of 15-20 professional drivers over a ten-month period. The field tests will begin in July 2008 and continue for about one year.

The procedures used to verify the crash warning system performance will consist of representative crash-imminent driving scenarios in which a crash warning should be issued, as well as driving scenarios in which a warning should not be issued [2]. Driving scenarios in which a warning should not be issued are also known as nuisance tests or "do not warn" scenarios.

The crash-imminent scenarios will be based on the most frequently occurring rear-end, lane change and run-off-road crash types being addressed by the IVBSS program. The nuisance tests or "do not warn" scenarios, on the other hand, will be developed from a variety of real-world driving conditions to test the capability and known limitations of state-of-the-art technologies in recognizing and classifying targets.

The remainder of this paper describes development of crash-imminent test scenarios that will be used in the IVBSS program to verify the prototype vehicle crash warning system performance. These tests are a subset of tests proposed in earlier research on crash warning systems [2, 5], as well as new scenarios that assess system operation when near-simultaneous warning conditions exist (called multiple-threat scenarios).

OVERVIEW OF TARGET CRASH PROBLEM

The most common pre-crash scenarios addressed by the IVBSS program appear in crash statistics reported in the 2000-2003 General Estimates System (GES) crash databases [3]. The following section contains a summary of the dynamically distinct vehicle movements and critical events occurring immediately prior to the crash that will form the basis for test scenario development.

Rear-End Pre-Crash Scenarios

Based on 2003 GES crash statistics, a light vehicle struck a lead vehicle in 1,677,000 police-reported (PR) rear-end crashes. A heavy truck was the striking vehicle in 46,000 PR rear-end crashes annually, based on 2000-2003 GES crash statistics.

Table 1 lists the most common pre-crash scenarios in rear-end crashes for striking light vehicles and heavy trucks in descending order based on their relative frequency of occurrence. The lead-vehicle-decelerating scenario encompasses crashes where the lead vehicle is struck while decelerating, and crashes where the lead vehicle has just decelerated to a stop and then is struck before turning at a junction or in the presence of a traffic control device.

Table 1. Target Rear-End Pre-Crash Scenarios

Rear-End Pre-Crash Scenarios	Light	Truck
Lead vehicle is decelerating	52%	35%
Lead vehicle is stopped	26%	32%
Lead vehicle is moving at constant speed	14%	22%
Following vehicle is making a maneuver*	5%	7%
Other scenarios where vehicle is striking	3%	4%
Total	100%	100%

* Passing, leaving a parked position, entering a parked position, turning right, turning left, making a U-turn, backing up, changing lanes, merging, corrective action, or other.

Lane Change Pre-Crash Scenarios

The lane change family of crashes typically consists of a situation in which a vehicle attempts to change lanes, merge, pass, leave or enter a parking position, drifts and strikes, or is struck by another vehicle in the adjacent lane while both are traveling in the same direction. Light vehicle and heavy trucks were changing lanes, passing, merging, turning, parking, or drifting in respectively 461,000 (2003 GES) and 48,000 (2000-2003 GES annually) PR lane change crashes.

Table 2 lists the most common pre-crash scenarios in lane change crashes for encroaching light vehicles and heavy trucks in descending order based on their relative frequency of occurrence. In the first scenario listed in the Table 2, the lane change maneuver refers to a vehicle changing lanes while maintaining constant longitudinal speed. The passing maneuver indicates that the vehicle is accelerating while changing lanes.

Table 2. Target Lane Change Pre-Crash Scenarios

Lane Change Pre-Crash Scenarios	Light	Truck
Vehicle changes lanes or passes	60%	48%
Vehicle turns	17%	29%
Vehicle drifts	14%	18%
Vehicle merges	5%	4%
Other scenarios where vehicle is encroaching	4%	1%
Total	100%	100%

Run-Off-Road Pre-Crash Scenarios

Run-off-road scenarios include crashes resulting from an unintentional road edge departure, as well as crashes where the driver loses control due to excessive speed on curves. The IVBSS program will target 549,000 PR run-off-road crashes involving light vehicles and 55,000 heavy truck PR run-off-road crashes annually.

