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Integrated Vehicle-Based Safety Systems (IVBSS)

Field Operational Test Plan

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16. Abstract

This document presents the plan for conducting a field operational test (FOT) of the Integrated Vehicle-Based Safety Systems (IVBSS) program. The plan describes the work that will be performed by the University of Michigan Transportation Research Institute using 16 passenger cars and 10 commercial trucks equipped with an integrated crash avoidance system.

The goal of the IVBSS program is to conduct a field test to collect data to objectively assess the potential safety benefits and driver acceptance associated with prototype integrated crash warning systems. Both platforms have three integrated crash-warning subsystem systems (forward crash, lateral drift, and lane-change/merge warnings); the light-vehicle platform also has a fourth subsystem, curve-speed warning.

For the light-vehicle portion of the FOT, 108 lay drivers will operate test vehicles in place of their own personal cars for a period of six weeks. Forty commercial-truck drivers from a commercial fleet will operate heavy trucks in place of the Class 8 tractors they normally use as their work vehicles for a period of five months.

All vehicles will be instrumented to capture information regarding the driving environment, driver activity, system behavior, and vehicle kinematics. Driver information will be captured through a series of subjective questionnaires, focus groups, and debriefing sessions to determine driver acceptance and to gain insight for improving future versions of integrated crash warning systems.

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List of Acronyms

ACAS	Automotive Collision Avoidance System
ABS	Antilock Braking System
CAN	Controller Area Network
CDL	Commercial Drivers License
CSW	Curve Speed Warning
CWS	Crash Warning System
DAS	Data Acquisition System
DBQ	Driver Behavior Questionnaire
DSQ	Driver Style Questionnaire
DIU	Driver Interface Unit
DVI	Driver-Vehicle Interface
FAD	Light-Vehicle Module for FCW, Arbitration, and DVI
FCW	Forward Collision Warning
FOT	Field Operational Test
GUI	Graphical User Interface
HPMS	Highway Performance Monitoring System
HT	Heavy Truck
ISO	International Organization for Standardization
IVBSS	Integrated Vehicle-Based Safety Systems
LAM	Look-Ahead Module
LCM	Lane Change-Merge warning
LDW	Lateral Drift Warning
LV	Light Vehicle
NHTSA	National Highway Traffic Safety Administration
NPTS	National Personal Transportation Survey
RDCW	Road Departure Crash Warning
SHRP 2	Strategic Highway Research Program 2
TCP/IP	Transmission Control Protocol/Internet Protocol
TLX	Task Load Index
TTC	Time to Collision
U.S. DOT	United States Department of Transportation
UM	University of Michigan
UMTRI	University of Michigan Transportation Research Institute
VOC	Voice of the Customer
VORAD	Vehicle Onboard RADar

1 Executive Summary

1.1 Overview

This document presents a plan for conducting a field operational test of the Integrated Vehicle-Based Safety Systems (IVBSS) program. The plan covers the work that will be performed by the University of Michigan Transportation Research Institute (UMTRI) using 16 passenger cars and 10 commercial trucks equipped with an integrated crash avoidance system.

This plan and its further development are collaborative and iterative processes that will engage the independent evaluators and the U.S. Department of Transportation (DOT). While the field test itself is to be discharged largely by UMTRI, the process of doing so must also satisfy the needs of the independent evaluators.

1.2 The IVBSS Program

The goal of the IVBSS program is to conduct a field test to collect data to objectively assess the potential safety benefits and driver acceptance associated with prototype integrated crash warning systems. The systems to be tested were developed and implemented by Visteon and Takata on the light-vehicle platform, and developed and implemented by Eaton and Takata on the heavy-truck platform. Both platforms have the following integrated crash warning functions:

- Forward crash warning (FCW), which warns drivers of the potential for a rear-end crash with another vehicle;
- Lateral drift warning (LDW), which warns drivers that they may be drifting inadvertently from their lane or departing the roadway; and
- Lane-change/merge warning (LCM), which warns drivers of possible unsafe lateral maneuvers based on adjacent or approaching vehicles in adjacent lanes, and includes full-time side object presence indicators.

In addition, the light-vehicle platform also includes the curve-speed warning (CSW), which warns drivers that they are driving too fast into an upcoming curve and, as a result, might depart the roadway.

For the light-vehicle portion of the FOT, lay drivers will be recruited and will receive equipped research vehicles to drive in place of their own personal cars for a period of six weeks. Commercial-truck drivers from a commercial fleet will operate equipped heavy trucks in place of the Class 8 tractors they normally drive for work. In both instances, a comprehensive set of objective and subjective data will be collected and used to evaluate the system effectiveness and driver acceptance of the integrated system.

Vehicles will be instrumented to capture information regarding the driving environment, driver activity, integrated system behavior, and vehicle kinematics. Driver information will be captured through a series of subjective questionnaires, focus groups, and debriefing sessions, to gather information regarding driver acceptance of the system and to gain insight into improving future versions of the integrated crash warning system.

1.3 Extended Pilot Testing

The conduct of extended pilot testing was an original requirement of the IVBSS program. Extended pilot testing uses a small number of participants to obtain early feedback on driver acceptance and to ensure the integrated system operate as planned. With few exceptions, the extended pilot FOTs will be conducted almost identically to the full FOTs, but with shorter durations and without baseline periods. Table 1 provides an overview of the scope planned for extended pilot testing. The plan is that participants in the extended pilot tests would receive the same types of training, monitoring, and post-drive interaction that FOT participants would receive, although the extended pilot test would also examine these testing procedures, revising as necessary.

Table 1. Variations in the extended pilot FOTs by platform

Light Vehicle	**Heavy Truck**
• 12 participants • 4 research vehicles • 19-day exposures	• 8 drivers • 1 research tractor • 1-month exposure in fleet

1.4 Field Operational Test

There are several considerations that influence the FOT experimental design, in particular the required number of participants to achieve statistically reliable results (sample size) and the capacity of data storage in the onboard data acquisition system (DAS). Experimental designs for both light-vehicle and heavy-truck platforms are proposed for consideration with modifications to be made on the basis of further discussion among UMTRI, U.S. DOT, and the independent evaluator. Table 2 provides an overview of the scope planned for the FOT.

Table 2. Variations in the FOT experimental design by platform

Light Vehicle	**Heavy Truck**
• 108 participants • 16 research vehicles • 40-day exposure/driver: - 12-day baseline period - 28-day treatment period	• 20 participants • 10 research tractors • 2 shifts (daytime and nighttime) • 10-month exposure/driver: - 2-month baseline - 8-month treatment period

1.5 FOT Data Collection and Analyses

A significant body of objective data describing vehicle and warning system performance will result from the conduct of the FOT, and this data will be critical to assessing any safety benefits attributable to the crash avoidance system. Additional data that will be essential are the subjective assessments provided by the participants that use the system in order to assess driver acceptance.

This report provides an overview of the analysis that is planned by UMTRI using the FOT data. When appropriate, special methods of analysis are described when they may affect the success of addressing the study questions. Otherwise, UMTRI will rely on numerous analytical approaches that it has previously developed or used in the evaluation of FOT data.

Generally speaking, the proposed analyses can be described as falling into one of four major study areas: exposure analyses; warning system performance analyses; safety-related observations; and driver perceptions and acceptance of the integrated system. In addition to these study areas, data from the FOT can be expected to provoke questions and observations that were unexpected during the planning stage. These discoveries may be significant enough to influence the tactics used to address the main study questions.

While UMTRI will perform various analyses of the data, all data will be transferred to Volpe on a regular basis. Ultimately it will be the independent evaluator that provides the final assessment of the system's acceptance and benefits.

1.6 Summary

The FOT plan summarizes all field-testing activity anticipated on the IVBSS program for Phase II. It is, however, subject to revision as UMTRI views this as a collaborative and iterative process that will engage the independent evaluators and U.S. DOT. Nonetheless, on the basis of previous FOTs that UMTRI has successfully conducted, what is outlined in this document serves as a solid basis on which to further our discussions with U.S. DOT and as a guide for the later stages of Phase II of the IVBSS program.

2 Introduction

This document constitutes the field operational test plan for conducting a field evaluation of the collision avoidance system developed under the IVBSS program. The plan covers the work that will be discharged primarily by UMTRI using a 26-vehicle fleet (16 passenger cars and 10 commercial trucks) equipped with the integrated safety system. The FOT will yield a set of data that will be provided to the program's independent evaluator, the Volpe National Transportation Systems Center. The goal of the FOT is to evaluate the integrated safety system in terms of its effectiveness in helping to reduce crashes and to gauge driver acceptance of the system. It is recognized that the Volpe team has developed its own evaluation plan, outlining its intent to analyze the data that are identified for collection here. Volpe's data needs have been integrated with those of the UMTRI-led partners in determining elements of this FOT plan. Nevertheless, revisions to this plan are likely to take place under further collaboration with Volpe.

The UMTRI-led team sees the experimental design and development of a data collection plan as a collaborative process that has engaged the independent evaluators and U.S. DOT. The field test itself is to be conducted largely by UMTRI following procedures that are described here for managing participants, the test fleet, and the data archives. Although the data is to be transferred to Volpe on a regular basis throughout the field test, both Volpe and UMTRI intend to begin the analysis and inquiry into this data while testing in underway. The plan for UMTRI analysis of FOT data is presented in this report, as is an outline for documenting the FOT methods and results upon completion of testing.

2.1 Program Overview

The goal of the IVBSS program is to conduct a field test to collect data to objectively assess the potential safety benefits and driver acceptance associated with prototype integrated crash warning systems. The systems to be tested were developed and implemented by Visteon and Takata on the light-vehicle platform, and developed and implemented by Eaton and Takata on the heavy-truck platform. Both platforms have the following integrated crash warning functions:

- Forward crash warning, which warns drivers of the potential for a rear-end crash with another vehicle;
- Lateral drift warning, which warns drivers that they may be drifting inadvertently from their lane or departing the roadway; and
- Lane-change/merge warning, which warns drivers of possible unsafe lateral maneuvers based on adjacent or approaching vehicles in adjacent lanes, and includes full-time side object presence indicators.

In addition, the light-vehicle platform also includes the curve-speed warning, which warns drivers that they are driving too fast into an upcoming curve and, as a result, might depart the roadway.

Two sets of drivers will be recruited, one for the light-vehicle platform and one for heavy trucks; each will receive an equipped research vehicle to drive. Lay drivers will be recruited to drive the light vehicles in place of their own personal cars. Commercial truck drivers from a commercial fleet (Con-way Freight, Inc.) will be recruited to drive vehicles on the heavy-truck platform in place of the Class 8 tractors they normally drive on the job. In both instances, a comprehensive set of objective and subjective data will be collected and used to evaluate system effectiveness and driver acceptance. The vehicles will be instrumented to capture information regarding the driving environment, driver activity, integrated warning system behavior, and vehicle kinematics. Driver information and acceptance of the warning system are captured through a series of subjective questionnaires, focus groups, and debriefing sessions to gather information regarding driver acceptance and to gain insight for improving future versions of the system.

An FOT differs from most designed experiments by the extent of its naturalism, or lack of control over the majority of test conditions. Participants will drive the equipped vehicles in place of their personal cars or work vehicles, going wherever, whenever, and however they choose. The driving is thereby largely unmanaged by the research team and derives, instead, from either the personal mobility needs of the individual participants (in the case of the light-vehicle platform), or the commercial delivery needs of the truck fleet taking part in the FOT. Thus, experimental control lies only in the commonality of the test vehicles that are driven, the sampling plan through which drivers are selected, and the types of data obtained for documenting the experience. Yet, even these controls are not common between the light-vehicle and heavy-truck platforms.

2.2 Main Study Areas to Be Addressed

Data from the FOT can be used as the basis for answering many questions concerning the warning system and how drivers used it. The FOT analysis will address three broad study areas:

- Driver acceptance and driver understanding of the crash warning system;
- Driving performance and driver behavior with and without the system, including safety-related findings; and
- Potential successes and challenges of integrated crash warning products, when deployed.

2.2.1 Driver Acceptance of the Warning System

Driver acceptance of the warning system will be examined using analyses of subjective responses in conjunction with observed use of, interaction with, and response to the system. Acceptance by drivers is one of the fundamental questions to be addressed by the FOT. While integrated crash warning systems may be technically feasible and sound, the general premise that such systems will be widely accepted by drivers remains unclear. This FOT will examine driver acceptance of integrated crash warning systems having functionalities similar to those of the fielded system.

Some key attributes on which the system will be assessed include driver comfort, utility, and convenience. Overall, driver acceptance of the warning system will be performed using analyses of subjective responses in conjunction with observed system use, system adjustment by the driver, and driver response to the presentation of system warnings. The key attributes on which the driver acceptance of the system will be assessed include, but are not limited to:

- **Comfort**: Assessment primarily of the system’s ability to convey the necessary warnings in a clear, logical, and timely manner;
- **Convenience**: The relative ease of learning and using the system; and

- **Utility**: The range of driving conditions in which the system is perceived to provide benefit and the relative worth of such benefit, including perceived safety value and willingness to purchase.

The primary method for assessing driver acceptance will be through questionnaires. However, driver acceptance will also be assessed through direct interaction between researchers and participants in post-drive debriefings and focus groups held after exposure to the system.

Important secondary sources of data for examining driver acceptance and understanding of the system include data collected onboard the vehicle. Onboard measurements will describe what drivers were exposed to, in terms of their driving behavior, route choices, and the resulting system feedback. Because system performance is strongly dependent on driving behavior and the conditions of the driving environment, the following subjective and objective data are needed to understand driver acceptance as it relates to specific driving conditions:

- Changes in driver performance relating directly to warning modalities including the frequency of significant lane exceedance, coming into close proximity to other vehicles while performing lane changes or merges, and coming into close proximity to the rear of other, slower-moving vehicles ahead; and
- Overall driving patterns that may be relevant to the potential for the warning system, such as the general distribution of lane-keeping performance, speed decrements and deceleration peaks, turn signal use, and other observed lateral-control and forward conflicts.

2.2.2 Effects on Driver Performance and Behavior

The FOT data will be used to study changes in driving performance, both during scenarios relevant to safety (e.g., lane exceedance events) and in longer-term driving performance metrics (e.g., statistics of lane position deviation). Driver behavior may also be influenced by the presence of the warning system. This may be manifested in low-level driver actions such as turn signal usage or the spectral distribution of steering wheel behavior (related to driver attention). Behavioral changes may also appear in higher-level activities such as the use of cell phones while driving.

Once drivers accept integrated warning systems, it is important to understand how such systems might influence their general driving performance, and other behaviors that may affect highway safety. Driving performance includes measures of vehicle motion relative to the roadway and other traffic. Driving behavior encompasses other driving-related decisions, such as choices of route, engagement in secondary activities (e.g., cell phone usage), and use of turn signals. Elements of the questionnaire will be posed to identify and quantify the effect of the warning system on driver performance and behavior.

2.3 Goals and Objectives of Extended Pilot Testing

In general, the goals and objectives associated with extended pilot testing are to ensure that the warning system is technologically sound and that the protocols being planned for the FOT are well thought out and effective. Data from the extended pilot testing will not be used in the more general assessment of driver acceptance or use of the warning system. Instead, the extended pilot tests are an opportunity to perform a “full dress rehearsal” of the FOT, and still have the opportunity to make minor adjustments prior to conducting the FOT. In this manner, the likelihood of encountering unanticipated events that may otherwise have occurred by proceeding directly into an FOT can be significantly reduced.

The entire integrated warning system, including the data acquisition system, will be evaluated in pilot testing to ensure that the systems are behaving in accordance with the functional requirements and that the data can be reliably retrieved. Each platform will have its own pilot test where a small number of drivers will be recruited and instructed on using the system. The drivers will then be provided equipped vehicles for shorter durations (approximately half as long as the FOT) in order to experience the system, but also to expose the research vehicle as a whole to conditions that are representative to those that are expected in the actual FOT.

Driver acceptance may play a role in the outcome of extended pilot testing to the extent that drivers may or may not approve of the system's performance. In the event that performance is not judged to be adequate by pilot test participants, changes would have to be carefully considered and revisions made only as necessary. The recruitment and instruction segments of the protocols will also be closely examined in conducting the extended pilot tests. Feedback from participants will be key in making any decisions on whether modifications to the protocol are required.

2.4 Goals and Objectives of the FOT

The primary goal of the IVBSS program is to assess the potential safety benefits and driver acceptance associated with prototype integrated crash warning systems. The prototype crash warning systems developed during Phase I will be evaluated during a field operational test to determine whether it: 1) is easy to use and understand by the average driver; 2) will yield measurable safety benefits; and 3) will not pose any additional risk by overwhelming, confusing, or distracting drivers.

To reach the goals of the FOT, it is necessary to obtain the users' appraisal of the system and to make an objective assessment of how it impacts the driving process. The unstructured character of naturalistic driving requires an investigative approach in making the objective assessment, and the extensive data set will need to be mined through creative inquiry modeled after similar previous UMTRI efforts.

2.4.1 Light-Vehicle FOT Goals and Objectives

Goals and objectives specific to the light-vehicle platform include ensuring that the system functions as intended on the Honda Accord, and that lay drivers find it acceptable in terms of its performance and ease of use. Because participants in the light-vehicle FOT will represent a random sample of licensed drivers with a wide range of driving experience and skills, the ability of the system to satisfy driver expectations may be challenging. Nonetheless, it is essential that as wide a range of driver characteristics as possible be examined in order to assess overall system benefit and driver acceptance.

Particular elements of the data that will be closely examined to determine their relationship with system acceptance and benefit will include driver age and gender, driving style, road class, weather, propensity to engage in secondary tasks (e.g., using a cellular telephone), exposure to the system (both in terms of miles driven and time), the frequency of warnings, and the types of warnings received by drivers. Examination and analyses of these elements and the associated data will help to better characterize those aspects of the system that are either acceptable or unacceptable to drivers, and those circumstances under which it provides safety benefits.

2.4.2 Heavy-Truck FOT Goals and Objectives

Goals and objectives specific to the heavy-truck platform include ensuring that the warning system functions as intended on the International ProStar 8600-series tractor, and that commercial drivers find the system acceptable in terms of its performance and ease of use. Participants in the heavy-truck portion of the FOT will represent a sample of commercial drivers operating within a freight carrier’s fleet.

Particular elements of the data that will be closely examined to determine their relationship with system acceptance and benefits will include driver age, delivery route types (long- or short-haul), road class, weather, propensity to engage in secondary tasks such as using a cell phone, exposure to the system both in terms of miles driven and time, the frequency of warnings, and the types of warnings received by drivers. Examination and analyses of these elements and the associated driving performance data will help to better characterize those aspects of the warning system that are either acceptable or unacceptable to drivers, and those circumstances under which it provides safety benefits. Feedback from the fleet operator and truck owners will also be important in determining the long-term viability of similar systems in commercial vehicles, as the fleet operators are ultimately the safety system purchasers in the majority of the commercial-truck market. Every attempt will be made to recruit participants in a manner that the data provided by the FOT represent reasonable samples based upon driver age and delivery route type.

2.5 Pilot and Field Test Schedules

Provide a high-level schedule outlining major milestones that will be addressed by the FOT for each platform.

2.5.1 Light-Vehicle Test Schedule

Figure 1 illustrates key Phase II tasks and the associated dates currently anticipated for the light-vehicle platform.

ID	Task Name	Start	Finish
69	**FOT Vehicle (Task 2.a)**	**Tue 2/19/08**	**Mon 4/13/09**
70	**Heavy-truck**	**Tue 2/19/08**	**Fri 3/6/09**
250	**Light-vehicle**	**Tue 4/1/08**	**Mon 4/13/09**
251	Procure Fleet Vehicles	Tue 4/1/08	Mon 4/28/08
252	Prototype DAS build	Tue 4/15/08	Mon 5/5/08
253	Subsystem Design	Tue 4/1/08	Fri 8/22/08
254	Calibration	Tue 4/1/08	Fri 8/22/08
255	Vehicle Integration and Safety Analysis	Tue 4/1/08	Thu 6/19/08
256	**IVBSS software revisions**	**Mon 6/2/08**	**Fri 8/22/08**
293	**Extended pilot software and hardware release (Eta)**	**Mon 6/2/08**	**Fri 8/22/08**
336	Data definitions of variables	Fri 6/13/08	Thu 8/28/08
337	Primary & secondary data signals verified (dictionary)	Wed 6/11/08	Tue 10/14/08
338	**Vehicle builds**	**Fri 6/20/08**	**Fri 1/30/09**
343	ICD Freeze	Fri 8/22/08	Fri 8/22/08
344	Eta Release	Tue 9/9/08	Tue 9/9/08
345	Calibration Signoff	Tue 9/9/08	Fri 9/26/08
346	FOT DAS in vehicle check-out	Wed 9/24/08	Mon 10/6/08
347	**Vehicle Rollout (upfit/check-out/mileage)**	**Mon 10/6/08**	**Thu 3/5/09**
352	Agreement with DOT on video rates and events	Fri 8/1/08	Tue 9/2/08
353	First FOT DAS build (DAS 2)	Thu 10/2/08	Thu 10/2/08
354	First FOT DAS builds (DAS 2 and DAS 3)	Mon 9/22/08	Fri 10/10/08
355	**DAS builds for FOT**	**Mon 10/13/08**	**Mon 4/13/09**
375	Remaining data signals verified (need new end date)	Wed 9/24/08	Wed 3/11/09
376	**Verification**	**Wed 4/9/08**	**Fri 1/16/09**
388	Subsystem Tuning based on Extended pilot data	Mon 2/16/09	Fri 2/20/09
389	Theta Release	Thu 3/5/09	Thu 3/5/09
390	Mini-verification (if required)	Fri 3/6/09	Wed 3/11/09
391	Milestone: Completed FOT vehicles	Thu 3/5/09	Thu 3/5/09
392	Milestone: Additional light vehicle for NHTSA	Wed 4/1/09	Wed 4/1/09
393	**Development of Final FOT Design Plan (Task 2.b)**	**Tue 7/1/08**	**Mon 11/17/08**
404	**Extended Pilot Test (Task 2.c)**	**Fri 7/25/08**	**Tue 3/24/09**
405	**Heavy-truck**	**Fri 7/25/08**	**Fri 1/16/09**
406	Finalize experimental design	Fri 7/25/08	Fri 7/25/08
407	Submit extended pilot test IRB application	Fri 8/1/08	Fri 8/1/08
408	Extended pilot test subject recruitment	Fri 8/29/08	Fri 10/31/08
409	**Conduct extended pilot test**	**Wed 11/12/08**	**Fri 12/12/08**
418	Weekly submission of data files	Thu 11/27/08	Wed 12/24/08
419	Data analysis	Thu 11/20/08	Tue 12/30/08
420	Deliverable: Extended Pilot FOT Results Summary Report	Fri 1/16/09	Fri 1/16/09
421	**Light-Vehicle**	**Fri 7/25/08**	**Tue 3/24/09**
441	**FOT (Task 2.e)**	**Mon 9/15/08**	**Mon 5/31/10**
442	**Heavy-truck**	**Mon 9/15/08**	**Mon 5/31/10**
449	**Light-Vehicle**	**Mon 12/1/08**	**Mon 5/31/10**
450	**Subject Recruitment**	**Mon 12/1/08**	**Mon 12/21/09**
453	Conduct FOT	Wed 4/1/09	Tue 3/30/10
454	Conduct focus groups	Wed 6/24/09	Tue 4/13/10
455	Deliverable: Monthly submissions of data files	Wed 5/27/09	Thu 5/27/10
456	Deliverable: Final FOT Program Report	Mon 5/31/10	Mon 5/31/10
457	**Data Analysis (Task 2.f)**	**Fri 10/10/08**	**Tue 7/20/10**
458	**Light-vehicle**	**Mon 11/17/08**	**Tue 7/20/10**
459	Deliverable: Data Analysis Plan Report	Mon 11/17/08	Mon 11/17/08
460	Data analysis	Fri 8/21/09	Tue 7/20/10
461	**Final Report**	**Mon 3/1/10**	**Tue 7/20/10**
462	Final Report Outline	Mon 3/1/10	Mon 3/1/10
463	Draft of Final Report	Fri 4/30/10	Fri 4/30/10
464	Deliverable: Final FOT reports: Methodology and Resu	Tue 7/20/10	Tue 7/20/10

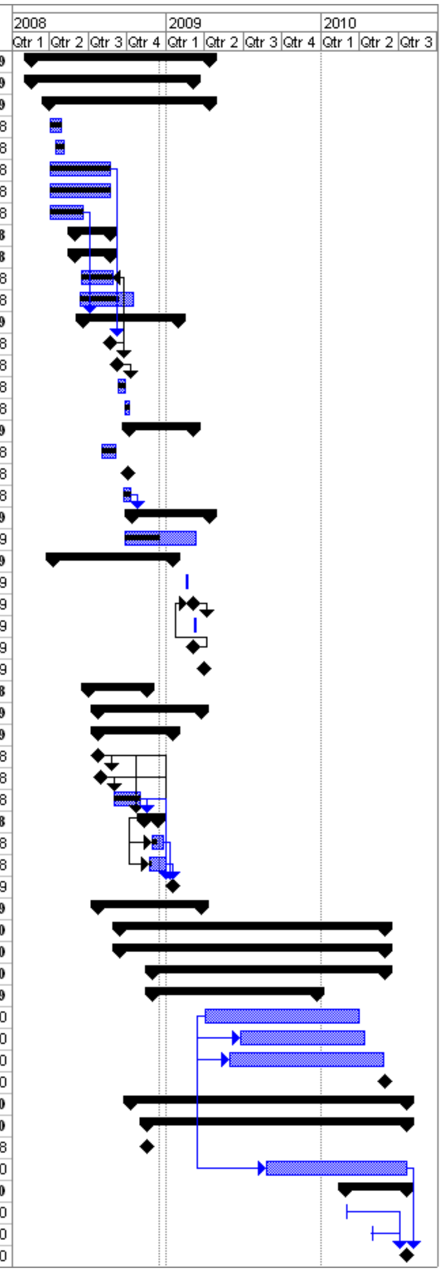


Figure 1. Light-vehicle test schedule (extended pilot and FOT)

2.5.2 Heavy-Truck Test Schedule

Figure 2 illustrates key Phase II tasks and the associated dates currently anticipated for the heavy-truck platform.

