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Onboard Monitoring and Reporting for Commercial Vehicle Safety (OBMS) Phase II: Field Operational Test

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ABSTRACT. Each year in the United States over 450,000 large trucks are involved in crashes, resulting in about 5000 fatalities and 120,000 injuries. Significantly, tuck driver error is a major causal factor to truck-involved crashes. This points toward onboard monitoring as a promising means to encourage good driving behavior, it would recognizing and provide necessary feedback to correct self-induced hazardous driving situations. This is the basis for our past prototype development effort, which has produced under Task Orders 5509 and 6609 a suite of hardware on a Freightliner Century Class. This suite allows for online measurement of a set of driving characteristics which are indicators of unsafe driving behavior, with feedback given in real time to the driver, and offline to the carrier (and ultimately, back to the driver). Under this Task Order, we extended our work to detail a Field Operational Test. While that FOT began with 15 trucks, the work undertaken was expanded at US DOT's request to consider additional teammates and a scope of over 200 trucks where the FOT could be collateral compared to the naturalistic data collection that could be accrued. We describe the original SOW, some of the transforming work in-between, then the finally-conceived FOT which in the end was submitted but not awarded to the PATH-Caltrans team.
Keywords: Onboard monitoring, truck safety, lane departure, lane keeping, speeding, curve overspeed, speeding, drowsiness, fatigue, real time feedback, carrier feedback.

1.0 Introduction and Executive Summary

The mission of the Federal Motor Carrier Safety Administration (FMCSA) is to reduce the number and severity of crashes on our Nation's Highways. Only about 15% of those killed and 24% of those injured in large truck crashes were occupants of large trucks.

In direct support of this mission, the *Onboard Monitoring and Reporting for Commercial Motor Vehicle Safety* (OBMS) demonstration project is being sponsored by FMCSA in collaboration with the California Department of Transportation (Caltrans),the University of California Partners for Advanced Transit and Highways (PATH) and their major partners and subcontractors including Virginia Tech Transportation Institute (VTTI) and Transecurity. The objective of the project is to demonstrate whether an onboard suite of driving performance monitoring technologies and feedback (both real-time and delayed) can reduce at-risk commercial driving behaviors, improve driver safety performance and can help keep the driver performing in a continued safe manner. This program consists of two phases. Phase I is the proof of concept and development of the prototypical technology suite completed May 2007.

Operator monitoring and feedback can be characterized as a behavior-based safety method. Safe behavior is rewarded and unsafe behavior is improved upon, thereby proactively improving overall safety. As identified in Sherry (2001), implementing an onboard driver-monitoring program requires the following four steps:

1. Identify behaviors which may be precursors to increased crash rates.
2. Determine cost-effective ways to monitor safe and unsafe behaviors.
3. Determine the best way to provide the driver with feedback which rewards safe behavior and discourages unsafe behavior.
4. Establish management and driver acceptance to the program.

The Phase I effort resulted in a prototype of the behavior-based safety method, but it went further as it developed a real-time feedback method. This could be characterized as "the best way"

allowed in Sherry's third step. Hence, the system conceived for the FOT also includes real-time feedback, off-line driver feedback and a management review program that must be designed and tailored to fit the needs of the FOT carrier partner.

The Phase I study consisted of four parts:

1. Prototype Suite Concept of Operations and Requirements Generation – conduct literature search to identify the driving behaviors that should be monitored e.g., best safety return on investment.
2. Human Factors Studies - determine type of driver feedback e.g. real time, off line, visual, auditory based on stakeholder guidance and literature/product search findings.
3. Onboard Monitoring Suite - develop the prototype suite of identified technologies and install the suite a Class 8 vehicle.
4. Field Operational Test (FOT) and Evaluation Plan – the initial development of a research design for follow on FOT (Phase II).

While the results are detailed in the Task Order 6609 Final Report, the driver interface shown in Figure 1-1 may be instructive in illustrating the concept, in this instance showing speed (where exceedances of the posted speed are shown as red on the scale) and vehicle following feedback (where the 3.8 seconds shown is green because a safety distance was maintained for the current road conditions).

Figure 1-1. Depiction of OBMS Driver Feedback

Phase II is the Field Operational Test, the subject of this Task Order. However, Phase II is not a simple follow-on to the Phase I effort, because at the same time the aforementioned was being conducted, as an independent initiative Transecurity was formed – largely based on Virginia Tech Transportation Institute driver behavior research and spinoff data collection and reduction technologies (Data Acquisition System, or DAS) – and with similar product goals as the OBMS Phase I. Of compelling interest is that not only are the same goals as Phase I addressed in an emerging commercial system (albeit with somewhat less functionality), the data collection and

analysis system used in the Transecurity DAS product are conducive to a large-scale naturalistic data collection effort. Hence, this FOT can serve a dual use: (i) an important evaluation of OBMS on real fleets, and at the same time (ii) collection of a large-scale commercial vehicle naturalistic driving database.

These two uses profoundly influenced this work. While the OBMS FOT was the primary goal, naturalistic commercial vehicle driver data will be collected and stored for subsequent analysis. The goals were therefore dual, perhaps complementary and certainly significant: (a) evaluate the effectiveness across multiple fleets and up to 250 trucks using the (Transecurity) DAS and (b) collecting the full set of non-OBMS data as naturalistic driving data. It should be noted that the full reduction of the naturalistic driving data was not to be conducted under this work scope; that was reserved for TBD potential future projects. However, some reduction wa tos be conducted, as a subset of the data will serve as baseline or comparison data to evaluate the efficacy of the OBMS system to influence driver behavior and ultimately, driver safety. These uses (i) and (ii) and goals (a) and (b) were influential in conceiving the work.

2.0 Point of Departure: Initial Work Statement

The initial proposal and SOW, developed under Phase I, is given as a reference point. As noted in Section 1.0, this was profoundly changed during the course of the work, with the final version shown in later sections.

2.1 Introduction

One of eight traffic fatalities results from collisions involving large trucks, amounting to more than 5,000 deaths a year and underscoring that reduction of commercial motor vehicle (CMV) crashes should be an essential element of highway safety. Although in 71-percent of truck-involved crashes with multiple vehicles, police assign error to passenger vehicle drivers., CMV driver error is still a major causal factor to truck-involved crashes. Consider that:

- A loaded tractor-trailer requires 20-40-percent further stopping distance than a car. This situation is worsened with downgrades and wet pavement.
- Crashes involving trucks are more likely to involve a serious injuries or fatalities than are crashes involving only passenger vehicles.
- Over a 10-year span (1992 to 2002) there has been a 31 percent increase in registered large trucks and a 40-percent increase in miles traveled by large trucks

One means to lower the amount of CMV driver errors is to improve driver performance through CMV Onboard monitoring systems, coupled with appropriate feedback to the driver. Onboard monitoring may provide a mechanism to encourage good driving behavior by recognizing and correcting self-induced hazardous driving situations.

The understanding that onboard monitoring may provide a mechanism to encourage good driving behavior by recognizing and correcting self-induced hazardous driving situations is the basis for

a Federal Motor Carrier Safety Administration Cooperative Agreement with Caltrans, which has turned into an active PATH project *Onboard Monitoring and Reporting for Commercial Motor Vehicle Safety*, henceforth referred to in this document as OBMS.

2.2 Background: Phase I Effort

The OBMS concept is that feedback from this system could be provided to the driver, either directly or through carrier management, to allow drivers to improve their safety performance. The OBMS Phase I effort is aimed at developing an onboard monitoring system prototype to address CMV driver/safety error and subsequent Field Operational Test (FOT) plan.

This prototype is currently being developed, integrated and tested in a Caltrans-PATH Freightliner Century Class (Class 8) tractor at the PATH Richmond Field Station Facility. Figure 2-1 shows cutaways of the system prior to installation of OBMS components.

Figure 2-1: Tractor Platform for OBMS Prototype

The work is being conducted with a systems engineering framework documented in a tailored Systems Engineering Management Plan (SEMP), with progression and milestones allowing for concept, requirements and design documentation to guide prototype, and eventually, product, development, shown in Figure 2-2.

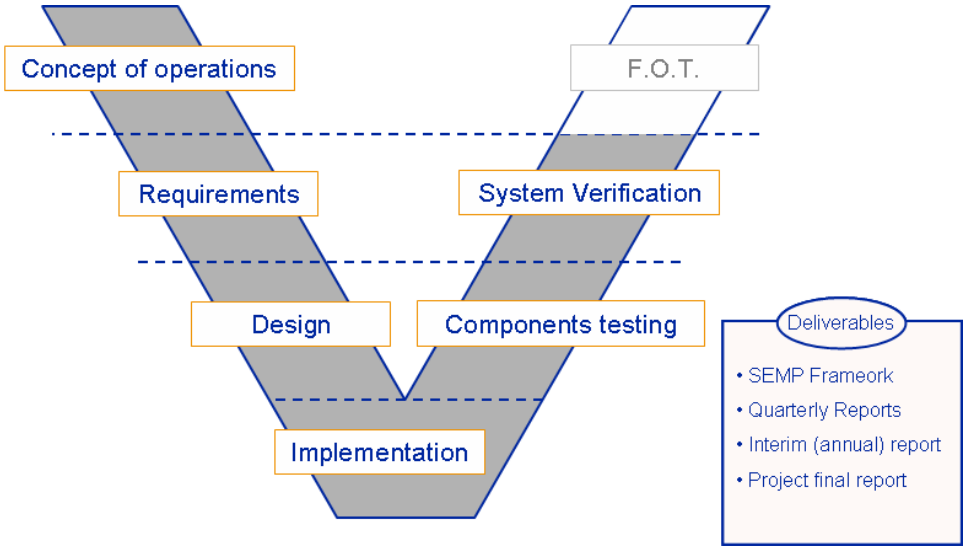


Figure 2-2: OBMS Systems Engineering Process

The developed hardware suite stem from Commercial Off-the-Shelf (COTS) systems, or are enabled via access into the truck standard serial buses (or "J-buses"). They are conceived for online measurement of the set of driving characteristics which are most indicative of unsafe driving behavior. These characteristics include speed, following distance, lane keeping performance, safety belt use, and the use of turn signals. Feedback can be provided to the driver, either directly or through carrier management, to allow drivers to significantly improve their safety performance. For example, if a driver receives a report that he/she is not using his/her turn signals during lane changes, that driver can then be monitored during a follow up period to determine if feedback had corrected the deficiency. This concept would be pioneered in commercial fleets because they have the resources and organizational structure to provide feedback and training to professional drivers.

We are currently working with a Los Angeles-based fleet of 100 drivers to determine the suitability of this hardware suite to the firm's management and truckers. In Phase II we will work with FMCSA and Caltrans – and maybe this fleet – to conduct a Field Operational Test, which would replicate this suite on a host of other vehicles and determine the technical and operational effectiveness of our OBMS suite of monitoring systems.

This document describes the results FOT work statement of the Onboard Monitoring System (OBMS) developed by the research team. The description of the OBMS is from the document "Onboard Monitoring and Reporting for Commercial Motor Vehicle Safety: Concept Of Operations" (Nowakowski et al., 2006) and also from its derivative "Onboard Monitoring and Reporting for Commercial Vehicle Safety: System Requirements" (Margulici et al., 2006).

2.3 Description of Onboard Monitoring System and FOT

The OBMS: (1) records and monitors hours of service, driver input commands, vehicle states, and environmental conditions and (2) provides recommended driving behavior by using selective feedback, either real-time and offline. Section 2.1 describes the present OBMS prototype system, and Section 2.2 presents the FOT research plan, including information on the experimental design.

Figure 2-3 diagrams the prototype OBMS currently under development. The OBMS consists of six subsystems:

- Core system
- Sensing equipment
- Data storage devices
- Real-time feedback devices
- Driver input devices
- Offline analysis tools.

In general, as the driver begins travel, the core system monitors driving behavior based on information obtained from the sensing equipment. Specifically, the core system stores a set of recommended driving behaviors as the reference. These behaviors will be based on values determined during the initial installation and testing (e.g., an acceptable violation of the speed limit) a review of the relevant literature, and, in the case of Commercial Off-The-Shelf (COTS) devices, manufacturer input. The system will compare driving behavior with referenced behavior, and its primarily intended use is to save event data into storage for carrier safety managers to process. It will also be used, where practicable and already within the COTS capabilities, to provide alerts to the driver. The data recorded in the storage devices can be processed by an offline analysis tool in the carrier back office. The offline analysis produces individual driver safety metrics which can be tracked over time.

