Wireless Roadside Inspection Phase II
Tennessee WRI CMRS Pilot Test
Final Report

May 26, 2011

U.S. Department of Transportation
Federal Motor Carrier Safety Administration

May 2011

FOREWORD

The Federal Motor Carrier Safety Administration (FMCSA) Wireless Roadside Inspection (WRI) Program is researching the feasibility and value of assessing truck and bus drivers and vehicles at least 25 times more often than is possible using only roadside physical inspection. The program is evaluating the potential benefits to both the motor carrier industry and to government.

This report summarizes the design, execution, and results of the Tennessee-based WRI Commercial Mobile Radio Services (CMRS) Pilot Test (Pilot Test). The goal of the Pilot Test was to determine the viability and effectiveness of wireless CMV inspections using currently-existing telematics technologies and systems. The platform's effectiveness and the CMRS method's ability to interface with the Government Back Office System (GBOS) were monitored and objectively evaluated. This goal was to be met by demonstrating the transfer of a CMRS-generated safety data message (SDM) to the GBOS, demonstrating WRI CMRS end-to-end system functionality via two CMRS partner systems, and demonstrating carrier, enforcement, and compliance decision-making using associated WRI graphical User Interface (UI) populated with the CMRS-generated SDM information.

The content of this report is organized in the following sections.

- Pilot Test Project Overview
- Pilot Test Description
- Conduct of the Pilot Test
    - Chronological Description of the Work
    - Evaluation and Use Cases Performed
    - Data Collected
    - Impact of the Test Environment
- Observations and Assessment
    - WRI System Functionality
    - WRI System Performance
    - WRI System Operations
    - WRI System Management
    - WRI System Costs
    - WRI System Security
- Lessons Learned
- Recommendations for Refinement and Enhancement
- References
- Appendices

This report will be of interest to carriers, regulators, and enforcement stakeholders who are seeking methods to improve highway safety and increase operational efficiency.

This is the final report for the CMRS portion of the WRI Pilot Test.

NOTICE

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16. Abstract

The Federal Motor Carrier Safety Administration (FMCSA) Wireless Roadside Inspection (WRI) Program is researching the feasibility and value of electronically assessing truck and bus driver and vehicle safety at least 25 times more often than is possible using only roadside physical inspections. The WRI program is evaluating the potential benefits to both the motor carrier industry and to government. These potential benefits include reduction in accidents, fatalities and injuries on our highways and keeping safe and legal drivers and vehicles moving on the highways.

WRI Pilot tests were conducted to prototype, test and demonstrate the feasibility and benefits of electronically collecting safety data message sets from in-service commercial vehicles and performing wireless roadside inspections using three different communication methods. This report summarizes the design, conduct and results of the Tennessee CMRS WRI Pilot Test. The purpose of this Pilot test was to demonstrate the implementation of commercial mobile radio services to electronically request and collect safety data message sets from a limited number of commercial vehicles operating in Tennessee. The results of this test have been used in conjunction with the results of the complimentary pilot tests to support an overall assessment of the feasibility and benefits of WRI in enhancing motor carrier safety (reduction in accidents) due to increased compliance (change in motor carrier and driver behavior) caused by conducting frequent safety inspections electronically, at highway speeds, without delay or need to divert into a weigh station.

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SI* (MODERN METRIC) CONVERSION FACTORS

Table of APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
In	inches	25.4	Millimeters	mm
Ft	feet	0.305	Meters	m
Yd	yards	0.914	Meters	m
Mi	miles	1.61	Kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
Ac	acres	0.405	Hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME	1000 L shall be shown in m^3	
fl oz	fluid ounces	29.57	Milliliters	mL
Gal	gallons	3.785	Liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		MASS		
Oz	ounces	28.35	Grams	g
Lb	pounds	0.454	Kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or “metric ton”)	Mg (or “t”)
		TEMPERATURE	Temperature is in exact degrees	
°F	Fahrenheit	5 × (F-32) ÷ 9 or (F-32) ÷ 1.8	Celsius	°C
		ILLUMINATION		
Fc	foot-candles	10.76	Lux	lx
Fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		Force and Pressure or Stress		
Lbf	poundforce	4.45	Newtons	N
lbf/in^2	poundforce per square inch	6.89	Kilopascals	kPa

Table of APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
Mm	millimeters	0.039	inches	in
M	meters	3.28	feet	ft
M	meters	1.09	yards	yd
Km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
Ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
G	grams	0.035	ounces	oz
Kg	kilograms	2.202	pounds	lb
Mg (or “t”)	megagrams (or “metric ton”)	1.103	short tons (2000 lb)	T
		TEMPERATURE	Temperature is in exact degrees	
°C	Celsius	1.8c + 32	Fahrenheit	°F
		ILLUMINATION		
Lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		Force & Pressure Or Stress		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003, Section 508-accessible version September 2009)

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ABBREVIATIONS, ACRONYMS, AND SYMBOLS

This section provides an alphabetical list of acronyms and their expanded names. The Glossary for the Wireless Roadside Inspection Program gives definitions and/or descriptions of selected terms.(1)

Aspen	not an acronym
BOS	Back Office System
CMRS	Commercial Mobile Radio Services
CMV	Commercial Motor Vehicle
CMVRTC	Commercial Motor Vehicle Roadside Technology Corridor
CSA	Compliance, Safety, Accountability
DSRC	Dedicated Short-Range Communication(s)
EOBR	Electronic On-Board Recorder
FMCSA	Federal Motor Carrier Safety Administration
FOT	Field Operational Test
GBOS	Government Back-Office System
HazMat	Hazardous Materials
HOS	Hours-of-Service
ID	Identification/Identifier
ISS	Inspection Selection System
MOU	Memorandum of Understanding
NTRCI	National Transportation Research Center, Inc.
NAS	North American Standard
OBE	On-Board Equipment
ORNL	Oak Ridge National Laboratory
Pilot Test	Wireless Roadside Inspection Commercial Mobile Radio Services Pilot Test
PIN	Personal Identification Number
PLC	Power Line Communications
SDM	Safety Data Message
SOAP	Simple Object Access Protocol
TPMS	Tire Pressure Monitoring System
TS	Timestamp
TT	Telematics Team
UI	User Interface
UT	University of Tennessee, Knoxville
VIN	Vehicle Identification Number
Volpe	John A. Volpe National Transportation Systems Center
WRI	Wireless Roadside Inspection
XML	Extendible Markup Language

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EXECUTIVE SUMMARY

This report summarizes the design, execution, and results of the Tennessee-based Wireless Roadside Inspection (WRI) Commercial Mobile Radio Services (CMRS) Pilot Test (Pilot Test). The purpose of this Pilot Test was to demonstrate the implementation of the commercial mobile radio services system to electronically request, collect and assess safety data message sets from commercial vehicles in operation in Tennessee. The results of this project have been used in conjunction with the results of the complimentary pilot tests to support an overall assessment of the feasibility and benefits of WRI in enhancing motor carrier safety (reduction in accidents) due to increased compliance (change in motor carrier and driver behavior) caused by conducting frequent safety inspections electronically, at highway speeds, without delay or need to divert into a weigh station.

The goal of the Pilot Test was to determine the viability and effectiveness of wireless CMV inspections using currently-existing telematics technologies and systems. The platform's effectiveness and the CMRS method's ability to interface with the Government Back Office System (GBOS) were monitored and objectively evaluated. This goal was to be met by demonstrating the transfer of a CMRS-generated safety data message (SDM) to the GBOS, demonstrating WRI CMRS end-to-end system functionality via two CMRS partner systems, and demonstrating carrier, enforcement, and compliance decision-making using associated WRI graphical User Interface (UI) populated with the CMRS-generated SDM information.

The Pilot Test was completed by defining the objectives and approach for the effort; establishing gratis partnerships with fleets, telematics providers, and safety sensor technology providers; facilitating private partner system development and equipment integration; conducting pilot testing in a real-world environment and staged data collection at fleet domiciles; performing a data analysis that explored the effectiveness of the implemented geofencing technology, validated the data contained in the SDM, and characterized the data collected; and drafting a final report that provided an overview of the CMRS pilot test activities and results.

During the Pilot Test, which extended from October 15, 2010 to January 31, 2011, two telematics teams were able to successfully submit SDMs to the WRI GBOS. These SDMs included vehicle identification information, driver identification information, and driver status information. A total of 1,705 messages were submitted during the period and were triggered at two inspection stations and at two domiciles. A self-test feature was also implemented by one of the telematics teams. The Pilot Test was successful in that many SDMs were transferred in real-time from vehicles moving at highway speeds and the primary goal and objectives of the effort were met. The Pilot Test also revealed some critical issues relative to WRI and these issues point to the need for an intermediate step between the just completed Pilot Test and the plan Field Operational Test. These issues include the need for a GPS boundary solution that can support triggering in corridors that have radiused roadways, neighboring secondary roads and bi-directional traffic to ensure SDMs can be reliably triggered; the need for a pull-in/by-pass function to allow WRI to be used in near-real-time enforcement and interdiction; to overcome the limitations of the Pilot Test GBOS by methodically dissect the current GBOS and develop a matrix of current functionality, maturity, scalability, and desired WRI production functionality; and revisit the viability and scalability of using XML as the only method of SDM data transfer to the GBOS.

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1. INTRODUCTION

1.1 WIRELESS ROADSIDE INSPECTION PROGRAM

Of the hundreds or even thousands of commercial motor vehicles (CMVs) that approach a typical weigh/inspection station in a given shift, each inspector may select only 6 to 10 CMVs for a thorough safety inspection. Today a vehicle is selected for inspection based on resource availability (e.g., whether an inspector is available, parking area at inspection site, traffic flow), safety history (e.g., safety fitness rating, date of last inspection), and other screening criteria (e.g., weight, visual observation of a potential problem). A safety inspection may take one half to one hour to complete, limiting the number that an officer can conduct in a day, and delaying the CMV and driver in reaching their destination as scheduled. New technologies and enforcement strategies could increase dramatically the number of times a commercial motor vehicle and its driver are examined without the need to detour into a weigh station, leading to better-targeted enforcement, safer operations, and reduced numbers of truck and bus crashes.

The Federal Motor Carrier Safety Administration (FMCSA) Wireless Roadside Inspection (WRI) Program is researching the feasibility and value of assessing truck and bus drivers and vehicles at least 25 times more often than is possible using using only roadside physical inspection (1). The program is evaluating the potential benefits to both the motor carrier industry and to government.

In a WRI, public sector entities (e.g. officers, inspectors and systems) electronically request driver and CMV compliance related data from onboard electronic equipment. The vehicle, and perhaps the motor carrier owner back office, compile driver hours of service data, and vehicle condition sensor data and deliver the data through direct wireless and/or internet communications to the government WRI system, all while the vehicle maintains its planned route and highway speed. The system conducts an assessment against a set of WRI inspection rules and electronically issues a WRI inspection report on the truck and driver to the requesting entity and the motor carrier. If enforcement officers receive a negative WRI result, they may use WRI data in screening to determine whether to pull the vehicle in for further scrutiny, use it to inform a traditional inspection, use it to trigger interception or choose to take no action. Data from the WRI assessment process will be used in the Compliance, Safety, Accountability (CSA) Program safety measurement system for motor carriers and drivers, managed by FMCSA. WRI supports multiple enforcement activities including real-time screening, inspection selection and traditional inspection processes as well as non-realtime interdictions.

FMCSA has developed a multi-year roadmap for the Wireless Roadside Inspection Program and has organized the program into three major phases with critical "go/no-go" decision points after each. The three phases are

- Phase I Proof of Concept Test (Technical Concept Development and Verification),
- Phase II Pilot Test (System and Strategy Definition), and

- Phase III Field Operational Test (Finalize Deployment Strategies and Impacts).

This report addresses the results of the Wireless Roadside Inspection Program Phase II Pilot Test (System and Strategy Definition). The program team collaborated with private-sector onboard equipment and service providers to complete a proof-of-concept test in August 2007. If the third phase is activated, it is planned as a field operational test of WRI, operating on multiple fleets across multiple state jurisdictions.

This phase of the WRI Program has supported prototyping three different WRI communication methods and a WRI back office system as well as testing and demonstrating all four in CMV operations. The four pilot tests conducted were

- New York Dedicated Short-Range Communications (DSRC) WRI Pilot Test
- Tennessee Commercial Mobile Radio Services (CMRS) WRI Pilot Test
- Kentucky Universal Identification (Universal ID) WRI Pilot Test
- Government Back Office System (GBOS) Pilot Test, supporting operations in all three states

Together the pilot tests were designed to assess the feasibility of the WRI strategy and the ability of the prototyped WRI system to support screening, assessments and interdiction by inspectors and enforcement.

1.2 CMRS WIRELESS ROADSIDE INSPECTION PILOT TEST OVERVIEW

This report summarizes the design, execution, and results of the Tennessee-based WRI CMRS Pilot Test (Pilot Test). The purpose of this Pilot Test was to demonstrate the implementation of the commercial mobile radio services system to electronically request, collect and assess safety data message sets from commercial vehicles in operation in Tennessee. The results of this project have been used in conjunction with the results of the complimentary pilot tests to support an overall assessment of the feasibility and benefits of WRI in enhancing motor carrier safety (reduction in accidents) due to increased compliance (change in motor carrier and driver behavior) caused by conducting frequent safety inspections electronically, at highway speeds, without delay or need to divert into a weigh station.

1.3 ORGANIZATION OF THIS DOCUMENT

The content of this report is organized in the following sections.

- Pilot Test Project Overview
- Pilot Test Description
- Conduct of the Pilot Test
    - Chronological Description of the Work
    - Evaluation and Use Cases Performed

- Data Collected
  - Impact of the Test Environment
- Observations and Assessment
  - WRI System Functionality
  - WRI System Performance
  - WRI System Operations
  - WRI System Management
  - WRI System Costs
  - WRI System Security
- Lessons Learned
- Recommendations for Refinement and Enhancement
- References
- Appendices

More details and background on Wireless Roadside Inspection, the WRI Program, other pilot tests and independent evaluation are provided in the reports listed in the reference section.

2. WRI CMRS PILOT TEST PROJECT DESCRIPTION

2.1 PURPOSE

This project, the WRI CMRS Pilot Test, was carried out in support of the WRI Program and was conducted by the Oak Ridge National Laboratory (ORNL). In addition, the John A. Volpe National Transportation Systems Center (Volpe) was responsible for developing the GBOS. The purpose of the GBOS was to demonstrate the functions necessary to collect wireless roadside inspection data from the pilot test sites in the form of a Safety Data Message (SDM), assess compliance and safety status, and issue an inspection report for possible enforcement action.. Further, the National Transportation Research Center, Inc. (NTRCI) via Battelle Memorial Institute (Battelle) was responsible for developing the Pilot Test requirements and functional specifications. The NTRCI was also responsible for conducting the overall evaluation of the WRI Pilot Test via the University of Tennessee (UT).

ORNL served as the initial evaluator for the CMRS platform with the purpose of verifying that the platform was ready to enter into the formal evaluation process. Once this verification was completed, the Evaluation Team began their evaluation of the CMRS platform.

An overview of the WRI System is shown in Figure 1. A “wireless inspection” is a process where public sector entities (people and systems) examine the condition of the vehicle and driver by assessing data collected by on-board systems. The data used in the assessment is termed safety data message, or “SDM.” SDMs will be delivered using wireless communications in real time to the public sector infrastructure. The SDM will contain basic identification data (for driver, vehicle, carrier, container, and cargo), record of duty status, and vehicle condition data that are typically available to safety inspectors during routine North American Standard (NAS) roadside inspections (See Figure 2 for the conceptual content of the SDM.) The roadside enforcement sites that will query and receive SDMs from CMVs are envisioned to include fixed inspection stations, unmanned remote sites on bypass routes and state borders. Depending on the availability of enforcement resources, interdiction strategies acting on the SDM will include real-time and non-real-time scenarios. The program will evaluate the potential benefits to both the motor carrier industry and government. Potential benefits to industry include keeping safe and legal drivers and vehicles moving on the highways without having to stop at roadside stations.

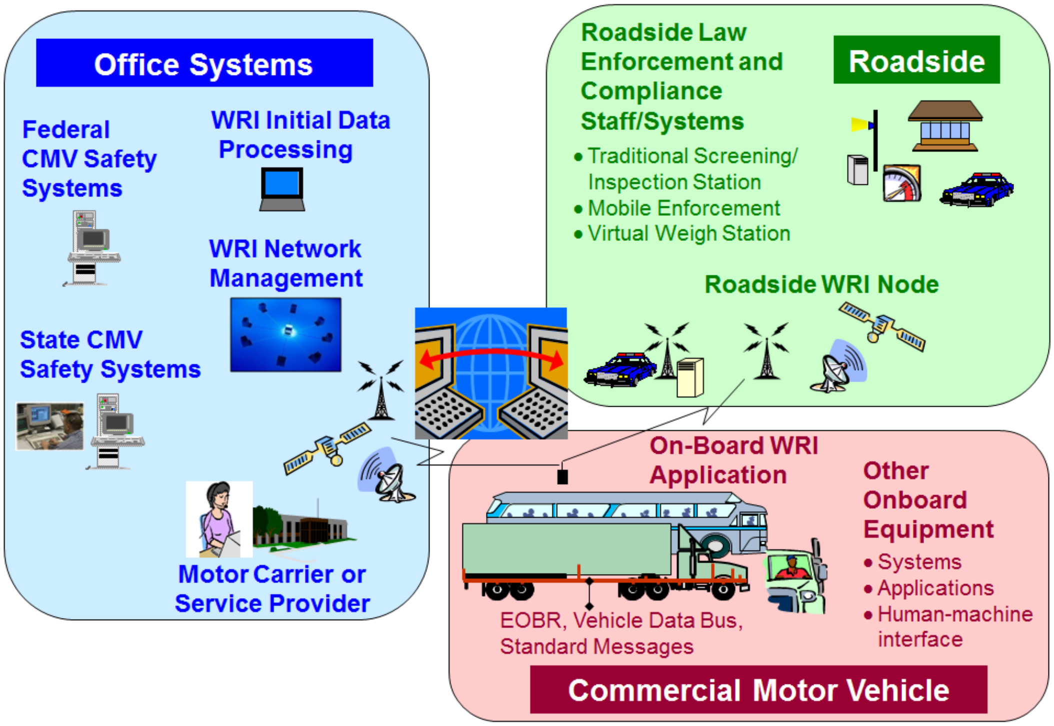

Figure 1. Wireless Roadside Inspection System Overview

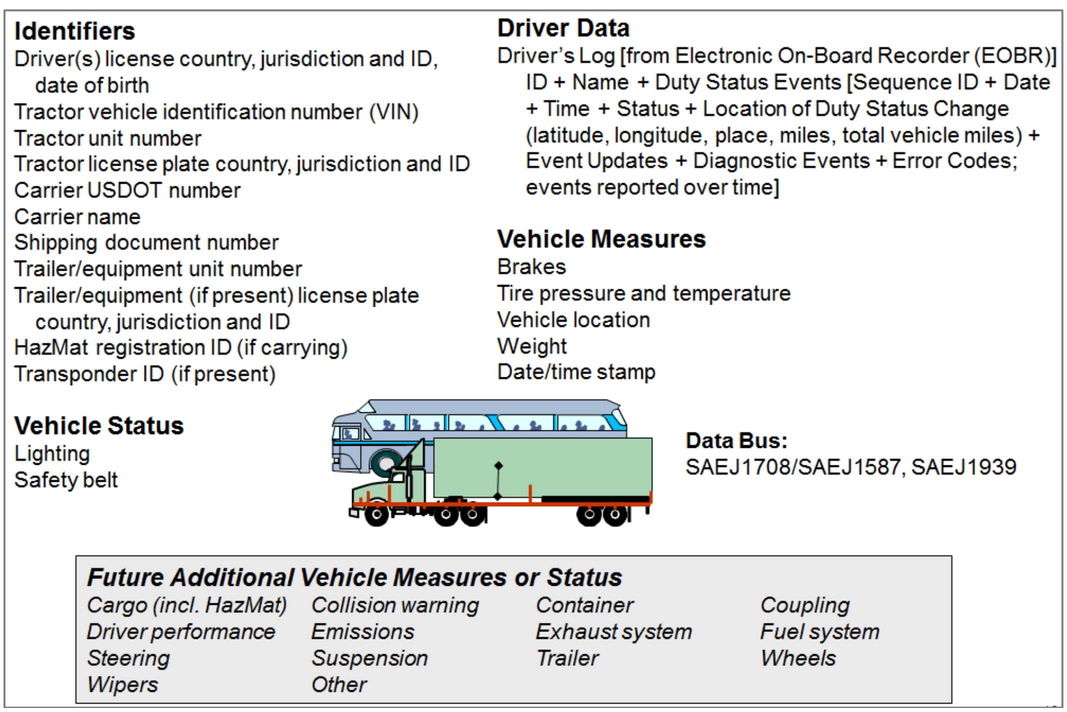

Figure 2. Conceptual SDM Contents

For the purposes of the Pilot Test, the CMRS platform involved the generation of the SDM for the carrier by a service provider. The information needed for the SDM may be contained on the

CMV, in the service provider's back office, or from a combination of both. The WRI CMRS platform demonstrated this method in the fixed (staffed) inspection station and a virtual (unstaffed or temporary, geofenced location) inspection station. A concept for the CMRS path is shown in Figure 3.

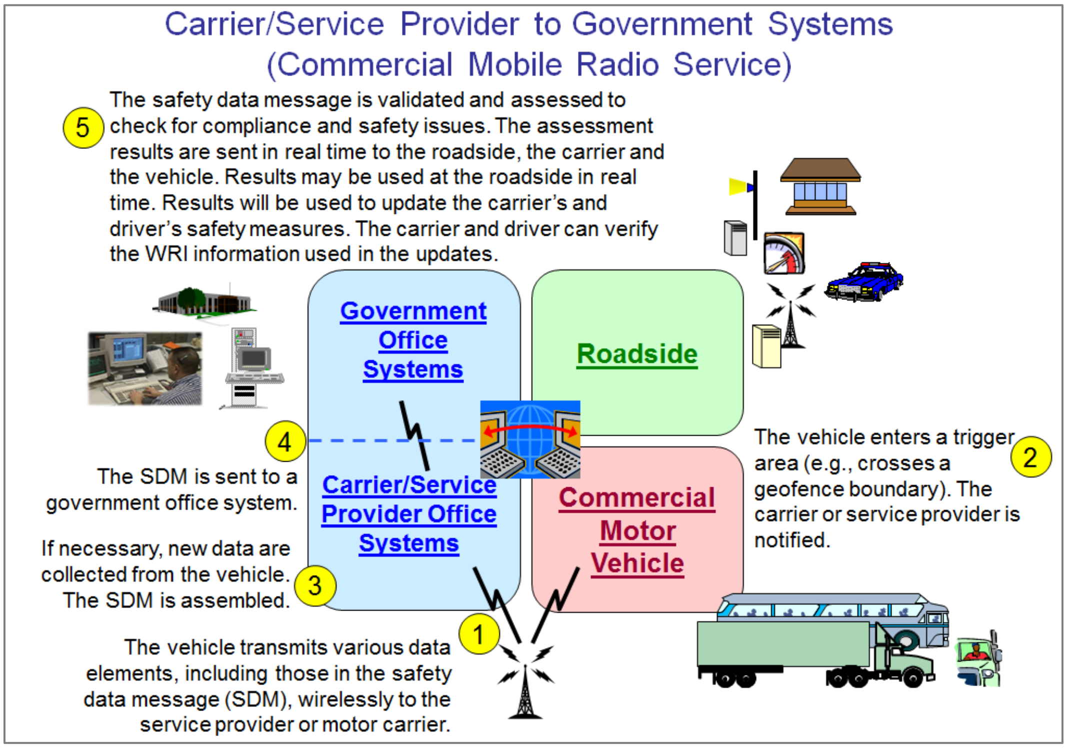

Figure 3. CMRS Concept

2.2 GOALS AND OBJECTIVES

The goal of the Pilot Test was to determine the viability and effectiveness of wireless CMV inspections using currently-existing telematics technologies and systems. The platform's effectiveness and the CMRS method's ability to interface with the GBOS were monitored and objectively evaluated.

The WRI CMRS goal was to be met by the following objectives:

- Demonstrate WRI via one or more CMRS Partner systems,
- Demonstrate the transfer of a CMRS-generated SDM to the GBOS,
- Demonstrate the transfer of the CMRS-generated SDM from the GBOS to the state centralized and roadside-based systems,
- Demonstrate WRI CMRS end-to-end system functionality via one or more CMRS partner systems, and

- Demonstrate carrier, enforcement, and compliance decision-making using associated WRI graphical User Interface (UI) populated with the CMRS-generated SDM.

These goals were achieved by conducting the tasks described in the following section.

2.3 TASKS

The WRI CMRS effort consisted of the following tasks.