ID	Task Name	Start	Finish
69	**FOT Vehicle (Task 2.a)**	**Tue 2/19/08**	**Mon 4/13/09**
70	**Heavy-truck**	**Tue 2/19/08**	**Fri 3/6/09**
71	Prototype DAS build	Tue 4/15/08	Fri 9/5/08
72	**IVBSS software revisions**	**Tue 4/8/08**	**Thu 1/8/09**
141	**Gold integration (less DAS)**	**Tue 2/19/08**	**Fri 9/26/08**
151	**FOT vehicle build**	**Thu 5/1/08**	**Fri 3/6/09**
229	First FOT DAS build (DAS 1)	Mon 7/7/08	Fri 9/12/08
230	Data definitions of variables	Tue 7/15/08	Wed 12/31/08
231	**DAS builds for FOT**	**Fri 10/24/08**	**Fri 2/13/09**
243	**Verification testing**	**Fri 9/26/08**	**Fri 10/17/08**
248	Agreement with DOT on video rates and events	Tue 9/2/08	Tue 9/2/08
249	Remaining data signals verified	Mon 9/15/08	Thu 1/15/09
250	**Light-vehicle**	**Tue 4/1/08**	**Mon 4/13/09**
393	**Development of Final FOT Design Plan (Task 2.b)**	**Tue 7/1/08**	**Mon 11/17/08**
404	**Extended Pilot Test (Task 2.c)**	**Fri 7/25/08**	**Tue 3/24/09**
405	**Heavy-truck**	**Fri 7/25/08**	**Fri 1/16/09**
406	Finalize experimental design	Fri 7/25/08	Fri 7/25/08
407	Submit extended pilot test IRB application	Fri 8/1/08	Fri 8/1/08
408	Extended pilot test subject recruitment	Fri 8/29/08	Fri 10/31/08
409	**Conduct extended pilot test**	**Wed 11/12/08**	**Fri 12/12/08**
418	Weekly submission of data files	Thu 11/27/08	Wed 12/24/08
419	Data analysis	Thu 11/20/08	Tue 12/30/08
420	Deliverable: Extended Pilot FOT Results Summary Report	Fri 1/16/09	Fri 1/16/09
421	**Light-Vehicle**	**Fri 7/25/08**	**Tue 3/24/09**
441	**FOT (Task 2.e)**	**Mon 9/15/08**	**Mon 5/31/10**
442	**Heavy-truck**	**Mon 9/15/08**	**Mon 5/31/10**
443	**Subject Recruitment**	**Mon 9/15/08**	**Mon 12/15/08**
444	Submit FOT IRB application	Mon 9/15/08	Mon 9/15/08
445	Recruit subjects	Mon 12/1/08	Mon 12/15/08
446	Conduct FOT	Fri 1/9/09	Mon 11/9/09
447	Deliverable: Monthly submissions of data files	Fri 2/6/09	Thu 12/10/09
448	Deliverable: Final FOT Program Report	Mon 5/31/10	Mon 5/31/10
449	**Light-Vehicle**	**Mon 12/1/08**	**Mon 5/31/10**
457	**Data Analysis (Task 2.f)**	**Fri 10/10/08**	**Tue 7/20/10**
458	**Light-vehicle**	**Mon 11/17/08**	**Tue 7/20/10**
465	**Heavy-truck**	**Fri 10/10/08**	**Tue 6/1/10**
466	Deliverable: Data Analysis Plan Report	Fri 10/10/08	Fri 10/10/08
467	Data analysis	Fri 4/3/09	Tue 6/1/10
468	**Final Report**	**Mon 3/1/10**	**Tue 6/1/10**
469	Final Report Outline	Mon 3/1/10	Mon 3/1/10
470	Draft of Final Report	Fri 4/30/10	Fri 4/30/10
471	Deliverable: Final FOT reports: Methodology and Resu	Tue 6/1/10	Tue 6/1/10

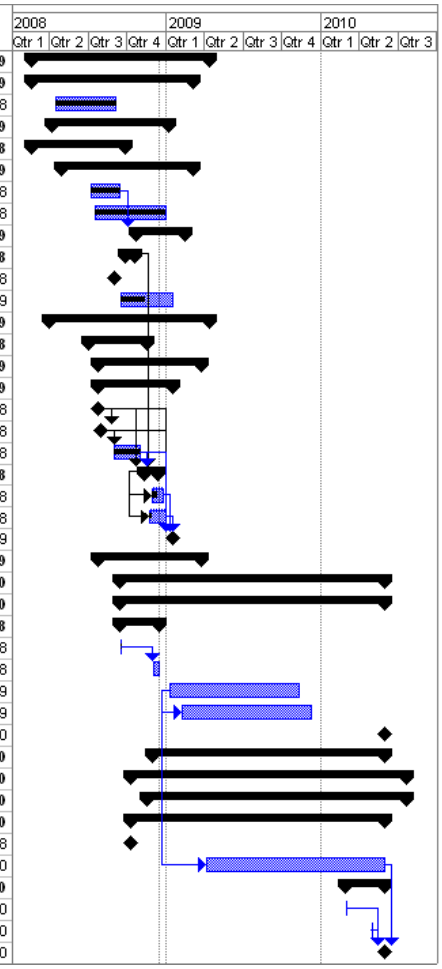


Figure 2. Heavy-truck test schedule (extended pilot and FOT)

2.6 Report Structure

The remainder of this report is organized as follows:

Section 3 describes the extended pilot test experimental design for both light-vehicle and heavy-truck platforms, including scope, participant sampling variables, participant recruitment, and schedules.

Section 4 discusses the FOT experimental design for both light-vehicle and heavy-truck platforms, including scope, participant sampling variables, participant recruitment, and schedules.

Section 5 covers objective data collection, including onboard and external data sources, and the light-vehicle and heavy-truck data acquisition systems.

Section 6 covers subjective data collections, including participant self-characterizations, post-drive questionnaires, and focus groups.

Section 7 describes management of the light-vehicle fleet, including the development plan, turnaround and release of vehicles, integrity of data, vehicle maintenance, and response to incidents in the field.

Section 8 describes management of the heavy-truck fleet, including the development plan, vehicle assignment, integrity of data, vehicle maintenance, and response to incidents in the field.

Section 9 discusses data processing, including adaptation of a previous data model to the IVBSS program, data validation, database creation, data transfer, and data analysis tools.

Section 10 describes light-vehicle data analysis of exposure data, driving environment, system performance (as a whole and as separate subsystems), and driver perception.

Section 11 describes heavy-truck data analysis of exposure data, driving environment, system performance as a whole and as separate subsystems, and driver perception.

Section 12 discusses the final reports for both light-vehicle and heavy-truck platforms.

Section 13 provides conclusions from the field operational tests.

Section 14 contains the list of references.

3 Extended Pilot Test Experimental Design

One of the original requirements of the IVBSS program is that pilot FOTs, using a small number of participants to obtain early feedback on driver acceptance and ensure that the integrated system operates as planned, must be conducted on both vehicle platforms prior to the actual FOT. With few exceptions, the pilot FOTs are conducted almost identically to the future full FOTs, but with shorter durations and without a baseline period. Table 3 provides a brief overview of the scope planned for the extended pilot testing, with greater detail provided in following sections. Participants in the extended pilot tests would receive the same types of training, monitoring, and post-drive interaction that FOT participants would receive, although the extended pilot test would also examine these procedures, revising them as necessary.

Table 3. Variations in the extended pilot FOTs by platform

Light Vehicle	**Heavy Truck**
• 12 participants • 4 research vehicles • 19-day exposures	• 8 participants • 1 research tractor • 1-week exposures

3.1 Light-Vehicle Pilot Test Experimental Design

3.1.1 Scope of Light-Vehicle Pilot Testing

For the light-vehicle platform, the extended pilot test would include the use of 4 prototype vehicles and 12 participants. The vehicles will collect virtually all of the same data that is planned for the actual FOT. Participants will receive training on the use of the safety system and the research vehicles, and then be expected to use the equipped Honda Accords in place of their own vehicles for a 19-day duration. One difference between the extended pilot test and the FOT is that there will be no baseline period of data collection in the extended pilot test. This will maximize both exposure to the system and insights from the participants regarding the safety system. Furthermore, a baseline period is not needed, as the extended pilot data will not be analyzed in the same fashion that the FOT data, nor would data from 12 participants be sufficient to draw conclusions regarding changes in driver behavior that might be associated with the system. Instead the emphasis will be on subjective impressions of the system and ensuring that the crash warning system is functioning properly.

3.1.2 Characterization of the Light-Vehicle Pilot Testing Fleet

The integrated warning system was installed in six 2006 Accord EXs during Phase I of the program for development purposes. Four of these development vehicles will be updated as necessary and used in the extended pilot test. Each vehicle contains a light-vehicle warning system having curve speed warning, forward collision warning, lane-change/merge warning, and lateral drift warning systems integrated into a safety system with a unified driver-vehicle interface.

Figure 3 provides a graphic representation of the sensor suite and zones of coverage.

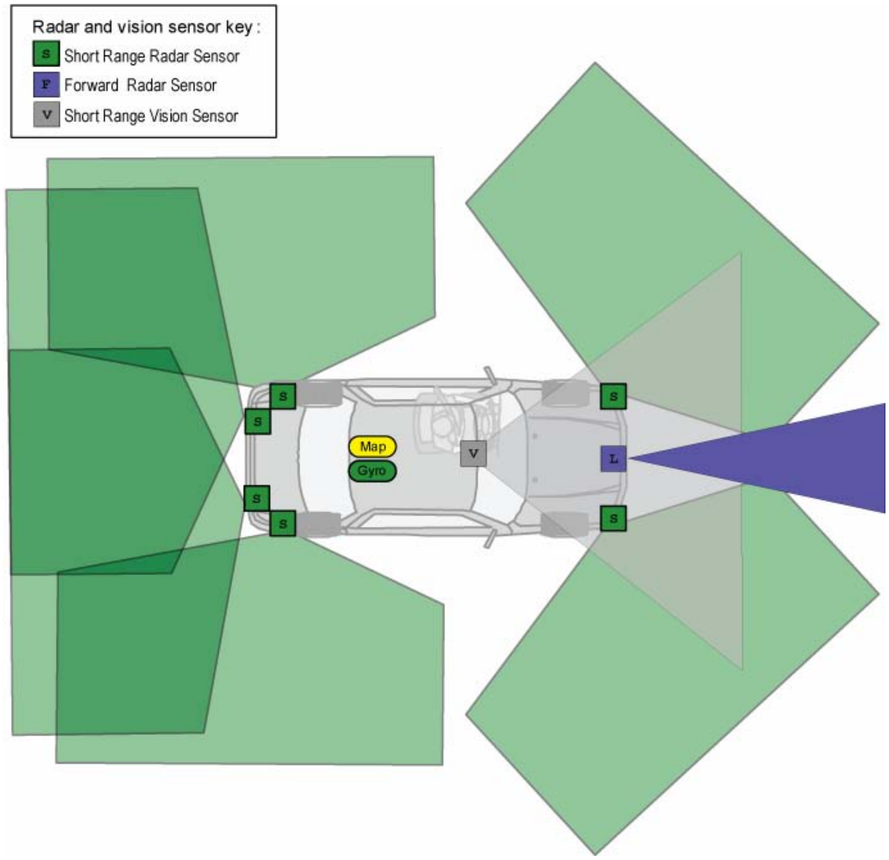


Figure 3. Light-vehicle sensor coverage overview (not to scale)

These vehicles will be modified to include the complement of sensors for monitoring driver behavior, including their participation in secondary tasks that was not implemented during system development, and as such, would be representative of vehicles ready for FOT deployment. This will include video cameras collecting images both inside and surrounding the vehicle, an in-cabin microphone, and data stored using an onboard data acquisition system designed specifically for the field operational test.

3.1.3 Light-Vehicle Participant Sampling Variables

Of the 12 participants selected for the extended pilot test, 4 will come from each of three age groups: 20 to 30, 40 to 50, and 60 to 70 years old. An equal number of male and female participants will be selected for each age group. Prospective participants having any felony motor vehicle convictions, such as driving while intoxicated or under the influence of alcohol, within 36 months of recruitment will be excluded from the extend pilot test.

3.1.4 Light-Vehicle Participant Recruitment

Participants will be recruited with the assistance of the Michigan Secretary of State (the State's driver licensing bureau). As in other FOTs UMTRI has conducted, a random sample of a few hundred driving records would be drawn from the Secretary of State's database for the population of licensed drivers from eight counties surrounding Ann Arbor (all within a 1.5-hour drive of UMTRI). These individuals will receive a postcard informing them that they qualify to participate in a study of new automotive technologies being conducted by UMTRI, and to call an 800 number if interested in learning more about participating. This sampling strategy would help ensure a wide geographical area that includes urban (where lane change conflicts are likely to be greater), suburban, and rural (where single-vehicle road departures are concentrated) driving conditions. All information obtained through State records would be treated with strict confidentiality.

3.1.5 Participant Orientation and Instruction for the Light-Vehicle Pilot Test

Participant orientation and training will begin with an introduction to the research vehicle and the warning system as provided in an instructional video developed by UMTRI. A briefing and opportunity to ask questions of a researcher will follow. The video will cover two principle areas: the location of standard controls and displays on the research vehicles, including use of the vehicle's safety equipment (air bag, seat belt, ABS, etc.), and all usability aspects of the system, including video examples of circumstances in which participants could expect to receive alerts or warnings.

Participants will also receive hands-on instruction with the research vehicle and the warning system. The experimental apparatus will be identified and their purposes explained. Participants will observe each warning or state in a static demonstration. Then, while accompanied by a researcher, each participant will experience the system in operation as a driver during an orientation run. This drive will last about 30 minutes and will take place on local roadways in normal traffic. The researcher who provides the orientation will thereafter be the primary point of contact for the participant should any questions or concerns arise.

Once participants complete the orientation and are comfortable with their understanding of the research vehicle, they will be free to leave with the vehicle, at which time a date and time to return the vehicle will be scheduled. The glove compartment of each vehicle will include the following informational material: the scheduled vehicle return date, a copy of the instructional videotape on VHS and DVD (as well a manual outlining all the material included in the video for persons without access to DVD or videotape players), a road map of Michigan, a log book in which to make comments, emergency contact information, a copy of the informed-consent form, and proof of insurance.

3.1.6 Light-Vehicle Schedule

Figure 4 shows the major milestones for the light-vehicle extended pilot test.

ID	Task Name	Start	Finish
404	**Extended Pilot Test (Task 2.c)**	**Fri 7/25/08**	**Tue 3/24/09**
405	**Heavy-truck**	**Fri 7/25/08**	**Fri 1/16/09**
421	**Light-Vehicle**	**Fri 7/25/08**	**Tue 3/24/09**
422	Finalize experimental design	Fri 7/25/08	Fri 7/25/08
423	Submit extended pilot test IRB application	Fri 8/1/08	Fri 8/1/08
424	Extended pilot test subject recruitment	Mon 11/10/08	Fri 11/21/08
425	**Conduct extended pilot test**	**Tue 11/25/08**	**Tue 3/3/09**
438	Monthly submission of data files	Mon 1/5/09	Mon 3/2/09
439	Data analysis	Mon 1/5/09	Wed 3/4/09
440	Deliverable: Extended Pilot FOT Results Summary Report	Tue 3/24/09	Tue 3/24/09

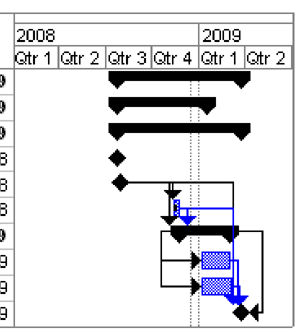


Figure 4. Light-vehicle extended pilot test schedule

3.2 Heavy-Truck Pilot Test Experimental Design

3.2.1 Scope of Heavy-Truck Pilot Testing

The extended pilot test would be run using a terminal and drivers who are part of the larger Con-way fleet, but not the same terminal or drivers who would be selected for the FOT. At least six drivers would participate in the extended pilot test. The terminal of choice is the Ann Arbor-Whitmore Lake terminal in part given its proximity to UMTRI in the event that troubleshooting of the unit is necessary and in part to aid in the collection of data from the units. A single International tractor equipped with the crash warning system will be deployed at the terminal for one month. This period would allow eight drivers to experience the system for one week each. The equipped truck will be used on regular Con-way routes to conduct scheduled deliveries. Routes and drivers will be selected from those drivers volunteering in order to maximize the range of driving environments to which the vehicle is exposed (urban or suburban, surface street or highway, etc.). Four drivers will operate the equipped tractor during the day as part of Con-way's P&D (pick-up and delivery) freight schedule, while four will operate the vehicle at night as part of Con-way's long-haul, terminal-to-terminal schedule.

There will be no baseline period, as the extended pilot data will not be analyzed in the same fashion that the FOT data is analyzed, nor would data from six to eight participants be sufficient to draw conclusions regarding changes in driver behavior that might be associated with the warning system. Instead, emphasis will be placed on the subjective impressions of the system, ensuring that it is functioning properly while evaluating the FOT protocol. Subjective data collection will be carried out in the HT extended pilot using either an online or printed version of the survey, depending upon the driver's preference. Only drivers will serve as formal participants, but feedback will be explicitly sought from terminal management.

3.2.2 Characterization of the Heavy-Truck Pilot Testing Fleet

The warning system is being installed in a single International ProStar 8600-series tractor that meets Con-way's specifications established during Phase I of the program. The tractor contains the heavy-truck warning system (forward collision warning, lane-change or merge warning, and lateral drift warning systems in an integrated safety system with a unified driver-vehicle interface). UMTRI will monitor the health of the fleet remotely using data transferred over the DAS cell modem. At the end of each trip (ignition off), this data will be sent directly to the servers at UMTRI and uploaded onto Web pages for review. This process is described in Section 9.2, Data Validation. Figure 5 provides a graphic representation of the sensor suite and zones of coverage.

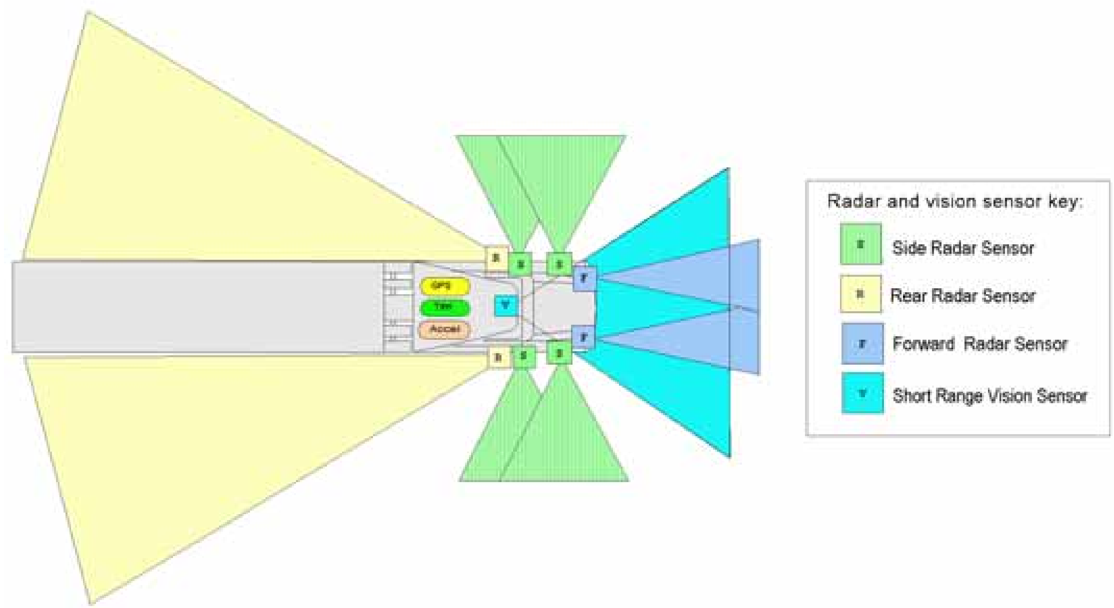


Figure 5. Heavy-truck sensor suite overview (not to scale)

This vehicle will include the complement of sensors for monitoring driver behavior that was not implemented during system development, and as such is representative of vehicles being readied for FOT deployment. Additional sensors on the tractor include video cameras collecting images both inside and surrounding the vehicle, an in-cabin microphone, and data stored using an onboard data acquisition system designed specifically for the FOT. In addition to collecting these measures, a substantive quality control process will be used to ensure data channel accuracy. This process is described in Section 9.2, Data Validation.

3.2.3 Heavy-Truck Participant Sampling Variables

UMTRI will attempt to select the eight drivers from a variety of age ranges and years of experience in operating heavy trucks. However, driver age is most likely to range between 30 and 55 years old. The Ann Arbor-Whitmore Lake terminal is small and has fewer drivers than the terminal to be used for the FOT. Participation will be strictly voluntary.

3.2.4 Heavy-Truck Participant Recruitment

Drivers will be recruited by an UMTRI representative addressing the terminal staff during a regularly scheduled driver information session. Recruitment will include a description of the warning system, and will allow the terminal drivers to inspect an equipped tractor and ask questions of UMTRI staff. Detailed information regarding driver history with commercial vehicles, such as the number of years that they have held a CDL and their years of service with Con-way, will be obtained.

3.2.5 Participant Orientation and Instruction for the Heavy-Truck Pilot Test

Driver training will begin with an introduction to the research vehicles and the warning system with an opportunity to ask specific questions of a research associate. The introduction will concentrate on the system’s usability aspects, including video examples of circumstances in which a driver could expect to receive a warning. This will include an explanation of what each

4 FOT Experimental Design

The UMTRI-led team acknowledges that the development of the experimental designs should be a collaborative process where they will work with U.S. DOT and Volpe on defining the plans for sampling, exposure, screening, etc. However, there are several considerations that influence the FOT experimental design, in particular the required number of participants to achieve statistically reliable results (sample size) and the capacity of data storage in the onboard data acquisition system. Experimental designs for both light-vehicle and heavy-truck platforms are proposed for consideration, with modifications to be made on the basis of further discussion among UMTRI, U.S. DOT, and the independent evaluator. Table 4 provides a brief overview of the scope planned for the FOT, with greater detail provided in following sections.

Table 4. Variations in the FOT experimental designs by platform

Light Vehicle	Heavy Truck
• 108 participants • 16 research vehicles • 40-day exposure/driver: - 12-day baseline period - 28-day treatment period • 10 drivers 80-day exposure - 12-day baseline period	• 20 participants • 10 research tractors • 2 shifts (daytime and nighttime) • 10-month exposure in fleet • 10-month exposure/driver - 2-month baseline - 8-month treatment period

4.1 Light-Vehicle FOT Experimental Design

4.1.1 Scope of the Light-Vehicle FOT

Sixteen late-model Honda Accords will be used as research vehicles for the participants. One additional vehicle will serve as a backup should a vehicle in the field develop problems. At least 108 passenger car drivers will take part in the FOT, and the sample will be stratified by age and gender. The age groups to be examined are 20 to 30, 40 to 50, and 60 to 70 years old. UMTRI will seek a gender balance in the sample, not knowing beforehand whether differences in system acceptance or use will be correlated with gender. Consenting drivers will drive the test vehicles in an unsupervised manner, simply pursuing their normal trip-taking behavior over a 40-day period, using the equipped vehicles as a substitute for their own personal vehicles. The first 12 days of vehicle use will serve as a baseline period in which no system functionalities are provided to the driver, but all system sensors and equipment are running in the background. On the 13th day of participation, the system's functionality will be shown to the driver and warnings provided where appropriate. This treatment period will last for 28 days, at which point the participant will return the research vehicle to UMTRI. Use of the test vehicles by anyone other than the designated participant will be prohibited, unless it can be considered to be an emergency.

The proposed experimental design would achieve approximately 648 weeks – or 12 years – worth of driving data on the light-vehicle platform (approximately four years worth of baseline driving and eight years worth of driving data with the system activated). The FOT will be conducted over 12 contiguous months, thereby exposing users to seasonal variations in weather and lighting conditions.

In what is considered a secondary goal and data collection effort, UMTRI will attempt to recruit 10 young males, 20 to 30 years of age, who will retain the vehicles for approximately 80 days. This sub-sample of drivers, hence forth referred to as "extended exposure" participants, would satisfy the original experimental design as objective and subjective data would be obtained after the initial 40-day period, but would also allow exploratory analyses associated with even more prolonged exposure to the warning system. Young males are the population of choice for the extended exposure due to the anticipated high mileage/exposure likely to be achieved.