Table 3 identifies target run-off-road pre-crash scenarios and their relative frequency. It should be noted that the heavy truck integrated safety system will not include the curve speed warning function and will not address loss of control due to excessive speed.

Table 3. Target Run-Off-Road Scenarios

Run-Off-Road Pre-Crash Scenarios	Light	Truck
Vehicle is going straight & departs road edge	47%	73%
Vehicle is negotiating a curve & departs road edge	21%	27%
Vehicle is negotiating a curve & loses control	31%	
Total	100%	100%

CRASH-IMMINENT TEST SCENARIOS

The crash-imminent test scenarios described in this section are based on the most common pre-crash scenarios previously identified in Tables 1-3. These scenarios represent the majority of driving conflicts that IVBSS functions will address on public roadways.

The test scenario figures that follow conceptualize each proposed test, but are not drawn to scale. The term subject vehicle (SV) and principal other vehicle (POV) refer respectively to the IVBSS-equipped vehicle (either light vehicle or heavy truck) and principal other vehicle involved in the crash scenario.

The subject vehicle's trajectory includes a red "x" that indicates the start of the abort path if no warning occurs by this point.

Rear-End Crash-Imminent Test Scenarios

Table 4 lists nine recommended scenarios to test the system's ability to sense and produce alerts for rear-end crash-imminent threats. The first four test scenarios follow directly from the most common rear-end pre-crash scenarios given in Table 1. The remaining five scenarios verify the system's ability to detect cars on curves, distinguish motorcycles in traffic, and recognize lead vehicles cutting in or out of traffic ahead.

Table 4. Rear-End Crash Threat Test Scenarios

No	Description
1	SV encounters slower* POV
2	SV encounters decelerating POV
3	SV encounters stopped POV on straight road
4	SV changes lanes & encounters slower POV
5	SV encounters stopped POV on curve
6	SV encounters slower motorcycle behind truck
7	SV encounters slower POV after cut-in
8	SV encounters decelerating POV1 after POV2 cut-out
9	SV encounters slower motorcycle

* Slower refers to a vehicle moving at slower constant speed
SV≡ Subject Vehicle, POV≡ Principal Other Vehicle

The first scenario, as shown in Figure 1, tests the ability of the system to recognize the dynamic state of a slower lead vehicle (constant speed) and issue an alert accordingly. This scenario should be conducted at a closing speed greater than 32 km/h (20 mi/h).

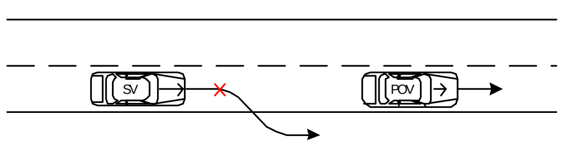

Figure 1. Slower Lead Vehicle

Figure 2 illustrates the second test scenario where the SV is initially following the POV at a constant time gap and then the POV suddenly decelerates. The objective of this scenario is to test whether a decelerating lead vehicle will be recognized and an alert is issued in a timely manner. This scenario should be performed under two different sets of initial conditions:

- Time gap ≤ 2 seconds and POV deceleration ≤ 2 m/s^2 (highway), and
- Time gap > 2 seconds and POV deceleration > 3 m/s^2 (arterial road).

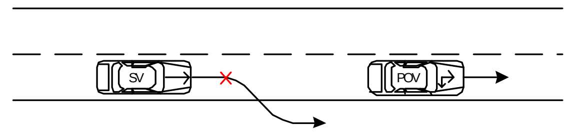

Figure 2. Decelerating Lead Vehicle

Figure 3 shows the third scenario that tests the ability of the FCW function to detect a stopped lead vehicle. This scenario should be conducted at a moderate speed (72 km/h (45 mi/h)) and a high speed (97 km/h (60 mi/h)).

