



**Connected  
Vehicles for  
Safety, Mobility,  
and User Fee  
Implementation**

**Operations  
Summary  
Report for the  
Minnesota Road  
Fee Test Project**

**February 2013**



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**Connected Vehicle for Safety, Mobility and User Fee Implementation  
Minnesota Road Fee Test Operations Report**

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16. Abstract (Limit: 250 words)  In 2007 Minnesota legislature approved a 5,000,000 project in order to demonstrate technologies which will allow for the future replacement of the gas tax with a fuel-neutral mileage charge. The Minnesota Department of Transportation (MnDOT) organized a study to examine the implementation and operation of a mileage based user fee program (MBUF), which might allow for the supplementation or replacement of traditional gas taxes. The primary objectives of the study were to: assess the feasibility of using consumer devices for implementing Connected Vehicle and MBUF applications. These applications included localized in-vehicle signing for improving safety, especially for rural areas, and the demonstration of the proposed Connected Vehicle approach for providing location-specific traveler information and collecting vehicle probe data. The study consisted of 500 voluntary participants, equipped with an in-vehicle system comprised of entirely commercially available components, primarily a smartphone using an application capable of tracking participant vehicle trips. Successfully meeting its primary objectives, the system was capable of assigning variable mileage fees determined by user location or time of day, as well as presenting in-vehicle safety notifications which had measureable effect on the participants driving habits. MnDOT contracted the company Battelle to develop and field the systems in this study. This document is the final report from Battelle, providing details for the development of the project systems, as well as the organization and operation of the participant study.			
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## EXECUTIVE SUMMARY

The Minnesota DOT (MnDOT) was authorized through a state legislation bill in 2007 to spend “\$5,000,000 for a pilot project to demonstrate technologies that will allow for the future replacement of the gas tax with a fuel-neutral mileage charge.” MnDOT subsequently initiated a two phased research program in response to this legislation.

In Phase I, MnDOT identified applications that would best meet their safety, mobility and funding goals including an in-vehicle signage application (Signage), a Mileage Based User Fee (MBUF) application, and a Cooperative Intersection Collision Avoidance – Stop Sign Assist application. Phase I of this demonstration produced a preliminary Concept of Operations (ConOps) a set of stakeholder requirements, and a Phase II Implementation Scope of Work. Phase II of the program was initiated in 2010 to conduct a demonstration of the technologies and applications in a real-world setting with the following objectives:

1. Assess the feasibility of using consumer devices for implementing Connected Vehicle and MBUF applications.
2. Evaluate the effectiveness of in-vehicle signing for improving safety using localized applications.
3. Determine if the in-vehicle signing approach being developed could be used to implement additional Connected Vehicle applications.
4. Assess if a mobile application could be used to implement mileage-based user fees.
5. Assess the viability of non-network Connected Vehicle safety applications, especially for rural deployments.
6. Demonstrate the proposed Connected Vehicle approach for providing location-specific traveler information and collecting vehicle probe data.

Phase II of the project included not only the design, development, and deployment of the technologies and applications, but also an extensive evaluation and qualitative assessment of the salient issues related to mileage-based user fees and the use of the technologies. Battelle was awarded the operations contract while SAIC provided evaluation support. Mixon-Hill served as technical advisors to MnDOT while others such as URS and Pierce Pini & Associates provided operational support for the project as part of the Battelle team.

The operations portion of the project was conducted using a rigorous system engineering and software development process that included an extensive requirement development, system design, development, testing, and then deployment. Throughout this process, an evaluation of various commercial off-the-shelf technologies was performed and compared to the requirements. Ultimately, it was determined that a Smartphone<sup>1</sup> based solution was the in-vehicle technology platform for the applications while a cloud-based solution was the best option for hosting the data warehouse and processing. A Samsung Captivate™<sup>2</sup> Smartphone was the Smartphone

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<sup>1</sup> The term smartphone is used throughout the document as a general term to refer to the off-the-shelf technology selected for this study. The term Aftermarket Navigation Device may also be used in this document when referencing legacy documentation.

<sup>2</sup> Galaxy S series

employed for the in-vehicle equipment and the Microsoft Azure cloud was utilized as the data warehouse.

Three waves of participants were recruited and participated in the study over the course of a year. Across the three waves, 500 participants were included in the study with each participant being required to install and operate their vehicle for a six-month duration with the technology. Odometer readings were manually recorded from each participant's vehicle prior to equipment installation, after two months of operation, and immediately following the removal of the equipment.

Participants did receive compensation for participation in the study through several different mechanisms based upon their involvement with the evaluation activities. Although active, no alerts or mileage-based user fees were assigned or assessed during the first two months of the field experience. Based upon their mileage during these two months, however, each participant was classified into a "High-Mileage" or a "Low-Mileage" group and received an initial check to offset the MBUF that would be collected during the remaining four months of the study. Additional functionality was then activated and participants began to receive in-vehicle signage and began to accrue miles that were subsequently invoiced to them on a monthly basis for payment. The payment process was completed by participants using PayPal, check, cash, or by credit card.

There are several significant findings associated with the operational components of the test:

1. A Smartphone is a reasonable and viable platform for MBUF as well as other Connected Vehicle applications such as in-vehicle signage.
2. The quality of GPS signal is variable from phone-to-phone and is dependent upon placement of the device.
3. There will be issues with Smartphone operating systems that make the ability to audit/post-process data critical and vital.
4. There is room for continued field support optimization.
5. Use of a vehicle power-port (voltage) for trip start/stop is not reliable.
6. Statewide deployment would require provisions for providing significant help support.

Ultimately, this project was successful in achieving the objectives of the Phase II portion of the MnDOT MBUF program despite many challenges to the deployment. One significant challenge was the temporary stop work on the project in the midst of the deployment as a result of the 2011 Minnesota State government budget crisis. Other challenges included overcoming the relative "newness" of Smartphones for study participants, which became significantly easier in later waves, as well as creating and implementing a design that guaranteed participant privacy but still protected the ability of a participant to audit and dispute the assessed fee.

## 1.0 INTRODUCTION

MnDOT has been developing an integrated strategy related to Connected Vehicles for several years and is a leader among state DOT's in pursuing Connected Vehicle related technologies and demonstrations, including those associated with mileage-based user fees (MBUF). In addition to the state DOT's efforts for moving forward with the concept of vehicle to infrastructure (V2I) local agencies in Minnesota have also initiated activities related to measuring vehicle miles traveled by Hennepin County residents.

Certainly, the USDOT has promoted a vision for Connected Vehicle applications that until very recently relied upon the extensive use of road-side equipment (RSE) with Dedicated Short Range Communications 5.9 GHz (DSRC) being the primary communications platform for vehicle to vehicle (V2V) as well as V2I communication. The California Path project extended this concept to demonstrate the ability to utilize cellular telephones as vehicle probes.<sup>3</sup> Projects in Oregon and Iowa have been conducted to develop devices for measuring vehicle miles traveled with the ultimate goal of using this information to establish mileage-based user fees (MBUFs). This project differed significantly from all previous MBUF and Connected Vehicle projects conducted prior to 2010 in that it did not rely upon prototype equipment or equipment that was developed specifically for the project, but rather, relied extensively on commercial off-the-shelf (COTS) hardware. Subsequent to the deployment of this study, and in no small part due to the success observed in Minnesota, additional Connected Vehicle applications and safety software leveraging Smartphones and other mobile platforms have been initiated.

One of the underlying goals of this project was to demonstrate that MBUF applications can be linked to Connected Vehicle components and successfully utilized for both purposes. This was important because the synergy between these two systems may provide the "spark" that is needed to launch wide scale adoption of both systems. DOT agencies could recognize the benefits of collecting probe data in real-time as well as the ability to improve safety and manage congestion through MBUF applications. At the same time, travelers could realize benefits related to traveler information, safety, as well as discounted usage fees for selecting alternative (non-congested) routes.

### 1.1 Demonstration Objectives

Phase II of the program was initiated in 2010 to conduct a demonstration of the technologies and applications in a real-world setting with the following objectives:

1. Assess the feasibility of using consumer devices for implementing Connected Vehicle and MBUF applications.
2. Evaluate the effectiveness of in-vehicle signing for improving safety using localized applications.
3. Determine if the in-vehicle signing approach being developed could be used to implement additional Connected Vehicle applications.
4. Assess if a mobile application could be used to implement mileage-based user fees.

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<sup>3</sup> The term probe is also referred to as travel trip data outside the context of this report.

5. Assess the viability of a non-network Connected Vehicle safety application, especially for rural deployments.
6. Demonstrate the proposed Connected Vehicle approach for providing location-specific traveler information and collecting vehicle probe data.

However, it is important to note that in addition to the explicit objectives of the study, there were a host of inherent objectives of the project, all of which had to be met for the demonstration to be successful. These objectives included:

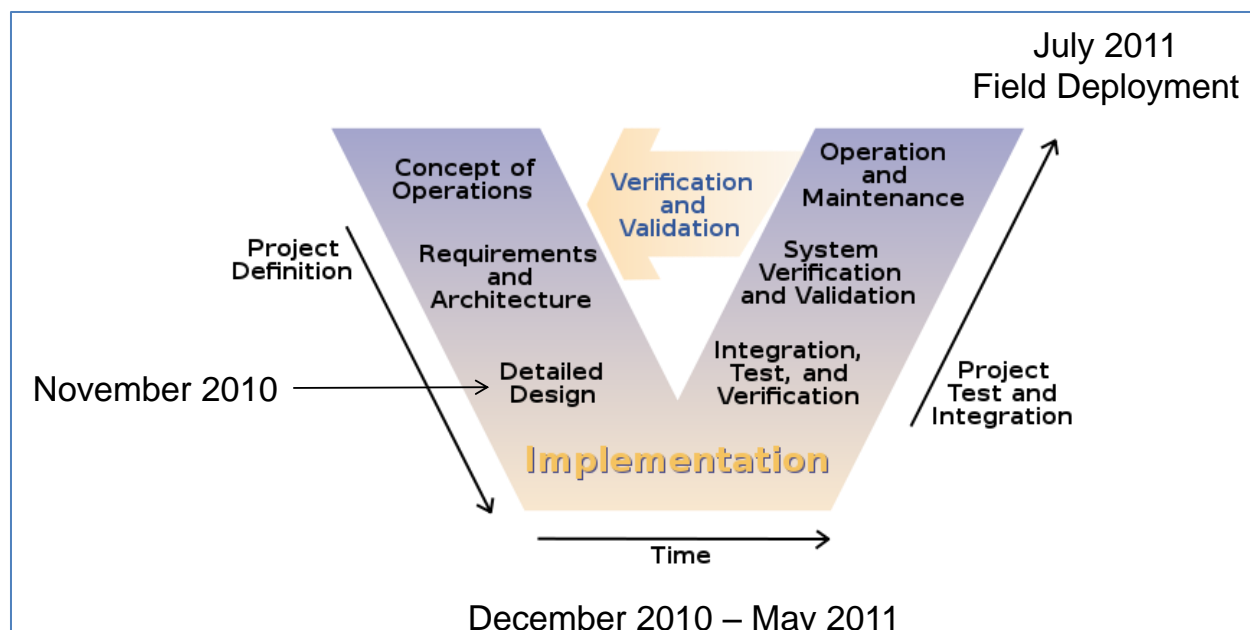
1. Utilization of a commercially available system (e.g., readily available to the traveling public).
2. The system must be simple to install and operate.
3. Users of the system must be able to readily recognize benefits of the technology (e.g., it has to provide relevant, accurate, and timely information).
4. The developed systems must be economically viable for future operation and maintenance (e.g., do not require MnDOT to provide continued maintenance and development).

Although the demonstration had a decidedly focused effort regarding the feasibility of the in-vehicle technologies as well as the data processing and payment mechanisms, a significant additional focus of the demonstration was to understand the public's willingness, acceptance, and usage of technology to record vehicle miles traveled as well as having faith and trust in a Smartphone/cloud-based data system for accurate and consistent collection of fees. This report focuses most heavily on the technology and deployment aspects of the demonstration while the public acceptance, use, and opinions on the technology are discussed in the evaluation report prepared by the Evaluation Contractor.

## **1.2 Organization of Operational Support for the Minnesota Road Fee Test**

The operational components of the demonstration project were conducted using a system development and design process that is summarized in Figure 1. This process included an in-depth requirements development and refinement process, a formal architecture and design process, software development and prototyping, and extensive testing prior to deployment of any software and hardware to the participants. Battelle led the operations team but received significant support with requirements development and testing from URS and operational and field support from Pierce Pini & Associates.

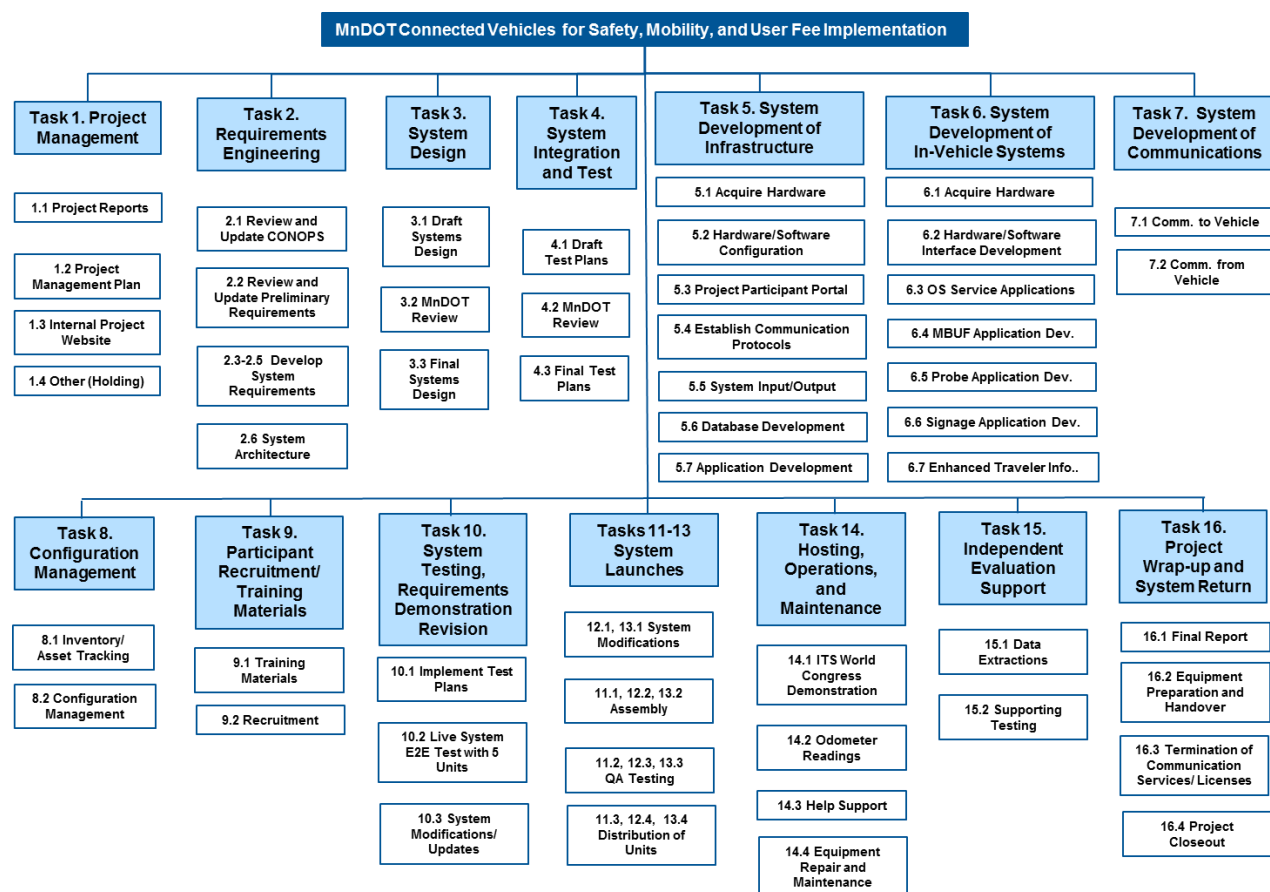




**Figure 1. System Design and Development Process**

The development, design, and deployment of the technologies were divided into a series of sixteen tasks as illustrated in Figure 2. Management of the operational side of the project was accomplished using a time-phased schedule with weekly progress reporting meetings between the Operational Team (Battelle, URS, Pierce Pini & Associates), the Evaluation Team (SAIC), and MnDOT.

# Connected Vehicle for Safety, Mobility and User Fee Implementation Minnesota Road Fee Test Operations Report



**Figure 2. Work Breakdown Structure for the Connected Vehicle for Safety, Mobility, and User Fee Implementation (Minnesota Road Fee Test)**

## 1.3 Supporting Documentation

This document serves as an operational summary report for the Minnesota Road Fee Test and should not be deemed comprehensive in scope. The documentation listed in Table 1 provides a complete description of functional architecture, system design and operation, and field operations conducted during the demonstration. The aim of this report is to orient the reader to the overall demonstration activity while providing pertinent details when applicable.

**Table 1. Applicable System Design Documents**

Reference
Mn/DOT, IntelliDrive(SM) for Safety, Mobility and User Fee Implementation Concept of Operations Document, 635110B0020A, July 9, 2010
Mn/DOT, IntelliDrive(SM) for Safety, Mobility and User Fee Implementation Stakeholder Requirements Document, 635110B0030B, September 10, 2010
Mn/DOT, IntelliDrive(SM) for Safety, Mobility and User Fee Implementation System Requirements Document, 645110B0040C, January 6, 2011
Mn/DOT, IntelliDrive(SM) for Safety, Mobility and User Fee Implementation Computing Module Vendor Item Control Drawing, 635110B1011C, February 4, 2011
Mn/DOT, IntelliDrive(SM) for Safety, Mobility and User Fee Implementation Navigation Software Vendor Item Control Drawing, 635110B1001C, February 4, 2011
Mn/DOT, IntelliDrive(SM) for Safety, Mobility and User Fee Implementation Aftermarket Navigation Module Vehicle Mount Vendor Item Control Drawing, 635110B1050C, February 4, 2011
Mn/DOT, IntelliDrive(SM) for Safety, Mobility and User Fee Implementation Power Management Module Vendor Item Control Drawing, 635110B1020C, February 4, 2011
Mn/DOT, IntelliDrive(SM) for Safety, Mobility and User Fee Implementation Vehicle Identification Module Vendor Item Control Drawing, 635110B1040C, February 4, 2011
Mn/DOT, IntelliDrive(SM) for Safety, Mobility and User Fee Implementation OBU Computing Platform and API Vendor Item Control Drawing, 635110B1030C, February 4, 2011
Mn/DOT, IntelliDrive(SM) for Safety, Mobility and User Fee Implementation ISMUF Software Design Document, 635110B0101C, February 4, 2011
Mn/DOT, IntelliDrive(SM) for Safety, Mobility and User Fee Implementation Positioning Software Design Document, 635110B0104C, February 4, 2011
Mn/DOT, IntelliDrive(SM) for Safety, Mobility and User Fee Implementation Logging Software Design Document, 635110B0103C, February 4, 2011
Mn/DOT, IntelliDrive(SM) for Safety, Mobility and User Fee Implementation Vehicle Communications Software Design Document, 635110B0108C, February 4, 2011
Mn/DOT, IntelliDrive(SM) for Safety, Mobility and User Fee Implementation Probe Data Collection Software Design Document, 635110B0107C, February 4, 2011
Mn/DOT, IntelliDrive(SM) for Safety, Mobility and User Fee Implementation Signage Software Design Document, 635110B0105C, February 4, 2011
Mn/DOT, IntelliDrive(SM) for Safety, Mobility and User Fee Implementation MBUF Collection Software Design Document, 635110B0106C, February 4, 2011
Mn/DOT, IntelliDrive(SM) for Safety, Mobility and User Fee Implementation CICAS-SSA Data Processing Software Design Document, 635110B0100B, February 4, 2011
Mn/DOT, IntelliDrive(SM) for Safety, Mobility and User Fee Implementation ISMUF Windows Azure Project Software Design Document, 635110B0201B, February 4, 2011

**Table 1. Applicable System Design Documents (Continued)**

Reference
Mn/DOT, IntelliDrive(SM) for Safety, Mobility and User Fee Implementation Vehicle Communication Web Role Software Design Document, 635110B0210C, February 4, 2011
Mn/DOT, IntelliDrive(SM) for Safety, Mobility and User Fee Implementation Participant Portal Web Role Software Design Document, 635110B0211C, February 4, 2011
Mn/DOT, IntelliDrive(SM) for Safety, Mobility and User Fee Implementation Admin Portal Web Role Software Design Document, 635110B0212C, February 4, 2011
Mn/DOT, IntelliDrive(SM) for Safety, Mobility and User Fee Implementation Data Repository Database Software Design Document, 635110B0230C, February 4, 2011
Mn/DOT, IntelliDrive(SM) for Safety, Mobility and User Fee Implementation Probe and Log Database Software Design Document, 635110B0231C, February 4, 2011
Mn/DOT, IntelliDrive(SM) for Safety, Mobility and User Fee Implementation Storage Account Software Design Document, 635110B0200C, February 4, 2011
Mn/DOT, IntelliDrive(SM) for Safety, Mobility and User Fee Implementation Vehicle Payload Processing Worker Role Software Design Document, 635110B0220C, February 4, 2011
Mn/DOT, IntelliDrive(SM) for Safety, Mobility and User Fee Implementation Report Generation Web Role Software Design Document, 635110B0223C, February 4, 2011
Mn/DOT, IntelliDrive(SM) for Safety, Mobility and User Fee Implementation Business Logic Library Software Design Document, 635110B0213C, February 4, 2011
Mn/DOT, IntelliDrive(SM) for Safety, Mobility and User Fee Implementation Message Set Dictionary, 635110B0070C, February 4, 2011



## 2.0 FUNCTIONAL ARCHITECTURE

The Connected Vehicle for Safety, Mobility and User Fee (CVSMUF) project work was divided into two phases. Phase I, which was already completed prior to award of this contract, consisted of tasks necessary to identify where deployment would take place, why the deployed system was necessary, what the proposed system would do, when the system should be deployed, and how the system should work. The Preliminary System Requirements Document developed in Phase I provided the basis for MnDOT's decision to proceed with Phase II.

A Stakeholder Requirements document was developed during Phase II that expanded on the Phase I Preliminary Requirements document by adding requirements collected during stakeholder meetings, and focused on the Stakeholder requirements for the proposed system.

The System Requirements document expanded upon the Stakeholder Requirements document by outlining the functions the system of interest had to perform to meet the documented stakeholder needs, and provided requirements that are unambiguous, measurable, achievable and verifiable. The System Requirements document established the requirements for a Connected Vehicle system that would meet the documented stakeholder needs by addressing State user fee collection. Although these capabilities might apply to a wide range of vehicle classifications, the initial demonstration was limited to passenger cars, SUVs, pickups, and vans. Core applications of the Connected Vehicle system covered by the requirements document included:

- Mileage-Based User Fee (MBUF) that accumulates miles driven in specific zones and reports this information to a back office system that assesses fees based on established criteria.
- Vehicle probe data provided from the vehicle to a back office system.
- Location-specific traveler information provided to the driver with current traffic information.
- In-vehicle signage that provides safety alerts to the driver, received from remote back office system(s).

The following subsections provide an overview of the System Requirements document for the Connected Vehicle for Safety, Mobility and User Fee Implementation project. For more information, please reference the MnDOT IntelliDrive<sup>SM</sup> for Safety, Mobility and User Fee Implementation System Requirements Document, 635110B0040C.

## 2.1 Functional Model

The CVSMUF system had many goals. The system of interest had to implement three separate applications to meet the needs of the stakeholders. As such, the requirements were organized into a functional model to facilitate readability and development. This functional model described the system of interest as a set of conceptual subsystems that created ‘bins’ to frame the system functions so that they could describe the intent of the system. The functional model in Figure 3 established the two main conceptual subsystems for the CVSMUF system.

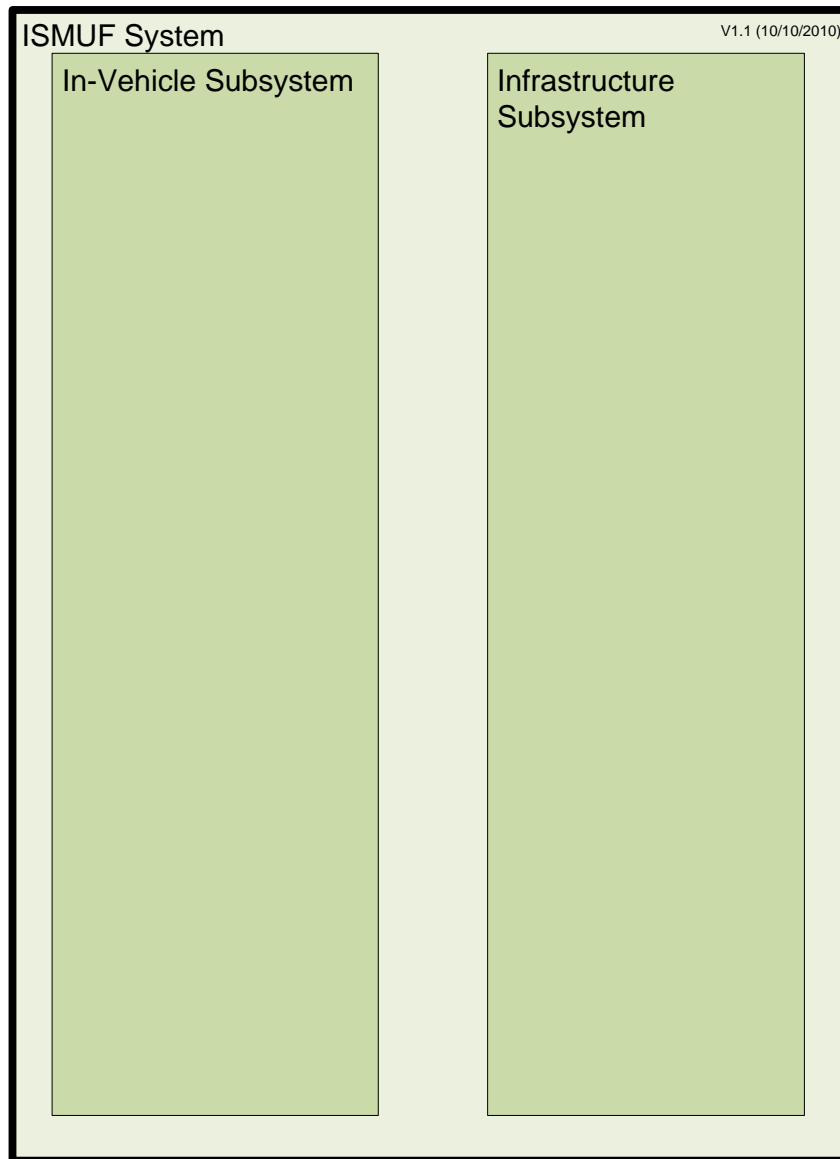


Figure 3. CVSMUF System Diagram<sup>4</sup>

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<sup>4</sup> In some Figures or Tables the use of “ISMUF” is used in place of “CVSMUF.” The “ISMUF” term refers to the original project name, IntelliDrive<sup>SM</sup> for Safety, Mobility, and User Fees. Both terms should be considered synonymous.

## **2.2 Conceptual Subsystems**

The conceptual subsystems contained related functions needed for the system to meet its functional goals.

### **2.2.1 In-Vehicle Subsystem**

The In-Vehicle subsystem of the CVSMUF system was constrained to use an aftermarket navigation device enhanced to provide to the participant real-time MBUF information, as well as enhanced safety features and vehicle specific traveler information. Ultimately a Smartphone was chosen to implement this system element. In addition, this device had to provide important traffic probe data to the infrastructure to allow better monitoring of traffic conditions and route planning. A participant had to be able to configure the CVSMUF application options through the device. The in-vehicle subsystem had to work with the infrastructure subsystem to automatically obtain updates without participant intervention.

### **2.2.2 Infrastructure Subsystem**

The Infrastructure subsystem managed the overall CVSMUF system. It registered and communicated with all operating instances of the In-Vehicle subsystem. It stored all data collected from In-Vehicle subsystem instances, enabled participant inquiries of usage patterns and routes, and supported management of the participants' CVSMUF Portal and electronic payment accounts and provided access to system data for reporting purposes. The Infrastructure subsystem also collected, logged, and coordinated configuration updates for all instances of the In-Vehicle subsystem.

## 2.3 System Internal Interfaces

To coordinate activities and to reach the end goal of the overall CVSMUF system, the identified conceptual subsystems were required to have interfaces with each other to carry out the functions required to fulfill the system goals. The interfaces described here are logical in nature, as multiple data items might use a given interface. Interfaces took into account constraints placed on the design by the stakeholders. Figure 4 illustrates the CVSMUF system with internal interfaces.

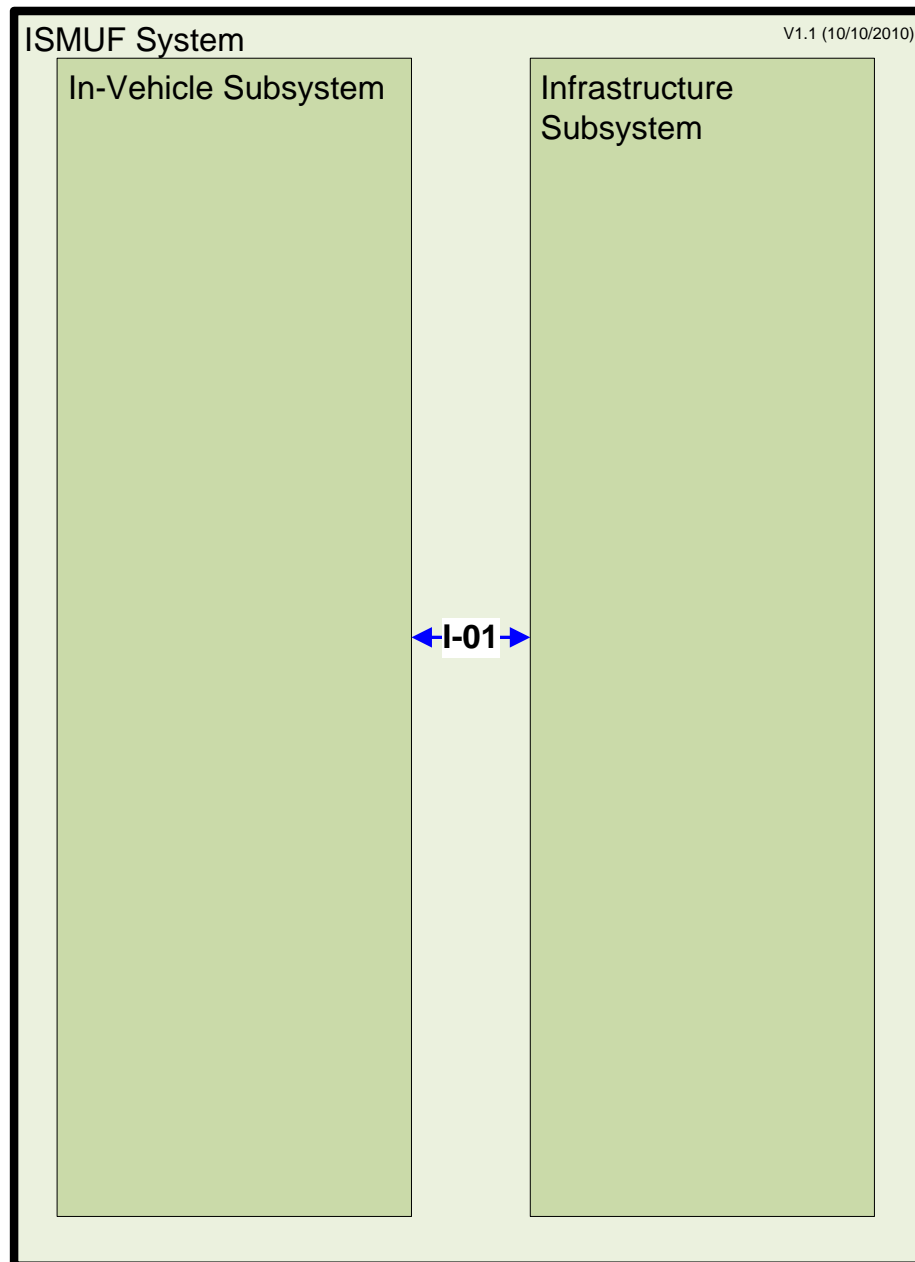


Figure 4. CVSMUF System Diagram with Internal Interfaces

### **2.3.1 I-01 – In-Vehicle Subsystem to Infrastructure Subsystem Interface**

Interface I-01 carried data between the two major subsystems within the CVSMUF system. Mileage driven on roadway segments collected within the In-Vehicle subsystem and safety and configuration data provided by the Infrastructure system were delivered using this interface.

## **2.4 System External Interfaces**

The CVSMUF system relied upon several external enabling systems to perform its intended purpose. It required hosting within and power from a participant vehicle. It required positioning services from the Global Positioning System (GPS) and traffic information from a commercial traffic provider. The CVSMUF system had to communicate with the Cooperative Intersection Collision Avoidance System – Stop Sign Assist (CICAS-SSA) system for assisting vehicles through dangerous intersections. Additionally, participants had to be able to interface with the system to make use of it, including having the ability to process e-payments. Finally, interfaces had to be established to monitor and control the system, and extract data from the system for evaluation purposes. Figure 5 illustrates the CVSMUF system with both the internal and external interfaces.

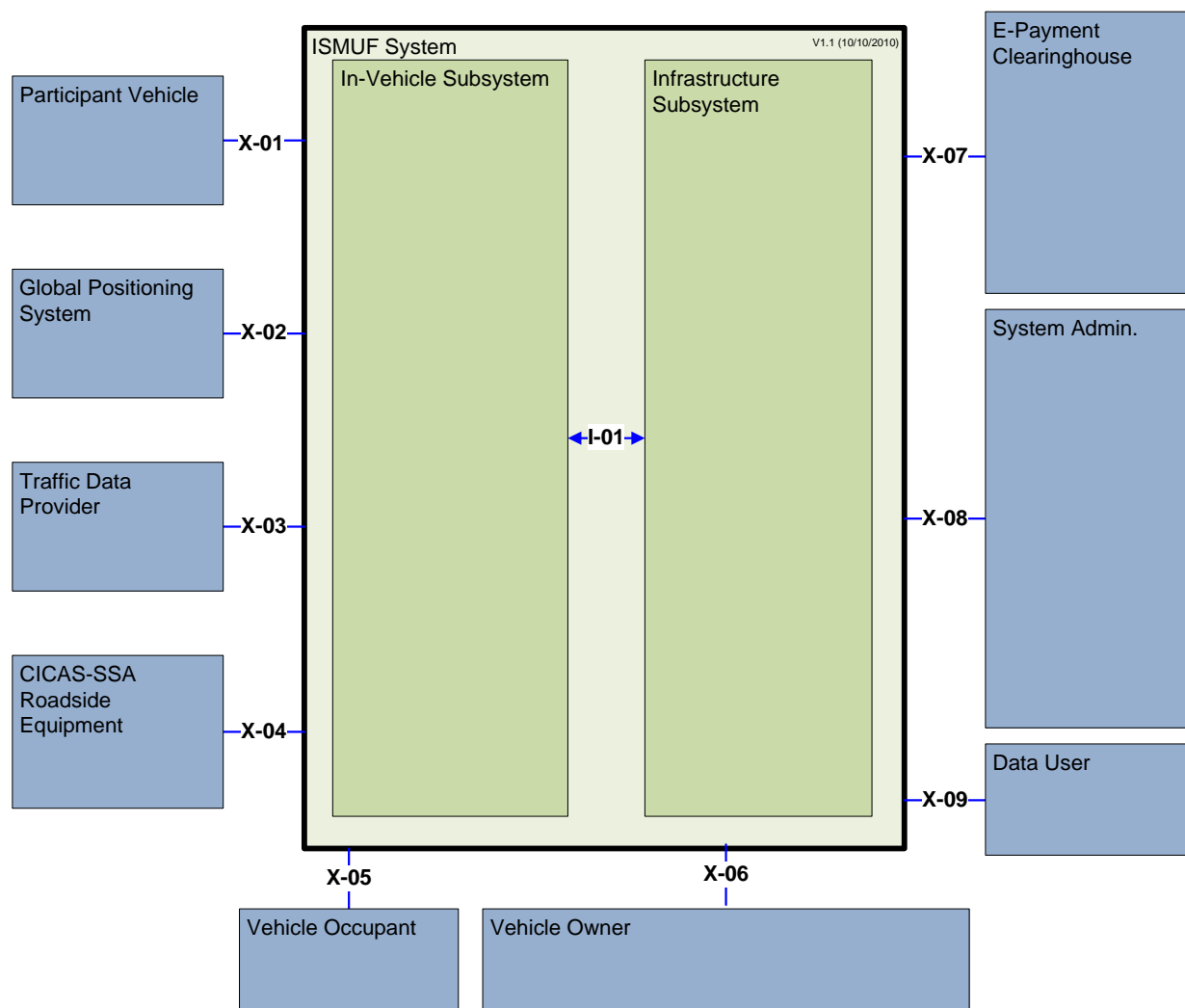


Figure 5. CVSMUF System Diagram with Internal and External Interfaces

#### **2.4.1 X-01 – CVSMUF System to Participant Vehicle Interface**

Interface X-01 provided the necessary 12 Volt DC power to the In-Vehicle subsystem via the vehicle's internal power bus. This interface also ensured that excessive battery drain did not occur by managing the current draw of devices in the non-operational state.

#### **2.4.2 X-02 – CVSMUF System to Global Positioning System Interface**

Interface X-02 provided vehicle position and current time information to the In-Vehicle subsystem via the terrestrial Navstar GPS segment. These two key data components were required to support all of the planned applications, including signage, probe data and mileage-based user fees.

#### **2.4.3 X-03 – CVSMUF System to Traffic Data Provider System Interface**

Interface X-03 provided traffic-related data to the In-Vehicle subsystem via the native capability of the Smartphone. This was to support the desire for route-specific real-time traffic conditions being made available to the driver as described in Section 3.1.2.

#### **2.4.4 X-04 – CVSMUF System to CICAS-SSA Roadside Equipment Interface**

Interface X-04 provided a 5.9 GHz Dedicated Short-Range Communication (DSRC) channel, compliant with the present USDOT Connected Vehicle initiatives, between the In-Vehicle subsystem and existing roadside equipment. DSRC was necessary to meet the performance requirements associated with implementing the Cooperative Intersection Collision Avoidance Systems (CICAS) application.

#### **2.4.5 X-05 – CVSMUF System to Vehicle Occupant Interface**

Interface X-05 provided the human-system interface between the CVSMUF participant and the In-Vehicle subsystem. This interface provided both the standard interface functionality within the Smartphone, as well as the enhanced user interface for the CVSMUF applications.

##### ***2.4.5.1 X-05 Display to Vehicle Occupant***

The visual component of the in-vehicle display associated with Interface X-05 allowed for the dynamic display of CICAS Warnings, current MBUF rates, and other prescribed signage events, in addition to the default behavior of the subsystem's navigation features.

##### ***2.4.5.2 X-05 Audible to Vehicle Occupant***

The audible component of the in-vehicle subsystem provided a notification mechanism to the driver in the case of critical system notifications related to the CICAS, MBUF and signage applications, in addition to the default behavior provided by the navigation software.

#### **2.4.6 X-05 Control by Vehicle Occupant**

The control component of the in-vehicle subsystem supported the participant's ability to enable/disable the various applications, including MBUF Data Collection, Probe Data Collection, and In-Vehicle Signage, as well as to configure certain display parameters.

#### **2.4.7 X-06 – CVSMUF System to Vehicle Owner Interface**

Interface X-06 provided access to a third-party, online, electronic payment system to enable participants or someone acting on behalf of the participant to add funds to a participant account, check account balances, or manage user information such as passwords, contact information, and others. This same interface also supported the ability of the participant to receive credits or funds from other entities associated with this demonstration program.