4.1.2 Characterization of the Light-Vehicle FOT Fleet

The passenger cars in which the integrated systems are being installed are a mix of model year 2006 and 2007 Honda Accord EXs (four 2006 and twelve 2007 models). These vehicles are four-door sedans with V6 engines. Eighteen vehicles in all will be equipped, 16 will serve as research vehicles and be lent to participants, one 2006 model will serve as a spare in the event a vehicle in the field needs to be replaced, and one 2006 model will serve as a development vehicle on which troubleshooting can be performed. All 18 vehicles are gold-toned with leather interiors, ABS, vehicle stability assist, six-CD stereo systems, and conventional cruise control. The vehicles do not include navigation systems.

4.1.3 Sampling Variables for the Light-Vehicle FOT

It is proposed that 108 drivers will participate in the light-vehicle portion of the FOT. It is also proposed that the sample contain an equal number of male and female drivers, divided among three age groups (20 to 30, 40 to 50, and 60 to 70 years old).

Participants will be recruited with the assistance of the Michigan Secretary of State (Michigan's drivers licensing bureau), as it has in past FOTs that UMTRI has conducted. A random sample of several thousand driving records will be requested, drawn from the population of licensed drivers from the eight counties surrounding Ann Arbor (all within a 1.5-hour drive of UMTRI). This sampling strategy will help ensure a wide geographical area that includes urban (where lane change conflicts will be greater), suburban, and rural driving conditions (where road departures are concentrated). All information obtained through the State records will be treated with strict confidentiality. It is proposed that an initial screening of driver records exclude people on the basis of the following criteria: (1) having one crash resulting in a fatality within the past 36 months, and (2) having been convicted of either driving while intoxicated or driving under the influence of alcohol or a controlled substance within the past 36 months.

A minimum annual mileage will be also required for a driver to qualify for the FOT. The estimated annual mileage requirement will vary as a function of participant age and gender. Minimum annual mileage requirements will be based on published average mileage in the National Household Transportation Survey (NHTS).

system does, how it works, and how to identify any operational problems. The experimental apparatus will be identified and their purposes explained. Each driver will be given an FOT manual that contains all the information covered in the training session, along with contact information and samples of “driver event” forms. Copies of this material will also be kept in each of the FOT tractors for the duration of the study, as well as a log book in which to make comments and emergency contact information. Drivers will also receive hands-on instruction in an equipped tractor. While accompanied by a researcher, each driver will experience the system first-hand during an orientation drive of approximately 30 minutes on local roadways in normal traffic. The researcher who provides the orientation will thereafter be the primary point of contact for the driver should any questions or concerns arise.

3.2.6 Heavy-Truck Schedule

Figure 6 shows the major milestones for the heavy-truck extended pilot test.

ID	Task Name	Start	Finish
404	**Extended Pilot Test (Task 2.c)**	**Fri 7/25/08**	**Tue 3/24/09**
405	**Heavy-truck**	**Fri 7/25/08**	**Fri 1/16/09**
406	Finalize experimental design	Fri 7/25/08	Fri 7/25/08
407	Submit extended pilot test IRB application	Fri 8/1/08	Fri 8/1/08
408	Extended pilot test subject recruitment	Fri 8/29/08	Fri 10/31/08
409	**Conduct extended pilot test**	**Wed 11/12/08**	**Fri 12/12/08**
418	Weekly submission of data files	Thu 11/27/08	Wed 12/24/08
419	Data analysis	Thu 11/20/08	Tue 12/30/08
420	Deliverable: Extended Pilot FOT Results Summary Report	Fri 1/16/09	Fri 1/16/09

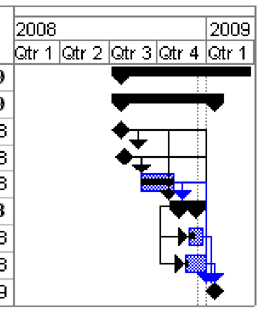


Figure 6. Heavy-truck extended pilot test schedule

4.1.4 Participant Recruitment for the Light-Vehicle FOT

Potential participants identified from the State records will be contacted through U.S. mail to solicit their participation in the FOT. The initial contact will not mention the nature of the study, but indicate only that participants will be asked to drive a car and will receive financial compensation for their time. Interested people receiving the response will be asked to contact UMTRI. An UMTRI research assistant will then screen respondents to ensure they meet the predetermined qualification criteria (such as age, gender, and miles driven in the past year) to satisfy the proposed experimental design.

Individuals who meet the qualifications and are needed to satisfy the experimental design will receive a brief overview of the IVBSS program and the FOT. The final selection of participants will be dependent upon the match of an individual with predefined selection criteria to the proposed experimental design and the participant's availability for taking and returning a vehicle per the test schedule. Potential participants will further be informed of any benefits or risks associated with their participation. If individuals find the conditions of participation to be generally agreeable, a specific date and time will be arranged for them to visit UMTRI for orientation and training.

4.1.5 Participant Orientation and Instruction for the Light-Vehicle FOT

Participant orientation and training will begin with an introduction to the research vehicle and the warning system as provided in an instructional video developed by UMTRI. A briefing and opportunity to ask questions of a researcher will follow. The video will cover two principle areas: (1) the location of standard controls and displays on the research vehicles, including use of the vehicle's safety equipment (air bag, seat belt, ABS, etc.); and (2) all usability aspects of the system, including video examples of circumstances in which participants could expect to receive a warning.

Participants will also receive hands-on instruction with the research vehicle and the warning system. The experimental apparatus will be identified and their purposes explained. Participants will experience each warning in a static demonstration. Then, while accompanied by a researcher, each participant will experience the system in operation as a driver during an orientation run. This drive will last about 30 minutes on local roadways in normal traffic. The researcher who provides the orientation will thereafter be the primary point of contact for the participant should any questions or concerns arise.

Once participants complete the orientation and are comfortable with their understanding of the research vehicle, they will be free to leave with the vehicles, at which time a date and time to return the vehicle will be scheduled. The glove compartment of each vehicle will include the following informational materials: the scheduled vehicle return date, a copy of the instructional video on VHS and DVD (as well as a manual outlining all the material included in the video for persons without access to VHS or DVD players), a road map of Michigan, a log book in which to make comments, emergency contact information, a copy of the informed-consent form, and proof of insurance.

4.1.6 Assisting Light-Vehicle Participants in the Field

Each research vehicle will be equipped with a cellular telephone that could be used by participants to contact researchers as necessary. A minimum of two researchers will carry pagers, having one common number, at all times during the FOT. Participants will be assured of contacting a researcher, if the need arises, on a 24-hour-a-day basis. UMTRI has an account with a local limousine company should a participant require transportation home in the event of a crash or breakdown involving the FOT vehicle. If it becomes necessary for a participant to receive another equipped vehicle, a researcher will contact the participant and make arrangements to swap vehicles at a location convenient for the participant.

4.1.7 Schedule for the Light-Vehicle FOT

Figure 7 shows the major milestones for the light-vehicle field operational test.

ID	Task Name	Start	Finish
69	**FOT Vehicle (Task 2.a)**	**Tue 2/19/08**	**Mon 4/13/09**
70	**Heavy-truck**	**Tue 2/19/08**	**Fri 3/6/09**
250	**Light-vehicle**	**Tue 4/1/08**	**Mon 4/13/09**
251	Procure Fleet Vehicles	Tue 4/1/08	Mon 4/28/08
252	Prototype DAS build	Tue 4/15/08	Mon 5/5/08
253	Subsystem Design	Tue 4/1/08	Fri 8/22/08
254	Calibration	Tue 4/1/08	Fri 8/22/08
255	Vehicle Integration and Safety Analysis	Tue 4/1/08	Thu 6/19/08
256	**IVBSS software revisions**	**Mon 6/2/08**	**Fri 8/22/08**
293	**Extended pilot software and hardware release (Eta)**	**Mon 6/2/08**	**Fri 8/22/08**
336	Data definitions of variables	Fri 6/13/08	Thu 8/28/08
337	Primary & secondary data signals verified (dictionary)	Wed 6/11/08	Tue 10/14/08
338	**Vehicle builds**	**Fri 6/20/08**	**Fri 1/30/09**
343	ICD Freeze	Fri 8/22/08	Fri 8/22/08
344	Eta Release	Tue 9/9/08	Tue 9/9/08
345	Calibration Signoff	Tue 9/9/08	Fri 9/26/08
346	FOT DAS in vehicle check-out	Wed 9/24/08	Mon 10/6/08
347	**Vehicle Rollout (upfit/check-out/mileage)**	**Mon 10/6/08**	**Thu 3/5/09**
352	Agreement with DOT on video rates and events	Fri 8/1/08	Tue 9/2/08
353	First FOT DAS build (DAS 2)	Thu 10/2/08	Thu 10/2/08
354	First FOT DAS builds (DAS 2 and DAS 3)	Mon 9/22/08	Fri 10/10/08
355	**DAS builds for FOT**	**Mon 10/13/08**	**Mon 4/13/09**
375	Remaining data signals verified (need new end date)	Wed 9/24/08	Wed 3/11/09
376	**Verification**	**Wed 4/9/08**	**Fri 1/16/09**
388	Subsystem Tuning based on Extended pilot data	Mon 2/16/09	Fri 2/20/09
389	Theta Release	Thu 3/5/09	Thu 3/5/09
390	Mini-verification (if required)	Fri 3/6/09	Wed 3/11/09
391	Milestone: Completed FOT vehicles	Thu 3/5/09	Thu 3/5/09
392	Milestone: Additional light vehicle for NHTSA	Wed 4/1/09	Wed 4/1/09
393	**Development of Final FOT Design Plan (Task 2.b)**	**Tue 7/1/08**	**Mon 11/17/08**
404	**Extended Pilot Test (Task 2.c)**	**Fri 7/25/08**	**Tue 3/24/09**
441	**FOT (Task 2.e)**	**Mon 9/15/08**	**Mon 5/31/10**
442	**Heavy-truck**	**Mon 9/15/08**	**Mon 5/31/10**
449	**Light-Vehicle**	**Mon 12/1/08**	**Mon 5/31/10**
450	**Subject Recruitment**	**Mon 12/1/08**	**Mon 12/21/09**
453	Conduct FOT	Wed 4/1/09	Tue 3/30/10
454	Conduct focus groups	Wed 6/24/09	Tue 4/13/10
455	Deliverable: Monthly submissions of data files	Wed 5/27/09	Thu 5/27/10
456	Deliverable: Final FOT Program Report	Mon 5/31/10	Mon 5/31/10
457	**Data Analysis (Task 2.f)**	**Fri 10/10/08**	**Tue 7/20/10**
458	**Light-vehicle**	**Mon 11/17/08**	**Tue 7/20/10**
459	Deliverable: Data Analysis Plan Report	Mon 11/17/08	Mon 11/17/08
460	Data analysis	Fri 8/21/09	Tue 7/20/10
461	**Final Report**	**Mon 3/1/10**	**Tue 7/20/10**
462	Final Report Outline	Mon 3/1/10	Mon 3/1/10
463	Draft of Final Report	Fri 4/30/10	Fri 4/30/10
464	Deliverable: Final FOT reports: Methodology and Resu	Tue 7/20/10	Tue 7/20/10

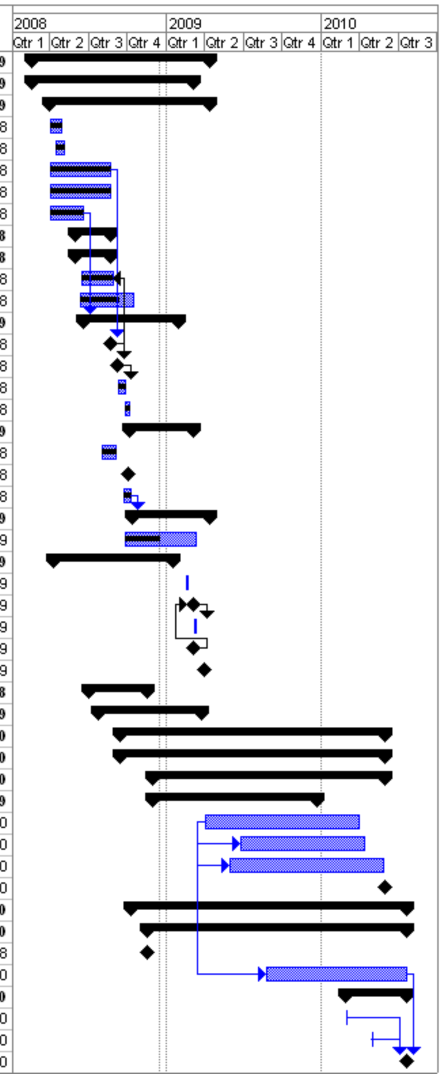


Figure 7. Light-vehicle field operational test schedule

4.2 Heavy-Truck FOT Experimental Design

4.2.1 Scope of the Heavy-Truck FOT

Ten 2008 International ProStar 8600-series tractors will be used as research vehicles. These vehicles will be built to specification for, and purchased by, Con-way Freight, the FOT fleet operator. One additional vehicle, which will reside at UMTRI, will serve as a backup should a vehicle in the field develop problems. Tractors will be built and equipped with the warning system in sets of three and introduced into the fleet in a staggered fashion. At least 20 commercial drivers from Con-way's Detroit terminal will participate. The sample will be all male, but attempts will be made to recruit drivers from a wide variety of age groups and years of experience in driving commercial trucks. Consenting drivers will operate the test vehicles, conducting Con-way's normal business, over a 10-month period. The first two months of vehicle use will serve as the baseline period, while the following eight months will be the treatment period. During the baseline period no system functionalities are provided to the driver, but all sensors and equipment are running in the background. At the beginning of the third month of participation, the system's functionality will be made available and warnings will be provided where appropriate. Use of the equipped tractors by anyone who has not received training from UMTRI staff will be strongly discouraged. Con-way drivers will be identified using either the logistics data from the fleet or by manually inspecting face video at the start and end of each trip. The relationship among tractor, trip, and driver ID will be shared with the independent evaluator. Generally speaking, however, drivers are assigned to trucks and stay with those trucks; only in instances where a driver is on sick leave or on vacation do the drivers change, and even then replacement drivers will often drive their own truck rather than that of the person normally assigned to the same route.

The proposed experimental design would achieve approximately 400 weeks – or 7.5 years – worth of driving data on the heavy-truck platform (about two years worth of baseline driving and 5.5 years worth of driving data with the warning system activated). The FOT will be conducted over 10 contiguous months that include significant seasonal variations in weather and lighting conditions.

4.2.2 Characterization of the Heavy-Truck Fleet

For the heavy-truck platform, the FOT will be conducted with the assistance and cooperation of the Con-way Freight. Con-way Freight is a regional and nationwide less-than-a-truckload (LTL) company that specializes in the transportation and delivery of palletized freight. Companywide, Con-way employs over 30,000 professional drivers and operates over 32,000 power units (tractors) and approximately 80,000 trailers. In addition to Con-way's willingness and commitment to participate in the FOT, the fleet also meets a number of other criteria necessary for a successful FOT. These include a willingness to purchase the tractors, logistical and operational constraints, personnel considerations, and proximity of the fleet to the other program partners.

Figure 8. Heavy truck used in the FOT

For the FOT, Con-way will operate tractors from its Romulus, Michigan, service and distribution center. At this terminal, Con-way operates approximately 80 tractors and 220 trailers in both line-haul[1] and a local pick-up and delivery (P&D) operations. Preliminary exposure estimates show that 80 percent of the miles traveled by the FOT vehicles will be on limited-access roads, while the remaining 20 percent will be on major surface roads. Each FOT tractor will be assigned to a specific line-haul and P&D route. During the day, a tractor will be employed on a P&D route, while at night the same tractor will be used for a line-haul route. The drivers for these routes are bid out every year and are based on seniority. Con-way does not run a “slip-seat” operation; rather, drivers are assigned to tractors and aside from vacations and sick time (and any intentional rotation of tractors per the experimental design), the same drivers will be driving the same tractors on the same routes for the entire FOT. This has been confirmed by Con-way and is part of the agreement with UMTRI. Tractors will be in operation approximately 20 hours per day with two drivers assigned to each tractor. The overall total mileage for the fleet is expected to be around 700,000 miles, with 15,000 hour of driving.

There are exceptions, but in general Con-way uses sets of 28-foot trailers for all line-haul operations. For P&D, Con-way typically uses a 48-foot trailer but can also use 28-, 40-, 45-, and 53-foot trailers. P&D trailer selection is a function of route and time of year, as the freight business varies during the year.

4.2.3 Sampling Variables for the Heavy-Truck FOT

Only drivers with valid CDLs and a minimum of two years experience in driving heavy-duty trucks will be included. Every attempt will be made to recruit a wide range of driver ages. However, gender cannot be balanced with the population of drivers at the Romulus terminal, as 99 percent of these drivers are male.

[1] A fixed-route system that moves freight between distribution terminals.

3.2 Heavy-Truck Pilot Test Experimental Design

3.2.1 Scope of Heavy-Truck Pilot Testing

The extended pilot test would be run using a terminal and drivers who are part of the larger Con-way fleet, but not the same terminal or drivers who would be selected for the FOT. At least six drivers would participate in the extended pilot test. The terminal of choice is the Ann Arbor-Whitmore Lake terminal in part given its proximity to UMTRI in the event that troubleshooting of the unit is necessary and in part to aid in the collection of data from the units. A single International tractor equipped with the crash warning system will be deployed at the terminal for one month. This period would allow eight drivers to experience the system for one week each. The equipped truck will be used on regular Con-way routes to conduct scheduled deliveries. Routes and drivers will be selected from those drivers volunteering in order to maximize the range of driving environments to which the vehicle is exposed (urban or suburban, surface street or highway, etc.). Four drivers will operate the equipped tractor during the day as part of Con-way's P&D (pick-up and delivery) freight schedule, while four will operate the vehicle at night as part of Con-way's long-haul, terminal-to-terminal schedule.

There will be no baseline period, as the extended pilot data will not be analyzed in the same fashion that the FOT data is analyzed, nor would data from six to eight participants be sufficient to draw conclusions regarding changes in driver behavior that might be associated with the warning system. Instead, emphasis will be placed on the subjective impressions of the system, ensuring that it is functioning properly while evaluating the FOT protocol. Subjective data collection will be carried out in the HT extended pilot using either an online or printed version of the survey, depending upon the driver's preference. Only drivers will serve as formal participants, but feedback will be explicitly sought from terminal management.

3.2.2 Characterization of the Heavy-Truck Pilot Testing Fleet

The warning system is being installed in a single International ProStar 8600-series tractor that meets Con-way's specifications established during Phase I of the program. The tractor contains the heavy-truck warning system (forward collision warning, lane-change or merge warning, and lateral drift warning systems in an integrated safety system with a unified driver-vehicle interface). UMTRI will monitor the health of the fleet remotely using data transferred over the DAS cell modem. At the end of each trip (ignition off), this data will be sent directly to the servers at UMTRI and uploaded onto Web pages for review. This process is described in Section 9.2, Data Validation. Figure 5 provides a graphic representation of the sensor suite and zones of coverage.

4.2.4 Participant Recruitment for the Heavy-Truck FOT

Ten FOT tractors will be based at Con-way's Romulus terminal. Based at this facility are over 100 drivers, 43 line-haul tractors, 33 daily-delivery tractors, 217 28-foot line-haul trailers, and 71 daily-delivery trailers ranging in size from 42 to 53 feet.

The following is a breakdown of drivers by age group:

- Age 20 to 29 (12%);
- Age 30 to 39 (28%);
- Age 40 to 49 (37%);
- Age 50 to 59 (19%); and
- Age 60 and older (4%).

A notice will be posted at the terminal and at least two information sessions will be held to inform potentially interested drivers what participation in the FOT entails. If there are more interested drivers than are needed for the FOT, then drivers will be selected somewhat randomly. For example, all other factors being equal, a driver with more experience at Con-way Freight would be selected to participate in the FOT over a driver with less Con-way experience. The rationale for this decision is that it is important to reduce the likelihood of driver turnover in the FOT, and while not a guarantee, it is assumed that a driver with more experience at Con-way would be less likely to leave the company in the midst of participating in the FOT.

4.2.5 Participant Orientation and Instruction for the Heavy-Truck FOT

Customized training will be necessary for drivers, mechanics, and fleet management personnel involved in this FOT. This training will be conducted in small groups or one-on-one sessions with UMTRI and FOT partners participating as appropriate. In previous FOT work, UMTRI has learned that frequent personal interaction and progress updates are important motivators for the drivers and mechanics at the fleet. In part, the success of the FOT relies on their input, so UMTRI will work actively to keep them involved in the ongoing FOT. Training is an important element toward this goal. To the extent possible, training will be integrated into the normal training procedures of the fleet, which serves two purposes. First, it ensures that the people in charge of the day-to-day fleet operation know the expectations placed upon the drivers and mechanics. Furthermore, their knowledge of the operation provides valuable input as to the most efficient way to get the work done. Second, fleet management personnel will need to become knowledgeable about the various system components involved in the study. Since most questions and problems will come first to these professionals, it is important that they have the necessary instruction and FOT contact information. In short, the supervisors need to be ready to play their front-line roles in the FOT.

Driver training will begin with an introduction to the research vehicles and how the warning system operates, with an opportunity to ask specific questions of a researcher. The introduction will concentrate on the usability aspects of the system, including video examples of circumstances in which drivers could expect to receive warnings. This will include an explanation about what each system does, how it works, and how to identify any operational problems. The experimental apparatus will be identified and their purposes explained. Drivers will be given FOT manuals that contain all the information covered in the training session along with contact information and samples of “driver event” forms. Copies of this material will also be kept in each of the FOT tractors for the duration of the study, including a logbook in which to make comments and keep emergency contact information. Drivers will also receive hands-on instruction in an equipped tractor. While accompanied by a researcher, each driver will experience the system first-hand during an orientation drive on local roadways in normal traffic. The researcher who provides the orientation will thereafter be the primary point of contact for the driver should any questions or concerns arise.

4.2.6 Assisting Heavy-Truck Participants in the Field

Each tractor will be equipped with a means by which drivers can contact researchers as necessary. A minimum of two researchers will carry pagers, having one common number, at all times during the FOT. Drivers are assured of contacting a researcher, if the need arises, on a 24-hour-a-day basis.

Every attempt will be made to not disrupt Con-way Freight’s business operations. In the event that an equipped tractor needs to be repaired, the tractor will be pulled from service and replaced with a fully functional tractor that UMTRI will maintain as a backup. Once the repairs have been completed, the FOT tractor will be returned to the Con-way terminal.

4.2.7 Schedule for the Heavy-Truck FOT

Figure 9 shows the major milestones for the heavy-truck field operational test.

ID	Task Name	Start	Finish
69	**FOT Vehicle (Task 2.a)**	**Tue 2/19/08**	**Mon 4/13/09**
70	**Heavy-truck**	**Tue 2/19/08**	**Fri 3/6/09**
71	Prototype DAS build	Tue 4/15/08	Fri 9/5/08
72	**IVBSS software revisions**	**Tue 4/8/08**	**Thu 1/8/09**
141	**Gold integration (less DAS)**	**Tue 2/19/08**	**Fri 9/26/08**
151	**FOT vehicle build**	**Thu 5/1/08**	**Fri 3/6/09**
229	First FOT DAS build (DAS 1)	Mon 7/7/08	Fri 9/12/08
230	Data definitions of variables	Tue 7/15/08	Wed 12/31/08
231	**DAS builds for FOT**	**Fri 10/24/08**	**Fri 2/13/09**
243	**Verification testing**	**Fri 9/26/08**	**Fri 10/17/08**
248	Agreement with DOT on video rates and events	Tue 9/2/08	Tue 9/2/08
249	Remaining data signals verified	Mon 9/15/08	Thu 1/15/09
250	**Light-vehicle**	**Tue 4/1/08**	**Mon 4/13/09**
393	**Development of Final FOT Design Plan (Task 2.b)**	**Tue 7/1/08**	**Mon 11/17/08**
404	**Extended Pilot Test (Task 2.c)**	**Fri 7/25/08**	**Tue 3/24/09**
441	**FOT (Task 2.e)**	**Mon 9/15/08**	**Mon 5/31/10**
442	**Heavy-truck**	**Mon 9/15/08**	**Mon 5/31/10**
443	**Subject Recruitment**	**Mon 9/15/08**	**Mon 12/15/08**
444	Submit FOT IRB application	Mon 9/15/08	Mon 9/15/08
445	Recruit subjects	Mon 12/1/08	Mon 12/15/08
446	Conduct FOT	Fri 1/9/09	Mon 11/9/09
447	Deliverable: Monthly submissions of data files	Fri 2/6/09	Thu 12/10/09
448	Deliverable: Final FOT Program Report	Mon 5/31/10	Mon 5/31/10
449	**Light-Vehicle**	**Mon 12/1/08**	**Mon 5/31/10**
457	**Data Analysis (Task 2.f)**	**Fri 10/10/08**	**Tue 7/20/10**
458	**Light-vehicle**	**Mon 11/17/08**	**Tue 7/20/10**
465	**Heavy-truck**	**Fri 10/10/08**	**Tue 6/1/10**
466	Deliverable: Data Analysis Plan Report	Fri 10/10/08	Fri 10/10/08
467	Data analysis	Fri 4/3/09	Tue 6/1/10
468	**Final Report**	**Mon 3/1/10**	**Tue 6/1/10**
469	Final Report Outline	Mon 3/1/10	Mon 3/1/10
470	Draft of Final Report	Fri 4/30/10	Fri 4/30/10
471	Deliverable: Final FOT reports: Methodology and Resu	Tue 6/1/10	Tue 6/1/10

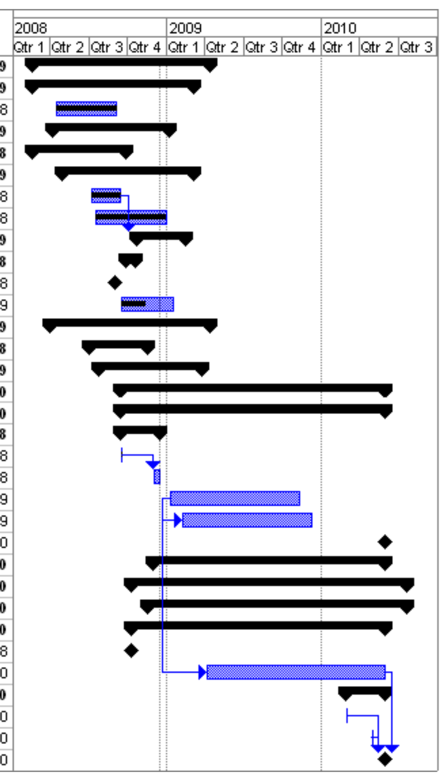


Figure 9. Heavy-truck field operational test schedule

5 Objective Data Collection

This section covers both numeric and video data that will constitute the FOT database for both light-vehicle and heavy-truck platforms. This data is objective in the sense that it is undistorted by emotion or personal bias and is based on observable evidence.