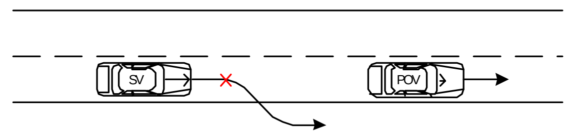

Figure 3. Stopped Lead Vehicle

The fourth test scenario involves the SV making a signaled lane change and then encountering a slower POV at a constant speed as indicated in Figure 4. This test verifies the ability to detect a slower vehicle and issue an alert in a timely manner following a lane change maneuver. The SV should complete its lane change just before entering the system's forward warning zone, and approach the POV at a closing speed below 16 km/h (10 mi/h).

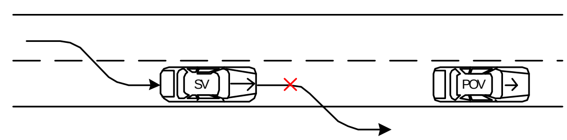

Figure 4. Slower Lead Vehicle after Lane Change

Figure 5 shows the schematic of the fifth test scenario dealing with a lead vehicle stopped on a curve. This test assesses the system's ability to detect stopped vehicles not in the direct line of sight and to issue a timely alert. It is recommended that a minimum radius curve (< 500 m), corresponding to a low vehicle speed and rural road setting, be used. This scenario should be conducted under two conditions:

- SV in transition from straight to curved road encounters POV at curve entry, and
- SV in the curve encounters POV at curve exit.

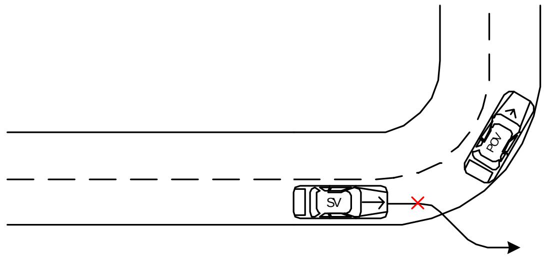

Figure 5. Lead Vehicle Stopped on Curve

The sixth test scenario will demonstrate the ability of the integrated system to discriminate between small and large targets closely following each other in the same lane ahead, and issue an alert based on proximity to the closer, small target. Figure 6 shows an SV closing on a slower motorcycle following a truck at the same speed.

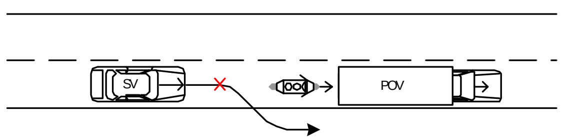

Figure 6. Slower Lead Motorcycle behind Truck

Figure 7 illustrates a slower lead vehicle cutting in ahead of the SV, testing the ability of the system to recognize a quickly emerging threat from adjacent lanes and to issue a timely FCW alert. The cut-in by the POV should be completed within the warning range of the system.

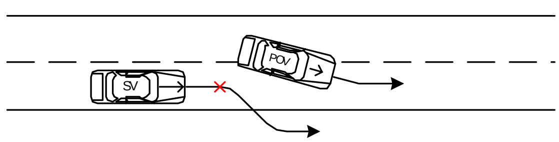

Figure 7. Slower Lead Vehicle Cut-in

The eighth scenario tests the system's ability to switch between targets in the same lane ahead, and to issue a timely FCW alert to the threatening target. Figure 8 shows one POV cutting out ahead of the SV while revealing another POV decelerating in front.

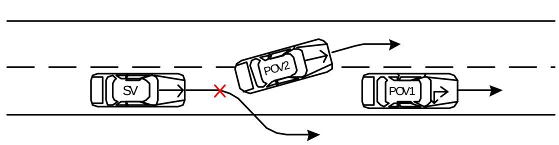

Figure 8. Lead Vehicle Cutting out Revealing another Lead Vehicle Decelerating

The final rear-end crash-imminent test scenario deals with a slower motorcycle ahead as shown in Figure 9. This test checks the ability to detect a small target and issue a timely FCW alert to prevent the host vehicle from striking the motorcycle.

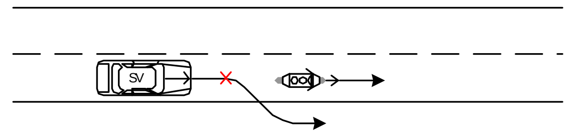

Figure 9. Slower Lead Motorcycle

Lane Change Crash-Imminent Test Scenarios

Table 5 lists five scenarios addressing the most common lane change crash-imminent threats previously described in Table 2.