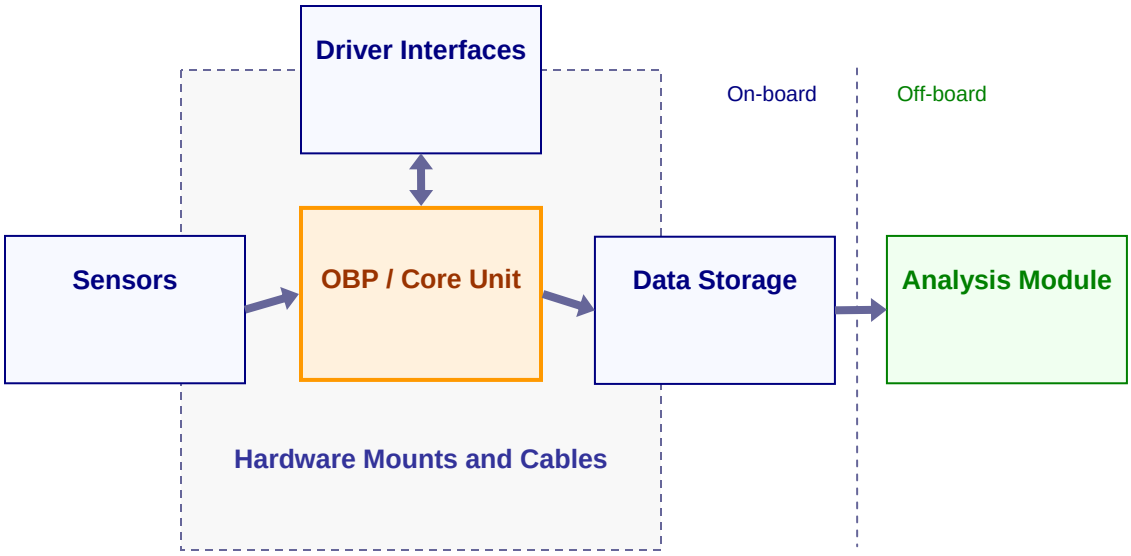


Figure 2-3: Onboard Monitoring System

The OBMS will perform the following operating modes:

- Driver identification
- Monitoring, recording, and as available, real-time feedback during normal driving conditions
- Incident and event recording
- Reporting (generated from system logs)
- Idle mode (when ignition is off)

Functionally, the system will monitor following parameters:

1. Driving behaviors related to vehicle speed.

This includes *vehicle speed relative to speed limit*, with speed transgressions recorded in storage devices. In this case, a visual/audible warning shall be given to the driver since this can be done quite easily, and speeding is widely acknowledged to be dangerous.

Another monitored parameter will be *vehicle speed relative to safe curve speed*, as determined by an online calculation of vehicle dynamics, coupled with road surface sensing. The feedback approach for unsafe speed is TBD.

Also to be measured is *vehicle speed relative to roadway (weather) condition*. The OBMS will provide offline analysis on the roadway and weather conditions by using information, such as stored regional weather map, wiper usage, and an *in situ* road surface (ice vs. no ice) sensor. The envisioned system will obtain wiper usage by COTS sensors mounted onboard (as wiper usage is not part of the serial data bus stream). The feedback approach for unsafe speed is TBD.

The final driver behavior related to vehicle speed to be monitored will be *vehicle speed relative to traffic flow*. The OBMS will include an Eaton VORAD EVT-300 with lane change detection. The feedback approach for unsafe speed is TBD.

2. Driving behaviors related to following distance.

This relates to *following too close for the combination of traveling speed and trailer loading*. The OBMS will be use of the same EVT-300 used to determine vehicle speed relative to traffic flow. In this case, however, the OBMS shall also combine EVT-300 information with the speedometer reading available through the truck data bus to determine unsafe following distance. Because of the risk of this behavior and the (relative) ease in displaying a warning, the OBMS shall provide real-time feedback in the form of a warning/status light in addition to offline processing and feedback.

Another monitored parameter will be *following too close for weather conditions*. The OBMS will provide, at a minimum, offline analysis on the roadway and weather conditions by employing information, such as stored regional weather map, wiper usage, and sensor output of road surface (ice vs. no ice) condition. If it is feasible to do so, real-time information will be given to the driver. The feedback approach for the unsafe following distance is TBD.

Also recorded will be *hard braking events* and the causes to include cut-ins. To do so requires speedometer, accelerometer, and video camera data. The OBMS will use DriveCAM, a product that combines accelerometer and video camera. Delayed or off-line feedback with summary statistics will be given to the driver.

3. Driving behaviors related to lateral control.

Lane position and lane changes will be recorded. The OBMS system will be Assistware's systems to provide lane position with respect to the lane marking. Such commercial systems can provide real-time lane departure warning in the form of a visual/audible warning. Delayed or offline feedback with summary statistics shall be given to the driver.

The *use of turn signal before merging*. The OBMS will include a turn signal "on" detector, for which we will wire. Delayed or off-line feedback with summary statistics will be given to the driver.

Also recorded will be *side or blind spot vehicle presence during lane changes*. The system will use a TBD side collision warning system to determine blind spot vehicle presence. The side collision warning system will provide real-time feedback in the form of a visual/audible signal to the driver. Delayed or offline feedback with summary statistics shall be given to the driver.

4. Other driving behaviors

A *surrogate measure of driver fatigue* will be recorded. The OBMS will incorporate the lane departure warning system to examine driver fatigue. The lane departure warning system shall give a real-time visual or audible warning to the driver.

Hours of service will be recorded. The system will utilize a COTS product to record such HOS information.

Driving behavior at intersections will be monitored. The primary candidate system incorporate GPS/GIS and speedometer information with NAVTEQ's system to determine if the vehicle stops for stop signs. Delayed or off-line feedback with summary statistics based on recorded data shall be given to the driver.

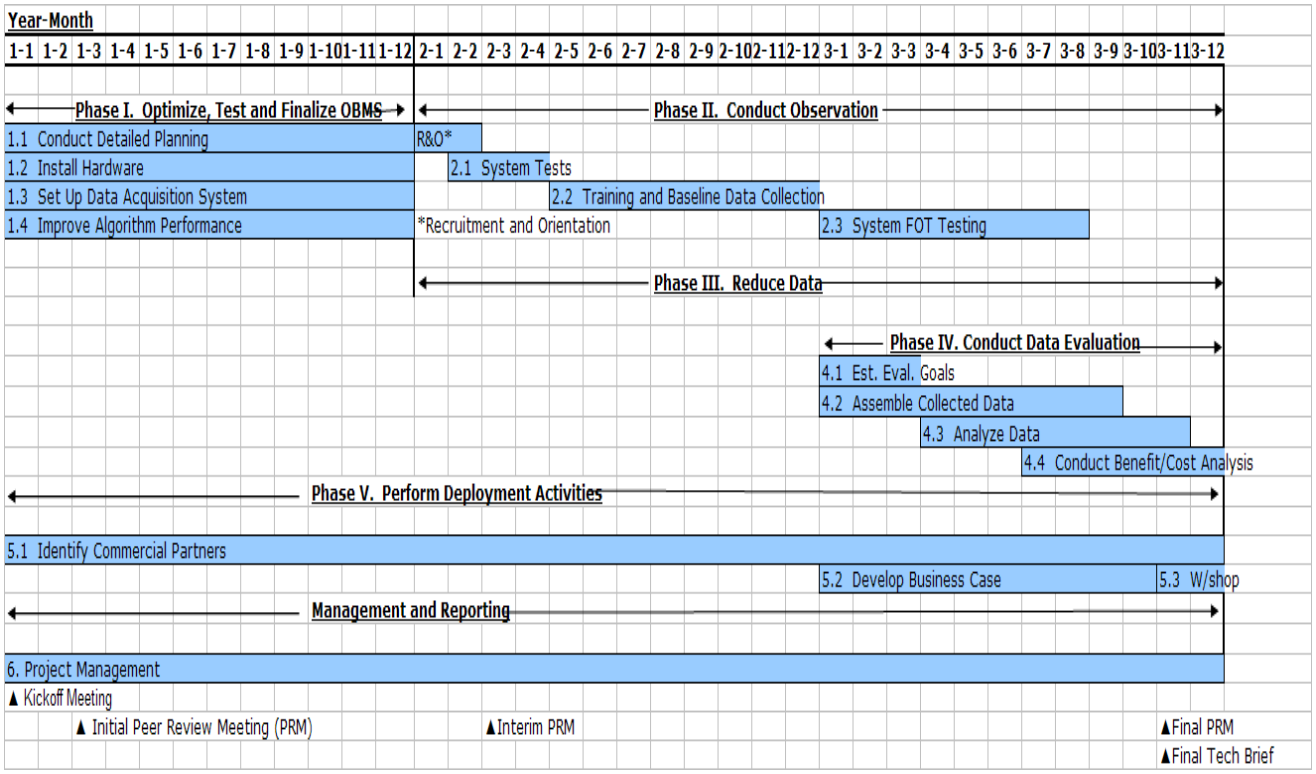
In addition, *driver attention will be monitored.* While the most direct measure for both distraction and drowsiness is monitoring eye scan behavior; the cost for such systems is prohibitive at this point. The primary candidate system, therefore, will use recognized (e.g., Rimini-Doering et al., 2005) surrogate measures including steering input, , lane position, and pedal inputs,. The offline feedback with summary statistics will be given to the driver.

2.4 Statement of Work

This project will take place over a period of 36 months. Within that time frame, the formal FOT will be conducted over 18 months period and will consist of three parts: *baseline*, *training*, and *final observation*. This formal FOT will be preceded by a 12 month period leveraging off the OBMS prototype development; during these initial 12 months, the OBMS design will be optimized, then it will be installed, tested, and refined. The final phase of testing and refinement will involve a pilot test to fine tune the overall approach and procedures. Table 1 shows the project timeline, tasks and milestones.

At the conclusion of the Statement of Work is a "Project Deliverables" section, where deliverables called out within the work statement are listed, along with specific due dates (with time annotated in months from project start date).

Table 1: OBMS FOT Milestone Chart



Phase I. Build, Test and Finalize OBMS

Task 1.1 Conduct Detailed Planning

We initiate this task with a sequence of detailed planning steps, beginning with preparation of a kickoff meeting to describe the work plan and schedule. We anticipate the interchange at the kickoff to significantly influence detailed planning. Hence, subsequent to the kickoff, the focus of this task will commence: further defining the work plan and schedule shown in Figure 1. Each of the tasks described in this SOW will be defined to at least two levels: subtasks and activities. Linkages and dependencies between activities and subtasks will be determined, and the entire project will be represented – and managed – within a critical path management nomograph.

What is key, of course, is the content that fulfills this structured approach: understanding of OBMS system, subsystems and algorithms – alternately expressed, how the system will work and the inclusion of logistical and other details and improvements by the carrier partner and drivers.

An important element of the OBMS FOT will be a Peer Committee, as this committee will perform a series of reviews, beginning with the advisory panel whose input was sought for the Phase I effort and whose names and affiliations are shown below. We will add to the Peer

Committee as FMCSA, Caltrans and other project participants and stakeholders feel appropriate, for example, the American Trucking Associations, American Transportation Research Institute.

Table 2: OBMS Phase I Advisory Panel

Last Name	First Name	Organization	Title	email address
Advisory Panel				
Ambrozlac	Alain	Pacific Coast Container Inc.	DOT / Safety Coordinator	alain@pcc.cc
Barberich	Bevin	Booz Allen Hamilton	Senior Consultant	barberich_bevin@bah.com
Chaul	Elias	California Intermodal Associates	Terminal Manager/Principal	echaul@clatrucking.com
DeDeaux	Brian	Coast Oil Company	East Bay Territory Manager	bdedeaux@coastoil.com
Hickman	Jeffrey	Virginia Tech	Research Associate	jhickman@vtti.vt.edu
Knee	Bill	Oak Ridge National Laboratory	Director, Intelligent Transportation Systems Program	upc@ornl.gov
Knipling	Ron	Virginia Tech	Senior Research Scientist	rknipling@vtti.vt.edu
Kynaston	Bruce	CHP	Lieutenant	bkynaston@chp.ca.gov
Leimbach	Rich	California Trucking Association	Director of Safety	rleimbach@caltrux.org
Naman	Gary	Gan-Trans	President	gary@gan-trans.com
Rule	Tom	Logex	VP Operations	Tom.Rule@Logexcorp.com
Thackery	Ronald	American Medical Response / EMSC	Vice President, Professional Services	ron.thackery@emsc.net
Torres	Tanisha	FedEx	Project Engineer	tmrees@fedex.com
Project Sponsors				
Bui	Triet	Caltrans Division of Research and Innovation	Technology Applications	triet_bui@dot.ca.gov
Robin	Jerry	FMCSA	Office of Research and Technology	jerry.robin@fmcsa.dot.gov
Walker	Martin	FMCSA	Research Division Chief	martin.walker@fmcsa.dot.gov
Woolley	Randy	Caltrans Division of Research and Innovation	Technology Applications	randy_woolley@dot.ca.gov
Project Team (partial)				
Margulici	JD	CCIT	Senior Engineer	jd@calcolt.org
Misener	Jim	California PATH	Program Manager, Safety	misener@path.berkeley.edu
Nowakowski	Christopher	California PATH	Associate Engineer	chrisn@path.berkeley.edu

The detailed FOT work plan will be the product of this task, and it will be developed in two installments: at month three, an interim work plan will be delivered, and at month twelve – at the end of the task – a final work plan will be delivered. In the intervening months 4 – 12, the participating carrier, FMCSA, Caltrans, Peer Committee and other stakeholder inputs, as well as PATH experience and knowledge during parallel tasks under this project phase, will be used to develop the final work plan.

The work plan will be a detailed statement describing tasks, subtasks, their interrelationships and the overall schedule. It is important to note that its starting points will be this document supplemented the accumulated documentation and project-specific knowledge documented as a

course of executing the systems engineering process of the current project, outlined in the Vee-diagram of Figure 4. Note that within this Vee-diagram context the FOT subject of this project occurs during Phase 2 and it the antecedent of systems deployment. This contextual setting provides the basic motivation and structure for the FOT.