5.1 The Objective Dataset

The primary goal of the FOT is to determine whether an integrated safety system brings about objectively measurable changes in driver performance parameters that are likely to affect heavy-truck and light-vehicle crash rates. The bulk of the data necessary to answer this question will be provided by a purpose-built data acquisition system that will be virtually transparent to the drivers on both platforms and have minimal impact on Con-way operations in general. In addition to data collected by the DAS, supplemental objective data will be taken from a variety of sources including existing road attribute databases, Con-way's logistical archive, and the National Weather Service (for examples of the data collected from the fleet, see Section 5.9.5). There will be extensive subjective data collected using driver questionnaires, focus groups, and driver interviews. This section characterizes the objective data that will be collected and stored in a relational database structure.

The DAS on both platforms will collect hundreds of signals of data along with substantial video of the scene around the vehicle and within the driver cabin environment. On a broad level, these measures are characterized in Table 5. Although this is not an exhaustive channel data list, it covers the general categories of data retrieval and shows within each category the type of data that will be collected to characterize and archive how the system performed, the activities of the driver, and the environment and state of the vehicle. For both platforms, the general configuration of the DAS is the same, but there will be some minor differences associated with the data retrieval mechanism, storage capacity, sampling rates, and data stored. In addition to collecting these measures, a substantive quality control process will be used to ensure data channel accuracy. This process is described in Section 9.2, Data Validation. Table 5 shows general data categories as a function of four classifications, defined as:

- **Source**: Most data collected by the DAS will be from a dedicated Controller Area Network (CAN) bus (or set of CAN buses) implemented, programmed, and structured specifically for this project. Specific details of this CAN implementation can be found in the Light- and Heavy-Vehicle Interface Control Documents. However, other data will come from the original equipment vehicle bus (engine and body on light vehicle and J1939 on heavy truck). UMTRI will install its own set of sensors on both platforms. These sensors will provide researchers at UMTRI with additional measures of vehicle and driver performance, which are independent of the warning system. Finally, a category classified as other includes objective data that will be linked to the onboard DAS data but will be culled from external data sources such as the National Weather Service, the Highway Performance Monitoring System, and Con-way's logistical databases.

- **DAS Format**: These data are stored into five general categories:
    - ***Custom***: Specifically this category applies to the radar and video cameras. For all radar units, the DAS will record all radar targets and their associated data with the exception of the forward radar on the heavy-truck platform. In this case the signals for the primary forward target will be recorded at 10 Hz while the signals for up to six secondary targets will be recorded at 2 Hz. Video on both platforms will be recorded at the highest frequency possible given the storage and compression considerations for the DAS. All video measures will also be triggered at least 10 Hz with a pre- and post-event window to capture and save the visual content of the scene surrounding a warning.
    - ***10 Hz Series***: Most objective data from the vehicle will be saved in a time-history format with a 10 Hz resolution.
    - ***Triggered Event***: Many objective data signals will be event-logged by the DAS. That is, when a signal transitions beyond a threshold or there is a warning, the start and end time of that event will be saved along with other relevant signals. These triggered events are the building blocks of more complex analysis methodologies that are used to address specific questions related to how the system and vehicle performed and, more critically, how the driver might have changed their driving behavior. Also, since these summaries are relatively small in size, they can be downloaded to UMTRI after each trip and used to monitor the health of the system and the experience of the driver.
    - ***Transitional***: Logged events contain the same content as time history events, but require less space and are often easier to summarize in large datasets.
    - ***Aggregated***: This general classification nearly always involves performing some type of operation on a specific signal, and results in a number or set of numbers that reflect an overall summary of the measure. Examples include distance traveled, which is the integration of the speed signal over the time resolution of that signal, and the count of brake applications by the driver. Another important aggregation is histograms or the categorization of a signal into predefined bins to produce a time-weighted distribution of a signal. In some cases, two-dimensional histograms are created showing the relationship between two signals such as road type and speed.
- **Platform**: Gives an indication of the differences between the objective data archive of each of the platforms as well as, more importantly, their similarities.
- **To Monitor**: Gives a general breakdown of what the objective data measure will be used for. In many cases, the individual measures will serve in multiple analysis approaches to better understand the driver, environment, warning system, or vehicle performance.

Table 5. DAS data collection variables

Data Category	Source				DAS Format					Platform		To Monitor			
	Vehicle Bus	System Bus(s)	UMTRI (AtoD)	Other	Custom	10 Hz series	Triggered Event	Transitional	Aggregated	Heavy Truck	Light Vehicle	Driver Activity	Environment	IVBSS	Vehicle
Radar															
Front		x			x					x	x	x	x	x	
Side		x			x					x	x	x	x	x	
Rear		x			x						x		x	x	
Lane-Departure															
Boundary types		x				x				x	x		x	x	
Lane position		x				x				x	x	x		x	
Lateral speed		x				x				x	x	x		x	
Lane change events		x				x		x		x	x	x		x	
Ambient light		x				x				x	x		x	x	
Future lane offset		x				x				x	x		x	x	
Road shoulder width		x				x				x	x		x	x	
Road curvature		x				x				x	x		x	x	
Alert request		x				x	x			x	x	x	x	x	
Status		x				x		x	x	x	x			x	
Lane-Change/Merge															
Lateral presence		x				x				x	x	x	x	x	
Lateral clearance		x				x				x	x	x	x	x	
Future lateral clearance		x				x				x	x	x		x	
Time to lane crossing		x				x				x	x	x		x	
Object position		x				x				x	x		x	x	
Object velocity		x				x				x	x		x	x	
Alert request		x				x	x			x	x	x		x	
Status		x				x		x	x	x	x			x	
Forward Collision															
Heading wrt road		x				x				x	x	x		x	
CIPV Range		x				x				x	x	x	x	x	
CIPV Range rate		x				x				x	x	x	x	x	
CIPV Azimuth		x				x				x	x	x	x	x	
CIPV Ax		x				x				x	x	x	x	x	
Target type		x				x				x	x			x	
Lane change flag		x				x				x	x	x		x	
Alert request		x				x	x			x	x	x		x	
Status		x				x		x	x	x	x			x	
Curve Speed Warning															
Map type		x							x		x		x	x	
Mapping quality		x							x		x		x	x	
Availability		x							x		x		x	x	

Data Category	Source				DAS Format					Platform		To Monitor			
	Vehicle Bus	System Bus(s)	UMTRI (AtoD)	Other	Custom	10 Hz series	Triggered Event	Transitional	Aggregated	Heavy Truck	Light Vehicle	Driver Activity	Environment	IVBSS	Vehicle
Maximum desired speed		x							x		x	x		x	
Required acceleration		x							x		x	x		x	
Most likely path		x							x		x			x	
Number of thru lanes		x							x		x		x	x	
Road curvature points (CPOI)		x							x		x		x	x	
Alert request		x				x	x				x	x		x	
Status		x				x		x	x		x			x	
DVI															
Display state		x				x				x	x	x		x	
System sensitivity		x				x		x	x		x	x		x	
System suppression		x				x		x	x	x	x	x	x	x	
Visual alert		x				x	x			x	x			x	
Audio alert		x				x	x			x	x			x	
Haptic alert		x				x	x				x			x	
Alertness index		x				x					x	x	x	x	
Status		x				x		x	x	x	x			x	
Vehicle Performance															
Transmission speed	x					x				x	x	x			x
Transmission gear	x							x			x	x			x
Fuel Used	x					x					x	x			x
Engine torque	x					x				x		x			x
Retarder torque	x					x				x		x			x
Coolant temp	x					x				x					x
Intake temp	x					x				x					x
Battery voltage	x					x			x	x	x			x	x
Traction control	x						x	x	x		x	x			x
ABS event	x						x	x			x	x			x
Status	x					x		x	x	x	x				x
Driver Activity and switches															
Wipers	x					x		x		x	x	x		x	
Turn signal	x					x		x		x	x	x		x	
Steer	x		x			x				x	x	x		x	
Accel. pedal	x					x		x		x	x	x			
Brake	x					x		x		x	x	x		x	
Head/parking lamp	x					x		x		x	x	x			
Horn	x							x		x		x			
Cruise control	x					x		x			x	x		x	
Parking brake	x							x		x		x			
Clutch state	x					x		x		x		x			

Data Category	Source				DAS Format					Platform		To Monitor			
	Vehicle Bus	System Bus(s)	UMTRI (AtoD)	Other	Custom	10 Hz series	Triggered Event	Transitional	Aggregated	Heavy Truck	Light Vehicle	Driver Activity	Environment	IVBSS	Vehicle
Vehicle State Measures															
Weight				x				x	x	x					x
Ax			x			x				x	x	x			x
Ay			x			x				x	x	x			x
Yaw rate			x			x				x	x	x		x	x
Speed	x					x				x	x	x		x	x
Roll angle			x			x				x	x	x			x
Roll rate			x			x				x	x	x			x
Lat. and Long.			x			x				x	x		x	x	x
Compass heading			x			x				x	x		x	x	x
System State and Diagnostic															
Versions		x						x		x	x			x	
Heartbeats		x				x				x	x			x	
Failure codes		x				x		x		x	x			x	
Histograms		x							x	x	x			x	
Enabled		x							x	x	x			x	
Road Characteristics															
Limited access		x				x					x		x	x	
Ramp		x				x					x		x	x	
Major surface		x				x					x		x	x	
Minor surface		x				x					x		x	x	
Local		x				x					x		x	x	
AADT		x						x		x	x		x		
Number of thru lanes		x						x			x		x		
Urban flag		x						x			x		x	x	
Paved flag		x						x			x		x	x	
Function class		x						x		x	x		x	x	
Time of Day															
Solar zenith angle			x			x				x	x		x	x	
Traffic															
Number of targets		x				x				x	x		x	x	
Location of targets		x				x				x	x		x	x	
Estimated traffic density		x				x				x	x		x		
Trip Summary Statistics															
Distance traveled				x					x	x	x			x	
Counts of events				x					x	x	x			x	
System availability time				x					x	x	x			x	
Vehicle location				x					x	x	x			x	
Vehicle ID									x	x	x			x	

Data Category	Source				DAS Format					Platform		To Monitor			
	Vehicle Bus	System Bus(s)	UMTRI (AtoD)	Other	Custom	10 Hz series	Triggered Event	Transitional	Aggregated	Heavy Truck	Light Vehicle	Driver Activity	Environment	IVBSS	Vehicle
Weather															
Precipitation				x				x		x	x		x		
Wind speed				x				x		x			x		
Wind direction				x				x		x			x		
Temperature				x		x				x	x		x		
Visibility				x				x		x			x		
Atm pressure				x				x		x			x		
Video															
Forward				x	x		x			x	x		x		
Left side				x	x		x			x	x		x		
Right side				x	x		x			x	x		x		
Cabin				x	x		x			x	x	x	x		
Face				x	x		x			x	x	x	x		
Driver Characteristics															
Age				x					x	x	x			x	
Gender				x					x	x	x			x	

5.2 Light-Vehicle and Heavy-Truck Dedicated Instrumentation

In addition to the measures from the warning system and the vehicle CAN, UMTRI will instrument each platform with a complementary set of sensors that will support and provide additional signals for the analysis phase of the project. These instruments are not part of the system and will be installed to provide an independent measure of critical metrics both for the analysis and confirmation of system and vehicle performance. For both platforms, the additional sensors will include the following:

- **DGPS**: UMTRI's own differentially corrected GPS module and associated antenna. Measures from this device include latitude, longitude, heading, speed, time and week, number of satellites, and Pdop (percent dilution of position, which is measure of the geometrical strength of the GPS satellite configuration).
- **Yaw Rate**: A stand-alone yaw rate sensor to measure angular velocity. The sensor is ruggedized for transportation applications and has a -60 to 60 deg/s resolution. A routine in the DAS software will zero the transducer each time the vehicle stops for at least 60 seconds.
- **Accelerations**: A bi- or tri-axial high-precision accelerometer will be used to measure at least longitudinal and lateral accelerations. The unit will be mounted near the lateral and longitudinal vehicle mid-point and as close to the vertical center-of-gravity as possible on light-vehicle. On the heavy truck, UMTRI will position the unit on the unsprung mass if

possible, ideally on the front axle; however, if this is not feasible, then on a rigid cross-member of the frame rail.

- **Steer Angle**: For light vehicles, steer angle is available via the engine control bus. For heavy trucks, UMTRI hopes to have ITE install a unit during production that is either part of a stability control package offered by a supplier (stability control devices are not normally part of the Con-way tractor specification and in these tractors any active control by this subsystem would be disabled). However, if this is not feasible, UMTRI would explore installing a customized steer-angle transducer as part of the DAS installation processes.

5.3 Camera Positioning for Video Collection

All FOT vehicles on both platforms will be instrumented with five cameras to capture images of the driving scene and driver activity. The exact placement of the cameras on each platform is currently under review; however, UMTRI will capture the following: (a) the forward scene; (b) rearward directed left- and right-side scenes; (c) the driver's face; and (d) the driver's hands via a cabin-mounted camera directed over the driver's right shoulder. Sample snapshots of these views are shown in Figures 10 through 12.

The major reasons for capturing the video data are to:

- Understand circumstances associated with individual episodes, including the forward scene roadway, environment, and traffic, as well as the driver's general direction of gaze;
- Provide samples of roadway type, environment, traffic, and driver behavior at periodic intervals; and
- Aid in determining certain "truth" variables through calculations based on manually assisted extracting of data from images.

The specifications of the five cameras on each platform are still being analyzed with selection criteria that include: field of view, vertical and horizontal resolution, minimum illumination, packaging and mounting considerations, and self-illumination (infrared) for images at night or in darkness. Currently, all cameras will be black-and-white CCD imagers with an analog output (RS170), with the exception of the forward camera, which is shared with the LDW system. For each of the cameras, the images captured by the DAS involve sub-sampling the original image.

Figure 10. Sample cabin and driver face images

Figure 11. Sample forward image

Figure 12. Sample left-side rear-looking image

5.4 Video Data Compression and Sampling Rates

As with previous FOTs, the video archive consumes large amounts of memory and is estimated to be approximately 80 percent of the total FOT data volume. For this FOT, all video data will be compressed both spatially and temporally using H.264 (MPEG-4) video compression.

Video data is likely to be collected using frame rates that vary between two or three discrete frame rate values, depending on the circumstances. Images from the cameras may also be sampled at different rates during the same time period. Without direct experience with the crash warning functionalities, the tentative plan is to collect video from each camera in two distinct modes. The first mode is referred to as an exposure mode with a constant frame rate per second. The frame capture rate for the exposure mode will vary by camera and be between 1 and 10 Hz. The second mode is a triggered or episodic mode. In this mode, warning- and driver-related events will trigger a higher-rate episode to be captured, which has both a pre- and post-view window surrounding the triggering event. The collection rate of episodes will be at least 10 Hz.

5.5 Audio Data Collection

Audio data will be collected using triggers that include those used for video. The time duration of audio data collection is not established; experience on another FOT project will prove useful.

Tentatively, audio might be collected for 10 sec around the time of these triggers. The purpose is to hear any audio tones. In addition, audio will be collected for 20 sec following a driver's comment button press. Again, this time may be adjusted based on experience gained before the launch of the FOT.

Audio data is collected using circular buffers, as is video. With audio, however, the buffers consist of 0.5-second-long chunks of audio data, so that the time at which audio data capture begins is "quantized" by 0.5 second. The data itself will be collected at 8 KHz (tentative), with one byte of resolution. The format of this file is not determined, but it is not likely to be a standard Windows desktop format (e.g., WAV file), and will require some simple software to replay. Again, the tradeoff is multiplying the amount of data coverage at the cost of a few dozen lines of computer code to view or hear the data.

5.6 Data Acquisition System

UMTRI will design and fabricate a data acquisition system for each vehicle on both platforms of the FOT. It will be installed in each vehicle as a complement to the system and function as both a data-processing device as well as permanent recorder of the objective and video data collected during the field tests. The sections below describe the design and operation of the DAS.

5.6.1 DAS Main Module

DAS packages are being designed and constructed to meet the test requirements of the FOT and physical configuration of the FOT vehicles. Figure 13 shows the unfolded light-vehicle prototype DAS. The heavy-truck DAS will be same except for a different arrangement of the external connectors to accommodate the integration of the DAS in the truck. The package consists of four subsystems comprising a main computer, video computer, power controller, and cellular communications unit.

The main computer consists of an EBX form-factor single-board computer (including display, and Ethernet controllers), two PC104-plus CAN cards, a PC104 analog and digital interface card, and an automotive hard disk. All of these components operate over a –30C to +85C temperature range.

The video computer consists on an EBX form-factor single-board computer (including display, audio, and Ethernet controllers), two PC104-plus Mpeg4 encoder cards, a digital interface card, and an automotive hard disk. The temperature range of this system also operates from –30C to +85C.

The computers are configured to permit headless operation while a subject has the vehicle and hot-pluggable keyboard, mouse, and video operation for maintenance and troubleshooting activities. Figure 14 shows the location of the connectors for use in data upload and maintenance. The two computers are normally connected to each other via a crossover cable between the two network connectors. During upload this cable is removed and the two computers are plugged into a building Ethernet switch. A battery charger, on-off switch, and mode select switch plug into the mode connector.

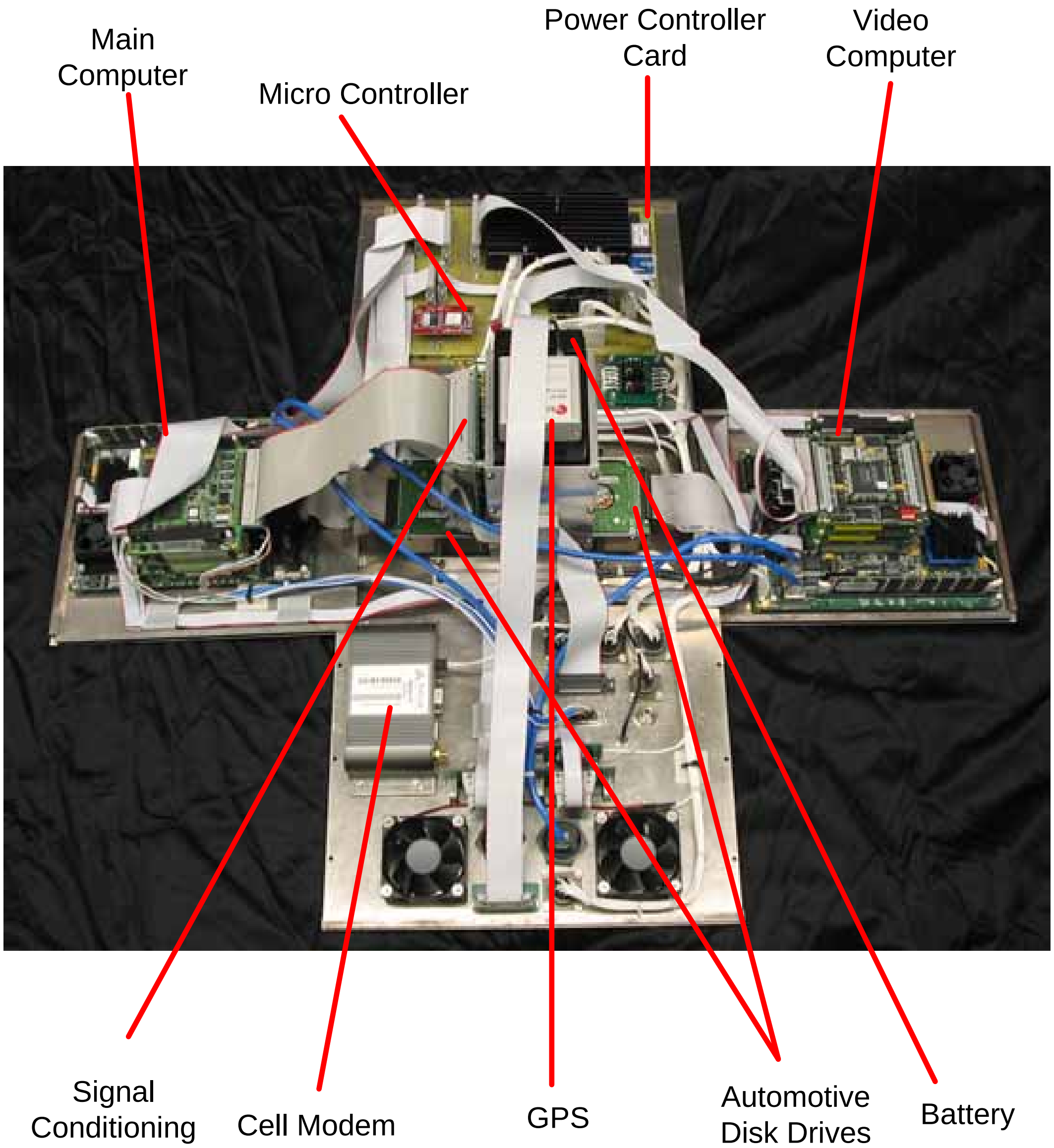


Figure 13. Major light-vehicle DAS components

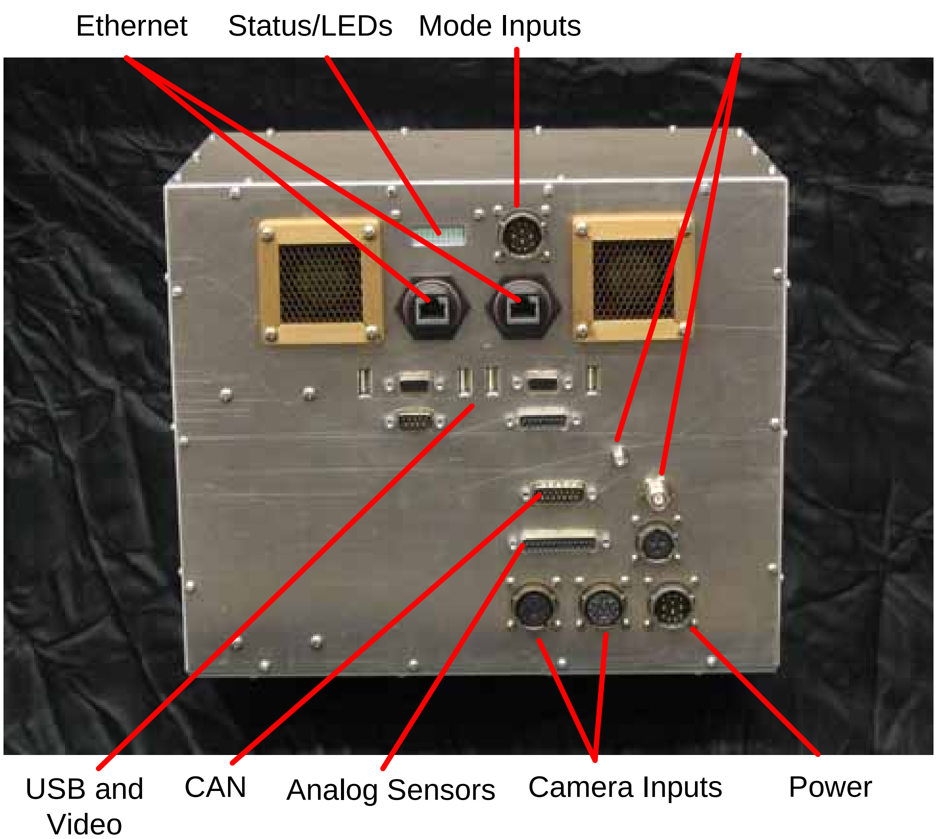


Figure 14. DAS, vehicle, and user interface

5.6.2 Modes of System Operation

The system can operate in one of eight modes: FOT, Characterization, Demo, GUI, Maintenance, Upload, No CPU, and Toggle. Figure 15 shows the mode control box that is currently in use. It consists of a rotary mode switch and a toggle power switch. These switches, along with a battery charger, are connected to the DAS via the mode connector. If nothing is plugged into the mode connector (normal FOT operation) or if the mode control box is plugged in and the rotary switch is in the "FOT" position, the ignition signal controls the power sequencing and the system runs in the unattended FOT mode. Otherwise the toggle switch powers the computers (the rest of the vehicle remains off), and the computers run the appropriate programs. The DAS mode box also has a shroud (which is not obvious in Figure 15) to prevent accidental movement of the toggle switch. The following sections describe the operational modes of the DAS.