#### **2.4.8 X-07 – CVSMUF System to E-Payment Clearinghouse Interface**

Interface X-07 supported the interface to an online electronic payment system, to enable the system to invoice participants for accumulated mileage fees.

#### **2.4.9 X-08 – CVSMUF System to System Administration Interface**

Interface X-08 provided the access to a system administrator as necessary to perform the various administrative tasks associated with establishing, monitoring, controlling, and maintaining participant accounts and related application settings and data.

#### **2.4.10 X-09 – CVSMUF System to Data User Interface**

Interface X-09 enabled an authorized user to view data and reports provided by the system.



## 2.5 System Performance Characteristics

System Performance Characteristics were used to define the characteristics, both functionally and physically, that the system had to exhibit to satisfy its intended purpose. As noted previously, these performance characteristics were organized by the In-Vehicle and the Infrastructure subsystems respectively, and were further broken down into functional and physical groupings (as applicable) within these areas. Figure 6 illustrates the CVSMUF system functions in the context of the system diagram.

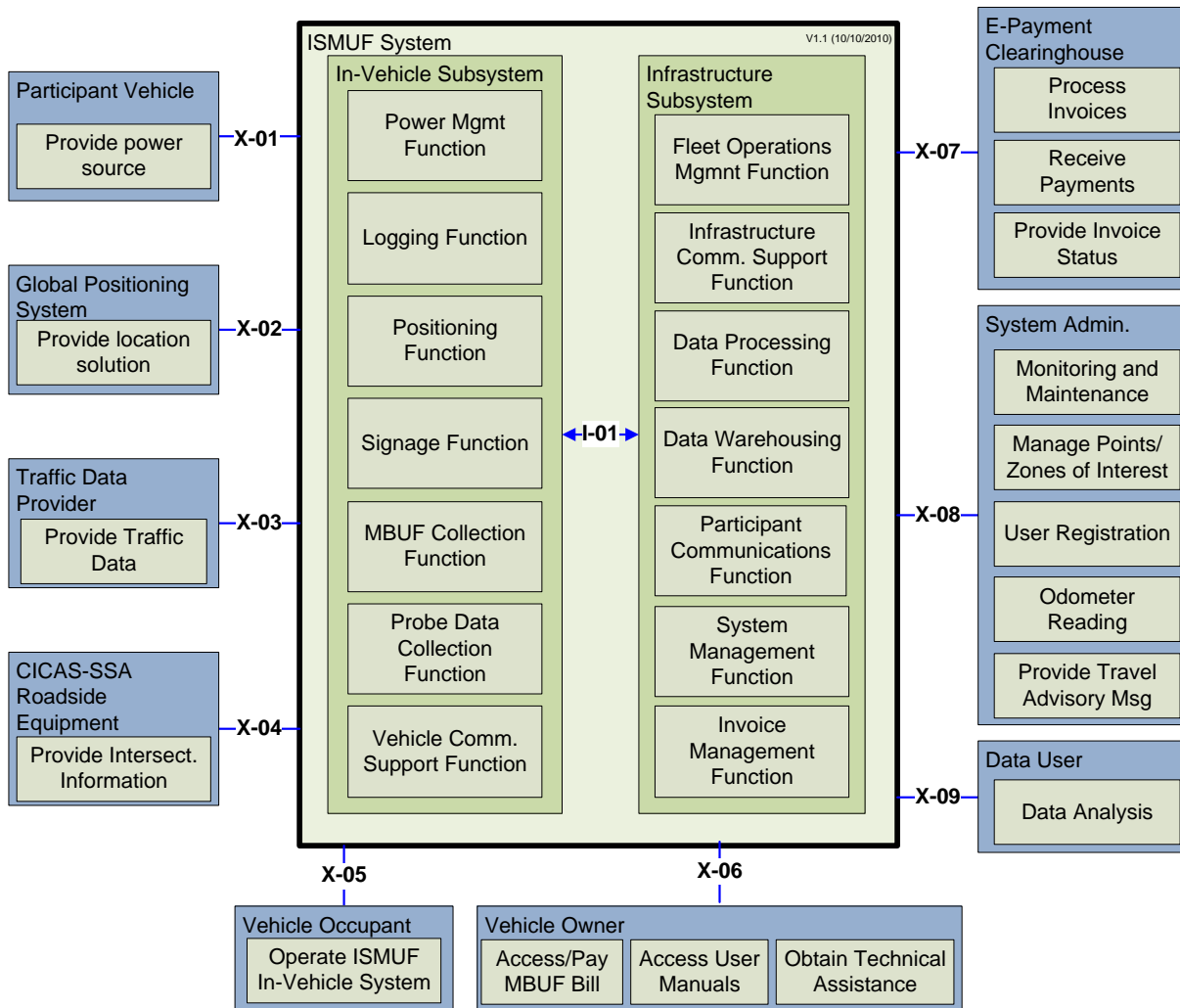


Figure 6. CVSMUF System Diagram with Functions

## **2.5.1 In-Vehicle Functional Characteristics**

These characteristics included the core positioning, logging, and communications capabilities, coupled with the probe, signage, and MBUF applications, which all utilized the core capabilities (or functions).

### **2.5.1.1 Power Management Function**

The Power Management function was responsible for logging all activities associated with the startup and shutdown of the In-Vehicle subsystem.

### **2.5.1.2 Logging Function**

The Logging function, located within the In-Vehicle subsystem, was responsible for logging all activities that were log-enabled regardless of whether user invoked or system invoked. This logging included at a minimum, timestamp, location, functional systems responsible for the log entry, and the appropriate log message. This log information was retained locally onboard the In-Vehicle subsystem until it was successfully transmitted to the Infrastructure subsystem.

### **2.5.1.3 Positioning Function**

The Positioning function located within the In-Vehicle subsystem was responsible for determining and/or calculating positioning and time information. It made available to other applications within the In-Vehicle subsystem, position-related information such as latitude, longitude, speed, heading, and time. This function was also responsible for logging to the In-Vehicle subsystem logging function, any occurrences when the state of the positioning information changes from available to unavailable, or vice-versa.

### **2.5.1.4 Signage Function**

The Signage function was responsible for maintaining a database of position-dependent signage zones and criteria (i.e. time of day, day of week); receiving position information from the Positioning Function, comparing this position info and criteria against the database, and responding accordingly by displaying/sounding the appropriate sign/message/alert. The types of zones may include speed, construction, school zone, and curve ahead. Additionally, the signage function was capable of displaying/sounding CICAS related alerts.

### **2.5.1.5 Mileage Based User Fee Collection Function**

The Mileage Based User Fee Collection function was responsible for maintaining a database of position-dependent pricing zones and criteria, receiving position information from the Positioning function, comparing this position info against the pricing zone criteria; updating the In-Vehicle subsystem display accordingly, and transmitting the logs in the form of an MBUF mileage report to the Infrastructure subsystem.

### **2.5.1.6 Probe Data Collection Function**

The Probe Data Collection function<sup>5</sup> was responsible for capturing position and heading-related information at regular programmable intervals, associating the information with a system- unique

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<sup>5</sup> Within the Connected Vehicle paradigm, “Probe Data” refers to the individual or collection of GPS location points associated with a vehicle movement or trip.

Trip ID, logging the activities, transmitting ‘packages’ of this position information to the infrastructure subsystem at regular intervals, and as necessary, buffering the information until a successful transmission occurred.

#### **2.5.1.7 Vehicle Communications Support Function**

The Vehicle Communications Support function was responsible for managing and logging all core communications between the In-Vehicle and Infrastructure subsystems. This included registering the In-Vehicle subsystem instance with the Infrastructure subsystem when the In-Vehicle subsystem instance came on-line, as well as ensuring that all In-Vehicle subsystem applications and databases were at the latest version, and if not, invoking an update process.

### **2.5.2 Infrastructure Functional Characteristics**

The Functional Characteristics of the Infrastructure included all of the applications it had to host, as well as the core capabilities it needed to have to satisfy the needs of the applications and managing the multiple in-vehicle subsystem instances. These characteristics included the core communications and data processing/storage capabilities required by all CVSMUF applications, coupled with account management, payment processing, analysis and reporting capabilities.

#### **2.5.2.1 Fleet Operations Management Function**

The Fleet Operations Management function serviced the needs of the In-Vehicle subsystem instances by tracking configurations, establishing signage zones, managing the MBUF scheme, processing probe data, and managing vehicle logs. Each of these areas is described in the subfunctions below.

##### **2.5.2.1.1 Fleet Configuration Tracking Function**

The Fleet Configuration Tracking function served to track the configuration version of each of the in-vehicle subsystem applications, to include both the application itself and any associated data, such as pricing or signage zones.

##### **2.5.2.1.2 Fleet Signage Management Function**

The Fleet Signage Management function provided the necessary capabilities for a system administrator to create, edit, or disable signage zones and their associated criteria (i.e. time of day, direction) for school, construction, speed and curve zones.

##### **2.5.2.1.3 Fleet MBUF Management Function**

The MBUF Management function provided the necessary capabilities for a system administrator to create, edit, or disable pricing zones and their associated criteria (i.e. time of day, vehicle direction, etc.) for various vehicle types and locations. The function also served to collect, parse and persist the MBUF mileage reports provided by each In-Vehicle subsystem instance.

##### **2.5.2.1.4 Fleet Probe Management Function**

The Fleet Probe Management function served to collect, parse and persist the probe information provided by each In-Vehicle subsystem instance.

#### **2.5.2.1.5 Fleet Log Management Function**

The Fleet Operations Log Management function served to receive, parse, and store all log entries from the in-vehicle subsystem instances associated with the specific vehicle instance.

#### **2.5.2.2 Infrastructure Communications Support Function**

The Infrastructure Communications Support Function served to notify the In-Vehicle subsystem of updates to any of the configurations or reference data sets (i.e. rates, zones, etc.). Similarly, the function could individually or broadly communicate administrative messages to the in-vehicle subsystem.

#### **2.5.2.3 Data Processing Function**

The Data Processing Function served to provide the calculations, analyses and queries necessary to support the reporting needs of the applications utilizing the reported in-vehicle position information, logs, and manual odometer readings. Additionally, maintenance and support services were also captured and reported. These reports included travel time, monthly MBUF and probe summaries, as well as export capabilities.

#### **2.5.2.4 Data Warehousing Function**

The Data Warehousing function stored copies of, and recorded in a transaction log, all events associated with all raw messages sent/received between the In-Vehicle subsystem and the Infrastructure subsystem, as well as records of all parsed and processed information from these messages. Additionally, this function stored copies of all system-generated reports, as well as retained copies of both the queries and query results for any ad-hoc information requests.

##### **2.5.2.4.1 Data Warehouse Management Function**

The Infrastructure subsystem's Data Warehouse Management function provided the features associated with administering and managing databases, including, access control, transaction logs and backups, archives, and modification tracking.

##### **2.5.2.4.2 Data Warehouse Performance**

The requirements associated with Data Warehouse Performance ensured that it was sufficiently scaled to support the needs of the CVSMUF demonstration over three overlapping waves and approximately 500 participants.

#### **2.5.2.5 Participant Communications Function**

The Participant Communications function provided for an online portal and underlying processes to allow a participant to, at a minimum, manage their online account information, including contact and billing information, view invoices and make payments for MBUF fees, enter support requests, or view trip information.

#### **2.5.2.6 System Management Function**

The System Management function provided for an online portal and underlying processes to allow a system administrator to add or delete participants, manage the equipment associated with each participant, record odometer readings, and process payments on behalf of the participant.

### 3.0 OVERVIEW OF SYSTEM DESIGN AND OPERATION

The CVSMUF system was centered on the use of a commercially available Smartphone (Samsung Captivate™), installed with the Android operating system, as the basic computing element with other support hardware as described below. The system enabled the collection of mileage-based user fees through the use of a custom software application. The Android operating system was further customized limiting functionality within the context of the study. For example, the Smartphone was configured so that it could not send or receive calls. The custom application was designed to collect and transmit mileage using GPS location information. This information was used to generate fees and provide anonymous diagnostic travel trip date (probe) for evaluation by the Evaluation Contractor. The system was installed inside a vehicle using existing off-the-shelf mounting hardware and used in-vehicle power to trigger the custom application and power the Smartphone. The system did not require user interaction before, during, or after operation.

Once collected, mileage was translated into a monthly billing based on an established fee structure. By design, participants were given the option to disable mileage collection at any time through system configuration options or simply by not using the in-vehicle equipment. In addition to collecting mileage, the Smartphone and custom application provided safety information to vehicle occupants in the form of on-screen signage alerts, audible speed warnings, and communication with the Collision Intersection Collision Avoidance System – Stop Sign Assist (CICAS-SSA) warning drivers of potential hazards.

The system was implemented in two major subsystems with their supporting network connections. The first subsystem was integrated within a participant's vehicle (In-Vehicle subsystem), and a second subsystem was implemented within a data center with network connectivity (Infrastructure subsystem). Figure 7 shows the high-level system design concept.

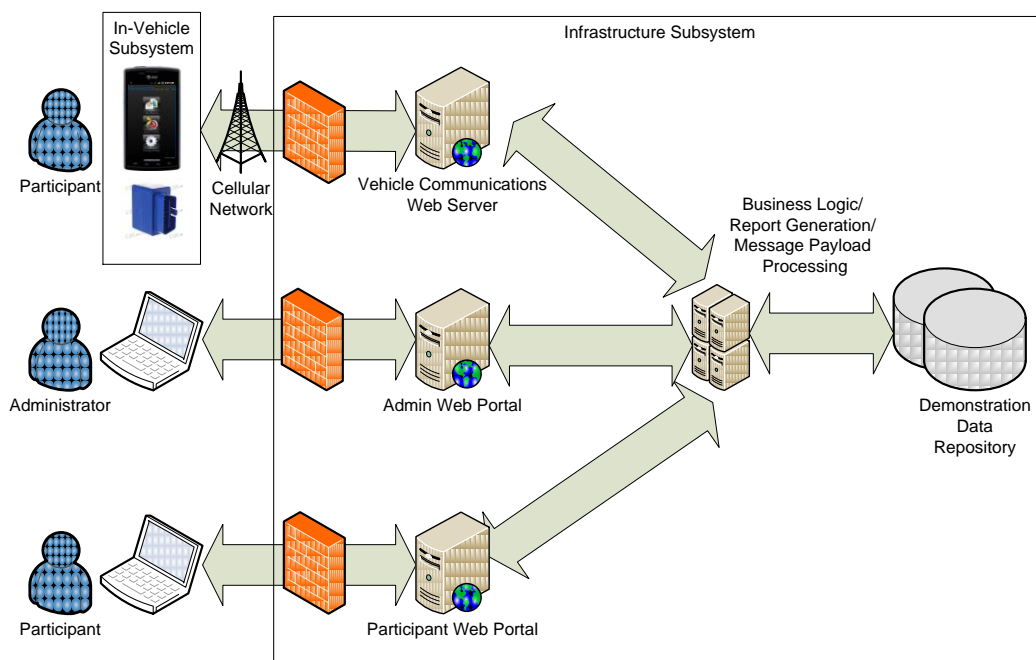


Figure 7. High Level System Design Concept

The following sections provide a high-level overview of system design and operation. For the purposes of this report the intent is not to include all pertinent details but rather orient the reader to the overall system design and operation. For more detail on system design and operation please refer to the appropriate design documentation as listed in Table 1 of this document.

### 3.1 In-Vehicle Subsystem

The In-Vehicle subsystem provided the main user interface for the CVSMUF system and collected all of the data that is processed by the system to determine the mileage-based user fee. It also provided the geo-location services, navigation functionality for use by the vehicle occupant and anonymous probe data to the infrastructure.

#### 3.1.1 Commercial Off-The-Shelf Hardware

The in-vehicle subsystem was assembled from several commercial off-the-shelf components centered on the use of a Samsung Captivate™ (Galaxy S Series) Smartphone shown in Figure 8. The hardware included the following list of off-the-shelf components described in more detail below.

- Smartphone (Samsung Captivate™ Galaxy S Series)
- Smartphone in-vehicle mount
- Power cables (Power Management Module)
- Vehicle Identification Module (VIDM)
- Dedicated Short Range Communications (DSRC) radio

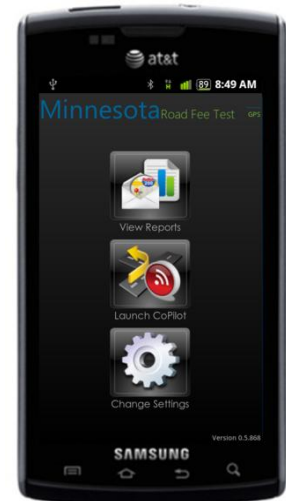


Figure 8. Smartphone

##### 3.1.1.1 Smartphone

The Smartphone, supported by a custom configured Android operating system, was the platform for the custom CVSMUF application and off-the-shelf navigation application. The Smartphone was at the center of the In-Vehicle subsystem receiving power from an in-vehicle power plug. Its purpose was to provide a platform for system applications, vehicle identification, and GPS location functionality. In particular, version 2.2 of the Android operating system provided four key services which were used by the custom CVSMUF application hosted by the phone. Those key services were:

- GPS location services
- Battery management services
- Local storage services
- Communication services (cellular and Bluetooth®)

##### 3.1.1.2 In-Vehicle Smartphone Mount

To present the computing module to the vehicle occupant in an easy to use and easy to reach fashion, a vehicle mounting solution was selected giving the participant the option to choose either a windshield mount or vent mount as shown in Figure 9. The windshield mount assembly consisted of a suction cup assembly and the vent mount consisted of a bracket with alligator clip assembly.



Figure 9. Main Vehicle Mount Assembly

### 3.1.1.3 Power Cables

The Power Management Module, an assembly of off-the-shelf power cables, managed the amount of current the Smartphone would draw from the vehicle depending on the state of the vehicle ignition. The vehicle ignition state was detected by the presence of a voltage fluctuation on the vehicle power bus located at either the cigarette lighter or auxiliary power port. When the vehicle was running, the voltage on the vehicle power bus was assumed to be higher than when the vehicle was not running, resulting in a drop in voltage when the engine was disengaged (and vice-versa when the engine was engaged). The Power Management Module detected these power fluctuations to manage the amount of power pulled by the Smartphone from the battery. Within 30 seconds of a voltage drop below a preset voltage limit, the power management module would shut off power to the Smartphone to prevent battery drain. Similarly, when the engine was engaged (i.e. vehicle turned on), power would be supplied to the Smartphone after the power bus voltage exceeded the voltage limit set for the Power Management Module.

The Power Management Module consisted of a four piece assembly provided by two separate vendors as shown in Figure 10. A male 12V vehicle auxiliary power connector at one end fed a small adapter box with a female 12V vehicle auxiliary power connector at the other end. A commercially-available Samsung vehicle charging cable was connected to the female connector and provided power to the Smartphone when the vehicle was running.

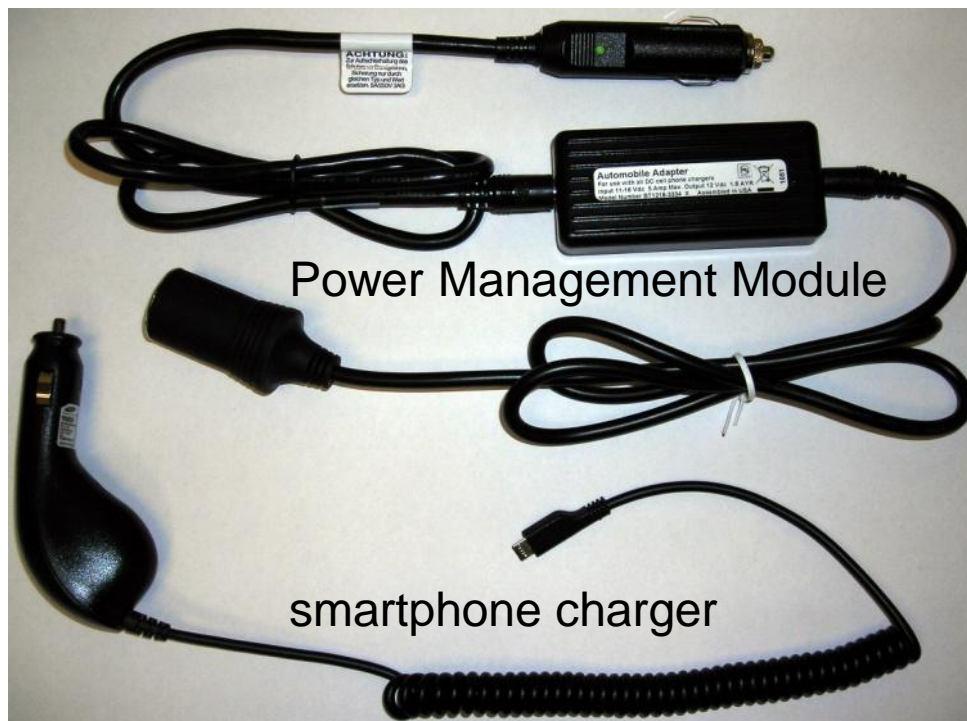


Figure 10. Power Management Module Assembly



#### **3.1.1.4 Vehicle Identification Module (VIDM)**

The purpose of the VIDM was to provide an indication that the Smartphone was being used in the vehicle assigned through the administrative portal. This indication was used to limit functionality of the system when the Smartphone was used in transport modes other than the assigned vehicle (e.g., walking, bicycling, motorcycling, different vehicle, etc.).

The VIDM was installed within a participant's vehicle without a physical connection to the Smartphone but instead provided a wireless Bluetooth "beacon" that was received by the Smartphone. The custom CVSMUF application would use this beacon to determine whether it was operating within the assigned vehicle. If the beacon from the VIDM was not in range, the custom CVSMUF application would limit functionality of the In-Vehicle subsystem. The VIDM deployed with the system is shown in Figure 11.



**Figure 11. VIDM Module**

#### **3.1.1.5 Dedicated Short Range Communications (DSRC) Radio**

Five In-Vehicle subsystems were equipped with an OBU (On-Board Unit) computing platform and API (Application Programming Interface) with a 5.9 GHz DSRC radio. This module communicated with the Cooperative Intersection Collision Avoidance System – Stop Sign Assist (CICAS-SSA) system at one intersection in the Minneapolis area<sup>6</sup> (see Evaluation Report for more details). The module was housed within the vehicle and communicated with the Smartphone using a Bluetooth wireless connection. Messages received from the CICAS-SSA system included the intersection Geographic Information Description (GID) as defined in SAE J2735 and a threat assessment of the main line. This information was used by the CVSMUF system to warn drivers of potential hazards. The CVSMUF system used the Arada Locomate<sup>TM</sup> device, shown in Figure 12, to implement the OBU Computing Platform and API within the vehicle.



**Figure 12. Arada Locomate OBU**

### **3.1.2 Smartphone Applications**

#### **3.1.2.1 Navigation Application**

CoPilot Live by ALK Technologies was chosen as the preferred Android OS-compatible navigation application for the Smartphone.<sup>7</sup> CoPilot Live was installed without modification, beyond the standard configuration options, as part of the initial Smartphone, Android, and application setup. CoPilot software also used the GPS location service provided by the Android operating system. Features included:

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<sup>6</sup> The CICAS-SSA enabled intersection was provided by the University of Minnesota.

<sup>7</sup> Participants were also provided with the option of using Google's navigation service as an alternative to CoPilot.



- Dynamic Route Guidance
- Detailed Street Maps
- Voice-Guided Turn Instructions
- 3D Navigation Displays

In addition to the basic software, the CVSMUF system employed the “Live” features of CoPilot Live including a range of useful real-time information services. Specifically the CoPilot Traffic service served as a traffic data provider using the mobile internet to check a route in real-time for reported traffic problems and displayed them on-screen. The user had the choice to manually or automatically reroute to avoid the reported traffic problem. Figure 13 illustrates some sample screen images from the Navigation Software.

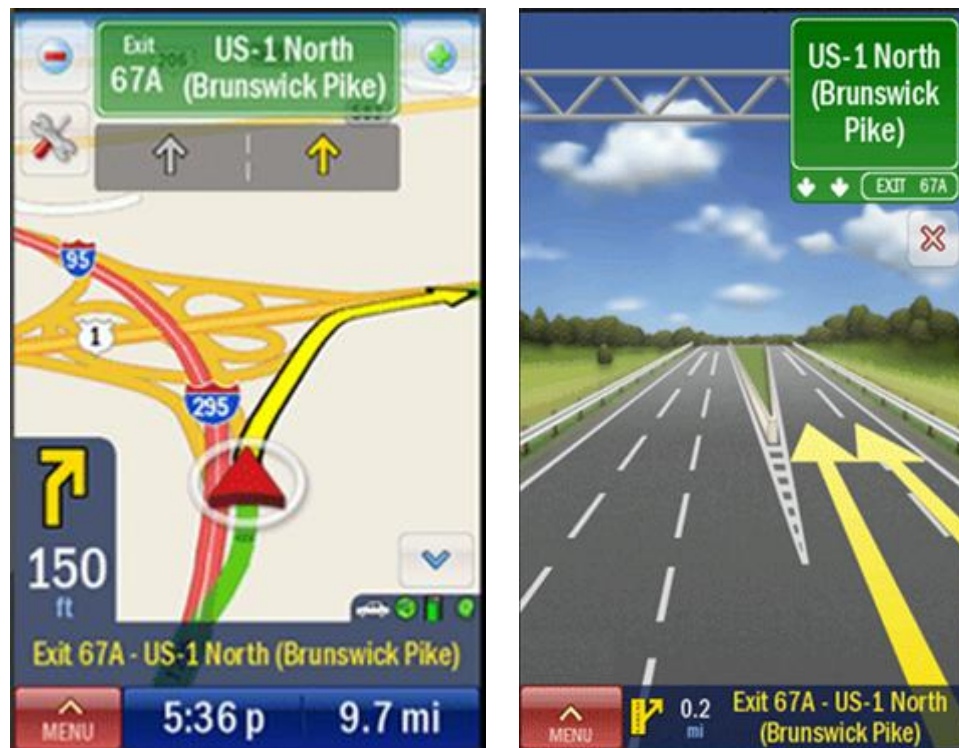


Figure 13. Co-Pilot Sample Screens

### 3.1.2.2 In-Vehicle Subsystem Development Software

The Smartphone hosted all functional software on the vehicle. Software services were provided by the Android OS as well as custom code developed by Battelle. The custom CVSMUF application was implemented using seven main software system elements:

- CVSMUF Software (Main System Element)
- Positioning
- Logging
- Vehicle Communications Support
- Probe Data Collection
- Signage
- MBUF Collection

An overview of the system elements comprising the CVSMUF In-Vehicle subsystem are shown in Figure 14. The subsections below provide operational details for each software element.

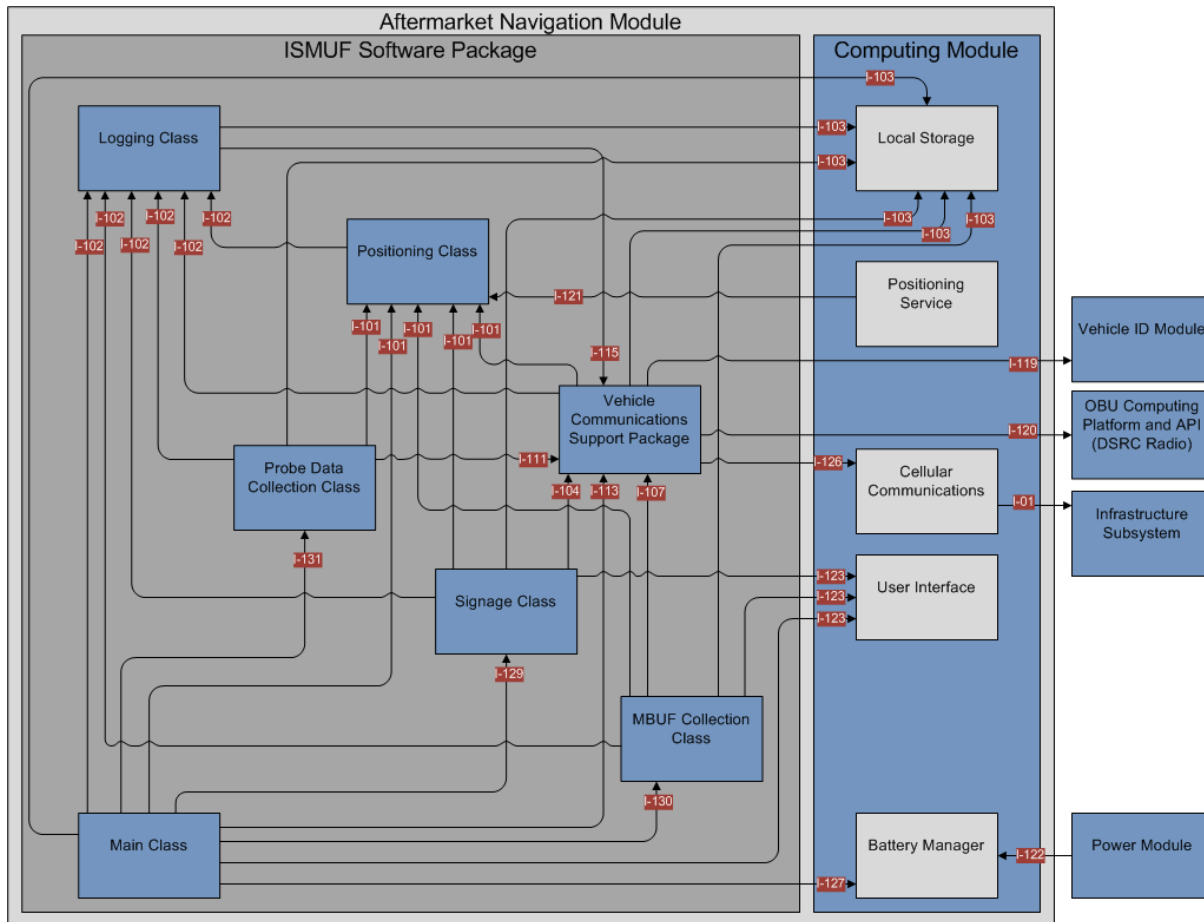
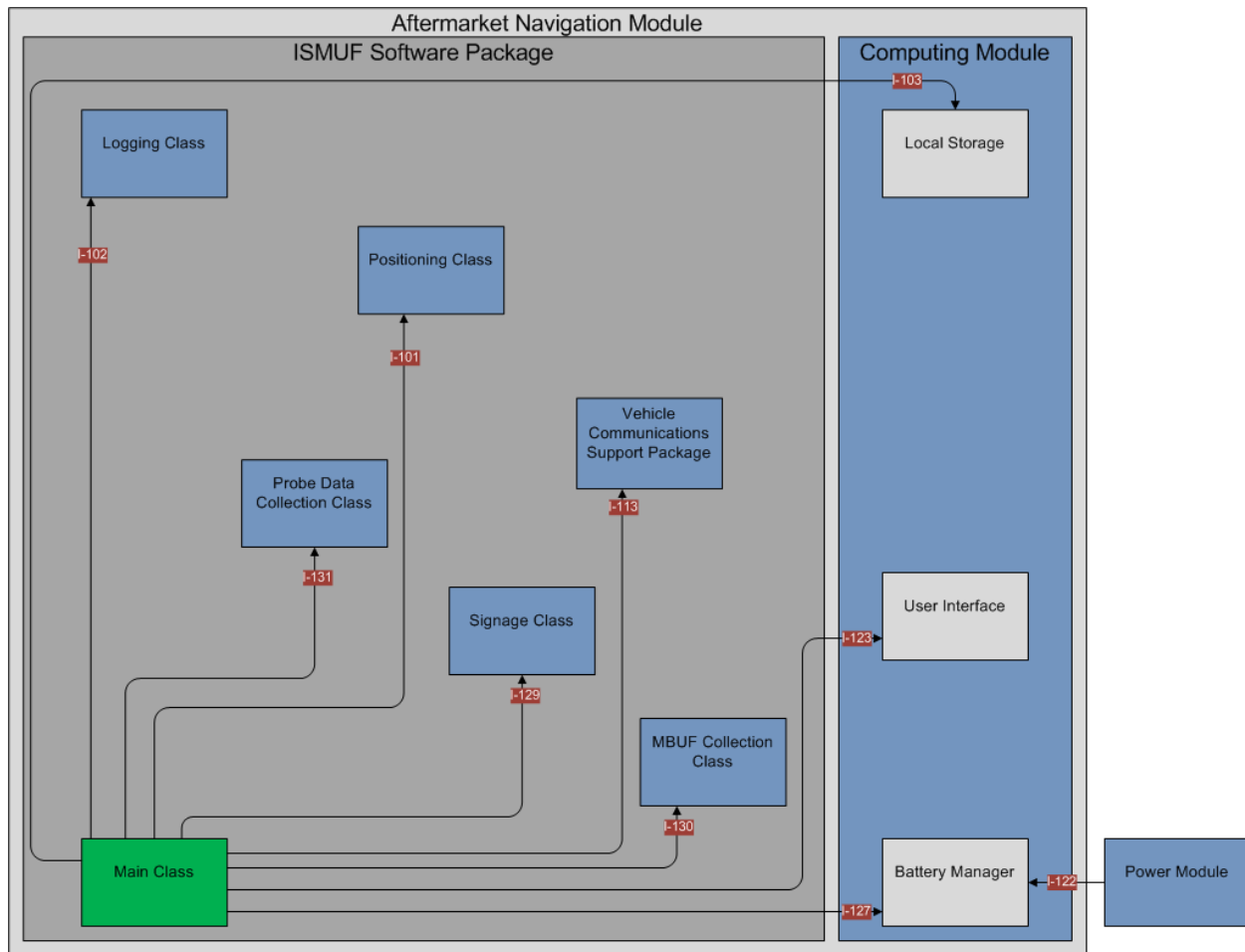


Figure 14. Overview of the System Elements Comprising the CVSMUF In-Vehicle Subsystem

### 3.1.2.2.1 CVSMUF Software (Main Software System Element)

The CVSMUF Software System Element communicates with every other CVSMUF Software System Element as well as other elements of the In-Vehicle subsystem. Figure 14 provides an alternative viewpoint of the CVSMUF In-Vehicle subsystem that highlights the Main Software System Element, shown in green, and illustrates all Software System Elements and other system elements that the Main Software System Element had direct communication with (i.e., are connected to the Main Software System Element by a single interface). It should be noted, however, that these other Software System Elements and system elements *also* had other Software System Elements and system elements that they were connected to via a dedicated interface. These second tier connections to the Main Software System Element are not included in Figure 15 or discussed in this document. These other connections are discussed within other CVSMUF design documents and can be found by examining Figure 14 and identifying the Software System Element that was directly connected, via a single interface, to the system element of interest.



**Figure 15. CVSMUF Software System from the Perspective of the Main Software System Element**

The primary software class contained within the CVSMUF Software System Element was the Main Class (MC) shown in green in Figure 15. As its name suggests, this software class was the primary startup application for the In-Vehicle subsystem and served to notify other Software System Elements that the system had been activated (or deactivated) and controlled the initialization and updating of those other Software System Elements. More specifically, the Main Software System Element, through the MC performed the following functions:

- Subscribe to Android Battery Events. The MC subscribed to Android battery events to detect power on and power off of the vehicle's ignition utilizing the device's battery power connected state.
- Submit a Registration (Deregistration) Message. When a power on event was received over interface I-127, the MC would send a registration message to the Infrastructure subsystem through the Vehicle Communications Support Package over interface I-113.
- Retrieve Application Configurations. Once the registration message had been sent, the MC would retrieve the application configurations from the Infrastructure subsystem through the Vehicle Communications Support Package over interface I-113 and write the new values to local storage using interface I-103.

- Initiate a New Trip Log. After the new application configuration had been stored, the MC would create a start trip log message and send it to the Logging Software over interface I-102.
- Instantiate other Software System Elements. Then the MC would create a Positioning Class, Probe Class, MBUF Class and Signage Class and call the start method on the Probe Class using interface I-131, MBUF Class using interface I-130, and Signage Class using interface I-129. This would result in the CVSMUF In-Vehicle software system being completely setup and running.
- Monitor for Power Off Events. Once the power off event was received over interface I-127, the MC would call the stop method on the Probe Class using interface I-131, MBUF Class using interface I-130, and Signage Class using interface I-129.
- Provide and Manage the CVSMUF User Interface. The MC was responsible for establishing, displaying, and controlling the operation of the CVSMUF User Interface.

The CVSMUF User Interface consisted of a customized screen displayed on the Android device providing the participant with the ability to select one of three menu options as illustrated in Figure 16:

1. View Reports. When the View Reports button was pressed, it would allow the user to access their Trip IDs and estimated fees as shown in Figure 17:  
View Estimated Fees. When the View Estimated Fees button was pressed, the current fee total that had not been sent to the infrastructure would be displayed to the user as shown in Figure 18.  
Trip IDs. When the Trip IDs button was pressed by the user, the MC would display a list of Trip IDs that had been saved, but not sent, to the Infrastructure subsystem. The display also had a button that would send that list of Trip IDs to the Infrastructure subsystem through the Vehicle Communications Support Package over interface I-113.
2. Launch CoPilot. When the Launch CoPilot button was pressed by the user, the CoPilot Navigation software was launched allowing the user to access the navigation features.
3. Change Settings. When the Change Settings button was pressed by the user, the MC would display a dialog with a list of check boxes that allowed the user to enable or disable the following: Probe, MBUF, MBUF Display, and Signage. When a setting was changed by pressing the checkbox, the new values for that setting were saved in local storage over interface I-103.