- Define Objectives and Approach – In order to accomplish the objectives listed previously within the time and budget constraints of WRI Phase II, an approach based on gratis industry partnerships was selected. The remaining tasks were defined based on this approach.
- Establish Partnerships – Arrangements were made with carriers, telematics providers, and safety sensor technology providers for their gratis participation to facilitate this research. Partnership development involved industry scans and making initial contacts, surveying potential partners to determine capabilities, and establishing a formal agreement with each partner prior to participate in the Pilot Test.
- Facilitate Private Partner System Development and Equipment Integrations – Once formal partnerships were established, ORNL worked with each telematics and safety sensor technology provider as needed to assist in the development of their system to facilitate wireless data transfer, and to integrate their systems into the partners' fleets. Prior to each telematics provider's entrance into the pilot test, the contents of sample SDMs from test vehicles were reviewed.
- Conduct Pilot Testing – The pilot test consisted of two main types of data collection. First, SDMs were generated as the test vehicles carried out their normal business operations and encountered geofences. The second element of data collection involved on-site visits to the test vehicles' bases of operation and/or an inspection station along their normal routes to collect information to corroborate the data contained in the SDM.
- Perform Data Analysis – The data collected throughout the pilot test was analyzed to explore the effectiveness of the implemented geofencing technology, validate the data contained in the SDM, and characterize the data collected.
- Reporting – This final report was written to provide an overview of the CMRS pilot test activities and results.

2.4 PARTICIPANTS AND STAKEHOLDERS

The participants and stakeholders for the WRI CMRS Pilot Test effort are subdivided into six (6) participant areas for the purposes of this report. Each area will be discussed in detail relative to the participants' roles and responsibilities. The participant areas are shown in Table 1.

Table 1. Participant Areas

Participant Areas
1. Management and facilitation
2. Government Systems
3. Law Enforcement
4. Telematics
5. Fleets
6. Sensors

In order to facilitate the WRI CMRS platform testing with limited financial resources while developing a system that would be near-to-market, early in planning phase of the project ORNL suggested to FMCSA the option of gratis partnerships with industry stakeholders to develop, test, and field a system to conduct WRI via CMRS. Further, this approach allowed multiple systems (multiple teams with different approaches) from multiple providers to be developed, better ensuring success and demonstrating diverse solutions. FMCSA approved this approach, and ORNL was tasked to form partnerships with private industry as a way to leverage existing technologies and systems to benefit the WRI effort.

These partnerships were formalized by putting in place a non-binding Memorandum of Understanding (MOU) between ORNL and each private industry partner that participated in the Pilot Test. These MOUs defined the scope of the effort and the roles and responsibility of each party.

One area of concern that surfaced in the early discussions with potential private industry partners was the protection of novel processes, proprietary methods and operations, and information resulting from the WRI process. ORNL presented a plan that would group the telematics providers, fleets, and sensor providers into teams so that individual companies would not be identified relative to the data collected, the resulting analysis, or lessons learned in this final report. These teams will be referred to for the purposes of this effort and this report as "*Telematics Team(s)*". A Telematics Team will always be comprised of a telematics provider and a fleet with at least one vehicle, although it may include multiple fleets and multiple vehicles. A telematics team may also include one or more safety sensor partner(s) with technology installed on one or more of the test vehicle(s). Fleet vehicles in this efforts included tractors, tanker-trailers, box-trailers, and motor coaches. To protect the identity of the fleets and their associated data, these vehicles in total will be referred to as CMVs.

2.4.1 Management and Facilitation

ORNL provided sole management and facilitation of the WRI CMRS effort at the direction of FMCSA under the umbrella of the Commercial Motor Vehicle Roadside Technology Corridor (CMVRTC), a research corridor operated by ORNL for FMCSA. ORNL was tasked to define, conduct, and report on the WRI CMRS Pilot Test, as well as to perform a cursory analysis of the data collected to provide input regarding lesson learned and recommendations for refinement and enhancement of the WRI system.

2.4.2 Government Systems

Via an agreement with FMCSA, Volpe provided the GBOS, which included SDM processing capabilities. Volpe also developed an interface to the GBOS to receive the SDM and defined the XML schema and specifications for the telematics teams to format the SDM. An interface was also developed to allow researchers and stakeholders to view SDM contents and inspection results.

2.4.3 Law Enforcement

The Tennessee Highway Patrol provided staff to inspect trucks to validate the SDM data collected during the Pilot Test, review and comment on the WRI concept, participate in the national WRI teleconferences, and provide end-user feedback to the UT evaluation team. This support was provided through an FMCSA Motor Carrier Safety Assistance Program grant under the CMVRTC.

2.4.4 Telematics

ORNL conducted a market survey to identify potential telematics providers to participate in the WRI Pilot Test. Sixty-two companies were identified; of these, 35 were found to be viable (in business at the time of the WRI effort and purported to have technology/systems capable of supporting WRI). ORNL was able to establish contact with 33 of the 35 and sent each a document of introduction to the Pilot Test. Of these 33, 28 expressed initial interest in the effort. As a next step in the down-selection process, ORNL sent out a questionnaire to ascertain the potential company's capability to support WRI relative to our preplanned Evaluation and Use Cases (See Section 3.2.1). ORNL eventually received 11 completed questionnaires, all of which indicated those companies met the technological requirements for participation (ability to generate and transmit identification for the vehicle, driver, and carrier; and status for the vehicle and driver). Offers of participation were extended to these 11 companies in the form of a MOU. Ultimately, three companies signed the MOU to participate in the Pilot Test. They were as follows:

- Innovative Software Engineering, LLC (ISE)
- PeopleNet, Inc. (PeopleNet)
- QUALCOMM, Inc. (QUALCOMM)

These three telematics companies participated in the Pilot Test by providing staff, hardware, software, and systems to attempt to meet the requirements of the Pilot Test by collecting the data required for the SDM, formatting the SDM, and transmitting the SDM to the GBOS.

In addition to providing the SDM to the GBOS (a fundamental requirement for participation in the Pilot Test), some telematics providers also implemented or attempted to implement the following additional features and or components the WRI CMRS system:

1. Self-Test – This feature would allow the vehicle operator to test the functionality of the WRI system in advance of starting their duty day and provide information about carrier, driver and/or vehicle deficiencies.

2. Pull-in/Bypass Indicator – This feature could indicate to a driver of a WRI-equipped vehicle to pull into the upcoming fixed inspection station for further review by enforcement personnel. Depending on yet-to-be-determined protocols, this feature could also inform a driver that he or she may bypass an upcoming inspection station upon the processing of a valid and violation-free SDM.
3. Safety Sensor – Integration of safety sensor data could be used as a screening tool for roadside enforcement as well as provide safety indicators to the vehicle operator and fleet maintenance personnel.

2.4.4.1 Innovative Software Engineering, LLC

Founded in 2002, Innovative Software Engineering, LLC (ISE) is a full-service custom software solutions provider including full life cycle custom software development services; wireless communications; mobile and embedded applications web, pc and mac based applications; transportation logistics, education, health informatics; engineering management services; system engineering services; software development services; and quality assurance services. Relative to the Pilot Test, ISE provided vehicle telematics systems using global positioning technology integrated with embedded computers and mobile communications. ISE provided two telematics systems for the Pilot Test effort.

2.4.4.2 PeopleNet, Inc.

Founded in 1994, PeopleNet is a privately-held onboard computing and carrier fleet communications provider offering onboard communications, onboard computing, electronic on-board recorder (EOBR), and geofencing. PeopleNet has a customer base of 1,500 fleets across the United States and Canada. PeopleNet provided 15 telematics systems for the Pilot Test effort.

2.4.4.3 QUALCOMM, Inc.

Founded in 1998, QUALCOMM Enterprise Services has provided integrated wireless systems, services, and applications to transportation and logistics companies around the world. QUALCOMM has more than 1.3 million mobile units shipped to businesses in 39 countries on four continents, with enterprise services meeting the needs of more than 2,500 clients. QUALCOMM provided 10 telematics systems for the Pilot Test effort.

2.4.5 Fleets

Based on recommendations from the participating telematics providers, a pool of 21 fleets was established and contacted for possible participation in the Pilot Test. Six of the 21 fleets agreed to participate in the WRI CMRS Pilot Test and entered into agreement with ORNL via MOU. The six participating fleets made available 27 vehicles to be up fitted with WRI telematics devices and safety sensors. These fleets are described in the following subsections.

2.4.5.1 Bridgestone Americas Tire Operations, LLC

Bridgestone Americas Tire Operations, LLC (Bridgestone) is a manufacturer of rubber products and tires for passenger cars, commercial vehicles, mining and agricultural vehicles, as well as specialty vehicles. These products are sold at more than 12,000 outlets. In addition, Bridgestone operates their own private truck fleet to deliver their products to the distribution centers and retail outlets as well as back-hauling non-related third-party freight to offset fleet operational costs. They have approximately 280 power units and 340 drivers traveling about 31 million miles each year. Bridgestone provided two tractors from their private fleet for participation in the Pilot Test.

2.4.5.2 Greene Coach Tours, Inc.

Greene Coach Tours, Inc. (Greene Coach) was founded in 1945 as an intercity and commuter bus service for Greene, Washington and Sullivan counties in Northeast Tennessee (TN). Today the company is primarily a charter bus service whose greatest market share are college and university athletic programs, public school field trips, churches, and civic organizations outings. Greene Coach is registered as a qualified (rating of 1) transportation provider for the Department of Defense and transports military personnel regularly. With operating authority covering all of the U.S. and Canada, Greene Coach conducts approximately 75% of its outbound charters within a 600-mile radius of their home terminal in Greeneville, TN. They have approximately 12 motor coaches and 24 drivers traveling about 450,000 miles each year. Greene Coach provided two motor coaches from their fleet for participation in the Pilot Test.

2.4.5.3 McKee Foods Corporation

Founded in 1934, McKee Foods Corporation (McKee Foods) is a privately held company with more than 6,000 employees and annual sales in excess of $1 billon. Their products are available across the U. S., Canada, Mexico, Puerto Rico, and at U.S. military installations around the world. McKee Foods operates their own private truck fleet (McKee Foods Transportation, LLC) to deliver their products to the distribution centers, as well as back-hauling non-related third-party freight to offset fleet operational costs. They have approximately 311 power units and 685 drivers traveling about 34 million miles each year. McKee Foods provided five tractors from their private fleet for participation in the Pilot Test.

2.4.5.4 Pilot Travel Centers, LLC

Pilot Travel Centers, LLC (Pilot) is the nation's largest retail operator of Travel Centers, catering to the professional driver and traveling motorist in more than 40 states with over 300 retail interstate properties. Pilot is headquartered in Knoxville, Tennessee and employs 13,000 nation-wide. They have approximately 325 power units and 750 drivers traveling about 45 million miles each year. Pilot provided five tractors and trailers from their private fleet for participation in the Pilot Test.

2.4.5.5 Tennessee Express, Inc.

Tennessee Express, Inc. (TN Express) is a subsidiary of Tennessee Commercial Warehouse (TCW) which was established in 1948 and is headquartered in Nashville, TN. TCW operates eight inland terminals and two port locations. This network of terminals provides transportation services to customers primarily in the southeastern region. The company holds both contract and common carrier authority serving all points within the continental United States. TN Express has approximately 192 power units and 277 drivers traveling about 25 million miles each year. TN Express provided five tractors from their private fleet for participation in the Pilot Test.

2.4.5.6 The H. T. Hackney Company, Inc.

Established in 1891, The H. T. Hackney Company, Inc., (H. T. Hackney) is one of the largest wholesale distributors in the United States. H. T. Hackney services over 20,000 retail customers and stocks over 25,000 products. With strategically located distribution centers, H. T. Hackney provides a distribution network covering 21 states. They have approximately 589 power units and 604 drivers traveling about 25 million miles each year. H. T. Hackney provided 10 tractors from their private fleet for participation in the Pilot Test.

2.4.6 Sensors

Safety sensor data, though not required by the test scenarios defined for the Pilot Test, is of interest to stakeholders for a variety of uses. Sensor data can be used by drivers in real time to assess the condition of their vehicle and can be used by maintenance staff for near-term and predictive maintenance. Such data could also be used by enforcement entities for screening of vehicles with potential brake, tire, or weight issues.

For the Pilot Test, vehicle weight, brake stroke information, and tire pressure and temperature were placed on the vehicles' J-1708 data bus for collection by a telematics provider. This information was both displayed for the driver and included in the SDMs from instrumented vehicles.

ORNL offered two former CMVRTC research partners an opportunity to participate in the Pilot Test by providing their sensor technology to specific fleet vehicles on a gratis basis. At the request of one of the telematics partners, PressurePro was also offered a gratis partnership. Each of these partners agreed to participate in the Pilot Test and the participation was formalized via MOUs between ORNL and the sensor partners.

2.4.6.1 Advantage PressurePro, LLC

Advantage PressurePro, LLC, is the founding company for PressurePro and was established in 1991 as a tire pressure monitoring system (TPMS) provider to all types of fleets. PressurePro is a tool for monitoring and displaying each tire's pressures and temperature to a display and alerting when a tire drops in pressure with both a visual and audible alert. Tire information can be displayed in the vehicle or sent to an office-based management program. As part of the WRI Pilot Test, PressurePro provided tire pressure and temperature information as well as the electronic interface to make the vehicle weight and brake stroke information available from the J-1708 data bus to the telematics device for use in the SDM. PressurePro has over 600,000 systems in the market in the U.S. and worldwide and is used in a variety of applications. Benefits of TPMS include increased fuel efficiency, reduced carbon emissions per vehicle, increased tire and casing life, increased safety, and less roadside downtime. PressurePro provided units for 15 tractors and five (5) trailers during the Pilot Test.

2.4.6.2 Hi-tech Transport Electronics, Inc. (DBA Air-Weigh)

Air-Weigh is based in Eugene, Oregon, and has been in business since 1995 with over 125,000 units installed by trucking and refuse fleets, both domestically and internationally. The Air-Weigh on-board scale is a true on-the-ground axle weight scale which is unaffected by temperature, humidity or altitude. With an Air-Weigh scale, drivers can accurately determine on-the-ground axle weights at the loading site. For the Pilot Test, the LoadMaxx Series of Truck/Tractor Scales and the 5802 Series of Trailer Scales were supplied to the fleets. The scale also included alarms and warnings for all axle, GVW, and net payload weights; J1708 and J1939 integration capability; a printer option, an RS-232 interface; and optional all-Spanish display. Air-Weigh provided 10 tractor units and five trailer units for the Pilot Test.

2.4.6.3 MGM Brakes, Inc.

MGM Brakes, Inc. (MGM), a division of Indian Head Industries, has been in business for over 50 years. MGM is an international manufacturer of air brake products and electronic brake monitoring systems for the commercial vehicle, transit, military, rail, and vocational markets. MGM designs as well as manufactures all of its products, and is considered an industry leader in spring parking brake and brake monitoring technology. Headquartered in Charlotte, North Carolina, with manufacturing locations in the U.S. and international licensee manufacturing in Asia, MGM products are used worldwide in a broad variety of air brake vehicle applications. MGM's electronic brake monitoring technology (e-STROKE) was used in the WRI Pilot Test. The e-STROKE product provides alerts to the driver regarding dragging brakes and inoperative brakes. MGM provided four tractor units and two trailer units for the Pilot Test.

3. CMRS PILOT TEST DESCRIPTION

3.1 PILOT TEST SYSTEM DESIGN

An overview of the data flow for the CMRS platform in shown in Figure 4. According to the original system design, when a CMV crosses into a pre-defined geofence, it sends vehicle data to the motor carrier's operations center. This system then compiles the SDM and submits it to the GBOS. There, the submitted message is evaluated and an inspection report is generated, which is made available to both the roadside enforcement staff and the carrier. The actual design of the CMRS Pilot Test systems was slightly different based on limitations of the prototype GBOS and incompatibilities between the GBOS and the architecture of each Telematics Team's system. These differences will be discussed further in the following subsections, with the identity of the partners protected in accordance with their respective MOUs.

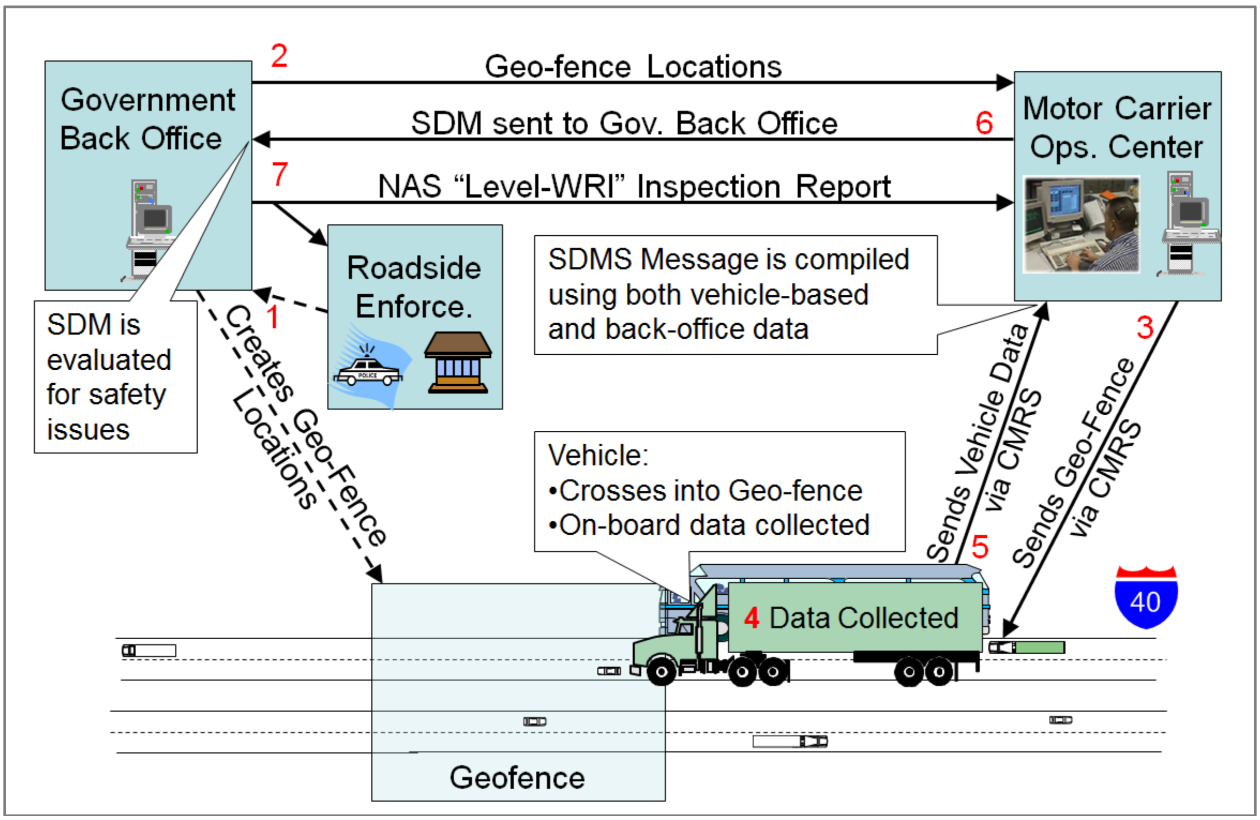

Figure 4. Overview of CMRS Data Flow

Two major differences between the nominal system design shown in Figure 4 and the design actually implemented in the pilot test were shared by all the telematics teams due to the limitations of the pilot test. First, the geofences did not originate from roadside enforcement or the GBOS but were manually distributed by ORNL for the purposes of the pilot test. Second, the inspection report was not generated in real-time.

A key concept setting CMRS apart from the other WRI platforms is the use of geofencing technology; a geofence is a virtual boundary on a geographic area. When a device that is capable of determining its spatial location (e.g., by using GPS technology) enters, exits, or is inside that area, a notification can be generated. Most CMRS providers offer geofencing capabilities to their customers and this feature is widely used by the trucking industry to improve their operations by, for example, helping to more precisely monitor drivers' arrivals, departures and route compliance. Geofences can also be used to trigger an event such as a WRI, which was the approach adopted by the CMRS platform.

Three inspection stations in east Tennessee actively participated in the test: the two Knox County inspection stations located on I-40 around mile marker 372 (see Figure 5) and the Greene County inspection station located on I-81 southbound around mile marker 22 (see Figure 6). All the participating CMRS partners were provided with information that allowed them to build geofences around these inspection stations. Specifically, ORNL provided each partner with geopoints marking the beginning of the off-ramps that are the entrances to the inspection stations (see insets in Figure 5 and Figure 6).

Figure 5. Knox County, Tennesee, I-40/I-75 Eastbound and Westbound Inspection Stations

Figure 6. Greene County, Tennesee, I-81 Southbound Inspection Station

As described previously, one of the features of the Tennessee platform system was a "pull in" driver notification capability. Although this feature was not tested because Telematics Team 1 – the only one implementing this feature – could not officially enter the test (although some preliminary testing was performed with test SDMS), it was one of the main considerations in selecting these geopoints at such specific locations. For a "pull in" driver notification implementation, these geopoints mark the "point of no return"; that is, if the driver were not to receive the pull in notification before reaching the specified geopoint, he/she would not be able to enter the inspection station. Therefore, each WRI geofence had to be placed upstream of the geopoint corresponding to the specific inspection station.

The size of the geofence depends on the frequency with which the WRI-ready vehicle checks its spatial position and the total time that it is required to generate a WRI report[1]. The entrance to the WRI geofence must be placed upstream of the defined geopoint such that a vehicle traveling at freeway speed could receive a "pull in" notification before reaching the entrance to the inspection station. Since the processing times, communication times, and frequency with which the vehicle checks its position vary with each CMRS provider, ORNL did not specify a particular geofence size or shape. Only the points themselves were provided, and the telematics partners implemented the shape and size of the geofences that worked best with their systems. ORNL also provided the participating telematics partners with other information related to the inspection stations as shown in Table 2 (note: for the station name, ORNL developed a procedure to

[1] The time to generate a WRI report includes the processing time required to assemble all the necessary information for the SDM (on board of the vehicle entering the WRI geofence and at the Telematics provider's BOS, if applicable), plus the communication time to submit the SDM to the WRI BOS, plus the processing time at the WRI BOS to generate an inspection report based on the information received, plus the communication time to rely the results of that inspection report to the vehicle.

uniquely identify the inspection station and also to recover the station's geopoint from the station's name).

Table 2 Permanent Inspection Stations in Tennessee

Inspection Station	Geopoint Latitude	Geopoint Longitude	Station Name (SDM Tag)	Time Zone*	Notes	WRI Active?
Knox - I40 E	35.891690	-84.202640	TNNZFQ7ZGSKNOXE	E	Fixed - Entrance	Y
Knox - I40 W	35.894580	-84.192220	TNNZG57ZHKKNOXW	E	Fixed - Entrance	Y
Greene - I81 S	36.216520	-83.063020	TNP12G82B8GREENES	E	Fixed - Entrance	Y
Coffee - I24 W	35.430529	-86.029429	TNNW4K7SWRCOFFEEW	C	Fixed - Entrance	N
Coffee - I24 E	35.434650	-86.034611	TNNW557SWDCOFFEEE	C	Fixed - Entrance	N
Robertson - I65 N	36.607338	-86.581868	TNP3137RJBROBERTSONN	C	Fixed - Entrance	N
Robertson - I65 S	36.611876	-86.579921	TNP31R7RJHROBERTSONS	C	Fixed - Entrance	N
Robertson(N) Hwy 31 N	36.602028	-86.584357	TNP3097RJ5ROBERTSON31N	C	NB Entrance toward Scales	N
Robertson(N) Hwy 31 S	36.618716	-86.572824	TNP32S7RK1ROBERTSON31S	C	SB Entrance toward Scales	N
Haywood - I40 W	35.463641	-89.297326	TNNW9J7JQPHAYWOODW	C	Fixed - Entrance	N
Haywood - I40 E	35.452800	-89.314712	TNNW7W7JPCHAYWOODE	C	Fixed - Entrance	N

*E: Eastern Time Zone; C: Central Time Zone

The SDMs had to contain information that identified the encounter of the vehicle with the geofence. This information was provided through the SDM ENCOUNTER_ID tag (a tag contained in the SDM METADATA block), which had to be an eight-digit number that was not used more than once during the entire test period. To simplify the data collection and analysis, ORNL assigned a "band" for the ENCOUNTER_ID tag to each one of the three Telematics Teams, denoted as TT1, TT2, or TT3. TT1 was assigned the interval 30,000,000 to 39,999,999; TT2 10,000,000 to 19,999,999; and TT3 50,000,000 to 59,999,999. The three telematics partners implemented procedures which ensured that the SDMs that they generated had ENCOUNTER_ID numbers that fell within these assigned intervals and would not repeat from one vehicle to another.

3.1.1 Telematics Team 1 (TT1)

The system designed by TT1 was very similar to that envisioned for the CMRS platform in general. As shown in Figure 7, the TT1 system was designed to implement a pull-in/bypass functionality. Based on analysis of the submitted SDM, the driver would be provided real-time instruction regarding whether or not to stop for additional physical inspection.