Figure 15. DAS mode control box

5.6.2.1 FOT DAS Mode

The FOT software will be configured to organize all of the gathered data by trip. The main system decodes the CAN messages and extracts the appropriate signals, and scales and converts the data as necessary. Derived channels are then calculated and selected information is logged to a time-history file. The system is capable of logging raw CAN messages to a separate file for debugging purposes. Slowly changing or intermittent channels are logged transitionally. That is, a transition log is created, capturing transition events by their channel identification, timestamp, and data values.

An episode-processing task will monitor the incoming primary and calculated channels for the occurrence of significant episodes (e.g., collision warnings, lane departures, etc.). When an episode is detected, the main system logs details of the alert in a triggered-summary file, and sends a message via Ethernet to the video system. The video system then captures a retrospective clip of audio data extending some time period back from the moment of the episode transition. Transition counts, histograms, errors, and other trip summary information will be recorded to a trip log at the end of each trip. When a trip ends, the main system activates the cellular system to transfer data via modem to UMTRI. Once the transfer is complete, all systems are turned off.

The audio/video system continuously digitizes, encodes, and buffers the output of five video cameras and one microphone. When an episode trigger is received from the main system, the audio is saved to disk (video is saved continuously).

5.6.2.2 Upload Mode

When the mode switch is in the “Upload” position, both computers will automatically transfer the files (of the returning driver) to their respective servers. The main computer maintains a catalog (in an Access database) of all data files generated for each trip. The upload program replicates the catalog to an SQL Server database, copies the files to a specific folder on the data server, and initiates the loading of data from files into tables in the database. The video computer logs onto the video server, uploads video catalog, and transfers the video files.

5.6.2.3 GUI DAS Mode

This mode is an enhanced version of the FOT DAS that includes real-time display capability for any of the data channels defined in the project. This mode will be used for DAS validation, on-track testing, and system troubleshooting. LCD panels (powered by their own DC-DC converters) will be plugged into the VGA connectors on the interface panel. Almost all the data on the CAN bus will be parsed, scaled, and available for display. The video system will show the images from both cameras on the screen enabling real-time feedback for camera adjustments. Figure 16 shows the vehicle page of the light-vehicle GUI DAS.

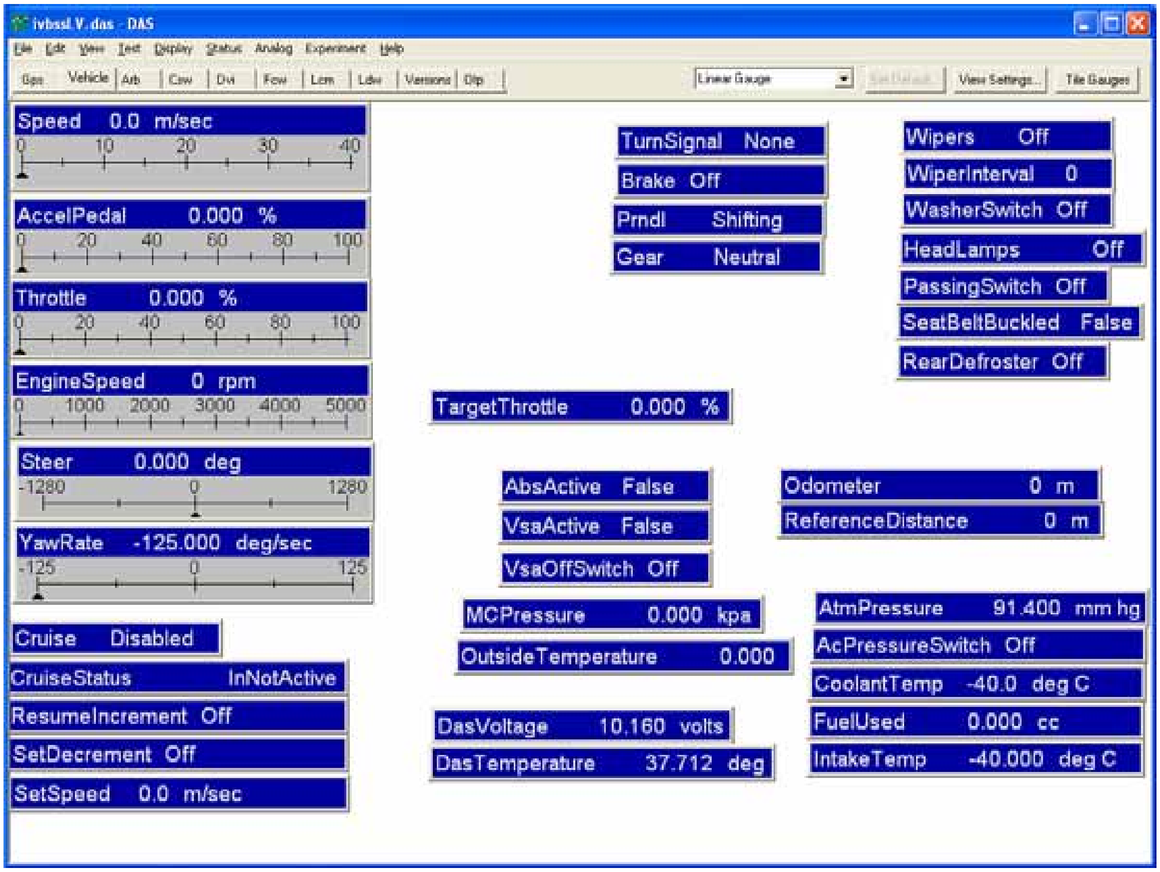


Figure 16. Vehicle page of the light-vehicle GUI DAS

5.6.2.4 Characterization and Demo Modes

These modes will be used during characterization-checkout experiments between drivers and for the driver training and demonstration trip. Data will be logged as in the FOT, but labeled and stored separately from the FOT data archive. Starting the computers by the toggle switch will cause the “System Enable” relay to be switched to the “system on” state.

5.6.2.5 Maintenance Mode

In maintenance mode, the computers will be connected to the building Ethernet (or a laptop if necessary in the field) and will run file-sharing (server) services. This will permit changing of software, configuring project databases, driver setup, and file management from a host PC.

5.6.2.6 No CPU and Toggle Modes

If the mode is set to “No CPU,” only the microcontroller is powered when the ignition switch is engaged. This setting is used when the vehicle is sent to the dealer for repair or maintenance. The

"Toggle" mode toggles the system-enable relay on and off. This allows a researcher to manually enable or disable system functionality as presented to the driver.

5.7 DAS Remote Monitoring

To monitor the functionality of the DAS and warning system, UMTRI will customize the DAS software to compute and report summary statistics that help flag and identify problems and failures with the system and the DAS itself. For example, specialized routines will compute the distance between the last and first GPS coordinates from sequential trips in order to determine if mileage (and therefore DAS trips) is missing from the data archive. Additionally, UMTRI will download and scrutinize the event logs from the DAS to look for unexpected operating system events from the main and video CPU modules in each DAS. The results of these efforts will then be loaded into a database and linked to specialized web pages to display functional and operational information to the program partners using a Web browser. On light vehicles these summary and diagnostic numbers will be downloaded using an on-board cell modem to an UMTRI server following each ignition cycle. On heavy trucks the data will be automatically downloaded to UMTRI, either through a wireless area network at the fleet distribution terminal in Romulus or by using a cell modem approach similar to the light-vehicle platform. With both platforms the approach is to provide current summary and diagnostic information for engineers to remotely monitor the fleet on both platforms on a continuous basis throughout the entire FOT. Figure 17 shows a sample of the Web interface from the Road Departure Crash Warning (RDCW) project.

Figure 17. Web interface for RDCW

5.8 DAS Data Retrieval

Data will be retrieved from the DAS on a regular basis for both platforms. As in past UMTRI FOTs, comprehensive routines and protocols will be used to ensure that all DAS recorded data has been copied, loaded into a database, and backed up before being deleted from the DAS itself. The approach for data retrieval is platform-dependent and outlined in the sections below.

5.8.1 Light-Vehicle Data Retrieval

Data retrieval for the light-vehicle platform will occur when the subjects return their vehicles to UMTRI at the conclusion of the testing period. Upon arriving at UMTRI, the subjects will be asked to complete some post-FOT questionnaires while the vehicle or DAS is being connected to the UMTRI intranet for the post-FOT driving scenario interview, in which a researcher presents the subject with detailed views of their driving experience while asking them questions related to their experience with the system. Following the interview, the contents of both the video and main computers on the DAS will be uploaded to computer servers for loading into the FOT database and file backup.

5.8.2 Heavy-Truck Data Retrieval

Retrieval of heavy-truck data will occur using manual data retrieval, as initial estimates in excess of 500 MB per hour for both video and objective data is beyond the capacity of a current wireless area network given the allowable time for the download to occur. That is, since the video files will be significant, there is a distinct possibility that a typical download cannot finish within the allowable time window. An on-site server and data download mechanism has been arranged with Con-way. The equipped tractors will have designated parking spots located alongside Con-way's trailer maintenance facility and adjacent to the tractor parking area. These spots will be equipped with data retrieval "umbilical" cords that need only to be plugged in to initiate data transfer. Con-way has agreed to assist UMTRI in this process to ensure that individual tractor units are downloaded on a regular basis. For data and system quality monitoring, UMTRI will use the on-board cell modem approach similar to that used in light vehicles to monitor the health of the fleet. Data from the fleet would then be uploaded into the appropriate database and backed-up for archiving.

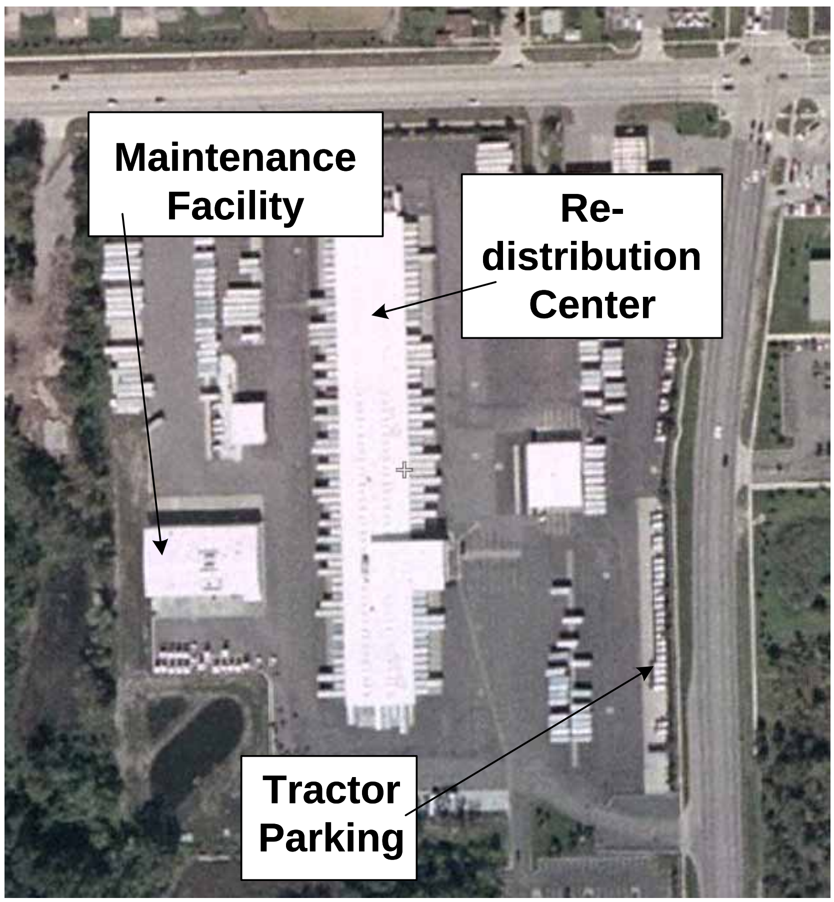


Figure 18. Plan-view of the Con-way facility at Romulus, Michigan

5.9 External Data Sources

5.9.1 Digital Maps

The light-vehicle fleet has chosen the NavTeq digital road map. The data signals associated with the onboard digital road map can be found in section 7.A.i. The availability of these maps is determined by the contract Visteon has with NavTeq. The project will provide access to Volpe for whatever NavTeq digital data is necessary. This access will be similar to that provided in the RDCW FOT project. The heavy-truck fleet will not be using an onboard digital map.

5.9.2 GIS Data

The project anticipates using a variety of spatial database resources, including the Highway Performance Monitoring System data for Michigan roads. The project will also use spatially calibrated aerial photos and a digital base map for southeast Michigan, both generated by the Michigan Center for Geographic Information. In addition, the traffic control inventories for Washtenaw and Oakland counties and the signalized intersections inventory for southeast Michigan are also available.

5.9.3 Crash History Data

The project has access to more than 10 years of Michigan Office of Highway Safety Planning crash data. The crash data fields include time of day, weather, driver, vehicle, and crash type information; and geographic location of the crash.

The project anticipates using two to five years of crash data to determine the clusters of crash types addressed by the program. The location of crash clusters addressed by system technologies will be determined using spatial statistical tools. These tools determine clusters of crashes that are statistically significant based on their location.

The project also anticipates developing spatially significant clusters of system warning alerts. The clusters of alert and crash history will be analyzed to help determine the predictive quality of the warning systems relative to actual crash patterns.

5.9.4 National Radar Weather Data

UMTRI has been engaged for some time in conversations with the Weather Systems and Assessment Program, Research Applications Laboratory of the National Center for Atmospheric Research (NCAR) in Boulder, Colorado. The preliminary plan is to post-process radar data that are obtained from the National Climatic Data Center with the assistance of NCAR. NCAR processes codes that will allow UMTRI to calculate active precipitation from the radar data using GPS time and location information recorded onboard the vehicles. This data can then be stored in a separate table in the FOT database and used in conjunction with the windshield wiper state from the vehicle data to determine any potential influence that active precipitation has on driver behavior, particularly driver reaction time to warnings.

5.9.5 Con-way Delivery Logs

To supplement the data collected onboard equipped tractors, UMTRI is currently working with Con-way to determine which of the following logistical data are available for electronic download from the fleet versus which are not electronic and therefore will have to be provided manually (driver activities, freight hauled, customers visited, driver, equipment used during the FOT and, more specifically, for a given tour or segment of a driver’s day). Since Con-way drivers do not use a fleet-based monitoring system to record their driver activities, UMTRI will rely on this logistics information for a number of critical associations in the FOT database (most importantly the association between data collected on a specific tractor on a given trip and the driver making the delivery). Since Con-way runs a quasi-slip-seat operation (i.e., there will be more than one driver for each of the FOT tractors), UMTRI cannot rely on a simple scheme of assigning drivers to tractors to make this critical association.

UMTRI will also use logistics information for estimating the total vehicle weight and configuration. A database of Con-way equipment specifications will allow UMTRI to track and classify the different vehicle configurations that the fleet runs. Generally, these are double-trailer combinations for their line-haul operations and single-trailer combinations in their pick-up and delivery routes; however, there are variations and this distinction will be important to fully understand system and driver performance issues. Drivers will input the trailer configuration via the DVI. Post-trip analysis of the M/A-COM radar may be used to verify the driver selection along with a quick review of the rear-looking video data. Tractor-trailer configuration will be part of the dataset. Regarding total vehicle weight, UMTRI will aggregate estimated pallet weight that is tracked by the Con-way logistics system. These data, along with an estimated weight value derived using tractor drive train performance measures (engine torque and speed, gear and vehicle speed), will provide insight into how driver and vehicle performance may vary as a function of the gross vehicle weight, which has already been shown to have a measurable effect on driver behavior.

The processes to retrieve logistical data will be tested in the extended pilot test. Additionally, vehicle maintenance information will be requested from Con-way.

5.10 Participant Descriptors and Assessments

UMTRI is currently engaged in the S05 Task 5 (Driver Assessment Plans) for the SHRP-2 Field Study. As part of this task, UMTRI has participated in the identification of numerous instruments that could be used in assessing, or describing, driver characteristics and capabilities. The goal on the S05 Task 5 was to develop an assessment program that could reasonably be applied to all participant age groups, and do so within a two-hour period.

However, in the IVBSS FOT, there will be only about 10 to 15 minutes to conduct assessments with the participants, and a limited amount of time to have the participants complete certain instruments at home, prior to arrival. As such, this program cannot attempt to replicate all of the assessments and descriptors being undertaken on the SHRP-2 program, desirable as it might be. Instead, a subset of the tools being proposed for use in SHRP-2 is proposed (see Table 6); in addition, it will be determined whether the item will be completed in-person or by the participant at home. All instruments will be administered to drivers on both platforms, but the content of the driving knowledge questionnaire will vary between platforms, with the heavy-truck drivers receiving questions that are pertinent to commercial driving requirements.

Table 6. Driver assessment and descriptor summary

Risk-Taking Behavior	Cox Assessment of Risk Driving Scale	At home	2
Risk Perception	CARDS items combined with DeJoy Risk Perception Questionnaire	At home	2
Driver Behavior	Manchester Driver Behavior Questionnaire	At home	5
Driver Style	Manchester Driver Style Questionnaire	At home	5
Thrill/Adventure Seeking	Sensation Seeking Scale	At home	5
Driving Knowledge	Custom questionnaire based on state licensing tests	In-person	10

5.10.1 Driver Biographical Information

Driver biographical information that will be collected includes age; gender; ZIP code; estimated income; highest level of education completed; occupation; and the make, model, and year of a participant's primary and secondary vehicles. Some of this information will already be known from the participant's driving record, while the drivers themselves provided other data. Additional information that will be self-reported includes years or driving experience, miles driven annually, whether the participant smokes, and whether the participant wears eyeglasses or contact lenses.

5.10.2 Michigan Driving Records

Michigan driving records (a listing of police-reported crashes, moving violations, and motor vehicle-related convictions) will be obtained for each participant in both the light-vehicle and heavy-truck field tests. UMTRI is now a repository of these driving records, receiving biannual updates from Michigan. As such, once approval to use the records on the IVBSS program is obtained, it will be possible to obtain relatively current versions of a participant's driving record.

6 Subjective Data Collection

6.1 Participant Self-Characterization

Both heavy-truck and light-vehicle participants will receive and complete the driver behavior questionnaire and the driver style questionnaire prior to their participation in the FOT. These instruments are described below in detail.

6.1.1 Driver Behavior Questionnaire

The driver behavior questionnaire (DBQ) is a 24-item questionnaire. The DBQ was developed in Great Britain and evaluates features of drivers' self-reported behaviors while driving. Each item on the questionnaire is a five-point Likert-type scale that lists a particular behavior and asks whether the driver engages in that behavior "never, hardly ever, occasionally, quite often, frequently, or nearly all the time." Because all of the questions ask about "negative" driving behaviors, lower scores on the DBQ represent positive attributes.

The version of the DBQ that will be used in this study was modified to better reflect the spelling, grammar, and driving situations present in the United States (Parker, Reason, Manstead, & Stradling, 1995). The items on the questionnaire can be grouped to examine three types of driver behaviors: errors, lapses, and violations (Reason, Manstead, Stradling, Parker, & Baxter, 1991). Errors are failures or misjudgments of an unintentional nature or the failure of a planned action to achieve its desired consequence. Errors are sometimes dangerous for other drivers. Lapses are more harmless events resulting from inattention or slips in memory. Violations are deliberate acts that break social norms such as speeding or running a stop sign (Parker et al., 1995). Errors and violations are the two behaviors theorized to contribute to road accidents (Reason et al., 1991).

Subscale scores for lapses, errors, and violations will be calculated by averaging the respective scores for all items that are included in the given factor. The scores will be used as factors in regression models to determine if they can be used to predict driver acceptance.

6.1.2 Driving Style Questionnaire

The driving style questionnaire (DSQ) is a 15-item questionnaire also developed in Great Britain that evaluates features of drivers' self-reported style while driving. The DSQ is structured almost identically to the DBQ (with five-point Likert-type scales and the same anchors). However, not all items are scored the same way; some are reverse-coded (which is described in greater detail below).

As with the DBQ, the version of the DSQ that will be used in this study is a modified questionnaire that better reflects the spelling, grammar, and driving situations present in the United States. The items on the DSQ can be used to evaluate six factors of drivers' style: focus, calmness, social resistance, speed, deviance, and planning (French, West, Elander, & Wilding, 1993). Focus relates to one's ability to drive cautiously and ignore distractions. The ability to stay calm in dangerous and quick-paced situations is measured by the calmness scale. The social resistance scale measures the driver's preference for being given advice about driving abilities. The speed scale contains questions related to whether one drives fast or over the posted limit. The deviance scale relates to behaviors that are inconsiderate to other drivers and often dangerous, like passing on the right or running a red light. Finally, planning contains questions regarding a driver’s tendency to plan ahead before setting out for a trip. The DSQ was constructed to include questions about behaviors related to accidents, decision-making styles, and reactions to advice that others give (West, Elander, & French, 1992). Scores for the six factors consist of averages across the items belonging to each factor. However, because of the reverse-coding for some items, not all factors follow the same relationship. Thus for the focus and planning subscales, higher scores represent positive attributes. All six driving style scores will be used as factors in regression models to determine if they can be used to predict driver acceptance.

6.2 Post-Drive Questionnaires

For the light-vehicle FOT, two post-drive questionnaires are anticipated. An extensive questionnaire will be completed during the debriefing session at UMTRI. Additionally, there will be a shorter, take-home questionnaire that drivers will complete after their debriefing sessions. The post-drive questionnaire from the RDCW FOT provides a detailed example of the types of questions that will be included in the post-drive questionnaires. In order to limit the debriefing session to two hours, the on-site, post-drive questionnaire will include questions of the highest priority and interest while the take-home questionnaire will include questions of interest, which are of lesser priority. UMTRI will work with Volpe to develop the questionnaires and to determine the priority of the questions. The questionnaires will be administered in an online questionnaire. For those drivers who do not have access to a computer or are not comfortable using a computer, paper copies of both questionnaires will be provided.

For the heavy-truck FOT, it is likely that there will only be one questionnaire that drivers will complete. UMTRI and Volpe will work collaboratively to develop the questionnaire. This questionnaire will also be administered online.

The light-vehicle and heavy-truck subjective data analyses will be conducted separately, but a similar approach will be used for both data sets. Factor analysis will be used to reduce the data from the post-drive questionnaires. Factor analysis is a data reduction procedure that endeavors to identify underlying factors that explain most of the variance observed in a much larger number of variables.

Stepwise regression analyses will be run to determine if models can be constructed to predict drivers’ perceptions of the system based upon a host of independent variables. Factor scores from the factor analyses will serve as the dependent variable in a series of multiple linear regressions. The independent variables for each analysis will be age (three levels for light-vehicle), gender, education (three levels: high school graduate, some college, and Bachelor’s degree or greater), median family income (obtained by driver ZIP code from the 2000 U.S. Census), alerts/100 miles, false alerts/100 miles, composite scores from the DBQ (error, lapse, and violation), and composite scores from the DSQ (calmness, deviance, focus, planning, speed, and social resistance).

Data from the Van der Laan scale of acceptance will be used to determine overall driver acceptance of the warning system as well as compare driver acceptance of the system to driver acceptance of other driver assistance systems (e.g., RDCW).

6.3 Post-Drive Debriefing

In past FOTs, the post-drive debriefing session was a two-hour session consisting of drivers completing an extensive questionnaire about their experience with the system and viewing selected video of situations in which a warning was received to provide an assessment of a subset of the warnings that they received. It is anticipated that the post-drive debriefing sessions will be conducted as follows. While a driver is completing the post-drive questionnaire, a researcher will review the video associated with as many warnings as possible. The researcher will select approximately 20 video clips to show to the driver. The driver will be shown a digital map displaying the location of the warning as well as the date and time that the warning was received. The driver will be asked to assess "how useful" and "how necessary" a particular warning was. Further, drivers will be asked for the rationale concerning their assessment of how useful or how necessary a warning was. Whenever possible, the researcher will select valid and false warnings for each type of warning.

Light-vehicle drivers will be debriefed at UMTRI. The specifics of when or where the heavy-truck drivers will be debriefed are yet to be determined.

An analysis of "how useful" the warnings were will be completed. This analysis will consist of a linear mixed model analysis including age group, gender, driving scenario, and any secondary behaviors in the model.

6.4 Focus Groups

By allowing group discussion and interaction, focus groups are capable of generating data that may not emerge from more structured written questionnaires. They not only provide details about what people think, but often why they think the way they do. However, focus group data does not lend itself to quantitative analyses for a variety of reasons; rather, it is more likely that patterns or themes may emerge. For example, the number of times certain issues are mentioned, the tone of voice that participants use, and even the things that are *not* said can often reveal subtleties of opinion. Thus, the range of information gleaned from past FOT focus groups provides a partial story concerning system acceptance.