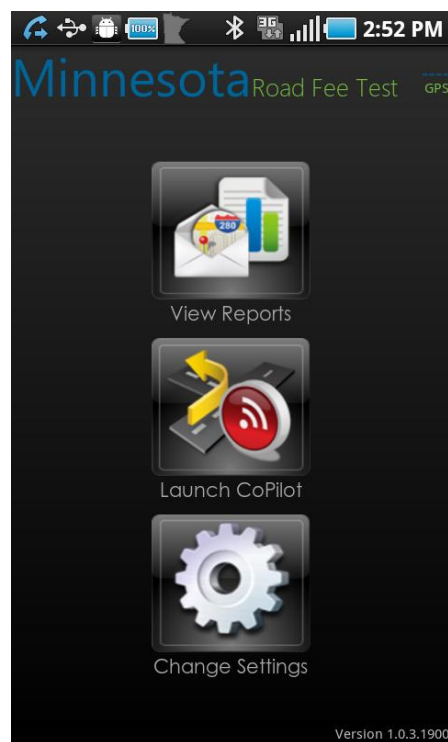
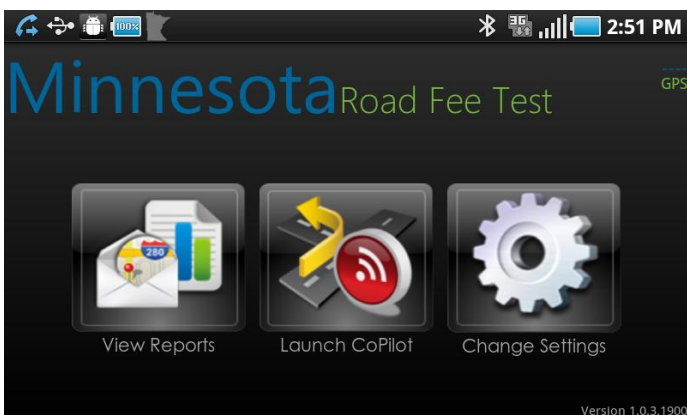


Figure 16. Main Menu

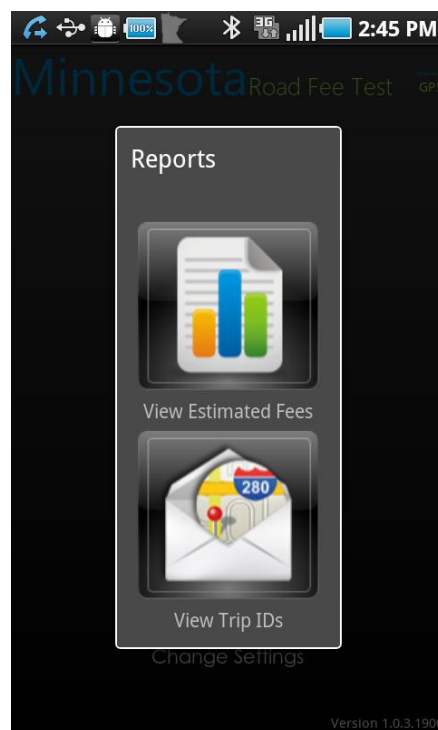
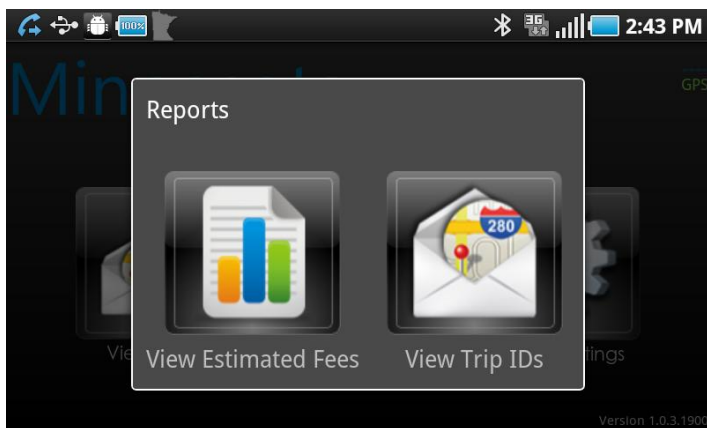
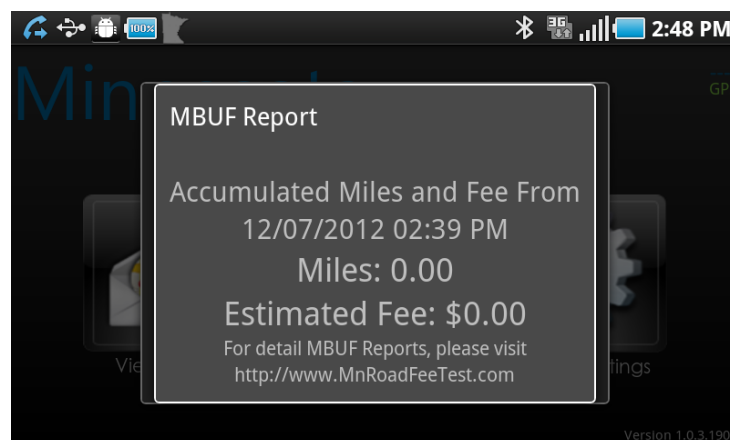


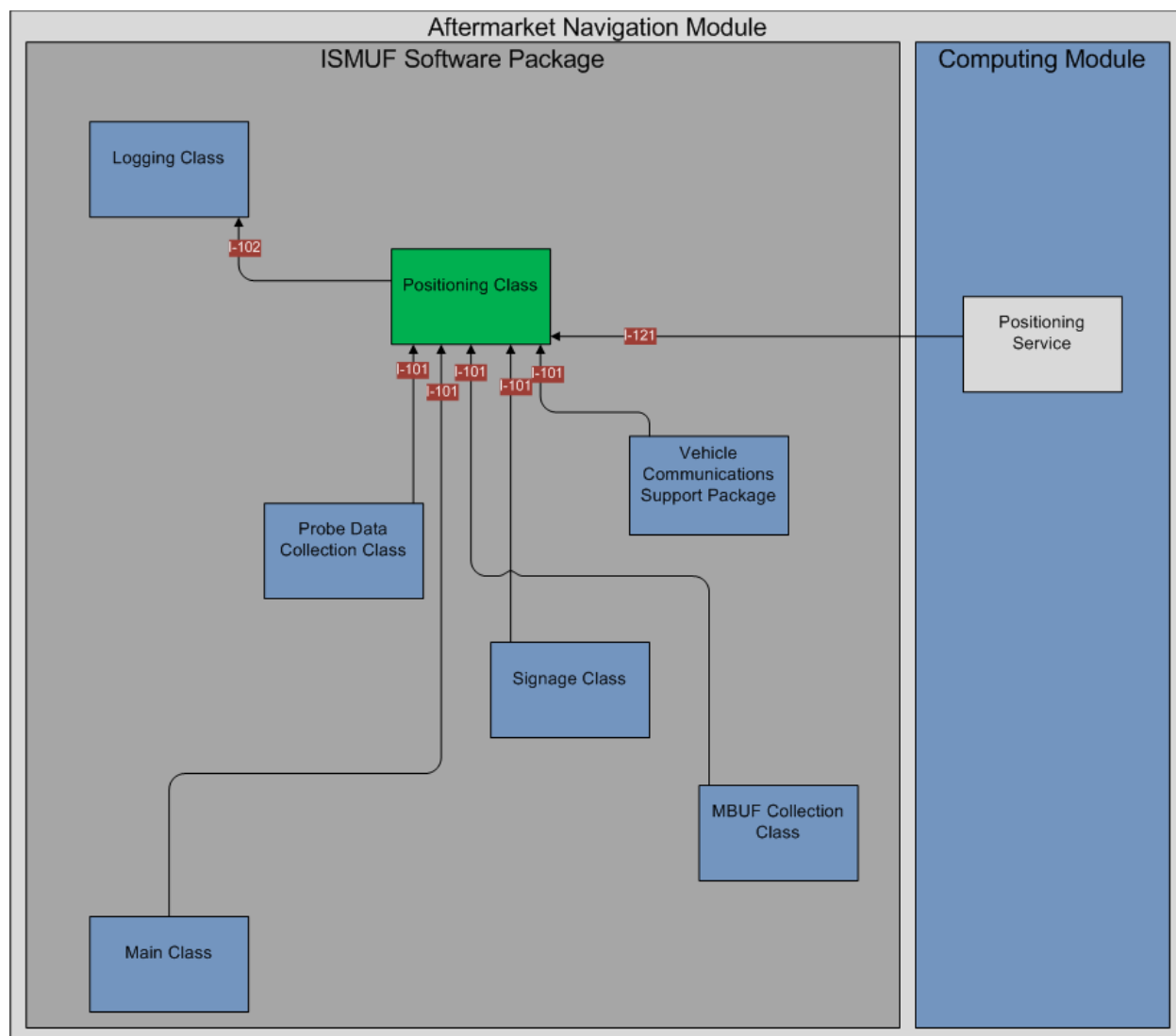
Figure 17. Activities Menu



**Figure 18. MBUF Report**

### **3.1.2.3 Positioning Software System Element**

As illustrated in Figure 19, the Positioning Software System Element resided within the CVSMUF software that was contained within the In-Vehicle subsystem. The Positioning Software System Element was the CVSMUF Software System Element that was responsible for providing positioning information through the I-101 interface upon request to the Signage Software System Element, MBUF Collection Software System Element, Probe Data Collection Software System Element, Main Software System Element, and the Vehicle Communications Support Software System Element. The Positioning Class would write a Log Message to the Logging Software System Element using interface I-102 when a change in the GPS status occurred from the Android Position Service over interface I-121.



**Figure 19. CVSMUF Software System from the Perspective of the Positioning Software System Element**

The singleton software class contained within the Positioning Software System Element was the Positioning Software Class. The Positioning Software System Element, through the Positioning Software Class performed the following functions:

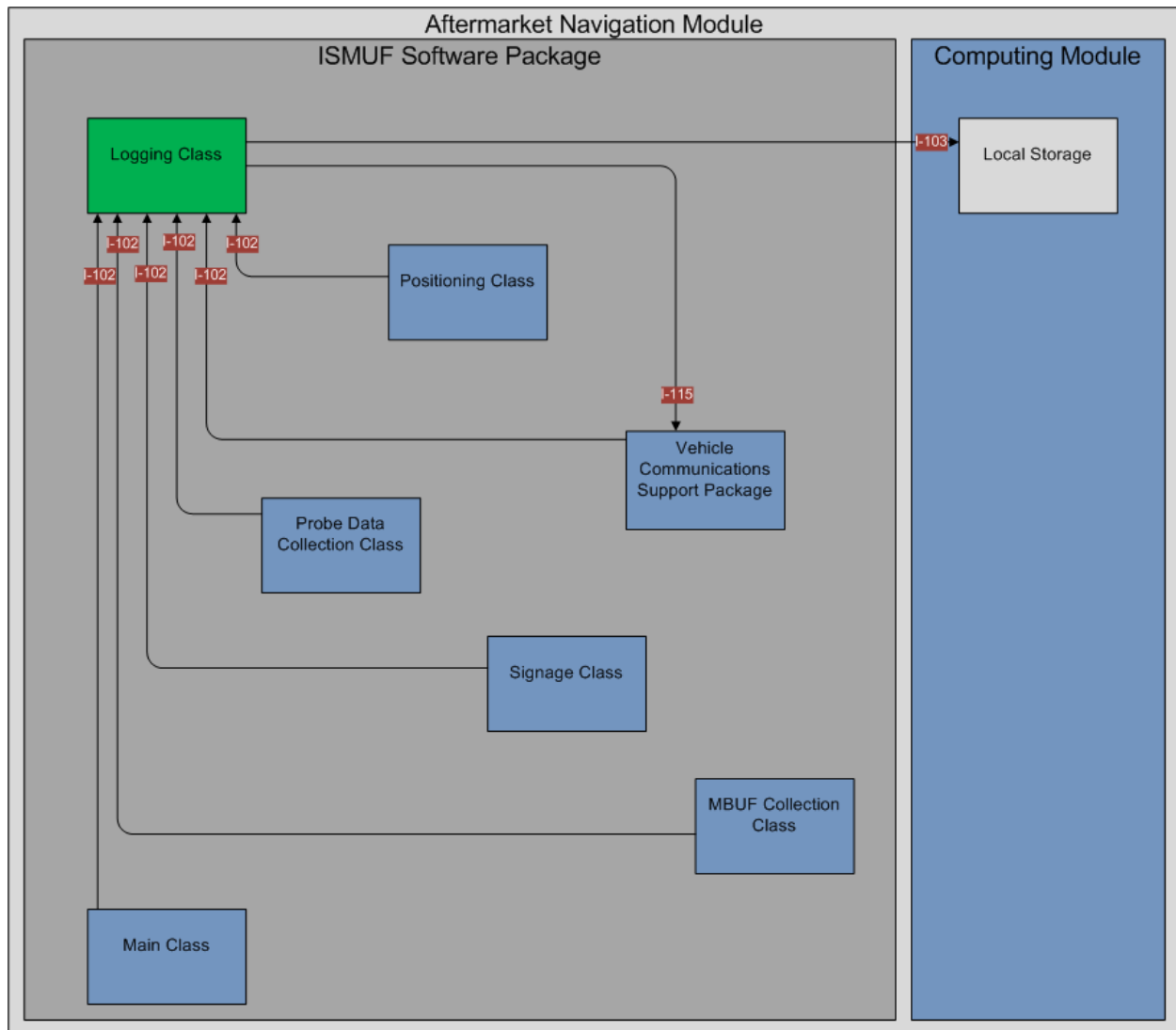
- Positioning Software Class. The Positioning Software Class was responsible for subscribing to the Android's location service and making location information available to other CVSMUF Software System Elements. The Positioning Software System Element achieved these actions through the following functions:
  - GetCurrentPositionSnapshot – Obtained the current location from the Android System's Location Manager.
  - StartPositioning – Started listening to the Android System's Location Manager for location updates.
  - StopPositioning – Stopped listening to the Android System's Location Manager for location updates.
  - Location Update Handler – Provided a mechanism for holding the current position steady when the vehicle was not moving (avoiding a random bounce due to satellite configuration changes).
  - GPS Status Change Handler – Listened for and logged changes to the GPS status of the Android device.

#### **3.1.2.4 Logging Software System Element**

This Logging Software System Element would communicate with most of the other CVSMUF Software System Elements as well as other elements of the in-vehicle subsystem. Figure 20 provides an alternative viewpoint of the CVSMUF in-vehicle subsystem that highlights the Logging Software System Element, shown in green, and illustrates the Software System Elements and other system elements that the Logging Software System Element had direct communication with (i.e., were connected to the Logging Software System Element by a single Interface). It should be noted, however, that these other Software System Elements and system elements *also* had other Software System Elements and system elements that they were connected to via a dedicated interface. These second tier connections to the Logging Software System Element are not included in Figure 20. These other connections are discussed within other CVSMUF design documents as referenced in Table 1 on this document and can be found by examining Figure 14 and identifying the Software System Element that was directly connected via a single interface to the system element of interest.

As illustrated in Figure 20, the Logging Software System Element resided within the CVSMUF software that was contained within the In-Vehicle subsystem. Log entries would be submitted to the Logging Software System Element by other elements of the CVSMUF Software through the I-102 interface. Log Reports, consisting of a collection of log entries, would be sent from the Logging Software System Element to the CVSMUF Vehicle Communications Support Package for ultimate submission to the CVSMUF Infrastructure subsystem through the I-115 interface. The Logging Software System Element would utilize the I-103 interface to store in persistent memory the log entries received.





**Figure 20. CVSMUF Software System from the Perspective of the Logging Software System Element**

The primary software class contained within the Logging Software System Element was the Logging Software Class. The Logging Software System Element, through the Logging Software Class performed the following functions:

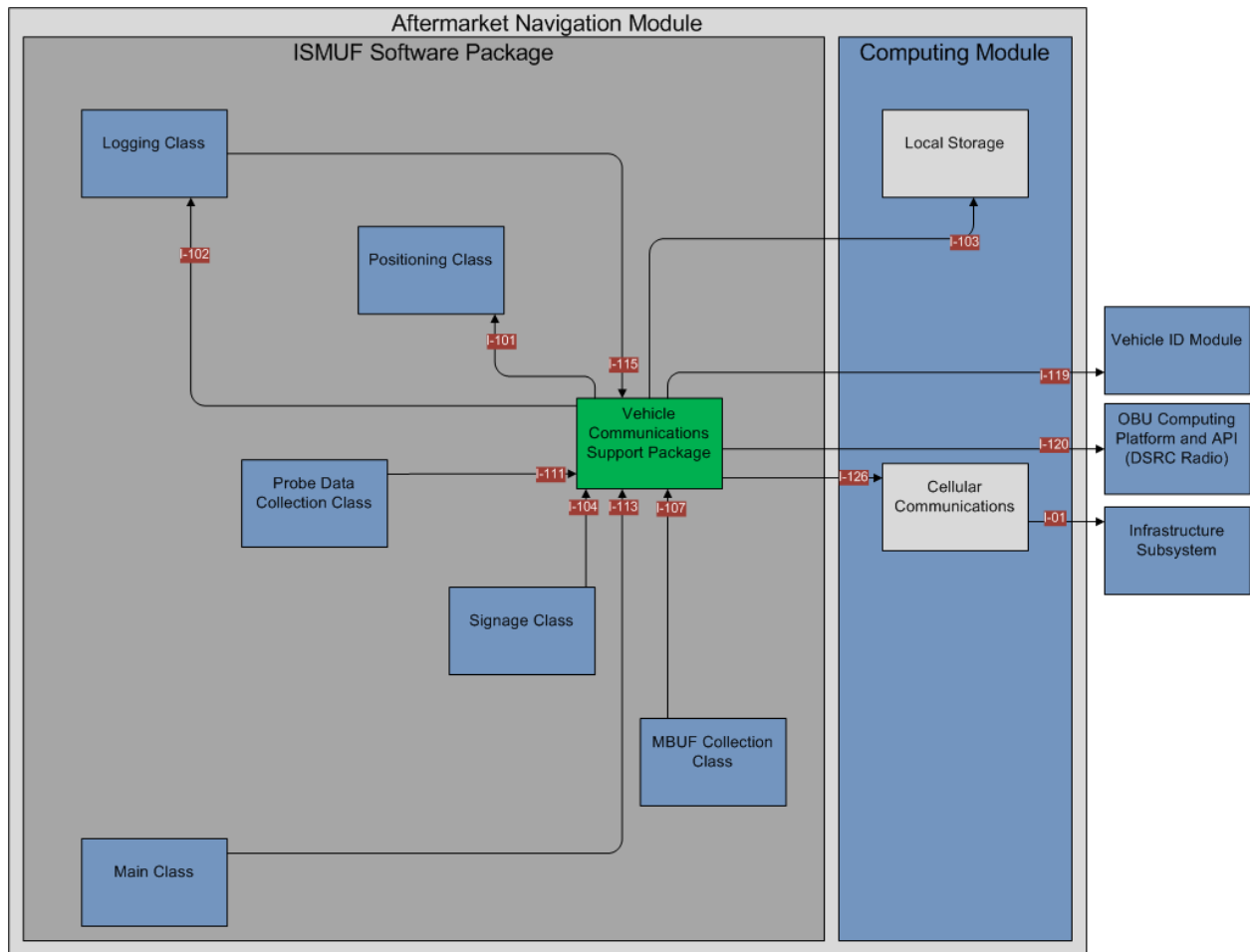
- Receive Log Entries. The Logging Software Class received “push” messages from other Software System Elements that pertained to events that other software system elements were required to log.
- Write Log Entries. The Logging Software Class validated the log messages received from other software system elements and created an entry in a persistent database table stored in the Android Local Storage system element.
- Send Log Messages. When directed by the Main Software System Element, the Logging Software Class would retrieve the log entries from the Android Local Storage system element and package the entries together, along with additional information, such as the

current Trip ID, and submit this package to the Vehicle Communications Software System Element for transmission to the CVSMUF Infrastructure subsystem.

- Error Handling. The Logging Software Class was responsible for identifying, capturing, and logging any errors encountered during its operation.

### **3.1.2.5 Vehicle Communications Support Software System Element**

As illustrated in Figure 21, the Vehicle Communications Support Software System Element was connected to all components of the In-Vehicle subsystem, including elements in the CVSMUF Software, Computing Module, and modules outside of the Smartphone. This connection was performed through numerous interfaces, with a separate interface defined for the communication with each of these system elements and modules. Each CVSMUF Software System Element communicated over a dedicated interface. For Probe Data Collection Software System Element, when a probe vehicle data message was sent to the Infrastructure subsystem, it was first transmitted from Probe Data Collection Software System Element to Vehicle Communications Support Software System Element over interface I-111. Vehicle Communications Support Package then would send it onto the Android Cellular Communications over interface I-126 who then would send it over interface I-01 to the Infrastructure subsystem. The MBUF Collection Software System Element did the same transmission for MBUF zone updates and MBUF accumulated mileage reports. Signage Software System Element also sent its Signage zone updates request to the Infrastructure subsystem through the Vehicle Communications Support Software System Element using interfaces I-104, I-126, and then I-01. A message containing the updates would then get passed back to the Signage class using interface I-01 and I-126 to reach the Vehicle Communications Support Software System Element who would then forward the message onto the Signage Software System Element using interface I-104.



**Figure 21. CVSMUF Software System from the Perspective of the Vehicle Communications Support Software System Element**

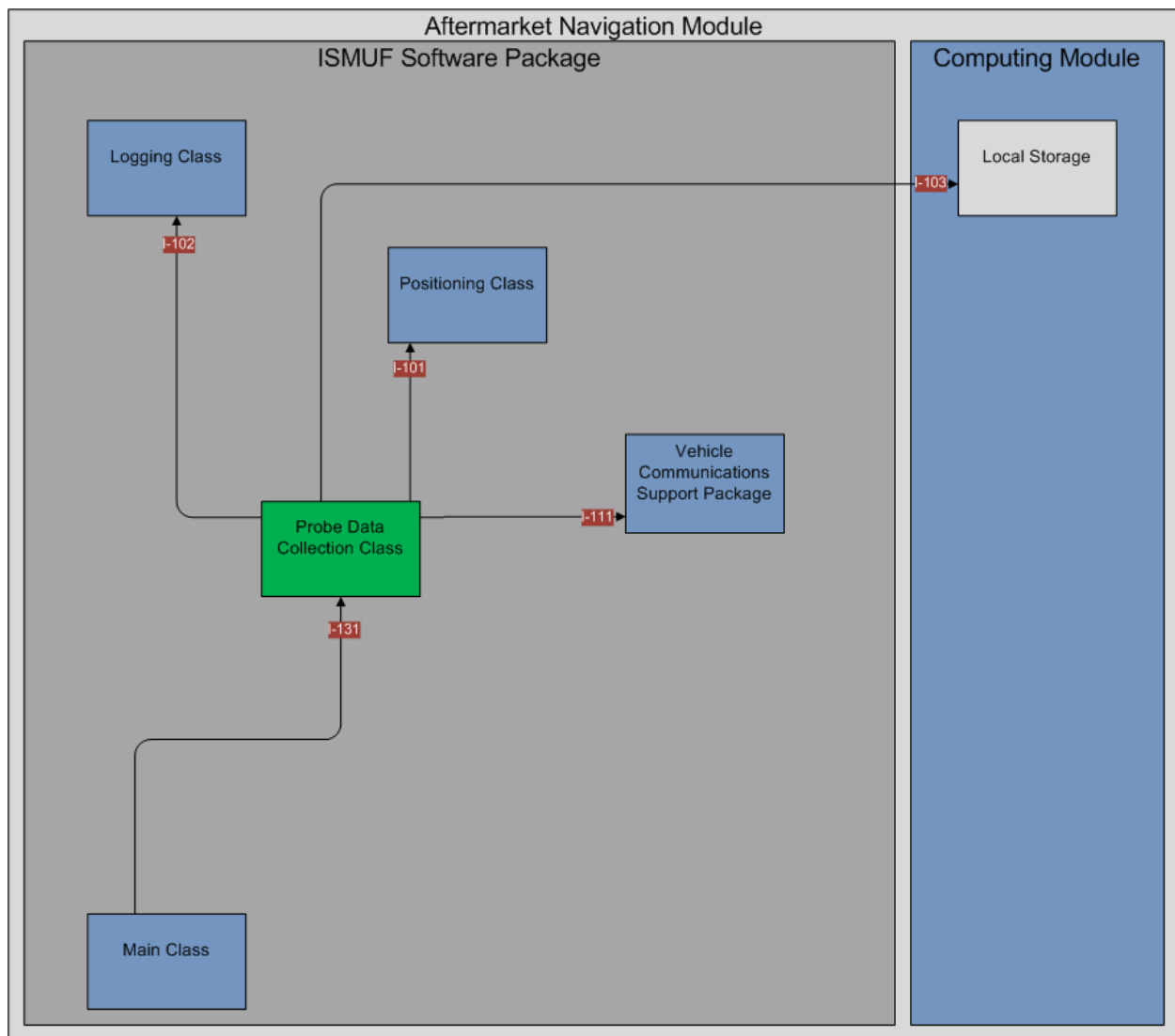
There were six software classes contained within the Vehicle Communications Support Software System Elements. These classes were separated both by functionality as well as by the specific CVSMUF Software System Element being communicated with. The following provides a brief summary of the functions that each Vehicle Communications Support Software System Software Class was responsible for achieving.

- Vehicle Communications Abstract Software Class. This software class had the responsibility of managing the communications functions at a high-level including managing the buffering and clearing of the communications buffer. Functions contained within this software class include:
  - Constructor – created and managed the communications credentialing activities
  - QueryData – selected the appropriate communication credential to use for communications
  - SendData – selected the appropriate communication credential to use for communications
  - ErrorHandling – captured and logged errors encountered during the communication credentialing process.

- CVSMUF Application Vehicle Communications Software Class. This software class was responsible for communication of the Trip ID submission as well as registration and configuration messages.
  - SendRegistration – sent a registration message to the Infrastructure subsystem
  - GetApplicationConfiguration – sent the CVSMUF Software configuration settings
  - GetVehicleID – obtained indication that the device was contained within the vehicle and communicated this to other CVSMUF Software System Elements
  - SendTripIDs – used to submit saved Trip IDs to Infrastructure subsystem
- MBUF Communications Software Class. This software class was responsible for all MBUF related communications.
  - ReceiveAndSendMBUFAccumulatedMileage – received the MBUF Trip Report as input and submitted this report to the Infrastructure subsystem.
  - GetMBUFZoneTableUpdates – received the MBUF criteria updates from the Infrastructure subsystem and provided this update to the MBUF Software System Element.
  - GetMBUFZoneTableRateUpdates – received the MBUF rate updates from the Infrastructure subsystem and provided this update to the MBUF Software System Element.
- Signage Communications Software Class. This software class was responsible for all Signage related communications.
  - GetAdministrativeMessages – received administrative messages from the Infrastructure subsystem and provided these to the Signage Software System Element.
  - GetSignageZoneUpdates – received updates to Signage Zones from the Infrastructure subsystem and provided these to the Signage Software System Element.
- Probe Data Communications Software Class. This software class was responsible for all probe related communications.
  - ReceiveAndSendProbeVehicleData – received probe messages from the Probe Software System Element and submitted these messages to the Infrastructure subsystem.
- Event Logging Data Communications Software Class. This software class was responsible for all Logging related communications.
  - ReceiveAndSendLogMessageReport – received Log messages from the Logging Software System Element and submitted these messages to the Infrastructure subsystem.

### 3.1.2.6 Probe Data Collection Software System Element

The Probe Data Collection Software System Element and its associated Interfaces are illustrated in Figure 22. The Probe Data Collection Software System Element handled the creation of position snapshots and the sending of the position snapshots to the Infrastructure subsystem. Once the Probe Data Collection Software System Element was started by the Main Software System Element over interface I-131, the Probe Data Collection Software System Element created a new trip id which was then stored in local storage using interface I-103. The Probe Data Collection Software System Element then kicked off a 1 second timer that retrieved the current position from the Positioning Software System Element over interface I-101. That position was stored in a local queue, and when the queue's size hit 20, the Probe Data Collection Software System Element packaged those 20 Position Snapshots into a Probe Vehicle Data Message and transmitted that to the Infrastructure subsystem through the Vehicle Communications Support Software System Element over interface I-111.



**Figure 22. CVSMUF Software System from the Perspective of the Probe Data Collection Software System Element**

The Probe Data Collection Software System Element consisted of two software classes. These classes were separated by functionality. The following provides a brief summary of the functions that each Probe Data Collection Support Software System Software Class was responsible for achieving.

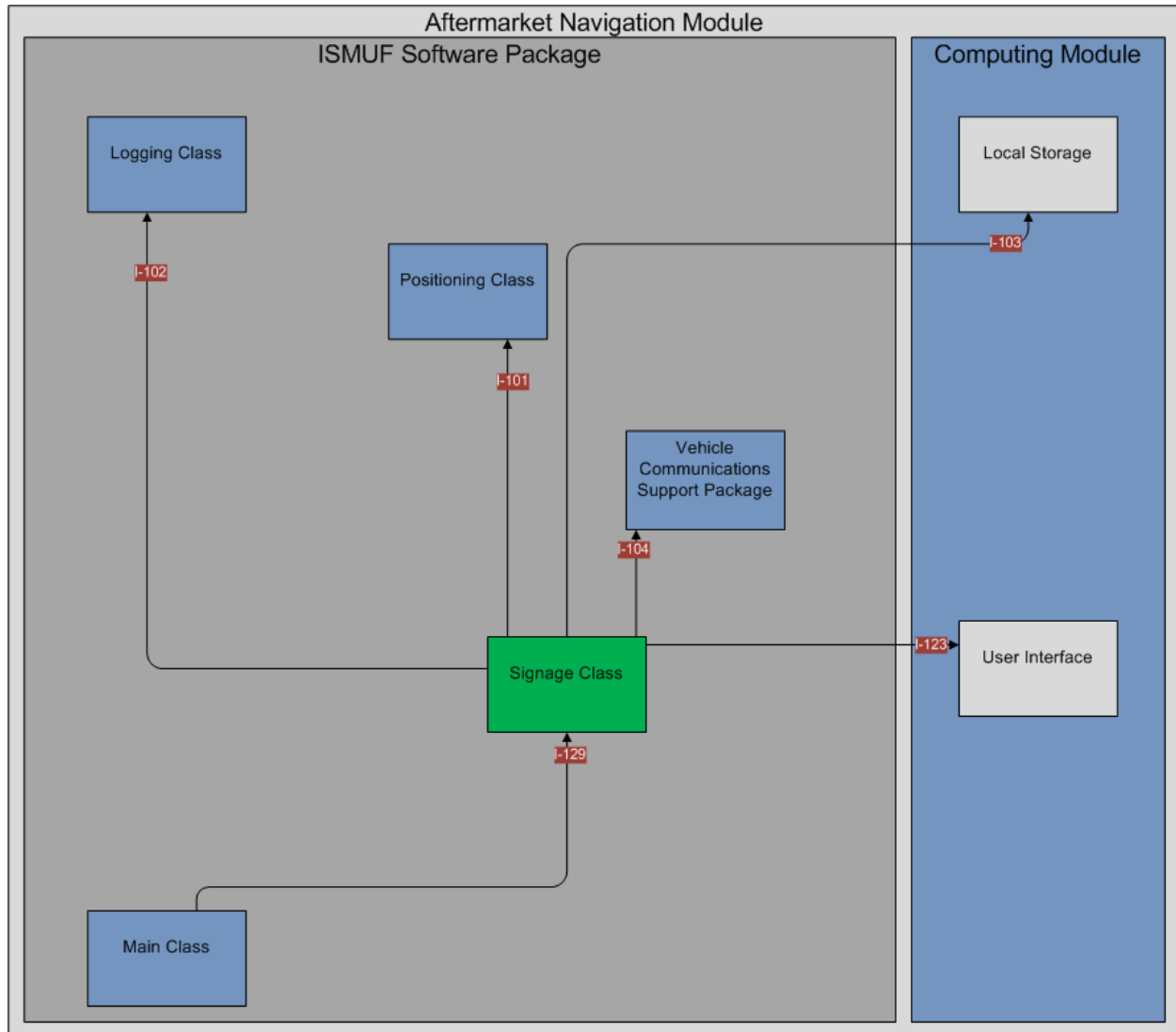
- Manage TRIPID Software Class. The TRIPID Class managed the function of creating TRIPIDs and querying the participant to determine if the TRIPID should be saved. This software class contained the following functions:
  - CreateTRIPID – Created a new TripID using the Java UUID class, and stored it in the Trip ID row in the Application Configuration Table in local storage.
  - DisplayTRIPID – Displayed the current TripID to a user in a message box asking them if they want to save the current TripID and then took action based upon the response.
- Probe Data Collection Software Class. This software class managed the function of creating probe location snapshots every second, bundling these snapshots into a single message every 20 seconds, and transmitting this message to the Vehicle Communications Support Software System Element. This software class contained the following functions:
  - Constructor – Created an instance of the Probe Data Collection Software Class with the latest configuration settings.
  - StartProbe – Initiated the generation of a TRIPID.
  - StopProbe – Cleared the Probe Snapshot buffer and ended the instance of the Probe Data Collection Software Class.
  - Probe – Obtained a position from the Android positioning service; entered this position into the Snapshot Queue, and called SendProbeVehicleData when the Snapshot Queue has reached a count of 20.
  - SendProbeVehicleData – Removed all the Position Snapshots from the Snapshot Queue; packaged them into a new Probe Vehicle Data message, and sent them to the Vehicle Communications Support Software System Element.

### **3.1.2.7 Signage Software System Element**

The primary focus of the Signage Software System Element was to provide audible and visual alerts to the vehicle occupant when specific location-based events occurred. To achieve this objective, the Signage Software System Element would determine, based upon vehicle location, whether a set of criteria had been met and if so, display the appropriate sign to the vehicle occupant. The Signage Software System Element operated irrespective of the participant in that no user interaction was needed to identify whether the criteria for a specific alert (Signage criteria) had been met. Nor was interaction from the participant needed to clear or remove the alert from the display of the Smartphone.

As illustrated in Figure 23, the Signage Software System Element resided within the CVSMUF software that itself was contained within the In-Vehicle subsystem. The Signage Software System Element handled the displaying of administrative messages (messages sent by system administrators for display on the Smartphone), and alert signs and audible tones to the user. The Signage Software System Element also was responsible for checking with the Infrastructure

subsystem for administrative messages and signage zone updates through the Vehicle Communications Support Software System Element over I-104 interface. When administrative messages and/or signage zone updates were received, the Signage System Element was then responsible for storing the new information into the Android local storage using interface I-103. Once the setup was complete, the Signage Software System Element retrieved the current position from the Positioning Software System Element over interface I-101, and checked the speed value. If the speed value was less than or equal to zero, the software assumed the vehicle was not moving and displayed the administrative messages (Note: administrative messages were not displayed while a vehicle was in motion).



**Figure 23. CVSMUF Software System from the Perspective of the Signage Software System Element**

Once the software classes contained in the Signage Software System Element were initiated by the Main Software System Element over interface I-129, the Signage Software System Element started a one second timer that obtained the current position from the Positioning Software System Element over interface I-101 and checked to see if the current position was inside of a signage zone. If a signage zone was found, the Signage Software System Element identified the type of zone, and associated image file, and sent a command to the Android User Interface to display the image and play the sound file using interface I-123.

The Software System Element consisted of two software classes and their associated properties and functions. These classes were separated by the nature of the sign displays. The following provides a brief summary of the functions that each Signage Software System Software Class was responsible for achieving:

- Signage Software Class. This class was responsible for finding and displaying signage information based on location, time of day, day of week, and direction of travel. The following functions were included in this software class:
  - Constructor – Created a Signage Communications Support instance.
  - UpdateSignage – Used to call other functions to update zones or retrieve administration messages.
  - StartSignage – Started the timer associated with this software class.
  - StopSignage – Stopped the timer associated with this software class and forced the display of administrative messages.
  - GetAdministrativeMessages – Retrieved administration messages from the Infrastructure subsystem.
  - GetSignageZoneUpdates – Retrieved signage zone updates from the Infrastructure subsystem.
  - CheckForSignageZones – Checked vehicle position against signage zones and determined if the vehicle is within a signage zone (and which one).
  - DisplayAdministrativeMessages – Determined whether an administrative messages should be displayed.
  - DisplayAdministrativeSignage – Displayed an administrative message.
  - DisplaySignage – Displayed a signage display and sounded alert.
- CICAS Software Class. Class that received CICAS data and displayed the information to the driver. This class included the following functions:
  - Constructor – Created an instance of the software class.
  - UpdateMapData – Received CICAS map data.
  - ProcessThreatAssessment – Processed threat assessment based on location and CICAS map; determined the appropriate image to display.
  - DisplayCICASSignage – Constructed and displayed an Android pop-up (toast) message based on CICAS Zone Type.

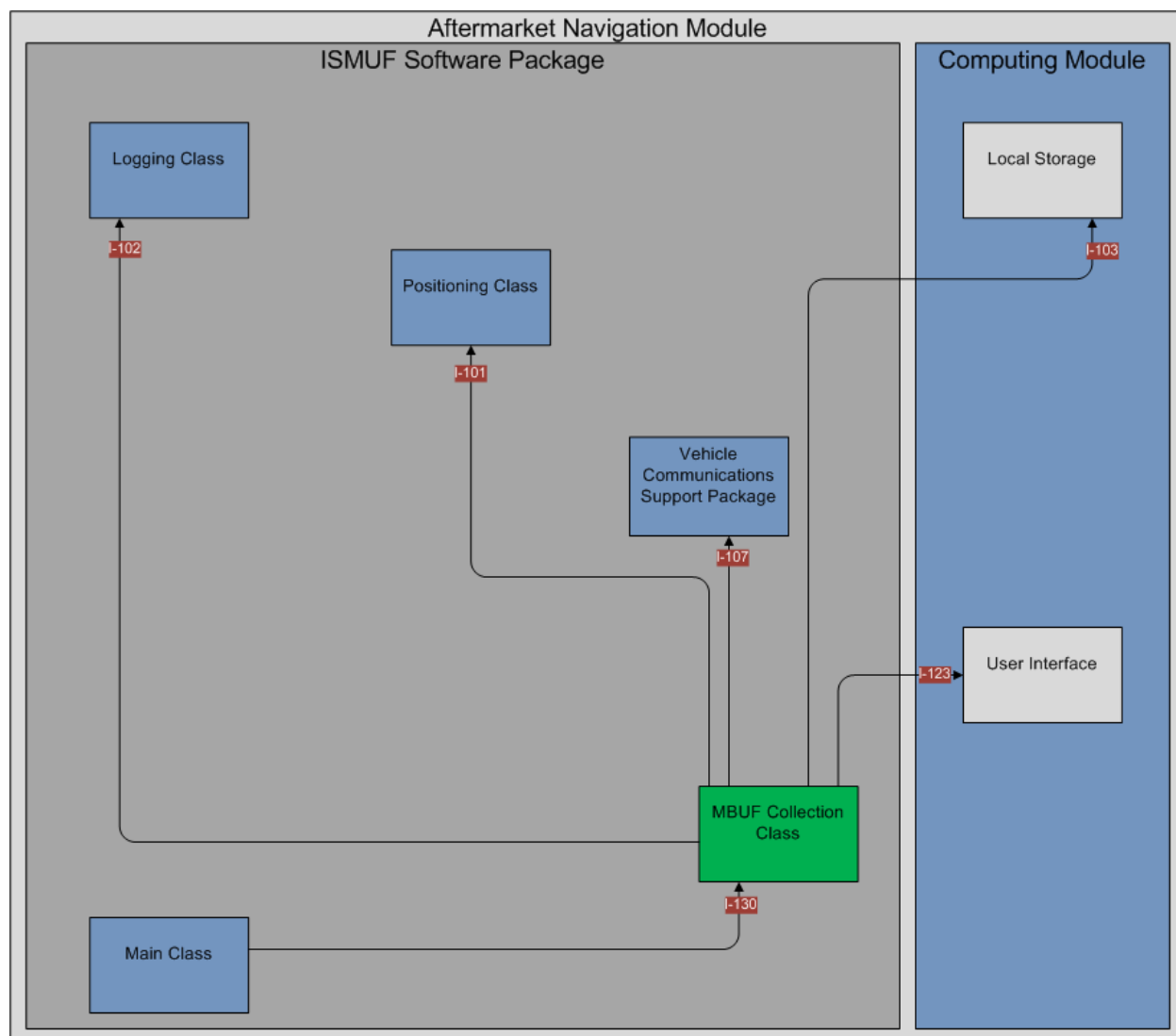


### **3.1.2.8 Mileage Based User Fee (MBUF) Collection Software System Element**

As illustrated in Figure 24, the MBUF Collection Software System Element resided within the CVSMUF software that was contained within the In-Vehicle subsystem. The MBUF Collection Software System Element was responsible for determining the current MBUF price, logging miles driven in MBUF zones, and estimating MBUF cost to the driver based on accumulated mileage and zone price. Additionally, the MBUF Collection Software System Element handled the retrieval of the current MBUF rate, displaying that rate to the user, and accumulating miles driven for all MBUF rate types.

When the MBUF Collection Software System Element was started by the Main Software System Element, it first checked with the Infrastructure subsystem for MBUF criteria updates. If updates were available, the MBUF Collection Software System received them and wrote the updates to the Android Local Storage using interface I-103. The second action undertaken by the MBUF Collection Software System Element was that it initiated a one second timer that obtained the current position from the Positioning Software System Element over interface I-101. The MBUF Collection Software System Element then determined which MBUF criteria were met and displayed the rate associated with the criteria to the participant. At the same time, distance between successive positions was calculated (in miles) and added to the miles driven for that MBUF rate criteria over interface I-103.

In order to enhance privacy, mileage was accrued over a minimum of 24 hours at which point the MBUF Collection Software System Element created a MBUF Accumulated Mileage report and sent this report to the Infrastructure subsystem using the Vehicle Communications Support Software System Element over interface I-107. When the report was sent, the MBUF Collection Software System Element would submit a log message to the Logging Software System Element over interface I-102 and clear all accumulated mileage values for the MBUF rate criteria in the Android Local Storage using interface I-103.