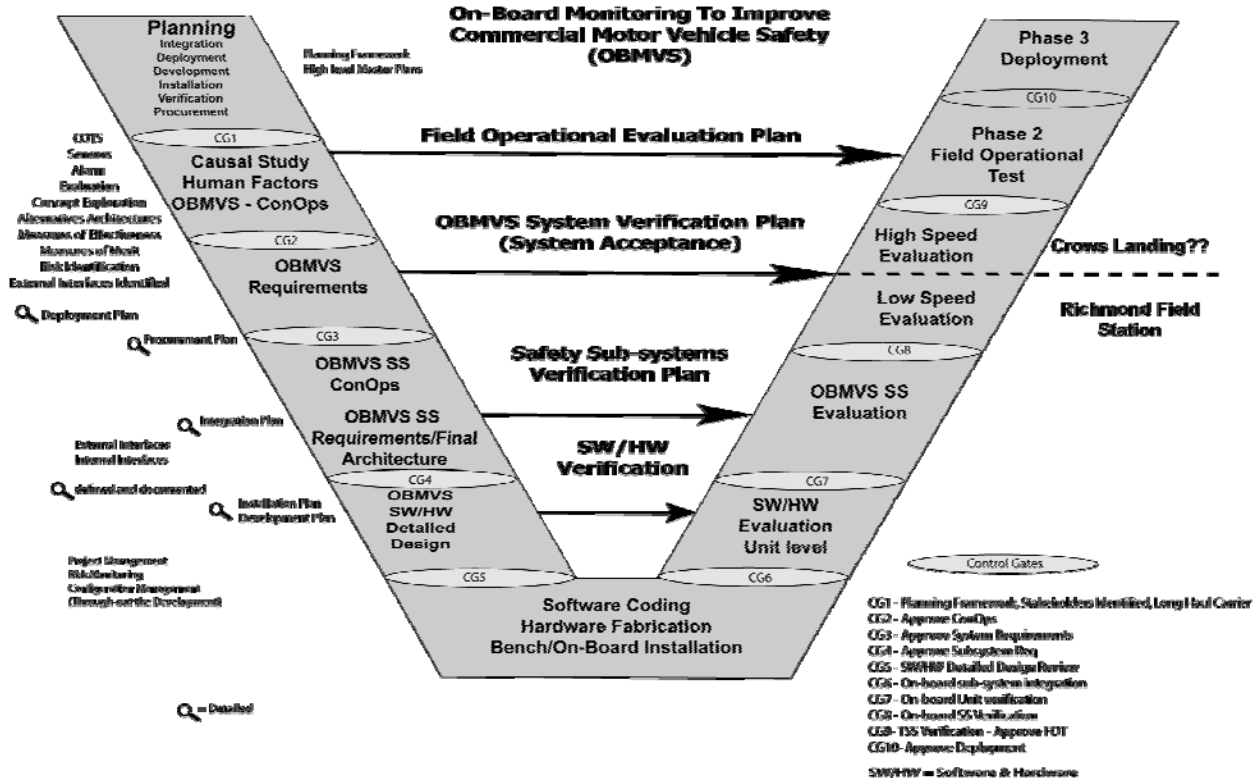


Figure 4. The Systems Design Process for OBMS

As a final note, another basis for the work statement will be the fulfillment of a systems requirements document, and as such for each of the two work plan iterations, a further-embellished (detailed) systems requirements document will be included.

Task 1.2 Install Hardware

In this task, we will replicate the OBMS hardware system on 20 trucks. We will leverage fromthe OBMS prototype system, replicating the exact hardware system developed under this effort. This system configuration, or generic equipment listing, is shown in Table 2. The specific system components, and in particular the software and serial bus interfaces that constitute the OBMS, is under current development.

Table 2: OBMS System Configuration

Processing	
1	PC-104

2	MPEG encoder (2)
3	Serial expansion board
4	Anolog I/O board
5	CAN card
7	PCMCIA slot board
8	WiFi card & antenna
Storage	
1	Hard Drive
Sensors and COTS	
1	Accelerometer
2	Driver ID reader
3	Electronic On-Board Recorder (EOBR)
4	Front radar
5	GIS roadway map
6	GPS receiver
7	Inward video camera
8	Lane departure warning system
9	Outward video camera
10	Road surface conditions sensor
11	Rollover sensor
12	Side radar (2)
13	Steering angle sensor
14	Thermometer
15	Throttle angle sensor
16	Wheel speedometer
17	Wiper usage sensor
Driver Interfaces	
2	LCD Display
3	Digital Sound Processor

Our baseline assumption is that the installation work will be performed by PATH development engineering staff, who will conduct the work at the carrier's or truck maintenance site, which is presumed to be in Southern California. While this entails travel, it utilizes experience from PATH staff while minimizing the out-of-service time for trucks. We believe this strategy is the most cost- and time-effective approach.

We estimate that while the first truck may take 4 – 6 weeks to configure to an OBMS tractor, subsequent installations will take less time due to experience and in the end, the average OBMS installation will consume approximately two weeks.

This task will begin at the onset of the project and continue for up to 1 year.

Task 1.3 Set Up Data Acquisition System

In this task we will configure FOT Data Acquisition System (DAS), composed of the following:

- Computer and operating system
    - PC-104 computer
    - Real-time operating system for data gathering – QNX6
- C programming language for driver development
- **S**oftware to interface COTs components

In configuring the FOT DAS, we will finalize input, output and interface characteristics of COTs components, install C code for interface through the RS232, then refine software for data gathering based on data requirement. We will test software for system components and software integrity, user interface/compatibility, then implement refinements based on test results as necessary. Finally, we will document software and testing procedures.

Task 1.4 Improve Algorithm Performance

In this task, we will improve the performance of our prototype OBMS algorithms, primarily by iteration and experimentation. We will conduct this task in full recognition that our algorithms will be hosted on the processors and hardware configuration being installed in Task 1 – and those will not be changed.

<u>Task 1.3.1 Refine real-time following algorithm</u>

In this task, we will improve the performance of the prototype real-time algorithm for forward vehicle tracking. We will estimate/predict the forward vehicle relative speed and relative distance based on tracking, determine vehicle trailer load current loading from J-Bus information, then develop recommended following distances based on road grade, weather condition and other factors such as road geometry and trailer load.

<u>Task 1.3.2 Refine speed exceedance algorithm</u>

We will improve the performance of vehicle speed vs. speed limit algorithm using GPS and map data, then develop recommended speed based on road geometry and weather conditions

<u>Task 1.3.3 Refine driver fatigue algorithm</u>

We will improve the performance of the algorithm to detect gradual degradation of lane-keeping performance and throttle control, which we use to predict driver fatigue.

Phase II. Conduct Observation

The FOT will be conducted from the carrier's terminal. A minimum of 20 tractors are to be equipped with the OBMS. The tractor will be used in normal service to make deliveries throughout California and possibly adjacent states. The FOT tractors will only be used on trips involving a single driver shift.

Task 2.1 System Tests

The purpose of the systems tests is two-fold:

(i) to conduct pilot testing in order to ensure the feasibility of the OBMS and test designs, and
(ii) as an outcome of item (i), take the OBMS "through its paces" as a rigorous means to conduct systems assessment.

The data collection for this task will focus on:

- Equipment reliability
- Reliability and quality of output data
- Driver reaction to OBMS real-time feedback
- Logistics of data download and transfer

During the two month baseline period of the FOT, the data collection instruments in the trucks will record information on driver behavior, but the OBMS will not provide any feedback to the driver nor will data be provided to fleet managers. In addition to establishing a baseline, data from this period will be compared to driver records compiled by fleet managers in order to validate both the OBMS data and manager perceptions of “at risk” drivers. Driver consent for data collection will be obtained at the beginning of the FOT.

At the end of the baseline period, managers will assess by their criteria whether the truck fleet is acceptable for FOT. They will also take part in a training session at which time they will be given all of the data collected which they will use for their initial feedback meetings with the test drivers. Information on data format and structure as well as standardized driver-manager feedback techniques will be discussed.

Task 2.2 Training and Baseline Data Collection

Per the timeline given in Table 1, there will be an eight-month data collection period. The first several hours driving an OBMS during this period will be spent in non-revenue driving with a supervisor who will familiarize the driver with the monitoring systems and real-time feedback. After the familiarization phase, drivers will be split into two groups, with one group meeting with the safety manager once a week for feedback and the other group meeting the safety manager every two weeks for feedback.

Data from this period, during which normal revenue routes, loads, and schedules will be utilized, will allow determination whether feedback has an effect on driver behavior and, if so, how the effect differs across drivers. Variables to examine include drivers who previously had good driving records versus those with bad driving records, as well as experienced versus inexperienced drivers. The length of this period may vary depending on how quickly baseline rates of behavior can be established. If the time to acquire baseline rates is high, the education period may need to be lengthened in order to see a change. If time to acquire baseline rates is low, changes may become evident more quickly.

Task 2.3 Conduct of FOT

During the final eight month period, all drivers will continue to have their behaviors monitored; however, only those drivers whose behaviors regress to an at-risk level (with TBD for the risk, depending on results from the baseline) will receive managerial feedback. With this technique, important information may be obtained:

1. how long the training effect lasts across drivers with different demographics,
2. how long it takes recidivist drivers to be brought back to safe driving behaviors, and
3. once the OBMS is deployed operationally, a good time interval for fleet managers to use for driver reviews.

It is recognized that once the OBMS is deployed, decisions regarding the use and timing of feedback can be decided on a company by company basis. The driver surveys and interviews during the FOT will help determine what type of feedback the drivers want and whether they only want feedback if there is a problem or would also like to be told that they are doing well. Also, once deployed, it may be possible for feedback to be contingent on an algorithm that regularly searches the OBMS data and alerts managers to a problem. These operational considerations will be examined during this period.

Data analysis will be conducted both during and after the field tests. From the schedule given in Table 1, it is anticipated that this will be completed within six months of the completion of the FOT. The study will use before-and-after design to test for changes in behavior. Conclusions will be drawn about the effect of the OBMS on individual drivers and on the group of drivers as a whole.

Our goal is to have up to 40 drivers involved in the FOT, representing a cross section of age, total driving experience, Class 8 driving experience, and driving record so that even with some turnover the study may have a pool of at least 30+ drivers who were involved from beginning to end. Given the length of the test, each of the drivers should have enough hours in a test vehicle for statistically meaningful results. Even though participation in the FOT will be voluntary, specific drivers will be asked to take part in the test in order to minimize self-selection bias. Care must be taken, of course, not to introduce any other selection bias.

Phase III. Reduce Data

We begin data reduction by refining data reduction and processing software, over and above that developed for prototyping. In short, we wish to determine and record hard-acceleration events with respect to weather and road geometry. We expect to develop an algorithm to monitor unnecessary large throttle angle with respect to slope, load, velocity, and inclement weather. The thresholds are determined by preset values and verified in the FOT.

We will also determine hard-steering events with weather and road geometry and to develop an algorithm to record large lateral acceleration events with respect to road curvature, yaw-rate, load, weather, and velocity. We will also use FOT data to determine lateral movement and lane change behavior to determine a threshold, which means we will analyze the driver response behavior to lane exceedances.

Finally, we will document for data processing, data set reduction and sensor recommendations.

Phase IV. Evaluation

Definitions and examples of key terms used in this section of the document are presented below.

Definition and Examples of Goal Areas, Objectives, Hypotheses, and Measures
Goal Area – Broad area of benefits, impacts, or factors to be evaluated. • Example: Assess Safety Benefits Objective – Specific type of information to be obtained within a goal area. • Example: Determine if drivers drive more safely with OBMS. Hypothesis – A specific statement, related to an objective, which is to be tested using data and analyses. Sometimes hypotheses are stated in the form of Research Questions. • Example hypothesis: Drivers using a collision warning system (CWS) will maintain greater following distances from lead vehicles than drivers without CWS. Measure – A variable or parameter used to test hypotheses. • Example: Expected number of rear-end crashes (derived from analysis) • Example: Number of times a vehicle's following distance is less than a safe following distance threshold (a surrogate measure used to derive the expected number of rear-end crashes).

Battelle (2003)

Task 4.1 Establish Evaluation Goals

It is important to note that performance measures specific to OBMS is comprised as a combination of the terms above and the OBMS data. While we will determine goals as an outcome of this task, we recognize that we measure these goals by performance measures, so as an up-front activity of Task 4.1, we will establish very specific performance measures and map them into the following five broad evaluation goals (benefits, acceptance and human factors, performance, product maturity, and institutional issues). These performance measures stem from the US DOT Intelligent Vehicle Initiative goals as listed in Battelle (2003) and shown above. The evaluation goals are described below.

Goal 1: Achieve an in-depth understanding of the benefits of the OBMS. This goal can be subdivided into a number of different categories, two of which, safety, and productivity, will be used here.

Goal 1A. Achieve an In-Depth Understanding of Safety Benefits. The primary safety benefit expected from the deployment of the OBMS is a reduction in the number and/or severity of crashes and the resulting reduction of injuries and fatalities. Because fatal and injury crashes are relatively rare events, the chances of a statistically significant number of them occurring during

the FOT are small. This evaluation will therefore seek to determine whether drivers drive more safely with the OBMS than without it using surrogate measures such as adherence to speed limits, maintaining a safe following distance, and lane keeping – essentially, the parameters measured by the OBMS. We note that because the OMBS is composed of several subsystems, each designed to address a specific driver behavior (e.g., speed and following distance), the effects on behaviors can be evaluated individually.