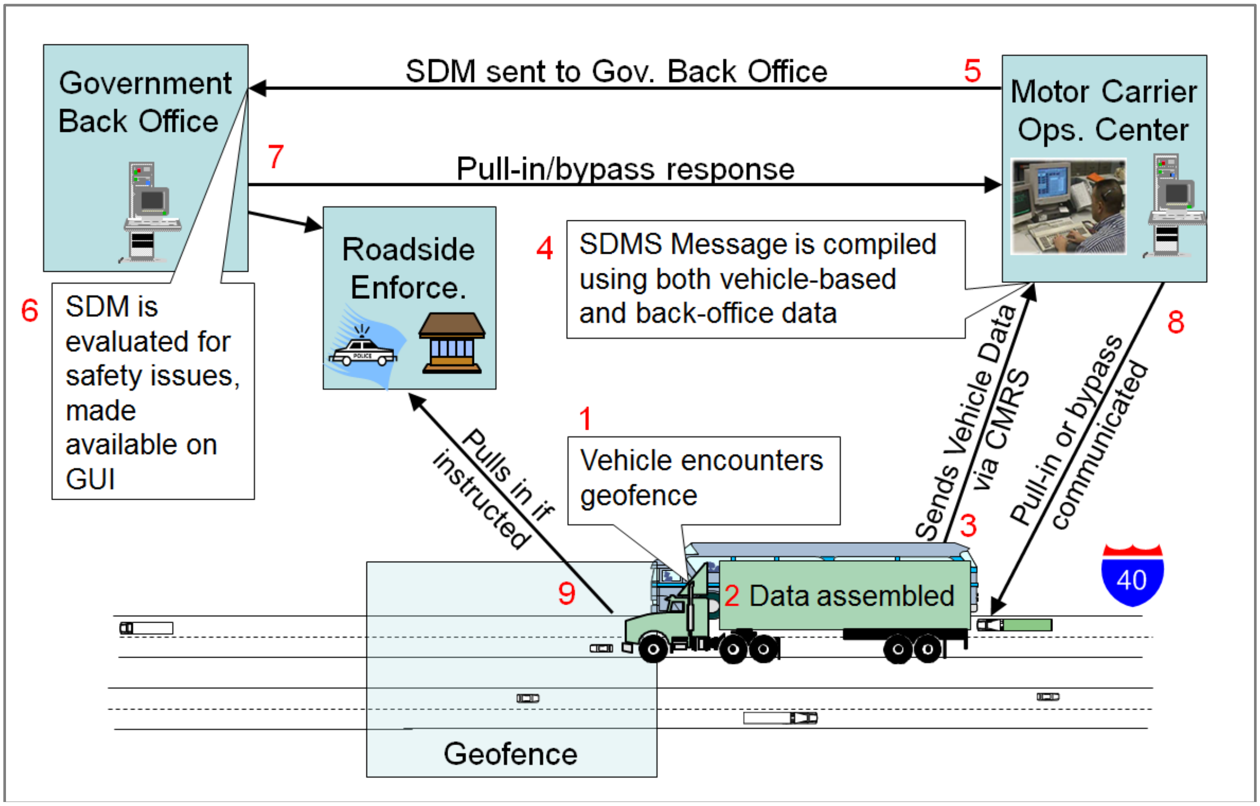

Figure 7. Overview of Data Flow for Telematics Team 1

The three telematics partners followed different approaches to design the geofences for the inspection stations. TT1 implemented polygons that enclosed the freeway lanes on the direction of travel that led to the inspection station. For example, Figure 8 shows the geofence adopted by TT1 for the Knox County, Tennessee I-40 Eastbound Inspection Station (TNNZFQ7ZGSKNOXE). As seen in the figure, the polygon had a long edge parallel to the direction of travel; this edge was placed on the median of the freeway right-of-way, with one end (the Eastern most end in this case) at the geopoint provided by ORNL and the other end at about three miles upstream of the first corner. To ensure that only vehicles traveling eastbound on I-40 would trigger an SDM for Inspection Station TNNZFQ7ZGSKNOXE, the remaining two sides converged at a point about two miles south of the inspection station.

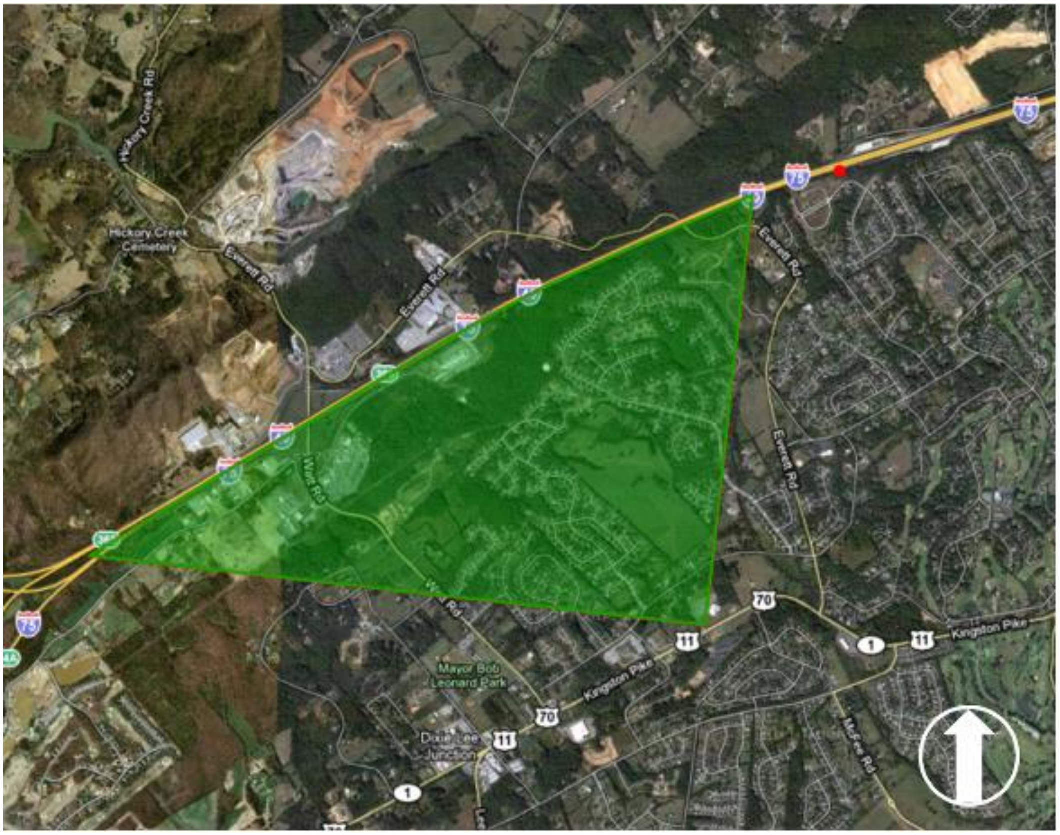

Figure 8. TT1 Implemented Geofence for Knox County, Tennessee I-40 Eastbound Inspection Station (TNNZFQ7ZGSKNOXE)

For the other two inspection stations, TT1 adopted geofences that were similar in shape and size to the one for the Knox County Eastbound inspection station (see Figure 9 and Figure 10).

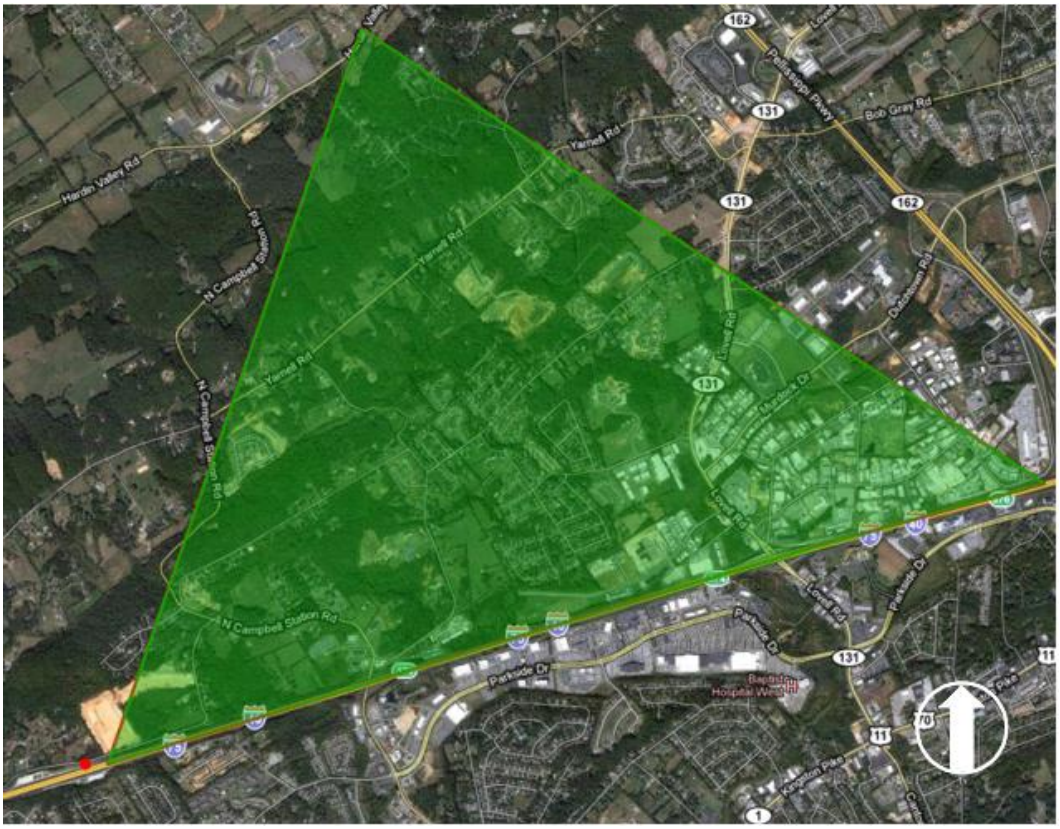

Figure 9. TT1 Implemented Geofence for Knox County Westbound Inspection Station (TNNZG57ZHKKNOXW)

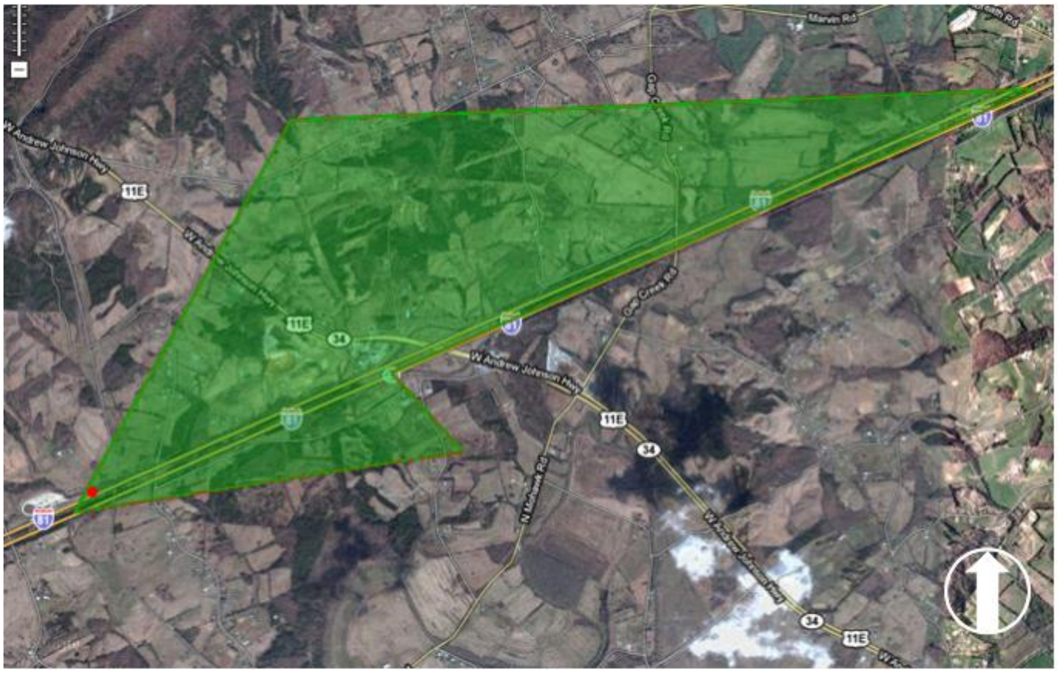

Figure 10. TT1 Implemented Geofence for Greene County Southbound Inspection Station (TNP12G82B8GREENES)

3.1.2 Telematics Team 2 (TT2)

Unlike the other telematics teams, TT2's system was designed to submit the SDM directly from the vehicle to the GBOS via a cellular modem without the use of the telematics provider's back office to facilitate the data transfer. This data flow is shown in Figure 11.

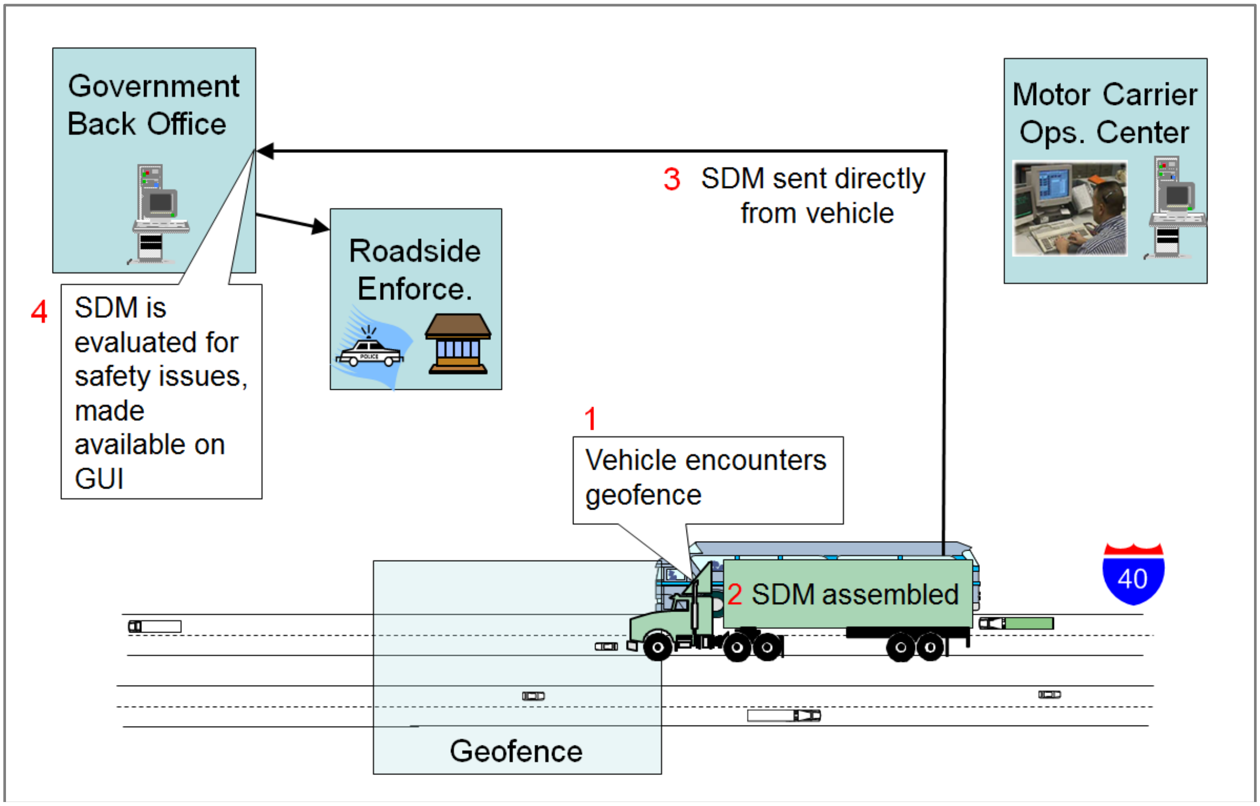

Figure 11. Overview of Data Flow for Telematics Team 2

Telematics Team 2 implemented circular geofences which were centered not at the geopoints provides by ORNL, but slightly upstream. In all three cases the radius of the geofences was 200 m, or about 656 feet (see Figure 10 to Figure 13).

Figure 12. TT2 Implemented Geofence for Knox County Eastbound Inspection Station (TNNZFQ7ZGSKNOXE)

Figure 13. TT2 Implemented Geofence for Knox County Westbound Inspection Station (TNNZG57ZHKKNOXW)

Figure 14. TT2 Implemented Geofence for Greene County Southbound Inspection Station (TNP12G82B8GREENES)

3.1.3 Telematics Team 3 (TT3)

Unlike the other two telematics teams, the vehicle portion of TT3's system did not assess whether a geofence had been crossed. Instead, the back-office monitored the on-board system at regular intervals and made a geofence determination based on the GPS data received. The SDM was then assembled and submitted to the GBOS if the vehicle was found to be in a designated geofence.

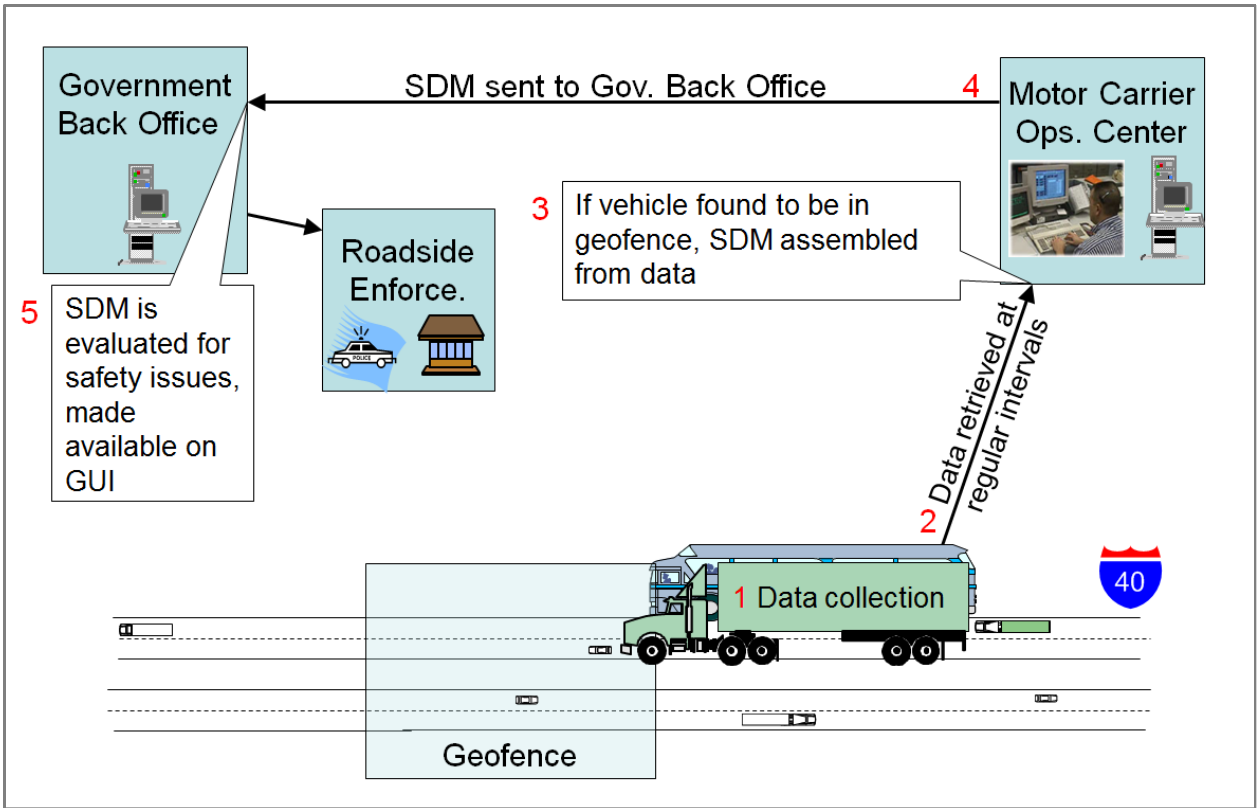

Figure 15. Overview of Data Flow for Telematics Team 3

Similarly to TT1, TT3 adopted polygon-shaped geofences; however, in this case the polygons were substantially larger (about 20 miles as opposed to 3 miles) and followed the roadway more closely. Figure 16 and Figure 17 show the geofences implemented by TT3 for the Knox County Eastbound Inspection Station and the Greene County Inspection Station.

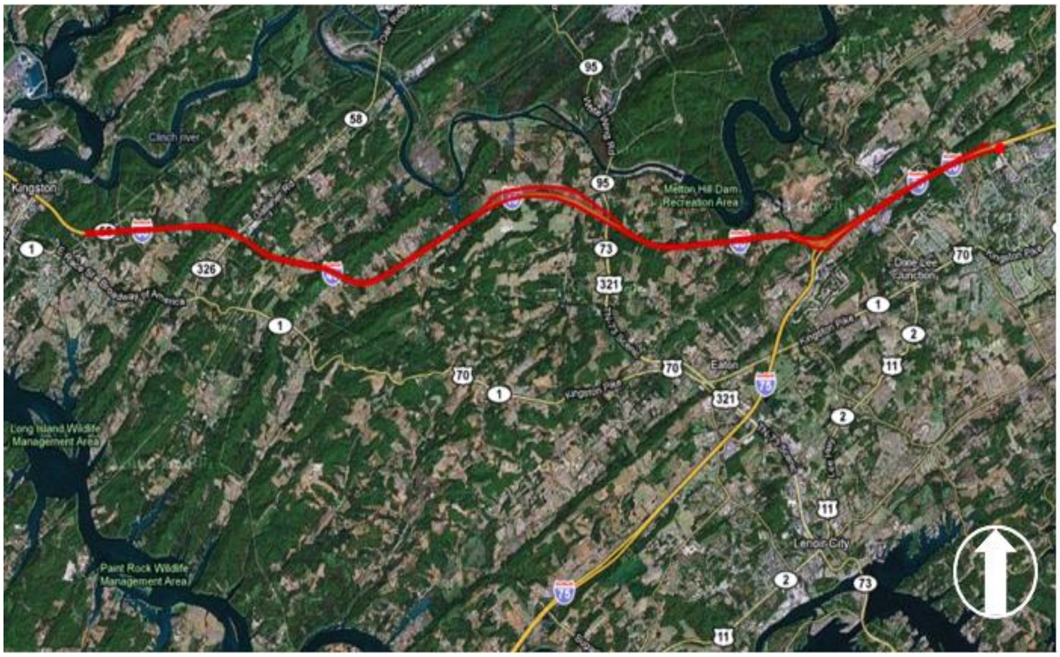

Figure 16. TT3 Implemented Geofence for Knox County Eastbound Inspection Stations (TNNZFQ7ZGSKNOXE)

Figure 17. TT3 Implemented Geofence for Greene County Southbound Inspection Station (TNP12G82B8GREENES)

3.2 PILOT TEST DESIGN

Testing took place from October 2010 through January 2011, with focused testing in January 2011. This testing was performed along the CMVRTC, the section of I-40/I-81 between the inspection stations at Knoxville and Bulls Gap, and at the fleet partners' bases of operations. Wireless inspection points include both the fixed inspection stations within the CMVRTC and inspection points to simulate temporary inspection stations.

In order to conserve WRI program funds, the CMRS Platform effort was conducted via gratis partnerships. Thus, the various partners used their own existing proprietary systems and methods to interface with the vehicle, driver, and carrier. The WRI program did not dictate or specify the methods that were used by the Partners, but provided the Partners with a set of functional specifications (provided by Volpe) that called out the system inputs, output (SDM), triggers, data freshness, and response time. The CMRS system thus could be cellular, satellite or a combination at the discretion of each telematics team. It was expected that most telematics providers with EOBR capability simply needed to "repackage" the data that they were currently collecting into an SDM and pass this message set to the GBOS for processing. Because this pilot test involved test fleets that were engaged in their normal commercial operation, the impact to their schedule was kept to a minimum.

3.2.1 Evaluation and Use Cases Planned

It was expected that the following use cases would be tested or supported in the CMRS platform to the extent possible:

- WRI fixed site data collection and assessment – including
  - Automatic compliance assessment at unstaffed roadside site,
  - Screening support to staffed fixed or temporary stations, and
  - Traditional (physical) inspection support.

Additional use cases were planned for testing and evaluation on a more limited basis provided the prototype back-office system supported the functionalities and the testing of these use cases would not place undue burden on the gratis partners in terms of time and resources. It was also anticipated that certain portions of these use cases would be outside the scope of the CMRS pilot test due to the nature of the test system (such as not being integrated with certain existing systems). These additional use cases were

- Post-processing analysis of WRI data and results,
- Carrier use of WRI data and results,
- Management of the WRI network,
- WRI system self-test by a motor carrier, and
- WRI system self-test by roadside or mobile enforcement or "training mode."