Table 5. Lane Change Crash Threat Test Scenarios

No	Description
1	SV changes lanes & encounters adjacent POV on straight road
2	SV changes lanes & encounters adjacent POV on curve
3	SV changes lanes & encounters adjacent POV during merge
4	SV changes lanes & encounters adjacent POV after passing
5	SV changes lanes & encounters approaching POV

The first lane change scenario, shown in Figure 10, tests the ability to detect a vehicle in the adjacent lane, on both sides alongside the host vehicle, and to issue an LCW alert accordingly. It is recommended that lane change be performed at a lateral speed less than or equal to 0.5 m/s. This test should be conducted under two conditions:

- POV in the blind spot to the right of the SV; POV front bumper behind SV driver position
- POV in forward position to the left of the SV; POV rear bumper ahead of SV driver position.

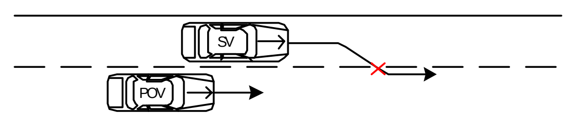

Figure 10. Lane Change on Straight Road

Figure 11 illustrates the second test scenario where the SV changes lanes to the left adjacent lane on a curve. The POV is in the blind spot of the SV. This test emulates a turning maneuver. A large radius curve is recommended for this test.

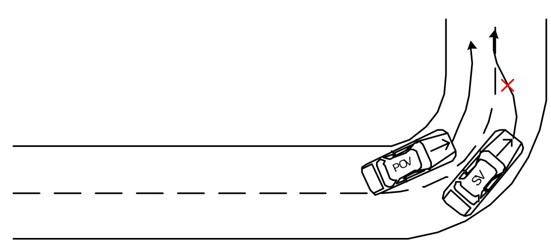

Figure 11. Lane Change on Curve

The third lane change test scenario depicts a merging scenario by the SV, as shown in Figure 12. This scenario tests whether a side collision threat during a merge maneuver where the lane markers disappear can be detected by the system. The SV may use the turn signal to indicate an intentional lane change.

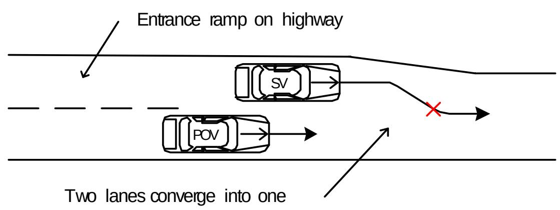

Figure 12. Lane Change/Merging

Figure 13 illustrates a passing maneuver with a side collision threat. The lane change maneuver should be performed with a lateral speed greater than 0.5 m/s and less than or equal to 0.8 m/s.

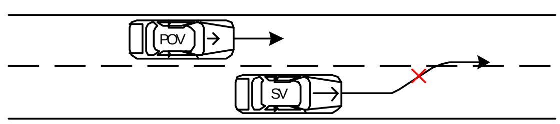

Figure 13. Lane Change after Passing

The fifth lane change test scenario given in Figure 14 deals with a POV moving at a speed faster than the SV in the adjacent lane. The SV initiates a lane change toward the POV at a low lateral speed (≤ 0.5 m/s), where the POV is inside a proximity zone extending 9 m back from the rear of the SV [4].

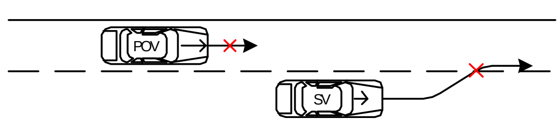

Figure 14. Lane Change onto Approaching Car

Run-Off-Road Test Scenarios

Table 6 lists five scenarios to test the system's ability to recognize the most common run-off-road pre-crash scenarios identified in Table 3. The first four scenarios address the LDW function for both light vehicles and heavy trucks. The fifth test scenario focuses on the CSW function for light vehicles only.