Goal 1B. Achieve In-Depth Understanding of Productivity Benefits. Deployment of the OBMS can result in productivity increases through cost savings from reduced numbers and/or severity of crashes and lower insurance rates. Any cost savings resulting from productivity gains would have to take in to account the cost increases associated with the purchase and maintenance of the systems, training costs for drivers and mechanics, and possibly operating costs. Per discussion of Goal 1A, we do not expect a reduction of crashes in a limited observation, so we will infer the benefits. However, we note that ancillary benefits, perhaps in fuel economy due to more careful driving, may arise. To the extent possible, all the potential accrued benefits will be reflected in the benefit/cost analysis discussed in Section 5.

Goal 2. Assess User Acceptance and Human Factors. The OBMS will primarily be used as a means for fleet managers to assess the safety performance of their drivers. In order to modify those behaviors viewed as unsafe, managers will meet with individual drivers on a regular basis to go over the data from the OBMS. While the introduction of some real-time feedback will affect the driving environment, after a short familiarization period, there should be little effect on the driving task. Interviews and surveys will be used to determine driver perceptions of the value of the OBMS as well as privacy concerns.

Goal 3. Assess OBMS Performance and Capability Potential. This goal address the ability of the system to perform its specified functions while meeting reliability and maintenance requirements. Performance will be measured using downloaded data from the FOT, while assessment of system reliability will be based on the need for servicing during the FOT as well as the self-diagnostic functions built into the system itself.

Goal 4. Assess Product Maturity for Deployment. Even if the OBMS benefit goals are met and both drivers and managers find it to be useful, the costs and feasibility of large scale production and deployment must be considered along with installation and operational costs.

Goal 5. Address Institutional and Legal Issues that Might Affect Deployment. There are a number of areas in which institutional challenges can arise including the political arena, labor-related issues, liability, and even the physical environment in which systems may be used. These must be addressed before any large scale implementation can be undertaken.

Task 4.2 Assemble Collected Data

In order to conduct the evaluation of the OBMS, data will be collected from the following sources:

Historical and OBMS FOT Crash/Incident Data. There are a number of publicly available databases that include information on truck involved crashes and incidents. These include the University of Michigan Transportation Research Institute's "Trucks Involved in Fatal Accidents (TIFA)," the General Estimates System (GES), and the newly released Large Truck Crash Causation Study (LTCCS) Database. Crash and incident from the company involved in the FOT will also be used.

Onboard Driving Data. This source includes all data collected from test vehicles during the FOT.

Surveys and Interviews. All carrier personnel involved in the FOT, including drivers, mechanics, and corporate staff, will be asked to participate in at least one survey or interview, in order to understand how the OBMS affects their job performance and working conditions. Those directly involved with the driving task will be surveyed several times over the course of the FOT.

Fleet Operations Records. System reliability, operating costs, and savings created through use of the OBMS will be established by using the carrier's maintenance and operational records.

The above four types of data that will be collected and analyzed over the course of the FOT are described to further detail below, with respect to use in the OBMS FOT.

1. Historical Crash Data

Annual rates of crashes, injuries, and fatalities will be based on ten-year averages from several sources. The primary national traffic safety databases all contain descriptive data primarily collected from police crash reports. NHTSA's Fatality Analysis Reporting System (FARS) includes descriptive data on vehicles, drivers, roadways, and environmental conditions collected from police reports, emergency medical service reports, hospital records, and coroner's reports. The Trucks Involved in Fatal Accidents database from the University of Michigan Transportation Research Institute supplements FARS data with additional data from interviews with police, drivers, and motor carriers. NHTSA's GES is a probability-based, nationally representative sample of all police-reported fatal, injury, and property-damage-only crashes, that collects descriptive data based exclusively on police crash reports.

It is hoped that the newly available LTCCS database will play a major role in the FOT.

The LTCCS contains the same type of descriptive data as the primary national traffic safety databases, but also focuses on pre-crash factors such as driver fatigue and distraction, vehicle condition, weather, and roadway problems. This makes the LTCCS the only national examination of all factors related to causation in large truck crashes.

Information from the various historical information sources will be examined in a four step process to identify driving conflicts as follows:

1. Separate data by crash type
2. Identify the predominant critical events and critical reason that led to the truck's

involvement in the crash for the crash type of interest
3. Identify the movements prior to those critical events
4. Use the combination of the critical events and the movements prior to define the driving conflicts.

2. Onboard Driving Data

The OBMS DAS will acquire data from several sources as shown below in Table 3. All sensors will be on the tractor.

Table 3: Attributes to be Monitored and Associated Feedback Methods

Attributes	**Incorporated Sensors/Equipment/Info**	**Real-Time Feedback?**
Speed limit	Wheel speedometer, GPS system, and GIS information	Yes. There is potential here to provide real-time feedback. The same warning light mechanism can be used as is planned to be used for following too close.
Safe curve speed	Speedometer and rollover stability advisor	Yes.
Speed relative to roadway condition	Stored regional weather map, wiper usage, and thermometer	No
Speed relative to traffic flow	Speedometer and Radar/Lidar	Yes
Following distance	Stored regional weather map, wiper usage, thermometer, speedometer, and Radar/Lidar	Yes
Driver attention	Steering input measurements, lane position, and hard braking events	No. Driver attention is not being monitored directly due to the current costs and limitations of eye-tracking systems. If we were monitoring the eyes for eyes-off-the-road time, then there could be several mechanisms to provide real-time feedback.
Hard braking events	Speedometer, accelerometer, and video camera	No. Correct, no real-time feedback should ever be provided for hard braking events or hard steering events. Providing any sort

		of feedback during or immediately after an event only risks distracting the driver and creating a situation that is even worse. With hard braking and hard steering events, what is important is not an individual event, but the frequency with which these events occur.
Lane position	Lane departure warning system	Yes
Turn signal use before merging	Turn signal use and lane departure warning system	No. There is no need for real-time feedback on turning signal use before merging. To do so would only risk distracting the driver during the maneuver and creating an unsafe condition.
Blind spot check during lane changes	Side collision warning system	No. We have no reliable method of monitoring "blind spot check" because the proposed system does not include eye-tracking capabilities
Hard steering events	Speedometer, accelerometer, and steering encoder	No
Collision warning activations	Speedometer, accelerometer, forward and side collision warning systems, throttle angle measurements, brake use, steering encoder reading, and camera	Yes
Seat-belt use	Seat-belt sensor	Yes
Crashes	Speedometer, engine RPM, accelerometer, collision warning systems, throttle angle measurements, brake use, steering encoder reading, and camera	N/A
Driver fatigue	Lane departure warning system	Yes
Hours of service	EOBR	No.
Driving behavior at intersections	GPS system, GIS info, and speedometer	No. Technologies to reliably perform real-time feedback during intersection movements do

		not exist.
Other vehicle parameters	Engine RPM (especially engine over speed), fully depressing/releasing clutch (for vehicles with manual transmission), driving time, non-driving time, engine idle time, acceleration/deceleration, and fuel rate/fuel economy	No

Additional features include the following:

- Driver identification: in order for the system to keep track of individual records, a driver identification method will be featured, such as a personal smart card or an access code.
- Storage portability: in order to generate reports in a back-office, the system logs will be portable. This could be achieved by storing them on portable memory, or enabling download via a physical port or a wireless link.
- Report generation: based on system logs, software will enable the generation of reports whose frequency and format is yet to be specified.

When an FOT tractor returns to the terminal it will establish communication with a server in the building via a wireless network to transfer data from the trip to a server which can then be accessed by PATH. PATH will then link the driving data with information supplied by the company such as load and schedule. Data will be archived at computer systems at the truck site, then transported to PATH.

3. Surveys and Interviews

Both written surveys and personal interviews will be conducted with drivers, maintenance, and corporate personnel at various stages in the FOT. Information from these contacts will be the primary source for assessing user acceptance and human factors**.** With drivers, the initial contact will be used to explain what types of information the OBMS will gather and informed consent will be obtained. The initial driver survey will be given prior to the start of the OBMS testing and will involve such matters as driving experience, number of times they have had to execute emergency maneuvers (e.g., hard braking or sudden lane change) to avoid a crash, prior use of warning equipment, and attitude and expectations regarding onboard monitoring equipment.

At the end of the baseline period, the drivers will be given a full description of the OBMS and how it will be used during the second (education) phase of the FOT. As the FOT continues, drivers will be asked to comment on the usefulness of the system and how it has affected their driving. The final interview, at the end of the FOT, will seek in-depth attitudes and opinions regarding the system, the overall effect it had on their driving, and what changes they would make in the OBMS and managerial feedback.

Managers will follow a pattern similar to the drivers, covering a great deal of the same subject matter with the exception of driving experiences. As the FOT progresses they will be asked to comment on driver attitudes and the acceptance of manager recommendations based on the

OBMS data. As with the drivers, the final interview will seek in-depth attitudes and opinions regarding the system, the overall effect they feel it had on the drivers, and what changes they would make in the OBMS and method of feedback.

During the course of the FOT, PATH personnel will remain in contact with the carrier's maintenance staff to ensure that the equipment is operating as expected and to make any necessary adjustments. At the end of the FOT, a formal meeting will be held to solicit comments and suggestions.

4. Operations Data

Daily fleet operations records, which will include driver assignments, destinations, and loads, will be recorded by the carrier and integrated with the data from the OBMS. The carrier will also provide its historic accident and incident data as well as relevant maintenance records. This information will be used to estimate the costs and benefits of extending the OBMS installation to the entire fleet.

Task 4.3 Analyze Data

In the following section we will discuss how the various data elements collected during the FOT will be brought together to meet the evaluation goals.

4.3.1 Goal 1A: Safety Benefits

As previously discussed, the primary purpose of the OBMS is to prevent fatal, injury, and property-only-crashes. Since it is probable that few if any crashes will occur during the FOT, safe-driving objectives will be used as surrogate measures of changes in driving behavior attributable to the OBMS. A preliminary list of these objectives is given below:

- Driving within a five mph of the posted speed limit
- Take curves at a safe speed
- Maintain a safe following distance
- Maintain a safe lane position
- Use turn signals prior to changing lanes
- Reduce hard-steering events
- Reduce the number of hard-braking events

These will be refined at the completion of the precursor OBMS prototype development effort.

Since some driving events will be much more common than others during the FOT, e.g., speeding versus hard-braking, rather than simply comparing the before-and-after raw numbers of specific driving events, a score will be computed and assigned to each event type, based on that event's importance as an indicator of unsafe driving as shown in historical data and the literature. The total baseline score for each driver will be compared to that same driver's scores from the education and final periods to determine the overall effect of the OBMS.

If the pre- and post-education scores show a significant change, the next step will be to use that difference along with historical crash data to compute the potential number of crashes prevented, injuries prevented, and lives saved should the OBMS be installed on a large scale basis under a number of deployment assumptions.

4.3.2 Goal 1B: Productivity Benefits

If installation of the OBMS can reduce the number or severity of crashes, reduce injuries, and fatalities as well as lower the level of what is considered "normal" wear-and-tear, cost savings will accrue to both the carrier and the public. To the extent that output remains unchanged or increases, the end result will be an increase in productivity. The value of this gain will be used as an input the benefit/cost analysis discussed in Section 5.

4.3.3 Goal 2: User Acceptance and Human Factors

Given that data from the OBMS will not be used for real-time warnings but rather will be used by managers to modify unsafe driver behaviors through one-on-one meetings, the objectives for this goal will focus on driver acceptance, perceptions of usefulness, and product quality. If the OBMS is viewed as obtrusive by drivers, a burden by managers, or difficult to operate and maintain by maintenance, then deployment would be difficult even if benefits could be shown.

Information from surveys and interviews will be the primary source for meeting the following objectives. Some questions are designed to be asked several times over the course of the FOT in order to gather longitudinal data representing the change in opinions or perceptions over time.

Objective 1: Determine manager perception of the value of the OBMS as well as driver acceptance of advice based on data from the OBMS. While the effects of the one-on-one driver/manager meetings will be reflected in the before/after driving behavior comparisons that take place under Goal 1 (Safety Benefits), it will be useful to know if the counseling sessions are viewed as adversarial by either party.

Objective 2: Determine driver perception of the value of the OBMS as well as their reaction to being monitored and counseled by managers. In addition, determine how the system feedback was incorporated into their driving task.

Objective 3: Determine perceptions of product quality, value, and maturity. Through surveys and interviews, opinions will be solicited from those directly and indirectly connected to the FOT.

4.3.4 Goal 3: Performance and Functionality

A key measure of the performance and functionality of the OBMS will be the consistency of the data for individual drivers as they drive the same routes, especially during the baseline period when little or no change in driving behaviors would be expected. Driver opinion of the data output compared to how they felt they drove will also be considered although this may turn out

to be too subjective to be of use. Assessment of system reliability will be based on the need for servicing during the FOT as well as the self-diagnostic functions built into the system itself.

4.3.5 Goal 4: Product Maturity for Deployment

Assessment of product maturity for the OBMS, in terms of large scale deployment, will be based primarily on interviews with carrier management, any associated vehicle manufacturers, and OBMS component and subsystem manufacturers, as well as comparisons of the life cycle development and safety system introduction of comparable systems (as applicable) in the past.

4.3.6 Goal 5: Institutional and Legal Issues

Trucks operate across multiple jurisdictional boundaries and involve numerous stakeholders with different motivations, which can complicate the decision-making process. Achieving consensus, or even agreement, among a diverse set of stakeholders can often be challenging. Also, institutional issues may arise within an individual company when concerns over funding priorities, scarce resources, the delegation of responsibilities, and increased responsibilities of staff may each result in internal resistance and morale issues.