The WRI mobile enforcement data collection and assessment use case was not under consideration for testing because it would require real-time geofencing capabilities and therefore could not be implemented using existing CMRS technology:

3.2.2 Components under Test

The pilot test for the CMRS platform focused on the geofence trigger functionality, communication between the private and public back-office systems, enforcement use of the data, and user feedback. Testing of those functionalities wholly within the private sector (such as communication between on-board telematics devices and the associated back-office) was not evaluated, with the exception of requesting timestamps and obtaining general user feedback regarding the implementation and use of the WRI system. The functionality of commercially-available off-the-shelf (COTS) technologies (such as the accuracy of safety sensors and the ability of EOBRs currently in use by the partnering fleets to record HOS) was not tested. This decision was made because the Pilot WRI back-office systems and interfaces were under test, not the partner technologies.

3.2.3 Key System Functions Under Test

The use cases tested were divided into several basic functions. While focused tests may concentrate on particular functions individually, end-to-end testing was also to be performed. This testing methodology did not include any parallel monitoring systems (such as stand-alone data acquisition systems) apart from the normal functionality of the telematics devices. These commercially-available devices and services were taken as ground-truth information for the purposes of the CMRS pilot test.

- Triggering by Geofence - Sending of the SDM would be triggered when a participating fleet vehicle crosses a geofence boundary during its normal operation. Because each inspection site was identified as a coordinate, the algorithm for expansion of the provided point to a more convenient shape was also at the discretion of the individual telematics providers.
- Assembly and Transmission of SDM to GBOS - Upon triggering, the telematics provider would submit an SDM containing up-to-date driver, vehicle, and carrier information to the GBOS. This could be communicated directly from the vehicle systems to the GBOS, or via the telematics provider’s back-office.
- Return of Bypass/Pull-in Message - Once the SDM was uploaded to the prototype back-office system, basic checks would be performed by the GBOS and the telematics providers that incorporated this feature would receive a bypass/pull-in message and pass it along to the driver via an in-cab signal such as an indicator light or message tone.
- Use of SDM at Roadside - The GBOS prototype would analyze the SDM, generate the WRI inspection report and/or safety alerts, and pass this information to the roadside/enforcement staff, where it would appear on a monitor in the inspection station or stationary enforcement vehicle. Testing in this area focused on the application of WRI data by enforcement personnel.

- Availability of Data to Carriers - Information regarding the SDM submitted, WRI inspection report, and/or safety alerts would be made available to the carrier via a UI provided by the GBOS. The partnering carriers would be asked to use this interface at their convenience to confirm the ability to access the WRI data and to provide feedback about their experiences.
- System Self-Tests - The carrier self-test feature would allow a driver-initiated inspection to take place, submitting an SDM to the GBOS to confirm the functionality of the system. Enforcement users would have the ability to perform a connectivity check, which could be tested at the beginning of each shift where WRI inspection reports were accessed.

In order to test the ability to assemble and transmit the SDM, the telematics providers were requested to maintain a log of timestamps for the triggering and submission of the SDM. Time stamps indicating intermediate steps in the process were also requested to the extent that they were not considered proprietary or business-sensitive information by the telematics partners and were limited to those listed in Table 3.

Table 3. Requested Timestamps for CMRS Telematics Partners

TSID	Sub-Process Step	Unique Identifier	Event causing time stamp generation
T2*	Geopoint Activation	Geopoint ID (distributed with coordinates)	The Telematics Providers pushes geopoint locations to truck on board computers, "activating" the corresponding geofences
T3	Trigger Event	SDM ID, composed of the VIN and trigger timestamp	The vehicle crosses the boundary of the geofence created by the geopoint, triggering the generation of an SDM and the vehicle is queried.
T5	Completion of SDM	SDM ID (see T3)	Completion of SDM (all fields included, formatted and ready for transmission)
T6	Transmission of SDM	SDM ID (see T3)	Transmission of SDM from Vehicle or Telematics BOS to GBOS Prototype
T32**	Receipt of Driver pull-in/bypass signal	SDM ID (see T3)	The bypass/pull-in response is received from the GBOS Prototype.

*Because the purpose of collecting timestamp T2 is solely to avoid checking for SDMs triggered for a given geopoint before this point is distributed to all systems, approximate times are sufficient.

** Applies only to telematics providers incorporating an in-cab signal for the driver. The location (latitude and longitude) should also be logged, if this can be done easily.

To verify the contents of the SDMs created, arrangements were made with participating fleets for each test vehicle to receive an NAS Level-2 inspection or equivalent data collection during the Pilot Test.

3.2.4 Summary of Planned Test Scenarios

Eight basic testing scenarios were to be used to gauge the performance of various aspects of the WRI CMRS system.

1. System "free running," with SDMs being uploaded as test vehicles cross geofences. (This case did not require any additional involvement from test engineers,

enforcement personnel, or partners. Driver response/feedback in the form of a bypass/pull-in message was not necessarily required for this case.)

2. Test vehicles selected (not screened) for a Level-2 inspection, primarily to perform spot checks and to compare results of physical inspection to SDM data. This was coordinated with partnering fleets in order to bring test vehicles into the inspection station regardless of the in-cab signal.
3. System used by enforcement personnel to select vehicles for further inspection. The system was providing enforcement personnel with real-time information such as safety alerts and directing drivers into the inspection station (via in-cab signal) based on automatic compliance assessment. (Note that possible violations which would result in a pull-in signal for the driver will be unlikely for the test vehicles. To test this functionality, this would be simulated by using an Inspection Selection System (ISS) score of 99 at pre-determined times to trigger a pull-in signal for vehicles with this capability.)
4. Carrier taking action as a result of real-time safety alerts (result of automatic compliance assessment performed in 1-3 above).
5. Non-real time access/use of WRI data.
6. Self-tests (to be performed at any convenient time).
7. Activating geopoint locations (turning points on/off during agreed-upon intervals of testing, without the use of a centralized geopoints database).
8. Test vehicle traveling prearranged route for short-term testing of geopoint triggering (very limited testing to be conducted for one or two vehicles).

3.3 PILOT TEST SYSTEM INTEGRATION AND VERIFICATION

The CMRS pilot test systems were implemented by the three telematics teams identified previously (in section 2.4.4) in conjunction with Volpe. The integration of the equipment, systems, and software to accomplish WRI CMRS was largely done by the private industry partners with guidance and direction provided by ORNL from the WRI Concept of Operations document, the WRI CMRS Test Plan, and the GBOS interface document. Due to the proprietary nature of these operations within the telematics arena, ORNL was not privy to the intimate details and issues with vehicle or telematics back-office system (BOS) integration. Because of the differences between telematics back-office systems, the level of functionality and features pursued in the pilot test effort, the type and level of resources devoted to this effort, and the timing for finalizing agreements and making other arrangements with all members of each telematics team, these teams had different implementation schedules and encountered different problems during the integration of their systems prior to testing. Because of these differences, each of the three telematics teams will be discussed individually in the following sections. ORNL's ability to monitor progress and total system capability was limited to viewing the GBOS UI and looking for SDMs from the partners, and gathering regular feedback from the partners and from Volpe as the CMVs operated from day-to-day during planned validation efforts. A log of incidents which occurred during throughout the CMRS pilot efforts is given in the Appendix.

3.3.1 Telematics Team 1 (TT1)

Telematics Team 1 formally signed their WRI CMRS MOU on February 23, 2010, and began working on the WRI effort in April of 2010. Their currently-fielded telematics devices would not support their planned WRI application, thus they needed to deploy the WRI application on their newest telematics devices. With their new telematics devices just being released, there was a shortage of telematics units. This added a delay of about 2 months to the efforts. The telematics devices were installed onto the CMVs in June 2010.

The approach for TT1 was to use their onboard device for HOS data entry by the driver and to store some SDM information locally on the device. Once a geofence boundary was crossed (SDM triggered), information was sent from the vehicle to the telematics BOS and the SDM was formatted in XML and transmitted to the GBOS from the telematics partner's BOS. TT1 agreed to implement a pull-in/by-pass alert to allow ORNL to test real-time interdiction of CMVs with safety or other high priority flags or suspected defects. Further, they agreed to implement a "self-test" component that would allow a driver to test the WRI CMRS system by generating an SDM, tagged as a self-test, that would be sent to the GBOS for processing. This processed SDM in concert with the pull-in/by-pass feature would provide a positive or negative indication to the driver about the results of the self-test.

TT1 was also chosen to be the test bed for the safety sensor technology. The safety sensors chosen for the WRI effort were not native to the CMVs and required their own installation and SDM data integration task. A device or method was needed to bring the signals from the safety technologies on the trailer to the tractor and then from the tractor to the telematics device. To bring the signal from the trailer to the tractor, the signals were transmitted wirelessly to an in-cab receiver or transmitted via wire through the J-560 connector (industry-standard 7-pin connector between the tractor and trailer) using PLC (power line communications) multiplexing. Once the signals arrived in the truck, they were posted onto the vehicle's J-1708 data bus. A special interface device was constructed by Advantage Pressure and funded by the telematics partners to pull the safety sensor data from the J-1708 bus and feed it into the telematics device via the telematics device's own PLC gateway input. This effort was completed in parallel with the overall WRI effort and did not add delay to the schedule. The safety sensor partners were quick to approve their respective MOUs and also provided their technologies in a timely manner as to not impede the pilot test progress. The integration of the safety sensor technology did require that the CMV be out of operation for a period of time, in some cases as much as 8 hours. Coordination between the CMV fleets and the telematics and safety sensor partners was difficult and in some case the technologies could not be installed in parallel. Thus, in some cases as many as four separation installations were required per CMV. The fleet partners were very sensitive to the down time of their vehicles.

TT1 struggled with the formatting of the SDM throughout the WRI Pilot Test. In May, a request was made to Volpe by the telematics partner to allow for an HTTP post as well as the planned Web Services SOAP (Simple Object Access Protocol) message. This required change to the GBOS added a 30 day delay to the deployment of the GBOS by Volpe. In August, the telematics partner was able to pass an SDM from their back office to the GBOS. In September, a request was made to Volpe to "relax" the rules for receipt and processing of an SDM to allow for inspection records to be generated from messages that might not contain full log information or have a driver's name that is on the GBOS list of names.

Ultimately TT1 was never able to successfully send an SDM from a moving vehicle via a geofence trigger. Thus, ORNL was never able to conduct pre-pilot test validation data or pilot test data collection. A small number of SDMs were sent from vehicles near the end of the pilot test as self-test messages. Table 4 shows the status of TT1 and the other telematics providers at the end of the Pilot Test and the SDM elements that were planned for their portion of the Pilot Test.

Table 4. SDM Contents for Telematics Teams

SDMS Elements		Telematics Team 1		Telematics Team 2		Telematics Team 3	
Description	**Schema Tag**	**Geofence**	**Self-Test**	**Geofence**	**Self-Test**	**Geofence**	**Self-Test**
Message type (should be SEND_SDMS)	MESSAGETYPE	W	W	Y	Y	Y	N
Decription Scheme (assumed correct)	DECRYPTSCHEME	W	W	Y	Y	Y	N
Encryption Scheme (assumed correct)	ENCRYPTSCHEME	W	W	Y	Y	Y	N
Method (Self-Test, Geo-fence)	TRIGGERTYPE	W	W	Y	Y	Y	N
Mode (Production)	WRIMODE	W	W	Y	Y	Y	N
Associated inspection station ID (or SELF_TEST)	STATION	W	W	Y	Y	Y	N
State (Platform)	STATE	W	W	Y	Y	Y	N
Time Stamp (message submission)	TIMESTAMP	W	W	Y	Y	Y	N
Source ("TENNESSEE" for all CMRS)	SOURCE	W	W	Y	Y	Y	N
Destination (WRIBOS)	DESTINATION	W	W	Y	Y	Y	N
Communication method (WEBSERVICE)	COMMUNICATION_METHODS	W	W	Y	Y	Y	N
SDM ID assigned by Volpe	UNIQUE_ID	N/A	N/A	N/A	N/A	N/A	N/A
Date message triggered	ENCOUNTER_DATE	W	W	Y	Y	Y	N
Time message triggered	ENCOUNTER_TIME	W	W	Y	Y	Y	N
Date vehicle polled for data	VEHICLE_POLL_DATE	W	W	Y	Y	Y	N
Time vehicle polled for data	VEHICLE_POLL_TIME	W	W	Y	Y	Y	N
Latitude (Geopoint encounter)	ENCOUNTER_LATITUDE	W	W	Y	Y	Y	N
Longitude (Geopoint encounter)	ENCOUNTER_LONGITUDE	W	W	Y	Y	Y	N
SDM ID assigned by telematics provider	ENCOUNTER_ID	W	W	Y	Y	Y	N

SDMS Elements		Telematics Team 1		Telematics Team 2		Telematics Team 3	
Description	Schema Tag	Geofence	Self-Test	Geofence	Self-Test	Geofence	Self-Test
Platform ("GEO_FENCE" for all CMRS)	TRIGGER_EVENT	W	W	Y	Y	Y	N
Transponder ID	TRANSPONDER_ID	N	N	N	N	Y	N
HOS - Event Sequence ID	EVENT_SEQUENCE_ID	W	W	Y	Y	Y	N
HOS - Event Status Code	EVENT_STATUS_CODE	W	W	Y	Y	Y	N
HOS - Date of Event	EVENT_DATE	W	W	Y	Y	Y	N
HOS - Time of Event	EVENT_TIME	W	W	Y	Y	Y	N
HOS - Latitude of Event	EVENT_LATITUDE	W	W	Y	Y	Y	N
HOS - Longitude of Event	EVENT_LONGITUDE	W	W	Y	Y	Y	N
HOS - Name of Event (?)	EVENT_NAME	N/A	N/A	N/A	N/A	N/A	N/A
HOS - Place of Event	PLACE_NAME	W	W	N	N	Y	N
HOS - Distance to Event Place	EVENT_PLACE_DISTANCE_MILES	W	W	Y	Y	Y	N
HOS - Odometer at Event	EVENT_TOTAL_VEHICLE_MILES	W	W	Y	Y	Y	N
HOS Update (likely N/A) - Status Code	EVENT_UPDATE_STATUS_CODE	N/A	N/A	N/A	N/A	N/A	N/A
HOS - Diagnostic Code (likely N/A)	EVENT_DIAGNOSTIC_CODE	N/A	N/A	N/A	N/A	N/A	N/A
HOS - Error Code (likely N/A)	EVENT_ERROR_CODE	N/A	N/A	N/A	N/A	N/A	N/A
HOS Update (likely N/A) - Date	EVENT_UPDATE_DATE	N/A	N/A	N/A	N/A	N/A	N/A
HOS Update (likely N/A) - Time	EVENT_UPDATE_TIME	N/A	N/A	N/A	N/A	N/A	N/A
HOS Update (likely N/A) - Person	EVENT_UPDATE_PERSON_ID	N/A	N/A	N/A	N/A	N/A	N/A
HOS - VIN number	EVENT_VIN_NUMBER	W	W	Y	Y	N	N
HOS Update (likely N/A) - Text	EVENT_UPDATE_TEXT	N	N	N	N	N	N
Trailer Number	TRAILER_NUMBER	W	W	N	N	N	N

SDMS Elements		Telematics Team 1		Telematics Team 2		Telematics Team 3	
Description	**Schema Tag**	**Geofence**	**Self-Test**	**Geofence**	**Self-Test**	**Geofence**	**Self-Test**
Trailer License Plate Number	EQUIP_LIC_PLATE_ID	W	W	N	N	N	N
Trailer License Plate Jurisdiction	EQUIP_LIC_PLATE_JURIS	W	W	N	N	Y	N
Trailer License Plate Country	EQUIP_LIC_COUNTRY	W	W	N	N	Y	N
Shipping Document Number	SHIPPING_DOCUMENT_NUMBER	N	N	Y	Y	Y*	N
Multiday Basis (7 or 8 day)	MULTIDAY_BASIS_USED	W	W	Y	Y	Y	N
Driver First Name	FIRSTNAME	W	W	Y	Y	Y	N
Driver Last Name	LASTNAME	W	W	Y	Y	Y	N
Driver PIN/ID	PINID	N	N	Y	Y	Y	N
Driver License Number	DRIVER_LIC_NUMBER	W	W	Y	Y	N*	N
Driver License Jurisdiction	DRIVER_LIC_JURIS	W	W	Y	Y	N*	N
Driver License Country	DRIVER_LIC_COUNTRY	W	W	Y	Y	Y	N
Driver DOB	DRIVER_DATE_OF_BIRTH	W	W	Y	Y	N*	N
Brakes - Chamber subtype	BRAKE_CHAMBER_SUBTYPE_CODE	N	N	N/A	N/A	N/A	N/A
Brakes - Right measure	LEFT_BRAKE_MEASURE	N	N	N/A	N/A	N/A	N/A
Brakes - Left Measure	RIGHT_BRAKE_MEASURE	N	N	N/A	N/A	N/A	N/A
Brakes - Stroke Status	BRAKE_ACTUATOR_STROKE_STATUS	W	W	N/A	N/A	N/A	N/A
Brakes - Lining	WHEEL_BRAKE_LINING	N	N	N/A	N/A	N/A	N/A
Brakes - Application Pressure	BRAKE_APPLICATION_PRESSURE	N	N	N/A	N/A	N/A	N/A
Tires - Location	TIRE_LOCATION	W	W	N/A	N/A	N/A	N/A
Tires - Pressure	TIRE_PRESSURE	W	W	N/A	N/A	N/A	N/A
Tires - Pressure Threshold Code	TIRE_PRESSURE_THRESHOLD	W	W	N/A	N/A	N/A	N/A

SDMS Elements		Telematics Team 1		Telematics Team 2		Telematics Team 3	
Description	**Schema Tag**	**Geofence**	**Self-Test**	**Geofence**	**Self-Test**	**Geofence**	**Self-Test**
Tires - Temperature	TIRE_TEMPERATURE	W	W	N/A	N/A	N/A	N/A
Weight - Axle Group Location	AXLE_GROUP_LOCATION	W	W	N/A	N/A	N/A	N/A
Weight - Axle Group	AXLE_GROUP_WEIGHT	W	W	N/A	N/A	N/A	N/A
Weight - Gross Combination Vehicle	GROSS_COMBINATION_WEIGHT	W	W	N/A	N/A	N/A	N/A
Lighting	LIGHTING	N	N	N	N	N	N
Safety Belt Use	SAFETY_BELT	N	N	N	N	N	N
Carrier USDOT Number	CARRIER_USDOT_NUMBER	W	W	Y	Y	Y	N
HOS - Event USDOT Number	EVENT_USDOT_NUMBER	W	W	Y	Y	Y	N
Carrier Name	CARRIER_NAME	W	W	Y	Y	Y	N
Tractor VIN	TRACTOR_VIN_NUMBER	W	W	Y	Y	N	N
Tractor License Plate Number	TRACTOR_LIC_PLATE_ID	W	W	Y	Y	N	N
Tractor License Plate Jurisdiction	TRACTOR_LIC_PLATE_JURIS	W	W	Y	Y	Y	N
Tractor License Plate Country	TRACTOR_LIC_COUNTRY	W	W	Y	Y	Y	N
Tractor Unit Number	TRACTOR_UNIT_NUMBER	W	W	Y	Y	Y	N
Hazmat ID	HAZMAT_REG_ID	W	W	Y	Y	N	N
HOS Period Start Time	PERIOD_STARTTIME_24HOURS	W	W	Y	Y	Y	N

KEY	
Y = Yes, field present	N = No, field not populated
Y* = Hardcoded value	N* = Data available, but not provided by TT due to privacy concerns
W = Worked on/attempted implementation but not successfully demonstrated end-to-end	N/A = Not applicable as configured

3.3.2 Telematics Team 2 (TT2)

TT2 formally signed their WRI CMRS MOU on June 24, 2010, and began working on the WRI effort immediately. Their approach was to use the onboard telematics device for HOS data entry by the driver to store the SDM information locally, to format the SDM once a geofence was identified (crossed), and to transmit the SDM to the GBOS. TT2 did not use a back office function for their system and used the onboard device as the sole part of the WRI CMRS system. TT2 did not integrate any safety sensor data or attempt to demonstrate a pull-in/by-pass alert. They did agree to implement the self-test component that would allow a driver to test the WRI CMRS system by generating an SDM tagged “self-test” message that would be sent to the GBOS for processing. Their device was not able to receive messages back from the GBOS, thus there were delays in identifying problems with SDMs during the integration and testing phase of the pilot test.

In July 2010, TT2 had successfully passed an SDM from their back office to the GBOS. In August, the telematics devices were installed onto the CMVs and testing began to transmit an SDM from the vehicle directly to the GBOS. On September 5, the first WRI CMRS inspection of a CMV during its normal operation was performed by TT2 as one of their CMV partners passed by the Greene County CMV Inspection Station.

Pre-evaluation data was collected from the CMVs in TT2 via geofence trigger and also via the self-test feature. The results of this testing are shown in Table 4. TT2 demonstrated the WRI CMRS process during the October 14 Safety Technology Showcase conducted at the Greene County CMV Inspection Station and they officially entered the pilot test on October 15. TT2 had the longest data collection period in the pilot test and remained operational until the end data of January 31, 2011.

3.3.3 Telematics Team 3 (TT3)

Initially, TT3 declined in November 2009 to participate in the WRI CMRS pilot test, but reconsidered after multiple requests by one of the fleet partners. This created a late start for them with their MOU not being signed until July 19, 2010.

As with TT1, TT3’s currently fielded telematics devices would not support their planned WRI application, thus they needed to deploy their WRI application on their newest telematics devices. This required that new units be made available and be installed into the fleet partner’s CMVs. The telematics devices were installed in September and development was conducted during October, November, and early December.

The approach for TT3 was to use their onboard device for HOS data entry by the driver and to store some SDM information locally, once a geofence is entered, information was sent from the vehicle to the telematics BOS, and the SDM is formatted in XML and transmitted to the GBOS. TT3 had concerns about driver data privacy and while they had access to this data and the capability to send it, they elected not to send this type of data in the SDMs during the Pilot Test. This was deemed acceptable by ORNL due to the research nature of the pilot test and the fact that this data was as not needed to validate the WRI CMRS process. Due to time constrains, TT33 elected not to integrate safety sensor data, the pull-in/by-pass feature, or the self-test feature.

Pre-evaluation data was collected from the CMVs in TT3 by operating the CMV inside their geofence area. This method was not based on the crossing of a geofence boundary, but rather based on being inside a geofence when the system is polled at pre-determined increments (in this case every 15 minutes). The results of this testing are shown in Table 4 above. On December 21, TT3 officially entered the pilot test and remained operational until the end date of January 31, 2011.

4. PILOT TEST CONDUCT

4.1 CHRONOLOGICAL DESCRIPTION OF THE TEST

4.1.1 Telematics Team 2 (TT2)

TT2 entered the pilot test with a fully-functional system in mid-October 2010. SDMs were geofence- triggered during the test vehicles' normal operation as they passed by the inspection stations in Greene and Knox Counties. Because these CMVs' routes did not take them near these inspection stations frequently, additional geofences were set up near where these test vehicles were parked and serviced between trips. This allowed an increased number of SDMs to be collected from these test vehicles, as at a minimum an additional SDM would be triggered at the beginning and end of each trip. However, this special arrangement also generated a few problems with the log files and some of the generated data, described in the following paragraphs.

When a participating vehicle's ignition was turned on within a geofence (initializing the on-board system), a message was triggered almost immediately, before communication could be established to support the submission of an SDM, resulted in "missing" SDMs. In addition, personnel performing maintenance or moving CMV around the shop did not typically log in as they were not logging in driving hours; therefore, a number of SDMs (the majority of those generated within the domicile geofences) did not include driver and associated identification information. Both of these issues were results of conditions which would never have occurred outside the special test conditions (domicile geofences) set up for the pilot test.

Toward the conclusion of the data collection period, it became apparent that none of the SDMs were fully processed due to a mismatch in the driver and carrier identifying information. Because at that point it was several months since TT2 had been informed that their system was completely working and because of the limited number of days left to complete the Pilot Test data collection and focused testing, the decision was made to forego modifications to the partners' systems which might jeopardize the data collection.

Although data was collected for several months, a day of focused testing was also performed to confirm geofence triggering, to verify the contents of the SDM, and to estimate timing. The results of this testing are detailed in section 4.3.

4.1.2 Telematics Team 3 (TT3)

TT3 officially entered the Pilot Test toward the end of the testing period on December 21. One issue encountered with the TT3 test vehicles was the difficulty intentionally triggering an SDM using the geofencing capabilities of the system. Although the telematics provider indicated that messages could be triggered by causing the on-board equipment (OBE) to communicate with the BOS in various ways within the geofence, this did not prove to be possible. This complicated the test regimen by requiring that all data collection associated with a triggered SDM needed to be collected along the test vehicles' normal routes.

During the tests it was observed that the SDMs that were triggered for TT3 did not appear on the Volpe UI unless a manual refresh consisting of a test message was performed by Volpe personnel. This situation continued until the end of the project; this was compensated for by Volpe's sending a test message at least every half hour during focused testing to make possible the monitoring of SDMs generated during the test period. This testing also served to verify the contents of the SDM.

4.2 EVALUATION AND USE CASES PERFORMED

Due to the limited nature of the Pilot Test and associated systems, not all use cases were tested. However, whenever a complete use case could not be supported, testing was conducted on as many system components and functions as possible.