Each past FOT (e.g., Automotive Collision Avoidance System [ACAS] and RDCW) focus group consisted of 6 to 10 drivers who had completed participation in the FOT. All of the drivers who participated in the FOTs were invited to attend a focus group with about one-third of the drivers participating in a focus group. Each of the focus groups was asked the same questions in the same order. Discussion was guided by a combination of the facilitator and a PowerPoint presentation that displayed the questions. Each focus group was videotaped and a transcriptionist was present.

Focus groups conducted during the IVBSS FOT will be conducted in a similar manner to those held during the ACAS and RDCW FOTs. Every driver who completes the FOT will be invited to attend a focus group.

Currently, holding focus groups with the heavy-truck participants is still under consideration. Given that all of the truck drivers know each other, there are confidentiality concerns.

Since focus group data do not lend them themselves to quantitative analyses, the focus groups' responses will be analyzed qualitatively to determine drivers' general impressions concerning the safety, convenience, comfort, and willingness to purchase the system.

7 Management of the Light-Vehicle Fleet

This section details the management of the light-vehicle fleet. During the 12 months of field operational testing, fleet management will entail: (1) vehicle circulation; (2) procedures for vehicle turnaround between subjects; (3) routine maintenance and verification of system functionality; and (4) procedures for handling incidents and emergencies. These items are elaborated upon in sections 7.1 through 7.4, respectively.

In support of the light-vehicle FOT, vehicles will undergo two types of tests: characterization tests and checkout tests. Characterization tests will take place during pre-deployment (i.e., between the time that each vehicle is received from Visteon or Rousch and its delivery to the first participant). These tests, therefore, are performed once per vehicle prior to the FOT. The procedures for characterization testing will be derived from a subset of the IVBSS light-vehicle verification test procedures. Checkout tests are performed as part of the turnaround process, taking a vehicle that has just been turned in by one participant and checking its readiness for release to the next.

7.1 Light-Vehicle Deployment Plan

The field operational test spans a total period of 52 weeks using a vehicle circulation plan as depicted in Table. In a typical week, either two or three vehicles will be returned at the beginning of the week and sent out again with new participants at the end of that week. The FOT startup will be staggered such that the deployed fleet ramps up to a total of 16 dispatched vehicles over the first six weeks. Given an experimental design based upon a six-week driving period for each test participant, the first vehicles to go out will return to UMTRI early in the seventh week. At that point, they will be put through the "turnaround process" and then dispatched to new participants later that week. Similarly, at the end of the FOT, the circulation pattern ramps down such that only two or three vehicles will be returned in the last week.

The total of 108 participants driving for six weeks each requires that 648 car-weeks of valid testing be accomplished in order to complete the FOT, as designed. In terms of the resources by which to satisfy this design, 52 calendar weeks and a 16-car active fleet (with a seventeenth car kept in reserve) make up the nominal plan. When these resources are totaled, given the necessary inefficiency of the ramp-up and ramp-down periods at the beginning and end of the test period, 700 car-weeks of capacity are seen to be available.

The FOT needs to assume a less-than-100-percent effective engagement for circulating vehicles across the test period because it is certain that less than full reliability will materialize in both the test fleet and in the human participants. That is, in the end, some number of candidate car-week slots will not have contributed to the FOT's valid dataset. Experience has shown UMTRI that something in the 80 to 90 percent range is a reasonable expectation for test efficiency.

The human- and equipment-based contingencies call for a flexible process of car assignment whose primary goal is to maximize the rate at which the cells of the experimental design are completed. Valid completion, of course, requires that the right data be collected from assigned persons who each complete the full assigned driving period with the warning system performing as intended.

Thus, for example, a subject who experiences some kind of critical system fault after, say, four weeks of driving must be provided almost immediately with a replacement vehicle for finishing the six-week cycle of the test assignment, lest the subject be lost entirely from the experiment. If a participant's driving assignment is interrupted by more than a day or two, for example because no spare car is available, the discontinuity in the person's experience using the warning system would be thought to invalidate any subsequent data gathered thereafter. This harsh reality calls for keeping at least the seventeenth car of the fleet on reserve from assigned circulation so as to be able to recover a subject who would otherwise be lost due to test interruption.

7.2 Procedures for the Turnaround and Release of Light Vehicles

During each typical week of the FOT, two or three vehicles would be rotated out of field service and then back in again. Monday and Tuesday will be designated as receiving days, while Thursday and Friday will be launching days in this turnaround procedure. Vehicles that were returned on Monday would be typically sent out again with a new subject on Thursday, and vehicles returned on Tuesday would be launched on Friday. Noting the turnaround gap in this procedure, the actual time duration of the typical person's test assignment is six weeks less two days, or 40 days. Depending upon one's personal availability for picking up or dropping off a test vehicle, or other contingencies, the total duration of an individual's participation could vary by one or two days from the basic design of a 40-day exposure.

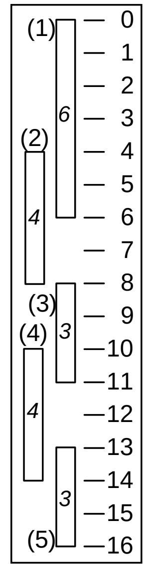
The plan for turnaround tasks, shown in Table 7, is based upon an available time period of two days (16 work hours) for completing the activity on an individual car. The table addresses both the automotive and system/data aspects of the test vehicle's readiness for the next launch, showing the nominal time blocks needed for completing each activity. A detailed checklist corresponding to Table 7 will be developed, and evolve over time as experience is gained from operating and maintaining the FOT vehicles.

7.2.1 Ensuring Integrity of Retrieved Data and DAS for Light Vehicles

Diagnostic tools will be incorporated into the data acquisition system (DAS) software and the processing that occurs after receipt of data onto the FOT servers at UMTRI. This form of monitoring will ensure (within feasible limits) proper system operation, so that UMTRI can readily detect (via the cellular modem trip summaries) any problems or limitations that have arisen with a vehicle in the field. This maintenance feature depends upon monitoring the data transmitted to UMTRI via cellular phone while vehicles are in the field.

UMTRI will screen and validate all FOT data as it is uploaded into the phone and FOT databases. As part of this process, trips found to have problems will be flagged and assigned a validity code describing the general nature of the data problem. Any data quality issues that are discovered while implementing the analysis and processing methodologies will be flagged and documented. The details of the data quality and tracking methods will be shared with the independent evaluator and FOT partners with the transfer of newly collected data, and also after the FOT has concluded.

Table 7. Plan for turnaround and release of light vehicles

(1) Data uploaded onto server.	
(2) Vehicle maintenance tasks. A checklist will be followed to cover items such as: - Safety, readiness, and functionality of all automotive systems; - Content of driver equipment (e.g., emergency tools, maps, etc.); - Content of documentation (e.g., instructions, insurance, etc.); - Periodic maintenance per OEM schedule; and - Cleaning	
(3) System maintenance tasks	
(4) Verification of the functionality of the system using a predefined set of driving maneuvers.	
(5) Verification that the DAS is working correctly and re-initializing the system for the next driver	

Hardware items will be inspected and adjusted, as necessary, during each vehicle's turnaround. The following checks will be performed by automatic data scan routines during each turnaround to ensure the integrity of the retrieved data and the DAS:

1. Consistency queries will be run automatically to check that:
   - The vehicle's odometer reading agrees with the accumulated distance recorded by the DAS;
   - The data file's duration agrees with the known (logged) test duration;
   - Start and end times of the recorded data correspond to the vehicle's launch and retrieve times; and
   - The data collection in any trip did not terminate prematurely (e.g., data files do not end with velocity > 0).
2. Confirmation that the DAS has properly captured the results of the checkout procedure tests (see next subsection).

7.2.2 Checkout Testing to Confirm Integrity of the Warning System Function

Prior to releasing a vehicle to the next participant, the integrity of the warning system will be tested to ensure both the safety and proper functioning of the system. Once a vehicle has been prepared and the data from the last participant have been uploaded, the vehicle will be test-driven by an experienced researcher to observe the warning system function. Such checkout tests will be performed at each vehicle turnaround.

Various aspects of the system will be exercised and, based on the observed response, the vehicle will be released or subjected to further examination. Data will be collected during these exercises to confirm the basic integrity of data collection and to document system performance, should any anomalies occur. The primary means to evaluate system performance in the checkout tests is the experimenter's subjective evaluation. Unless a problem is noted, the performance data are unlikely to be examined. Throughout this checkout process, the experimenter will also observe display interfaces to ensure that the proper adjustment settings and warnings are shown.

7.2.3 Normal Vehicle Maintenance

Normal vehicle maintenance will be done both by UMTRI staff and by an authorized Honda service shop. The maintenance task will be carried out through the following subtasks:

- UMTRI inspection; and
- OEM maintenance. Any repairs, if needed, and periodic maintenance per the manufacturer-recommended schedule will be performed by an authorized Honda service shop in the vicinity of Ann Arbor, Michigan. From the standpoint of service, each test vehicle differs greatly from the configuration of the as-sold Honda Accord. For this reason, arrangements will be made for one dedicated point of service; that is, a dealer that will assign dedicated maintenance personnel who are acquainted with the special nature of these test vehicles. The intention is that a test vehicle would be serviced only by the selected dealer unless road emergencies necessitate other arrangements.

7.3 Characterization of the Warning System Function

Each vehicle will be characterized prior to starting the FOT, from the time it is received from Visteon or Rousch until its assignment to an FOT participant. These tests, therefore, are performed once per vehicle. The purpose of this testing is twofold: to characterize the system's functionality and to exercise the vehicle and its DAS package before it is fielded. It is estimated that the effort associated with these tests is approximately one day per vehicle. Once the characterization of a vehicle is completed, the data will be examined to confirm system performance, as captured by the DAS. The intention is not to do an extensive engineering analysis on performance, but rather to determine that the dataset is complete and that each of the intended test maneuvers is properly recorded in the data.

Results from these tests will be used to ensure maintenance of consistent performance during the FOT. A list of tests will be derived from the verification tests performed in Phase I of the program.

7.4 Procedure for Responding to Incidents in the Field

At least two UMTRI staff members will be on call at all times via pagers or cell phones. These will generally be Human Factors staff that can address issues concerning the participant and contact UMTRI engineers as necessary should technical questions arise. While a vehicle is in the hands of a participant, a spare key will be hidden on each car and a spare set of keys will be retained at UMTRI to ensure ready access to the vehicle if needed. In the event of an accident or system failure, decisions are made on a case-by-case basis as to whether a particular driver should continue to participate in the FOT. These decisions will be made in collaboration with the U.S. DOT whenever possible, but always with an emphasis first on the welfare of the participants – followed closely by the success of the IVBSS program.

Accidents: In case of an accident, the participant will be instructed to contact the police and file a police report. If the accident involves an injury or another form of emergency, they will use the provided cell phone to contact 911 services. They will be instructed to notify the UMTRI contact person immediately if possible. UMTRI personnel and other team members will attempt to interview the participant to learn more about the causes of the crash and why the warning system did not help to prevent the crash. A decision will be made on a case-by-case basis whether the participant should be furnished with a replacement vehicle, so as to allow a completion of the test period and the collection of data.

Failed warning system or DAS: If either the system or the DAS fail, UMTRI will be notified by the participant or will discover the fault by means of the scrutiny of data via the automated cellular link. Depending on the type of failure, and after a consultation with Visteon/Takata if needed, one of the following courses of actions will be taken:

- Ask the participant to return the vehicle to UMTRI; or
- Dispatch UMTRI personnel to replace the vehicle in the field; or
- Dispatch UMTRI personnel to attempt a repair of the system in the field.

Unless the nature of the failure is seen as having excessively corrupted the driver's FOT experience, the general intention is to replace the vehicle in the field to allow completion of the driving assignment.

Failed Vehicle: In the case of a failure in one of the vehicle's automotive systems (unrelated to the warning system), the following procedures will take place:

- If the car is determined to be safe to drive, arrangements will be made for the participant to return the vehicle, or for UMTRI personnel to retrieve and replace the car. The vehicle will then be taken for repairs at the designated local Honda service center. A possible exception for this procedure will involve a failed vehicle at a location far from UMTRI; in that case the vehicle will be taken to the nearest Honda service center, together with direct communication from UMTRI to ensure that the service personnel recognize the unique nature of the FOT vehicle.
- If the car cannot be safely driven back to UMTRI, a tow vehicle will be dispatched to retrieve it. Depending on the type and level of damage, the vehicle will be towed to the nearest repair shop, or to UMTRI, or to Visteon's Technical Center.
- If stranded by the breakdown, the participant will be driven to home or work as needed by means of an UMTRI request to Metro Cars—a contracted limousine service operating in the Detroit area. UMTRI will establish an open account with Metro Cars to cover this contingency.

Underutilized Vehicle or Other Driver-Related Issues: If UMTRI determines that a vehicle is being underutilized, placed at risk, mishandled, or should otherwise be taken away from the participant, the vehicle will be retrieved after consultation with, and concurrence of, the U.S. DOT whenever such consultation is practically feasible.

7.5 Light-Vehicle Deployment Plan

Figure 19 shows the light-vehicle deployment plan, as discussed in the previous sections.

ID	Task Name	Start	Finish
1	FOT Light Vehicle 1	Thu 4/2/09	Mon 3/1/10
2	FOT Light Vehicle 2	Thu 4/2/09	Mon 3/1/10
3	FOT Light Vehicle 3	Fri 4/3/09	Tue 3/2/10
4	FOT Light Vehicle 4	Thu 4/9/09	Mon 3/8/10
5	FOT Light Vehicle 5	Thu 4/9/09	Mon 3/8/10
6	FOT Light Vehicle 6	Fri 4/10/09	Tue 3/9/10
7	FOT Light Vehicle 7	Thu 4/16/09	Mon 3/15/10
8	FOT Light Vehicle 8	Thu 4/16/09	Mon 3/15/10
9	FOT Light Vehicle 9	Fri 4/17/09	Tue 3/16/10
10	FOT Light Vehicle 10	Thu 4/23/09	Mon 3/22/10
11	FOT Light Vehicle 11	Thu 4/23/09	Mon 3/22/10
12	FOT Light Vehicle 12	Fri 4/24/09	Tue 3/23/10
13	FOT Light Vehicle 13	Thu 4/30/09	Mon 3/29/10
14	FOT Light Vehicle 14	Thu 4/30/09	Mon 3/29/10
15	FOT Light Vehicle 15	Fri 5/1/09	Tue 3/30/10

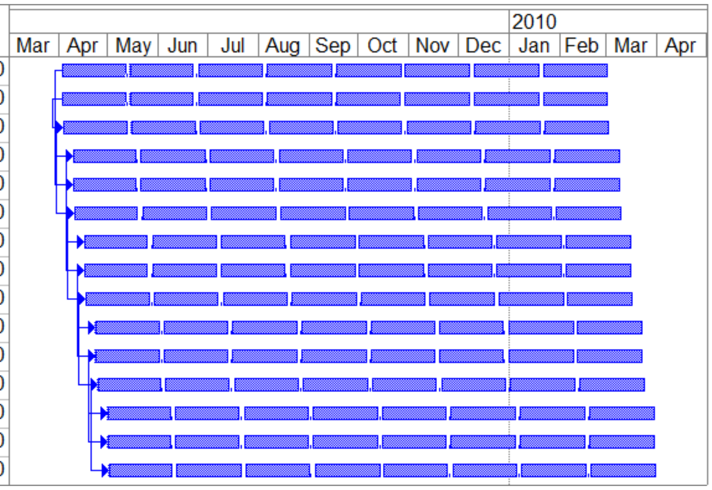


Figure 19. Light-vehicle deployment schedule

8 Management of the Heavy-Truck Fleet

This section provides details regarding the management of the heavy-truck fleet. During the 10 months of field operational testing, fleet management will include: (1) characterization of the warning system; (2) ensuring integrity of system functionality; (3) routine maintenance; (4) procedures for handling incidents and emergencies; and (5) deployment of the fleet. These items are elaborated upon in sections 8.1 through 8.5, respectively.

In support of the heavy-truck FOT, vehicles will undergo characterization tests during pre-deployment (i.e., between the time that each vehicle is received from Eaton/International and its delivery to Con-way). These tests, therefore, are performed once per vehicle prior to the FOT. The procedures for characterization testing will be derived from a subset of the IVBSS heavy-truck verification test procedures.

8.1 Heavy-Truck Deployment Plan

The heavy-truck FOT spans a total period of 12 months (52 weeks) with a staggered introduction of equipped vehicles at the start of the FOT. The 10-truck fleet will be deployed over a 3-month period. In mid-January the first four trucks will be given to the fleet to initiate the FOT. One month later, a second set of four trucks will be deployed. The final two trucks will be given to the fleet one month later. The deployment schedule was developed to put as many trucks into service as possible, while minimizing carrying costs for trucks owned by the fleet but not used in normal operations.

Once in service, each truck will be assigned to both a line-haul and P&D (pickup and delivery) route and be driven by the same two drivers on a daily basis for the duration of the FOT. Projections by the fleet suggest that these vehicles will be in service delivering freight for 16 to 20 hours per day during the business week. Based on this usage rate a total of 33,000 hours of operating time will accumulate for the entire fleet during the 12-month period.

8.2 Procedures for Downloading Data From the Heavy-Truck Fleet

Current plans are to download the data from each tractor every three weeks on a rotating basis by manually connecting a power/download cable to each DAS while it is parked at the distribution facilities on the weekends.[2] An outline of the procedure for downloading is shown below:

- Drive to the fleet on Saturday late afternoon or early evening.
- Move the candidate tractors to a dedicated outdoor-download location at the fleet and connect power and the download cable to the DAS on each tractor.
- Connect an external large-capacity hard drive to a dedicated project server located at the fleet.

[2] In previous FOTs, UMTRI has successfully implemented an autonomous wireless approach to downloading data; however, the volumes collected during this study will make this approach unfeasible without either excessive idle activity by each tractor or the supply of remote house-power to the DAS.

- Start the download process on each tractor to automatically move the data from each DAS to the local server and the external hard drive.
- Leave the fleet and monitor the download process remotely via the Internet.
- When the download is complete, return to the fleet, shut down and disconnect the dedicated download cables from each DAS.
- Return the vehicles to their designated parking spots.
- Disconnect the external hard drive and return with it to UMTRI.
- At UMTRI upload the files from the hard drive to the project server and load the database.
- Flag files that have been successfully loaded and backed-up for deletion.

To minimize the risk of losing data, files will not be deleted from each DAS during the download process but will be managed remotely during the periodic cell modem calls from each truck to UMTRI during the FOT.

8.2.1 Ensuring System Functionality and Integrity of Retrieved Data for Heavy Trucks

Diagnostic tools will be incorporated into the DAS software and the processing that occurs after receipt of data onto the FOT servers at UMTRI. This form of monitoring will ensure (within feasible limits) proper system operation, so that UMTRI can readily detect (via the cellular modem trip summaries) any problems or limitations that have arisen with a vehicle in the field. This maintenance feature depends upon monitoring the data transmitted to UMTRI via cellular phone while vehicles are in the field. UMTRI will also monitor DAS hard drive capacity remotely via the cellular phone and perform operating system level tasks, such as file deletion remotely through cellular phone activities.

UMTRI will screen and validate all FOT data as it is uploaded into the phone and FOT databases. As part of this process, trips found to have problems will be flagged and assigned a validity code describing the general nature of the data problem. Any data quality issues that are discovered while implementing the analysis and processing methodologies will be flagged and documented. The details of the data quality and tracking methods will be shared with the independent evaluator and FOT partners with the transfer of newly collected data, and also after the FOT has concluded.

Hardware items will be inspected and adjusted as necessary. Additional checks will be performed by automatic data scan routines at pre-specified intervals during the FOT. These include consistency queries to check that:

- The vehicle’s odometer reading agrees with the accumulated distance recorded by the DAS;
- The data file’s duration agrees with the known (logged) test duration;
- Start and end times of the recorded data correspond to the vehicle’s launch and retrieve times; and
- The data collection in any trip did not terminate prematurely (e.g., that data files do not end with velocity > 0).

8.2.2 Vehicle Repairs

Since the FOT vehicles differ greatly from the configuration of the as-sold ProStar 8600, arrangements will be made with a dedicated member of the Con-way maintenance staff who is acquainted with the special nature of the test vehicles. The intention is that a test vehicle would be repaired by the selected staff member unless on-road emergencies necessitate other arrangements.

8.3 Characterization of the Warning Function

Each vehicle will be characterized prior to starting the FOT, between the time that it is received from Eaton/International and its delivery to Con-way. These tests, therefore, are performed once per tractor. The purpose of this testing is twofold: to characterize system functionality and to exercise the vehicle and its DAS package before it is fielded. It is estimated that the effort associated with these tests lasts approximately one day per vehicle. Once the characterization of a vehicle is completed, the data are examined to confirm system performance, as captured by the DAS. The intention is not to do an extensive engineering analysis on performance, but rather to determine that the dataset is complete and that each of the intended test maneuvers is properly recorded in the data.

8.4 Normal Vehicle Maintenance

Normal vehicle maintenance will be done by Con-way staff or an authorized International Truck dealer. The maintenance task will be carried out through the following subtasks:

- Con-way inspection; and
- OEM maintenance. Any repairs, if needed, and periodic maintenance per the manufacturer-recommended schedule will be performed by Con-way. Because the FOT vehicles differ greatly from the configuration of the as-sold ProStar 8600, arrangements will be made with a dedicated member of the Con-way maintenance staff who is acquainted with the special nature of the test vehicles. The intention is that a test vehicle would be serviced only by the selected staff member unless on-road emergencies necessitate other arrangements.

8.5 Procedure for Responding to Incidents in the Field

At least two UMTRI staff members will be on call at all times via pagers and/or cell phones. These will generally be Human Factors staff that can address issues concerning the participant and contact UMTRI engineers as necessary should technical questions arise.

Accidents: In case of an accident, the participant will be instructed to contact the police and file a police report. If the accident involves an injury or another form of emergency, the participant will use the provided cell phone to contact 911 services. They will also be instructed to notify the UMTRI contact person immediately if possible. UMTRI personnel and other team members will attempt to interview the participant to learn more about the causes of the crash and why the warning system did not help to prevent the crash.

Failed Warning System or DAS: If the warning system or the DAS systems fail, UMTRI will either be notified by the participant or will discover the fault by means of the scrutiny of data via the automated cellular link. Depending on the type of failure, and after a consultation with Eaton if needed, one of the two following courses of actions will be taken:

- Ask Con-Way to replace the vehicle with the spare held by UMTRI; or
- Dispatch UMTRI personnel to attempt a system repair when the tractor returns to the terminal.

Failed Vehicle: In the case of a failure in one of the vehicle's systems (unrelated to the warning system), Con-way will be responsible for retrieval and repair of the vehicle. However, arrangements will be made to replace the failed unit with the spare unit retained by UMTRI.

8.6 Heavy-Truck Deployment Plan

Not all FOT vehicles will be deployed simultaneously. Instead, the test startup will be staggered such that the deployed fleet ramps up to a total of 10 vehicles over a three-month period. The heavy-truck deployment plan is shown below.

ID	Task Name	Start	Finish
1	FOT Heavy Vehicle 1	Thu 1/15/09	Fri 11/13/09
2	FOT Heavy Vehicle 2	Thu 1/15/09	Fri 11/13/09
3	FOT Heavy Vehicle 3	Thu 1/15/09	Fri 11/13/09
4	FOT Heavy Vehicle 4	Thu 1/15/09	Fri 11/13/09
5	FOT Heavy Vehicle 5	Mon 2/16/09	Mon 12/14/09
6	FOT Heavy Vehicle 6	Mon 2/16/09	Mon 12/14/09
7	FOT Heavy Vehicle 7	Mon 2/16/09	Mon 12/14/09
8	FOT Heavy Vehicle 8	Mon 2/16/09	Mon 12/14/09
9	FOT Heavy Vehicle 9	Mon 3/16/09	Mon 1/4/10
10	FOT Heavy Vehicle 10	Mon 3/16/09	Mon 1/4/10

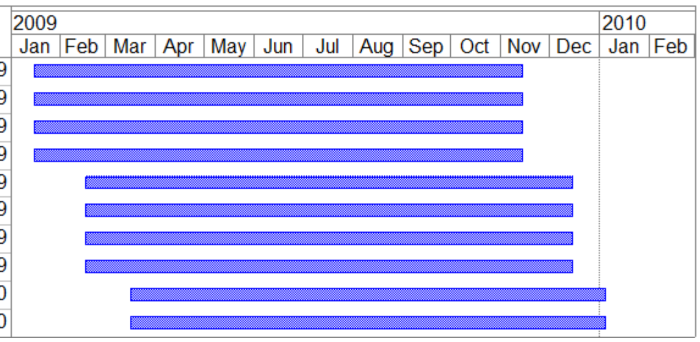


Figure 20. Heavy-truck deployment schedule

9 Data Processing

9.1 Adaptation of UMTRI's Previous Data Model to the IVBSS Program

The data collection, validation, organization, and analysis for the FOT will be based on an evolving data system that UMTRI has used in other FOTs that have collected large amounts of data. Conceptually, the system is based on a model that explicitly describes how data is organized to support interactions and use. More specifically, the data model addresses creation, organization, user access, manipulation, updating, querying, and sharing of the data. The data system also interfaces with tools, both developed by UMTRI and off-the-shelf, to allow users to view, analyze, validate, and understand the data.

The core elements of the UMTRI data system are the relational database and the customized UMTRI DAS. Figure 21 conceptualizes the elements of the entire model, as described below:

Warning system: As designed and implemented by Visteon and Eaton.