**Figure 24. CVSMUF Software System from the Perspective of the MBUF Collection Software System Element**

The MBUF Collection Software System Element consisted of a single software class, “MBUF Collection Software Class.” The MBUF Collection Software System Element, through the MBUF Collection Software Class, performed the following functions:

- MBUF Software Class. The MBUF Software Class was responsible for finding the current MBUF criteria set, displaying the associated rate to the driver, and accumulating mileage for the current MBUF criteria set.
  - Constructor – Created a MBUF Communications Support Class.
  - UpdateMBUF – Managed the process of updating the MBUF criteria sets.
  - StartMBUF – Started the MBUF Collection Software Element activities.
  - StopMBUF – Stopped the collection of MBUF mileage.
  - IsOnInterstate – Determined if the vehicle was located on an Interstate.

- IsInState – Determined if the vehicle was located in Minnesota.
- FindMBUFCriteria – Determined the criteria set for the current position.
- CalculateMileage – Calculated mileage between successive positions by rate category.
- DisplayCurrentMBUFRate – Displayed the current rate to the participant.
- DisplayMBUFReport – Displayed the MBUF Report to the participant.
- SendMBUFAccumulatedMileage – Sent the MBUF Accumulated Mileage report to the Infrastructure subsystem.

### **3.1.2.9 CICAS-SSA Data Processing Software System Element**

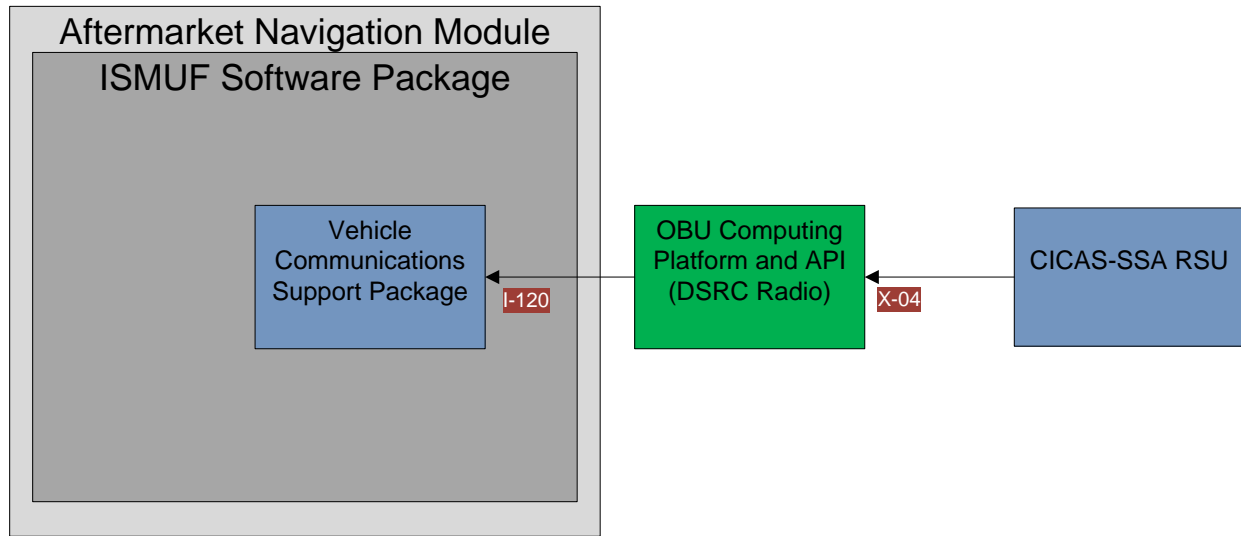
As shown in Figure 25, the CICAS-SSA Data Processing Software resided on the DSRC On-Board Unit and interfaced with the unit's WAVE API to receive messages from the Roadside Equipment using interface X-04. The software checked the validity of the message and forwarded a subset of the messages to the Navigation Module over the I-120 interface.

The CICAS-SSA Data Processing Software launched its main class that Interfaced to the DSRC On-Board Unit's WAVE API and created a connection on the X-04 interface. The software would also create a connection with the Navigation Device over the Bluetooth interface I-120 that was used to forward needed incoming messages. The software then waited for incoming messages from the Roadside Equipment to the DSRC OBU. These messages were received when the vehicle moved into the range of the Roadside Equipment's wireless radio.

When the vehicle came into range of the Roadside Equipment the On-Board radio began to receive CICAS-SSA messages. These messages were forwarded through the API to the CICAS-SSA Data Processing Software ReceiveMessage function that began the processing of the message. The message was verified through the VerifyMessage function which ensured that the message was a valid CICAS-SSA message by checking the digital signature and the format of the message. Once the message was verified to be valid, processing of the message took place.

There were two message types that were received from the Roadside Equipment. The first type of message contained the map data for the intersection or the Map GID. The second message contained the threat assessment for the intersection. The Roadside Equipment continuously transmitted these messages to any receiver within range. The main purpose of the CICAS-SSA Data Processing Software was to filter the messages so the Navigation Device would not have to process all of the incoming data. The CICAS-SSA Data Processing Software would only send the messages to the Vehicle Communications Support Package when the data within changed from the previous message received. When a vehicle moved into the range of the Roadside equipment the first Map Data message was forwarded to the Vehicle Communications Support Package. This data was static for the intersection for the time when the vehicle was within the range of the radio. Any subsequent Map Data messages were not forwarded to the Vehicle Communications Support Package unless the data changed or a disconnection of the X-04 Interface or I-120 Interface occurred. The Threat Assessment message changed whenever the status of the traffic changed. The CICAS-SSA Data Processing Software would forward this message to the Vehicle Communications Support Package whenever the threat assessment changed. The ProcessMapMessage function was used to check for changes in the Map Data message and the ProcessTAMessage was used to check for changes in the Threat Assessment

message. Both of these functions forwarded messages to the Vehicle Communications Support Package using the SendMessage function.



**Figure 25. CVSMUF Software System from the Perspective of the CICAS-SSA Data Processing Software System Element**

### 3.2 Infrastructure Subsystem

The In-Vehicle subsystem was complimented by the Infrastructure subsystem. As described previously, the In-Vehicle subsystem was centered on the function of the Smartphone mounted in the vehicle. The primary function of the Smartphone was to collect mileage, calculate fees, and provide diagnostic probe data. These functions resulted in the accumulation of data that was then sent up to the infrastructure subsystem for analysis and presentation. The infrastructure subsystem also provided configuration settings for the Smartphone based on participant group. The interface between Infrastructure subsystem and In-Vehicle subsystem occurred over the use of the Smartphone mobile network.

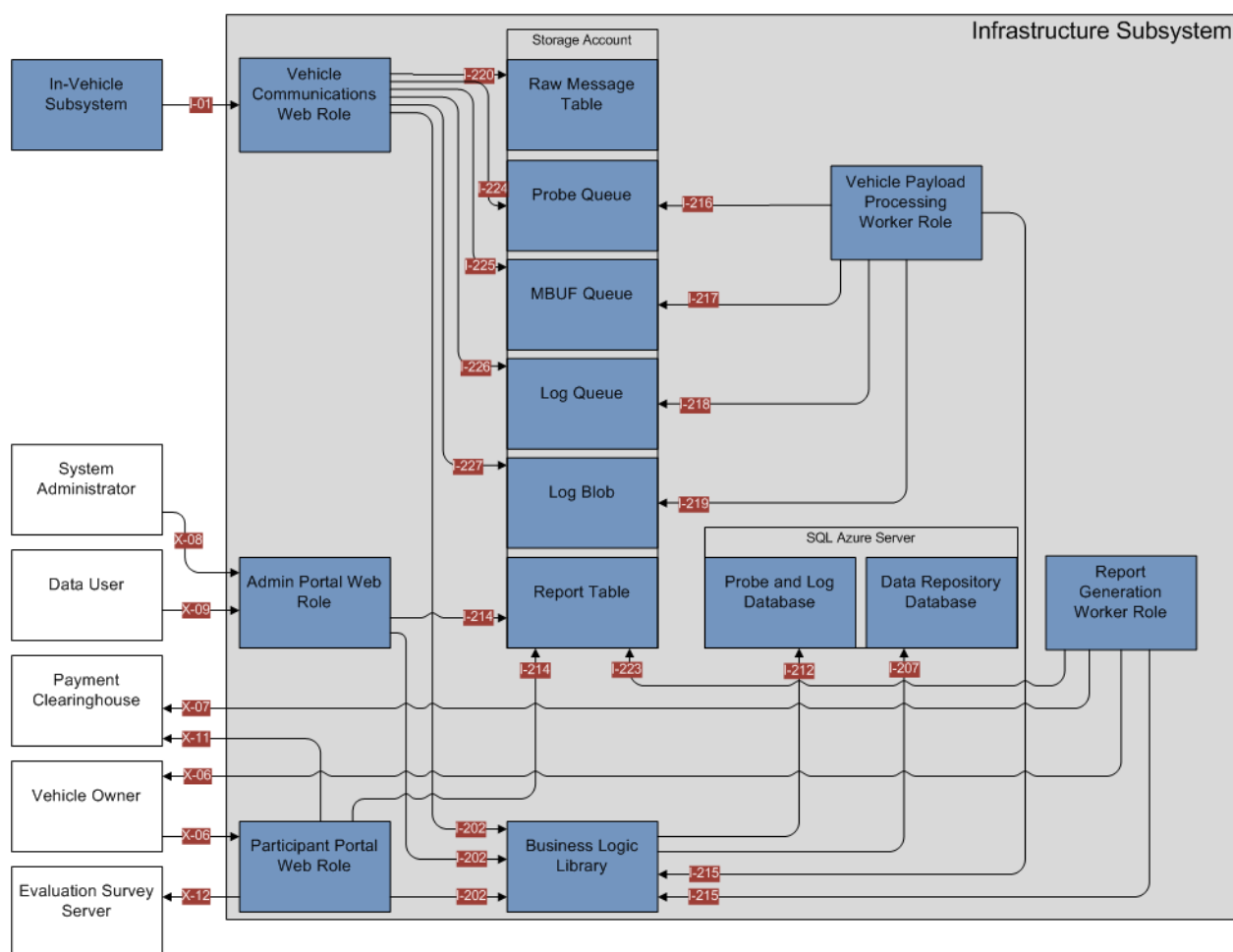
The Infrastructure subsystem, shown in Figure 26, was an internet-enabled data collection, analysis and presentation tool that provided a set of common services across all CVSMUF In-Vehicle subsystems. This subsystem was referred to as the “back-end support system” and was required to help facilitate back-end operations such as billing and technical support in addition to data collection, analysis and presentation. The Infrastructure subsystem was implemented using the Microsoft Windows Azure Cloud computing services.

In its simplest form, Windows Azure is a cloud services operating system that served as the foundation for running Windows applications and storing data in a scalable Internet-accessible virtual environment. Windows Azure is part of the Windows Azure platform which consists of a hosted infrastructure of hardware, software, network, and storage resources. Windows Azure handled load balancing and resource management and automatically managed the life cycle of a service based on requirements that the owner of the service established.

Scalability was achieved through virtualization. As needed, new virtual machines were acquired to handle the added traffic. When the extra capacity was no longer needed they were released.<sup>8</sup>

The CVSMUF Infrastructure subsystem was constructed of 3 types of Azure services:

- Hosted Services
- Storage Services
- SQL Azure Server Instances



**Figure 26. Overview of the System Elements Comprising the CVSMUF Infrastructure Subsystem**

Security is a key concern when hosting data and applications in the cloud. Microsoft leveraged an array of layered controls to provide a secure and confidential platform. Windows Azure provided confidentiality; ensuring customer's data was only accessible to authorized entities, through strong identity and access management, data isolation and data encryption. Integrity of the data, provided by Microsoft, and the system hosting the applications was managed by the underlying Windows Azure Fabric and was inherent in the platform design. Data stored on the platform was protected from failure by being replicated across multiple servers.

<sup>8</sup> <http://msdn.microsoft.com/en-us/library/ff960705.aspx>

Not only was network and platform security important, but physical security of the facility and operating staff was addressed as well. Microsoft employed multiple levels of monitoring, logging and reporting to help protect against unauthorized developer and/or administrator activity. Formal processes were in place which govern the actions of Microsoft personnel when administering the system.

The Microsoft Windows Azure was regularly reviewed and audited for compliance with respect to multiple industry certification standards. Windows Azure operated in the Microsoft Global Foundation Services (GFS) infrastructure, portions of which are ISO27001-certified. ISO27001 was recognized worldwide as one of the premiere international information security management standards.<sup>9</sup>

For additional details regarding the security of the Windows Azure platform see the whitepaper “Information Security Management System for Microsoft Cloud Infrastructure.”<sup>10</sup>

### 3.2.1 Windows Azure Hosted Services

Windows Azure hosted service contained a web role, a worker role, and VM role instances. As its name suggests, a web role instance accepted incoming HTTP or HTTPS requests and supported web application programming hosted in IIS. By running multiple instances of an application, Windows Azure helped that application scale. Worker role instances were similar to, but not quite the same as a web role. The main difference was that a worker role instance was not hosted by IIS. Instead, they were executable in their own right. Applications could consist of solely web role instances, only worker role instances, only VM role instances, or a combination of all three to create a Windows Azure application.<sup>11</sup> The CVSMUF system only implemented Web Roles and Worker Roles within Hosted Services.

- **Web Role:** A service component that was customized for web application programming as supported by Internet Information Services (IIS) 7 and ASP.NET. The web role was intended to serve as the front-end to a hosted service.<sup>12</sup>
- **Worker Role:** A service component that was useful for generalized development, and was capable of performing background processing for a web role. A worker role was frequently used for long-running tasks that were non-interactive, but any type of workload can be hosted.<sup>13</sup>

### 3.2.2 Windows Azure Storage Services

The storage account was the highest level of the namespace for accessing each of the fundamental services. It was also the basis for authentication. To control access to the information in this account, Windows Azure provided a secure encryption key. Each request an application made to information in this storage account—blobs, tables, and queues—carried a

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<sup>9</sup> [http://www.globalfoundationservices.com/security/documents/WindowsAzureSecurityOverview1\\_0Aug2010.pdf](http://www.globalfoundationservices.com/security/documents/WindowsAzureSecurityOverview1_0Aug2010.pdf)

<sup>10</sup> <http://www.globalfoundationservices.com/security/documents/InformationSecurityMangSysforMSCloudInfrastructure.pdf>

<sup>11</sup> <http://msdn.microsoft.com/en-us/library/ff960705.aspx>

<sup>12</sup> <http://msdn.microsoft.com/en-us/library/gg433065.aspx>

<sup>13</sup> <http://msdn.microsoft.com/en-us/library/ff960705.aspx>

signature created with this secure encryption key. In other words, authorization was at the account level (although blobs did have another option, described later). Windows Azure Storage didn't provide access control lists or any other more fine-grained way to control access the data it contains. Blobs, Tables, and Queues were accessible through the Windows Azure Storage Services REST API.<sup>14</sup> However, Battelle also implemented additional data security measures that limited data access through requiring authenticated access. Data was protected against loss by triple replication to back up storage.

This CVSMUF System implemented the following Windows Azure Storage services:

- Blobs. Used to store unstructured binary and text data.
- Queues. Used for storing messages that may be accessed by a client and providing reliable messaging between role instances.
- Tables. Used to store non-relational structured data.<sup>15</sup>

### 3.2.3 SQL Azure Server Instances

The CVSMUF system was implemented in two Microsoft SQL Azure Databases. These Microsoft SQL Azure Databases were cloud-based relational database platforms built on SQL Server technologies.

### 3.2.4 Vehicle Communications (Hosted Service) Web Role

The Vehicle Communications Web Role System Element was the gateway for all information exchanges between the Infrastructure subsystem and the In-Vehicle subsystem. These exchanges took place over interface I-01 as described previously. The Vehicle Communications Web Role and its associated Interfaces are illustrated in Figure 27.

As shown in Figure 27 below, the Vehicle Communications Web Role had several different interfaces connecting it to several different entities within the Infrastructure subsystem. A critical interface, I-01, provided the sole mechanism for information exchange between the Infrastructure subsystem and the In-Vehicle subsystem. The Vehicle Communications Web Role was implemented as a Representational State Transfer (REST) web service that allowed for a standard Internet connection from the Smartphone. This system element and corresponding web services were used to collect all MBUF, Probe and Log data generated by the Smartphone. This data was transmitted at regular intervals over interface I-01.

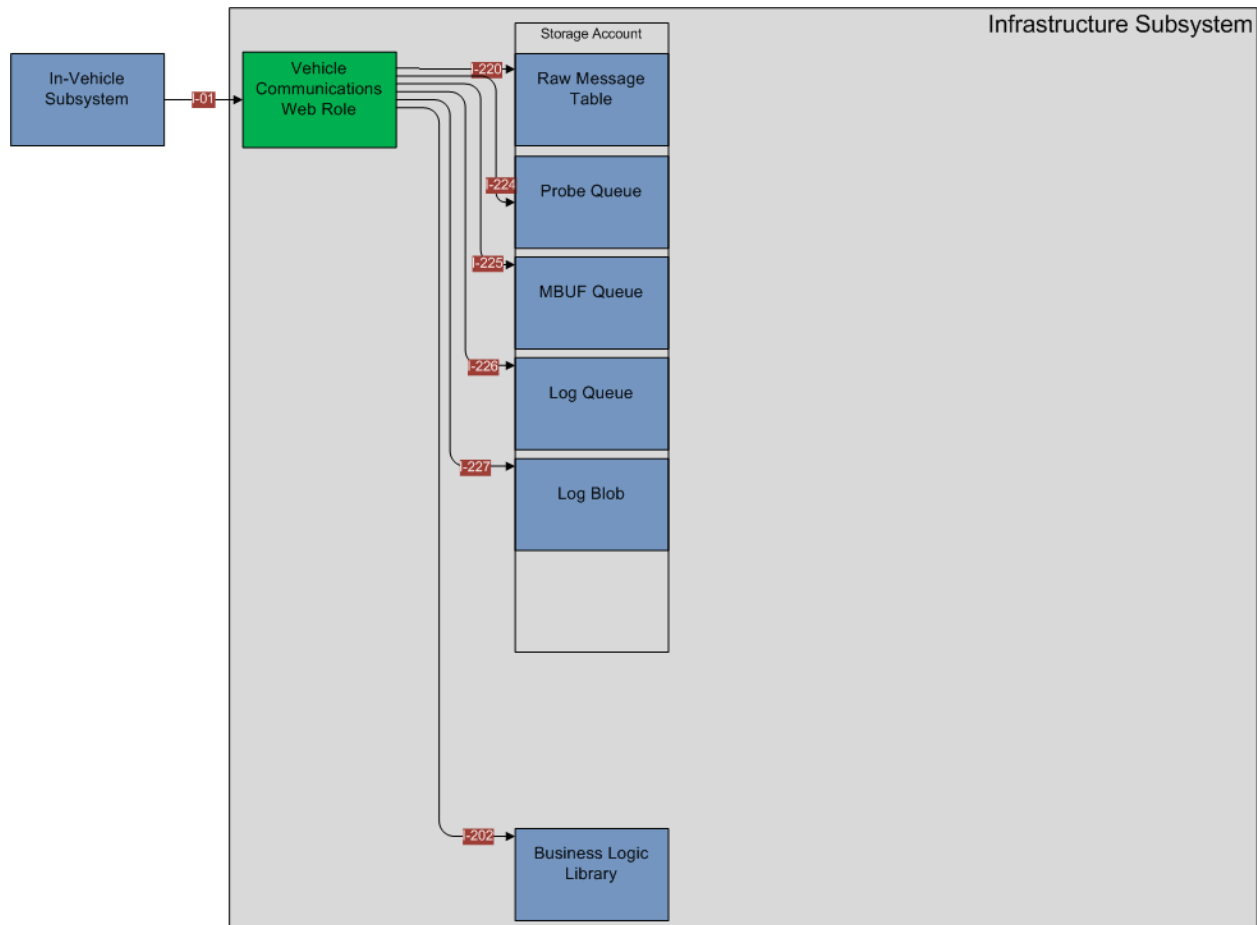
The six (6) internal interfaces, I-2XX, appear somewhat complicated in this diagram, but in reality, are simply artifacts of the Windows Azure cloud computing platform. For purposes of this system element, the combination of the three Queues and the Log Blob supported the system requirements to ensure that no messages were lost while waiting for processing. The Raw Message Table was used to support the requirements driving the need to persist all raw Probe, Log and MBUF messages that were received from the in-vehicle. The Blob was necessary due to the potential size limitation of the Queue and the expected size of Log Messages.

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<sup>14</sup> <http://msdn.microsoft.com/en-us/library/ff960705.aspx>

<sup>15</sup> <http://msdn.microsoft.com/en-us/library/ff960705.aspx>

The final internal interface I-202, connected to the Business Logic Library and provided the pipeline for messages that were transmitted back to the In-Vehicle device from the infrastructure, including configuration settings, zone and rate updates and administrative alert messages.



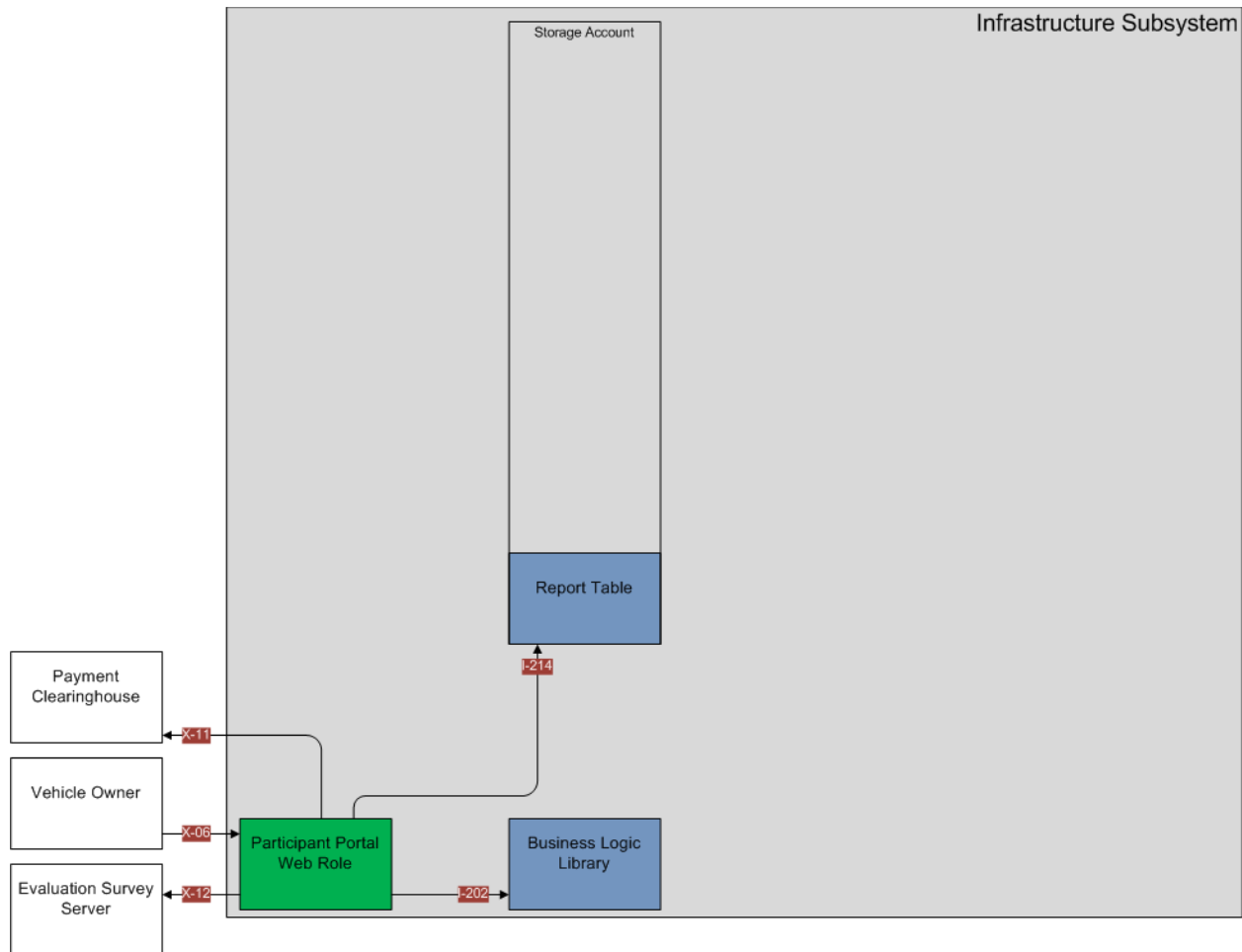
**Figure 27. CVSMUF Software System from the Perspective of the Vehicle Communications Web Role Software System Element**

### 3.2.5 Participant Portal (Hosted Service) Web Role

The Participant Portal Web Role, hosted as part of the Participant Portal Hosted Service, provided the Internet accessible web pages for the 500 CVSMUF demonstration participants. This portal provided access to information and data related to their participation in CVSMUF as well as to manage their MBUF accounts. This included the ability to make online payments as well as to submit service and help requests. Participants were provided with a logon and password to insure secure access to information pertaining to their account. The Participant Portal Web Role and its associated interfaces are illustrated in Figure 28.

The Participant Portal Web Role provided an external interface (X-06) from the CVSMUF Infrastructure subsystem to the study participant. This Interface was implemented through the use of numerous web-based user interfaces to support the various requirements and needs of the study participant. This interface supported both inputs from the study participant as well as conveyed data from the internal resources to the study participant.





**Figure 28. CVSMUF Software System from the Perspective of the Participant Portal Web Role Software System Element**

The Participant Portal Web Role also provided an interface (X-11) to allow for the study participant to access an external third-party payment clearinghouse to pay an invoice. Additionally, an interface (X-12) to access the Evaluation Service survey features was also provided.

Internally, the Participant Portal Web Role interfaced directly with both the Report Table, contained within the Azure Storage Account, via Interface I-214, and with the Business Logic Library, via interface I-202.

The Participant Portal Web Role served primarily as a presentation layer, and as such, the majority of the processing was deferred to the Business Logic Library layer. The Business Logic Library, in turn, interfaced with the Data Repository Database and the Probe and Log Database, for persistence of the data. In presenting information to the user, the Portal was organized into two major categories of functionality, the Public webpage, and the restricted access Participant web pages. Under the later, additional organization, as manifested in the User Interfaces (UI) design, allowed for the participant to manage user information and passwords, request or schedule service and to view invoices and other reports.

### 3.2.6 Administration Portal (Hosted Service) Web Role

The Administration Portal Web Role, hosted as part of the Administration Portal Hosted Service, provided the Internet accessible web pages for both the System Administrator and Data User roles to access and revise information and data related to their support of the CVSMUF demonstration. This portal was utilized by Battelle and the Evaluation Contractor throughout the demonstration project, but was not accessible to MnDOT staff.<sup>16</sup> This included the ability to create and revise participant accounts, change or modify MBUF invoices, and log and process help, odometer, and equipment maintenance requests. The Administration Portal Web Role and its associated interfaces are illustrated in Figure 29.

The Administration Portal Web Role provided external interfaces to both the System Administrator and Data User roles via interfaces X-08 and X-09 respectively. These interfaces were implemented through the use of numerous web-based user interfaces to support the various requirements and needs of these two roles. This interface supported both inputs from the System Administrator or Data User, as well as conveyed data from the internal resources to the user upon request.

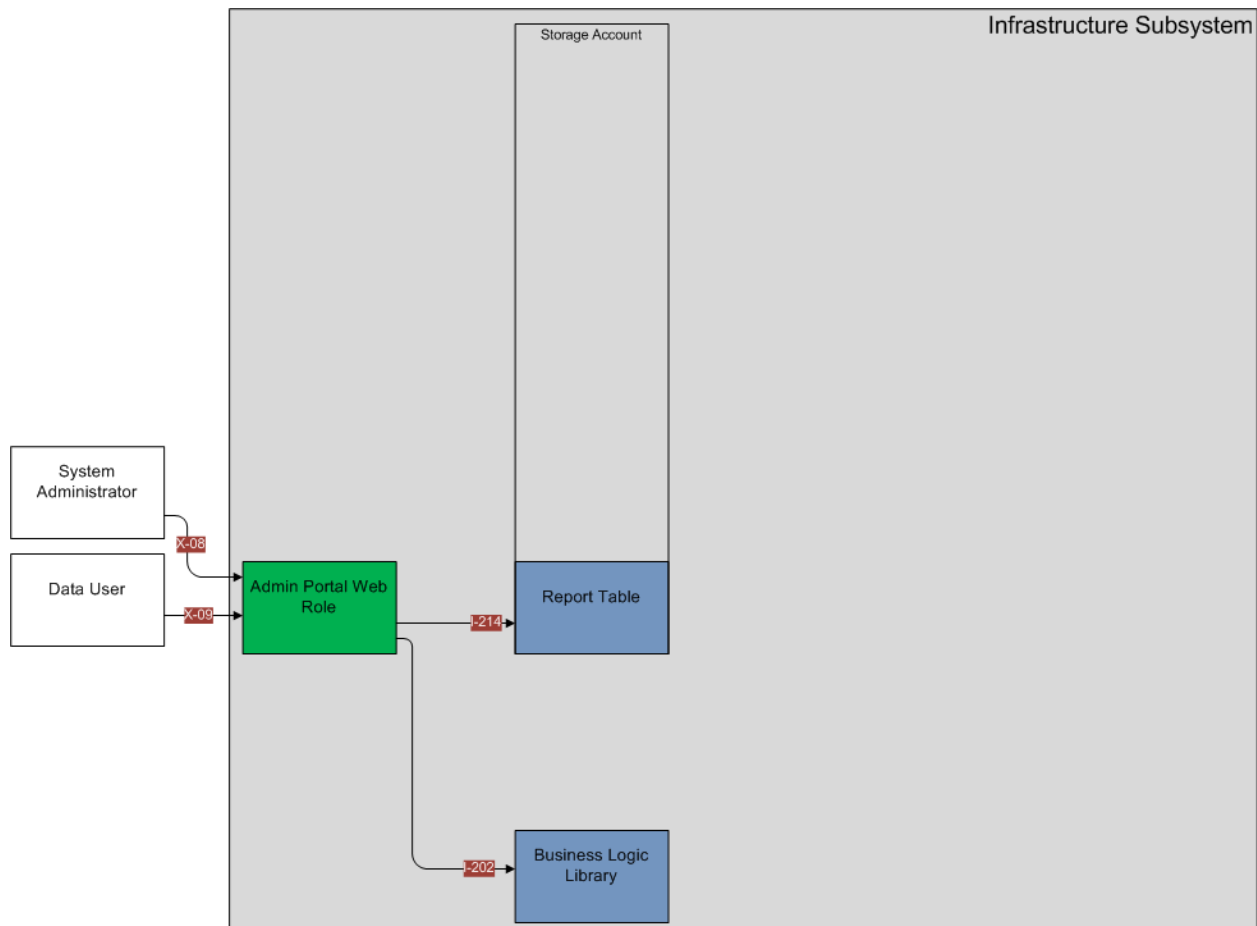
Internally, the Administration Portal Web Role interfaced with both the Report Table, contained within the Windows Azure Storage Account, via interface I-214, and with the Business Logic Library via Interface I-202.

The Administration Portal Web Role served as a presentation (view) layer in the implementation of the model view controller (MVC) pattern, and as such, processing was deferred to the Business Logic Library.

The Report Table served as a repository of previously generated reports, requiring minimal processing, and as a design decision, allowed the Administration Portal Web Role to directly access these archived reports. Being a secure website, access was only available for users who had entered valid credentials.

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<sup>16</sup> Participant specific information such as demographic information and responses to survey questions were not available to Battelle to preserve privacy. Similarly, SAIC did not have full access to the administration portal.



**Figure 29. CVSMUF Software System from the Perspective of the Administration Portal Web Role Software System Element**

### 3.2.7 Data Repository (SQL Azure Server) Database

The Data Repository Database was part of the CVSMUF infrastructure architecture and served as the primary storage location for a majority of the CVSMUF-related data to include participant MBUF data, MBUF rate tables, signage and MBUF zones; participant, device and vehicle details; invoicing and payment information; and service and maintenance activities. Essentially, with the exception of Probe and Log data, which was persisted in the Probe and Event Database, and the raw message storage, which was persisted by the Storage Account worker role, the Data Repository was responsible for persisting all other data maintained within the Infrastructure subsystem.

In addition to the storage capabilities, the data repository also served to generate or support the generation of most of the key systems reports associated with this project and the associated evaluation, again with the exception of probe data and log reports.

The Data Repository, along with the ASP.NET Membership classes, also served to provide the user and role-based security necessary to satisfy the requirements of this project. This includes

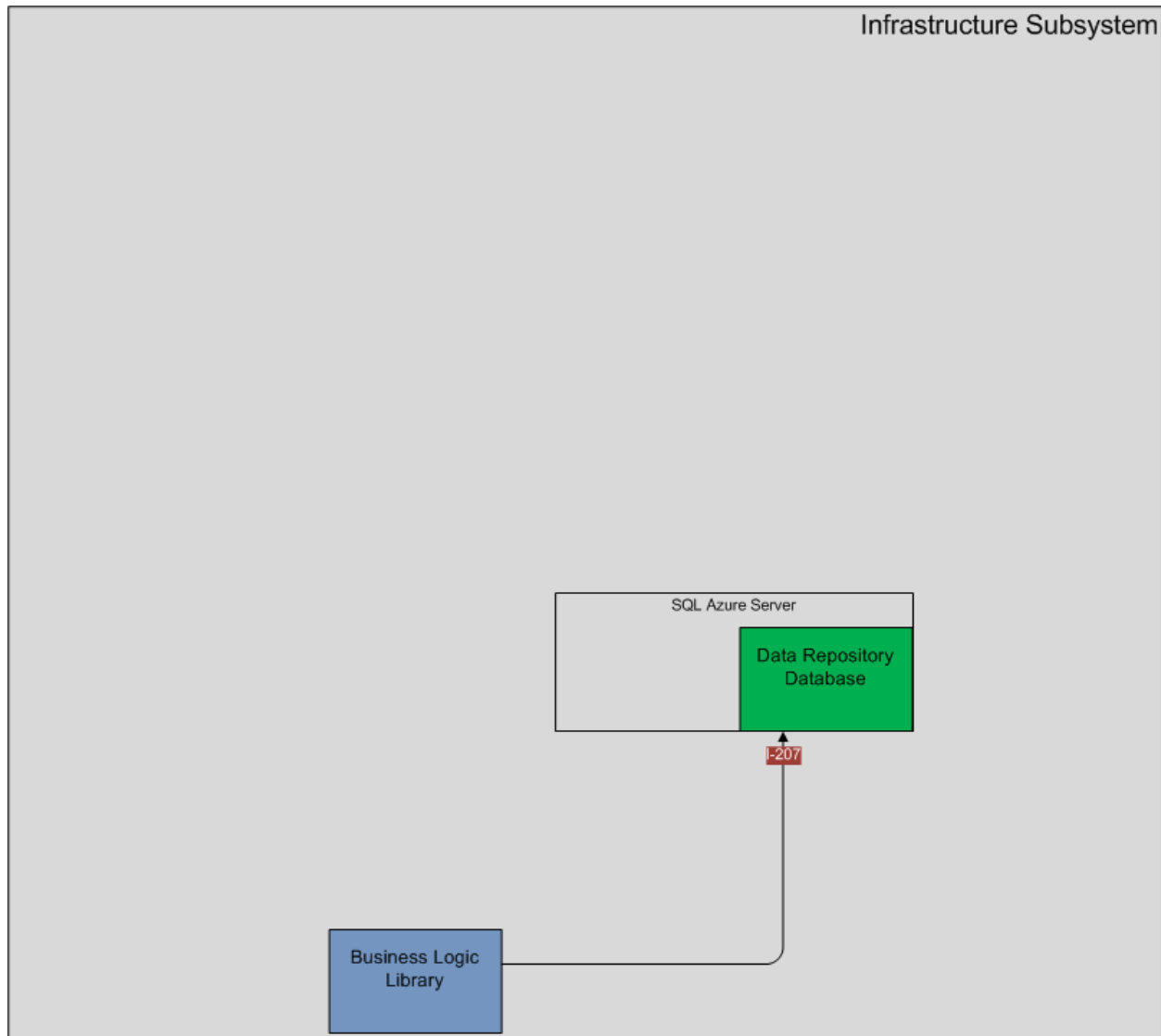
the storage of user accounts and roles available in the system and the mapping of which users were granted to which role.

Figure 30 represents the relationship between the Data Repository and other System Elements.

The Data Repository was located internal to the CVSMUF Infrastructure Architecture and contains only local interfaces within the infrastructure. While this system element received inputs and provided data to nearly all other system elements in the infrastructure (and to external interfaces) all access to the data and processing provided by this system element passed through the Business Logic Library system element via interface I-207. No other interfaces, internal or external were associated with this system element.

The Business Logic Library created, read, updated and deleted data in the Data Repository. This is a capability commonly referred to as CRUD in the software community. In addition, the Business Logic Library accessed pre-defined Queries and executed Stored Procedures as necessary to satisfy the business logic functions.

As with most traditional relational database management systems (RDBMS), the Data Repository consisted of the tables, views, relationships, constraints, triggers, and stored procedures necessary to perform the required functionality of the persistence layer associated with this overall system being implemented.



**Figure 30. CVSMUF Software System from the Perspective of the Data Repository Database Software System Element**

### 3.2.8 Probe and Log (SQL Azure Server) Database

The Probe and Log Database System Element was part of the CVSMUF infrastructure architecture and served as the primary storage location for the two large volume messages, Probe Snapshots and Log Messages.

In addition to the storage capabilities, the Probe and Log Database also served to generate or support the generation of several of the key systems reports associated with this project and the associated evaluation.

The Probe and Log Database was located internal to the CVSMUF Infrastructure Architecture and contained only a single local interface within the infrastructure. All access to the data, and processing provided by this system element, passed through the Business Logic Library system element, via interface I-212. No other interfaces, internal or external, were associated with this

system element. As this database was established for the specific purpose of persisting probe and log information, it served to receive only data that originated in the in-vehicle device and was subsequently passed from the Vehicle Communications Web Role to the Storage Account, where it was operated upon by the Vehicle Payload Processing Worker Role, which subsequently passed it on the Business Logic Library for inserting it into the Probe and Log Database.