The first step in addressing this goal will be to identify potential public and private institutional and legal issues. This will be achieved primarily by interviewing stakeholders as well as individuals in the public and private sector who have dealt with similar issues. The second step will be to examine current laws, regulations, and case studies, as well as to enlist the individuals used to identify the potential problems, to aid in formulating possible mitigation strategies.

4.4 Conduct Benefit-Cost Analysis

Even if an FOT meets all of its operational goals the system must still be economically feasible if it is to progress to the large scale implementation stage. We describe the benefit-cost analysis (BCA) that will be performed to ascertain the net economic results of deploying the OBMS.

4.4.1 Benefit-Cost Analysis Approach

A BCA carried out on public sector projects involves more than measuring corporate net benefits. Social benefits and costs, opportunity costs, and other, often intangible, impacts that may be difficult to valuate must be monetized and factored into the analysis. Ultimately, the final question remains the same: are total benefits greater than total costs? If the answer is yes, BCR is greater than 1, and the project can be said to be economically feasible.

The framework of benefit-cost analysis involves:

- Identifying all the users and sponsors of the project.
- Identifying all the benefits and disbenefits of the project.
- Quantifying all benefits and disbenefits in dollars or some other unit of measure.
- Selecting an appropriate interest rate at which to discount benefits and costs to a present value

4.4.2 Benefits and Costs Included in this Benefit-Cost Analysis

For the OBMS, the list of potential benefits include savings due to reduced number and severity of crashes and gains in productivity. Costs include initial startup costs and maintenance. These are summarized in Tables 4 and 5. Also included in the tables are the sources for the "monetization" of the benefits and costs. Examples of the types of literature to be used as sources are:

- Benefit-Cost Evaluation of a Highway-Railroad Intermodal Control System, Lee et al., 2004
- Annual Report Of Fatal And Injury Motor Vehicle Traffic Collisions, California Highway Patrol 2003.

Table 4: Benefit Measures and Information Sources

Benefit	**Measure**	**Sources**
Safety	Reduced number and severity of crashes	Crash avoidance analysis Historic crash data
	Avoided fatalities, personal injury, vehicle damage, third party damage, and hazardous materials impacts per crash	Literature
Productivity	Avoided Cargo Damage Less Truck "Wear & Tear" Reduced Hwy user delay Reduced driver stress Lower turnover	Literature Maintenance records Health cost records
Improved Environmental Quality	Dollar value of reduced numbers of incidents	Literature (included in $ value of crash)

Table 5: Costs and Information Sources

Cost	Measure	Sources
Initial Start-Up	Dollar value of capital equipment and installation	Interviews and site visits
	Dollar value of initial driver & manager training	Interviews and site visits
Recurring	Dollar value of recurring equipment replacement	Interviews, maintenance records, and site visits
	Expected service life (years) of capital equipment (used to determine recurring capital costs)	Interviews, site visits, and literature search
	Dollar value of ongoing driver/staff training	Interviews and site visits
	Potential increased driver turnover due to dissatisfaction with being monitored	Interviews and literature search

Phase V. Perform Deployment Activities

In parallel to the Phase I – VI activities, deployment activities will be conducted as part of the project. The rationale for conducting the proposed research and FOT put forward in this proposal is the anticipation that the results can ultimately lead to widespread OBMS-based truck safety improvements. This raises the question of how to deploy the research results to bring about these improvements. This set of tasks is predicated on the premise that ultimate success may be accelerated if deployment plans are laid out from the onset and carried out in parallel with the FOT investigation, rather than sequentially.

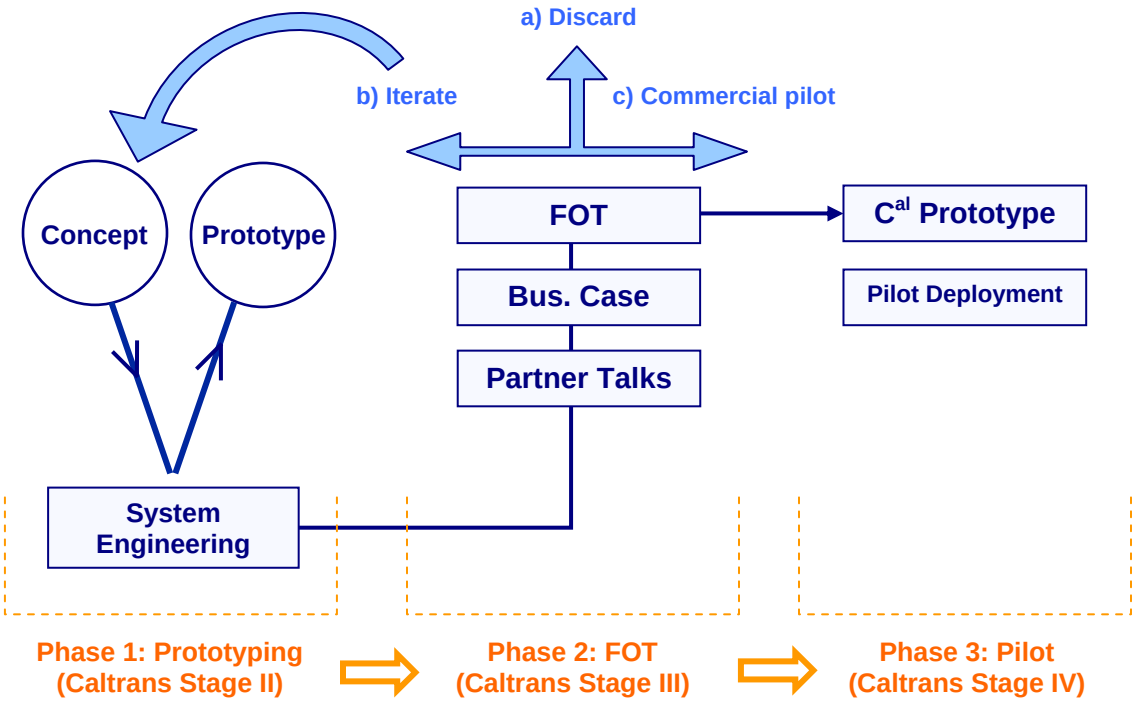
In general, the research may ultimately result in two types of outcomes:

- Policy guidance and funding of follow-on research if needs are identified
- Packaging of research findings into commercial products

The first type, policy and follow-on, requires that the research results are effectively and broadly communicated to policy makers and the research community. The second type, commercialization, requires two components: a business case that demonstrates the commercial potential, and early identification of commercial partners that can turn these results into products.

In order to communicate the results of the FOT to a large audience of regulators and research partners, a workshop will be organized in Washington DC towards the end of the project. The workshop will complement regular stakeholders meetings as well as research conferences where the project team may present its work, and bring together a broader audience for maximum impact. In order to facilitate possible commercialization, the truck and equipments manufacturing industry will be engaged as the FOT proceeds. In addition, the project team will leverage the cost-benefit analysis of Task 4 to develop a more comprehensive business case. In addition to the benefits and costs picture, the business case will identify and delineate the foreseeable market and investigate deployment questions such as legal implications and drivers acceptance.

A more detailed discussion on possible outcomes and the deployment process of this research can be found in the OBMS Concept of Operations. The diagram below is extracted from that document and depicts that process in the various stages of the project, and based on the evaluation of the FOT. Note that the phases outlined on that schematic can be linked to Caltrans' framework for research deployment, consisting of five stages[1].



The following tasks in this phase will be carried out as part of the deployment activities:

Task 5.1 Identify Commercial Partners

As soon as the FOT is underway, we will systematically contact possible commercial partners in the truck and equipment manufacturing industry. Companies that already manufacture and sell on-board recorders and other safety products will be particularly well suited candidates. The team will leverage its already existing network in the trucking and manufacturing industries. This network results from PATH's many past collaborations with the industry, and from previous investigations conducted as part of the precursor OBMS prototype development.

In the initial stages, the team's communication tools will consist of the OBMS Concept of Operations and the FOT design; they will enable business and technical discussions to take place with potential partners.

The expected outcome of this task is to establish a short list of companies that can engage in the project by studying the concept, keeping abreast of the progress and development, and considering its deployment in the market place.

[1] http://www.dot.ca.gov/hq/research/deployment_support/5_stages.htm

Task 5.2 Develop Business Case

In this task, we will combine the technical results and the cost-benefit analysis to identify product options. Once product options are identified, their specific costs and benefits to a carriers will be highlighted. The next step will be to conduct first-stage market research to roughly determine the nature and size of the foreseeable market for each product option. The methodology employed for the market research will be:

1. Compile data on truck equipment sales, including on-board recording and other safety equipment

2. Dialogue with commercial partners

3. Focused interviews with trucking companies, professional organizations and industry experts

4. Historical comparisons with other vehicle safety products and their rate of adoption

The last step in the development of the business case will be to examine additional factors financial that may help or impair product commercialization. An example is the legal framework. Monitoring and recording driving behavior can be both an opportunity and a liability for trucking companies and drivers alike. How current laws and regulations would treat a commercial offshoot of the system will be a major decision factor for trucking companies interested in acquiring it. With this case, results from Task 4.3.6 will be synthesized in this task.

The deliverable for this task will be a business case document that summarizes the findings of the business investigations.

Task 5.3 Conduct Diffusion Workshop

Towards the end of the project, a workshop will be organized to present the research, preliminary results from the FOT, and deployment or next-step activities underway. The objective of the workshop is to spread the results to a large audience of decision makers, regulators, practitioners and researchers. In turn, this may facilitate follow-up actions such as policy or priority changes, or more focused research to investigate promising areas.

The workshop will be organized jointly with FMCSA and Caltrans, and aim for a national audience. The format of the workshop is expected to be a one- or two-day event combining presentations and interactive sessions. This diffusion meeting will have, among other attendees, the Peer Review Committee formed under Task 1.1.

The deliverable of this task is the workshop itself and its proceedings.

Task 6. Management and Reporting

PATH will manage the project, to include staffing and other resources to technical, schedule and cost compliance with this proposal. PATH will also provide to Caltrans and FMCSA quarterly

technical and cost reports, no later than one month after the end of each quarterly reporting period. As an integral part of this effort, PATH will prepare research papers at academic and technical symposiums and conferences, as well as host at the end of this project a technical review meeting. Finally, PATH will assure that reports to FMCSA, to include web postings, are compliant to Section 508.

PROJECT DELIVERABLES:

Phase I.

1. Kickoff Slides, Other Preparatory Material and Summary Notes (Month 1)
2. Initial Peer Review Slides, Other Preparatory Material and Summary Notes (Month 4)
3. Work Plan (with updated systems reuqurements)
    a. Interim Work Plan (Month 3)
    b. Final Work Plan (Month 12)
4. Twenty OBMS-equipped tractors to measure attributes described in Table 1. (Month 12)
5. Report documenting "as built" tractor design (Month 12)

Phase II.

1. Baseline Data Collection Report (Month 18)
2. OBMS Training Report (Month 26)
3. Final Observation Report (Month 36)

Phase III. Data reduction software and documentation. (Month 36)

Phase IV. Evaluation Report (Month 26)

Phase V.

1. Business Case Document (Month 34)
2. Deployment Workshop Proceedings (Month 36)
3. Deployment Report (Month 36)

Task 6. Management and Reporting

<u>Scheduled Meetings</u>

Kickoff Meeting (Month 1)
Peer Review Meetings (Months 3, 15 and 35)
Final Technical Briefing (Month 35)

<u>Primary Reports</u>

Final Report (Month 36)

1. Documenting Phase I – V and derived from prior reports
2. Analysis of FOT, to include approach and results for
    - Safety benefits
    - Productivity benefits
    - User acceptance

    and an assessment of
    - performance and functionality
    - product maturity
    - institutional and legal issues

Quarterly Project Reports

3.0 Final Statement of Work

The transformation conducted in this project led to the final, submitted proposal and work statement provided (sans costs for this report although a fully-costed proposal was indeed produced) below. This transformation was painstaking and iterative, as a host of participants were considered:

Participant	Role
FMCSA	Research Sponsor – User Lead Agency on Peer Review Board
Caltrans	Research Sponsor – User Prime Contractor to FMCSA Under Cooperative Research Agreement Major Participant on Peer Review Board
University of California PATH Program	SOW Manager Lead FOT Evaluator Prime Contractor to Caltrans
Transecurity	OBMS Systems Provider Data and Resource Subcontractor (to PATH)
Virginia Tech Transportation Institute	Naturalistic Data Collection Lead Cost Share Participant
Montana State University	FOT Evaluator Subcontractor (to PATH)
ASE Consulting	Systems Engineering Subcontractor (to PATH)
Carrier 1 (TBD)	Participating with X vehicles and Y terminals.
Carrier 2 (TBD)	Participating with X vehicles and Y terminals.
Carrier 3 (TBD)	Participating with X vehicles and Y terminals.

Peer Review Board	Independent Review Panel

Onboard Monitoring and Reporting for Commercial Vehicle Safety (OBMS) Phase II: Field Operational Test

Draft Statement of Work (SOW)

The mission of the Federal Motor Carrier Safety Administration (FMCSA) is to reduce the number and severity of crashes on our Nation's Highways. Only about 15% of those killed and 24% of those injured in large truck crashes were occupants of large trucks.