Table 6. Run-Off-Road Threat Test Scenarios

No	Description
1	SV departs road toward opposing traffic lane
2	SV departs straight road onto clear shoulder
3	SV departs curve onto clear shoulder below excessive speed
4	SV departs road (no lane marker) toward Jersey barrier
5	SV approaches curve at excessive speed

Figure 15 illustrates a run-off-road test scenario where the LDW function must recognize a crossing of the double solid line boundary into opposing traffic lanes. Crash statistics show that light vehicles and heavy trucks depart the left edge of the road respectively in 31 and 21 percent of road edge departure crashes on straight roads. This test should be conducted twice with two different lateral speeds:

- Low lateral speed below 0.5 m/s, and
- High lateral speed between 0.5 and 0.8 m/s.

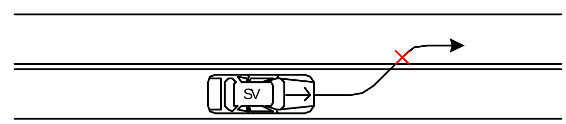

Figure 15. Lane Departure toward Opposing Traffic Lane

The second run-off-road test scenario addresses lane departure on to the shoulder of the right side of the road as shown in Figure 16. This test should be performed twice, with low and high lateral speeds as indicated above.

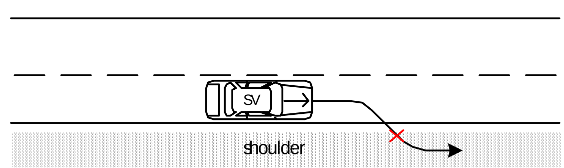

Figure 16. Right Road Edge Departure

Figure 17 depicts a road edge departure scenario on a curve to test the ability of the system to recognize curved roadways and issue timely LDW alerts. This test should implement a low lateral speed departure below 0.5 m/s. Moreover, this test should be performed for the following set of conditions:

- Small radius curve and low travel speed, and
- Large radius curve and high travel speed.

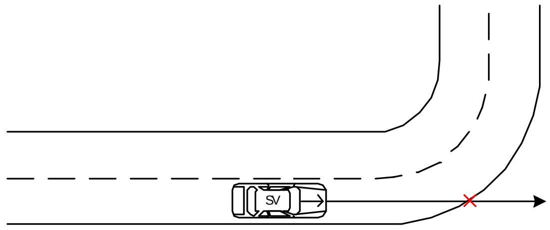

Figure 17. Road Edge Departure on Curve

Figure 18 illustrates the SV departing the left edge of a straight road bounded by a Jersey barrier instead of lane markings. This scenario tests whether the integrated system would produce a side collision warning even if lane tracking were unavailable.

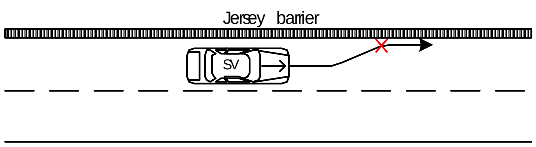

Figure 18. Road Departure toward Jersey Barrier

The last run-off-road test scenario, shown in Figure 19, addresses the performance of the CSW function. The SV approaches the curve at a speed that is unsafe to negotiate the curve. This test should be performed twice under two different environmental conditions:

- Warm temperature (simulated) and dry (wiper off) conditions, and
- Cold temperature (simulated) and wet (wiper on) conditions.

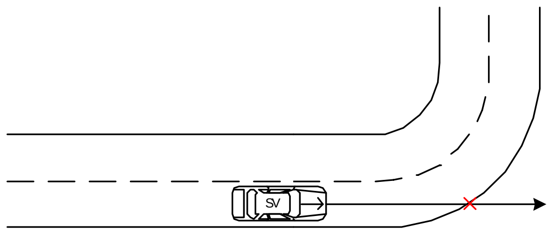

Figure 19. Approaching Curve at Excessive Speed

Multiple-Threat Test Scenarios

In this section, a set of crash-imminent scenarios to evaluate the ability of an integrated system to recognize and issue crash alerts in near-simultaneous threat events is proposed. The main purpose of these tests is to assess the integrated system's ability to recognize, prioritize and manage warnings when multiple collision threats exist.