- WRI fixed site data collection and assessment – Because the UI did not automatically refresh or generate alerts as would be required for real-time enforcement, the testing of this use case was limited to verification of the contents of the SDM and triggering and timing of the SDM generation and communication.
- Post-processing analysis of WRI data and results – The ability to perform analyses of the WRI data in post-processing was not implemented in the Prototype GBOS UI and therefore not included in the Pilot Test
- Carrier use of WRI data and results – Due to the research/prototype nature of the UI and carrier access to more useful interfaces through their telematics providers, this use case was not tested
- Management of the WRI network – Network management was tested only to the extent needed that communication/interface functionality was regularly monitored.
- WRI system self-test by a motor carrier – This feature was implemented by TT2 and tested during the Pilot Test.
- WRI system self-test by roadside or mobile enforcement or "training mode" – Because this functionality was not implemented in the Prototype GBOS, this use case was not tested in the pilot test

4.3 DATA COLLECTED

During the Pilot Test, which extended from October 15, 2010 to January 31, 2011, TT2 and TT3 were able to successfully submit SDMs to the WRI GBOS from the WRI-ready vehicles which carried their technology. These SDMs included vehicle identification information, driver identification information. The identifiers included complete information for TT2 and partial information for TT3; while these identifiers were available in TT3's system, current company policy prevented them from disclosing this type of information, and therefore it was not included in the SDMs. HOS information was also included in the SDMs submitted.

TT1 attempted to develop a more sophisticated system that could provide not only the vehicle ID, driver ID, and HOS information, but also information such as tire pressure, tire temperature, brake status information, and vehicle weight gathered from deployed sensors. The design of the system also included the pull-in/by-pass notification feature which could also be triggered from the inspection station by a direct communication with the WRI-ready vehicle. This more sophisticated system was challenging to develop and was in the beta-testing phase when the WRI Pilot Test ended. A few messages were submitted from stationary vehicles carrying the TT1 technology (i.e., none from moving vehicles encountering one of the three WRI geofences).

4.3.1 SDM Test statistics

TT2 submitted a total of 1,098 messages, 56 of which were triggered by the Knox County Inspection Station geofences and 77 by the Greene County Inspection Station geofence. TT2 implemented a self-test feature (i.e., a functionality of the on-board device that allowed the driver to manually trigger a wireless inspection). In future implementations of the WRI system, this feature would be used to obtain WRI results to check that vehicle and driver are in compliance with regulations before start of driving. Out of the 1,098 SDMs sent, 45 were self-tests. This information is presented in Table 5. Notice that the table also includes a line labeled "Domicile Geofences." In the case of TT2, ORNL implemented additional geofences close to the parking lots of the participating vehicles in an attempt to generate a higher number of trigger events and collect additional data.

Table 5. TT2 Submitted SDM Statistics

Trigger Type	SDMs with at Least One TSs	SDMs with All TSs	SDMs with All TSs (after OCT 14, 2010)
TNNZFQ7ZGSKNOXE	29	13	13
TNNZG57ZHKKNOXW	27	1	1
TNP12G82B8GREENES	77	12	4
Domicile Geofences	920	81	74
SELF-TEST	45	11	6
Total	1,098	118	98

Similar information for TT3 is presented in Table 6, showing separately the data collected after their last software change (January 16). A total of 607 messages were submitted to the WRI BOS, most of them from the Knox County, Tennessee Inspection Stations. In the case of TT3, no domicile geofences were implemented and the system did not have a self-test capability.

Table 6. TT3 Submitted SDM Statistics

Trigger Type	All SDMs	SDMs with All TSs (after JAN 16, 2011)
TNNZFQ7ZGSKNOXE	591	289
TNP12G82B8GREENES	16	8
Domicile Geofences	N/A	N/A
SELFTEST	N/A	N/A
Total	607	297

4.3.2 Data Issues

4.3.2.1 Geofences

Of the three geofence approaches taken, the circular geofence shape required the least number of calculations to determine whether or not a WRI-ready vehicle had crossed it. That is, as the vehicle travels, the distance d between the vehicle and the center of the geofence (an offset of the Inspection Station geopoint) can be computed and compared to the radius R of the circular geofence (e.g., Figure 12) . When $d < R$ (condition 1) then the vehicle has entered the geofence and an SDM needs to be assembled and sent to the WRI GBOS. However, there are two main issues associated with this type of approach. First, it is necessary to know and take into account the general direction of travel of the WRI-ready vehicle when it crosses the geofence. This is important in cases where the Inspection Station is on both sides of the highway such as in Knox County case. If the direction of travel is not taken into account, or if a time-delay feature is not implemented such that a SDM is only transmitted to the WRI BOS if a certain amount of time has elapsed since the last SDM was sent out, then multiple messages will be transmitted. This was the case with TT2.

The second issue is related to vehicles traveling on roads that are inside the geofence but do not have access to the Inspection Station. If such a vehicle were to be issued a pull-in message, it would not be able to comply with the request. This second issue does not arise exclusively with circular geofences; a polygonal geofence such as the one implemented by TT1 has the same problem. Nevertheless, polygons are better at capturing the direction of travel because they can be designed in such a way that they cover only one side of the highway. For systems that have navigation capabilities, this would not be an issue, however in this test, none of the partners offered navigation capabilities to their participating fleets).

The difference in size of the implemented geofences (i.e., TT1 and TT2 vs. TT3) is a direct consequence of the operational configuration of the WRI system implemented by the telematics providers. Both TT1 and TT2 could check the spatial position of the WRI-ready vehicle with a high frequency and therefore the geofence could be relatively small. In the case of TT3, the frequency was much lower (every 15 minutes) and therefore the geofence had to be larger.

4.3.2.2 SDM Processing Times

During the Pilot Test, ORNL collected several timestamps (Table 3) and log files from the CMRS partners participating in this Pilot. As soon as each TT officially entered the Pilot Test, ORNL requested to be periodically provided with log files containing timestamps indicating the date and time when the vehicle entered a WRI geofence or when a self-test was triggered, when the final SDM was assembled (either on board of the vehicle or at the CMRS BOS), and when the message was submitted to the WRI BOS. Each record in the log files was also required to show the ENCOUNTER_ID assigned by the CMRS provider to the particular SDM, as well as the name of the WRI geofence that triggered the message (or an indication that it was triggered by a self-test). Log files were submitted to ORNL by TT2 beginning October 15, 2010 when they officially entered the test. TT3 began providing log files for SDMs submitted on January 17, 2011, and thereafter, about four weeks after officially entering the test on December 21, 2010. Thus TT2 provided about 3.5 months of log data and TT3 provided about 2 weeks of log data.

Telematics Team 1: As described above, TT1 attempted to create a sophisticated WRI system that included many features not implemented by the other two teams for this Pilot Test. This added additional levels of complexity to the software being developed by TT1, which resulted in a system that was not completely functional by the end of the Pilot Test. Therefore, TT1 did not formally enter the test. However, during the software development and testing phase, many SDMs were sent to the WRI BOS from devices similar to the ones that were to be installed in the TT1 vehicles. Towards the end of the Pilot Test, some of these devices with the TT1 WRI software were deployed in the field, and messages were sent to the WRI BOS from participating vehicles, although the trigger mechanism was a self-test and not an actual crossing of a WRI geofence.

During the software development and testing phase, TT1 submitted 70 SDMs to the WRI BOS at Volpe. Timestamp information was logged for these messages by Volpe with summary results presented in ons were collected for TT1.

Table 7. The table shows elapsed times for four different processes at the WRI BOS, with the last column (4) showing the time from when the message was received to the end of the compliance evaluation. That same information is shown in graphical form in Figure 18.

The information contained in ons were collected for TT1.

Table 7 cannot be considered to be representative of a national deployment for several reasons. First, the messages submitted by TT1 were incomplete or did not include some critical information relevant to WRI. SDMs containing all the required and additional WRI information (e.g., sensor information) will take longer to process. Second, the information provided in the SDM was not compared against the complete government databases, but rather to a very small subset of those databases. Longer processing times would be expected when larger databases need to be searched. Third, the system never experienced information overload (i.e., it is almost certain that the three TTs never sent and the WRI BOS never received two SDMs at the same time). Although this problem could be handled with more computing capacity, it will nevertheless affect system performance (either cost or processing time). For these reasons, the information shown in ons were collected for TT1.

Table 7, and in subsequent tables in this chapter, is shown in italics and in a light font color and noted in the table (note: the information is simply provided as a means to compare the performance of the three TTs).

Notice that because TT1 never formally entered the Pilot Test, no information regarding SDM processing times at the CMRS provider level and delays introduced by over-the-air communications were collected for TT1.

Table 7. WRI BOS Processing Times for TT1 SDMs

	Elapsed Time [s]*			
From	**Message Received by WRI BOS**	**Start of Validation**	**Message Received by WRI BOS**	**Message Received by WRI BOS**
To	**End of Validation**	**End of Validation**	**Message Saved in DB**	**End of Compliance Evaluation**
	(1)	**(2)**	**(3)**	**(4)**
No Obs.	*70*	*70*	*70*	*24*
Mean	*0.55*	*0.41*	*0.58*	*0.65*
Std. Dev.	*0.32*	*0.19*	*0.32*	*0.20*
Min	*0.05*	*0.05*	*0.08*	*0.26*
Max	*2.84*	*1.47*	*2.85*	*0.99*
95%CI LL	*0.48*	*0.37*	*0.50*	*0.57*
95%CI UL	*0.63*	*0.46*	*0.65*	*0.73*

*Information shown in italics (columns 1-4) indicates that it cannot be considered as representative of a national deployment.

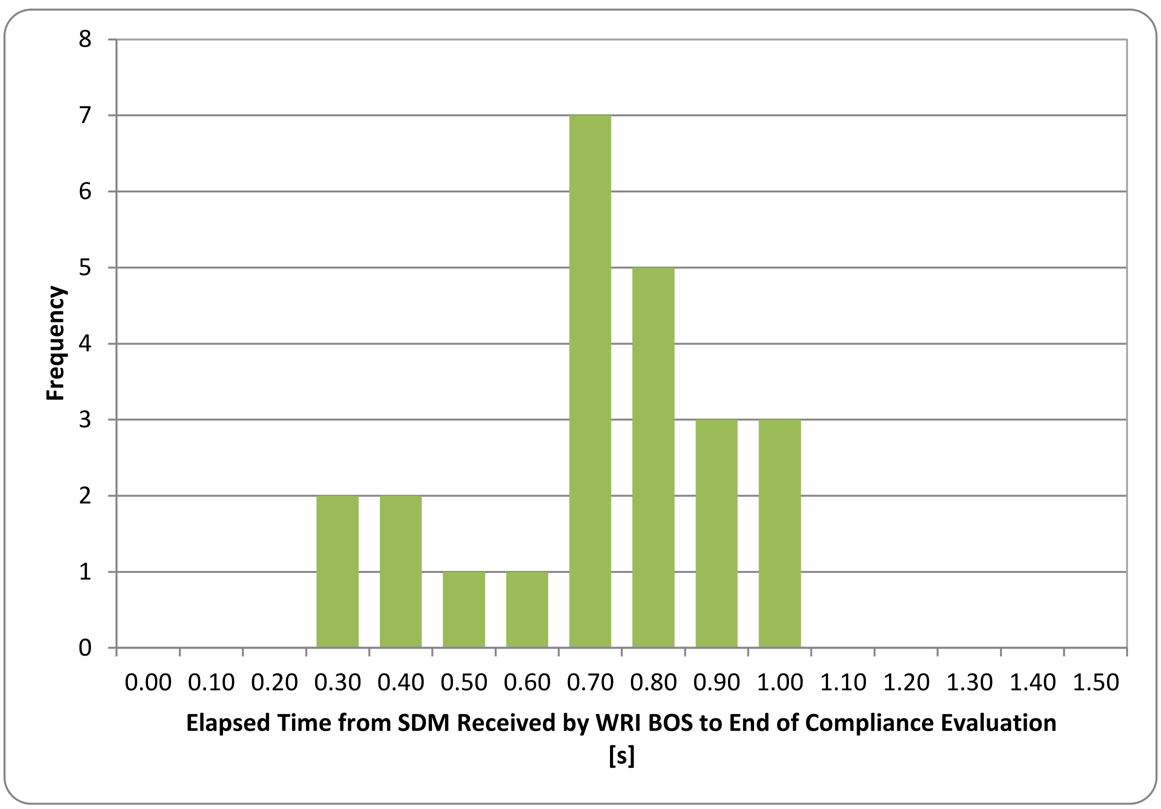

Figure 18. WRI BOS Processing Times for TT1 SDMs: SDM Logged to End of Compliance Evaluation

Telematics Team 2: TT2 was the only team that provided a complete set of information regarding timestamps. For each SDM, those timestamps included the trigger time, the SDM assembled time, the SDM submission time, and a timestamp indicating when the vehicle exited the WRI geofence (for cases where this was the trigger mechanism for that particular SDM). Since information existed at the WRI BOS for when a particular SDM was received, then it was possible, at least in theory, to measure processing time and communications/message transmission times for this TT. This theory proved problematic as described in the following paragraphs. In order to be able to determine elapsed times of events that start in one computer and end in another one, it is necessary for the computer clocks to be synchronized. For desktop computers connected to the Internet and running commercially-available operating systems, this is done automatically. However, this proved not to be the case for some of the on-board devices, and even some of the BOS computers. While a small time drift of an on-board device would not introduce errors in the calculation of HOS, it can be the source of significant errors when communication/transmission times are to be assessed. In some cases these time-drifting errors can be measured, as ORNL did when the team gained access to the on-board WRI ready devices. However, for time drifting/synchronization errors at BOS computers this was not possible because of lack of accessibility.

With the data log information provided by TT2 and the information collected at the WRI BOS, it was possible to create a variable that measured the elapsed time from the moment a TT2 WRI-ready vehicle entered a WRI geofence (or triggered a self-test) to the instant when the generated SDM arrived at the WRI BOS. This variable is important because it measured the processing and communication time that is necessary to generate and submit an SDM (called *SDMgst*). By adding to *SDMgst* the time that it takes to process the SDM at the WRI BOS to generate a WRI Level report and submit that information to the vehicle or the CMRS provider, it would be possible to determine how large the geofence has to be so a "pull-in notification" message can be safely executed by the WRI-ready vehicle.

For messages sent by TT2, Figure 19 shows the elapsed time in seconds from SDM-triggering to SDM-received by the WRI BOS as a function of time (i.e., elapsed days since TT2 entered the Pilot Test). The figure shows that on average, the processing plus transmission time increased over the pilot test period. This could be attributed to several factors, including time-drifting issues at either end (i.e., on-board device where the SDM trigger timestamp is generated, or WRI BOS where the SDM is received) and increases in processing time to create the SDM.

On January 18, 2011, ORNL and the evaluation team from the University of Tennessee (UT) conducted several tests using some of the TT2 vehicles that participated in the Pilot Test. On that day (marked in Figure 19 with an arrow) it was observed that there was a 90 to 120 second difference between the on-board device clock and laptop computer clock running Windows 7 and connected to the Internet (i.e., a reasonably synchronized laptop computer clock).

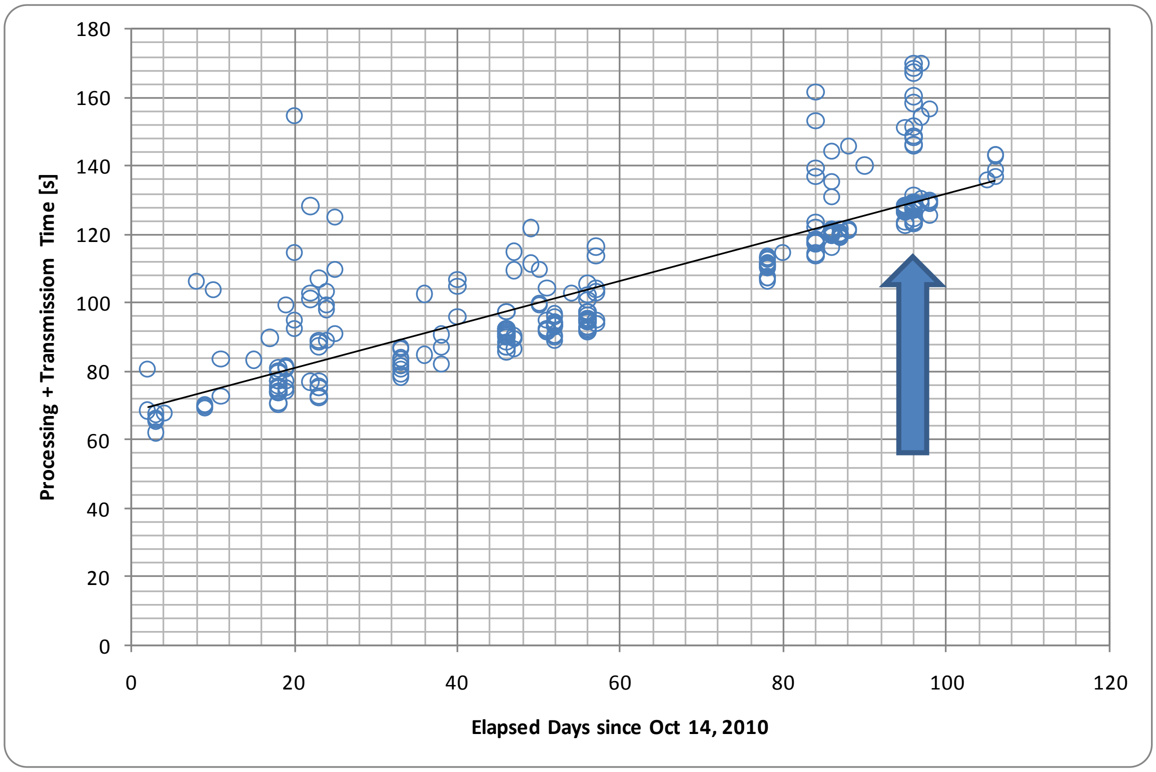

Figure 19. Processing plus Transmission Time for TT2 Generated SDMs as a Function of Days in Test

Assuming that all the time-drifting effect is attributed to the on-board device clock and that it increases proportionally with time since a certain date (e.g., the date when the device was installed), then it is possible to make corrections to the trigger timestamp to eliminate this effect. The results of these corrections are shown in Figure 20. Although there is no apparent time drifting effect, there are observations that are now negative (i.e., the message arrived earlier at the WRI BOS than when it was triggered). This is an indication that either the on-board device time drifting effect is not linear, or that there are (or were at some point) time drifting effects at the other end (i.e., WRI BOS).[2]

[2] The developers who set up the GBOS indicated that the WRI GBOS servers were synchronized with government servers, and were manually verified periodically to have the same time (within a second) as NIST's time server (see http://www.time.gov), and no time drift was detected on the GBOS servers during the pilot test.

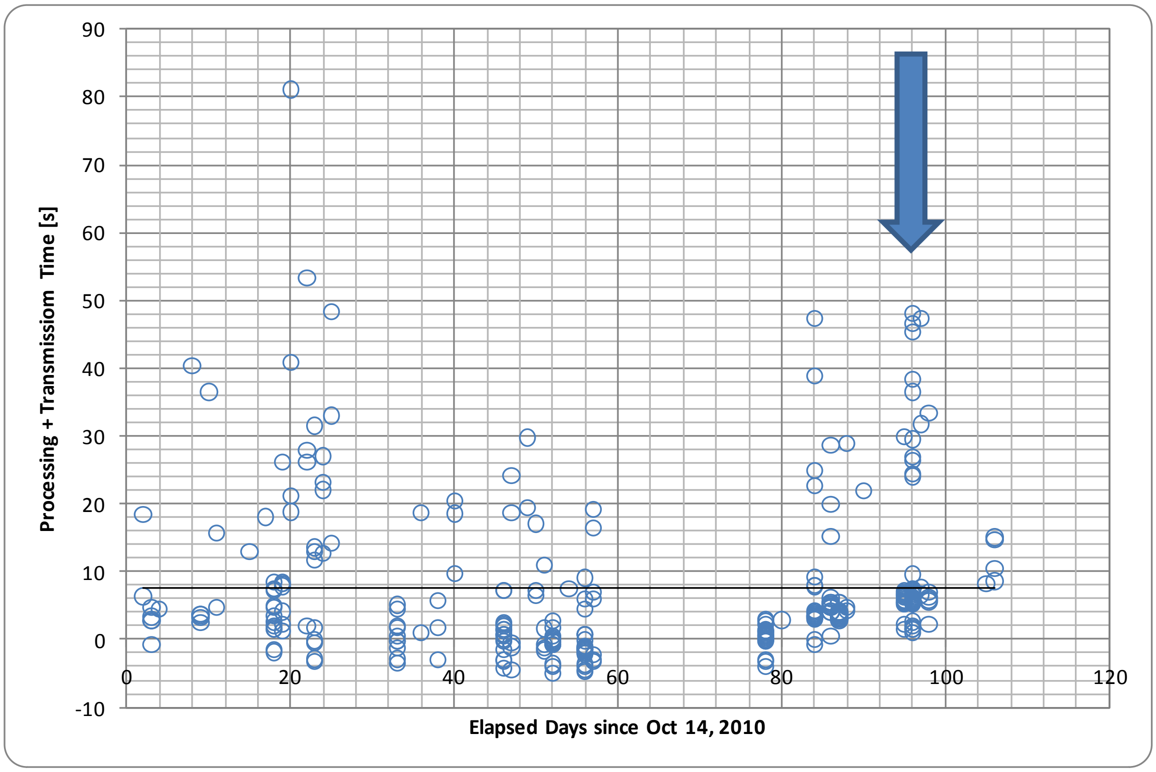

Figure 20. Processing plus Transmission Time for TT2 Generated SDMs with Linear Corrections for On-board Device Time Drifting

The potential issue of non-linearity of the time drifting effect attributed to the on-board devices' clocks can be avoided by simply using information collected around the date when the effect was measured (i.e., Jan 18, 2011). In this way, even if there is a non-linear drifting effect, a linear correction of the data collected around January 18 will only introduce very small errors. This was the approach taken in this analysis.

The information collected from TT2 related to the generation, transmission, and processing of SDMs is presented in Table 8. The first two columns of the table show statistics related to the SDM assembly time (column 1) and submission time (column 2). The average SDM assembly time was 2.6 seconds, with a 95% confidence interval ranging from 2.5 seconds to 2.8 seconds. The submission time was much shorter, with an average of 0.01 seconds. Figure 21 and Figure 22 present these two distributions. Notice that all the data processing to create, assemble, and submit the SDM message was done on-board for TT2 with no communication with their BOS. For this reason, the information shown in columns (1) and (2) of Table 8 can be assumed to be the same, or very similar, in a national deployment for a system similar to the one deployed by TT2. Columns (4) to (7) in Table 8 presents information related to the SDM processing times at the WRI BOS. This information is similar to the one presented in Table 7ons were collected for TT1.

Table 7 for TT1.