UMTRI Sensors: To better evaluate differences in vehicle and driver performance between the baseline (non-treatment) and treatment periods, UMTRI will install a suite of high-fidelity sensors that are independent of the prototype warning system.

Audio/Video: A set of five cameras will be used to record the driving scene and driver. Video will be recorded in both exposure and episodic modes, most likely at different collection rates.

DAS: A dual CPU computer that is ruggedized for the light-vehicle and heavy-truck environment. More details about the UMTRI DAS can be found in sections 5.6, 5.7, and 5.8.

Project Servers: At least two servers will be used to house databases and video files.

Analysis Tools: A variety of software tools will be used to perform data handling, loading, validation, visualization, enhancement, and analysis.

Data Definition: Shared among all elements is a common data definition structure that defines each data element of the entire system from its original location on a CAN bus to its location in one of many databases on the project server. As data are processed and analyzed both during and after the FOT, the project database is evolved to contain the definition of the new data elements.

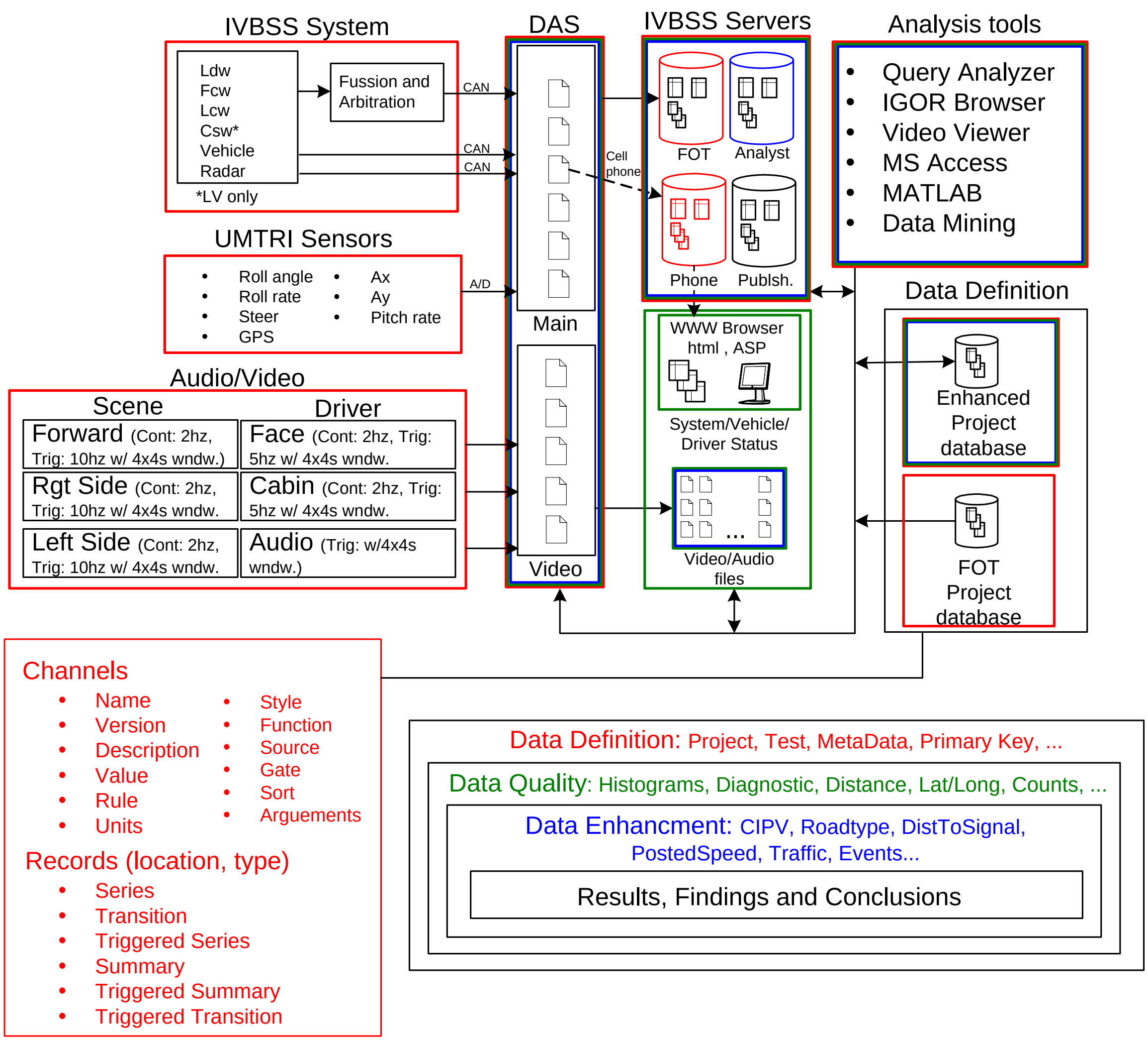


Figure 21. UMTRI data architecture

The concept of the model is a layered approach to data management. The outermost layer is data definition, which begins at the project level and is refined into smaller tests within the project. Tests are then decomposed into collections of channels called records. Some of the elements of a channel and record are shown in Figure 22. An important concept to the whole model derives from the expendability of the these levels to accommodate and define additional information as the model matures and evolves in all phases of a project from development, to deployment, to the initial analysis phase and in its ‘life’ after the project is officially over.

Following data definition is data quality. UMTRI uses a host of analysis techniques to measure and document the quality of all data elements in the model. This process also begins in the development phase of a project and is carried through all subsequent activities leading up to and including the conduct of the FOT and the post-FOT analysis process of the collected measures.

Data enhancement is both the processing of existing data measures as well as the creation of new measures from raw signals. Processing of existing measures includes the creation of event tables. Event tables form the core elements of complex inquires into the dataset and allow the efficient sub-setting of the entire database. Finally, all three of these layers surround any meaningful results and findings that can be derived from the data archive. Although pictured in a linear sense, the whole model is recursive in that results and findings, data enhancements, and data quality activities all get defined within the data model allowing new inquires to be part of future analysis.

Figure 22. Elements of a data definition channel and record

9.2 Data Validation

There are many layers of data processing in the FOT, beginning onboard the field test vehicles while they are being driven by the subjects in the FOT. In addition to storing time history and transitional and video data, the DAS will calculate derived measures, such as time-to-impact and headway-time margin. Some of these derived variables will be logged continuously or transitionally, while other measures may just be resident in temporary memory to serve as thresholds or triggers for events and processes within the DAS.

The task of data validation is critical to the FOT. Even though thorough testing of all the systems and subsystems of the vehicle will have occurred before the launch of the test, it is expected that problems will occur with the test fleet and it shall be UMTRI’s responsibility to detect these problems and coordinate with the partners to resolve them as quickly as possible.

In many situations the problems are obvious and can be identified easily by both UMTRI personnel and the subject drivers involved in the FOT. Examples include the illumination of dash lights or the failure of a critical function. However, there is a class of problems that will not easily present itself without close scrutiny and reconciliation of the data collected by the DAS. These validation tasks will occur on a daily basis throughout the FOT.

During the field tests the data validation begins with the files that UMTRI receives via the cellular phone at the end of each ignition cycle by the driver. These files will include histograms, counts, averages, first and last values, and diagnostic codes. UMTRI will build routines to automatically scan the UMTRI server for these files and load them into the database for immediate processing by the data validation routines. These routines, which will also be scheduled to run automatically, will query these data and generate summary reports which will then be broadcast by a Web-based server for viewing via the Internet from anywhere at any time. To the extent possible, these data will provide validation that the warning system on both platforms is working as intended. Following is a list of validation checks that will occur with the summary files sent to UMTRI via the cell phone:

Small Multiples: Histograms of most measured variables will be displayed in a condensed form that shows the shape of the distribution. Because the human eye is adept at seeing patterns, these distributions can be reviewed quickly by scanning. This is quick way to visually review a lot of data in a time-efficient way.

Histogram Statistics: Counts, means, most-likely values, and standard deviations of histograms will be calculated and tabulated for visual review. By using columns of data that are similar in nature one can quickly scan for values that deviate from an acceptable range.

Summary Numerics: Like histogram counts, there will be summary reports and values that characterize each trip. These values will include initial and final GPS location, test time, and velocity. From these data it is easy to see if there is continuity in the data on a trip-by-trip basis. For example, the ending GPS location should agree closely with the starting GPS location of the subsequent trip. Failure to agree would indicate that a trip or multiple trips were somehow not recorded by the DAS. Similarly, nonzero initial and final speeds may indicate that data were missed during a trip or that the DAS unexpectedly quit during a trip.

Mileage Values: The summary file will also contain a final distance traveled for each trip. These values will be aggregated and compared to the odometer values logged from each vehicle at the start and end of each subject's use of the vehicle. This also serves as a method of validating that the warning system and DAS were working correctly and all vehicle use was recorded.

Diagnostic Codes: A summary report by trip for all the diagnostic codes will be generated and reviewed as the data become available over the cellular lines. This will enable UMTRI to monitor the vehicles continuously throughout the testing period of each participant.

Upon return of the light vehicles to UMTRI, or upon data retrieval from the heavy-truck platform, UMTRI will upload each file into a database that also serves as a means of validation since many of the database tables are indexed, and hence any duplicate value in the keyed fields will cause an error in the loading process. Also, the process of parsing the binary trip files serves as a means of detecting spurious file errors that may have occurred either during the file generation or in the transfer of the file from the car or tractor to the UMTRI server.

Incorporated into the UMTRI data system will be documentation of the data authenticity. As data are reviewed and processed, a record of anomalous, false, or compromised data will be kept in a form that can be easily linked in queries when processing and analyzing warning system data. These records will be shared with the project partners and independent evaluator to aid in their processing and understanding of the data archive. This documentation also serves as a record of what has been changed or corrected in the database. This archive can be a very important resource if the database ever needs to be regenerated from the raw binary files generated by the DAS.

9.3 Creation of Databases

Both platforms of the IVBSS program will have a core set of five different database categories for collecting, maintaining, and analyzing the data generated by the FOT vehicles and gathered through other data sources. A brief description of each category follows:

Project Database: A highly structured database that evolves continuously and contains the project metadata. At its inception, the project database defines all the channels and associated properties being collected by the DAS onboard each FOT vehicle. This core description serves as a common reference for exploring and understanding each data element within a project. During and after the FOT, the project database evolves to include the new data elements that are calculated from existing data signals or appended to the database from outside sources. The core elements that define a data channel include: name, version, description, value, rule, units, style, source, gate, and arguments. These elements, along with associated data channel history, serve the data dictionary used to locate, use, and understand the contents of a given project's entire data archive.

FOT Database: A read-only database that contains all the data elements collected by the DAS onboard each FOT vehicle. It is a record of what was collected during the FOT and is no longer changed when the FOT is finished.

Phone Database: A diagnostic and summary database used during the FOT to monitor the health of all the warning system and DAS components. It also shows summary driver activity and events that allow UMTRI staff and partners to monitor individual drivers as well as aggregated statistics for the FOT as a whole. UMTRI researchers use these data as a snapshot into the health and progress of the FOT and also to make preliminary decisions related to the post-FOT interviews in which drivers are shown videos of their driving experience and asked to reflect on the their experience with the system and its meaningfulness in terms of a variety of factors such as safety, convenience, and usefulness. This database also has a Web interface for full-time remote access to these important summary data.

Analyst Database: A personalized database created for each of the primary researchers in a project. It contains tables and procedures that are developed and populated with data drawn from the project, FOT, and other databases and typically serves as an archive for work that is done by a particular researcher. Generally, these data are available to other researchers but are considered preliminary and shared through close consultation to ensure appropriate interpretation and use of these data. Generally, when data are processed, refined, and trusted by an individual researcher, they are published in a common database that serves as a container for verified secondary data related to the FOT or other projects.

Published Database: A general database that contains data derived from the FOT and individual analysts' databases. This database serves as a common source for measures and results that have been verified. The published database also contains links to an enhanced project database for quick reference to the definition of the data archive and its elements as a whole.

Finally, among the software tools that UMTRI has developed is a specialized program that can link to the metadata of a project and efficiently parse and read into a database the binary files that have been generated by the UMTRI DAS. Since the structure and content of the binary files are explicitly described by the metadata, any changes to the metadata will automatically be reflected in the program that loads the database. This program can also generate new tables automatically if the structure of the core data system has changed. Also, subjective results will reside in database tables to allow statistical analysis of these results and to join them with the objective data for meaningful query generation and analysis. All tables will be indexed for efficient data sampling and to expedite the so-called “join” properties that are such an important element of relational database programming.

9.4 Transfer of Data to the Independent Evaluator

This project will generate a tremendous amount of data that must be shared with the program partners and independent evaluator. Current estimates are that approximately 5 to 10 TB of data will be transferred to NHTSA and Volpe for both platforms. The estimated collection rate for both video and objective data is 400 MB per hour for light vehicles and 200 MB per hour for heavy trucks. The estimated exposure for each platform is 60 hours per light-vehicle driver and 3,000 hours per tractor driver. UMTRI will perform the following processes before delivery of the data:

- Parsing the agreed set of raw CAN messages into individual variables;
- Scaling into engineering units;
- Removing any known biases or scale factors;
- Making simple transformations of information that do not impute any information loss;
- Making quality checks;
- Compiling histogram calculations (these may always be recomputed by NHTSA since the constituent input variables will always be part of the retained record);
- Loading data into database tables; and
- Correcting any known errors.

UMTRI does not plan to deliver to NHTSA the results of any analyzed data, such as smoothed signals, queried or processed data streams, and so on, except in the context of the UMTRI final FOT report.

UMTRI will copy project database files to a suitable medium, which will then be shipped to the partners and independent evaluator. Although the particular media to be used will be selected jointly with the independent evaluator, the currently favored method is an external hard drive that is shipped back and forth by overnight courier. The entire export and import processes for this transfer can be defined as jobs to be executed by the SQL Server Agent. Text files will be used for data transfer in light of their portability between various database management systems and the ease with which they can be created and imported using SQL Server.

Project data will be bundled by driver on the light-vehicle platform and by tractor and trip on the heavy-truck platform. Each transfer of data to the independent evaluator will include all relevant data for some specific group of drivers or time period in the case of tractors. This will make it simple to track which data has been sent. Data will be sent every two to four weeks depending on the rate of data generation relative to the size of the portable hard drive and the evaluator’s need to stay current.

9.5 Tools for Data Analysis

A variety of tools can be used to create, load, and analyze the data archive. Some of these tools are coded in Visual Basic and C^{++} programs created by UMTRI, while others are supplied by software companies like Microsoft. One example of an off-the-shelf program that can be very efficient when transferring data from a more traditional relational database to a data warehouse is Data Transformation Services (DTS). This tool is part of the Microsoft SQL Server software package and allows easily importing and exporting data between a data warehouse and more traditional relational databases. UMTRI will use a variety of tools to export and import data in both the data warehouse and FOT databases. These include:

WaveMetrics IGOR: A powerful plotting and analysis program customized for viewing, manipulating, and processing time-history formatted data. IGOR has a built-in scripting language and UMTRI has taken advantage of this feature to customize and automate the presentation of time-history data in report-quality plots and graphics.

Microsoft Access: This client-based relational database program can easily be linked to the RDCW tables residing in SQL Server. Then using the developed query interface, the exact SQL can be developed either for querying from Access or to be input into Views or stored procedures within the SQL Server.

Mathworks MATLAB: UMTRI has used the processing power of MATLAB for a variety of data processing tasks ranging from simulation to Kalman filtering.

Microsoft SQL Query Server Analyzer: This client-based program allows engineers to develop and decode SQL statements using an interactive/command line interface. This is particularly useful to develop data analysis procedures that will run automatically on the data server since often they involve large datasets and can take many minutes (or hours) to execute. By using the Query Server Analyzer, engineers can test segments of their procedures before implementing the entire procedure, thus reducing the time to develop and debug large procedures that act on the entire dataset.

UMTRI Tools: UMTRI has developed a variety of tools for viewing and exchanging data with a data warehouse or traditional database. These include a TripMapper, VideoViewer, DataExplorer, and a host of other programs that automate the process of summarizing data by generating histograms and event tables. More specifically, a viewer program is being developed for the IVBSS program along with the DAS to allow researchers to view multiple aspects of the data simultaneously, at real time or faster. The viewer is shown in Figure 23 and includes the following windows:

- **Video**: A separate video window can be displayed (at normal, half, or double size) for each camera in the vehicle. The video window can be overlaid with dashboard information, including speed, brake, and turn signal. Cameras can be added or have their parameters altered without requiring a change in the viewer program.
- **Radar/Multi-Display Window**: Displays all targets identified by the vehicle's radar. It also can display lane lines for LDW, and a comparison of the calculated most-likely path with the actual path taken (as recorded by GPS) for CSW applications.

- **Data Tracking**: Allows the researcher to plot up to four fields from the database over the course of an event.
- **Audio**: Audio recorded during a trip/event can be identified and played back in sync (approximately) with the other windows.
- **Map**: Uses Microsoft MapPoint to plot the course of the trip and the vehicle's position.
- **Control Window**: Is used to select a trip and navigate through it, with start/pause, step, replay, reverse, and other controls available to review trips.
- **Query Window**: Allows researchers to use SQL queries to identify and quickly view events without having to load complete trips.

Figure 23. The UMTRI data viewer

10 Light-Vehicle Data Analysis

This section describes the analysis of light-vehicle FOT data to address the three broad study areas posed in Section 2. This section elaborates on the study questions, posing more specific questions amenable to analysis. When appropriate, special methods of analysis are described when they are new methods that may affect the success of addressing the study questions.

This section covers the analysis of light-vehicle exposure data, warning system performance, safety-related observations, and light-vehicle driver perceptions of system. In addition to the study areas described throughout this section, the FOT can be expected to provoke questions and observations that were unexpected during this planning stage. These discoveries may be significant enough to influence the tactics used to address the main study questions.

10.1 Analysis of Light-Vehicle Exposure Data

Characterizing the domain of driving circumstances encountered in the FOT is necessary to understand the interaction between drivers and the warning system. The domain of exposure is simply describing where and how the vehicle was driven, and under what conditions. This section describes the major elements of that characterization, except for additional items related to driving performance, which are covered in a later section.

Characterizing the exposure involves aggregating occurrences in which certain variables took on certain values. This aggregation is done for many variables, individually and jointly. The results will include histograms, events, patterns, etc. Together, these can be used to depict the test conditions, and are also necessary pieces of almost all the analyses.

Some of these individual variables may be:

Travel patterns:

- Distributions of the number of total trips, trip distances, and trip times;
- Trip objective metrics, where available (e.g., fraction of trips on roads previously traveled); and
- Distribution of the number of times individual drivers pass over roads they have previously traversed (thereby suggesting familiarity and supporting later analyses of false alarm databases).

Roadway variables, including these and other variables:

- Road class and roadway attributes;
- Characteristics of curves encountered (speed, radii, and roadway type);
- Maneuvering room statistics; and
- Occurrences of advisory-speed road segments (establishing exposure to "opportunities" curve speed warning).

Infrastructure and map characteristics encountered:

- Availability of digital map coverage, including exposure to roadways having the higher accuracy ADAS coverage; and
- Availability of GPS.

Environmental factors including:

- Weather variables (precipitation, temperature);
- Ambient lighting (time of day); and
- Local traffic densities (using surrogate metrics based on onboard data).

The warning system is also "exposed" to the participating drivers' driving patterns. Some of these are useful to include in studying exposure, such as:

- Driver characteristics and information (age, gender, typical mileage, years of driving experience, driving record, etc.);
- Travel patterns for this individual driver;
- Driving styles observed (based on measures that portray degrees of conflict tolerance);
- Driver speeds; and
- Use of cruise control.

While many exposure results may be computed and aggregated onboard the vehicle, most will require post-processing of data. Additional characterization of the exposure that the system will have in the FOT will also be provided within several of the analyses that follow.

10.2 Analysis of System Performance in Light Vehicles

Analysis of performance refers to the characterization of the occurrence or nonoccurrence of crash alerts and advisories during the field test. This includes simple counts of alert and advisory events, as well as characterizing in several dimensions (individually and jointly) the circumstances in which alerts or advisories occur or do not occur. This serves several purposes:

- Characterizes the fraction of travel distance or time that system functions are available to the driver;
- Characterizes the rate and circumstances of various types of alerts and advisories, including false alerts and all alerts; and
- Identifies technical successes of the system, as well as remaining challenges that may impact safety and acceptance.

Overall, the performance section also describes the experience that the drivers had, as necessary background for the analysis and interpretation of subjective perception data.

10.2.1 Availability of the Warning System

Availability refers to the fraction of time or travel during which the system is capable of issuing crash alerts or advisories. Availability will be considered for individual functions (such as CSW) and for the entire system. Overall, there are three types of unavailability:

- Design-specified unavailability, such as the intended suppression of the function when traveling at speeds below the minimum for each function, as well as short-term unavailability designed to improve the system/driver interaction, such as suppression of LDW alerts when the turn signal is applied or suppressions of secondary alerts that occur within a few seconds of a previous alert;

- Absence of one or more measurements needed for a primary system function (e.g., lack of viable lane markings for visual tracking, lack of digital map coverage, extended loss of GPS signals, loss of radar tracking due to buildup of snow/slush on a fascia, etc.); and
- Temporary or persisting malfunctions of the system, including hardware or software issues such as a failure of a subsystem to boot.

These times of unavailability will be documented and described in the FOT analyses, characterizing them in terms of appropriate variables such as the duration of unavailability, the cause of the unavailability, the conditions in which unavailability events occur (e.g., vehicle speed, road class, environmental conditions, sensor blockages [video] or outages [GPS], and/or absence of lane markings). This level of data recording will allow the determination of availability on a per-trip, per-driver, and overall basis by individual subsystem or the collective system.

Note that unavailability due to system malfunction is specific to this experimental context and is significant only if its occurrence disrupts a driver's experience enough to influence subjective responses or driving patterns. For purposes of the FOT, these driver data would likely be discarded. System failures will be readily apparent through the use of health or status flags from the subsystems, as well as examination of the dataset for each driver. More subtle algorithmic bugs, such as those that result in unintended RDCW decisions, are typically encountered early in an FOT, when the data are scrutinized regularly. They appear as unexpected displays of alerts or information (or missing displays) that are associated with unusual conditions.

10.2.2 Crash Alerts and Advisories

This section forms the bulk of the system performance analyses and includes the characterization of situations in which the system issues driver displays and similar situations in which it does not. Furthermore, when possible, crash alert events are classified into driving scenarios, which will include one or more classification of false alerts. Sample scenario classifications are found in the ACAS FOT methodology and findings report (Ervin et al., 2005).

This analysis will include an accounting and classification of alert events similar to those employed in recent light-vehicle FOTs (Ervin et al., 2005; LeBlanc et al., 2006). However, the requirements of the system and advances in technical performance will likely provide drivers with a somewhat different experience, in terms of reducing the number of alerts and improving the quality of those alerts (e.g., fewer false alerts). This may be most noticeable with FCW, which is expected to have a much lower rate of alerts than in ACAS and therefore may have a different "signature" in terms of the scenarios in which alerts occur.

Note that the team will not classify alerts as nuisance alerts *per se*, since this requires assumptions about driver preferences (i.e., a mapping from alert circumstances to the individual driver's subjective judgment) that previous research shows is very difficult or impossible to do at the level of individual alerts. Instead, the FOT analysis will classify the crash alert events according to the circumstances and driver actions following the alert. Furthermore, drivers will be queried about their reactions to a sample of their own individual alerts during the post-drive debriefing. This provides a pool of events with associated driver judgments. Previous FOTs have shown that while there are trends in driver ratings as a function of driving circumstances, the variation across drivers and individual events within drivers is very wide. However, together, the objective and subjective analyses have been powerful indicators in past FOTs of the level of acceptability of types of alerts and the influence of driving scenario on that acceptance.

As the system is intentionally integrated to provide the driver with the most useful and intuitive interface, this analysis will be done in the following sections: FCW alone, LDW and LCM combined, CSW alone, multiple-threat scenarios, and a sum total of all system information. While the LDW and LCM events will be identified separately in the analysis, they are discussed together in this document – and possibly within the FOT analysis reports – because the system provides these warnings to the driver as a unified whole.

10.2.2.1 Accounting of Alerts and Advisories

All crash alerts and advisories will be counted and analyzed, with separate analyses for the crash alerts and advisories. Furthermore, the analyses will be broken down by the type of conflict: rear-end, curve-speed, lane change (including aspects of LDW and LCM), road departure, and multiple-threat scenarios. The number of crash alerts and the rate of their occurrence by travel mile will be counted as a function of several variables including travel speed, road type, state of cruise control engagement, number of same-direction lanes, relevant lane boundary, presence of adjacent traffic or roadside threats, etc. Furthermore, individual and joint distributions of counts and alert rates will be done as functions of metrics such as kinematic conflict levels (e.g., for rear-end crashes, using the CAMP model of conflict as a speed-dependent function of TTC), closing speeds, level of lead vehicle deceleration, and so on.

Crash alert events will be classified into scenarios at two levels: a broader classification of events using automatic computations, and a classification of a sample of approximately 2,000 crash alerts according to a detailed set of scenario descriptors similar to that employed for FCW in the ACAS FOT (Ervin et al., 2005). An example of a broad scenario classification label for FCW is, "subject vehicle approaching a slowing vehicle with both vehicles remaining in the same lane throughout the episode." A detailed scenario label would append to the broad label more contextual information that can only be gathered from manual review of video, such as "…the deceleration of the slowing vehicle ahead is not predictable by the subject vehicle driver."