There are very few police-reported crashes in the GES that involve one vehicle taking a prior evasive maneuver to prevent a crash and then being involved in another crash. In these cases, the GES does not identify the critical event associated with the prior evasive maneuver. Thus, the following three multiple-threat test scenarios were developed by combining selected crash-imminent test scenarios presented above for rear-end, lane change, and run-off-road crashes:

1. Rear-end and lane change crash-imminent threats
2. Rear-end, lane change, and run-off-road crash-imminent threats
3. Rear-end and run-off-road crash-imminent threats

Figure 20 illustrates the first multiple-threat test scenario. The SV is moving at a constant speed and encounters a stopped lead vehicle (POV1) ahead. The SV then attempts to change lanes to the right adjacent lane occupied by another vehicle (POV2). For safety reasons, the figure shows POV2 steering clear to avoid a collision. The integrated system should provide time for the driver to slow and avoid the rear-end collision and be made aware of an impending side collision.

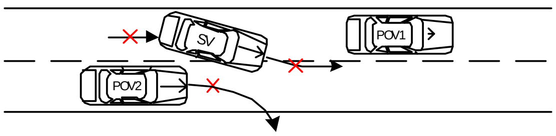

Figure 20. Rear-End and Lane Change Threats

The second multiple-threat test scenario, depicted in Figure 21, reverses the order of threats and includes a third threat. The SV driver encounters a vehicle (POV2) in an adjacent lane during a lane change maneuver. After receiving an LCW alert, the SV driver steers back into the initial lane and encounters a lead vehicle (POV1) decelerating ahead. After an FCW alert, the SV driver departs the right edge of the road onto a clear shoulder to avoid hitting POV1. Again, the warning system should provide time for the driver to slow down prior to the rear-end collision and to make the driver aware of an impending side collision.

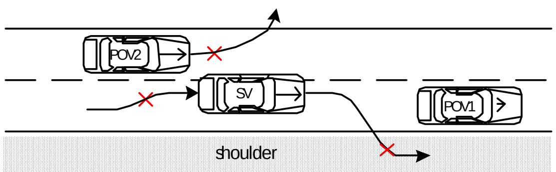

Figure 21. Lane Change, Rear-End and Run-Off-Road Threats

As shown in Figure 22, the third multiple-threat test scenario exposes the SV to a stopped POV in the same lane ahead. After an FCW alert, the SV driver departs the right edge of the road onto a clear shoulder and then stops.

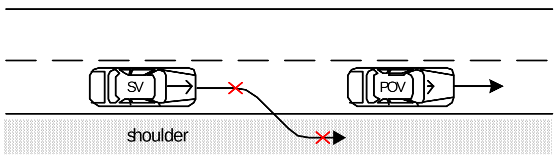

Figure 22. Rear-End and Run-Off-Road Threats

EVALUATION OF CRASH ALERT TIMING

Once a candidate set of test scenarios has been identified, they should be validated on a test track. Test procedure validation includes demonstrating that it is possible to perform the test in a safe and efficient manner, and that the data and information needed to assess system performance can be collected and produce repeatable results.

Crash-imminent alert timing is evaluated using quantitative metrics and data collected from a measurement system that is independent of the crash warning system under test. The quantitative metrics are based on kinematic equations for each scenario and expected driver response [6].

INDEPENDENT MEASUREMENT SYSTEM

The IVBSS program will use an independent measurement system (IMS) developed by the National Institute of Standards and Technology (NIST).