In direct support of this mission, the *Onboard Monitoring and Reporting for Commercial Motor Vehicle Safety* (OBMS) demonstration project is being sponsored by FMCSA in collaboration with the California Department of Transportation (Caltrans),the University of California Partners for Advanced Transit and Highways (PATH) and their major partners and subcontractors including Virginia Tech Transportation Institute (VTTI) and Transecurity. The objective of the project is to demonstrate whether an onboard suite of driving performance monitoring technologies and feedback (both real-time and delayed) can reduce at-risk commercial driving behaviors, improve driver safety performance and can help keep the driver performing in a continued safe manner. This program consists of two phases. Phase I is the proof of concept and development of the prototypical technology suite completed May 2007.

Operator monitoring and feedback can be characterized as a behavior-based safety method. Safe behavior is rewarded and unsafe behavior is improved upon, thereby proactively improving overall safety. As identified in Sherry (2001), implementing an onboard driver-monitoring program requires the following four steps:

5. Identify behaviors which may be precursors to increased crash rates.
6. Determine cost-effective ways to monitor safe and unsafe behaviors.
7. Determine the best way to provide the driver with feedback which rewards safe behavior and discourages unsafe behavior.
8. Establish management and driver acceptance to the program.

The Phase I effort resulted in a prototype of the behavior-based safety method, but it went further as it developed a real-time feedback method. This could be characterized as "the best way" allowed in Sherry's third step. Hence, the system conceived for the FOT also includes real-time feedback, off-line driver feedback and a management review program that must be designed and tailored to fit the needs of the FOT carrier partner.

The Phase I study consisted of four parts:

5. Prototype Suite Concept of Operations and Requirements Generation – conduct literature search to identify the driving behaviors that should be monitored e.g., best safety return on investment.

6. Human Factors Studies - determine type of driver feedback e.g. real time, off line, visual, auditory based on stakeholder guidance and literature/product search findings.
7. Onboard Monitoring Suite - develop the prototype suite of identified technologies and install the suite a Class 8 vehicle.
8. Field Operational Test (FOT) and Evaluation Plan – the initial development of a research design for follow on FOT (Phase II).

Phase II is the Field Operational Test which this Statement of Work (SOW) addresses.

At the same time Phase I research was conducted, and as an independent initiative Transecurity was being formed – largely based on VTTI driver behavior research and spinoff data collection and reduction technologies (Data Acquisition System, or DAS) – and with similar product goals as the OBMS Phase I. Of compelling interest is that not only are the same goals as Phase I addressed in an emerging commercial system (albeit with somewhat less functionality), the data collection and analysis system used in the Transecurity DAS product are conducive to a large-scale naturalistic data collection effort. Hence, this FOT can serve a dual use: (i) an important evaluation of OBMS on real fleets, and at the same time (ii) collection of a large-scale commercial vehicle naturalistic driving database.

These two uses are served in the tasks of this work statement. While the OBMS FOT is the primary goal, naturalistic commercial vehicle driver data will be collected and stored for subsequent analysis. The goals are therefore dual, complementary and significant: (a) evaluate the effectiveness across multiple fleets and up to 250 trucks using the (Transecurity) DAS and (b) collecting the full set of non-OBMS data as naturalistic driving data. It should be noted that the full reduction of the naturalistic driving data will not be conducted under this work scope; that is for TBD potential future projects. However, some reduction will be conducted, as a subset of the data will serve as baseline or comparison data to evaluate the efficacy of the OBMS system to influence driver behavior and ultimately, driver safety. These uses (i) and (ii) and goals (a) and (b) are addressed through the SOW described in the next section.

1 WORK STATEMENT

The OBMS FOT will be conducted as shown in the Gantt chart sent as an attachment to this SOW.

The OBMS FOT Budget is also sent as an attachment to this SOW.

Roles and responsibilities of project participants are summarized at top level in Table 1 below.

2 TABLE 1. PROJECT PARTICIPANTS AND ROLES

Participant	Role
FMCSA	• Primary Research Sponsor – User • Lead Agency on Peer Review Board • Collaborative partner with Caltrans in the Cooperative Agreement
Caltrans	• Research Sponsor – User • Collaborative Partner with FMCSA in the Cooperative Agreement • Project Manager (Manages Scope, Schedule, Budget) • Major Participant on Peer Review Board
University of California PATH Program	• Lead Independent FOT Evaluator • Prime Contractor/ Partner to Caltrans • Subcontracts to other team partners
Transecurity	• OBMS Systems Provider • Data Collection and Resource (Subcontractor to PATH) • Primary contact with Carrier Partners
Virginia Tech Transportation Institute	• Naturalistic Data Collection Lead (Subcontractor to PATH) • Cost Share Participant for Transecurity
Montana State University	• FOT Evaluator (Subcontractor to PATH)
Systems Engineering Consultant	• Systems Engineering (Subcontractor to PATH)
Carrier 1 (TBD)	• Participating with X vehicles and Y terminals.
Carrier 2 (TBD)	• Participating with X vehicles and Y terminals.
Carrier 3 (TBD)	• Participating with X vehicles and Y terminals.
Peer Review Board	• Independent Review Panel (Members from each of the above and others to be named)

3 TASK 1. CONTRACT EXECUTION

1.1 Cooperative Agreement Amendment by FMCSA

1.2 PATH Contract Execution by Caltrans

13 Transecurity Contract Execution by PATH

4 TASK 2. DATA COLLECTION PLANNING

2.1 Select Partners

2.1.1 Select Carrier Partners

A target of three carrier partners will be selected to provide up to 250 total tractors for OBMS FOT testing and naturalistic driving. Criteria for carrier partner selection are: (i) operation of Class 8 tractors with safety need, (ii) significant commercial operations in California, and of course, (iii) willingness to participate in the FOT and data sharing per stipulation of this SOW. Desired additional attributes allow flexibility in experimental design. These include multiple terminal operations and modes of OBMS FOT experimental design, e.g., junior drivers in one terminal, senior drivers in another terminal and various feedback intervals, depending on terminal. Also, long versus medium haul differences are desired.

The final section will be coordinated with the FMCSA focal point for approval. The process will include a review of the carrier's safety record. Of particular importance for this task is to assess the current safety program and daily operations of the FOT carrier partner to assess their needs and to determine how the ultimate design of the OBMS suite of technologies and real time driver feedback/off line delayed feedback can best fit into their overall safety program. We will also explore the feasibility of providing limited real time feedback to their carriers' dispatcher, if the participating carrier is interested in this option and this is possible to do. The design of the FOT strategy plan, in which the carrier will also participate, will also depend on how willing/unwilling the FOT carrier partner will be willing to share their fleet operation safety records and historical data. The carrier will also participate in the development of the suite and other tasks as appropriate to assure program success and that the OMBS system meets their needs.

The OBMS team will conduct planning with FMCSA and the carrier partners and others, as appropriate, in order to, in subsequent tasks, develop, build, test and finalize the OBMS system, subsystem, hardware, software, protocols and algorithms to be used in the FOT. Included in this task are the hardware fabrication and software development, configuration of the data acquisition system and interfaces, enhancements and finalization of the performance of the algorithms addressing at a minimum, excessive speed, following distance, and driver fatigue.

4.A.1 2.1.2 Constitute Peer Review Board

An important element of the OBMS Research Design is the Peer Reviews. The OBMS team will develop a peer review plan and at the completion of the study a statement of the overall peer review panel. The OBMS team will be responsible for conducting two peer review meetings with a minimum of at least five industry experts including representatives of trade associations, motor carriers, CMV drivers, insurance companies and other stakeholders

the contractor feel is appropriate. Previous participants from the Phase I Review Committee will be used as a starting point

2.2 Develop Detailed Experimental Plans

4.A.2 2.2.1 Develop Naturalistic Data Collection Plan

Details of this plan will be contingent on characteristics of the fleets from carrier partners determined in Task 1.1. This is a leveraging activity, based on provision of a data acquisition system (DAS) with the OBMS equipment; thus, significant naturalistic data will be collected as a consequence of the OBMS installation.

4.A.3 2.2.2 Develop FOT Plan

The OBMS team will prepare a detailed FOT Work Plan and timetable to develop the necessary process, procedures, and documentation for the successful accomplishment of the project. The FOT Work Plan must also address the installation and testing of the technology suite into the trucks. In addition, the work plan must include and provide for Institutional Review Board Approval (IRB) and two Peer Reviews, one near the beginning of the project to obtain expert feedback/ideas and one near the end of the project to report findings. The OBMS team must, as part of this task, prepare a Systems Engineering Master Plan (SEMP) and Concept of Operations (ConOps) to support the overall Work Plan. The Work Plan must also include Contingency Plan(s) addressing areas of potential vulnerability and alternative plans of action.

It is envisioned that the ConOps and OBMS Research Methodology/Strategy Plan will be conducted in parallel, noting that the Strategy/Plan at this stage cannot be fully developed until the system concept has been agreed; however, a first iteration must be produced.

The ConOps will address what feedback information gets transmitted to the driver in both real time and on a delayed basis. This task will require several trips for PATH's systems engineering contractor to meet with the participating carrier.

Of particular importance for this task is to assess the current safety program and daily operations of the FOT carrier partner to assess how the off-line feedback program can fit into their overall safety program which will directly feed into the ConOps document. It must also explore the feasibility of provide some of the real time feedback to their dispatcher, if the participating carrier is interested and this is possible to do. The design of the FOT strategy plan will also depend on how willing/unwilling the FOT carrier partner will be willing to share their fleet operation safety records and historical data.

4.A.4 2.2.3 Systems Engineering Review and Documentation

A systems engineering consultant will work with the OBMS research team to formalize the FOT plan, and in particular transition the ConOps and the OBMS Research Methodology/Strategy Plan into an OBMS Requirements document and Requirements Verification Plan (System Acceptance Test Plan).

2.3 Conduct Design Review with FMCSA and Peer Review Board

4.A.5 2.3.1 Hold Peer Review

Results of Task 1.3 and in particular the Concept of Operations Document, Requirements Document, Requirements Verification Plan (System Acceptance Test Plan), and the OBMS Research Methodology/Strategy Plan will be reviewed to FMCSA. Comments from FMCSA will be included into the documents.

4.A.6 2.3.2 Hold FMCSA Review

Results of Task 1.3 and in particular the Concept of Operations Document, Requirements Document, Requirements Verification Plan (System Acceptance Test Plan), `and the OBMS Research Methodology/Strategy Plan will be reviewed to FMCSA. Comments from FMCSA will be included in the development of the OBMS Requirements document.

5 TASK 3. DATA STORAGE INFRASTRUCTURE AND ANALYSIS METHODS

3.1 Develop Data Storage, Transfer, and Retrieval Solutions

In this task, the California PATH OBMS FOT computer hardware configuration will be determined, then procured. The objective is to acquire and set up computational and data storage to receive and in subsequent tasks, analyze Transecurity data (It is important to note that the Transecurity OBMS and VTTI computer hardware *configuration* is already available and not part of this task.)

Our point of departure solution derives from requirement to store engineering and video data from 250 trucks for the one and a half year duration of the study. Based on prior experience, roughly 20,000 incidents of technical interest, such as unsafe lane changes or collisions, are expected during this time, and another 40,000 pseudo-incidents will be randomly collected background to document background conditions. Video storage requirements swamp engineering data requirements. Costs for extremely large data storage systems increase more than linearly with the storage required, as do the maintenance and support issues. Therefore we chose a relatively modest system with 23 TB of storage that would be sufficient to initiate the program comfortably as we assess our long term requirements. This point of departure solution will be reinvestigated during the course of this task to ensure that we have sized and costed the solution accurately.

Based on the aforementioned sizing, we propose a baseline system consisting of a Dell Computer System modeled on the systems configured by Transecurity for its portion of the OBMS FOT project. We preliminarily choose a PowerEdge 2900 III server box and packed it with eight 1-TB disks, the maximum allowable internal storage. We also choose a PowerVault MD1000 storage expansion box with 15 additional 1-TB disks, the maximum capacity of the MD1000, to bring raw storage to a total of 23-TB. The Dell 2900 II server is built to accommodate up to three attached MD1000 storage expansion boxes. Therefore, we could add an additional 30-TB of storage by adding two MD1000 boxes at a cost of about $20K per box.

We note that prices of large terabyte storage solution are dropping rapidly but there is still little justification for buying massive storage on the scale of 150-TB until it is truly needed.

3.2 Develop Data Processing/Coding Protocols and Tools

5.A.1 3.2.1 Review of Incident Coding Protocols

The OBMS team (and specifically, PATH members) will gain familiarity with Transecurity incident review data coding. In this task, PATH personnel will be trained on incident coding protocols and procedures in use by Transecurity/VTTI. This will allow PATH to spot check incident coding, and independently analyze the details of incidents with some consistency with the interpretations made by Transecurity/VTTI.

5.A.2 3.2.2 Detailed Data Analysis Plan

We will determine the data analysis plan based on lessons learned from OBMS prototype development work. In that work, the monitored parameters and the type of feedback to be given was systematically examined by first investigating commercial vehicle crash causes, and from that, deriving five categories or "core behavioral categories" which as a whole comprise the feature set recommendations for an ideal onboard driver monitoring system. The five monitoring categories or behaviors are:

1. Speed Selection
2. Following Behavior
3. Attention (or Inattention)
4. Fatigue
5. General Safety

From examination of these categories and by synthesizing literature examined (and reported) during the course of Phase I, specific monitoring methods, parameters and feedback were determined, and a prototype suite was developed.

The functions, monitored elements and feedback attributes that stemmed from the prototoype (Phase I) activity is given in Table 2. While this table provides a foundation for parameters and OBMS data onboard monitoring for the FOT, it does not provide the final list; the final list may not have recommended speed, nor hours of service.