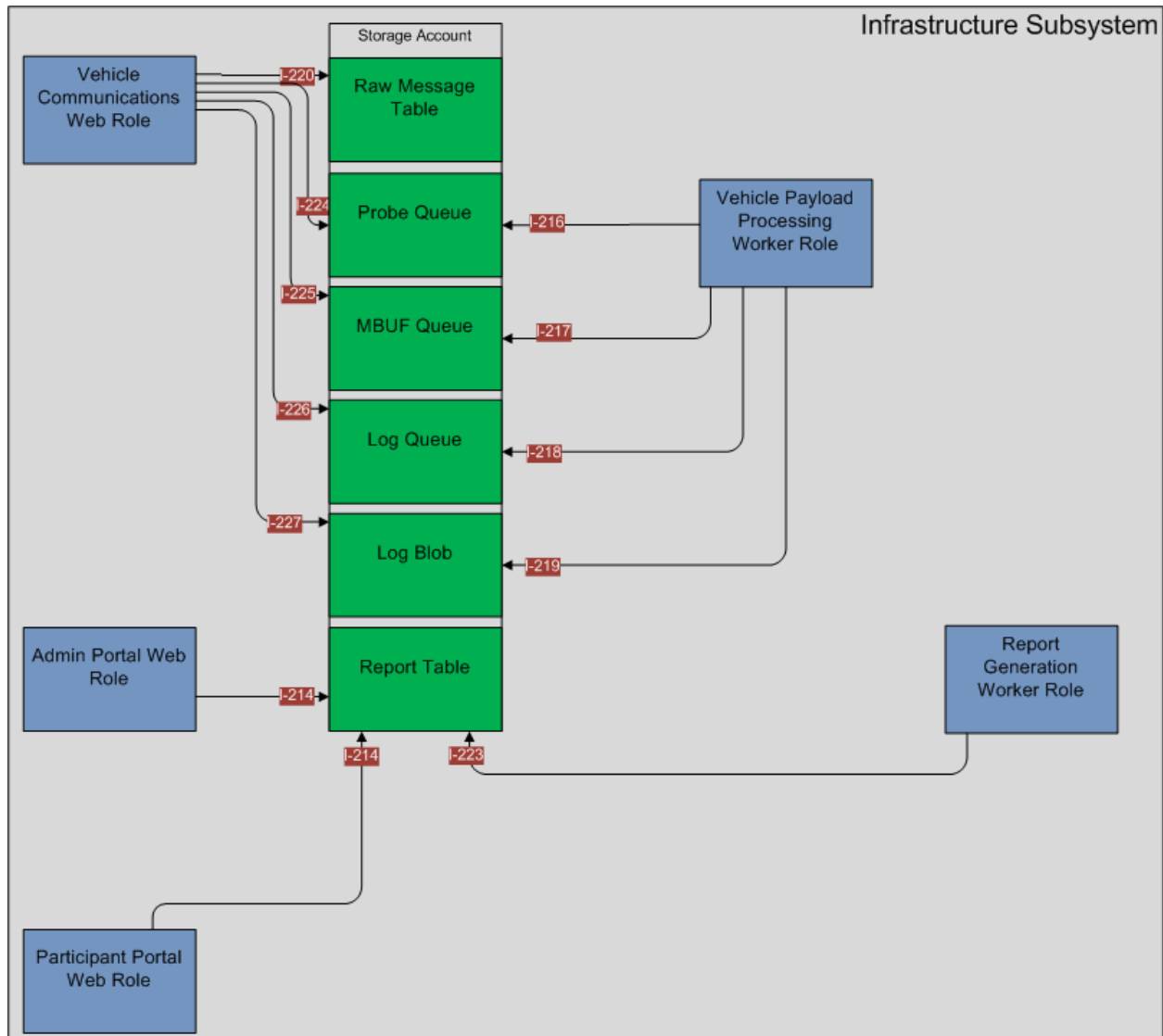
The Business Logic Library created, read, and updated data in the Probe and Log Database, and was responsible for all such actions with this system element. Additionally, the Business Logic Library accessed pre-defined Views and executed Stored Procedures as necessary to satisfy the business logic functions.

The database satisfied reporting needs of both the Participant and Admin/Data User. The Business Logic Library provided this information to the Report Generation Worker Role and Storage Account, which in turn, presented it to the requestor via the Participant and Administrative Portal Web Role's, as appropriate.

As with most traditional relational database management systems (RDBMS), the Probe and Log Database consisted of the tables, views, relationships, constraints, triggers, and stored procedures necessary to perform the required functionality of the persistence layer associated with the overall system being implemented.

### **3.2.9 Storage Account**

The Windows Azure storage services provided persistent, durable storage “in the cloud.” The fundamental storage services included Blob storage, Queue Storage, and Table Storage. The storage services were used for three primary purposes. The first was to temporarily store data messages received by the Vehicle Communications Web Role until they can be processed by the Vehicle Payload Processing Worker Role. The second was to provide a storage location where the raw data messages received from the In-Vehicle devices was persistently stored intact for potential re-processing in the event an error occurs with the original message processing. The third use of the storage services was to store the generated reports for later review and retrieval by the users of the Admin Portal. The Storage Account components (highlighted in green) and the associated interfaces are illustrated in Figure 31.



**Figure 31. CVSMUF Software System from the Perspective of the Storage Account Software System Element**

Figure 31 illustrates how the Storage Account was used to provide temporary storage for data messages received by the Vehicle Communications Web Role and processed by the Vehicle Payload Processing Worker Role. By utilizing this temporary storage, the process of transmitting the data messages and their being processed was de-coupled and performed asynchronously.

When the Vehicle Communications Web Role received a new Log Message Report (MSG\_015), it stored that data into the Log Blob via interface I-227. The location of where that message was stored in the Log Blob was then be entered into the Log Queue using interface I-226. The Vehicle Payload Processing Worker Role received the location of where the Log Message Report (MSG\_015) was stored via interface I-218 and retrieved the saved Log Message Report (MSG\_015) from the Log Blob over interface I-219. After the Log Message Report had been

successfully processed, the message in the Log Queue and the persisted data in the Log Blob were deleted via the same interfaces used to retrieve the data.

The process by which the Vehicle Communications Web Role and the Vehicle Payload Processing Worker Role was very similar to that employed to process the Log Message Reports (MSG\_015). The difference however was in the fact that a temporary Blob storage was not needed as a result of the content being added to the Queue did not exceed the 8 KB limit. Therefore, interface I-224 and I-225 were used to add the Probe Vehicle Data (MSG\_037) message and the MBUF Accumulated Mileage (MSG\_016) to the Probe Queue and the MBUF Queue respectively. On the processing side of the queues, the Vehicle Payload Processing Worker Role utilized interfaces I-216 and I-217 to retrieve the Probe Vehicle Data (MSG\_037) message and the MBUF Accumulated Mileage (MSG\_016) for processing. Just like the processing of Log Message Reports (MSG\_015), once the queued messages had been successfully processed, the messages were deleted from their respective queues.

Because of the critical nature of the data in the data messages transferred from the In-Vehicle device, a requirement was imposed by Battelle requiring that an intact copy of each raw data message as it was received by the Infrastructure system be stored. By storing these backup copies, there was the opportunity to re-process any lost or damaged data messages should it be necessary. The diagram in Figure 31 shows that each of the three message types were stored into a common raw message table. The storage of these messages into the Raw Message Table was performed by utilizing the I-220 interface.

The Infrastructure subsystem generated a number of periodic reports. The Storage Account was used to store those reports until requested by the Participant, System Administrators or Data Users. Figure 31 shows that the reports were created and stored by the Report Generation Worker Role using interface I-223. Access to the saved reports was served through the Participant and Admin Portal Web Roles both using interface I-214.

### **3.2.10 Vehicle Payload Processing (Hosted Service) Worker Role**

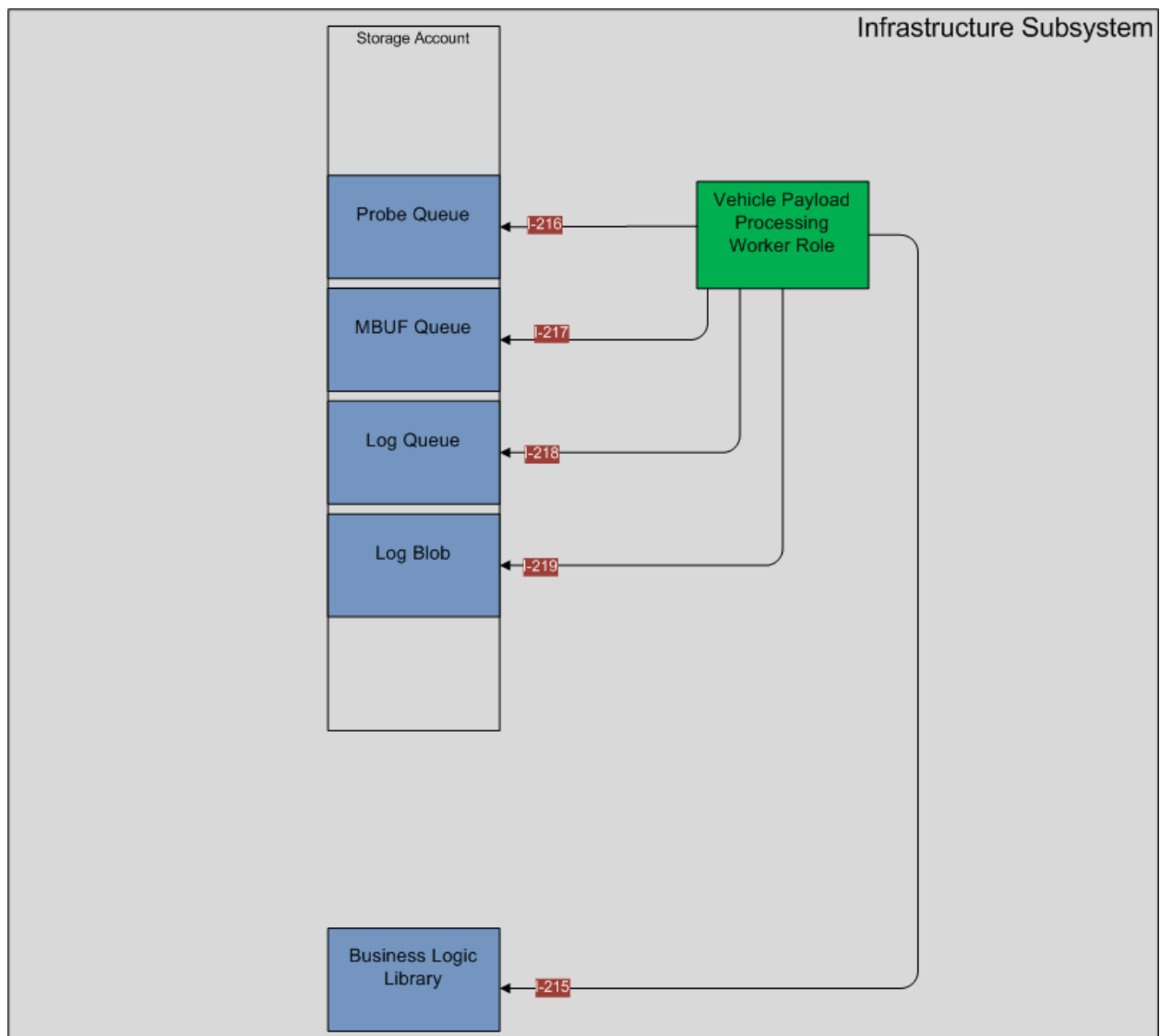
The Vehicle Payload Processing Worker Role served to process and parse all received MBUF Reports (MSG\_016), Probe Vehicle Data (MSG\_037) messages, and Log Message Report (MSG\_015) messages. Following this parsing, the Vehicle Payload Processing Worker Role was responsible for transmitting the parsed data to the corresponding data stores via the Business Logic Library.

The Vehicle Payload Processing Worker Role was located internal to the CVSMUF Infrastructure Architecture and contained only local interfaces within the infrastructure. Additionally, the Vehicle Payload Processing Worker Role served only as an implementer or “talker,” invoking services on other system elements, but it itself was not formally invoked by any other system element other than upon initiation of the worker role in the Azure Fabric. Rather, the Vehicle Payload Processing Worker Role was a data driven element that was situated between the various data Queues established in the Azure Storage Account service and the Business Logic Library. There were three specific Queues, as well as a binary large object (Blob) storage service that the Vehicle Payload Processing Worker Role was connected with to process messages. Separate threads for each message type, along with a scheduler to invoke the retrieval of queued messages were executed within the Vehicle Payload Processing Worker Role.



Upon completion of processing (parsing) the messages, services running on the Business Logic Library were invoked to persist the processed data in the respective databases.

As shown in Figure 32, I-216 was the interface between the Probe Queue and the Vehicle Payload Processing Worker Role. I-217 was the interface to the MBUF Queue and I-218 and I-219 to the Log Queue and Log Blob respectively. The Log Queue and Blob were unique in that potential size constraints prevent storage of the Log Message Report messages in the Queue, and as such, the Log Blob was used to temporarily persist the Log Message Report (MSG\_015) until it was processed. These queues were populated with the RAW messages generated by the in-vehicle device and as transmitted to the Infrastructure via the Vehicle Communications Web Role. Data processed by the Vehicle Payload Processing Worker Role was ultimately persisted in the Data Repository Database or the Probe and Log Database, as applicable. Access to the Business Logic Layer is over the I-215 interface.

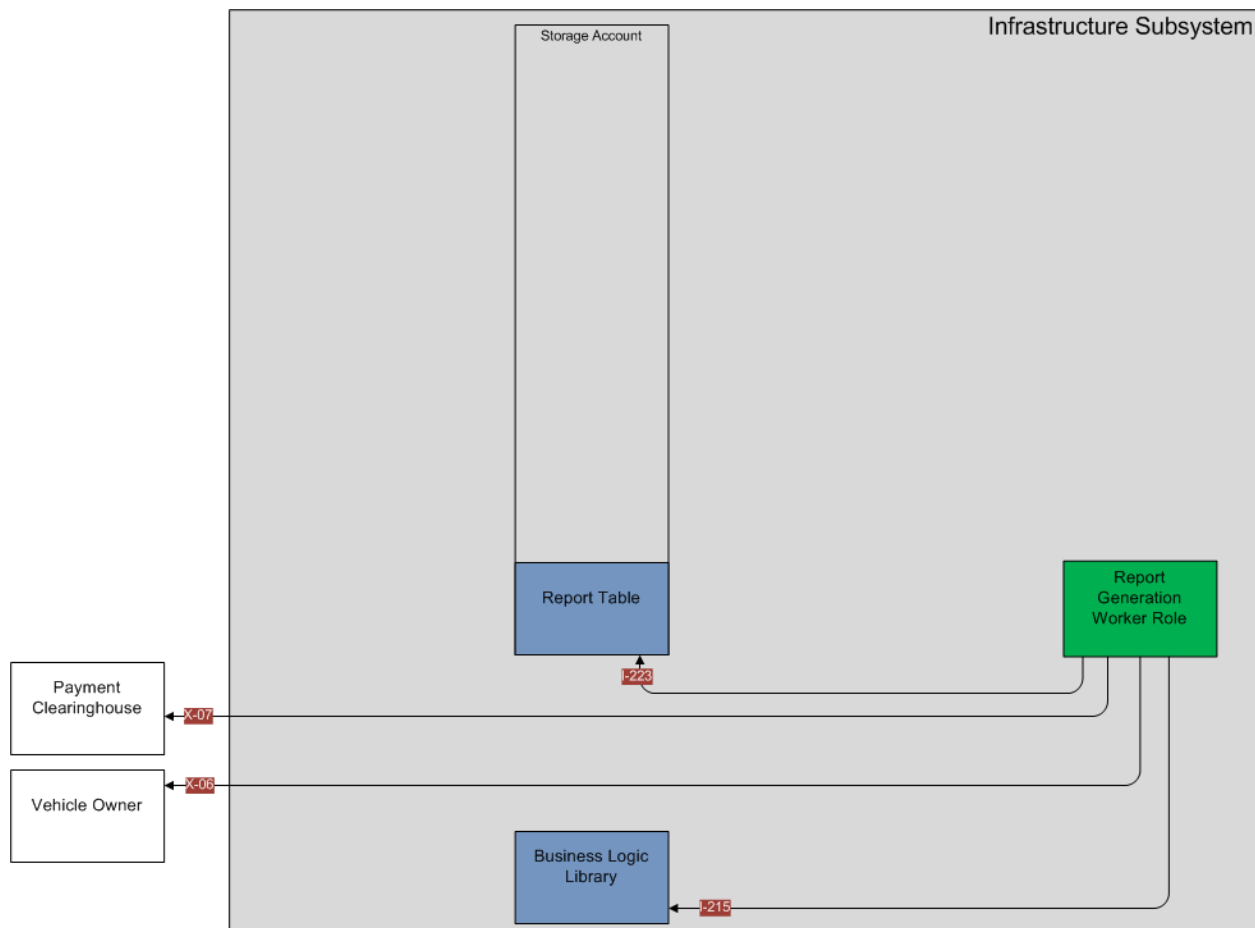


**Figure 32. CVSMUF Software System from the Perspective of the Vehicle Payload Processing Software System Element**

### 3.2.11 Report Generation (Hosted Service) Worker Role

The Report Generation Worker Role served the function of producing the recurring, regularly scheduled reports defined to support the evaluation and system management efforts. The Report Generation Worker Role also archived these reports for permanent storage and managed the PayPal payment status of invoices.

As shown in Figure 33, the Report Generation Worker Role was located in the Infrastructure Subsystem of the CVSMUF System and had four interfaces directly associated with it. Internally, this System Element interfaced with the Business Logic Library via I-215 and with the Report Table component of the Storage Account system element via I-223. These two interfaces and corresponding software components of this worker role served to execute the functions of the Business Logic Library associated with generating the predefined and regularly scheduled reports and persisted a copy of these reports in the Report Table for subsequent access by the CVSMUF team via the Administrative Portal Web Role.



**Figure 33. CVSMUF Software System from the Perspective of the Report Generation Software System Element**

The list of predefined reports that this worker role processed includes those listed in Table 2.

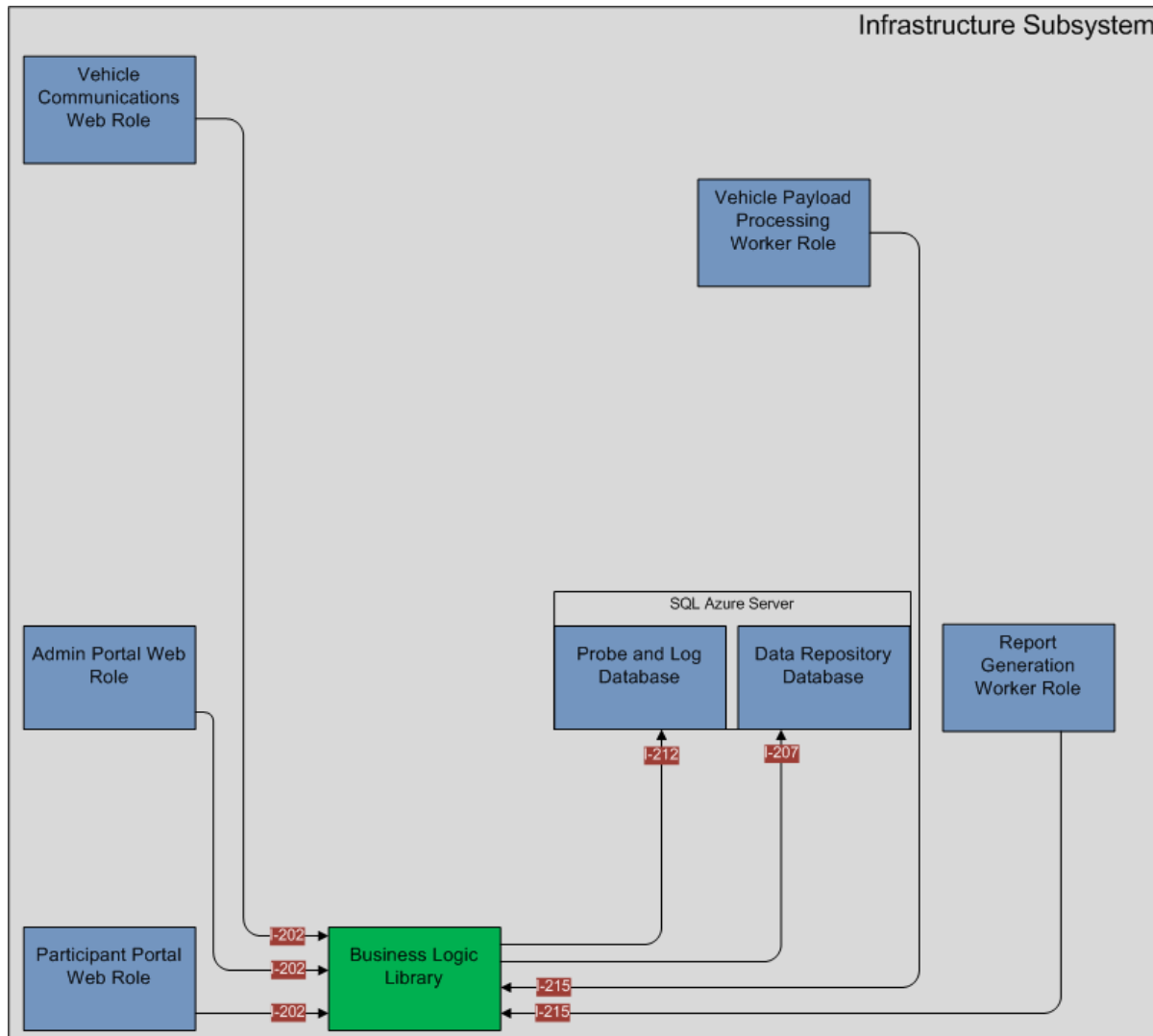
**Table 2. Predefined Reports**

Report Name	Frequency	Recipient	Description
Invoicing Report	Monthly	Evaluation Team	Comprehensive list of participant monthly invoices summarizing mileage by fee category
Maintenance Logs and Help Requests	Monthly	Evaluation Team	Table summarizing the maintenance logs and help requests captured in the CVSMUF system
Odometer Reading Report	Monthly	MnDOT	Table summarizing the status and recorded information corresponding to the Odometer readings
Number of Trips through Signage Zones	Monthly	MnDOT	Summary report of the number of trips that have crossed a signage zone for each signage zone
Device Usage	Weekly	MnDOT	Summary report that summarizes whether or not the participant's device had at least one registration event on a given day
Invoice Status Report	Weekly	MnDOT	Table that summarizes the current status of each invoice for each participant
Trip ID Report	Post-Wave	Evaluation Team	Participant submitted Trip IDs associated with the Participant ID
Travel Time Summary Report	Post-Wave	MnDOT	Demonstrate use of probe snapshots to generate travel times on select segments.
MBUF Monthly Invoices	Monthly	Participant	Monthly invoices on a per participant basis

To support the invoicing and payment status actions associated with the MBUF portion of this design, external interfaces X-06 and X-07 were also connected to the Report Generation Worker Role. Interface X-06 served as the conduit for forwarding an e-mail to the Participant with the current monthly invoice as an attachment. Interface X-07 connected with the external Payment Clearinghouse service, PayPal, and retrieved the summary of recently paid invoices. This list was forwarded to the Business Logic Library where it was subsequently processed and the account information updated accordingly.

### 3.2.12 Business Logic Library

From a high-level perspective, the Business Logic Library was the middle layer between the presentation layer (Web Portals, Vehicle Payload Processing and Report Generation) and the data layer (databases). This middle layer was responsible for managing the intake of inbound data, controlling access to the data, directing communications between the various components and providing rules and logic for how the data was to be formatted and processed. In short, the Business Logic Library was the “central controller” of the infrastructure subsystem. The Business Logic Library and its associated Interfaces are illustrated in Figure 34.



**Figure 34. CVSMUF Software System from the Perspective of the Business Logic Software System Element**

The Business Logic Library was fully internal to the CVSMUF Infrastructure Subsystem and as such, has no interfaces that extend outside of the Infrastructure. It did however handle nearly all data exchanged between system elements within the Infrastructure. Consistent with standard database practices for a three-tier architecture, all access to the data layer passed through the Business Logic Library. CVSMUF utilized two major database components, the Data Repository Database and the Probe and Log Database, which were accessed only via the Business Logic Library through interfaces I-207 and I-212 respectively.

On the outward facing side of the three-tier architecture, all externally facing ‘presentation’ layers were also connected to the Business Logic Library. In this case, the business logic provided the intelligence behind the visual components (web pages or web services) provided by these externally facing system elements. From a CVSMUF perspective, there were three primary, external facing system elements, the Vehicle Communications Web Role, the

Participant Portal Web Role and the Administrative Portal Web Role. All three of these system elements interfaced with the Business Logic Library via a single interface, I-202.

The other two system elements shown here were the Vehicle Payload Processing Worker Role and the Report Generation Worker Role. Both served in specialized roles to interface with components of the cloud-computing environment. The role that the Business Logic Library played in this relationship was consistent with what was described above, serving as the layer between the data and the services creating and using the data. Both the Vehicle Payload Processing Worker Role and the Report Generation Worker Role communicated with the Business Logic Library over interface I-215.

### **3.3 Software Application Operational Description**

The functional intersection of the In-Vehicle subsystem and Infrastructure subsystem occurred with the operation of the mileage based user fee software application. In all cases, the Infrastructure subsystem was required to be continuously operating. The Infrastructure subsystem served as the backend for operation of the custom CVSMUF application. Beyond the core software application operation described herein, base Smartphone functionality was limited. In particular, the ability to send and receive calls was disabled and texting was disabled. Only critical or embedded applications remained on the Smartphone. Participants were unable to download additional applications beyond those provisioned by the design team. The Smartphone and software application system elements in particular, were configured to operate with the infrastructure subsystem

To facilitate a description of how each of the software application system elements work with each other and the infrastructure, a number of sequence steps and associated diagrams were created to describe how the system functioned and how each of these system elements contributed to the required functionality.

#### **3.3.1 In-Vehicle Device Initialization**

This section describes the sequence of events that occurred when the system was started. This was the typical sequence of a normal driving startup experience and was performed over 500,000 times. The driver of the vehicle did not perform any of the procedure except for plugging in the phone correctly and starting the vehicle. The vehicle then provided power to the phone initiating the custom CVSMUF application to initialize a new trip. The application automatically started when the Smartphone was powered on and was running at all times. This procedure took approximately 3 to 4 seconds and required the GPS service to locate the vehicle before a fee displayed on the Smartphone screen indicating mileage recording has started.

##### **3.3.1.1 In-Vehicle Subsystem Startup Sequence**

The initialization began when a participant entered the vehicle and verified the Smartphone was installed correctly. The Smartphone was connected to the Power Management Module which received power from the vehicle's cigarette lighter or auxiliary power port. Once the participant started the vehicle, a sequence of software application processes occurred signaling to the CVSMUF system that a trip was beginning. That sequence is described in the following numbered list and in Figure 35 and Figure 36. The numbered list corresponds to the circled

numbers on the left of Figure 35. This sequence occurred for Operational Scenarios A-E as described in the Concept of Operations Documents.

- 1) The vehicle supplied voltage to the Smartphone.
- 2) The CVSMUF Software Main class was the main startup application for the In-Vehicle system. The Main class subscribed to Android battery events to detect power on and power off of the vehicle's ignition (MSG\_034).
- 3) The Main Class created a Trip ID and stored it in the Trip ID Table (TBL\_V01) and then created a new log message with the Trip ID and sent it to the Logging Class (MSG\_014).
- 4) Main class created a start trip log message and sent it to the Logging Software (MSG\_014).
- 5) The Vehicle Communications Support Package verified that the Navigation Device was in the targeted vehicle by receiving a Vehicle ID message (MSG\_055) from the Vehicle ID Module.
- 6) When the vehicle ID had been verified, the main user interface was displayed.
- 7) In parallel with the display of the user interface the Main class would send a registration message to the infrastructure subsystem through the Vehicle Communications Support Package (MSG\_040).
- 8) Once the registration message had been sent, the Main class retrieved the application configuration from the infrastructure subsystem through the Vehicle Communications Support Package (MSG\_005 and MSG\_006) and wrote the new values to local storage.
- 9) The Main class would then create a Positioning Class, Probe Class, MBUF Class and Signage Class. The Main class would call the start method on each class (MSG\_059).
- 10) When the MBUF Collection class started, it would query (MSG\_022) the Infrastructure Subsystem for any MBUF Zone Updates. If updates were available, the infrastructure would send back any new MBUF Zones (MSG\_023) and they were stored in the MBUF Zone Information Table (TBL\_V06).
- 11) The MBUF Collection class would then query (MSG\_021) the Infrastructure subsystem for any MBUF Zone Rate Updates. If there were any updates, the infrastructure would send back any new MBUF Zone Rates (MSG\_024) and store them in the MBUF Zone Rate Information Table (TBL\_V05).
- 12) When the Signage class started, it would query (MSG\_003) the Infrastructure subsystem for any Administrative Messages. If there were any messages, the infrastructure would send back the new messages (MSG\_001) and they would be stored in the Administrative Message Table (TBL\_V04). If the vehicle was not moving any Administrative messages were shown to the operator.
- 13) The Signage class would then query (MSG\_046) the Infrastructure subsystem for any Signage Zone Updates. If there were any updates, the infrastructure would send back the new zones (MSG\_047) and they would be stored in the Signage Zone Table (TBL\_V03).
- 14) The system was now setup and running and the Main class would wait for the power off event.

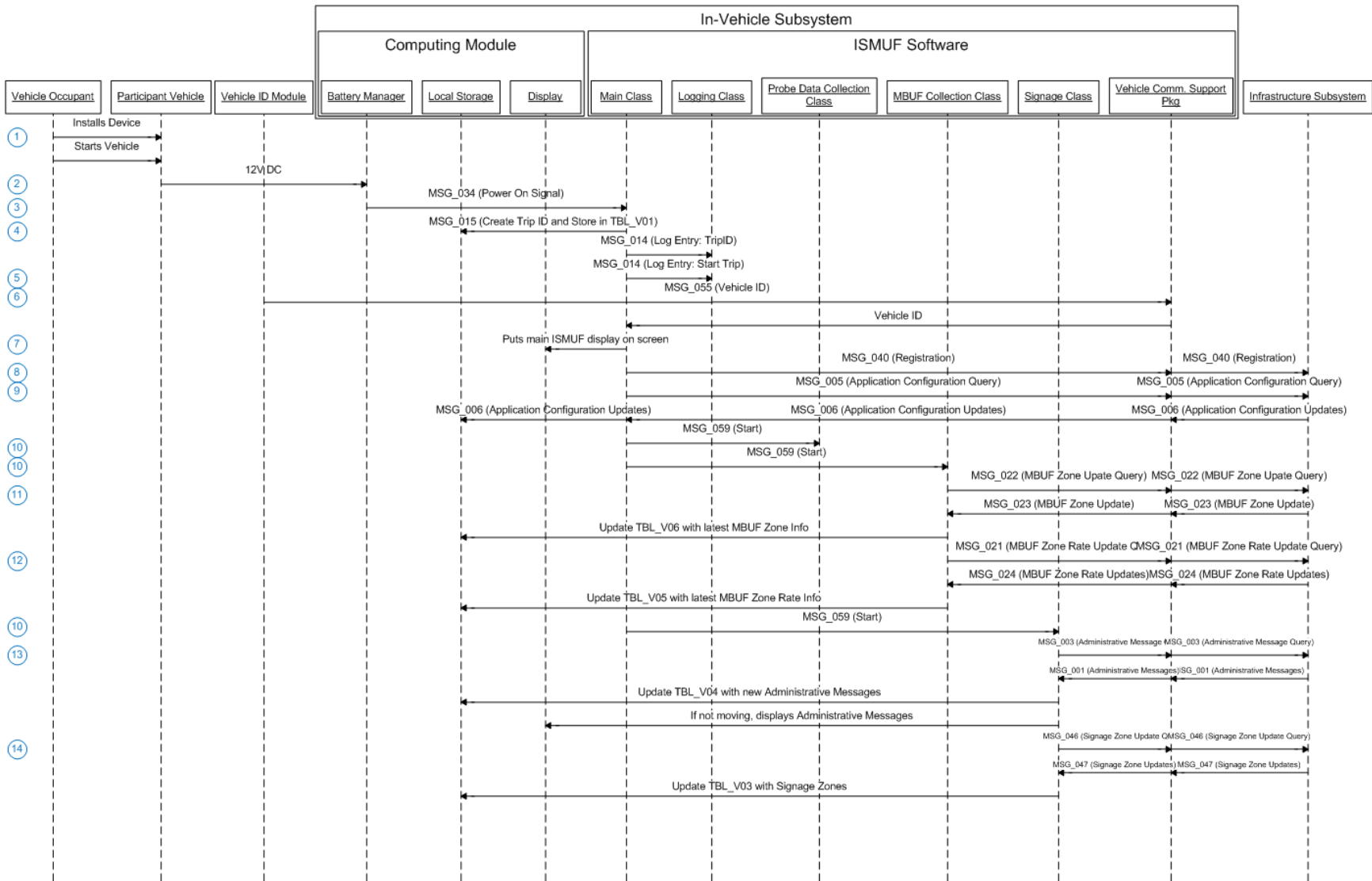


Figure 35. In-Vehicle Device Initialization (In-Vehicle Sequence)

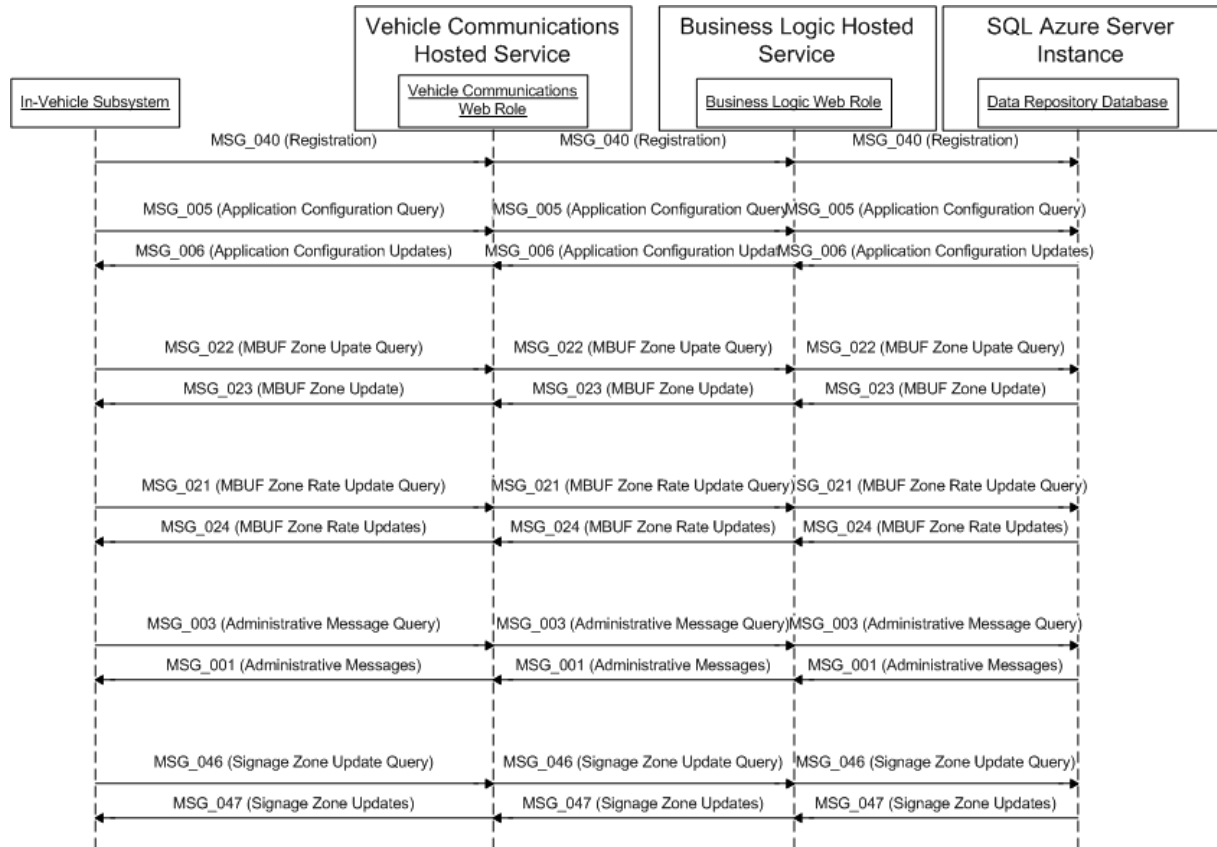


Figure 36. In-Vehicle Device Initialization (Infrastructure Sequence)

### 3.3.2 MBUF

The MBUF Collection Software was responsible for determining the current MBUF price, logging miles driven in MBUF zones, and calculating MBUF cost to the driver based on accumulated mileage and zone price. The sequence of events for the MBUF Class is shown in Figure 37 and Figure 40. Figure 37 shows the interaction between the different entities of the system but does not necessarily show the time sequence of the events. Figure 40 shows the flow of the software that could not be clearly shown in the sequence diagram. The two figures give a complete view of the MBUF Software.



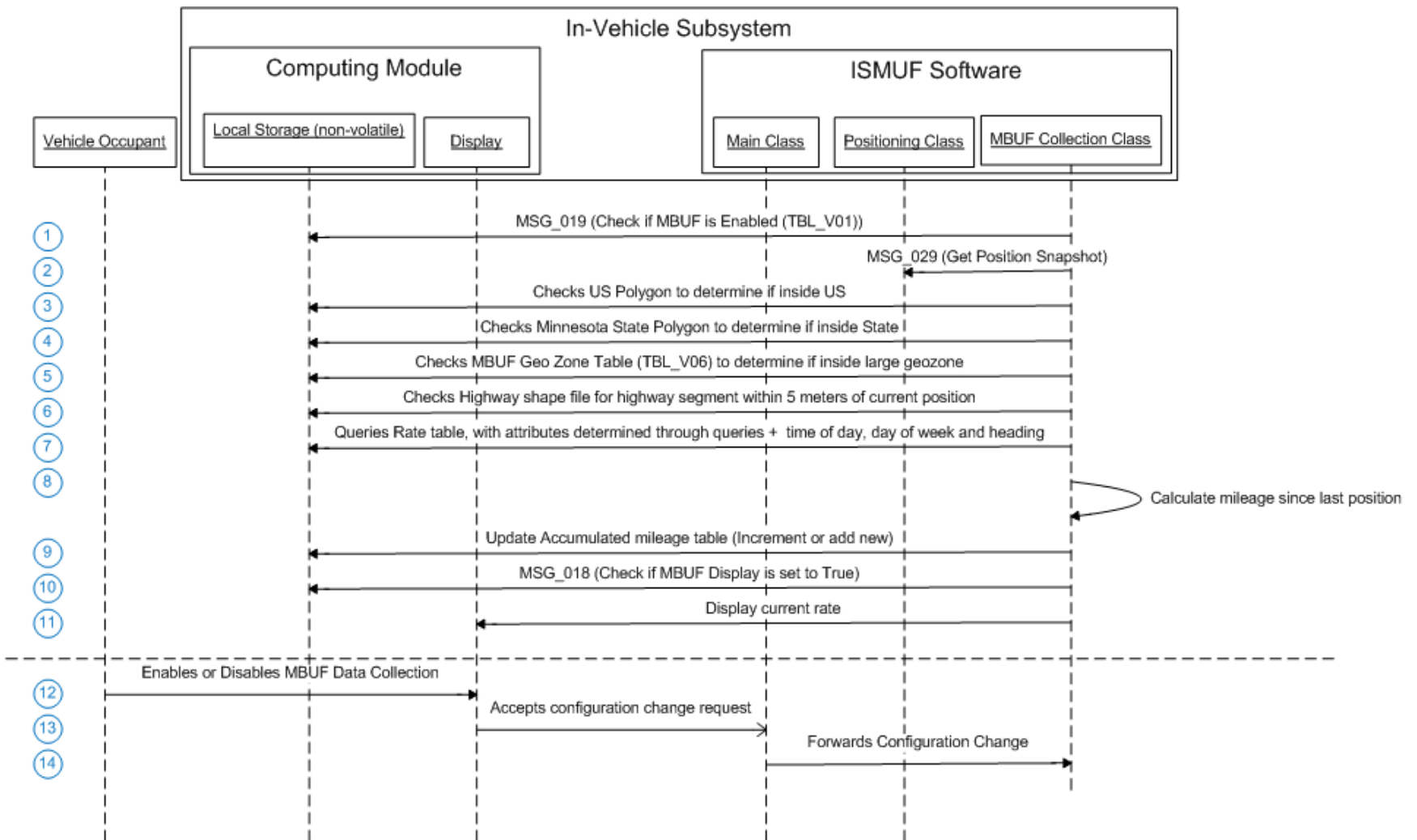


Figure 37. MBUF In-Vehicle Sequence

This numbered list corresponds to Figure 37.