System Requirements

The main purpose of the IMS is to collect data needed to verify that the warning system issues proper alerts and to evaluate the alert timing for each crash-imminent test scenario. The IMS should be able to:

1. *Operate on closed-course test tracks and public road environments*: Certain IMS implementations may provide increased accuracy in test track conditions, for example, equipping every vehicle with differential global positioning system (GPS). However, equipping all vehicles during on-road tests is not feasible.
2. *Operate for light vehicle and heavy truck tests*: Heavy trucks with trailers present particular challenges during lane change or merge tests with fast approaching vehicles.
3. *Not affect warning system operation or performance*: The vehicle-mounted IMS must not interfere with warning system sensors by occluding their field of view or affect warning system operation if electrical connection to the vehicle's power or warning system data busses is required.
4. *Achieve accuracy greater than the warning system under test*: Prior work [2] suggests that test instrumentation errors should be no greater than a maximum of 2 m or 5 percent of the range being measured (95 percent confidence). Characterization tests to verify IMS accuracy are discussed below.

System Description

The independent measurement system under development for the IVBSS program is based on an earlier design that was used to assess the performance of a roadway departure collision warning system [7]. The earlier system included calibrated cameras to measure range to adjacent objects and to the road edge at distances up to 4 m [7]. The IMS is being extended to measure range and range-rate to longer-range objects, either in front of the vehicle or to the rear of the vehicle in the adjacent lane. The minimum requirements for the range measurement system include (desirable capability in parentheses):

- Range out to 60 m (100 m)
- Field of view (FOV) of 180 degrees (360 degrees) horizontal with 0.5 degrees (0.25 degrees) resolution, and
- 10 Hz (30 Hz) update rate.

Figure 23 shows a dual-head, laser-range scanner system that meets these requirements.

Figure 23. Test-bed Vehicle with Dual-head Laser-range Scanner

Measurement System Validation

Before the IMS can serve as a reference for judging warning system performance, its accuracy must be characterized and results documented. System validation of the laser scanner includes static and dynamic characterization tests aimed at obtaining quantitative measures of range error, range resolution, angular resolution and maximum range.

Static tests evaluate system performance from a stationary position and determine the “best case” system error and uncertainty. Table 7 summarizes the factors considered in the static tests.

Table 7. Static Test Variables

Variable Factor	Value Tested
Range to Target	1 m, 20 m, 40 m, 60 m, 72 m
Target Reflectance	99 % R, 50 % R, 2 % R
Target Angle of Incidence	0°, 30°, 60°
Field of Regard	-60°, 0°, 60° Sensor Azimuth

Static tests rely on repeated measurements under the same conditions. The test involves placing a target at a known range and measuring the error (difference between reference range and the mean value of measurements) and the uncertainty (standard deviation of measurements). Table 8 summarizes the laser scanner static test results.

Table 8. Static Test Results for IMS laser scanner

Variable	Value
Observed Field of Regard	184°
Range Error (1)	0.1 m - 0.01(r) ±
Range Resolution (2)	25 cm
Angular Error (3)	± 0.5°
Maximum Range for a 50% Target (4)	72 m
Maximum Range for a 2% Target (4) (5)	60 m < r < 72 m

Notes: (1) r = measured range; (2) over full range - 3σ; (3) estimate from rotation testing (4) 0.6 m x 0.6 m planar target; (5) 2 % target visible at 60 m but not at 72 m.

The static test results are used for calibrating the laser-scanner and provide a baseline for range accuracy.

Static tests do not characterize all sources of potential errors. Dynamic tests from a moving platform reveal timing and synchronization errors, which produce errors in range that are a function of vehicle speed. Since it is difficult to take consecutive measurements to a target from a known range while the vehicle is moving, target range measurements are combined from repeated trips around a surveyed course. This test requires a time measurement system (TMS) to capture the precise time the vehicle crosses over a surveyed point on the track [8].

Reflective strips at longitudinal distances of 0, 20, 40, and 60 meters from a cylindrical target serve as known reference ranges (see Figure 24). An emitter-detector switch mounted on the test vehicle’s bumper causes the TMS to time stamp when the vehicle crosses a reflector. GPS Universal Time Code time is chosen, since all IMS data use GPS as a time reference. Test data is gathered from at least 10 runs past the target. A complete characterization includes running the vehicle at speeds of 30 m/s (67 mi/h) and 10 m/s (22 mi/h).