Table 2. Summary of OBMS Suite: Functions, Monitored Elements, Feedback

Core Behavioral Categories	Potential Behaviors and Parameters to be Monitored	Potential Driver Feedback Real-Time	Off-Line (Delayed)
1. Speed Selection	Speed vs. - Speed Limit - Traffic Flow - Curve Speed - Road Surface - Grade	Visual feedback of recommended and maximum speed limits	Summary metrics such as the time spent over the recommended and maximum speed limits
2. Following Behavior	Following Distance Forward Collision Warnings Driver response to Cut-ins	Visual feedback of following time-gap shown Auditory alerts for following too close and approaching too fast	Summary of time spent following too close, # of warning incidents, video review of warning incidents
3. Attention (or Inattention)	Road/Lane Departures Hard Braking Events Hard Steering Events Eye-Off-The-Road	Visual and auditory alerts of lane departures or eyes-off-the-road for too long	Summary metrics such as the frequency of lane departures, hard braking, and hard steering incidents
4. Fatigue	Road/Lane Departures Lane Position Keeping Hard Braking Events Hard Steering Events Eye Closure (PERCLOS) Hours of Service (HOS) Compliance	Visual and auditory alerts of lane departures, lane weaving, eye closure, and HOS compliance	Summary metrics such as the frequency of lane departures, hard braking, hard steering incidents, and HOS compliance
5. General Safety	Safety Belt Use Lane Change Turn Signal Use Lane Change Blind Spot Check Proper Mirror Adjustment Fuel Economy Engine Overspeed (RPMs) Acceleration Deceleration (Downshifting) Gear selection on grades	Visual and auditory alerts if safety belt is not use Visual feedback on other parameters	Summary metrics such as time spent using the safety belt and the other listed parameters

5.A.3 3.2.3 Develop Program Evaluation Instruments

Based on the OBMS system characteristics, experimental design and the objective data that would be derived from the data analysis plan, the subjective component for program evaluation will be determined, and from this determination focus group topics, questionnaires, interviews to gather driver/management feedback during the data collection period will be developed.

6 TASK 4. OBMS INSTALLATION AND TRAINING

4.1 Develop Carrier OBMS Infrastructure

Transecurity will work with carriers to develop the Carrier OBMS Infrastructure on the trucks and at the carrier terminals

4.2 Install OBMS and DAS Systems

Transecurity will work with carriers to install OBMS and data recording instrumentation on 250 trucks across carrier fleets. It is anticipated that the installation process details will differ among the carriers, but it is also anticipated that the end-result will be a uniform and consistent installation of the same product. A systems engineering consultant will review and 'spot check' installation progress for conformance with the process vetted and reviewed in Task 1.4.

4.3 Conduct Training Sessions

6.A.1 4.3.1 Conduct Carrier Management Training

Transecurity will conduct carrier management training topics such as how the system functions, how to access and interpret the data, and how to perform driver-management counseling sessions to provide drivers with adequate feedback. California PATH will document the management and driver training and obtain driver signatures on appropriate consent forms.

6.A.2 4.3.2 Conduct Driver Baseline Training

The initial driver training provided before the baseline data collection begins will be provided by California PATH and in two rounds, each corresponding a data collection round (with duration defined in Task 4.2).

4.3.2.1 Conduct Baseline Driver Training Round 1

4.3.2.2 Conduct Baseline Driver Training Round 2

6.A.3 4.3.3 Conduct Driver OBMS Training

As the baseline data collection nears completion, Transecurity will provide a training session to the drivers which covers both the real-time feedback provided by the OBMS and how to interpret the off-line feedback reports that will be provided to the drivers. For each of the two rounds (with duration defined in Task 4.2), California PATH will document the management and driver training and obtain driver signatures on appropriate consent forms.

4.3.3.1 Conduct Driver Training Round 1

4.3.3.2 Conduct Driver Training Round 2

7 TASK 5. DATA COLLECTION

The driver behavior monitoring system field operational test includes three different data collection components that all operate in parallel as the study is being conducted:

First, the primary data collection activity involves the standard data capture and flow processes that comprise the Transecurity safety system. The data being captured, transferred, reduced and presented to the carriers by this system are used to provide feedback to drivers,

inform carrier management of driver performance, and to coach drivers with the goal of changing unsafe or costly behaviors.

Secondly, to assess the effectiveness of the Transecurity safety system, additional data items will generated during the data reduction process. Transecurity currently provides a standard set of classifications for each epoch that is captured and reduced. Additional measures have been added to the data reduction set to provide more detailed information about incidents and driver behavior from which we can assess the impacts of the system on operator performance.

Finally, to maximize the benefit to FMCSA, continuous data will be captured during the field operational test to create a naturalistic database that can be used by researchers to answer high priority safety related questions in the future.

5.1 Data Collection for the FOT

The OBMS FOT data collection is planned to run for 18 months. At any particular location, data collection will run for a nominal duration of 14 months, composed of two rounds of data collection lasting 7 months each. Thus, each driver enrolled in the study will use the system for 7 months. The first 3 months with the system will be designated as baseline. During the baseline, the system will be capturing how the participants drive normally, without any feedback. During the second 4 months, the feedback provided by the system will be enabled, and the drivers will be provided feedback reports and carrier management review sessions.

Although much will depend on individual carrier organization, if possible, a second round of data collection utilizing a new set of drivers will be conducted with the same trucks. This might be accomplished simply enrolling a new set of drivers at the same location. The second round of data collection would proceed the same as first, with 3 months of baseline driving and 4 months with the system's feedback enabled for a total of 7 months.

While the nominal data collection period is only 14 months, it is recognized that not all carriers or carrier locations need to start data collection at the same time. Thus, approximately 4 months of additional time is scheduled to allow for a rolling start by location. It is, however, desirable that each physical location start the data collection on all of the outfitted trucks at the same time.

7.A.1 5.1.1 Baseline Data Collection

For each of the two rounds, a baseline data collection will be conducted.

The purpose of the baseline is to collect data to document current driver behavior without the use of the OBMS feedback. The baseline allows for a reference point to determine whether or not the system had any immediate influence on driver behavior. Each driver will start the FOT with a minimum of a three-month data collection period where the onboard driver monitoring system is enabled, but all driver and carrier feedback mechanisms, both real-time and off-line, are disabled.

However, if the trucks that the drivers (of a particular carrier) typically drive already have real-time safety systems built in, such as forward collision warnings or lane departure warnings, those systems will remain active and available to the drivers for the duration of both the baseline and OBMS data collection phases.

Where possible, objective and subjective measures of historical driver performance will be collected. These may include driver accident histories with the company or subjective assessments done by fleet managers to rate each driver without having seen the feedback collected by the OBMS system.

5.1.1.1 Baseline Data Collection Round 1

5.1.1.2 Baseline Data Collection Round 2

7.A.2 5.1.2 OBMS Data Collection

For each of the two rounds, an OBMS data collection will be conducted.

After collecting three months of baseline data from each driver, the OBMS real-time and off-line feedback will be enabled for a total of four months. Training for the drivers on how to use this feedback will be provided in Task 3.2.3. For the first month, weekly reports will be provided to the driver, and bi-weekly review sessions will be held with the driver's carrier management personnel. After the first month, the off-line feedback may be reduced to bi-weekly reports provided to the driver and monthly review sessions with management.

California PATH, either alone or in conjunction with Transecurity, will conduct survey questionnaires, driver and management interviews, and/or driver focus groups throughout the duration of the data collection to assess the usability and effectiveness of the Transecurity OBMS system and individual driver review processes established within each carrier and at each location.

5.1.2.1 OBMS Data Collection Round 1

7.A.3 5.1.2.2 OBMS Data Collection Round 2

7.A.4 5.1.2.3 Program Evaluation Data Collection

PATH will have unlimited access to all data collected during the course of the field operational test. There are several methods that PATH will use to gain access to the data depending on where the data is stored and what type if data it is.

Transecurity will grant PATH personnel "super user" level id's to the live commercial database for the duration of the field operational test. PATH will be supplied with a royalty-free license to Transecurity's FleetMetrix software and DataDistillery software for the study duration. PATH will be required to review and sign Transecurity's acceptable use policies and undergo VTTI's Human Subjects Internal Review Board training and the UC Berkeley equivalent. PATH personnel will be expected to follow Transecurity's acceptable use policies during and after the field operational test. Access to the live commercial driver monitoring database will allow PATH personnel to review driver performance statistics in exactly the same format that the carrier management and safety personnel will. Data can be viewed using built in graphing and reporting mechanisms or filtered and exported to third party tools.

5.2 Naturalistic Data Collection

7.A.5 Continuous Data Capture

There are essentially two distinct data collection efforts that will be conducted during the FOT. The primary data collection activity is focused on the commercial driver behavior monitoring system. The commercial system has a set of data that it identifies, collects, and manages for purposes of identifying risky or costly driving behaviors and reducing them

through coaching and feedback. The previous sections of this proposal have described that process and data set in detail. The secondary data collection activity is a naturalistic data collection activity. The naturalistic data collection activity is focused on capturing a continuous stream of video and data on-board the vehicle to document real world driving behavior. Unlike the commercial data set which has a very specific intended use, the naturalistic data set can be used as an information source to address high-priority research questions as they arise now and in the future.

8 TASK 6. PERFORM DATA ANALYSIS

6.1 Data analysis questions shall include:

8.A.1 6.1.1 Can the OBMS system accurately distinguish "good" drivers from "at risk" drivers?

During the baseline data collection period, OBMS assessments of driver's performance will be compared to the driver records as compiled by fleet managers and subjective assessments of driver perceived performance by management. The goal of this analysis is to determine whether or not the OBMS system effects system safety. The data analysis tools such as cluster analysis could be used to establish which drivers fall into which category based on the number and types of incidents generated, as well as an analysis of mean OBMS metrics, such as speed and following distance.

8.A.2 6.1.2 Does individual driving performance improve over time with OBMS feedback?

The bulk of the FOT data analysis will utilize a within-subject design across time to chart individual improvements. Between subject factors may include subject driving experience, initial "risk" classification, shift, and/or type of driving (local vs. short haul vs. medium haul or team driving), carrier affiliation, and/or home base location

Of particular interest is whether or not those drivers initially categorized as "inexperienced" or "at risk" can be brought up to the levels of "normal" or "good" drivers, and how long that process takes. The primary measures for this analysis include incident frequency, mean OBMS metrics, and changes in the feedback advice being reported to both management and the driver.

8.A.3 6.1.3 How does the OBMS and feedback program improve safety?

The most difficult question to answer is whether the OBMS and feedback program actually improves safety. Improvements in safety might manifest themselves in a number of way, and the analyses in this section will attempt to quantify the safety improvements. As an example, a reduction in the frequency or severity of incidents recorded by the system could indicate that the OBMS and feedback system was having an effect. This analysis will compare incidents collected during the baseline data collection with incidents collected once the OBMS feedback has been enabled.

Additionally, changes in mean driving metrics such as speed, following distance, and lane keeping could also indicate that the system was having an effect. This analysis will compare the non-incident epochs collected during the baseline data collections with the non-incident epochs collected once the OBMS feedback has been enabled.

8.A.4 6.1.4 How do the driver's opinions and attitudes towards the OBMS system and program change over time?

One of the goals of the periodic subjective data collection (surveys, interviews, or focus groups) over the course of the FOT is to gather longitudinal data representing the change in opinions or perceptions over time. This includes overall opinions of the OBMS and feedback

program, as well as opinions over which specific features became more or less useful from both the driver's and management's points of view.

9 TASK 7. REPORTING AND REVIEWS

7.1 Conduct Final Review

9.A.1 7.1.1 Hold Peer Review

A workshop will be organized to present the research, preliminary results from the FOT, and deployment or next-step activities underway. The objective of the workshop is to objectively spread the results to a large audience of decision makers, regulators, practitioners and researchers. In turn, this may facilitate follow-up actions such as policy or priority changes, or more focused research to investigate promising areas.

The workshop will be organized jointly with FMCSA and aim for a national audience. The format of the workshop is expected to be a one- or two-day event combining presentations and interactive sessions. This diffusion meeting will have, among other attendees, the Peer Review Committee formed under Task 1.

9.A.2 7.1.2 Hold FMCSA Review

Results of the FOT and suggested deployment or next-steps activities will be reported to FMCSA. Comments from FMCSA will be included in the development of the subsequent peer review.

7.2 Develop Deployment Strategies

As OBMS FOT results warrant, deployment strategies will be developed for submission into the final report. The question of how to deploy the research results to bring about these improvements is predicated on the premise that ultimate success may be accelerated if deployment plans are laid out from the onset and carried out in parallel with the FOT investigation, rather than sequentially. In general, the research may ultimately result in two types of outcomes:

- Policy guidance and funding of follow-on research if needs are identified
- Packaging of research findings into commercial products

The first type, policy and follow-on, requires that the research results are effectively and broadly communicated to policy makers and the research community. The second type, commercialization, requires two components: a business case that demonstrates the commercial potential, and early identification of commercial partners that can turn these results into products.

7.3 Develop Final Report

We will develop a comprehensive final report and associated briefing material to reflect all tasks with the OBMS FOT.