The analysis of any advisories would be similar but less extensive than the analyses just described for crash alerts. Counts, rates, and circumstances would be characterized, as well as any more detailed discussion of particular driving circumstances that lead to an unexpectedly high or low number of advisory events.

10.2.2.2 Accounting of Driver Visual Attention Measures

Driver visual attention and awareness are recognized as critical components in successful crash avoidance. Thus the same sample of alert events mentioned above in the scenario classification work will be reviewed using video and associated data to code driver visual glance behavior shortly before and after FCW alert events. Currently, UMTRI does not plan to trigger video collection on the light-vehicle platform. For the heavy-truck platform, current estimates are that video data will be collected continuously at 10 Hz for the forward and face cameras, and at 2 Hz for the cabin left- and right-rear looking cameras.

10.2.2.3 Summary of Crash Alert and Advisories

A summary of the findings of the previous sections will be tallied to provide an overall view of the driver's experience. A basic premise of the entire project is that the driver's experience should not necessarily be the sum of the standalone systems, nevertheless it is important to present the results of the analyses described in the previous subsections to give a single view of the driver's experiences. This will be done by summing alert counts and rates, as well as combining types of scenarios across the conflict types (e.g., tallying false alerts). Finally, any notable observations regarding driver visual measures will be made.

10.3 Safety-Related Observations in Light Vehicles

Analysis of driver behavior using the FOT data will provide insights into possible safety impacts of the system. The data collected during the light-vehicle portion will represent approximately 12.5 years of driving spread across the test participants. Given that a driver can expect to be involved in a police-reported crash once every 25 to 30 years (LeBlanc et al., 2006), it is clear that the experiment is not large enough to use crashes as a measure of safety effectiveness. Furthermore, it is understood that the Volpe Center, in its role as independent evaluator, will extend its previous analytical methods to compute estimates for the number of crashes that would be reduced if the prototype warning system were deployed in the fleet of U.S. passenger vehicles. Thus, the focus of the UMTRI team's analyses on safety will be analyzing the interaction of the warning system with safety-related phenomena, including:

- Driver responses to crash alert or advisory events, with and without active displays to the driver;
- Changes in patterns of driving performance metrics that may have safety implications; and
- Changes in driver involvement in secondary (non-driving) tasks.

This analysis approach is similar in spirit to analyses reported in Ervin et al. (2005) and LeBlanc et al. (2006). The differences in the FOT analyses will be in terms of methods and depth of findings, as described below.

10.3.1 Driver Responses to Events

Recall that during the baseline period, the system is active "in the background," even while the warning displays are not active. Thus, during baseline, the onboard data provides the timing and circumstances of decisions to warn, allowing a direct comparison of driver behavior with and without the display of alerts. Therefore this type of analysis looks at driver control and visual attention responses with and without the displays. The hypothesis to be tested is that when an event occurs, the presence of information will cause the driver to respond faster, more firmly, and with better visual attention than in the baseline period. A second analysis will factor in whether the presence of the system changes the frequency of events, so that the combination of exposure to the system events and the driver response can be shown. If aspects of a positive or negative effect are confirmed statistically, then there is a suggestion of potential safety benefit or disbenefit, respectively, due to event-specific performance change. (The next section addresses more generic changes in driving performance.)

The driver responses of interest include not only vehicle control inputs (braking, steering/lane-change behavior, and speed control), but also visual attention (eyes forward, eyes on driving task). The analysis will again include two subtasks: a broad analysis that is computed for all events (partitioned into FCW, LDW/LCM, CSW, and multiple threats), and a detailed investigation of approximately 2,000 events using scenes from the five video cameras and human interpretations. Note that visual attention studies are limited to the latter method of analysis because the fleet will not have eye- or head-tracking equipment onboard.

10.3.2 Changes in Conflict Management Associated With the System

This section addresses driver performance in conflict events as well as pre-conflict driving. The conflict event portion is a variation of the event study described above, with the definition of event tied to more general conflict measures. The intention is to look for any significant changes in how drivers manage the conflicts that the system addresses, both in terms of exposure to relatively high conflict events and driver responses in those events. The definition of conflicts will draw upon existing studies that directly address that question. UMTRI will also leverage its experience with crash warning field test data to extend the definition to account for indicators of driver intent and anticipation (e.g., the near-crash metric of a same-lane FCW scenario will be different from the metric for a scenario in which the lead vehicle is turning).

Driver responses to be studied will include both vehicle control responses (braking, steering, throttle modulation) and eye glance responses. An example question is: Do drivers brake earlier or later to events with significant forward conflict with the system (within a scenario group)? Is the braking harder? Is the maximum conflict during the response event higher or lower?

The primary method of analysis will be statistical comparison of performance metrics, such as using the speed-indexed time to collision model developed in CAMP for forward conflicts (Kiefer et al., 2005). An example of this analysis type can be found in the study of forward conflict levels with and without the ACAS FOT FCW system (Ervin et al., 2005). Another example is the study of the rate of lane excursions with and without lateral drift warning, as reported in LeBlanc et al. (2006).

A secondary analysis method to address the same conflict-targeted questions will be to study changes in the parameters of a driver model that result from fitting the model to data from driving with and without the warning system. This method will be supplementary to the statistical comparisons of performance metrics, and is based upon the success of developing models and fitting techniques that result in solid predictions of driver behavior. Driver models will be pursued because the statistical comparison of performance metrics is an inefficient use of information, and often FOT analyses suffer from a scarcity of data because of this. Models are more powerful in using the same data, and hence have become central in engineering as a compact and powerful representation of system behavior.

10.3.3 Changes in Pre-Conflict Driving Measures

Pre-conflict driving behavior includes choices of headway times, turn signal use, speed, lane position, gap sizes during lane changes, and initiation of maneuvers such as lane changes. These types of behaviors have been seen to be influenced in past studies, and may well provide a major portion of any safety benefits that the system provides. This is presumably because when drivers allow themselves and nearby drivers more time and distance to react, the probability of conflicts building to dangerous levels decreases. Thus the distributions of the measures noted above will be characterized with and without the warning system.

10.3.4 Changes in Secondary Task Behavior

An analysis of video and associated data will be conducted to determine whether the system influences drivers' choices to engage in secondary (non-driving) tasks. Previous UMTRI studies have looked at both alert events as well as randomly selected data. Over 5,600 events were coded between the ACAS FOT and RDCW FOT projects, and such behaviors as cell phone use, eating/drinking, grooming, conversations, manipulation of vehicle controls not related to vehicle control, and others were coded with subfields for the level of involvement. This resulted in findings that only during the initial period of system availability did drivers engage more frequently in secondary tasks, and that effect disappeared after one week. The same finding is anticipated here, but a careful analysis is important to study whether the system could contribute to additional secondary involvement and therefore potentially reduce the safety benefits.

10.4 Driver Perceptions of the Warning System in Light Vehicles

Driver perception of system performance will be measured primarily through analyses of the post-drive questionnaires and debriefing sessions. The information gathered in focus groups will also add to the knowledge of driver perception, however, past FOTs have shown that only about one-third of the drivers will attend a focus group.

Currently, the post-drive questionnaires have not been developed. It is anticipated that the on-site questionnaire will be divided into five major sections: Overall system performance, FCW performance, CSW performance, LDW performance, and LCM performance. Within each section, questions will be asked concerning comfort and convenience, ease of use, safety, and willingness to purchase. In past FOTs, almost all of these questions were answered using a seven-point Likert-type scale with higher numbers indicating positive attributes. These data will be used in analyses along with objective data (e.g., the number of warnings) to investigate the effects of warning rates on comfort and convenience, ease of use, safety, and willingness to purchase.

Additionally, the Van der Laan scale will be included in the post-drive questionnaire. The Van der Laan scale represents one way to broadly capture drivers' subjective assessments of usefulness and satisfaction with a new automotive technology. The use of the Van der Laan scale will also allow comparisons to be made between system acceptance and the acceptance of other automotive technologies (e.g., ACAS). During the driver debriefing sessions, drivers will view video from a selected group of the warnings that they received. They will rate the extent to which the warning was necessary and useful. An analysis of these ratings will also contribute to the drivers' overall impression.

11 Heavy-Truck Data Analysis

This section describes the analysis of heavy-truck FOT data to address the three broad study areas posed in Section 2.2 and the goals and objectives in Section 2.3. This section elaborates on the study questions, posing more specific questions amenable to analysis. When appropriate, new special methods of analysis, which may affect the success of addressing the study questions, are described.

In addition to the study areas described throughout this section, the FOT can be expected to provoke questions and observations that were unexpected during this planning stage. These discoveries may be significant enough to influence the tactics used to address the main study questions.

11.1 Analysis of Heavy-Truck Exposure Data

Characterizing the domain of driving circumstances encountered in the FOT is necessary for understanding the interaction between drivers and the warning system. The domain of exposure is simply describing where and how the truck was driven, and under what conditions.

There is one key difference between the light-vehicle and the heavy-truck driving patterns. In the case of light vehicles, there will be multiple drivers for each vehicle driving a variety of routes. Heavy trucks, on the other hand, are constrained by Con-way Freight’s operating models that essentially pair two drivers with a truck (tractor). One driver will typically operate the truck with one or more trailers for long haul during one shift. Once this driver returns to Con-way’s terminal, the second driver will use the same truck, possibly with a different set of trailers for short-haul pick-up and delivery. Each driver-truck pair usually runs the same routes over an extended timeframe, which presents opportunities as well as limitations in how the FOT data can be analyzed. Therefore, there will necessarily be some differences in how the light-vehicle and heavy-truck data is aggregated and analyzed.

This section describes the major elements of that characterization, except for additional items related to driving performance, which are covered in a later section. Characterizing the exposure involves aggregating occurrences in which certain variables take on certain values. This aggregation is done for many variables, individually and jointly, and results typically include histograms, events, patterns, etc. These can be used to depict the test conditions and are also necessary pieces of almost all analyses. Examples of individual variables are:

Travel patterns:

- Distributions of the number of total trips, trip distances, and trip times;
- Trip objective metrics, where available (e.g., fraction of trips on roads previously traveled); and
- Distribution of the number of times individual drivers pass over roads they have previously traversed to support analyses of false alarm databases.

Roadway variables:

- Road class and roadway attributes;
- Characteristics of curves encountered (speed, radii, and roadway type); and

- Maneuvering room statistics.

Infrastructure and map characteristics encountered such as:

- Availability of digital map coverage, including exposure to roadways having the higher accuracy ADAS coverage; and
- Availability of GPS.

Environmental factors including:

- Weather variables (precipitation, temperature);
- Ambient lighting (time of day); and
- Local traffic densities (using surrogate metrics based on onboard data).

The integrated warning system is also "exposed" to the participating drivers' driving patterns. Some of these are useful to include in studying exposure, such as

- Driver characteristics and information (age, gender, typical mileage, years of driving experience, driving record, etc.);
- Travel patterns for individual drivers;
- Driving styles observed (based on measures that portray degrees of conflict tolerance); and
- Driver speeds.

While many exposure results may be computed and aggregated onboard the vehicle, most will require post-processing of data. Additional characterizations of system exposure in the FOT are provided within several of the following analyses.

11.2 Analysis of System Performance in Heavy Trucks

Analysis of performance refers to the characterization of the occurrence or nonoccurrence of crash alerts and advisories during the field test. This includes simple counts of alert and advisory events, as well as characterizing in several dimensions (individually and jointly) the circumstances in which alerts or advisories occur or do not occur. This serves several purposes, including:

- Characterizes the fraction of travel distance or time that system functions are available to the driver;
- Characterizes the rate and circumstances of various types of alerts and advisories, including false alerts and all alerts; and
- Identifies technical successes, as well as remaining challenges that may impact safety and acceptance.

Overall, the performance section also describes the driver experience as necessary background for the analysis and interpretation of subjective perception data.

11.2.1 Availability of the warning system

Availability refers to the fraction of time or travel during which the system is capable of issuing crash alerts or advisories. Availability will be considered for individual functions (such as LCM), as well as for the entire system ensemble. System unavailability broadly falls into the following categories:

- Design-specified unavailability, such as the intended suppression of the function when traveling at speeds below the minimum for system function, as well as short-term unavailability designed to improve the system-driver interaction, such as suppression of LDW alerts when the turn signal is applied or suppressions of secondary alerts that occur within a few seconds of a previous alert;
- Absence of one or more measurements needed for a primary system function, such as lack of viable lane markings for visual tracking, lack of digital map coverage, extended loss of GPS signals, loss of radar tracking due to buildup of snow or slush on a fascia, etc.; and
- Temporary or persisting malfunctions of the system, including hardware or software issues such as a failure of a subsystem to boot.

System unavailability will be captured in the FOT analyses, in terms of appropriate variables such as the time duration of unavailability, causality, conditions under which unavailability occurred (e.g., vehicle speed, road class, environmental conditions, sensor blockages (video) or outages (GPS), and absence of lane markings), etc. Unavailability due to system malfunctions is specific to this experimental context and is significant only if its occurrence disrupts drivers' experience sufficiently enough that their subjective responses or driving patterns may be influenced. For purposes of the FOT, these driver data would likely be discarded. System failures will be readily apparent through the use of health or status flags from the subsystems, as well as examination of the dataset for each driver. More subtle algorithmic bugs, such as those that result in unintended LDW decisions, are typically encountered early in such FOTs, where the data are scrutinized regularly. They appear as unexpected displays of alerts or information (or missing displays) that are associated with unusual conditions.

11.2.2 Crash Alerts and Advisories

This section forms the bulk of the system performance analyses and includes the characterization of situations in which the system issues driver displays and, conversely, the study of situations that are otherwise similar, but do not result in similar displays. Furthermore, when possible, crash alert events are classified into driving scenarios, which will include one or more classifications of false alerts. An example of scenario classifications can be found in the ACAS FOT methodology and findings report by UMTRI (Ervin et al., 2005).

UMTRI does not plan to classify alerts as nuisance alerts *per se*, since this requires assumptions about driver preferences (i.e., a mapping from alert circumstances to the individual driver's subjective judgment) that previous research shows is very difficult or impossible at the level of individual alerts. Instead, the FOT analysis will classify the crash alert events according to the circumstances and driver actions following the alert. Furthermore, drivers will be queried about their reactions to a sample of their own individual alerts during the post-drive debriefing session. This provides a pool of events with associated driver judgments. Previous FOTs have shown that while there are trends in driver ratings as a function of driving circumstances, the variation across drivers and individual events within drivers is very wide. However, together, the objective and subjective analyses have been powerful indicators in past FOTs of the level of acceptability of types of alerts and the influence of driving scenario on that acceptance.

As the system is intentionally integrated to provide the driver with the most useful and intuitive interface, this analysis will be done in the following sections: FCW alone, LDW and LCM combined, multiple-threat scenarios, and a sum of all system information. While the LDW and LCM events will be identified separately in the analysis, they are discussed together in this document – and possibly within the FOT analysis reports – because the system provides these warnings to the driver as a unified whole.

11.2.2.1 Accounting of Alerts and Advisories

All crash alerts and advisories will be counted and analyzed, with separate analyses for the crash alerts and advisories. The analyses will be broken down by the type of conflict: lane change (including aspects of LDW and LCM), road departure, FCW, and multiple-threat scenarios. The number of crash alerts and the rate of their occurrence by travel mile will be counted as a function of several variables including, but not limited to, travel speed, road type, state of cruise control engagement, number of same-direction lanes, relevant lane boundary, presence of adjacent traffic or roadside threats, and so on. Individual and joint distributions of counts and alert rates will be done as functions of metrics such as kinematic conflict levels, closing speeds, level of lead vehicle deceleration, etc.

Classification of crash alert events into scenarios will be done at two levels: a broader classification of events using automatic computations and a classification of a sample of approximately 2,000 crash alerts according to a detailed set of scenario descriptors similar to that employed for FCW in the ACAS FOT (Ervin et al., 2005). An example of a broad scenario classification label for FCW is, "subject vehicle approaching a slowing vehicle with both vehicles remaining in the same lane throughout the episode." A detailed scenario label would append more contextual information that can only be gathered from manual review of video, such as "…the deceleration of the slowing vehicle ahead is not predictable by the subject vehicle driver."

The analysis of any advisories included in the system would be similar but less extensive than the analyses just described for crash alerts. Counts, rates, and circumstances would be characterized, as well as any more detailed discussion of particular driving circumstances that lead to an unexpectedly high or low number of advisory events.

11.2.2.2 Accounting of Driver Visual Attention Measures

Driver visual attention and awareness is recognized as a critical component in successful crash avoidance. Thus the same sample of alert events mentioned in the scenario classification work will be reviewed using video and associated data to code driver visual glance behavior shortly before and after alert events.

11.2.3 Summary of Crash Alerts and Advisories

A summary of the findings of the previous sections will be tallied to provide an overall view of the driver's experience. A basic premise of the entire project is that the driver's experience should not necessarily be the sum of the stand-alone systems; nevertheless, it is important to present the results of the analyses described in the previous subsections to give a single view of the driver's experiences. This will be done by summing alert counts and rates, as well as combining types of scenarios across the conflict types (e.g., tallying false alerts). Finally, any notable observations regarding driver visual measures will be made.

11.3 Safety-Related Observations in Heavy Trucks

Analysis of driver behavior using the FOT data will provide insights into possible safety impacts of the warning system. The focus of the UMTRI team's analyses on safety will be analyzing the interaction of the warning system with safety-related phenomena, including:

- Driver responses to crash alert or advisory events, with and without active displays to the driver;
- Changes in patterns of driving performance metrics that may have safety implications; and
- Changes in driver involvement in secondary (non-driving) tasks.

This analysis approach is similar in spirit to analyses reported in Ervin et al. (2005) and LeBlanc et al. (2006). The differences in the FOT analyses will be in terms of methods and depth of findings, as described below.

11.3.1 Driver Responses to Events

Recall that during the baseline period, the system is active "in the background," even while the warning displays are not active. Thus, during baseline, the onboard data provides the timing and circumstances of system decisions to warn, allowing a direct comparison of driver behavior with and without the display of alerts. Therefore, this type of analysis looks at driver control and visual attention responses with and without the displays. The hypothesis to be tested is that when an event occurs, the presence of information will cause the driver to respond faster, more decisively, and with better visual attention than in the baseline period. A second analysis will factor in whether the presence of the system changes the frequency of events, so that the combination of exposure to events and the driver response can be shown. If aspects of a positive or negative effect are confirmed statistically, those would suggest a potential safety benefit (or hazard), due to event-specific performance change.

The driver responses of interest include not only vehicle control inputs (braking, steering/lane-change behavior, speed control), but also visual attention (eyes forward, eyes on driving task). The analysis will again include two subtasks: a broad analysis that is computed for all events (partitioned into FCW, LDW and LCM, and multiple threats), and a detailed investigation of approximately 2,000 events using scenes from the video camera and human interpretation. Note that visual attention studies are limited to the latter method of analysis because the fleet will not have eye- or head-tracking equipment onboard.

11.3.2 Changes in Conflict Management

This section addresses driver performance in conflict events as well as in pre-conflict driving. The conflict event portion is a variation of the event study described above, with the definition of event tied to more general conflict measures. The intention is to look for any significant changes in how drivers manage the conflicts that the system addresses, both in terms of exposure to relatively high-conflict events and driver responses in those events. The definition of conflicts will draw upon existing studies that directly address that question. UMTRI will also leverage its experience with crash warning field test data to extend the definition to account for indicators of driver intent and anticipation (e.g., the near-crash metric of a same-lane FCW scenario will be different from the metric for a scenario in which the lead vehicle is turning).

Driver responses to be studied will include both vehicle control responses (braking, steering, and throttle modulation) as well as eye glance responses. A possible question is:

- Do drivers brake earlier or later to events with significant forward conflict with the system (within a scenario group)? Is the braking harder? Is the maximum conflict during the response event higher or lower?

The primary method of analysis will be statistical comparison of performance metrics, such as using the speed-indexed time-to-collision model developed in CAMP for forward conflicts (Kiefer et al., 2003). A secondary analysis method to address the same conflict-targeted questions will be to study changes in the parameters of a driver model that result from fitting the model to data from driving with and without the system. This method will be supplementary to the statistical comparisons of performance metrics, and is based upon the success of developing models and fitting techniques that result in solid predictions of driver behavior. Driver models will be pursued because the statistical comparison of performance metrics is an inefficient use of information, and often FOT analyses suffer from a scarcity of data. Models are more powerful in using the same data, and hence have become central in engineering as a compact and powerful representation of system behavior.

11.3.3 Changes in Pre-Conflict Driving Measures

Pre-conflict driving behavior includes choices of headway times, turn signal use, speed, lane position, gap sizes during lane changes, and initiation of maneuvers such as lane changes. These types of behaviors have been seen to be influential in past studies, and may well provide a major portion of any safety benefits that the system provides. This is presumably because when drivers allow themselves and nearby drivers more time and distance to react, the probability of conflicts building to dangerous levels decreases. Thus the distributions of the measures noted above will be characterized with and without the warning system.

11.3.4 Changes in Secondary Task Behavior

An analysis of video and associated data will be conducted to determine whether the system influences drivers' choices to engage in secondary (non-driving) tasks. Previous UMTRI studies have looked at both alert events as well as randomly selected data. Over 5,600 events were coded between the ACAS FOT and RDCW FOT projects, and such behaviors as cell phone use, eating/drinking, grooming, conversations, manipulation of vehicle controls not related to vehicle control, and others were coded with subfields for the level of involvement. This resulted in findings that only during the initial period of system availability did drivers engage more frequently in secondary tasks, and that effect disappeared after one week. The same finding is anticipated here, but a careful analysis is important to study whether the system could contribute to additional secondary involvement and therefore potentially reduce the safety benefits.

11.4 Driver Perceptions of the Warning System in Heavy Trucks

Driver perception of system performance will be measured primarily through analyses of the post-drive questionnaires and debriefing sessions. It has yet to be determined whether focus groups will be held with heavy-truck participants due to concerns about confidentiality given that all of the truck drivers know each other. If focus groups are held, the information gathered will also add to the knowledge of driver perception.

Currently, the post-drive questionnaires have not been developed. It is anticipated that the on-site questionnaire will be divided into four major sections: overall system performance, FCW performance, LDW performance, and LCM performance. Within each section, questions will be asked concerning comfort and convenience, ease of use, and safety. In past FOTs, almost all of these questions were answered using a seven-point Likert-type scale with higher numbers indicating positive attributes. These data will be used in analyses along with objective data (e.g., the number of warnings) to investigate the effects of warning rates on comfort and convenience, ease of use, and safety.

Additionally, the Van der Laan scale will be included in the post-drive questionnaire. The Van der Laan scale represents one way to broadly capture drivers' subjective assessments of usefulness and satisfaction with a new automotive technology. The use of the Van der Laan scale will also allow comparisons to be made between system acceptance and the acceptance of other automotive technologies (e.g., ACAS).

During the driver debriefing sessions, drivers will view video from a selected group of the warnings that they received. They will rate the extent to which the warning was necessary and useful. An analysis of these ratings will also contribute to the drivers' overall impression.

12 Final FOT Reports

Currently, the UMTRI-led team envisions that the final reporting of the IVBSS program will consist of three reports. The first will be a summary report that details that entire program, Phases I and II, presenting summary results for both platforms. The second and third reports will be detailed analyses of the light-vehicle and heavy-truck FOTs. This approach is proposed as we see the need for a high-level summary report of the entire program, yet the obvious need to provide very detailed analyses of the FOT that are independent for the two platforms. The belief that the detailed analyses ought to be independent by platform is driven by the expectation that the majority of readers will have an interest in either one platform or the other, but that very few will have a detailed interest in the results of the FOTs for both platforms.

Relative to the detailed FOT reports on the outcome of the light-vehicle and heavy-truck FOTs, UMTRI is prepared to document the methods, equipment, and results of the field operational test for the analyses we ourselves conduct. The reports will detail the field test methodologies such that others accessing the data archive can properly understand the data elements and the process by which they were generated. The reports will also document the DAS and the techniques by which data were processed to yield the presented high-level results.

The majority of the detailed FOT reports will address the results of data analysis, as outlined in sections 10 and 11. Conclusions will address the experience arising from driving a vehicle equipped with the warning system, as well as fundamental aspects of the normal driving process that are discovered through testing with a rich complement of remote sensing onboard. The performance of the system will be assessed in objective terms from numerical data, via the subjective appraisals of participants, and by means of correlation between both types of results.

13 Conclusions

This document presented the FOT plan for the Integrated Vehicle-Based Safety Systems program. The plan provided detailed descriptions regarding UMTRI's intended protocols and methods to field 16 passenger cars and 10 commercial trucks equipped with the crash warning system, the dataset that will result and be provided to the government's independent evaluator, and an overview of the analyses that UMTRI will perform as part of conducting the FOT.

As stated previously, UMTRI views this embodiment of the test plan, and its further development, as collaborative and iterative processes that will engage the independent evaluators and the U.S. DOT. While the field test itself is to be discharged largely by UMTRI, it is acknowledged that the process of doing so must satisfy the needs of the independent evaluators and meet the original goals of the U.S. DOT to assess the benefits and acceptance associated with an integrated crash warning system.

The plan is based on UMTRI's experience in conducting previous FOTs, and as such we believe that it will serve as a solid basis on which to further our discussions and a guide the later stages of Phase II of the IVBSS program.

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