As a final step in the validation process, the IMS is installed on each of the vehicle platforms and calibrated. Data collected using the IMS is compared with warning system data to ensure consistency. This step, combined with the results from the static and dynamic characterization tests will be used to demonstrate that the IMS data collected during crash-alert scenarios are accurate and reliable.

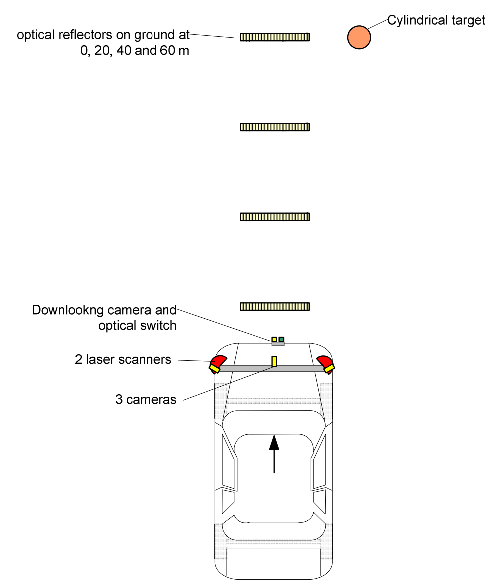

Figure 24. Dynamic Test Configuration

CONCLUSIONS

This paper introduces the IVBSS program and describes the set of test scenarios that will be used to verify that the IVBSS crash warning system meets its performance requirements and is safe for use by drivers prior to the start of planned field operational tests. The test scenarios are based on the most frequently occurring crash types represented in National crash databases.

The test scenarios identified will guide development of detailed test procedures that will include:

- Test track requirements,
- Initial kinematic conditions,
- Instructions for conducting each test,
- Expected system response,
- Test instrumentation and roadside props,
- Data to be collected,

- Analysis techniques, and
- Pass-fail criteria.

Activities are currently underway to develop the test procedures, characterize the independent measurement system, and select suitable test sites to accommodate both test platforms. Validation of the test procedures and the IMS will take place in the spring and summer months of 2007, with the final verification tests scheduled for September and October of 2007.

REFERENCES

1. J. Ference, "The Integrated Vehicle-Based Safety Systems Initiative". ITS World Congress, London, United Kingdom, October 2006.
2. R. Kiefer, D. LeBlanc, M. Palmer, J. Salinger, R. Deering, and M. Shulman, "Development and Validation of Functional Definitions and Evaluation Procedures for Collision Warning/ Avoidance Systems". National Highway Traffic Safety Administration, DOT HS 808 964, August 1999.
3. W.G. Najm and J.D. Smith, "Development of Crash Imminent Test Scenarios for Integrated Vehicle-Based Safety Systems". National Highway Traffic Safety Administration, December 2006.
4. S. Talmadge, R. Chu, C. Eberhard, K. Jordan, and P. Moffa, "Development of Performance Specifications for Collision Avoidance Systems for Lane Change Crashes". National Highway Traffic Safety Administration, DOT HS 809 414, August 2001.
5. S. Szabo and R. Norcross, "Recommendations for Objective Test Procedures for Road Departure Crash Warning Systems". National Institute of Standards and Technology Internal Report 7288, January 30, 2006.
6. S. Szabo, B. Wilson, "Application of a Crash Prevention Boundary Metric to a Road Departure Warning System". Proceedings of the Performance Metrics for Intelligent Systems (PerMIS) Workshop, National Institute of Standards and Technology, Gaithersburg, MD, August 24-26, 2004. http://www.isd.mel.nist.gov/documents/szabo/PerMIS04.pdf
7. S. Szabo and R. Norcross, "An Independent Measurement System for Performance Evaluation of Road Departure Crash Warning Systems". National Institute of Standards and Technology Internal Report 7287, January 3, 2006.
8. H. Scott and S. Szabo, "Evaluating the Performance of a Vehicle Pose Measurement System". Proceedings of the Performance Metrics for Intelligent Systems (PerMIS) Workshop, National Institute of Standards and Technology, Gaithersburg, MD, August 13-15, 2002. http://www.isd.mel.nist.gov/documents/scott/PerMIS_2002.pdf