Table 8. TT2 SDMs Creation and Submission Times and WRI BOS Processing Times

	Elapsed Time [s]						
From	Encounter Time	SDM Completion	Encounter Time	SDM Received by WRI BOS	Start of Validation	SDM Received by WRI BOS	SDM Received by WRI BOS
To	SDM Completion	SDM Sent to WRI BOS	SDM Received by WRI BOS	End of Validation	End of Validation	SDM Saved in DB	End of Compliance Evaluation
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
No Obs.	98	98	*57*	*618*	*618*	*623*	*4*
Mean	2.62	0.01	*13.60*	*0.46*	*0.39*	*0.49*	*0.85*
Std. Dev.	0.76	0.02	*14.55*	*0.24*	*0.23*	*0.25*	*0.10*
Min	1.06	0.00	*0.49*	*0.11*	*0.09*	*0.12*	*0.73*
Max	4.05	0.11	*51.74*	*2.37*	*1.28*	*2.38*	*0.97*
95%CI LL	2.47	0.01	*9.82*	*0.44*	*0.37*	*0.47*	*0.76*
95%CI UL	2.78	0.02	*17.38*	*0.48*	*0.41*	*0.51*	*0.95*

*Information shown in italics (columns 3-7) indicates that it cannot be considered as representative of a national deployment

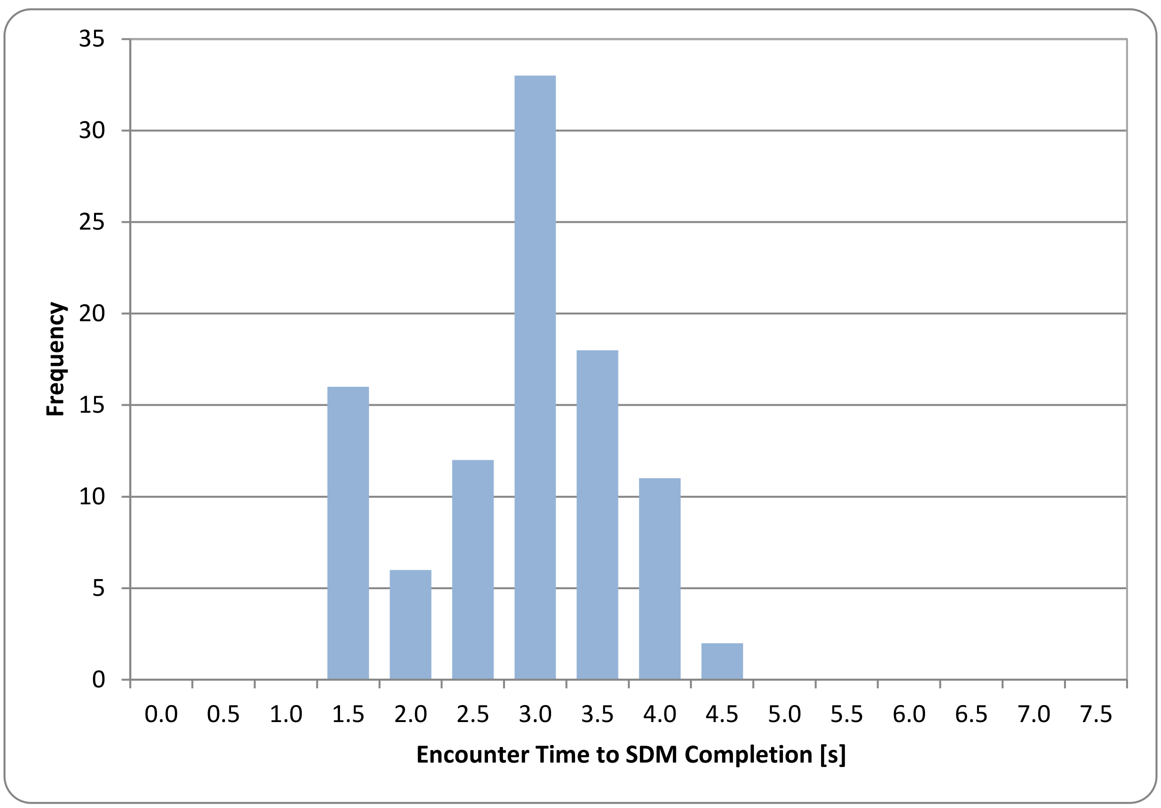

Figure 21. TT2 SDMs: Encounter Time to Completion Time

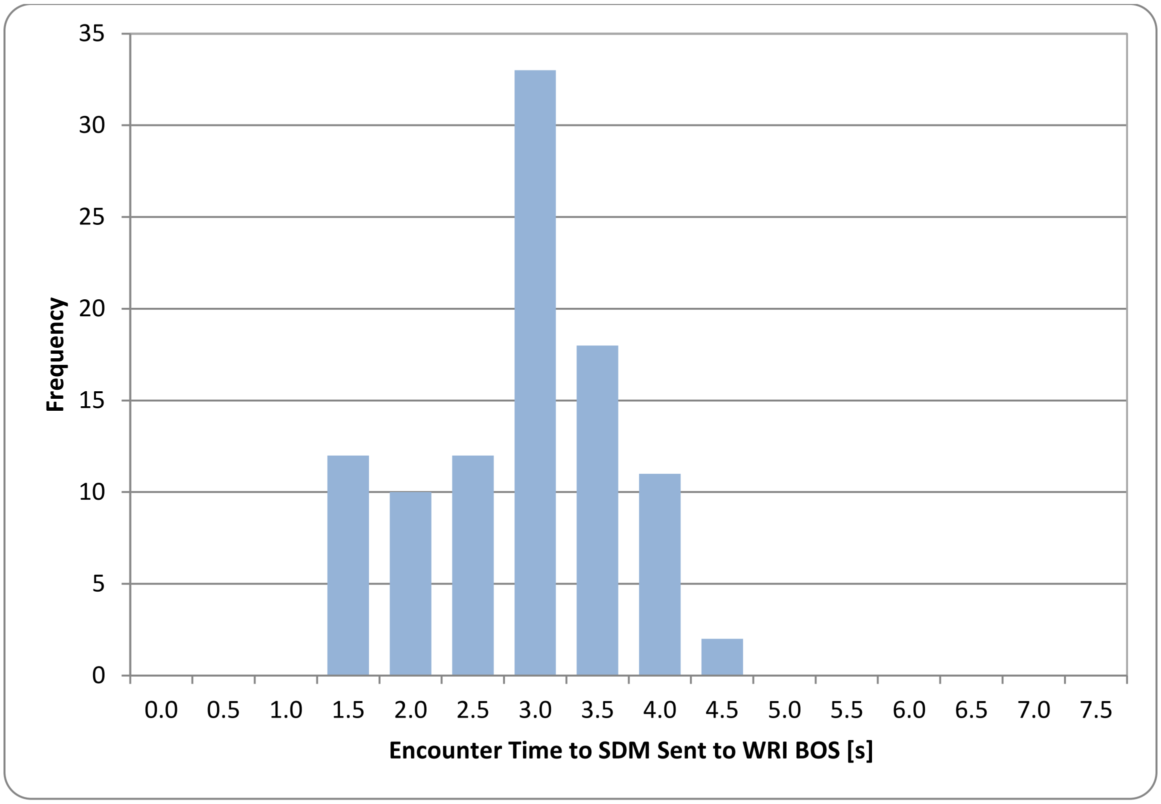

Figure 22. TT2 SDMs: Encounter Time to Submission Time

Column 3 of Table 8 shows the time it took from the time a message was triggered to the time it was logged at the WRI BOS. The information presented in that column has been corrected for the observed time-drift effect as described above (i.e., only messages sent on January 18, 2011 were used to generate the information shown in column 3). The distribution of these times is shown in Figure 23, which resembles a Poisson distribution as expected for a distribution of communication times.

Table 9 presents just the communications portion of the time interval shown in column 3 of Table 8. The communications time distribution summarized in column (1) of Table 9 was built with information gathered from January 16-20, 2011; that is, a five-day period centered on January 18, 2011 which was the day ORNL measured the TT2 on-board device time drifting for each one of the participating vehicles. Elapsed times for January 16, 17, 19, and 20 were corrected using a linear approximation as described above. Similarly, the distribution presented in column (2) of Table 9 was built with information collected from January 8 to January 28, 2011, a 20-day period centered on January 18, 2011. Linear corrections were applied to the measured elapsed times to account for the observed time drifting effect. A statistical test showed that a null hypothesis stating that the means of the two distributions were the same could only be rejected with less than 80% confidence.

By adding the average times of columns (1), (2) and (7) of Table 8 and column (1) or (2) of Table 9, it is possible to estimate the total elapsed time from when an SDM is triggered until when the message was completely processed at the WRI BOS during this Pilot Test. The estimate obtained in this way, (13.6 seconds using Table 9 column 1, or 15.8 seconds using column 2), is very close to the average value of 14 seconds obtained from informal tests conducted by ORNL. These informal tests consisted of using stopwatches that were started when a self-test was triggered from one of the TT2 WRI-ready vehicles and stopped when the message was posted at the WRI website.

Table 9. TT2 Communication Time

	Elapsed Time [s]	
	Jan 16, 2011 to Jan 20, 2011	Jan 08, 2011 to Jan 28, 2011
From	SDM Sent to WRI BOS	SDM Sent to WRI BOS
To	SDM Received by WRI BOS	SDM Received by WRI BOS
	(1)	(2)
No Obs.	13	24
Mean	10.11	12.35
Std. Dev.	11.08	10.99
Min	1.76	1.76
Max	31.87	39.64
95%CI LL	4.09	7.95
95%CI UL	16.14	16.75

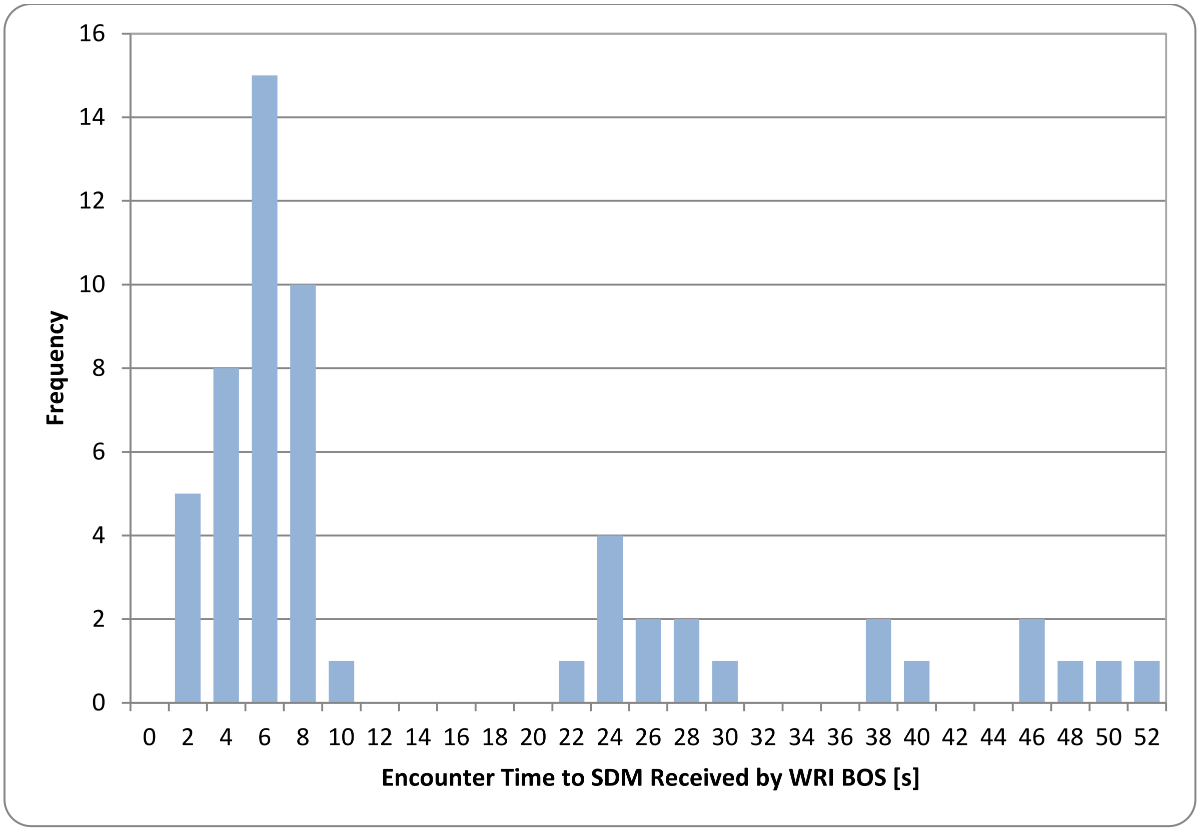

Figure 23. TT2 SDMs: Encounter Time to Message Received by WRI BOS

The time to create and transmit a SDM from TT2 was also parsed by trigger type (i.e., WRI Geofence and Self-test). Parameters characterizing these distributions are presented in Table 10. On average, it took about 1/3 of a second longer to generate a SDM triggered by a Self-test than an SDM triggered by entering a WRI geofence. This slightly longer time was due to the fact that in a Self-test there is a UI involved (i.e., the user touches a button on the screen of the on-board device, and then the software needs to process that event) which is not present when the message is triggered by a WRI geofence. In the latter case, the creation of the SDM is completely transparent to the driver and it does not require his/her input. However, a statistical test showed that a null hypothesis stating that the means of the two distributions were the same could only be rejected with less than 80% confidence.

Table 10. TT2 SDMs Creation and Submission Times by Trigger Type

	Elapsed Time [s]			
	All WRI Geofences		Self-test	
From	Encounter Time	SDM Completion	Encounter Time	SDM Completion
To	SDM Completion	SDM Sent to WRI BOS	SDM Completion	SDM Sent to WRI BOS
	(1)	(2)	(3)	(4)
No Obs.	18	18	6	6

	Elapsed Time [s]			
Mean	3.13	0.01	3.44	0.02
Std. Dev.	0.49	0.02	0.34	0.03
Min	2.55	0.00	3.02	0.00
Max	4.05	0.06	3.90	0.06
95%CI LL	2.91	0.00	3.17	0.00
95%CI UL	3.36	0.02	3.72	0.04

Table 11 further disaggregates the information collected for SDMs triggered by WRI geofences (columns 1 and 2) into messages generated at the Knox County, Tennessee (columns 3 and 4) and Greene County, Tennessee (columns 5 and 6) WRI geofences. Notice that the average times for SDM creation was very similar for both locations (only 1/5 of a second shorter for the Greene County Inspection Station than from the Knox County Inspection Station). A statistical test showed that a null hypothesis stating that the means of the two distributions were the same could only be rejected with less than 95% confidence.

Table 11. TT2 SDMs Creation and Submission Times by Inspection Station

	Elapsed Time [s]					
	All WRI Geofences		Knox County Geofences		Greene County Geofence	
From	Encounter Time	SDM Completion	Encounter Time	SDM Completion	Encounter Time	SDM Completion
To	SDM Completion	SDM Sent to WRI BOS	SDM Completion	SDM Sent to WRI BOS	SDM Completion	SDM Sent to WRI BOS
	(1)	(2)	(3)	(4)	(5)	(6)
No Obs.	18	18	14	14	4	4
Mean	3.13	0.01	3.29	0.01	3.06	0.01
Std. Dev.	0.49	0.02	0.45	0.02	0.17	0.01
Min	2.55	0.00	2.67	0.00	2.86	0.00
Max	4.05	0.06	4.05	0.06	3.22	0.02
95%CI LL	2.91	0.00	3.05	0.00	2.89	0.00
95%CI UL	3.36	0.02	3.52	0.02	3.22	0.02

Telematics Team 3: Telematics Team 3 officially entered the Pilot Test on Dec 21, 2010 and started providing ORNL with log files on January 17, 2011. For each SDM generated by TT3, the log files contained the ENCOUNTER_ID, the name of the WRI geofence that triggered the message (no self-test capabilities were deployed by TT3), the encounter time (generated by the on-board devices when it became aware that it was inside a WRI geofence), and the message completion time (generated by the BOS computers since the message was submitted to the WRI BOS from the CMRS BOS and not from the vehicle as it was the case with TT2).

Using the message completion timestamp and the "data record creation" timestamp provided the WRI BOS at Volpe, it is possible to assess the communication time between the two BOSs.

Notice that in the elapsed time computed in this way there is a component that corresponds to the time from when the message was completed to when the message was actually submitted to the WRI BOS. This, in general, is a very short time (e.g., 0.01 seconds, on average, for TT2), but it was not measured in the case of TT3 (i.e., no corresponding timestamp was provided by TT3) and therefore it cannot be quantified.

Figure 24 shows a graphical representation of this variable as a function of time. The general trend of this variable is to increase with time (i.e., the linear regression line shown in the figure slopes upwards as time increases). However, this is not a constant increase, but rather a "pulsating" increase. The data is clearly clustered in four groups, three of them in which the variable decreases almost linearly over a relatively long period of time, and one in which the variable increases abruptly(days 9 and 10). This seems to be an indication of time drifting and periodic corrections (once a week, day 2 and day 9). If this time drifting effect were to happen at only one end (e.g., TT3 BOS), then the corresponding correction would be biased since the beginning of each corrected cluster in Figure 24 is higher than the previous one, where it should be approximately the same. If this were the case, then the time discrepancies would have probably been already noticed (and corrected) by the TT3 BOS.

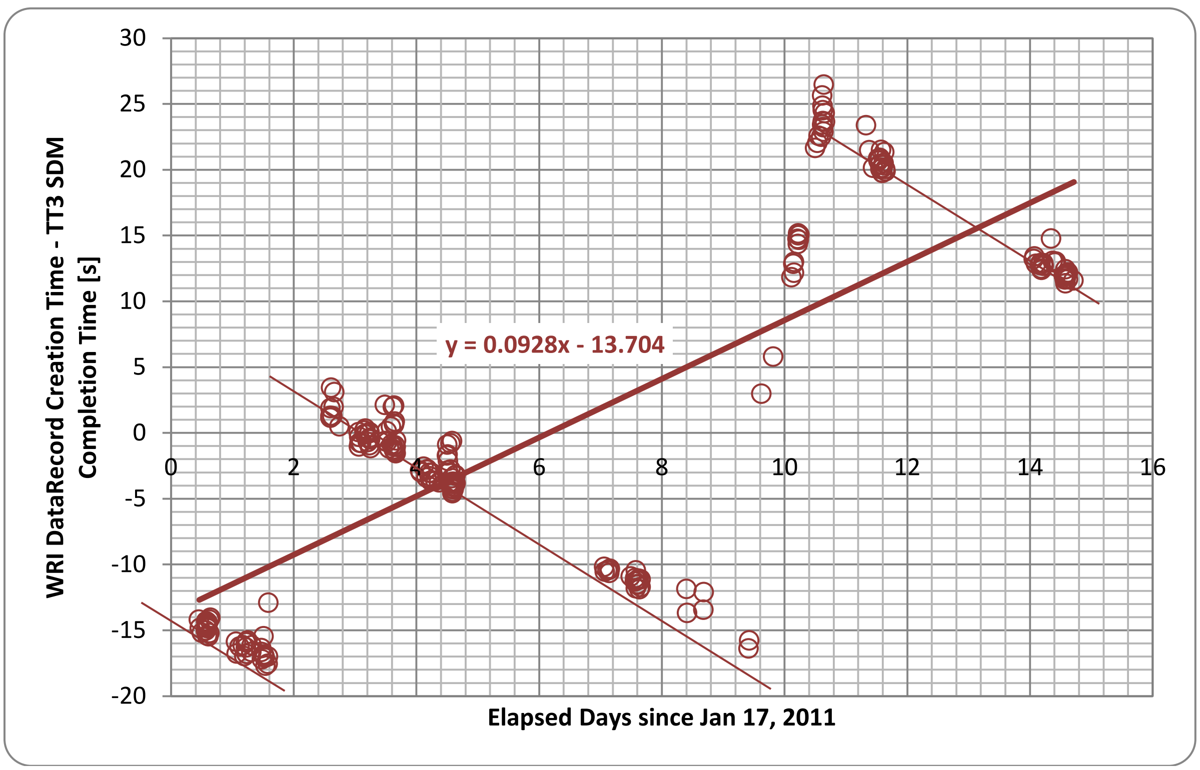

Figure 24. Time Elapsed from SDM Completion to WRI Data Record Creation (TT3 Generated SDMs).

Another possibility is that there is time drifting at the other end as well. In fact, a constant time drifting *tdse* at the sending end that is corrected with a given frequency *tdsef* combined with a constant drifting at the receiving end *tdre* that is smaller than *tdse* and that is not corrected or is corrected with a frequency lower than *tdcf* would produce a graph similar to the one shown in Figure 24.

Table 12 presents summary statistics related to the generation, transmission, and processing of TT3 SDMs. Column 1 show statistics related to the SDM assembly time. In the case of TT3, this elapsed time includes a transmission time –i.e., from the vehicle to the CMRS BOS– and therefore is larger than that of TT2 –which submitted the SDM to the WRI BOS directly from the vehicle (see Table 8). Notice that for TT3 there were some observations of the elapsed time between encounter time and SDM assembly that were negative (e.g., the minimum value shown in column 1 is -9 seconds), which implies a time drifting factor. On January 21, 2011, ORNL conducted some tests at the Knox County Westbound Inspection Station in which TT3 vehicles participated. ORNL checked the accuracy of the clock of the on-board devices and found them to be synchronized within +/-2 seconds of a laptop computer clock. The implication is of a time drifting factor at the TT3 BOS as observed above and possibly at the GBOS as well.

Table 12. TT3 SDMs Creation and Submission Times and WRI BOS Processing Times

	Elapsed Time [s]						
From	**Encounter Time**	**SDM Completion**	**Encounter Time**	**SDM Received by WRI BOS**	**Start of Validation**	**SDM Received by WRI BOS**	**SDM Received by WRI BOS**
To	**SDM Completion**	**SDM Sent to WRI BOS**	**SDM Received by WRI BOS**	**End of Validation**	**End of Validation**	**SDM Saved in DB**	**End of Compliance Evaluation**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
No Obs.	*295*	#N/A	*223*	*369*	*369*	*369*	*1*
Mean	*36.92*	#N/A	*35.61*	*0.52*	*0.50*	*0.56*	*1.08*
Std. Dev.	*19.87*	#N/A	*16.30*	*0.21*	*0.18*	*0.22*	*#N/A*
Min	*-9.00*	#N/A	*1.13*	*0.19*	*0.16*	*0.19*	*1.08*
Max	*204.00*	#N/A	*205.86*	*2.84*	*1.42*	*2.86*	*1.08*
95%CI LL	*34.65*	#N/A	*33.47*	*0.50*	*0.48*	*0.53*	*#N/A*
95%CI UL	*39.18*	#N/A	*37.75*	*0.54*	*0.51*	*0.58*	*#N/A*

*Information shown in italics (columns 1 and 3-7) indicates that it cannot be considered as representative of a national deployment

Because TT3 did not provide information regarding submission times for their SDMs, column 2 of Table 12 does not contain any information. Column 3 shows the elapsed time since the SDM was triggered (by the on-board device becoming aware that the test vehicle was inside a WRI geofence) to when a data record of this SDM was created at the WRI BOS. Notice that as discussed previously, there are indications of time drifting at both BOSs and possibly at the on-board devices level as well. However, the time drifting factors at the on-board device level and WRI BOS appear to be small and therefore the statistics presented in column 3 of Table 12 may be only slightly off. For example, in Figure 25 (which shows the variable that was used to compute the parameters presented in column 3) there are no signs of significant time drifting factors, although there are some outliers (1.1 and 205.9 seconds, with a third observation at 107.9 seconds).

Columns (4) to (7) in Table 12 present information related to the SDM processing times at the WRI BOS. This information is similar to the one presented in ons were collected for TT1.

Table 7 for TT1 and in Table 8Table 8 for TT2.

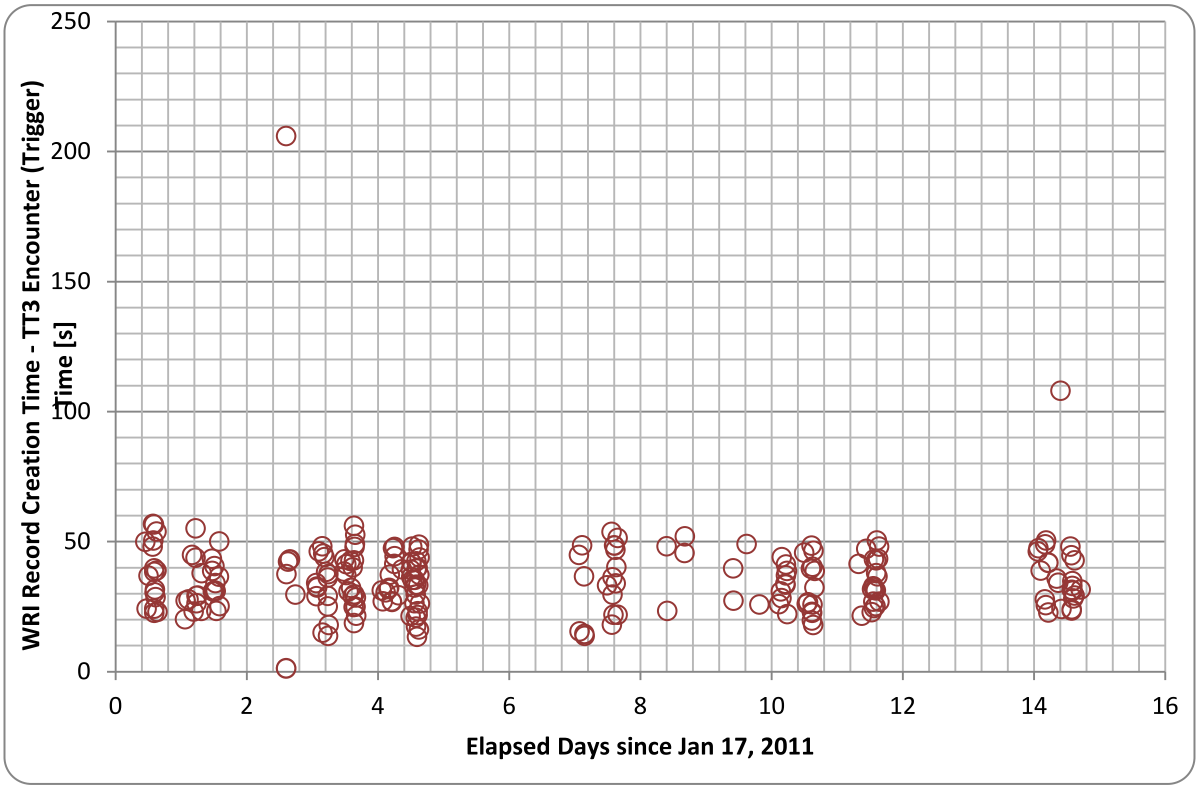

Figure 25. TT3 SDMs: Encounter Time to Message Received by WRI BOS

4.3.2.3 Hours of Service, Driver Information, and Vehicle Information

The SDM data structure used in this Pilot Test seeks to provide as much information related to the vehicle (e.g., vehicle ID, information collected from on board tire, brake, and weight sensors, etc.) and driver (e.g., driver ID, HOS) as is available. There is, however, a minimum subset of information that needs to be included in the SDMs which covers vehicle ID, driver ID, and HOS information. The three telematics teams included HOS information in their SDMs (all three of the participating CMRS providers offer EOBRs to their customers).