- 1) The top sequences, steps 1 through 11, were executed once a second. The first step was to check the MBUF enable flag. If MBUF was enabled proceed to the next step, if it was disabled return to step 1.
- 2) Received the position and heading of the Vehicle from the Positioning Class.
- 3) Calculated if the vehicle position was within the United States polygon.
- 4) Calculated if the vehicle position was within the Minnesota state polygon.
- 5) Calculated if the vehicle position was within a MBUF Geo Zone Area by accessing the MBUF Geo Zone Table (TBL\_V06).
- 6) Calculated if the vehicle position was within 5 meters of a Highway.
- 7) Queried rate table based on the calculations in steps 3 through 6, time of day, day of week and vehicle heading.
- 8) Calculated the mileage since the last position update.
- 9) Updated the Accumulated Mileage Table by incrementing existing entry or adding a new entry.
- 10) Checked the Display Enable flag was set from local storage using MSG\_018.
- 11) Displayed current rate on display if the Display Enable flag was true.

The Vehicle Occupant was able to asynchronously change the state of the enable. The sequence for this input is described in steps 12 through 14.

- 12) The Vehicle Occupant was able to asynchronously change the state of the enable so the sequence for this input started with the occupant selecting the enable/disable button.
- 13) The enable change request event was sent to the Main Class.
- 14) The MBUF Enable state was store forwarded to the Probe Data Collection Class.

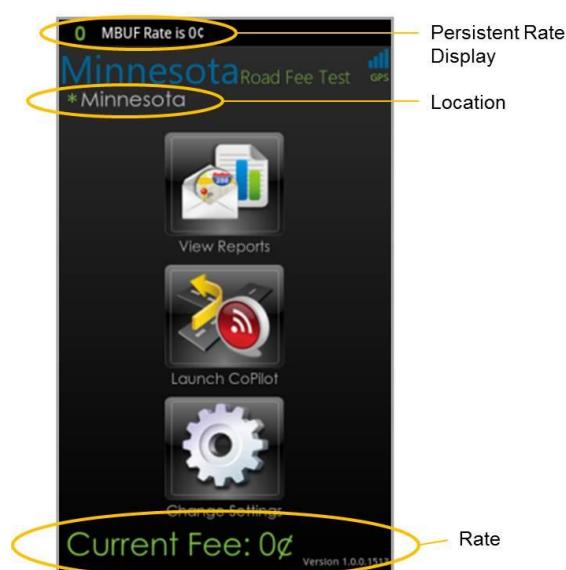
The MBUF software application utilized a predetermined rate structure assigned to the Smartphone at the first odometer reading. The rate structure was based on geographic location (polygons derived from GPS data), time of day and roadway. The rate structure was configured within the infrastructure prior to deployment of the Smartphone. The table of rates employed across all participant groups is shown in Figure 38. For those miles not collected by the MBUF software application a default rate of \$.03 was applied.

Current Driving Location	Peak Times Monday, Tuesday, Wednesday, Thursday, Friday 7AM-9AM 4PM-6PM	Off Peak Times
Outside of Minnesota	\$.00	\$.00
Inside Minnesota and Outside the Twin Cities	\$.01	\$.01
Inside the Twin Cities	\$.03	\$.01

**Figure 38. Rate Table for All Participant Groups**

A sample Smartphone screen displaying rate and location information is shown in Figure 39. Note the display of the MBUF rate in the top information bar on the screen. This display was persistent during use of the navigation application or when the Android home screen was displayed. The MBUF application would continue to run despite use of the navigation application. The location display included a description of where the participant was currently located. The asterisk symbol (\*), to the left of the location label, indicated the participant was on an interstate roadway.

A report was sent to the infrastructure of all miles and associated fees accumulated every 24 hour period. This report included details of location and time associated with the rate. The information was then available to the participant via the participant web portal. Accumulated fees were combined and presented in the form of an invoice at the end of every month.



**Figure 39. Sample Screen Showing Rates and Location**

This numbered list corresponds to Figure 40.

- 1) If the MBUF was enabled the MBUF Class started checking the MBUF Rates. If it was not enabled, it would wait then recheck the enabled state.
- 2) Received the current position and heading from the Positioning Class.
- 3) Checked if the vehicle was in the same geography zone.
- 4) If the vehicle was not in the same geography zone, calculated current zone.
- 5) Calculated if the vehicle was on an interstate.
- 6) Calculated mileage since last update and current MBUF rate.

- 7) Updated the Accumulated Mileage Table.
- 8) Displayed the MBUF rate.
- 9) The MBUF Rate was checked every second via the one second timer.
- 10) The Vehicle Occupant could asynchronously change the state of the enable so the sequence for this input started with the occupant selecting the enable/disable button.

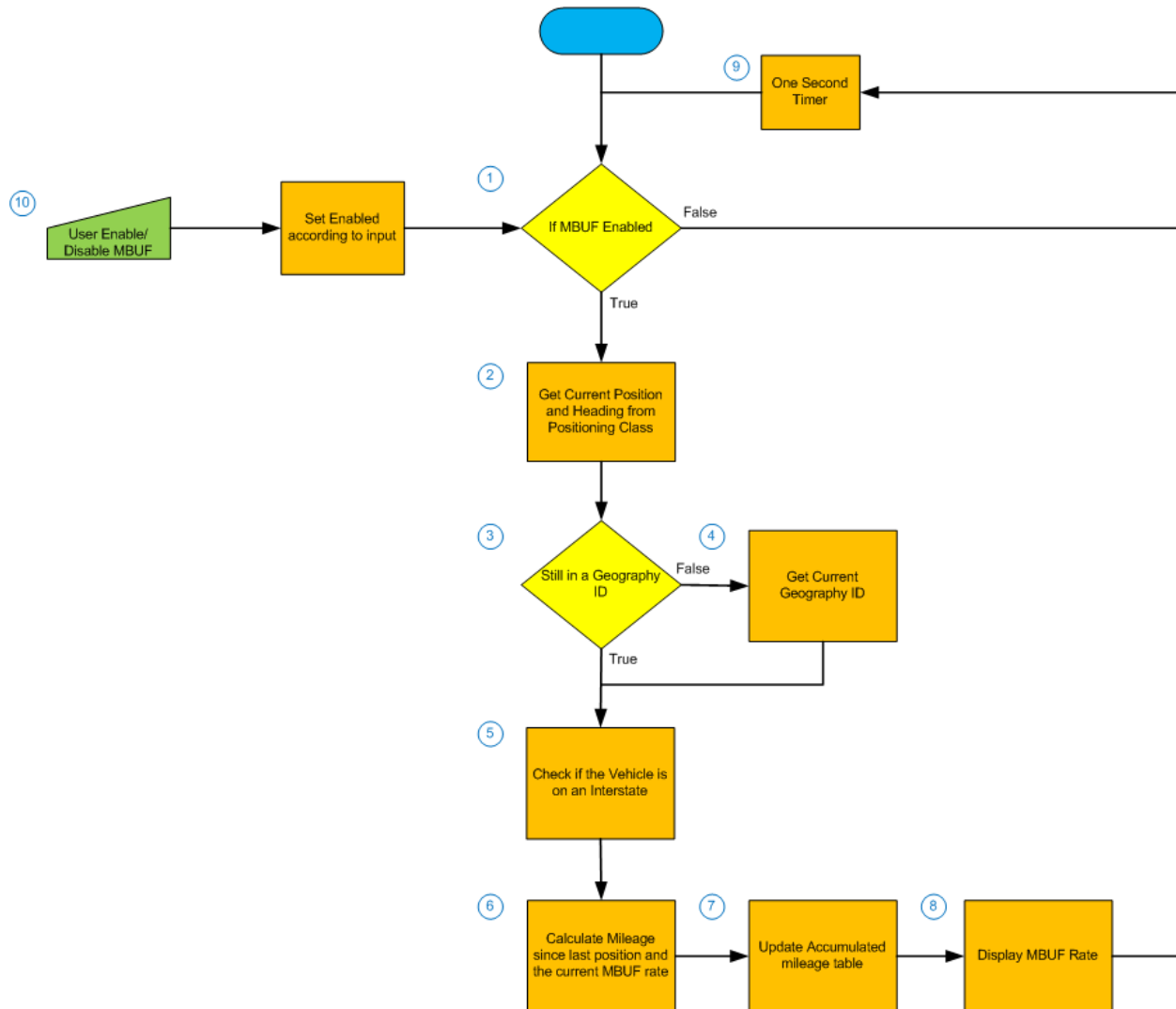


Figure 40. MBUF In-Vehicle Flow

### 3.3.3 Probe Data

Individual Probe data could be sent to the project Infrastructure subsystem. This Probe data transmission was optional to all test participants. Each participant also had the choice to send their Probe data anonymously or link their Probe data to their account. Participants had the option to either keep their data on their phone only, chose to send each Trip ID individually after each trip, or setup a default setting to send each Trip ID without prompting after each trip.

Many of the participants chose to send their Probe data and Trip IDs. As discussed herein, over 660 million Probe Data Snapshots were collected over the entire study.

The collection and transmission of this trip information was termed Probe Data Collection. Probe Data Collection was part of the custom CVSMUF application and was responsible for collection of Probe Data Snapshots, packaging those snapshots into a Probe Data Message and transmitting them to the Infrastructure subsystem. The Probe Data Message consisted of the Latitude, Longitude, elevation, speed and heading. The Probe Data Collection was also responsible for generating a unique Trip ID associated with the time period from when the vehicle was powered up to when the vehicle was turned off. This Trip ID was used by the Probe Data Collection to tag individual snapshots and was the common element linking logs and log entries to vehicle position as collected and submitted by the Probe Data Collection system. The Probe Data Message was transmitted to the System infrastructure where it was stored in the Probe Raw Message Table and in the Probe and Log database.

This section will describe the sequence of collecting probe messages and sending them to the System Infrastructure. The process is broken into two sections describing the In-Vehicle Sequence and the System Infrastructure Sequence.

#### **3.3.3.1 Probe Data In-Vehicle Sequence**

The Probe Data Collection was started in the custom CVSMUF application by the Main class as described in Figure 41. The sequence of events after the Probe Data was started is described in the following numbered list and in Figure 42 and Figure 43. Figure 41 shows the interactions between the different parts of the system. This chart does not clearly state the Probe Data Collection so Figure 42 was added to show the detailed flow within the class.

This numbered list corresponds to Figure 41.

- 1) When the Probe Data collection started it checked for an enable (i.e. the participant has enabled probe collection on the Smartphone)
- 2) If the probe was enabled, the Probe Data Collection Class would start collecting data snapshots.
- 3) Once 20 snapshots were collected the message was sent to the Infrastructure subsystem.
- 4) The vehicle occupant could asynchronously change the state of the enable so the sequence for this input started with the occupant selecting the enable/disable button. This event was sent to the Probe Data Collection Class.
- 5) The Probe Data Collection Class checked the state of the Disable Probe Override if the selection was to disable otherwise it would continue to send messages if the override was true. If the enable state was true the collection would start.

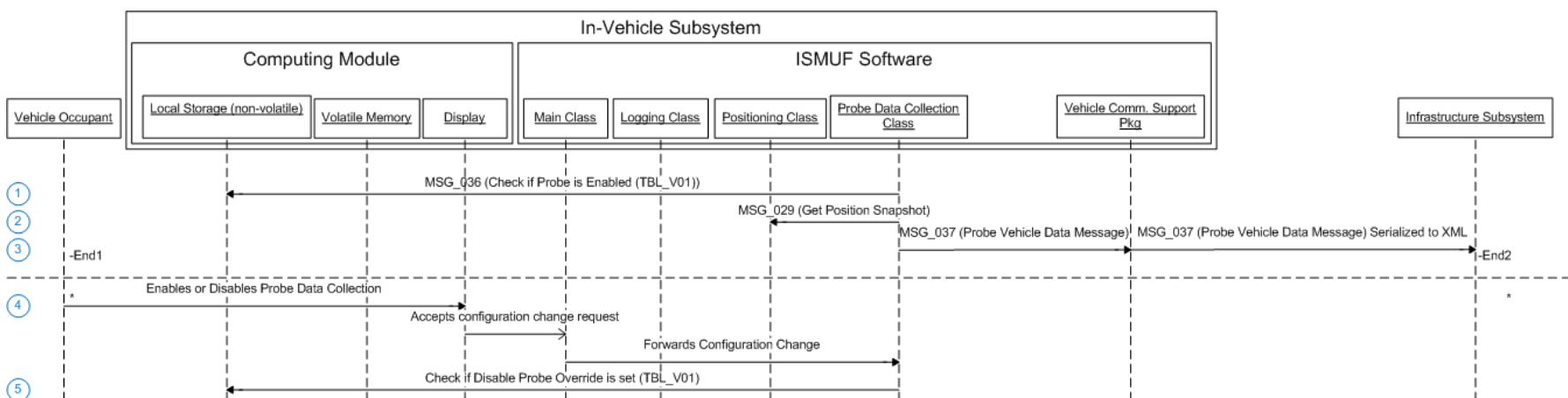
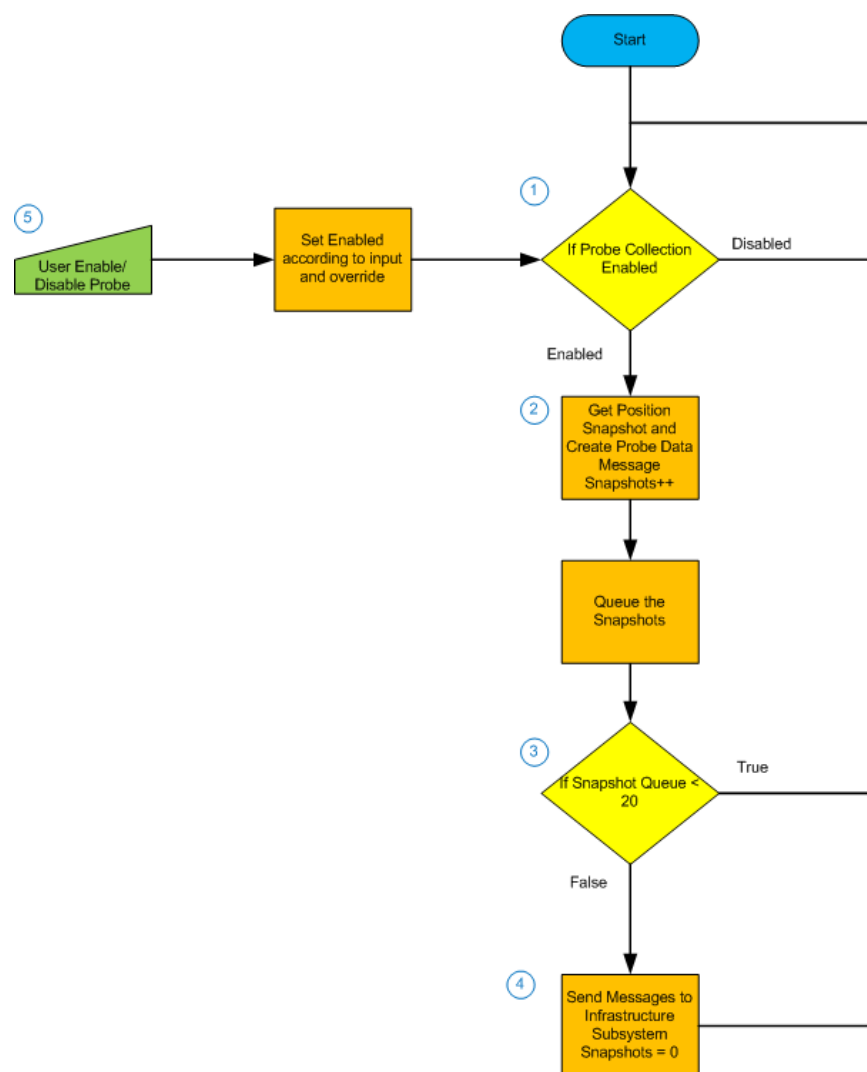


Figure 41. Probe Data In-Vehicle Sequence

This numbered list corresponds to Figure 42.

- 1) If the probe was enabled the Probe Data Collection Class would start collecting data snapshots. If it was not enabled, it would wait then recheck the enabled state.
- 2) Received a position snapshot from GPS location and created the Probe Data Message. Placed the message in a queue.
- 3) If Snapshots were less than 20 collect more snapshots.
- 4) Once 20 snapshots were collected the message was sent to the Infrastructure subsystem
- 5) The Vehicle Occupant could asynchronously change the state of the enable so the sequence for this input started with the occupant selecting the enable/disable button.



**Figure 42. Probe Data Collection Flow**

### **3.3.3.2 Probe Data Infrastructure Sequence**

The Probe Data Infrastructure received the Probe Data Message, stored a raw message and then stored the individual probe data items in the Probe and Log database. The sequence of events after the Probe data was received by the infrastructure is described in the following numbered list and in Figure 43.

This numbered list corresponds to Figure 43:

- 1) Probe Data message was received by the Infrastructure subsystem.
- 2) The Vehicle Communications Web Role would place the raw message in the Probe Raw Message Table.
- 3) The Vehicle Communications Web Role would place the Probe Data Message in the Probe queue for use by the Vehicle Payload Processing Web Role.
- 4) The Vehicle Payload Processing Web Role would get a Probe Data Message from the queue.
- 5) The Probe Data Message was sent to the Business Logic Library to be parsed into a Position Snapshot.
- 6) The Probe Data Message was deleted from queue and the Position Snapshot was sent to the Probe and Log Database.
- 7) The Vehicle Payload Processing Web Role checked the queue for more messages to process.
- 8) If no more messages were available, wait 30 seconds.
- 9) Returned to Step 4.



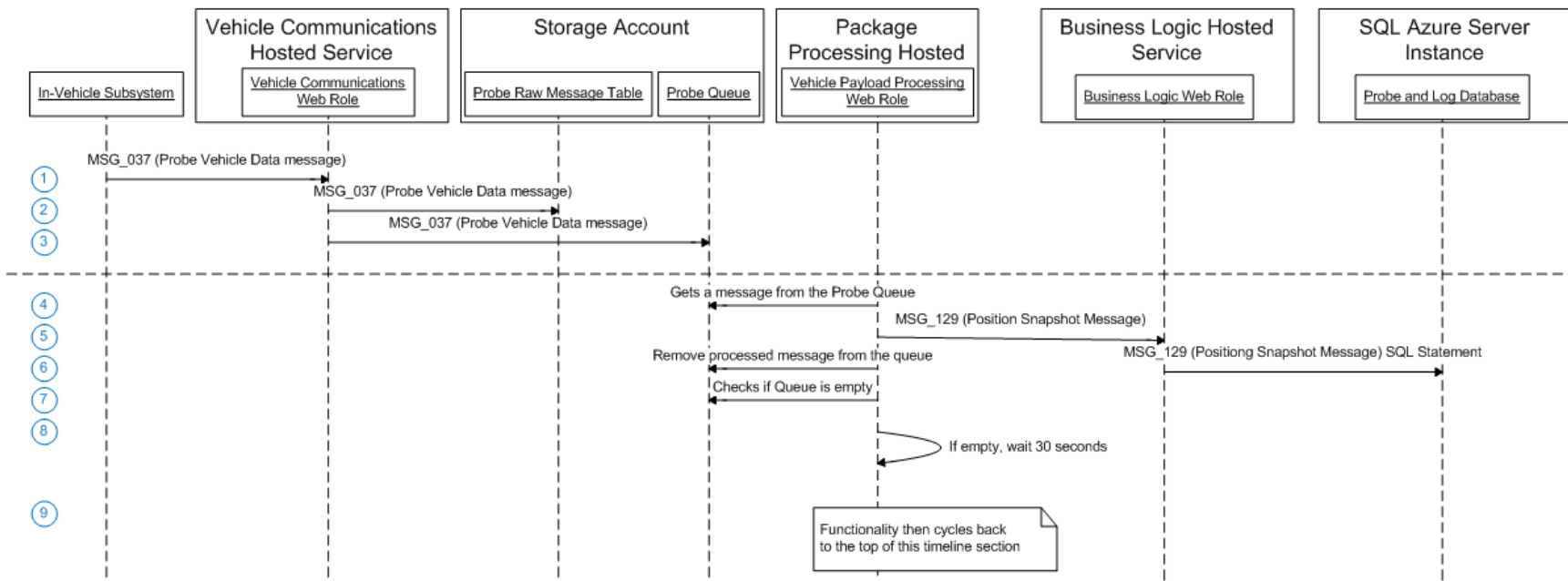


Figure 43. Probe Data Infrastructure Sequence

### 3.3.4 Signage

The Signage Software provided audible and visual alerts to the vehicle occupant when specific location-based events occur. To achieve this objective the Signage Software determined whether a set of signage criteria had been met based upon vehicle location. If these criteria had been met the software would display the appropriate sign to the driver and play an audible alert if appropriate. The sequence of events for the Signage Class is shown in Figure 44 and Figure 45. Figure 44 shows the interaction between the different entities of the system but does not necessarily show the time sequence of the events. Figure 45 shows the flow of the software that could not be clearly shown in the sequence diagram. The two figures should give a complete view of the Signage Software. This numbered list corresponds to Figure 44.

- 1) The top sequences, steps 1 through 8, were executed once a second. The first step was to check the signage enable flag. If Signage was enabled proceed to the next step, if it was disabled return to step 1.
- 2) Received the position and speed of the Vehicle from the Positioning Class.
- 3) Queried Signage Zone Table (TBL\_V03) to determine if the vehicle was within a signage zone.
- 4) If the vehicle was within a signage zone, retrieved the appropriate zone type, graphic and sound.
- 5) If the vehicle was within a signage zone, displayed the graphic and signage and play the sound.
- 6) If the vehicle was within a signage zone, create Log Message (MSG\_014) and send to the Log Database.
- 7) If the vehicle was within a signage zone and the speed was greater than 5 mph over the limit, play the speed alert sound.
- 8) If the vehicle was within a CICAS-SSA zone, check the threat assessment and display the appropriate graphic.

The Vehicle Occupant could asynchronously change the state of the enable. The sequence for this input is described in steps 9 through 11.

- 9) The sequence for this input started with the occupant selecting the enable/disable button.
- 10) The enable change request event was sent to the Main Class.
- 11) The Signage Enable state was stored in the table TBL\_V01.

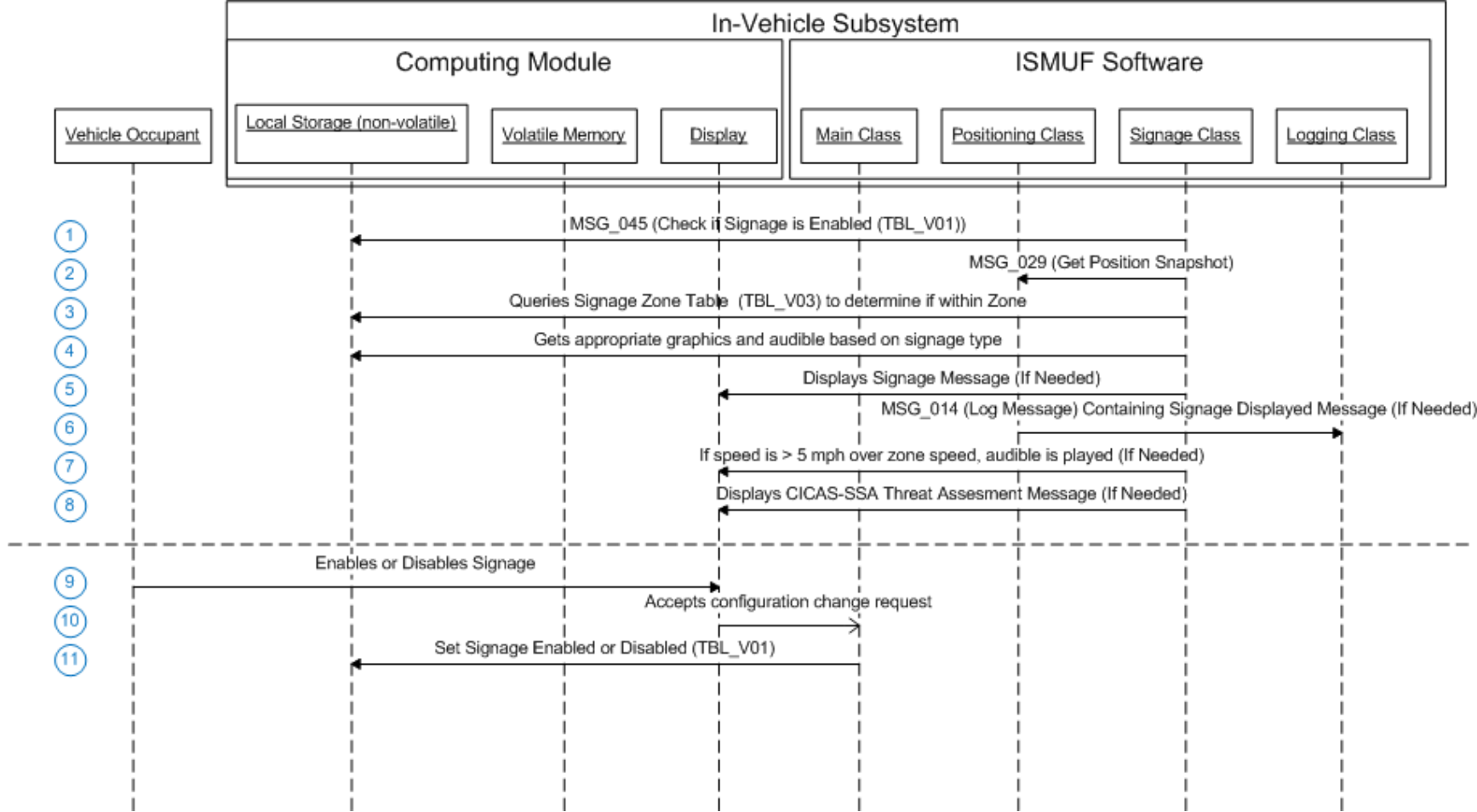
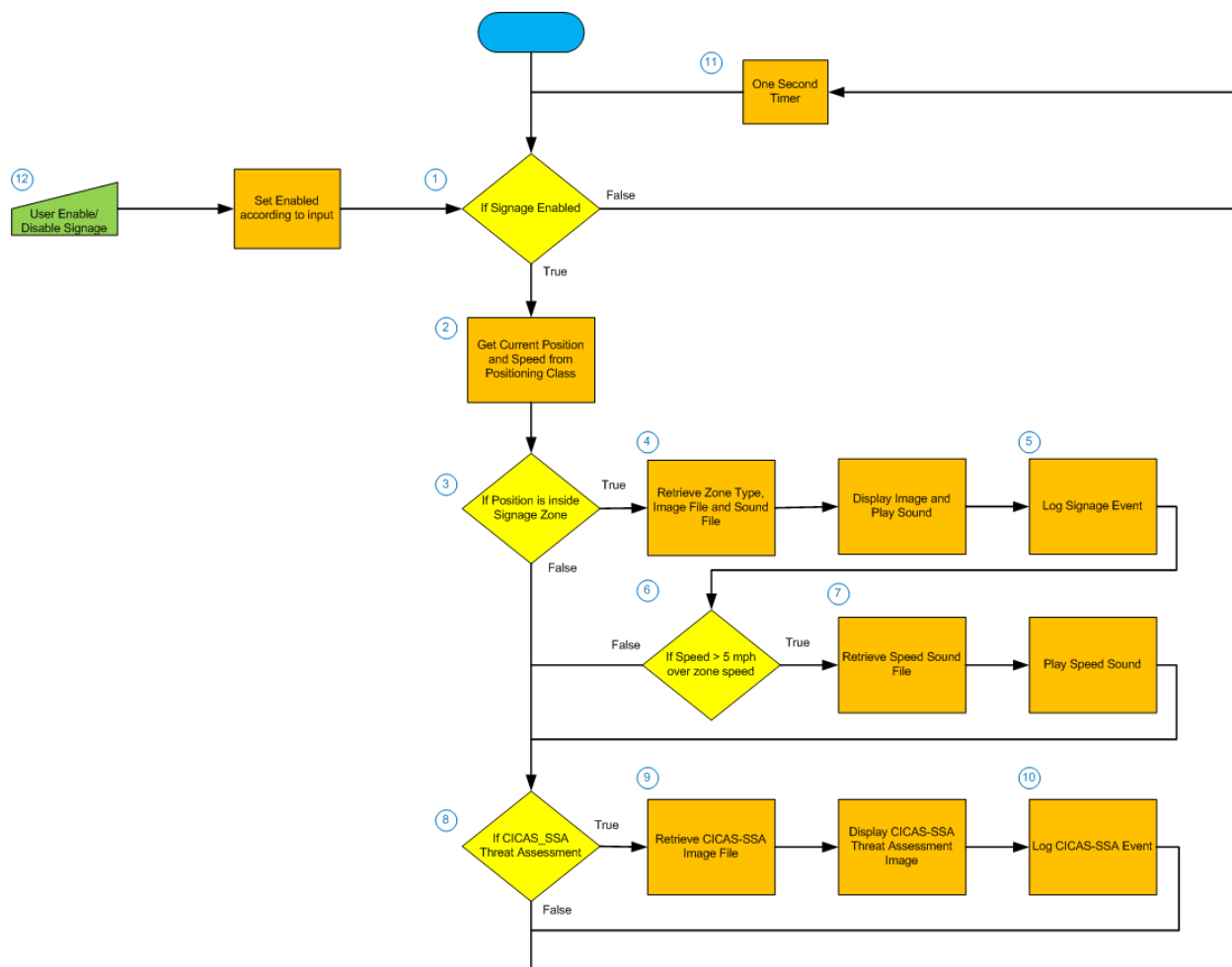


Figure 44. Signage In-Vehicle Sequence



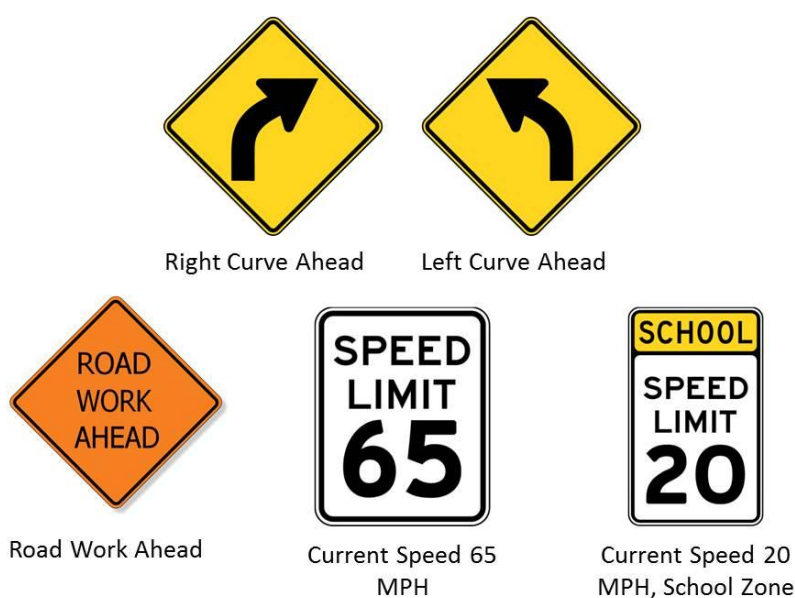
**Figure 45. Signage In-Vehicle Flow**

This numbered list corresponds to Figure 45.

- 1) If the Signage was enabled the Signage Class would start checking the signage zones. If it was not enabled, it would wait then recheck the enabled state.
- 2) Received the current position and speed from the Positioning Class.
- 3) If the Position was inside of a signage zone.
- 4) Retrieved the zone type, image file and sound file from local storage. Displayed the image and play the sound file.
- 5) Sent the signage event in the Logging Class.
- 6) Checked the speed of the vehicle and compare to the zone speed limit.
- 7) If the speed was 5 mph over the zone speed limit, retrieve and play speed zone sound.
- 8) Checked the position and the CICAS-SSA Threat Assessment if within a CICAS zone
- 9) Retrieved the appropriate CICAS-SSA Threat Assessment Image and display on the In-Vehicle Device.

- 10) Sent the CICAS-SSA event to the Logging Class.
- 11) The signage would be checked every second via the one second timer.
- 12) The Vehicle Occupant could asynchronously change the state of the enable so the sequence for this input started with the occupant selecting the enable/disable button.

Figure 46 shows the signage icons displayed on the Smartphone screen when the signage option was enabled.



**Figure 46. Signage Displayed on Smartphone**

### 3.3.5 Device Power Down

A participant signaled an end of a trip by turning the vehicle ignition off. The Power Management Module sensed the ignition off event by a drop in the available voltage and removed power from the Smartphone. This initiated the end of trip sequence described below.

- 1) Once the power off event was received the Main class would call the stop method on the Probe Class, MBUF Class, and Signage Class (MSG\_032). These power down sequences are described in detail in the following sub-sections.

### **3.3.5.1 Probe In-Vehicle Power Down**

The Probe In-Vehicle Power Down sequence of events is described in the following numbered list and in Figure 47. There is no shutdown sequence for the Probe Infrastructure.

This numbered list corresponds to Figure 47.

- 1) Vehicle Occupant turned off the vehicle ignition.
- 2) The Probe Data Collection Class would get any remaining snapshots, create a Probe Vehicle Data message and send the message to the Infrastructure subsystem.
- 3) The Probe Data Collection Class would signal the Main Class to display the Trip ID to the Vehicle Occupant.
- 4) The Trip ID was displayed to the Vehicle Occupant.
- 5) If the Vehicle Occupant confirmed that they wanted to store the Trip ID it would be stored to the Local Storage.
- 6) If the Vehicle Occupant wanted to delete the Trip ID it would not be stored on the device.

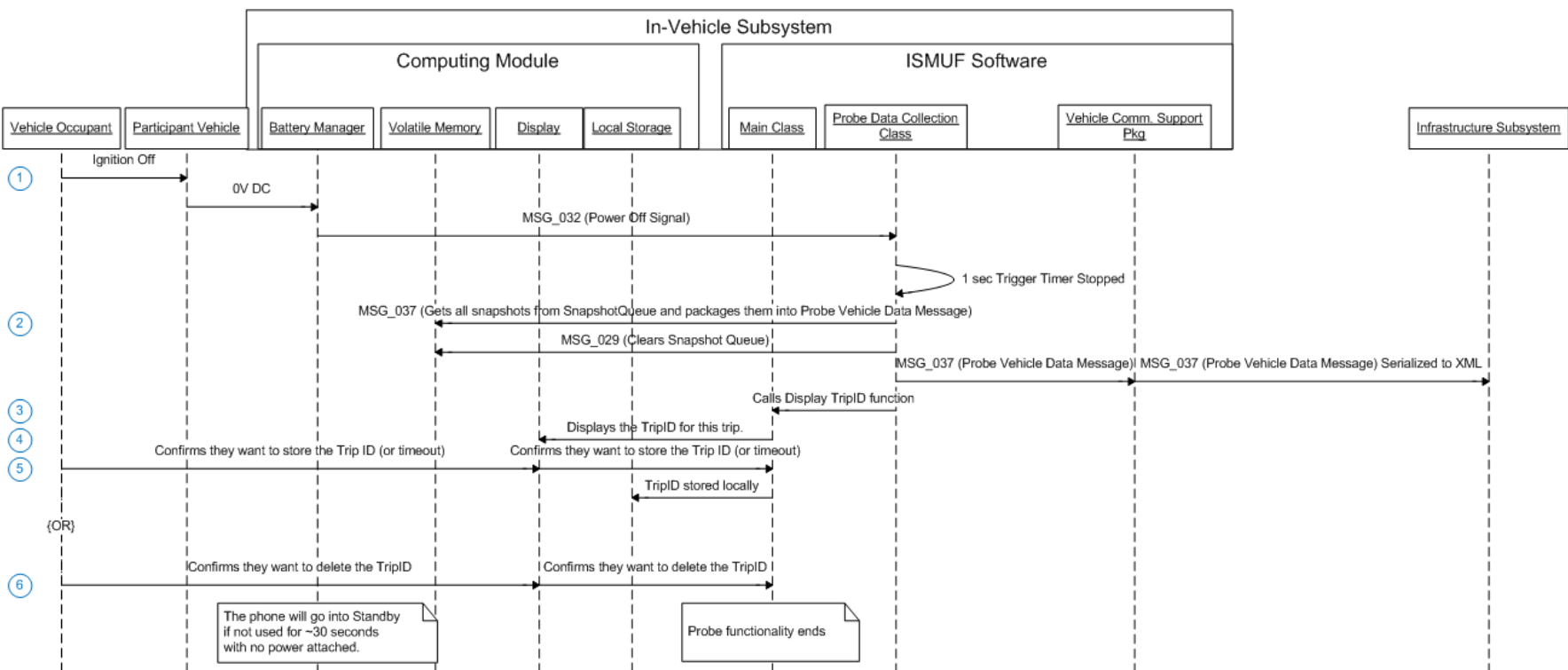


Figure 47. Probe In-Vehicle Power Down Sequence

### **3.3.5.2 MBUF In-Vehicle Power Down**

The MBUF In-Vehicle Power Down sequence of events is described in the following numbered list and in Figure 48. There was no shutdown sequence for the MBUF Infrastructure.

This numbered list corresponds to Figure 48.

- 1) Vehicle Occupant turned off the vehicle ignition.
- 2) Stop message was sent from the Main Class to the MBUF Collection class and the timer was stopped.
- 3) The MBUF Collection Class would get the current time and the last time the accumulated mileage was sent to the Infrastructure subsystem. If the time difference was less than 24 hours the class would exit. If the time difference was greater than 24 hours the MBUF Collection Class would get the lists of accumulated mileages and the Device ID. This data would be used to create a Send Mileage Message that was sent to the Infrastructure subsystem.
- 4) If the MBUF Collection Class had sent the Mileage Message, it would clear the MBUF Zone Accumulated Mileage Table.
- 5) If the MBUF Collection Class had sent the Mileage Message, it would log a message stating message was sent.
- 6) End of MBUF Collection Class power down sequence.



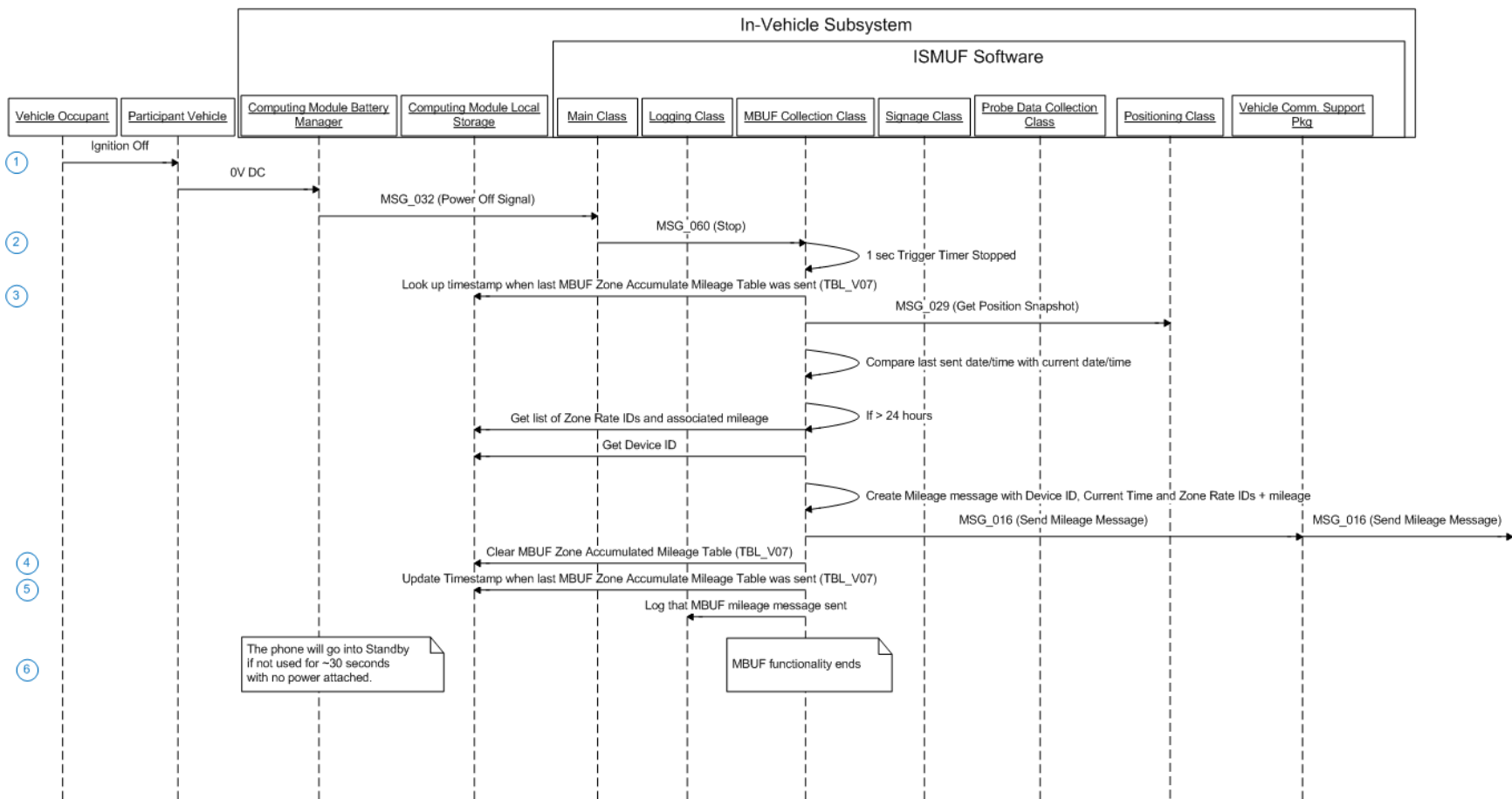


Figure 48. MBUF In-Vehicle Power Down

### 3.3.5.3 Signage In-Vehicle Power Down

The Signage In-Vehicle Power Down sequence of events is described in the following numbered list and in Figure 49. There was no shutdown sequence for the Signage Infrastructure.