10 TASK 8. MANAGEMENT

This task consists of several activities, from project execution to delivery of the final report and the project management closure meeting(s) required by FMCSA. Included at a minimum are:

Management team meetings as needed (may be telecom)
Providing a detailed work plan
Interacting with the carrier partner

Managing the systems engineering consultant subcontract
Forming the advisory team
Conducting the kickoff meeting
Producing monthly technical and quarterly progress reports
Managing a workshop to be delivered to FMCSA in Washington, DC
Conducting project management closing meeting and briefing in Washington, DC

Deliverable Schedule

List of Written Deliverables (these deliverables are listed major activities in the Work Statement).	**Proposed Delivery Dates**
Months ACA is from Execution of Cooperative Agreement Amendment	**Months ACA**
PATH Contract Execution	2
Transecurity Contract Execution	3
Carrier Partners Selected/ Signed	5
FOT Plan/ Strategy	6
OBMS ConOps, Requirements, Acceptance Test Plan	8
Readiness Review Documentation	8
Design Review Presentation Powerpoints	8
Peer Review of Documents	9
FMCSA Review of Documents	10
First Truck on Road Collecting Data	13
Documentation of Data Storage Transfer and Retrieval Solution	10
All Trucks on Road Collecting Data	17-35
Data Processing Plans: Coding Protocols, Data Analysis, Strategy	14
Data Collection Complete	35
OBMS FOT Data Analyses Results	39
Final Review Presentation Powerpoints	40
Peer Review of Documents	41
FMCSA Review of Documents	42
Quarterly Reports	Each quarter
Comprehensive Final Report	47

4.0 Additional Work

As an appendage to the considerable work conducted in concepting, meeting, coordinating and developing the SOW, two categories of collateral development and output were developed: data storage concepts and driver feedback concepts. While not exhaustively developed because of the relatively modest scope of this task order, they are noteworthy:

4.1 Data Storage Requirements

The California PATH OBMS FOT computer hardware configuration derives from the requirement to store engineering and video data from 250 trucks for the one and a half year duration of the study. Based on prior experience, roughly 20,000 incidents of technical interest, such as unsafe lane changes or collisions, are expected during this time, and another 40,000 pseudo-incidents will be randomly collected background to document background conditions. Video storage requirements swamp engineering data requirements. Costs for extremely large data storage systems increase more than linearly with the storage required, as do the maintenance and support issues. Therefore we chose a relatively modest system with 23 TB of storage that would be sufficient to initiate the program comfortably as we assess our long term requirements.

We chose to go with a Dell Computer System modeled on the systems configured by TranSecurity, Inc. for its portion of the OBMS FOT project. We chose the PowerEdge 2900 III server box and packed it with eight 1-TB disks, the maximum allowable internal storage. We chose a PowerVault MD1000 storage expansion box with 15 additional 1-TB disks, the maximum capacity of the MD1000, to bring raw storage to a total of 23-TB. The Dell 2900 II server is built to accommodate up to three attached MD1000 storage expansion boxes. Therefore, we could add an additional 30-TB of storage by adding two MD1000 boxes at a cost of about $20K per box.

Prices of large terabyte are dropping rapidly. There is little justification for buying massive storage on the scale of 150-TB until it is truly needed.

4.2 Off-Line Feedback and Reporting

While the bulk of the interface design under TO 5509 and 6609 was focused on the real-time, in-cab feedback for the driver, off-line feedback and summary reporting will still need to play an integral role in any successful driver monitoring and feedback program. The purpose of the off-line feedback and summary reporting is two-fold. First, the off-line feedback supplements the real-time feedback as there are some measures of driving performance that may only be useful when summarized over time or compared across drivers. Second, the summary reporting needs to convey the results of the driver monitoring to management, allowing for the identification of which drivers need improvement in which areas.

Two monitoring parameters that will primarily use off-line feedback include hard braking and hard steering incidents. For either parameter, a single incident alone may not be significant, but a pattern of repeated incidents might indicate an underlying problem such as aggressive driving or excessive inattention.

The content and timing of the incident recording – plus the feedback frequency and mode of delivery – were covered in the prior Task Orders but not to the extent that a FOT could be conceived and priced to the rigor of this work. Hence, the look and feel of a system that would record, save, and sort incidents (such as speeding, hard braking, hard steering, and seat belt nonuse) was conceived and developed. In Figures 4-1 through 4-4, a report format for the carrier based on actual prototype system data is given for following time gap, hours of service and fatigue, seat belt use and speed-related parameters. As can be seen, we conceived and used a common data base and similar format.

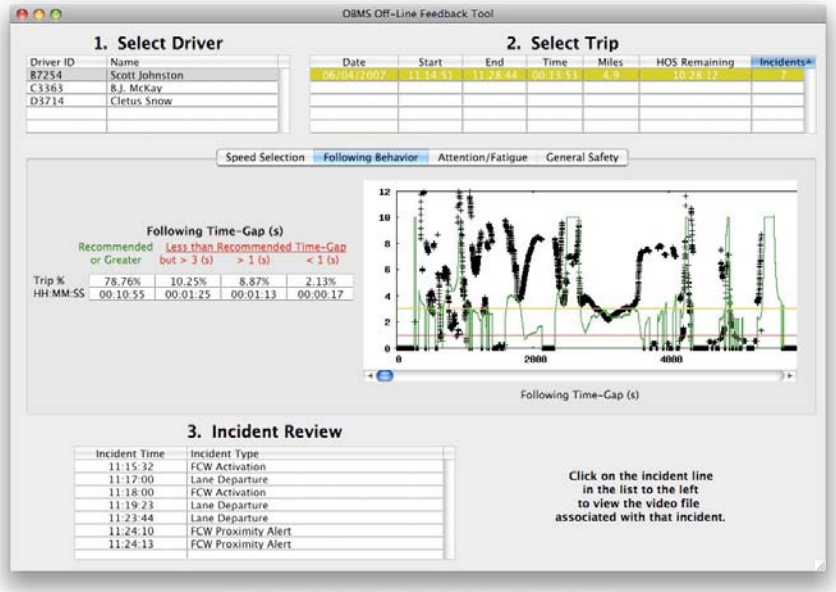


Figure 4-1. Exemplar Report Format for Following Time Gap Parameter

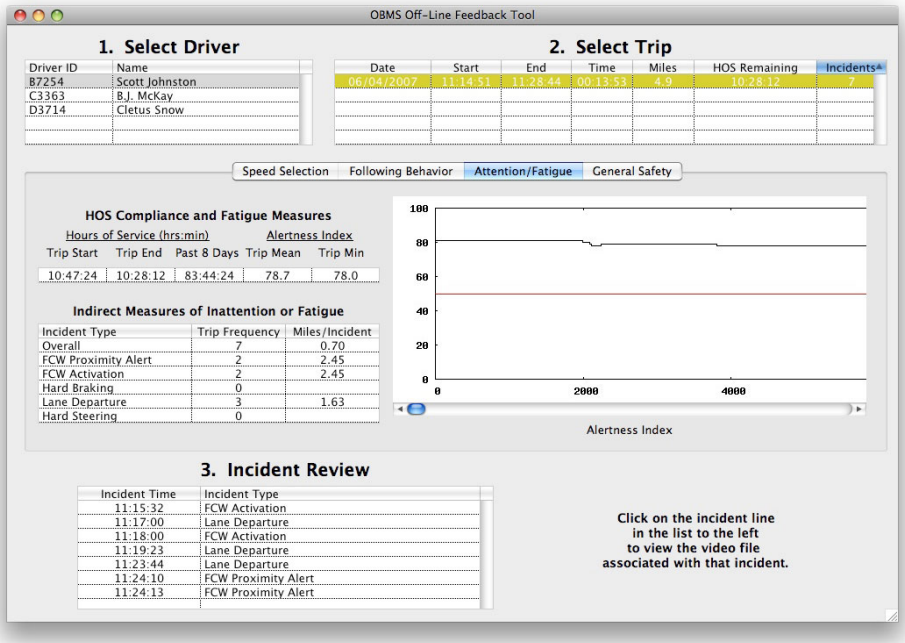


Figure 4-2. Exemplar Report Format for Hours of Service and Fatigue Parameters

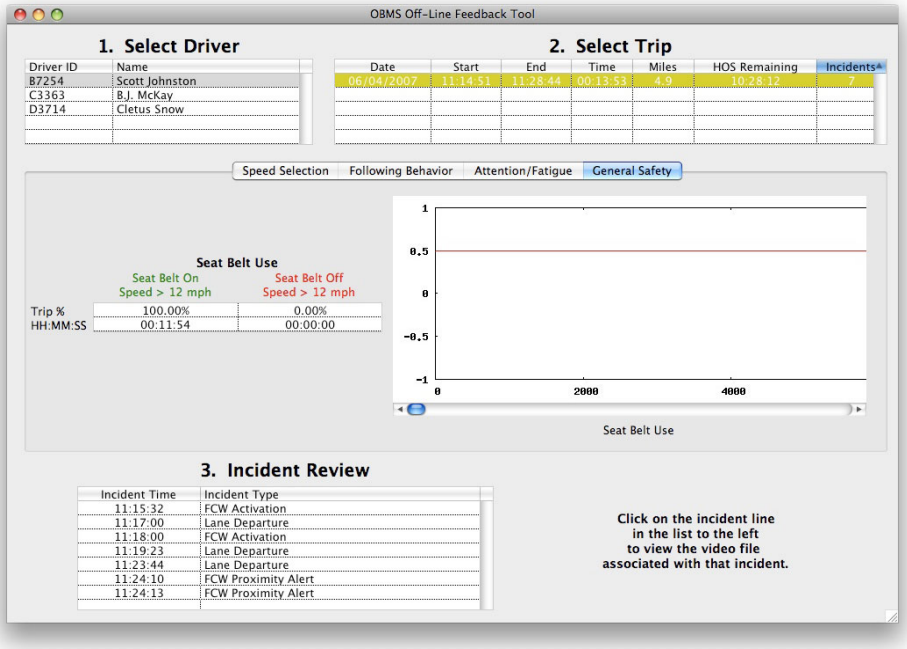


Figure 4-3. Exemplar Report Format for Seat Belt Use Parameter

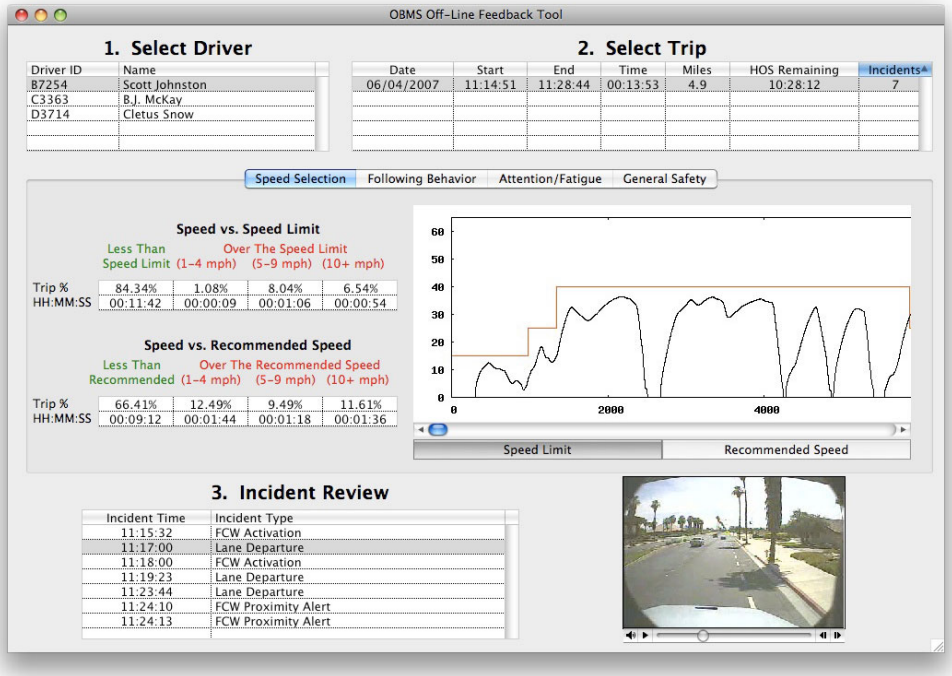


Figure 4-4. Exemplar Report Format for Speed-related Parameters

5.0 Discussion and Conclusions

The OBMS prototype development was based upon prior research which points to progression of four steps toward implementing an onboard driver-monitoring behavior-based safety approach:

1. Identify behaviors which may be precursors to increased crash rates.
2. Determine cost-effective ways to monitor safe and unsafe behaviors.
3. Determine the best way to provide the driver with feedback which rewards safe behavior and discourages unsafe behavior.
4. Establish management and driver acceptance to the program.

This project did not complete, nor was it designed to complete, the four steps, each in their entirety; rather, the project did a thorough review – and where possible, expert interviews with a carrier – to implement a prototype that addressed steps 1 – 3. Step 4 would require strong carrier participation, and ideally, a field trial.

This ideal state was never achieved because the Field Operational Test development under this Task Order was profoundly influenced by FMCSA, and while PATH and Caltrans worked assiduously to comply with the direction change, the effort to change 15 to 250 trucks greatly reduced the functional needs developed in the prior Task Orders. Moreover, our estimation of resources necessary to achieve the type of highly-functional and safety-focused onboard monitoring suite to deliver the degree and type of safety to drivers and their carriers greatly exceeded the US DOT's estimate, which had evolved toward giving priority to naturalistic 250-truck data collection effort, with a FOT as a smaller collateral goal. Therefore, in the end, the SOW and approach were developed (Section 3.0), but it is the authors' estimation that the prior approach would provide a better scientific basis to assess the efficacy of highly-functional and 'safety first' onboard monitoring systems to effect driver and traffic safety.

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