For the two TTs that officially entered the Pilot Test (i.e., TT2 and TT3), ORNL corroborated the information included in the SDM by applying the following procedure. For TT2, some tests were run using the test vehicles on January 18, 2011. The tests consisted of having one of the drivers to log in, drive the vehicle a few miles, park it, and trigger a WRI self-test (done through the on-board device and using its touch-screen capabilities). At the same time ORNL obtained odometer information from the vehicle dashboard and immediately after running the self-test, pictures were taken from the EOBR HOS screen. The SDMs generated in this way were obtained later from Volpe and the information included in the message was checked against the information collected in the field.

Both vehicle and driver identification information was correctly included in the SDMs for each one of the vehicles tested. Regarding the HOS, the information included in the SDM was, on average, 9 minutes 5 seconds behind the information provided by the EOBR. Figure 26 shows the HOS information obtained from one of the SDMs submitted by TT2 to the WRI BOS. The last status change (colored in orange) was not included in the SDM but was displayed by the EOBR. All the status changes present in the SDM matched those shown by the EOBR.

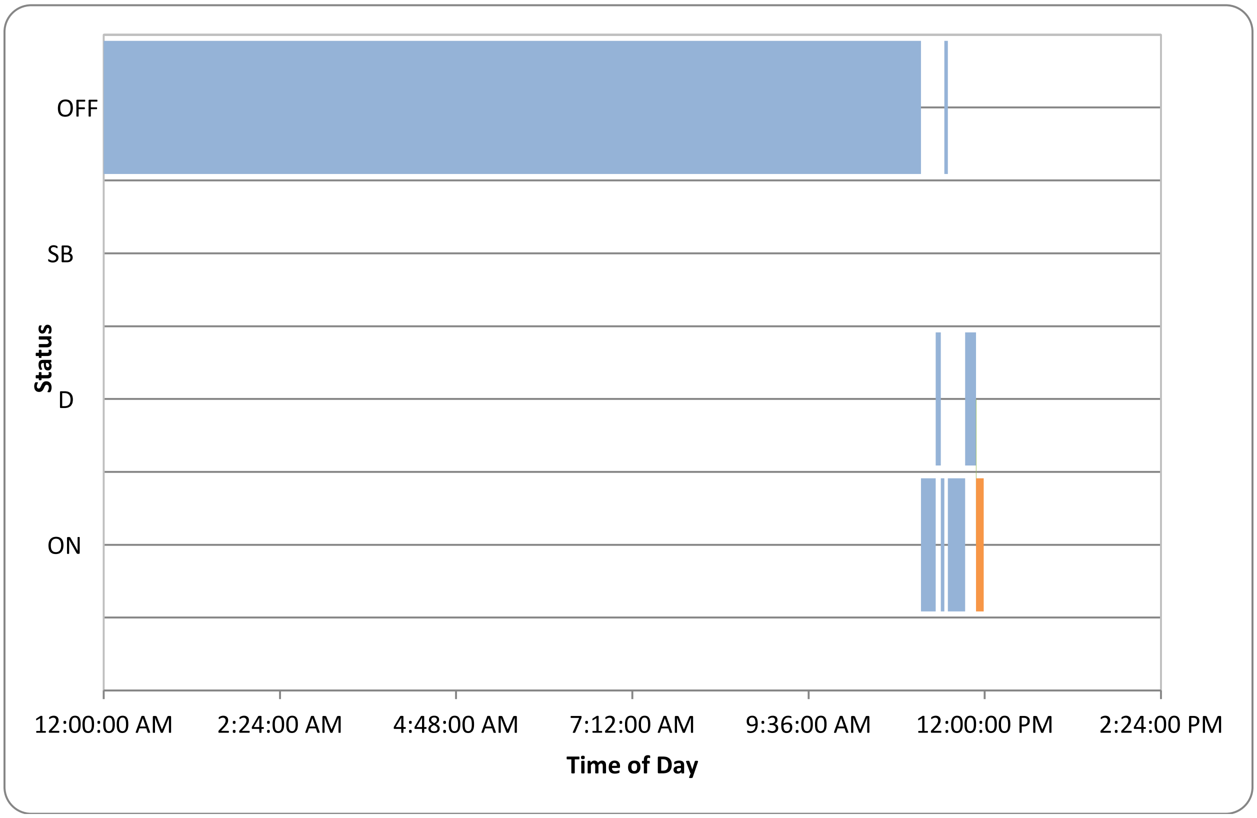

Figure 26. TT2 SDM HOS Information

For TT3, the procedure used by ORNL and UT to corroborate the SDM information was slightly different. ORNL requested that all the TT3 participating vehicles stop at the Knox County Westbound Inspection Station on January 21, 2011 to have a Level 3 inspection conducted on the vehicles and drivers by Tennessee Highway Patrol officers. All of the participating TT3 vehicles, with the exception of one, stopped at the Inspection Station and received a Level 3 inspection. During this time, ORNL took pictures of the EOBR showing the HOS information. As was done in the TT2 case, ORNL requested the SDMs for January 21, 2011 from Volpe and compared the information included in those messages to the information collected at the Knox County Inspection Station on that date. The vehicle ID information and driver name were correctly included in the SDMs (note: as discussed previously, currently in-place company policies do not allow TT3 to disclose driver identification information, and therefore only the driver name was included in the SDM). With respect to the HOS, the information included in the SDM was, on average, 2 hours 29 minutes 50 seconds behind the information provided by the EOBR, indicating a potential problem correctly generating the HOS data in the SDM. Figure 27 shows the HOS information obtained from one of the SDMs submitted by TT2 to the WRI BOS. In that figure the last four status changes (colored in orange) were not included in the SDM but were displayed by the EOBR (note: all of the status changes present in the SDM matched those shown by the EOBR).

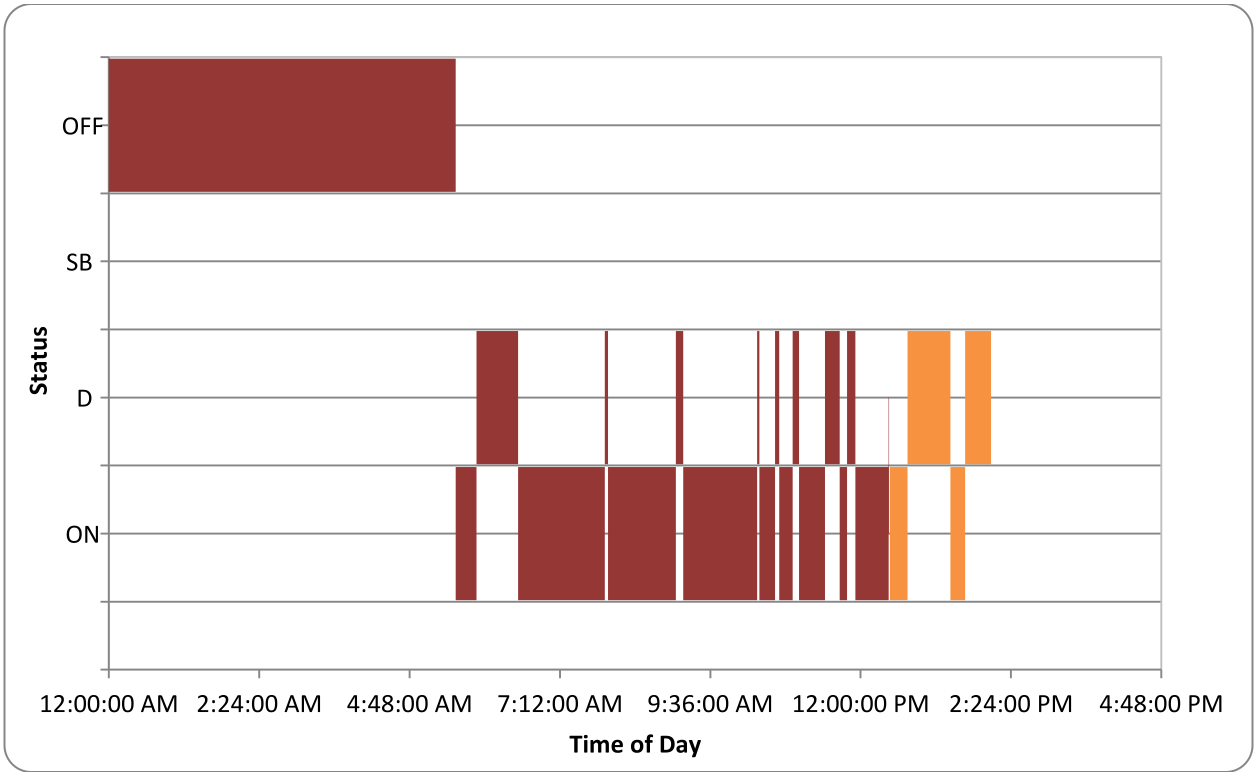

Figure 27. TT3 SDM HOS Information

TT1 never entered the Pilot Test; however, some messages were submitted to the WRI BOS from instrumented vehicles. ORNL did not corroborate any of the information included in these SDMs. As an illustration, Figure 28 shows the HOS information included in one of the TT1 SDMs. In this particular case, the HOS information was missing just three minutes of data when compared to the encounter time (i.e., the time when the SDM was triggered).

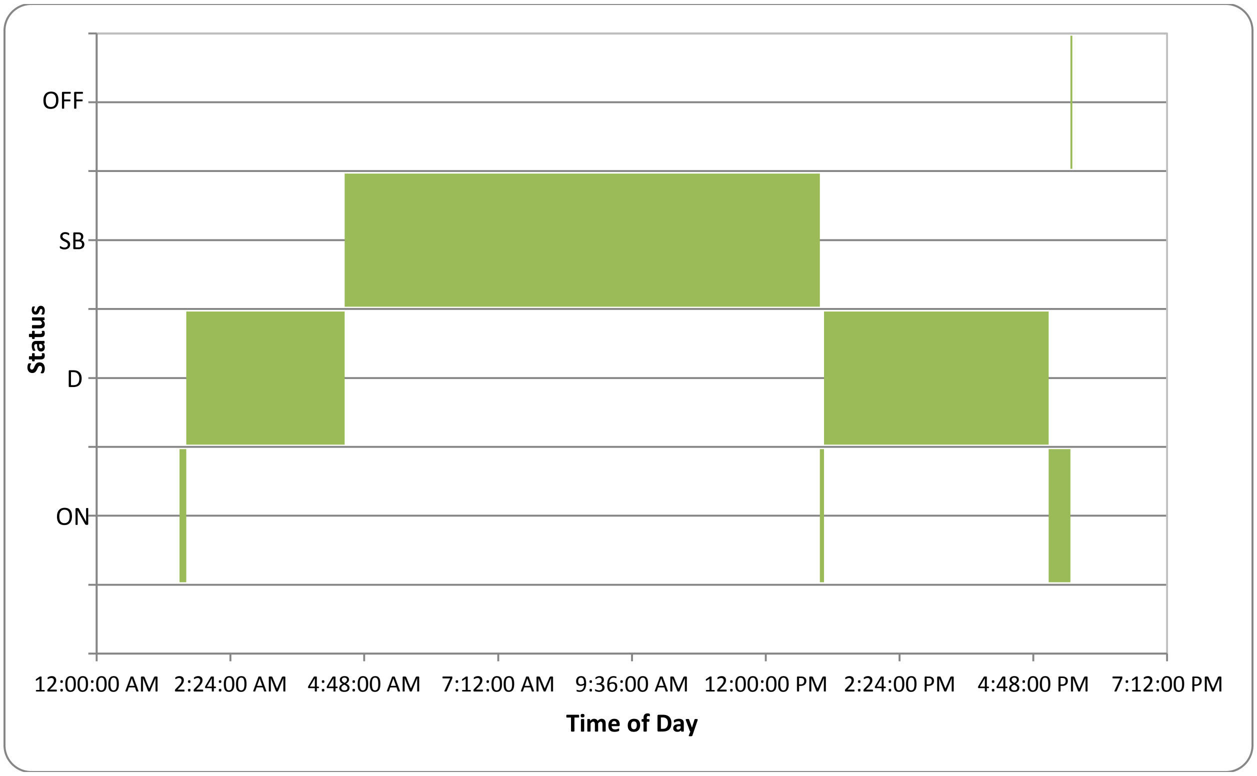

Figure 28. TT1 SDM HOS Information

4.3.2.4 Additional Sensors

The only telematics team that included sensor information in this Pilot Test was TT1. This team did not officially enter the Pilot Test so no sensor data corroboration was possible. However, from the few SDMs that were submitted from instrumented vehicles it was observed that brake status information was included in the message, as well as tire temperature and pressure data transferred by tire position, and weight data transferred by axle group.

4.4 IMPACT OF THE TEST ENVIRONMENT

One way in which the pilot test environment differed from an operational environment was related to the implementation of log files and generation of unique encounter IDs by the telematics providers for each SDM submitted. This required the partners to develop and implement a logging system and a method of generating a unique identifier for each method. The limited number of telematics providers simplified this somewhat, as each was assigned a range of possible values to be used for this identifier. This arrangement would likely be unmanageable in an operational environment.

The test environment did not test the performance from the GBOS as fully as an operational environment would have. The GBOS's handling of more SDMs than those generated by the few test vehicles would likely impact processing time. In addition, the test environment never presented a situation where two SDMs were sent to the GBOS at the same instant in time; this situation would likely be a regular occurrence in a nationally-deployed system.

The type of communication implemented in the TT2 system (sending the information directly from the vehicle) may seem scalable to a larger number of vehicles from the telematics provider's standpoint, but since it would require Volpe to accept communication from a source system for every vehicle, such a communication path would likely be unsuitable for national deployment. The communication path implemented by TT3 (submitting SDM through the telematics BOS), however, may present a similar problem for the telematics back-office, depending on the number of SDMs triggered at a given time.

Another area in which a nationally-deployed system would differ from the test environment is in the definition and implementation of geofences. For the pilot test, there were only a few geopoints defined, and the partners constructed geofences manually according to their preferred implementation strategy. However, the manual generation of geofences is not practical for national deployment; thus, sufficient information must be provided for each geopoint (e.g., series of points along the highway leading up to the geopoint) to allow the telematics providers to automatically generate and deploy a variety of geofence shapes.

5. OBSERVATIONS AND ASSESSMENT

Data collected through the CMRS Pilot Test provided an opportunity to gain insight into the system functionality, performance, and related information to form the design of a WRI system for national deployment. These observations are briefly described in the following subsections.

5.1 WRI CMRS SYSTEM FUNCTIONALITY

5.1.1 Functionality for different operational scenarios and their specific needs

Due to the limited nature of the Pilot Test and associated systems, not all use cases were fully supported by the Pilot Test system. However, where not all the elements existed to support a given use case, testing was conducted to gain as much information as possible regarding the operational scenarios.

- WRI fixed site data collection and assessment – Because the UI did not automatically refresh or generate alerts as would be required for real-time enforcement, the testing of this use case was limited to verification of the contents of the SDM and triggering and timing of the SDM generation and communication. The integration of WRI with other systems such as Aspen would likely also make the system more useful to enforcement.
- Post-processing analysis of WRI data and results – The ability to perform analyses of the WRI data in post-processing was not implemented in the Prototype GBOS UI and therefore not included in the Pilot Test
- Carrier use of WRI data and results – Due to the research/prototype nature of the UI and carrier access to more useful interfaces through their telematics providers, this use case was not tested
- Management of the WRI network – Network management was tested only to the extent needed that communication/interface functionality was regularly monitored.
- WRI system self-test by a motor carrier – This feature was implemented by TT2 and tested during the Pilot Test.
- WRI system self-test by roadside or mobile enforcement or "training mode" – Because this functionality was not implemented in the Prototype GBOS, this use case was not tested in the pilot test

5.1.2 Interfaces

Three interfaces relevant to the Tennessee platform were developed in this project. One of these interfaces was developed by Volpe to serve as the main real-time SDM data access interface this interface was used by the three WRI platforms. The other two interfaces were developed by the CMRS providers for their respective fleets (TT1 and TT2). The interface under development by TT3 was not fully completed.

Figure 29 shows the WRI BOS GUI developed by Volpe. The screen presented in the figure was captured on December 28, 2010 at approximately 8:05 AM and shows the ten latest SDMs, received at that time by the WRI BOS, sorted by date and time. The information presented to the user included the US DOT number (blocked in the picture to maintain the anonymity of the information shown), the Encounter ID number (also blocked), the name of the WRI Geofence that triggered the SDM, the date and time when the message was triggered, the name of the driver (blocked), and the VIN (blocked). Notice that the Encounter ID presented to the user was clickable. By following that link, the user was directed to a summary page that allowed him/her to access vehicle information (including sensor information), driver information (including HOS), and metadata information. From the main screen shown in Figure 29, the user could also access other pages by clicking on the "Inspections" and "Alerts List" buttons shown on the left-hand side of the screen.

For a casual user interested in looking at the information contained in the most recent SDMs, this interface worked well. However, there was no search feature to locate particular inspections, requiring the user to navigate through lists of previous inspections a single page at a time. In a national deployment, this problem would be seriously aggravated. As shown in Figure 29, all SDMs for the state are shown together on the interface. The interface did not provide a means to "filter" the information by Inspection Station, thus making it more difficult (almost impossible in a national deployment) to be used by enforcement personnel at a particular Inspection Station.

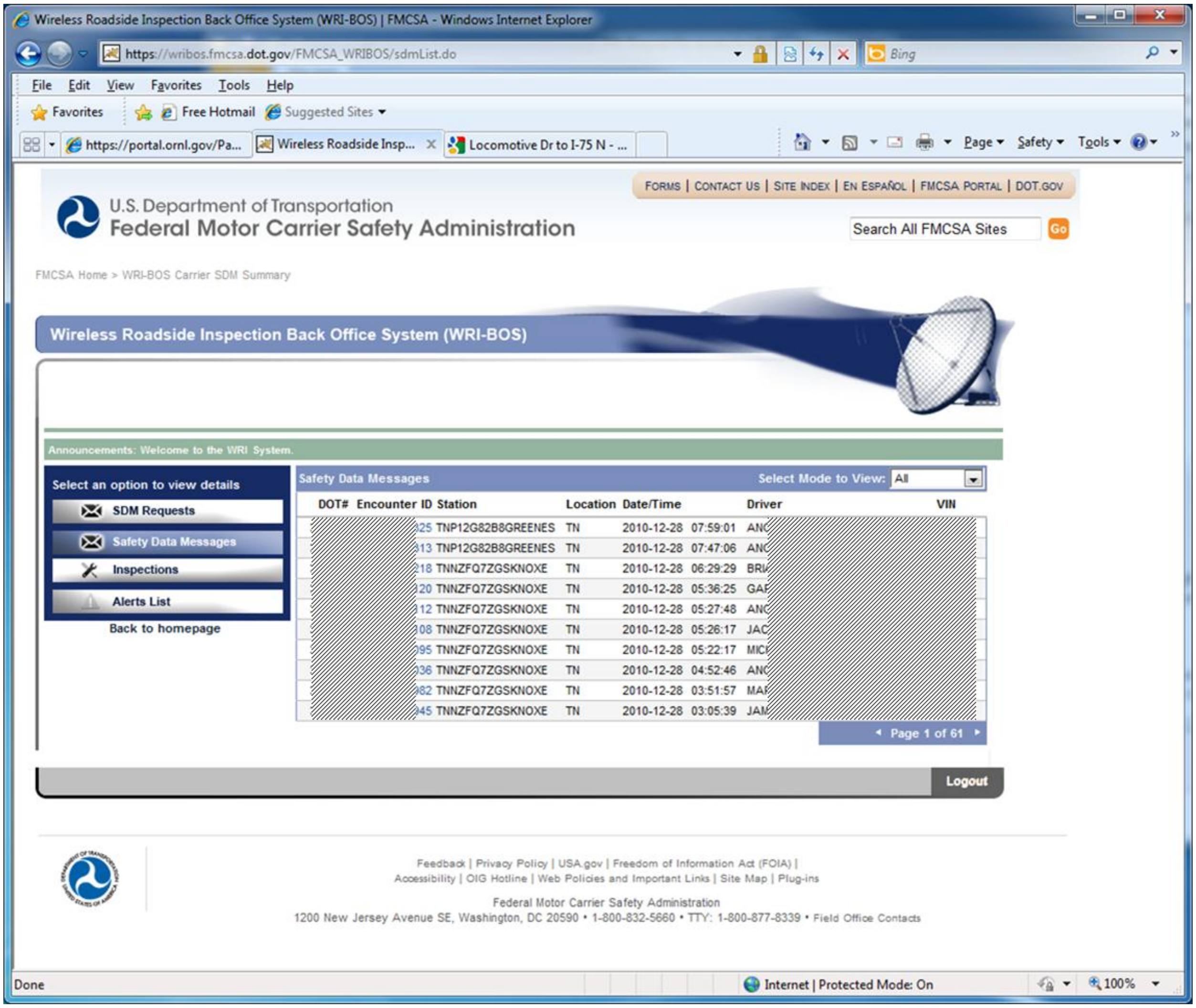

Figure 29. Screen Capture of the GBOS Website Interface

Telematics Team 1 developed an interface specifically for this project. To access this interface, a WRI tab was included in the main screen that any user of their on-board device would see when starting the system. By clicking/touching that tab, the user was able access other screens to provide additional information relevant to WRI. This included the driver's DOB, license number, and jurisdiction; tractor and trailer information; and shipping document information (including Hazmat ID, if any). The driver could also access other screens showing the readings from different deployed sensors such as tire status (pressure and temperature), vehicle weight by axle, brake stroke and other brake information. The WRI interface also provided a tab to submit a self-test, and a screen notifying the driver that he/she needed to enter the inspection station ahead –pull-in notification screen. (Note: because TT1 never officially entered the test, none of these capabilities were tested by ORNL researchers.)

Telematics Team 2 also developed an interface for this project and deployed such interface to the on-board devices of the participating vehicles. In this case the interface was simpler than for TT1 and it was restricted to providing the driver with the means of reviewing the HOS logs and submitting a self-test to the WRI BOS. This interface was tested by ORNL researchers and the evaluation team, and it was found to be satisfactory for the designed purpose.

5.2 WRI CMRS SYSTEM PERFORMANCE

Two of the three TTs entered the Pilot Test and successfully submitted SDMs from WRI-ready vehicles. Those messages were triggered by the vehicle entering a WRI geofence (TT2 and TT3) or by the driver through a self-test (TT2). Each one of the three TTs implemented a different type (in terms of shape and size) of geofence. Two of them (TT1 and TT3) used polygons, and the other (TT1) implemented circular geofences. For TT1 and TT2, the size of the geofences was relatively small (from 200 yards to 3 miles).

Precise system performance with respect to SDM transmission time was not measurable due to clock-synchronization issues. The lack of synchronization among the many different systems that were involved in generating, transmitting, and receiving the SDMs proved to be very difficult. Although in some cases it was possible to measure time drifting values with the corresponding corrections applied to the data collected, elapsed time measurements between the pair of systems were not error free since these corrections were evaluated and applied to only one end of the transaction (ORNL and the evaluation team did not have access to many of the systems involved in the processing of the SDMs). For systems that generate and transmit the SDM directly from the vehicle (TT2) the average SDM assembly time (i.e., the elapsed time from the moment the message was triggered to when it was ready to be submitted) was 2.62 seconds, and the average submission time (i.e., from when the message was assembled to when it was sent to the WRI BOS) was 0.01 seconds. The total time from message triggered to message processed at WRI was, on average, between 13.6 seconds and 15.8 seconds. These measured values were very close to the figures obtained from informal tests conducted by ORNL (ORNL measured 14 seconds). These informal tests consisted of using stopwatches that were started when a self-test was triggered from one of the TT2 WRI-ready vehicles and stopped when the message was posted at the WRI website. For deployments that rely on BOSs (TT3), the average SDM assembly time and the elapsed time from when the message was triggered to when it was received by the WRI BOS was much longer because it included an additional transmission time between the vehicle and the CMRS provided BOS. Due to time drifting issues, it was not possible to determine these values with more precision.

Driver and vehicle ID information was correctly included in the SDMs and transmitted to the WRI BOS. The HOS information provided in the SDMs was on average 9 minutes 5 seconds behind the corresponding information shown on the EOBR for TT2 and 2 hours 29 minutes 50 seconds for TT3. In both cases, all of the status changes present in the SDM matched those shown by the EOBR.

The only telematics team that included sensor information in this Pilot Test was TT1 (note: TT 1 never officially entered the Pilot Test). Although the data included in a few SDMs that were submitted from instrumented vehicles was not corroborated, it was observed that brake status information was included in the message, as well as tire temperature and pressure data (which was transferred by tire position) and weight data (by axle group).