This numbered list corresponds to Figure 49.

- 1) Vehicle Occupant turned off the vehicle ignition.
- 2) Stop message was sent from the Main Class to the Signage class and the timer was stopped.
- 3) If the vehicle was not moving any Administrative Messages would be shown to the Vehicle Occupant.

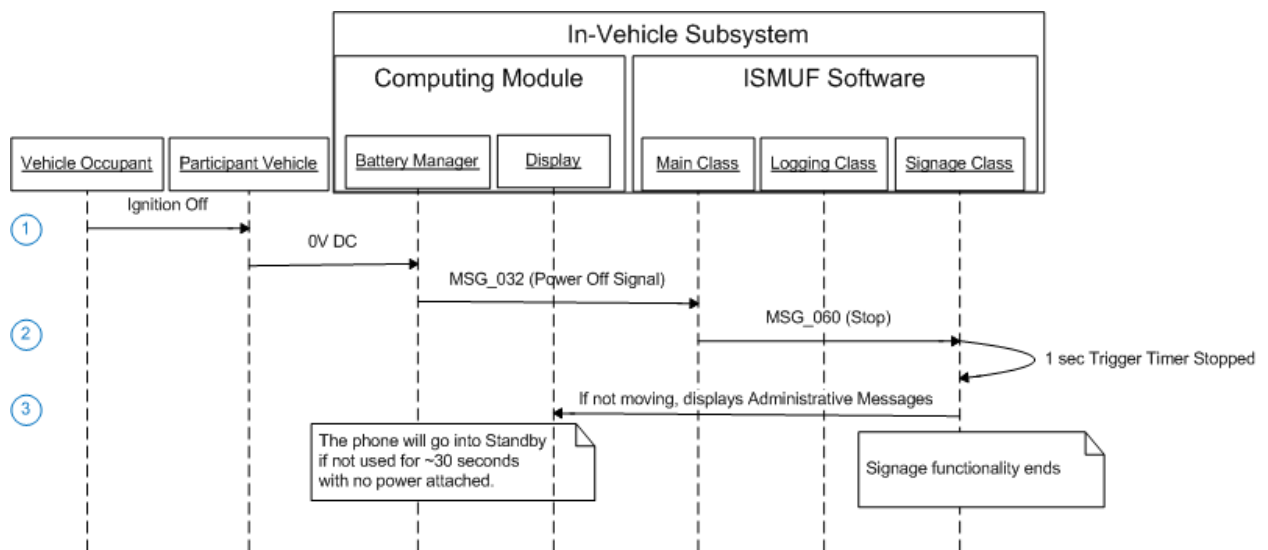


Figure 49. Signage In-Vehicle Power Down Sequence

## 4.0 CONCEPT AND OVERVIEW OF FIELD OPERATIONS

Having discussed what was planned, designed, and built for the Connected Vehicle for Safety, Mobility, and User fee project, the following discussion is of the operations of that system and using the prescribed system to achieve the project goals. Recall the principal goal of the project was to demonstrate a system that would collect a Miles Based User Fee. With that goal in mind, many operational activities had to occur. The first activity was determining a name to call the project that the public could use to better understand the intent of the project. The projects public facing name was then determined to be the Minnesota Road Fee Test (MRFT).

Further, operational activities for the Minnesota Road Fee Test (MRFT) included participant infrastructure data loading, equipment provisioning, scheduling, field deployment, support, invoicing, and close-out. These activities were conducted in the context of deploying a system composed of in-vehicle equipment and supporting infrastructure working in concert to provide a mileage based user fee (MBUF) capability. In addition to MBUF, the system was deployed with additional capabilities including vehicle Probe Data, in-vehicle signage, and enhanced traveler information (i.e. navigation and traffic services). A complete description of system operation and architecture is described in “Concept of Operations Document,” document number 635110B0020. The following discussion expands on the specific operational activities related to deployment and support of the overall system.

Beginning in September 2011 and concluding in October 2012, activities spanned three participant groups, Wave A, Wave B, and Wave C, consisting of three distinct participant field engagement milestones termed odometer reading #1, #2, and #3. Odometer readings marked the beginning, intermediate, and end activities for a two month baseline period and four month test period for each participant group; Wave A, Wave B, and Wave C. Odometer readings and support activities accounted for the most significant portion of total operational activity from the perspective of staff time. Additional operational milestones included infrastructure data loading, scheduling, and invoice distribution for each participant group.

Prior to beginning operations, procedures were established to address the wide range of operational activities associated with the various operational milestones and tasks including infrastructure data loading, equipment provisioning, scheduling, field deployment, support, invoicing, and close-out. The collection of procedures, as shown in Table 3, includes specific instructions for operational activities that may be encountered over the course of operational activities. For example, the document, “How to Conduct First Odometer Reading,” provided specific instructions and guidance to field staff on how to conduct an initial field engagement with the participant.

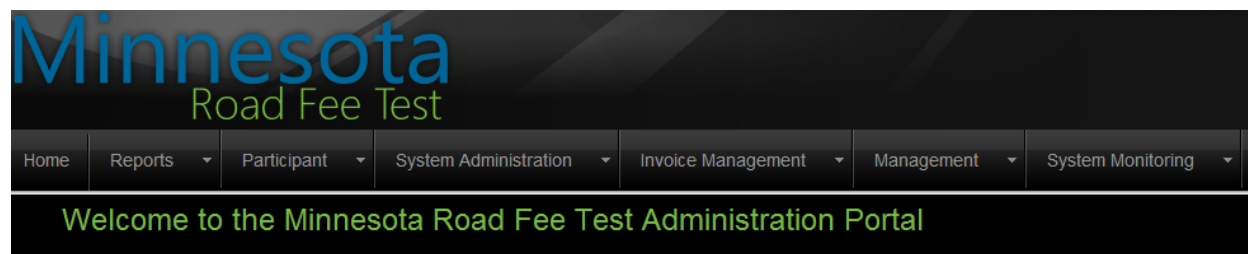
**Table 3. Operational Procedures**

635110B3001	ADMINISTERING A LOST OR STOLEN DEVICE
635110B3002	DEVICE REPORTED AS MALFUNCTIONING
635110B3003	PARTICIPANT VOLUNTARILY ENDS INVOLVEMENT
635110B3004	ADDRESSING COMPUTER NETWORK (WEBHOSTING) DOWNTIME
635110B3005	PARTICIPANT IN ACCIDENT WITH DEVICE INSTALLED
635110B3006	PARTICIPANT VEHICLE CHANGE
635110B3008	KITTING PROCEDURES
635110B3010	PROCESSING CHANGES IN WAVE SETTINGS
635110B3011	PROCESSING CHANGES IN SIGNAGE ZONES
635110B3013	RECEIVING A RETURNED DEVICE
635110B3015	HOW TO HANDLE DISPUTES WITH AN INVOICE
635110B3016	WHAT HAPPENS WHEN AN INVOICE IS NOT PAID
635110B3017	HOW TO HANDLE A CALL OR INQUIRY FROM THE MEDIA
635110B3018	VIEWING ROUTE INFORMATION
635110B3019	PROCESSING LEGAL REQUEST FOR MRFT SYSTEM DATA
635110B3020	PROCESSING A SERVICE REQUEST
635110B3021	REINSTATE DISABLED ACCOUNT
635110B3022	CUSTOMER SUPPORT RECORD: LOGGING AND REPORTING REQUIREMENTS
635110B3023	HOW TO PROCESS A CASH OR CHECK PAYMENT
635110B3024	HOW TO SCHEDULE ODOMETER READING/IN-PERSON SUPPORT
635110B3026	HOW TO DISABLE A DEVICE
635110B3027	IN-VEHICLE INSTALLATION INSTRUCTIONS
635110B3028	HOW TO PREPARE A DEVICE FOR A PARTICIPANT
635110B3029	PARTICIPANT IS NOT COMPLIANT WITH TERMS OF AGREEMENT
635110B3030	HOW A PARTICIPANT BEGINS INVOLVEMENT IN MRFT
635110B3032	HOW TO PERFORM A DEVICE INSTALLATION CHECK
635110B3034	CANCELLING AT&T SERVICE FOR LOST OR STOLEN PHONE
635110B3036	END USER LICENSE AGREEMENTS (EULAs) FOR MINNESOTA ROAD FEE TEST (MRFT)
635110B3037	IN-VEHICLE IDENTIFICATION MODULE SECURITY STICKER SHOWS "VOID"
635110B3038	HOW TO FORCE SENDING OF AN MBUF REPORT
635110B3039	CONTENT FOR MESSAGES SENT TO PARTICIPANTS
635110B3040	HOW TO RESTORE PHONE TO STOCK IMAGE
635110B3041	HOW TO CONDUCT FIRST ODOMETER READING
635110B3042	HOW TO CONDUCT SECOND ODOMETER READING
635110B3043	HOW TO CONDUCT THIRD (FINAL) ODOMETER READING

## 4.1 Infrastructure Data Loading

The process of loading data into the infrastructure at the beginning of each participant group (i.e. Wave A, Wave B, and Wave C) was initiated with the receipt of participant information from the Evaluation Contractor at the conclusion of participant recruitment. Participant information received from the Evaluation Contractor included participant name, address, phone numbers(s), e-mail(s), and vehicle make and model. Data entry was performed manually by Pierce Pini & Associates and Battelle staff. Information pertaining to system configuration, assigned Smartphone, and in-vehicle equipment were entered during the process of distributing in-vehicle equipment during odometer reading #1.

Vehicle odometer mileage from the assigned vehicle was entered directly into the infrastructure during each odometer reading engagement by field staff through the administrative portal shown in Figure 50. The odometer mileage entry included date, time, and photograph of the vehicle odometer. During odometer reading #2 and #3 reports generated by the system were initiated with entry of the vehicle odometer mileage.



**Figure 50. Administrative Portal Home Screen**

## **4.2 Equipment Provisioning**

In preparation for system deployment it was necessary to procure and provision in-vehicle equipment for distribution to participants. Equipment procurement included the acquisition of hardware, software, packaging materials, and participant facing materials. A complete parts list of procured items is shown in Table 4. A detailed description of participant facing materials is provided in Section 7.0 of this document.

After acquiring the required materials, Battelle production staff assembled equipment into individual kits for distribution to each participant. Each kit contained a Smartphone (Samsung Captivate™) to be assigned to a specific participant during the odometer reading #1 engagement. Smartphones delivered to production staff were updated and configured to support the MRFT system. In particular, the Smartphone Read Only Memory (ROM) was updated to a custom ROM tested with the MRFT application. Additional navigation software was added to the device including road maps for North America available locally on the device. As discussed in Section 3.1.2 a traffic data provider service was also enabled showing traffic patterns for a given location. Together, with the MRFT application, each device required 60 minutes to complete the installation, update, and configuration of software. Before sealing each kit for shipment to the MRFT field office, each Smartphone was tested in operation with other in-vehicle equipment to ensure proper function. Time to produce each kit averaged 75 minutes. This time represents total staff time to provision, test, and quality check each kit. Assembled kits were shipped directly to field staff for deployment prior to odometer reading #1. A total of 539 kits were provisioned and shipped across all three participant groups over the entire operational period (September 2011 through October 2012). All equipment provisioning was completed by Battelle production staff in Columbus, Ohio before shipment to the MRFT field site.

**Table 4. In-Vehicle Equipment Parts List**

	1	17	635110B9003-01	79986	SEAL LABEL, 5 ½ X 8 ½ IN	
	1	16	STOCK	79986	MFG ID LABEL	
	1	15	635110B3053-01	79986	IN-VEHICLE INSTALLATION INSTRUCTIONS WITH VIDM	
	1	14	635110B9001-150	79986	SOFTWARE CONFIGURATION	
	1	13	1350-07BL	39UH1	DIARY	
	1	12	S-1304	7Z049	BAG, 9 X 12 IN	
	2	11	S-1302	7Z049	BAG, 4 X 6 IN	
	2	10	S-1711	7Z049	BAG, 6 X 8 IN	
	1	9	635110B9002-01	79986	SUPPORT LABEL, 5 ½ X 8 ½ IN	
	3	8	5163	0YDE1	LABEL, 2 X 4 IN	
	1	7	107120037512	5MZ00	5/16 X 12 X 36 IN BUBBLE WRAP	
	1	6	S-276	7Z049	12 X 9 X 4 IN BOX	
	1	5	XSG39-47RE	1RLL4	SECURITY TAPE	
	1	4	CAD300UBEB/STD	3HR26	DEVICE CHARGER	
	1	3	635110B3050-01	79986	VEHICLE IDENTIFICATION MODULE	
	1	2	SM410	3HR26	NAVIGATION DEVICE VEHICLE MOUNT	VICD 635110B1050
	1	1	SGH-i897	1TCL1	COMPUTING MODULE (NAVIGATION DEVICE)	VICD 635110B1011
	-10	FIND NO	PART OR IDENTIFYING NUMBER	CAGE CODE	NOMENCLATURE OR DESCRIPTION	NOTES OR REMARKS
QTY REQD						
PARTS LIST						

### 4.3 Participant Scheduling

Participants recruited for each participant group were contacted prior to odometer reading #1, odometer reading #2 and odometer reading #3 to schedule appointments to meet with field staff at the designated field location for system deployment, transition from baseline to test periods, and close-out activities, respectively. Efforts to contact participants to schedule odometer readings began two weeks before the beginning of each odometer reading period. The odometer reading period, or available appointment times for participants from a given participant group, spanned 11 days for Wave A and improved to 6.5 days by Wave C.

Over the course of successive odometer readings process improvements and efficiencies led to a shorter odometer reading period and thus more compact scheduling. Beginning with participant group Wave A, odometer reading #1, participant appointments were scheduled in 1 hour blocks every 30 minutes averaging 14 appointments per day over a two week odometer reading period (i.e. 11 active days). With participant group Wave C, odometer reading #1, scheduling was condensed to 30 minute blocks every 20 minutes averaging 30 appointments per day across 7.5 days.

A summary of odometer reading #1, #2, and #3, for all three participant groups, is provided in Figure 51. As shown in the figure, overall improvements and efficiencies gained across the entire operational period are presented by labor hours and number of days.

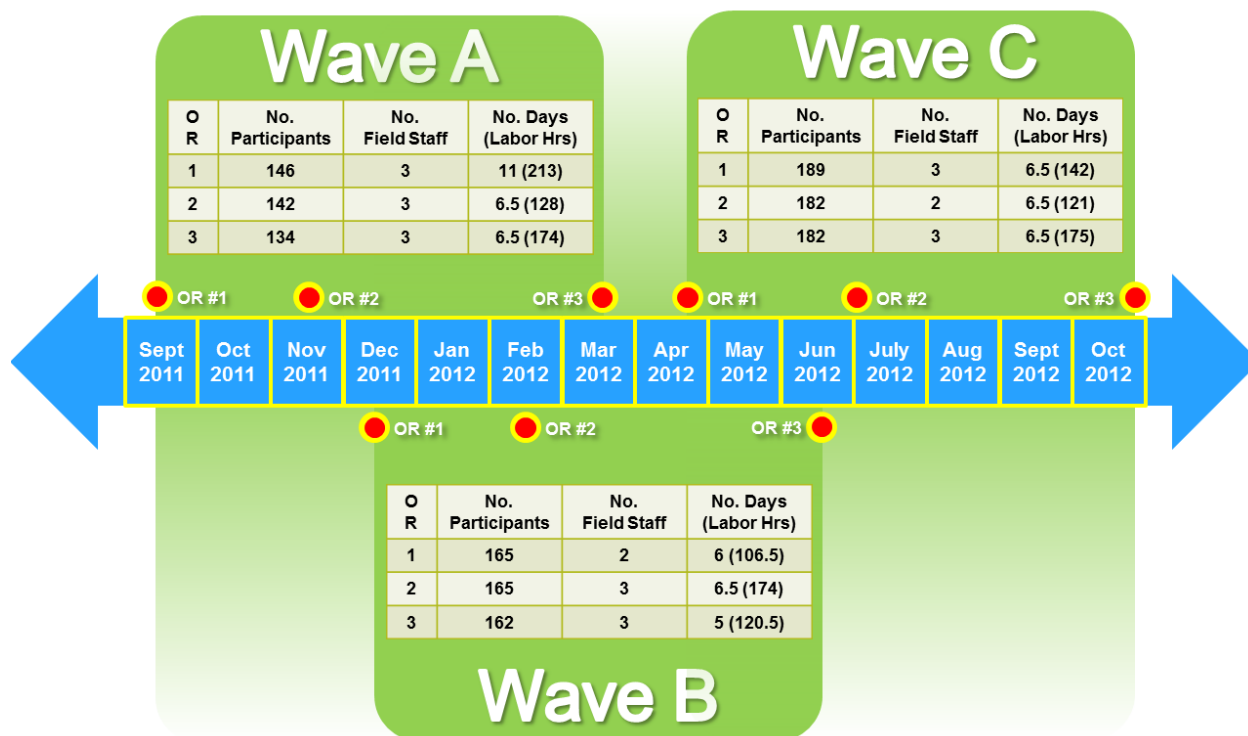


Figure 51. Summary Odometer Reading (OR) Periods by Participant Group

#### 4.4 Field Deployment and Baseline Period to Test Period Transition (Odometer Reading #1 and #2)

Once scheduled, participants would arrive, on their appointment day and time, at the designated field site located in St. Michael, Minnesota; approximately 12 miles northeast along I-94 after the I-94/I-494 interchange. Initially, the selection of a site included an alternative location in Rockford, MN; approximately 13 miles east of the I-94/I-494 interchange. Both locations were initially considered based on proximity to the primary participant recruiting areas of Hennepin and Wright counties. Upon further consideration, the St. Michael site offered several distinct advantages including a large open parking lot, I-94 proximity, a direct parking lot line of site from the internal field office, and additional space for equipment storage.

Odometer reading #1, the first of three participant field engagement milestones, was highlighted by the initial deployment of in-vehicle equipment and participant orientation. Participants would arrive at the designated field site at their scheduled appointment date and time having received advance notice via postal mail of appointment details and required materials. The objective of odometer reading #1 was to initiate the participant into the MRFT system, install in-vehicle equipment, record odometer mileage, and provide user materials and training. For example, participants were given the opportunity to view a training video prior to installing the in-vehicle equipment showing a brief overview of the MRFT project and odometer reading #1 activities. The participant was also required to review and sign an End User License Agreement (EULA) relating to the use of the in-vehicle equipment and software. Prior to installation into the participant's vehicle, field staff provided the option for the participant to automatically transmit MBUF and trip information to the infrastructure. If the participant did not elect this option, they

were responsible for manually transmitting MBUF and trip information at the conclusion of every trip or sometime thereafter. Installation of the in-vehicle equipment was largely left to the participant; however, field staff provided assistance as needed. Prior to leaving the field site, field staff and the participant conducted a system validation test ensuring proper function and operation. After completing odometer reading #1, participants entered into the baseline period of operation.

The duration of each participant group baseline period was approximately two months. During the two month period, participants utilized the MRFT system but were not able to view the roadway fees or safety signage information. The participant was not required to pay invoices during the baseline period. Mileage was collected by the in-vehicle equipment and made available to the Evaluation Contractor via the web-based administrator portal for the purposes of startup fund determination. In effect, the baseline period provided a means to orient the participants to having the in-vehicle equipment installed in their vehicle, baseline participant driving behavior, and identify potential system issues.

At the conclusion of the two month baseline period, participants were again contacted to schedule an odometer reading #2. Odometer reading #2 was highlighted by the introduction of expanded system functionality and participant invoicing. The objective of odometer reading #2 was to install any critical software updates and provide the participant with a four month startup fund to pay invoices throughout the test period. In part, the startup funds provided to the participant were determined by active use of the system during the baseline period as well as mileage driven. Participants would be categorized by startup funds as either “High Mileage” or “Low Mileage.” The participant infrastructure record was updated to reflect this designation. Participants received startup funds in the form of a bank check. Participants were informed of an established rate structure based on system use as shown in Figure 52. Participants were also informed of a default rate of 3 cents per mile will be applied to all miles not collected by the system should the participant choose not to actively use the system.

Current Driving Location	Peak Times Monday, Tuesday, Wednesday, Thursday, Friday 7AM-9AM 4PM-6PM	Off Peak Times
Outside of Minnesota	\$ .00	\$ .00
Inside Minnesota and Outside the Twin Cities Metro Zone	\$ .01	\$ .01
Inside the Twin Cities Metro Zone	\$ .03	\$ .01

**Figure 52. Established Rate Structure Provided During Odometer Reading #2**

In addition to startup funds, participants were instructed on additional Smartphone functionality available during the test period not previously available during the baseline period. Additional functionality included MRFT software options such as toggling fee and signage displays on or off. A map of the zones designated for the test period was provided to the participant during odometer reading #2.



## 4.5 Support

Participants were provided with several options for system support during both the baseline and test periods. Participants could contact MRFT support staff via e-mail or on the project participant portal 24 hours per day, seven days per week. Phone support was also available Monday through Friday, 8:00 AM - 5:00 PM CST. Issues were managed and tracked from within the MRFT administrative portal. Should a participant contact support, a Service Request (SR) was generated detailing the date and time of contact, issue description, issue cause, and issue resolution. SRs were further categorized by issue type.

In addition to addressing participant questions and operational issues via participant portal, e-mail and phone, support staff provided direct field support through scheduled ad-hoc appointments during the baseline and test periods. Support staff also responded to equipment repair and replacement requests. From July 2012 through October 2012, support staff processed 57 shipments responding to requests for equipment repair and replacement.

## 4.6 Invoicing

During the test period following odometer reading #2, participants were provided with a startup fund based, in part, on baseline system usage. The startup fund was used by participants to pay invoices generated on a monthly basis as a result of system use. Charges in excess of the startup fund were not charged back to the participant limiting liability to the initial startup fund provided during odometer reading #2.

Invoices reflected the total monthly charges accumulated for system use during the invoicing period. The invoicing period began on the first day of a given month and concluded on the last day of the same month. Invoices were sent via postal mail and e-mail. Sending invoices via postal mail required the MRFT support team to compile all invoices for the given invoicing period upon being generated by the infrastructure. The labor intensive process of preparing hardcopy invoices for mailing lagged behind e-mail distribution by 5-10 days depending on resource availability, postal routes, and the inclusion of additional inserts or flyers.

Participants had two primary options for invoice payment not associated with an odometer reading engagement; postal mail (i.e. check) or PayPal account. In the case of PayPal, payments were made through access to the project participant portal. Every transaction processed by PayPal was charged a service fee of 2.90 percent of the transaction amount plus \$0.30 per transaction. In contrast, the Square credit card reader used during odometer reading engagements charged a service fee of 2.75 percent of the transaction amount with no additional transaction fees. In total, participants received four invoices across four months of participation in the test period following odometer reading #2. Participants were required to pay invoices by the 14<sup>th</sup> day of the month following the invoice period. Failure to pay an invoice by the 14<sup>th</sup> day triggered an automatic system notice sent to the participant via e-mail and Smartphone alert indicating the invoice was overdue. Invoices 30 days past due, from the date of invoice generation, triggered the system to automatically lock the participant out of both the participant portal and Smartphone applications. Unlocking the Smartphone and portal required the participant to contact the MRFT support team and bring current all outstanding invoices.

## **4.7 Close-Out (Odometer Reading #3)**

Odometer reading #3 followed the conclusion of the test period and was highlighted by participant close-out and invoice reconciliation. Like odometer reading #1 and #2, participants would arrive at the designated field site for their scheduled appointment. In the case of odometer reading #3, participants were notified in advance that all invoices must be paid at the time of odometer reading #3. During final processing, participants returned all in-vehicle equipment. All collected equipment, including the Smartphone, was shipped back to the MRFT support team for final disposal. After collecting all participant equipment, field staff entered the final odometer mileage into the infrastructure and generated a final report outlining total mileage captured by the MRFT system compared with total vehicle odometer mileage recorded during odometer reading #2. The result was reported as a percentage of use. Any miles not captured by the MRFT system in-vehicle equipment were categorized as unaccounted miles and charged at a default rate of \$0.03 per mile.

During the process of generating a final report, close-out invoices were generated. Close-out invoices included an invoice for mileage traveled during the final month of operation, an invoice for unaccounted miles charged at the default rate, and any outstanding invoices that might still require payment. Payment was accepted by field staff in the form of check, cash, or credit card. Initially, credit card transactions were only accepted through PayPal. Participants were provided web access to log into a PayPal account while on-site. During Wave C field staff switched to a Square credit card reader attached to a project tablet to streamline participant processing. Every Square credit card reader transaction was charged a service fee of 2.75 percent of the transaction amount. The final step in the close-out process was to provide the participant with a refurbished Smartphone for recognition of their participation in the MRFT. The participant was directed to the Evaluation Contractor for any questions regarding close-out interviews, focus groups, or stipend payments.

## **4.8 Summary of Lessons Learned from Operations**

### **4.8.1 Infrastructure Data Loading**

The process of infrastructure data loading was made efficient through the administrative portal interface. Although much of the data loading was completed manually by field staff, the portal interface simplified the task with streamlined administrative screens and navigation. In most cases, form fields were setup to validate input reducing potential data entry mistakes.

In a large scale implementation many of the data loading tasks would be automated using existing database connectivity standards and application programming interfaces. Automation would reduce the potential for data entry issues; particularly for large data sets. In a similar way, providing direct participant data entry via web portal interface might also streamline data loading and reduce errors.

### **4.8.2 Equipment Provisioning**

Equipment provisioning began with the procurement of essential in-vehicle equipment. This equipment including the Smartphone, were assembled into individual kits for distribution to participants. The Smartphone required an additional step to install and configure both

commercial and custom software. In particular, the MRFT application was installed and configured to operate with the Vehicle Identification Module.

When installing and configuring software for the Smartphone technicians processed multiple Smartphones in parallel providing for greater efficiency but maintaining repeatability. Technicians installed and configured as many as six phones simultaneously at any given time. Starting with Wave B equipment provisioning, the ability to install and configure the MRFT application using the device internet browser, as opposed to using a serial cable connection, also greatly improved efficiency. This facilitated the installation of the MRFT software over the internet and registering software that required licensing (e.g. navigation software). After installing and configuring software on the Smartphone the remaining in-vehicle equipment was packaged into kits. Prepacking materials, prior to kit assembly, contributed to faster cycle times reducing overall labor costs.

Cost savings were also uncovered through improvement of equipment returns, repairs, and spare parts processes. Initially, equipment in need of replacement or repair required field staff to contact the participant for resolution. Spare parts were handled in a similar fashion. Toward the end of the Wave B baseline period, support team members began working with technicians and materials handlers to address participant requests directly. Equipment was received directly from participants using prepaid shipping materials and returned to participants with next day shipping. This change contributed to faster resolution of equipment issues and ensured participants were receiving the latest software or hardware upgrades.

In general, equipment provisioning on a larger scale balances costs associated with nonrecurring engineering, capital expenditures, and labor. In the case of MRFT, although a small sample, there is evidence of potential process efficiencies at a larger scale. In particular, improvements in material handling, procurement, testing, and software registration would reduce unit costs considerably. In addition, processes for equipment returns, repairs, and spare parts would be greatly expanded reducing costs from economy of scale.

#### **4.8.3 Field Deployment and Baseline Period to Test Period Transition (Odometer Reading #1 and #2)**

Across all three participant groups; Wave A, Wave B, and Wave C, nine odometer reading appointments were scheduled including six targeting either deployment or transition of the MRFT system. During deployment, participants were presented with a kit of in-vehicle equipment to be installed into their vehicle. The installation process, depending on participant, took between 20-60 minutes. Initially, during the process of assigning kits, participants were presented with a hardcopy instruction of how to install the in-vehicle equipment. Although helpful, field staff found some participants did not fully read or understand the instructions provided. For that reason, during the Wave B deployment, a video was introduced summarizing the in-vehicle installation process and basic Smartphone operation in addition to the hardcopy instruction provided with the kit. Field staff were also made available during installation to answer questions, and when asked, assist with installation.

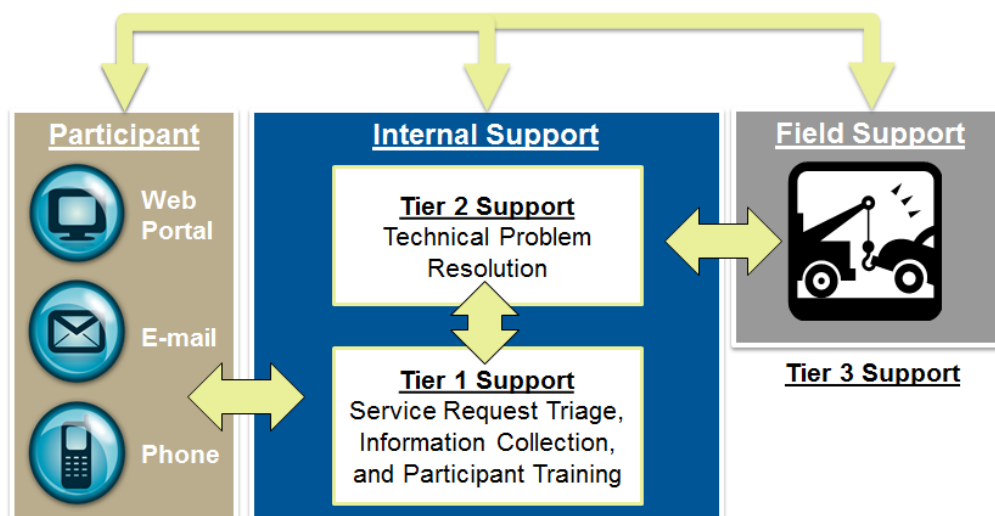
In addition to the task of completing the installation of in-vehicle equipment, field staff recorded the initial odometer reading from the participant's vehicle, verified participant and vehicle information in the administrative portal, and verified system function before the participant left

the field site. All of these activities were documented in a completed odometer reading form. This form provided both documentation and a check list of the field staff assisting the participant with the initial deployment. After conducting several appointments field staff found completing parts of the odometer reading form in advance of the participant's scheduled time helped to streamline in-office activities; particularly when several appointments were scheduled in close succession. Partially completing the odometer reading forms in advance ultimately contributed to condensing scheduling for all odometer readings.

The transition from baseline period to test period occurred during odometer reading #2. Although some tasks, and thus improvements, were similar across all three odometer readings, odometer reading #2 was distinct in that participants received a startup fund check and would apply any updates to the software as needed. In the case of software updates, it became clear after Wave A odometer reading #2, that a dedicated technical specialist was required to manage updates and ensure the overall system was functioning as intended. In parallel, field staff then had time to process information related to the baseline period, and instruct participants on new functionality, fee structure, and startup funds. This division of tasks also improved efficiency in the long-term allowing odometer reading appointments to be scheduled in a more efficient and condensed manner.

#### **4.8.4 Support**

The three tier support model implemented during the MRFT, as shown in Figure 53, was composed of an initial Tier 1 support layer tasked with receiving inquiries and providing answers to basic issues (e.g. account access, invoicing, or basic Smartphone operation). Tier 2 support received more complex technical issues passed from Tier 1. The escalated issue was further diagnosed and the participant contacted to resolve the issue. If direct in-person participant support was required, Tier 3 support was directed by Tier 2 to contact the participant and arrange an appointment to address the issue in-person. In many cases the participant might interact with both internal and external support staff on several occasions to resolve the issue as depicted by the yellow arrows shown in Figure 53. In the context of a 500 participant study, this model was effective. Participants received timely support for most issues involving basic inquiries. Depending on the mechanism for communicating more complex issues to Tier 2 and the nature of the issue, more complex issues took more time to resolve.



**Figure 53. Tiered Support Model**

The notion of improving communication between the various support levels drove the establishment of a standardized procedure for documenting Service Requests (SRs) within the administrative infrastructure. Prior to establishing a standard best practice for SR capture, information collected by support staff was entered into the administrative infrastructure with varying degrees of detail. Critical information might be included but presented in a way difficult to discern within the description or resolution narrative. The method and nature of participant contact might also be described differently depending on the knowledge of the support staff entering the information. In response, the support team adopted a comprehensive standard best practice for SR entry during the Wave A test period. SRs documented after this time were presented in a standard format including a category designation for each SR. Descriptions for each participant problem and/or resolution were presented in chronological order with a formatted header distinguishing one period of contact from another. A formatted header also allowed for the generation of regular SR reports based on predefined searches allowing the support team to monitor trends and developing issues.

In a future deployment of a system similar to that introduced with the MRFT, resource allocation and management for support activities will require further consideration. Despite the plurality of inquiries being limited to basic access and operation, participant engagement, at times, was time consuming and resource intensive. Participants would generally provide more detail than what was needed to resolve the immediate issue or resolution of a simple issue might be prolonged by continuous attempts to contact the participant.

#### **4.8.5 Invoicing**

Invoices were distributed to participants on a monthly basis during the test period. Participants from each participant group; Wave A, Wave B, and Wave C, would receive a total of four invoices during the respective test period. Invoices were distributed electronically via e-mail and hardcopy via postal mail. Participants had the option to remit payment via mailed check or through online access to PayPal. Invoices paid during an odometer reading appointment could be paid with cash, check, or credit card. Of the 478 participants that completed odometer

reading #3 (i.e. completed the entire study), a breakdown of the total number of invoices issued, total invoiced charges, and total fees collected is presented in Table 5. These findings are derived from a query of invoices not associated with diagnostic activities (i.e. issued to the participant) or associated to participant accounts setup for the purpose of administration, testing, or system demonstration. Only invoices issued to the participants during the time September 12, 2011 through October 31, 2012 were considered. Finally, zero dollar duplicate invoices generated in error due to system irregularities or data entry errors and cancelled invoices were also removed.

**Table 5. Summary Invoice Statistics**

Participants Completing Odometer Reading #3	478
Invoices Issued	2748
Total Invoice Charges	\$32,638.99
Total Fees Collected	\$31,182.82 (95.5%)

Like support activities, processing invoices was resource intensive. In particular, mailing hardcopies lagged behind electronic invoices by as much as ten days depending on available resources, number of participants and inserts. At times inserts were included in invoice mailings to provide additional information on a critical software update or upcoming odometer reading appointment.

With a total of twelve mass invoice mailings several changes were identified to improve processing hardcopy invoices. In most cases minor improvements or observations contributed to significant time savings. Several examples of this include, the use of #9 return envelopes that fit directly into #10 outside envelopes doing away with the need to fold return envelopes, the switch to self-adhesive envelopes, direct envelope printing as opposed to address labels, and presorting invoices and envelopes all contributed to making invoice processing more efficient throughout each test period.

In expanding invoice processing to a larger participant group, consideration for the use of a contracted billing service would reduce cost and potential errors while improving overall participant engagement through regular on-time delivery of both electronic and hardcopy billing statements.

#### **4.8.6 Close-Out (Odometer Reading #3)**

Like odometer reading #1 and #2 appointments, participants would arrive at the field site with advanced knowledge of appointment activities and what materials to bring. As with odometer reading #1 and #2, a dedicated technical specialist greatly improved in-office efficiency during close-out by supporting the upload of any remaining MRFT data still resident in Smartphone memory and managing Smartphone refurbishment. Partially completing odometer reading forms in advance of participant's appointments also contributed to in-office efficiencies during odometer reading #3 appointments.

Unique to odometer reading #3, participants were given the option to pay remaining invoices by cash, check, or credit card. Credit card payments were processed with an existing PayPal

account. Accessing PayPal accounts proved time consuming and unreliable. Connectivity, access, and security issues were prevalent as participants attempted to pay using an existing or guest PayPal account. In response to these challenges, during the Wave B participant group, odometer reading #3 appointments, field staff employed a credit card reader in combination with a mobile tablet. In addition to reducing transaction costs, efficiencies gained reduced overall participant appointment times. During the Wave C participant group, odometer reading #3 appointments, with a fully implemented credit card reader, 43 percent of all payment transactions occurred with credit card.

## 4.9 Summary of Operational Issues and Participant Comments

### 4.9.1 Operational Issues

Table 6 provides a list of those SR categories accounting for more than 2 percent of total SRs and thus the most frequently asked questions by category. As evidenced by the information contained in Table 6, issues pertaining to general Smartphone use and operation accounted for the largest percentage of the total issues followed by participant portal password resets and account verification. Participants were most often engaged over the phone and, as circumstances warranted, in the field or during odometer reading appointments.

**Table 6. All Non-Scheduling Service Requests > 2% of Total Service Requests**

All Service Requests, Non-Scheduling, Greater than 2% of Total		
<u>Category Description</u>	<u>Qty</u>	<u>% of Total SRs</u>
1. General Smartphone use and operation	228	17.6
2. Password reset or account verification	151	11.6
3. Android data service auto turn-off	112	8.6
4. Payment clarification	74	5.7
5. Swapped device on request	53	4.1
6. MBUF assessment questions	51	3.9
7. Participant equipment requests	39	3.0
8. Damaged car charger or power outlet	32	2.5
9. Smartphone battery replacement	32	2.5
10. IMEI Not Found error	30	2.3
11. Unrecoverable data at ORs or as reported	30	2.3
12. No or poor GPS signal	29	2.2

- **General Smartphone used and operation;** participant questions relating to Smartphone operation, function, and use. In particular, questions related to additional operation, function, and use of the Android Smartphone platform. Examples included interactions with the Smartphone interface, screen time-out conditions, and Smartphone charging.
- **Password reset or account verification;** requests for participant portal password resets or account verifications.

- **Android data service auto turn-off;** issues related to mobile data service automatically switching off due to a Smartphone low power state (a known function for the early release and versions of Android operating system).
- **Payment clarification;** participant questions related to invoice clarification, acceptable methods of payment, or late payments.
- **Swapped device on request;** instances of replacing a device in the field due to operational issues (e.g. poor GPS performance), damage, or theft.
- **MBUF assessment questions;** questions directed to the Evaluation Contractor for clarification on participation points, interviews, focus groups, and access to the participant “MyPoints” portal.
- **Participant equipment requests;** requests for in-vehicle equipment replacement due to damage, loss, or theft not including the Smartphone.
- **Damaged car charger or power outlet;** specific issues related to power cord damage, faulty power outlets, or the need for a power management module.
- **Smartphone battery replacement;** requests for battery replacement due to shortened life or Smartphone power issues. Requests increased over time due to Smartphone reuse.
- **“IMEI Not Found” error;** specific instances of the MBUF application reporting “IMEI Not Found” errors when communicating with the cloud environment. This issue was more prevalent in earlier versions of the application and resolved with later updates.
- **Unrecoverable data at odometer readings or as reported;** difficulty uploading MBUF related data due to excessive data storage on the Smartphone during odometer readings. Excessive data storage would occur in instances where participants would unknowingly lose Smartphone mobile data connectivity for extended periods of time.
- **No or poor GPS signal;** reports of chronic GPS signal loss or weak GPS signal. This condition was heavily dependent on hardware and/or Smartphone placement in the vehicle.