5.3 WRI CMRS SYSTEM OPERATIONS

As discussed previously, the ability of the WRI system to support enforcement was limited by the research nature of the GBOS UI. A more user-friendly interface would allow the enforcement community to view only the inspections associated with their geofence locations and provide alerts when violations were detected. In addition, the incorporation of a bypass/pull-in component to provide instruction to the driver based on the results of the inspection (not tested in the Pilot Test) is fundamental to a WRI CMRS solution which does not require any additional infrastructure. Due to limitations of the GBOS and the participation of safety-conscious fleet partners, no safety problems were detected through the WRI assessment processes in place for the Pilot Test.

5.4 WRI CMRS SYSTEM MANAGEMENT

The management of the WRI system was not under the purview of the CMRS test team. Instead, the various portions of the system were managed by Volpe (GBOS) and the telematics providers (on-board and private BOS). System-management-related issues encountered after the official start of the data collection included short periods during which the GBOS was offline.

5.5 WRI CMRS SYSTEM COSTS

For the CMRS Pilot Test, the telematics equipment, services and related user fees were provided gratis by the telematics partners or were included in the preexisting contracts between the telematics partners and the fleet partners. Additionally, the Tennessee Highway Patrol used their in-house computers to facilitate the UI to view WRI information.

To date, no WRI CMRS system, component, or usage fee information exists. However, cost information does exist for telematics devices, systems, and services used for tracking, communications, maintenance, and as EOBRs. It is assumed by this research team that the costs for WRI CMRS equipment, systems, and services would be similar. Thus, each telematics team was polled as to the expected cost of a fully realized WRI CMRS system (based on currently existing telematics systems) including the monthly service or user fee.

The following assumptions and caveats exist for the cost information provided in Table 13:

- No additional BOS systems will be needed by the telematics partners to conduct WRI CMRS. However, modifications to existing systems will be needed to support WRI and no cost information was available for these modifications due to the fact that scope of these modifications will be highly dependent on the final government WRI system which is not defined at this point.
- The cost for a CMV onboard device is per truck.
- The CMV initially has no other telematics device or has an EOBR with limited capabilities (does not repurpose to WRI CMRS).

- Equipment and monthly service fees would vary depending on the telematics provider that a carrier uses and the options that the carrier selects as part of their provider-based plan.
- The cost information is based on information provided by the participating telematics partners as an estimate (no WRI CMRS equipment or services exist at this time).
- Roadside enforcement would use their existing desktop or laptop computers.
- The user interfaces for the motor carrier and roadside enforcement will be supplied by FMCSA.

Table 13. WRI CMRS Cost Information

Entity	Location	Equipment, User Fee, Other	Cost Range
Telematics	Telematics Back Office	Modification to BOS to support WRI	Not defined at this time
Enforcement	Roadside	Readers, nodes	$0; none required
Enforcement	Roadside	User Interface	$0; supplied by FMCSA
Motor Carrier	Motor Carrier Back Office	User Interface	$0; supplied by FMCSA
Motor Carrier	CMV	Monthly Service Fee	$25 to $50/month
Motor Carrier	CMV	Telematics Device	$200 to $2,475

5.6 WRI CMRS SYSTEM SECURITY

The WRI CMRS system consisted of two closed systems: the GBOS and the telematics systems. Thus, there were no security elements under the purview of the CMRS testing team. Volpe followed their standard data security procedures and safeguarded the SDM contents during data transfer by dictating the encryption procedures for communication between the telematics providers and the GBOS. For systems internal to the telematics providers (such as storing driver data and handling communication between on-board units and the back-office), the partners made use of their proprietary systems, each with their own security protocols to protect data for their fleet customer. Because the WRI CMRS platform was designed to treat each TT system as a closed system, ORNL did not pursue business-sensitive information regarding their security methodologies and system design.

6. LESSONS LEARNED

The gratis partnership arrangement suggested and facilitated by ORNL reduced the cost to FMCSA, allowed for a credible number of partners for the pilot test, and reduced the time to get partners onboard as opposed to a contracting process. However, this methodology did not afford the pilot test the ability to force architecture or methods onto the partners, and it did not allow ORNL the ability to control resources within the partners operations. These shortcomings allowed for a great diversity of approaches and associated problems (i.e. time synchronization) and were not conducive to meeting deliverables or schedules. For example, not all telematics partners systems were able to work, not all potential system features could be tested, and the actual data collection period was very short due to partners systems coming online late in the Pilot Test. Gratis partnerships give great rewards in terms of time and monetary savings as well as flexibility in partnering. For them to work effectively, however, there must be very structured advanced planning and solid agreement by all parties.

A substantial amount of time is needed to get legal documentation in place when working with fleets and companies who are working day-to-day in commerce. The arrangements and agreements needed for future similar efforts should take into consideration the considerable amount of time needed for the approval of legal documentation.

Changes or late clarification in FMCSA policy can be detrimental to retaining partners. Policy should be disclosed at the beginning and remain constant throughout the process. If not, schedule and cost impacts must be accepted. This was the case for FMCSA's policy of "no regulatory relief" for carriers participating in the WRI pilot test. Essentially, the fleet partners' exposure to regulation, scrutiny, and possible punitive action increased as a result of their gratis involvement in WRI. Several fleet partners elected not to participate once this policy was disclosed. Ultimately, this FMCSA policy was not an issue for the fleet partners who did participate in the WRI CMRS pilot test due to the lack of the GBOS hitting against real data bases, real-time HOS calculations, or any substantial use of the enforcement UI by law enforcement. However, the late policy clarification did affect the number of fleet partners that were involved.

For a Pilot Test of this nature and magnitude, having the GBOS as the only tool for accessing the function of a full WRI system was not sufficient as we were not able to see what was really going on at any given time in a true end-to-end sense. At times, the telematics partner's system would not be working, but there was no real-time means to verify. At times the GBOS would not process an SDM, but there was no real-time way to validate. At times the GBOS system would be down and there was no method for real-time assessment of the cause or corrective action. Alternate methods of monitoring a future WRI system are needed for the facilitators and the evaluators.

Time synchronization of data is an issue that must be addressed in next WRI phase. We found that the telematics partners did not synchronize to the same source as the GBOS and that, in some cases, the telematics devices were free-running with only an initial time sync.

Initially, the GBOS would reject any SDM that appeared to be generated in time before it arrived at the GBOS (due to synchronization issues). This SDM would be seen as fraudulent.

With non-standard time synchronization, this was a possibility. The rules for this rejection should be examined and adjusted to a reasonable difference in possible time between the incoming SDM and the GBOS.

There was great diversity in geofencing methodology from partner to partner. Geofencing for WRI should be quick and easy to establish, be corridor based, and allow for vehicle direction discernment. However, there are technical and systems challenges that must be addressed with the telematics providers to determine what is realistic and viable for the future. Geofencing requirements for future WRI systems must balance needs with telematics provider cost to upgrade systems and software to meet geofencing requirements.

Driver-log portability should be addressed as both a policy issue and a technical issue. One situation to be considered is that of a driver who works part time for two companies that have two different telematics devices (or one uses a paper log); the question of how the HOS records of that driver would be reconciled must be addressed. From the pilot test, we see that there is no imminent reconciliation plan or method.

Participating fleet partners had some very positive comments on the concept of WRI and especially the ability to gather and have access to vehicle and driver data. The concept of conducting a self-test before a driver would begin their day was seen of value as well.

Certain assumptions were made by the WRI team in the Concept of Operations and in the approach to the pilot test which proved to be risk areas. Examples included ease of telematics providers to format the SDM in XML; willingness of the telematics partners to share personal identification information; ability of the GBOS to display HOS and safety sensor data in a meaningful manner; incompatibilities between the GBOS and telematics BOS or on-board device. Many of these assumptions proved to be wrong and caused delays and failed attempts. For future efforts, stakeholder input (i.e., fleets, enforcement, telematics, safety sensor provider) is needed throughout the process, not just at the beginning as was done with the WRI stakeholder session.

The availability of the WRI BOS interface documentation was out of sync with the needs of the telematics providers. In future efforts, this material should be available to the partners as soon as the partnership opportunities are announced to allow sufficient time for system development.

The decision by two of the telematics partners to develop the WRI application on their newest telematics platform offering (meaning the WRI application would not work on existing, fielded hardware) caused ORNL to lose several committed fleet partners, because the telematics partners could not provide enough new devices to all these carriers and their vehicles. This was unforeseen in the project planning and in initial conversations with the telematics partners. Hardware, systems, and software requirements and versions should be discussed and agreed upon very early in discussions with the telematics providers and be considered when recruiting fleet partners.

While ORNL attempted on many occasions to make clear that the Tennessee Department of Safety and the fleet partners had no intention of investing financial resources in developing their own prototype interface for the WRI pilot test, the notion that they would seemed to linger well into the effort. Clear roles and responsibilities documents need to be developed at the beginning of any future effort.

The telematics partners were allowed to make changes to their software even after the pilot test had begun. The purpose for these changes was to facilitate a better-formed SDM to allow full processing by the GBOS. It is standard practice not to change any system under test once testing starts and that system has been deemed viable for testing. ORNL had “certified” two of the telematics team’s systems to be officially accepted in the pilot test. It was several days after this that Volpe stated that there were problems with their SDM and recommended that the partners make changes. These changes created other issues with the SDMs. In the future, a thorough proving of information (in this case via SDM) should be made by all parties and changes to partner software should not be made once the official testing period has begun.

7. RECOMMENDATIONS FOR REFINEMENT AND ENHANCEMENT

Below are the critical issues identified by ORNL in regard to the WRI CMRS platform moving forward. Based on the results of the Pilot Test, there needs to be an intermediate step between this completed Pilot Test and the FOT planned for the future. These steps might best be accomplished in micro-projects coming together in something akin to a pre-FOT test to validate system functionality prior to an FOT.

- Specify, develop, test, and validate a logical, backwards compatible (if possible) GPS boundary solution for SDM trigger via telematics device. This is a complex issue from a software point of view, hinging on the logic used in the mapping methodology. This methodology must allow high confidence of functioning at locations that have radiused roadways, neighboring secondary roads and bi-directional traffic to ensure SDMs can be reliably triggered. This item could likely be accomplished with the support of the telematics industry in some reasonable cost-share model.
- Specify, develop, test, and validate a logical, safe, backwards compatible pull-in/by-pass function to allow WRI to be used in near-real-time enforcement and interdiction. For WRI CMRS to be viable for at-speed inspections, screening, and interdiction, this functionality is crucial. It is anticipated that this item could also be accomplished with the support of the telematics industry in some cost-share arrangement.
- Methodically dissect the current GBOS and develop a matrix of current functionality, maturity, scalability, and desired WRI production functionality. Based on this information, develop a clear path (with measurable metrics) to specify, develop, test, validate, and rework the next generation (pre-production, large scale) GBOS. This item would best be accomplished by gathering input at stakeholder user meetings of the three WRI platforms. The entity tasked with gathering information and proposing a solution should be from the information technology community with a track record in working with large integrated systems.
- Revisit the viability and scalability of using XML as the only method of SDM data transfer to the GBOS. Gather stakeholder feedback as well as expert advice and finalize the data transfer protocol for WRI. To ensure success with this item, it is recommended that an oversight panel be established, consisting of members with relevant experience from government/academia (development of large networks and data base systems), industry (fleets, telematics, and sensor), and enforcement (state, federal CMV and state IT/IS). The main objectives of this panel would be to ask the right questions, guide the process, eliminate assumptions, recognize errant planning and systematic weaknesses, and provide broad insight from stakeholders to mitigate short-falls in system capability.

While only three major issues for WRI CMRS to be viable are listed above (and one for WRI globally), these are not trivial. Further, while total success in these areas was not possible in the Pilot Test, valuable insight was gained into the complexity of these issues.

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APPENDIX – CMRS PILOT TEST LOG

WRI CMRS Pilot Test Log Sheet for Issues, Lessons Learned, and Events				
Item	**Date**	**Issue**	**Fallout**	**Action**
1	N/A	Gratis Partnerships	Must work with what telematics providers and other partners have to offer and on their timeline	Work with partners to achieve best results within the gratis partnerships
2	N/A	Safety Sensors not currently native to CMV	Must install individual sensors on individual CMVs	Work with safety sensor providers to provide limited number of systems (gratis) for Pilot Test
3	N/A	Narrow window for Pilot Test Testing	Some telematics may not make window; data collection may be limited for evaluation	ORNL recommends extending Pilot Test
4	N/A	Testing to involve real-world, working fleets	Very limited access to vehicles; no control over vehicles or routes; must coordinate data collection around vehicle's schedule	Plan to inspect vehicles as they routinely enter inspection station; go to vehicle and perform self-test at base of operations; set up local geopoint (near base of operations)
5	N/A	Article negative to WRI appears in trade magazine	Fleets and telematics providers shy about participation.	FMCSA considered response article, but none to date
6	N/A	Volpe system will not collect and distribute geo-points	Not able to test this functionality	ORNL to send geopoints to partners via e-mail
7	N/A	FMCSA policy of "No regulatory relief position" for WRI fleet partners	Increases difficulty in recruiting fleet partners	None
8	N/A	Small fleets are concerned about exposing their HOS	No small fleet participation	None
9	N/A	Tough economy	Only 3 of ~ 40 solicited telematics providers participate in the Pilot Test; some potential fleets elect not to participate	None

WRI CMRS Pilot Test Log Sheet for Issues, Lessons Learned, and Events				
Item	**Date**	**Issue**	**Fallout**	**Action**
10	N/A	Telematics companies require latest OBE to be able to participate in Pilot Test	Limits number of fleets who can participate. Basically, the new equipment does not currently exists in fleets	None
11	N/A	Legal concerns over data captured during the Pilot Test in the event of an accident	Some potential fleets elect not to participate	None
12	N/A	Telematics partners only willing to lend a small number of new OBE devices for Pilot Test	Limited number of vehicles for Pilot Test	Encouraged telematics partners to increase number of units…time will tell
13	May-10	TT1 has shortage of new OBEs	Delay in start of pilot test (~ 2 to 3 weeks to get equipment)	Units became available over time
14	N/A	Telematics devices not readily able to receive safety sensor data	Limited number of vehicles with safety sensors (TT1 only); delay in start of Pilot Test	TT1 pays one of the safety sensor technology providers to develop interface
15	Mid-June - Aug10	Telematics devices not readily able to communicate with GBOS	Delay in start of pilot test	None
16	4-Aug-10	TT2 devices not able to interpret vehicle heading (for incorporation into geofence triggering)	Yet to be fully determined, but issue with bi-directional weigh stations and vehicles on secondary roads	None
17	June-10	TT3 decides to enter Pilot Test	Late start; limited design/development time for TT3	None
18	3-Aug-10	Telematics devices not readily able to receive confirmation from GBOS or By-pass/pull-in indication	Potentially no by-pass/pull-in indication	None
19	22-Sep-10	TT2 using ignition switch signal for HOS data (i.e., start accruing driving time)	HOS driving time includes time which should instead be recorded as on duty rather than driving	Signal wire from engine used to trigger driving time

WRI CMRS Pilot Test Log Sheet for Issues, Lessons Learned, and Events				
Item	**Date**	**Issue**	**Fallout**	**Action**
20	22-Sep-10	Driver for TT2 fleet was able to accidentally input his personal id number in place of vehicle ID	Corrupted data in BOS	Vehicle ID corrected
21	22-Sep-10	Not enough character positions in SDM schema to accommodate tire pressure value	Volpe modified system to include sufficient character positions	Discussed issue with Volpe, who modified system accordingly
22	27-Sep-10	WRI UI timeout is set to 15min for security reasons	Not practical for a roadside system; makes pre-evaluation work frustrating	ORNL requested change, but request was denied due to security reasons
23	27-Sep-10	Data does not appear on the UI when new SDM is received; user must refresh screen to see new data	Not practical for a roadside system; makes pre-evaluation work frustrating	Basic functionality of system, not changed
24	29-Sep-10	Minor problems with TT2 data: HOS problem, coordinates of vehicle when a self-test is triggered (should show current coordinates), and use of the WRIMODE field to pass "TEST" for self-test and "PRODUCTION" for a crossing of a geo-fence	Requested TT2 make the indicated corrections	Fixed 09/30/2010
25	29-Sep-10	Regular operations of TT2 fleets do not take vehicles near the participating inspection stations frequently	Requested TT2 to add two new geo-points close (1/4 mile) from fleet base of operations (one east and one west of garage). Sent TT2 coordinates of these new geo-points and names for these "stations"	TT2 added new geo-points 09/30/2010

WRI CMRS Pilot Test Log Sheet for Issues, Lessons Learned, and Events				
Item	**Date**	**Issue**	**Fallout**	**Action**
26	30-Sep-10	Some of the TT2 messages sent to the WRI site did no make it to the main page.	Discussed issues with Volpe (main problems: time stamps are different in the IDENTIFICATION section and the METADATA section; also, STATION can only handle [0-9] and [A-Z])	Renamed stations to comply with Volpe's rules and passed information to TT2 and other TTs
27	1-Oct-10	TT2 use of GMT in timestamps when Volpe expected local time	Discussed time stamp issues with TT2 and Volpe	TT2 modified program; Volpe relaxed rules
28	1-Oct-10	For TT2's geofence-triggered SDMs, the geopoint coordinates are shown rather than the actual coordinates at which the SDM is triggered, making it difficult to determine vehicle direction of travel and make determinations regarding latency	Asked TT2 to post in SDM the actual coordinates of when the geo-fence is crossed and not the geo-point coordinates.	TT2 changed coordinates reported in the SDM to represent to actual coordinates where SDM triggered
29	1-Oct-10	TT2's on-board devices show central time instead of Eastern.	Programmer believes this has to be changed by an Administrator at fleet through TT2's website.	Fleet notified of how to make change if desired
30	1-Oct-10	HOS info included by TT2 in the SDM sent to Volpe was not being displayed on the WRI Site	Issues with HOS were discussed with Volpe; Volpe indicated that they were working on these issues. Volpe was to resolve the HOS issues on Monday Oct 4th	Oct 4 - Volpe indicated that they have deployed a new version of their system where the HOS issues have been resolved. Station Name is now being displayed also; Asked TT2 to re-send SDM messsages to check if HOS issues have been resolved. The issue was resolved and HOS info displayed.

WRI CMRS Pilot Test Log Sheet for Issues, Lessons Learned, and Events				
Item	**Date**	**Issue**	**Fallout**	**Action**
31	13-Oct-10	Volpe WRI system down due to someone's SDM crashing the system		Volpe had all parties stand down and we went forward with TT2 on 14Oct10
32	14-Oct-10	GBOS down prior to Showcase Event	System rebooted	Slight delay; added stress for event
33	14-Oct-10	TT2 System down prior to Showcase	System rebooted	Slight delay; added stress for event
34	26-Oct-10	WRI UI - unable to log onto system	Contacted Volpe	Volpe reset system, corrected problem
35	27-Oct-10	Volpe system has a bug that causes the system to crash if TT1 send empty data in optional tags or sends DOT number that is not on file with Volpe	TT1 decided to stop testing until Volpe deploys their next build that should fix the bugs on 29Oct10	Volpe's new build to rollout on 29Oct10
36	3-Nov-10	Delay of ~4.5 hours in getting answer to TT1 questions (messages being flagged for invalid drivers; Volpe provided TT1 a set of valid drivers/cdls for each partners)	Only a fews days left in the Pilot Test, time is of the essence	None (documentation only)
37	3-Nov-10	WRI team notified of TT2's official entry into ready to start in pilot test	SDMs submitted by TT2 beginning 15Oct may be used in the evaluation (note: revision from earlier "start date" due to TT2 back-office problems on 14 Oct)	None
38	4-Nov-10	TT1 still having trouble providing the 7 days of logs required; Temporarily suspending efforts for several days due to pressing funded projects	Additional delay (expect to resume efforts 15Nov10)	Notified Volpe of timeline
39	2-Dec-10	TT3 is having trouble with geopoint coding and subsequent sending of SDM to Volpe	Issue has existed since 24Nov10. At that point, TT3 thought they were done and ready for production	TT3 has begun to address the issue with Volpe (as of Dec 2); intervening time has been lost

WRI CMRS Pilot Test Log Sheet for Issues, Lessons Learned, and Events				
Item	**Date**	**Issue**	**Fallout**	**Action**
40	6-Dec-10	TT3 system still not posting SDMs to GBOS from vehicles	Window of participation closes 30Dec10	E-mail to contacts at TT3 and Volpe to ensure they are aware that system still not working
41	7-Dec-10	TT3 is not providing an encounter id within the ORNL/UTK assigned range	ORNL discussed the encounter ID issue with TT3	Contact at TT3 will provide the Encounter IDs in the SDM based on ORNL request.
42	7-Dec-10	TT3 is not using the station names provided by ORNL	ORNL discussed the Inspection Station naming issue with TT3. TT3 pointed out that they cannot separate the westbound from eastbound Inspection Station in Knox County at the present time due to the design of their system, so they will use just one station name in this case	TT3 will start using the official names for the WRI inspection stations. For the Knox County Inspection Stations, ORNL aked TT3 to use the name of the east bound IS. TT3 vehicles go by the Knox County eastbound station in the morning and by the westbound station in the afternoon so they can be differentiated by the timestamps
43	7-Dec-10	Some identifying information such as VIN and driver license number missing in SDMs from TT3.	ORNL discussed missing fields with TT3. The VIN is not in the SDM since this is not a piece of information that TT3 keeps in their DB. TT3 does not release PII either, so driver license number is not included in the SDM. This presents an issue for Volpe since it makes it virtually impossible to identify the driver.	None

WRI CMRS Pilot Test Log Sheet for Issues, Lessons Learned, and Events				
Item	**Date**	**Issue**	**Fallout**	**Action**
44	7-Dec-10	Log files have not yet been received from TT3	ORNL discussed the log files with TT3	Programmer at TT3 will generate a log file (per vehicle) with information that includes Encounter ID, time stamp, name of the geofence, and event identifier.
45	30-Dec-10	Volpe Server Down (8:30 AM). Trying to access the WRI website and when the “Safety Data Message” button is pressed an error page (HTTP Status 500) is displayed.	At 8:50 I pressed the Inspections button, then an Encounter ID (50044644) which took me to the summary page, and from there I was able to access the "Safety Data Message" page	Notified Volpe via email.
46	30-Dec-10	At 1:45 PM and still Encounter ID 50044644 (received from TT3 at 6:19 AM) is the last message displayed by Volpe. By this time, many of the TT3 vehicles should have come back and new messages displayed. This may imply a Volpe problem.		Spoke to Volpe where someone was going to check on this. At 2:20 PM the system seemed to be working since two new messages from TT3 vehicles were displayed.
47	11-Jan-11	Issues with HOS data being submitted by TT3 (status codes, mileage, etc. inconsistent)	Requested that TT3 made corrections to the HOS information being distributed in their SDMs	On Jan 18th TT3 notified ORNL that the changes/corrections were made; however, the issue was not corrected. ORNL contacted TT3 in this regard again.

WRI CMRS Pilot Test Log Sheet for Issues, Lessons Learned, and Events				
Item	**Date**	**Issue**	**Fallout**	**Action**
48	18-Jan-11	During the TT2 tests it was observed that the Volpe system froze when several users (ORNL and UTK) were viewing the WRI website and constantly refreshing the screen to determine the time when the SDM arrived at the Volpe BOS.	GBOS unavailable for a period of testing	ORNL/UTK notified Volpe and the system was rebooted.
49	19-Jan-11	Many messages from TT3 appear corresponding to the same WRI Geofence because of a programming issue. TT3 indicated that every time the device is powered on or off, or every time the driver sends a message, or every 15 minutes the device reports its position to the TT3 BOS. If the device is inside a WRI Geofence, then a message is sent to Volpe through the TT3 BOS.	Implementation not consistent with WRI concept (generation of SDM at time geofence encountered)	On Jan 19th ORNL tried to reproduce these triggers with no success.
50	19-Jan-11	During the tests at a TT3 fleet's domicile, it was observed by ORNL that the SDMs that were triggered did not appear on the Volpe website unless a "manual refresh" was performed.	This situation continued until the end of the project.	ORNL requested that Volpe performed periodic "manual refresh" of the WRI website while ORNL was conducting the tests on the 19th and on the 21st of January.
51	20-Jan-11	TT3 SDMs had incorrect information related to timestamps	Changes implemented too late to be tested	ORNL requested TT3 correct these issues; TT3 notified ORNL on Jan 31 that these changes had been implemented.

WRI CMRS Pilot Test Log Sheet for Issues, Lessons Learned, and Events				
Item	**Date**	**Issue**	**Fallout**	**Action**
52	20-Jan-11	TT3 data not being processed due to missing identifiers	Changes implemented too late to be tested	ORNL (in coordination with Volpe) provided TT3 synthetic information regarding drivers and requested they include this information in the SDMs (since TT3 does not disclose PII); TT3 notified ORNL on Jan 31 that these changes had been implemented.

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