#### 4.9.2 Participant Comments

General participant comments during staff engagements, over the phone or in the field, included discussions on system feasibility, questions about large scale implementations, and local impact on communities. Participants were generally open to offering opinions on the overall study, existing and future state policies, and alternatives to a mileage based user fees. Concerns about privacy were voiced on occasion. Some participants were very engaged in documenting trip information while others were more passive. On only two occasions of note participants become irate over use of the system or mileage disputes. The most common concerns voiced by participants were related to understanding how the system works or the need for greater support coverage to answer questions regarding operation of the system. In nearly all instances, regardless of the participant’s opinion on the concept of mileage based user fees, participants were cooperative and willing to take part in the study.



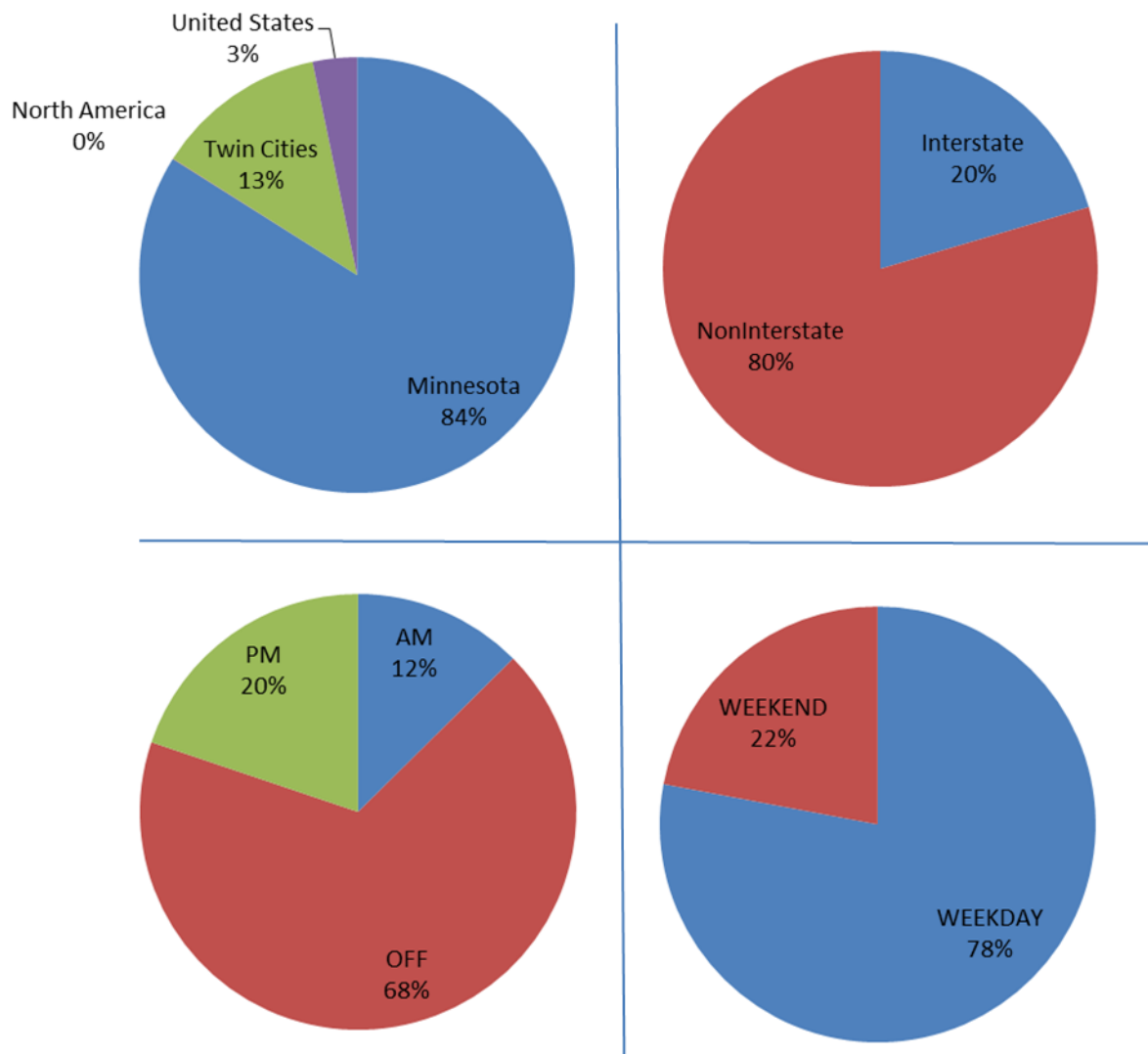
## 4.10 Usage

As summarized in Table 7, 500 total participants were initiated into the study. A high-level view of usage is presented as the total number of probe snapshots and associated trips collected. These findings are derived from a query of all participants initiated into the system during the time September 12, 2011 through October 31, 2012. Participant accounts established for administration, testing, or system demonstrations were removed from the totals. Associated trips refer to those Trip IDs paired by the participant to their respective account.

**Table 7. MRFT Vital Statistics, September 2011-October 2012**

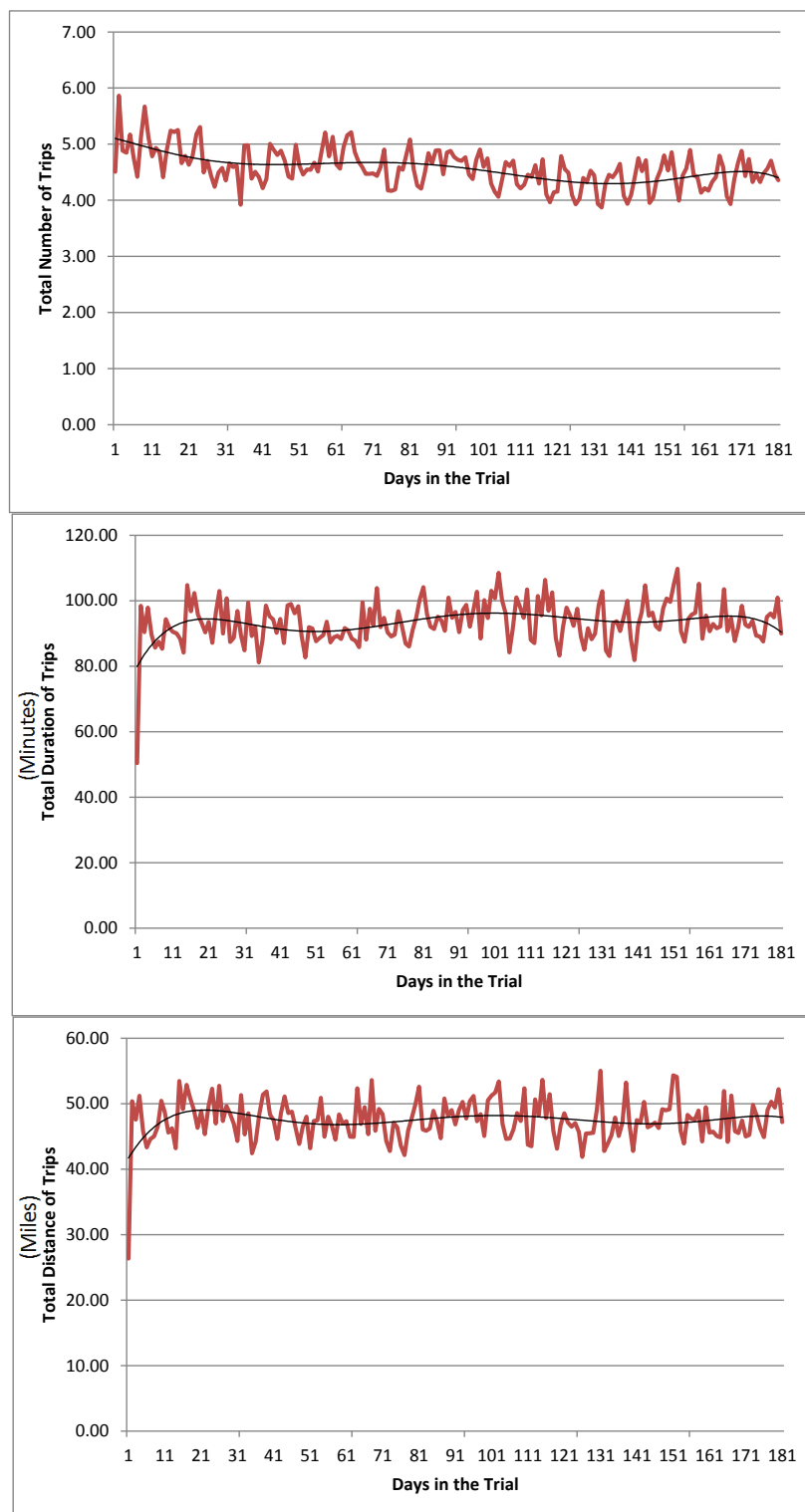
Initiated Participants	500
Probe Snapshots Collected	660,958,334
All Trips Collected	493,867
Associated Trips Collected	408,854

Usage is further broken down by mileage category as shown in Figure 54. Each pie graph shows the proportion of miles collected for a given set of categories. For example, the upper-left pie graph shows the majority of miles collected were within Minnesota but outside the Twin Cities beltway (i.e. I-494/694). The subsequent pie graphs show most miles were accumulated on non-interstate roadways during off-peak times defined as times not including 7 AM – 9 AM and 4 PM – 6 PM weekdays.



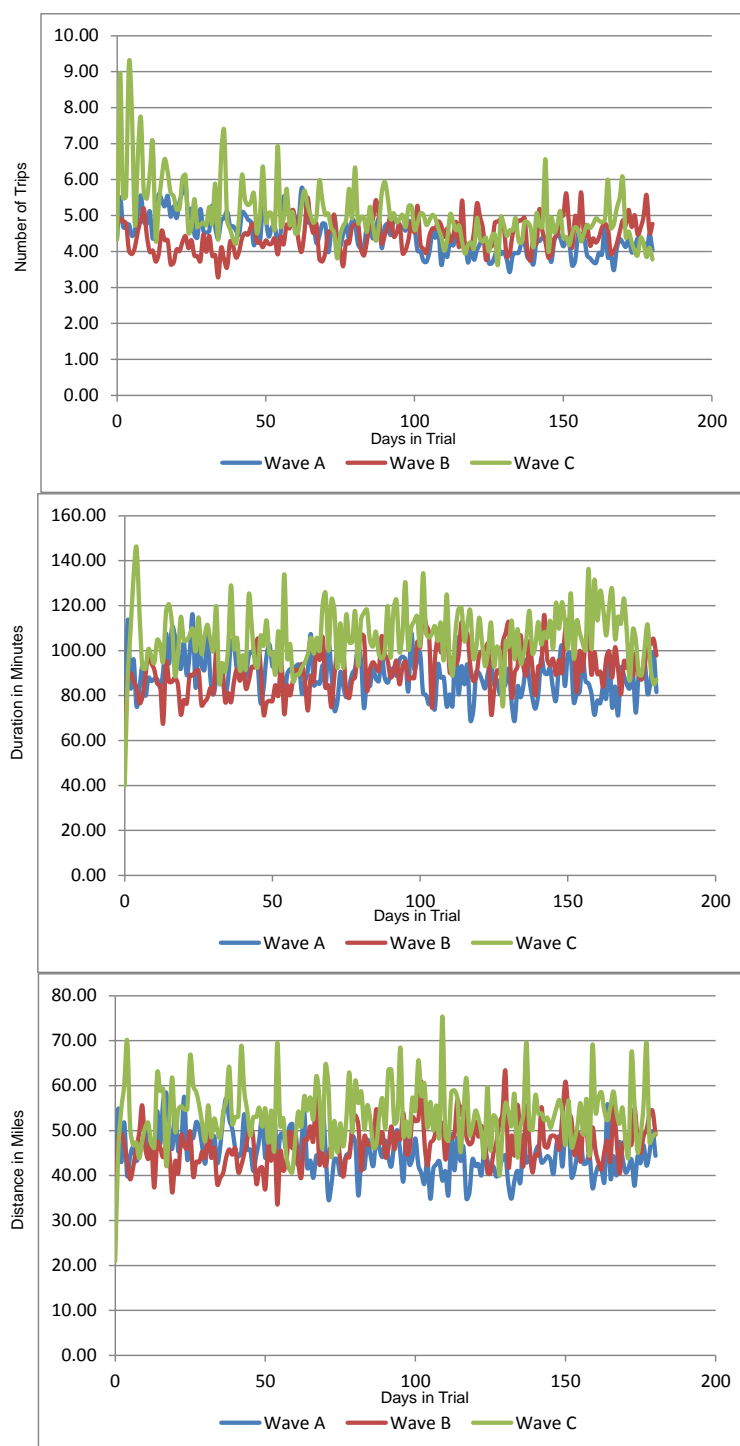
**Figure 54. Miles by Category**

The average number of trips per person per day as well as the total average duration of all trips and the total distance traveled per day is illustrated in Figure 55.



**Figure 55. Average Number of Trips, Duration of Trips, and Total Distance of Trips Per Participant Per Day**

A breakdown of the average number of trips per person per day, total average duration of trips per day, and total average distance traveled per day by participant group (i.e. Wave A, Wave B, Wave C) is shown in Figure 56 as a function days in the trial.



**Figure 56. Average Number of Trips, Total Travel Duration and Total Distance Traveled per Participant Per Day by Wave**

Invoices were generated at the end of every month and sent to participants via e-mail and postal mail. Invoices presented total mileage collected for the preceding month and total charges for that mileage.

#### **4.11 Comparison of Odometer Reading and Equipment Collected Mileage**

The analysis of data collected during the extent of the MRFT has shown a system capable of accurately and reliably supporting a mileage based user fee architecture centered on the implementation of off-the-shelf Smartphone technologies. Of the 500 participants that were initiated into the study, nearly 60 percent reported MBUF mileage within  $\pm 10$  percent of actual odometer readings at the conclusion of the study and had consistent trip performance over time. However, this same analysis also indicates the use of off-the-shelf technologies, on-board vehicle power cues, and an evolving Smartphone platform introduced variability that led to mixed results for some participants. Operational constraints, participant's technology awareness, and related human factors also contributed to variability and mixed results for some.

##### **4.11.1 Reported Odometer vs. MBUF Recorded Mileage**

As described previously, the source of odometer reading data was the direct visual reading of each participant's vehicle odometer taken at three distinct times for each participant group. An odometer reading occurred at the beginning of the baseline period, at the end of the baseline period/beginning of the test period, and at the end of the test period. The difference between successive readings accounted for the total odometer mileage for the entire period that a given participant was active in the study. Figure 57 shows each participant group and the associated odometer readings over time. In comparison, MBUF mileage was collected by the Smartphone on a continuous basis while mounted in the vehicle and uploaded every twenty-four hour period when in the presence of an available mobile data connection. In the event a mobile data connection was not available, MBUF recorded mileage was saved locally to the Smartphone memory for upload when a mobile connection became available. A summary of reported odometer mileage vs. MBUF recorded mileage is shown in Figure 58 for all participant groups. A 10 percent margin of error is shown as a band across all data points as an illustrated reference of known odometer in-accuracies.



Figure 57. Participant Groups and Odometer Reading Timelines

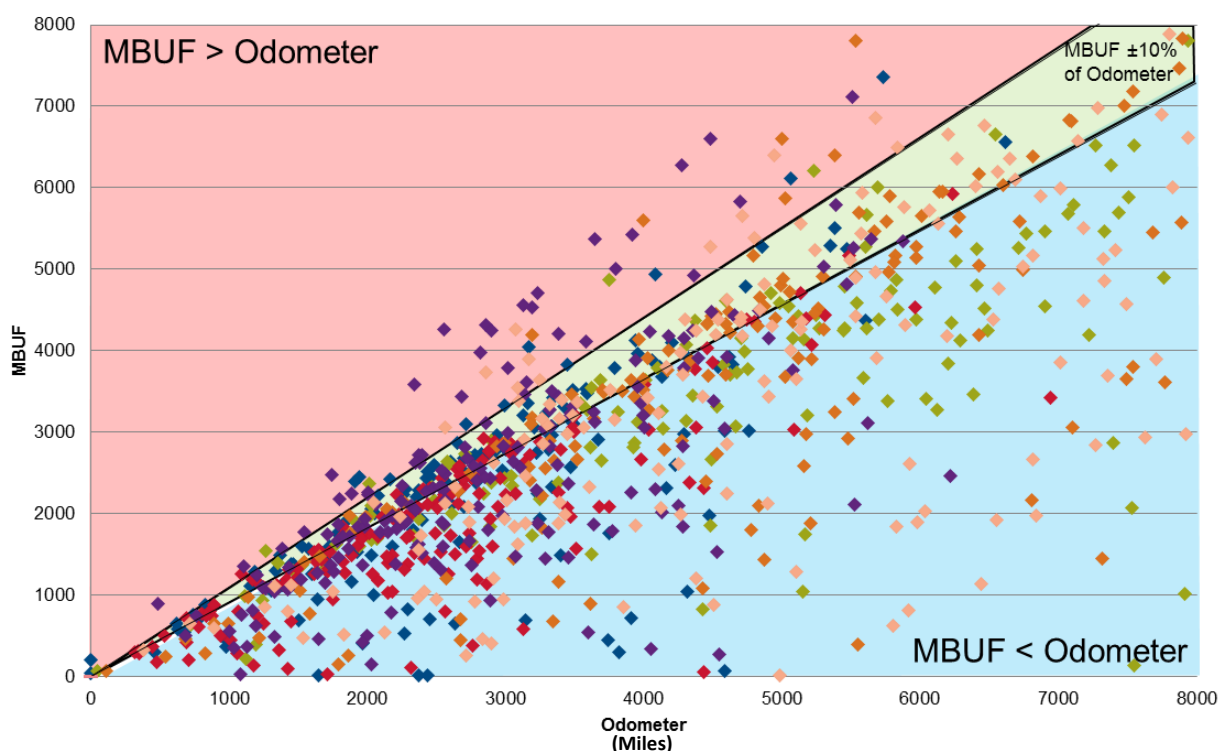


Figure 58. Odometer vs. MBUF Recorded Mileage

Data points grouped below the 10 percent band indicate participants accumulated more odometer mileage than MBUF. Data points grouped within and around the 10 percent band show participants where the MBUF mileage was comparable to odometer mileage. Finally, data points grouped above the 10 percent band suggest accumulated MBUF mileage was greater than odometer. A more detailed analysis reveals the nature of these findings and factors that contribute to each result.

#### 4.11.1.1 Device Usage

In those cases where odometer mileage was greater than MBUF mileage, participant usage of the device was identified as a significant largest contributing factor. As shown in Figure 59, total occurrences of collected MBUF and probe data was limited in example (a) as compared to a

participant from the same participant group in example (b). The low usage participant generated 199 trips while the high usage participant generated 1,201 trips across both baseline and test periods of use. It should be noted that participants were not required to use the Smartphone technology to collect distance traveled for every trip. It was left up to the participant to determine the trips that were captured using the technology option, with the understanding that any mileage captured by the odometer, but not the Smartphone will be charged at the maximum rate. As with any new technology, user challenges were identified during the study impacting the usability of the device. When those inefficiencies and challenges were identified the software team identified and implemented safeguards within the software to reduce the effects of human factors that might contribute to this effect. For example, the MBUF application was updated to automatically launch when the Smartphone was powered on. In addition, training materials were updated to emphasize the most challenging usability issues. Usability issues might include difficulties interacting with the Smartphone touch screen, understanding how to wake the Smartphone from sleep mode, and best practices for charging the Smartphone in the house.

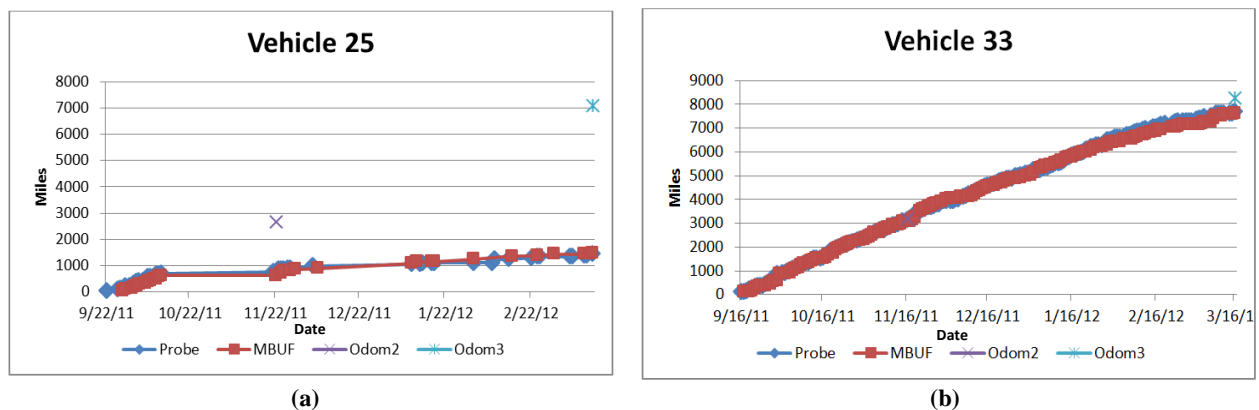


Figure 59. (a) Low Usage Participant (b) High Usage Participant

#### 4.11.1.2 GPS Accuracy

Other factors contributed to the effects of odometer mileage exceeding MBUF mileage. Across all participant groups, GPS accuracy varied by location and Smartphone (i.e. hardware). GPS accuracy was found to be highly dependent on mounting location in the vehicle. If a GPS fix could not be acquired, new MBUF mileage was lost as the MBUF calculation is dependent on an accurate calculation of vehicle location. Instances of no or poor GPS connectivity were reported in approximately 2 percent of all participant service requests. Poor average GPS accuracy indicates the potential for lost MBUF mileage by these participants.

In an effort to understand the impact of GPS accuracy on MBUF applications, an analysis was conducted to determine the sources of error and the implications of that error on collecting distance.

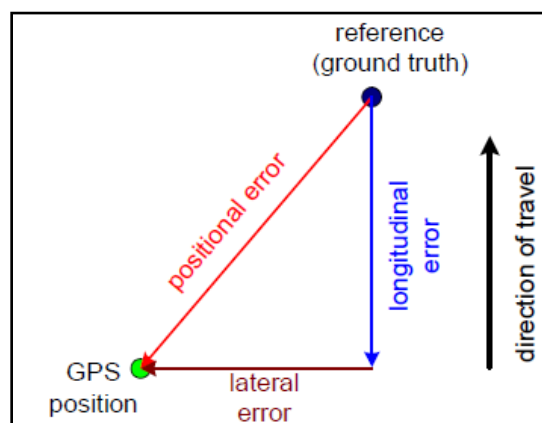
#### 4.11.1.2.1 Defining Accuracy for Road User Fee Applications

The accuracy of GPS is measured by the difference between the actual position of an object compared to the GPS-provided estimate of its position.

Numerous factors can affect the accuracy of GPS readings for any given location over time, including clock errors on the GPS receiver, positional errors caused by minor variations in satellite orbits, the earth's atmosphere, multipath errors caused by satellite signals reflected from buildings or water, satellite geometry, and ground obstructions like buildings or trees.<sup>17,18,19,20</sup> For a given location, GPS accuracy can be treated as a statistical measure, i.e.,

for a given direction a Gauss curve would represent the probability of a position being reported for a point based on the actual position.<sup>21</sup> For a moving

object, Figure 60 shows the three types of error from a GPS measurement: longitudinal, lateral and positional error, where positional error is the total distance between the estimated and actual location, while longitudinal and lateral error are vectors parallel and perpendicular to the direction of travel, respectively.<sup>21</sup> Another source of error is the accuracy of digital maps, e.g., positions of locations on a map relative to the actual positions; an inaccurate map compounds the errors already found in GPS readings.



**Figure 60. Error Components of GPS Measurement for a Moving Object<sup>21</sup>**

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<sup>17</sup> Perry, Calvin D. and Rains, Glen C. *Explaining GPS: the Global Positioning System*. s.l. : University of Georgia, 2009.

<sup>18</sup> Pickford, Andrew T. W. and Blythe, Philip T. *Road User Charging and Electronic Toll Collection*. Boston, MA : Artech House, 2006.

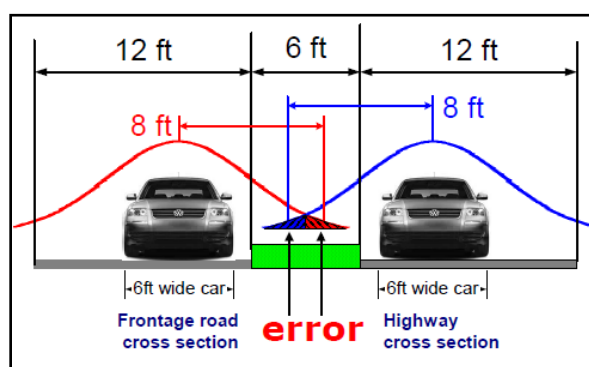
<sup>19</sup> Hatcher, S. G., Bunch, J., Hardy, M., McGurrin, M., and Hardesty, D. *Mileage-based User Fee Technology Study*. Washington, DC : Research and Innovative Technology Administration (RITA), Federal Highway Administration (FHWA), 2009.

<sup>20</sup> Forkenbrock, David J. and Kuhl, Jon G. *A New Approach to Assessing Road User Charges*. Iowa City, IA : Public Policy Center, The University of Iowa, 2002.

<sup>21</sup> Donath, M., Skekhar, S., Cheng, P. -M., and Ma, X. *A New Approach to Assessing Road User Charges: Evaluation of Core Technologies*. Minneapolis, MN : Department of Mechanical Engineering, University of Minnesota, 2003.



The desired degree of GPS accuracy for road user fees will inherently vary according to the type of deployment being implemented, potentially varying from a few feet to several thousand feet, e.g., for a lane-based application versus a zone-based application, respectively. Positional error will be the concern for jurisdictional or zone-based road user fee systems where boundaries are more arbitrarily defined for large areas and relatively large errors would likely be acceptable. For road user fee systems where distinguishing parallel roads and lanes is required, lateral error will be the primary concern; for these applications, the accuracy of digital maps used will be particularly important as well, to help reduce lateral error. Figure 61 shows an example where there is an eight-foot lateral error that would need to be reduced for use in a RUF system that required differentiation of travel on the highway from travel on the adjacent frontage road. The width of the Gauss curve represents the probability of the GPS position data being reported for a given location, based on the actual vehicle positions in the worst-case scenario at the edges of the lanes. Thus, to ensure accuracy in a road-based road user fee application, overall lateral error could not be more than one-half the width of a vehicle plus one-half the distance between the closest two parallel roads in a given area. A lane-based application would require overall lateral error no greater than one-half of the width of a vehicle because of the minimal horizontal distance between lanes. In the most extreme case for a congestion-based road user fee application, lateral error would still need to be minimized to determine the specific lane a vehicle is traveling, i.e., general purpose lane versus a high-occupancy toll (HOT) lane, and because speed would be recorded, longitudinal error must be minimized.



**Figure 61. Reducing Lateral Error is Necessary for this Example to know with 100% Certainty Whether a Car is Travelling on the Highway or Parallel Frontage Road<sup>21</sup>**

From a road user fee standpoint, the accuracy of the overall mileage estimated per trip is important as well. The challenge in assessing GPS accuracy for mileage-based road user fees is to establish a sufficiently accurate ground truth reference for the miles traveled. Two ground truth references are often considered – odometers, or a digital map – but both have inherent challenges associated with internal measurement errors. National Institute of Standards and Technology (NIST) specifications for odometers require only a +/- 4 percent tolerance. Some car manufacturers set a higher tolerance (Honda for example has a +/-2.5 percent tolerance for their cars) but regardless, the mileage reported by odometers might vary from a “true” mileage by a small amount. As such, mileage calculated by GPS-based systems between +/-4 percent of the odometer, can be considered as accurate as an odometer based reading.

An estimate of “true mileage” can also be determined by comparing the GPS trip logs to a “external” digital map database (such as ArcGIS, Google Earth, MapQuest or any other map provider). Here, the challenge lies in the variations between the digital maps that are currently available today. Using data from the Minneapolis Road Fee Test, 10 random GPS traces were plotted against three digital maps (ArcGIS, Google Earth and Mapquest). As the table shows, the mileage calculated by the digital maps varies based on the source indicating a need for a “standard” or acceptable map for road user fees which can serve as the ground truth for road user fee systems.

**Table 8. Traces of Trips from Minnesota Road Fee Test Mapped to ArcGIS, Mapquest and Google Earth**

Trip ID	Average GPS Accuracy (feet)	Miles Logged by the Smartphone GPS	Estimated Trip Miles from Various Map Sources		
			ArcGIS	MapQuest	Google Earth
...53f4b545ab5c	5.97	16.58	16.81 (+1%)	16.56 (-)	16.6 (-)
...010a839b5c5e	6.36	32.62	33.06 (+1%)	32.62 (-)	32.7 (-)
...d09f63b906fa	6.48	15.91	16.24 (+2%)	15.9 (-)	16 (+1%)
...d3f4b5759ad1	6.72	12.46	12.72 (+2%)	12.4 (-)	12.5 (-)
...cf603744308c	7.09	0.68	0.7 (+3%)	0.71 (+4%)	0.69 (+1%)
...916fecda554a	8.22	1.13	1.2 (+6%)	1.15 (+2%)	1.16 (+3%)
...cd67a959f4fb	10.15	32.25	33.56 (+4%)	35.41 (+10%)	33.2 (+3%)
...86d31bb6ecf9	11.18	1.42	1.41 (-1%)	1.31 (-8%)	1.4 (-1%)
...3bc27afa7d3f	11.77	1.25	1.31 (+5%)	1.5 (+20%)	0.57 (-54%)
...6b92f905c4b2	12.13	1.06	1.02 (-4%)	0.87 (-18%)	1 (-6%)

Note: Odometers are +/-4 percent accurate (NIST Specification)

#### 4.11.1.2.2 Defining Reliability for Road User Fee Applications

In addition to accuracy, reliability of the GPS signal is a major concern for road user fee charging. Reliability concerns hinge on two primary factors: latency and signal availability. Latency is the amount of time between a request for a position and delivery of the positioning information; while delays over 20 minutes have been documented, some road user fee applications may require a faster response, e.g., for fees that vary by time of day on a given route.<sup>18</sup> Additionally, numerous factors and conditions can hinder GPS signal availability, particularly tall buildings in dense urban areas and heavily forested areas.<sup>18,19,21</sup> Ideally, GPS signals would be accessible at all times, but not all road user fee applications would require this. Where necessary, other technologies can be combined with GPS to make a more reliable, robust system, as discussed below.<sup>20</sup> Although this may be required for some systems, such as a lane-specific application, other systems may more easily tolerate relatively short GPS signal interruptions. Also important to reliability, is the ability of the GPS system to get a lock on its position with minimum elapsed time from the start of the trip or when the signal is lost during a trip.

Table 9 shows the GPS accuracy and reliability requirements for each type of road user fee system, which will determine the necessity for more accurate or complementary technology to correct for error.

**Table 9. Accuracy and Reliability Requirements Based on the Type of Road User Fee Application<sup>22</sup>**

Road User Fee Application	Accuracy Requirement	Reliability Requirement
Jurisdictional-based	Low: Jurisdictions would likely be relatively large areas; positional error need not be particularly low	Low: It is unlikely that a vehicle would frequently cross jurisdictional boundaries
Road-based	Medium-high: Urban areas would require higher levels of accuracy, i.e., low lateral error, specifically where a frontage road would need to be distinguished from a freeway, for example. Lateral error is no greater than one-half of vehicle width plus one-half of the smallest distance between parallel roads.	Medium: Periodic delays in recording a position would be acceptable; routes traveled could be estimated
Lane-based	High: Distinguishing between lanes, e.g., general purpose lanes versus HOT lanes, would require even higher levels of accuracy since they are closer together. Lateral error is no greater than one-half of vehicle width, i.e., very low lateral error	Medium-high: Presumably, a driver could enter or exit a lane on a fairly regular basis, requiring higher reliability.
Congestion-based	Very high: In addition to distinguishing individual lanes, longitudinal error would also have to be minimized to potentially reflect accurate speeds	Very high: To record accurate speeds, frequent readings would be required.

#### **4.11.1.2.3 Current Status of GPS Accuracy and Reliability**

##### **4.11.1.2.3.1 *Evolution of Technology***

Originally developed for military and defense purposes, GPS first became publicly accessible in 1983. Traditional GPS devices have been shown to have positional accuracy of about 8.5 meters (27.6 feet) with 95 percent confidence.<sup>23</sup> To improve accuracy, numerous systems have been deployed to improve accuracy including High Sensitivity GPS, which involves time averaging; and Differential GPS (DGPS), using ground stations or additional satellites to transmit corrections to signals, such as National Differential GPS (NDGPS) and the Wide Area Augmentation System (WAAS), or subscription-based DGPS providers<sup>24</sup>.

Generally, DGPS utilizes a series of GPS receivers at base stations with known locations that continuously calculate the error between the GPS position and the known location.<sup>17</sup> This calculated error is then transmitted to GPS receivers in the field so that it may correct for this error and thus improve its own calculations for GPS position, which results in an improved accuracy ranging from 1.5 to 15 feet, depending on the system being used.<sup>17</sup>

<sup>22</sup> Further statistical details on calculating desired accuracy of GPS and digital maps can be found in “A New Approach to Assessing Road User Charges: Evaluation of Core Technologies” (5).

<sup>23</sup> Prasad, R. and Ruggieri, M. *Applied Satellite Navigation using GPS, GALILEO, and Augmentation Systems*. London, UK : Artech House, 2005.

<sup>24</sup> Cottingham, David N., Beresford, Alastair R. and Harle, Robert K. *A Survey of Technologies for the Implementation of National-Scale Road User Charging*. 4, s.l. : Transport Reviews, 2007, Vol. 27.

The U.S. Coast Guard began a DGPS program in the late 1980s that was later expanded to provide national coverage known as NDGPS. Under good conditions, NDGPS improves accuracy to 3 to 6 feet.<sup>17,25</sup> NDGPS is typically not affected by heavy foliage, terrain, or buildings, unlike satellite-based systems.<sup>25</sup> Further, NDGPS is designed to have dual coverage, when the full network is complete, to provide redundancy, while also having systems in place to provide backup power and redundant control stations to guarantee high reliability.<sup>25</sup>

The Federal Aviation Administration developed WAAS, using additional satellites, instead of ground-based stations to broadcast correction signals that improve accuracy to 9 to 15 feet.<sup>17</sup> A drawback of this DGPS for road user fee applications, however, is that it was designed for altitudes above 40 meters not ground-based applications, and is thus less reliable.<sup>25</sup> Specifically, users have difficulty receiving signals on the north-side of obstructions or even in open areas at higher latitudes.<sup>25</sup>

Additionally, there are various types of subscription-based DGPS providers such as NavCom Technology, Inc., OmniSTAR, and Thales Landstar that can offer accuracy up to 10 centimeters.<sup>17,21,25</sup> These systems, however, typically require purchasing proprietary software or equipment like a dual-frequency receiver and paying annual fees as high as \$2500 per receiver.<sup>25</sup> Additionally, many of these systems, like WAAS, are satellite-based and struggle with impedances like heavy foliage cover.<sup>25</sup> Real-time Kinetic (RTK) applications require lengthy waits of about 20-45 minutes to begin using the high accuracy system and then cannot be easily moved, and are also prohibitively expensive, making them impractical for road-user fee applications.<sup>25</sup>

GPS devices vary greatly in cost, largely based on the level of accuracy provided. Without DGPS capabilities, a standard GPS receiver can easily be purchased for under \$100. The price for a DGPS compatible device goes up to about \$150, and further increases for even greater accuracy as shown in Table 10. Thus, the current issue for road user fee applications is not so much the availability of the technology, but the prohibitive cost. However, several studies conclude that the price of GPS technology would fall if there was a larger market requiring mass production.<sup>21,26</sup>

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<sup>25</sup> Pruitt, Gary and Fly, Carl E. *NDGPS Assessment Report*. McLean, VA : Operations Research and Development, Federal Highway Administration, 2008.

<sup>26</sup> Whitty, J. M. *Oregon's Mileage Fee Concept and Road User Fee Pilot Program, Final Report*. Oregon Department of Transportation, Salem, OR, 2007.

**Table 10. GPS Receiver Classifications**

	<b>Class I</b>	<b>Class II</b>	<b>Class III</b>	<b>Class IV</b>
Price	\$100 - \$800	\$800 - \$3000	\$3000 - \$10,000	\$20,000 - \$50,000
Differential Correction Source	WAAS	WAAS, NDGPS, fee-based subscriptions	Dual Frequency	Real-time Kinetic (RTK) with base station
Update Rate	0.5 - 1 Hz	1 - 10 Hz	1 - 10 Hz	1 - 10 Hz
Static Accuracy	5-12 feet	<3 feet	4-12 inches	<2 inches
Advantages	Compact size, mobile	Higher quality than Class I, faster update rates	Greater accuracy for precise applications	Highly accurate, survey grade, repeatability

Source: Explaining GPS: the Global Positioning System<sup>17</sup>

#### 4.11.1.2.3.2 GPS Signal Impedances

One of the downsides of GPS is the number of impedances that can hinder the signal and accurate positioning. Dense urban areas, sometimes called urban canyons, limit GPS signals, particularly when tall buildings are found on both sides of a street.<sup>17,18,19,20,21</sup> Tunnels, mountainous terrain, forested areas, interference from other radio signals, time of day, multipath errors from reflected signals, and various weather and atmospheric conditions can also hinder GPS.<sup>17,18,19,20</sup> For example, an Oregon State University study showed that although a GPS device collected 100 percent of miles logged on an odometer in a small city environment (Corvallis, Oregon), it only logged 94 percent of miles traveled in a large city environment (downtown Portland, Oregon) and 75 percent of miles traveled in forested or mountainous regions.<sup>27</sup> Other studies have shown similar results.<sup>19,21</sup> Although NDGPS can help alleviate some of these constraints, other concerns are added regarding adequate coverage and declining accuracy as distance from the base station increases. For areas in which GPS devices do not work well, it is also possible to rely on other sensors like odometers to log mileage. There may be some concern with fraud or tampering using GPS, but this can be alleviated with on-board units or map-matching techniques.<sup>27,28</sup> A proposal made in 2011 by LightSquared Subsidiary LLC would integrate a national 4G-LTE wireless broadband network with satellite coverage and would operate near the GPS signal radio band.<sup>29</sup> If this proposal is approved by the Federal Communications Commission (FCC), it is possible that GPS devices might be overloaded or jammed by the new network, requiring many GPS users to upgrade or replace their devices.<sup>29</sup>

<sup>27</sup> Kim, David S. and Porter, J. David. *Appendix F: Technology Development and System Integration for a Vehicle Miles Traveled Based Revenue Collection System Prototype*. Corvallis, OR : Oregon State University, College of Engineering, 2005.

<sup>28</sup> Vonk Noordegraaf, D. M., et al. *Technology Options for Distance-Based Road User Charging Schemes*. Delft, Netherlands : Delft University of Technology, 2008.

<sup>29</sup> Space-Based Positioning Navigation & Timing National Executive Committee. LightSquared and GPS. [Online] July 7, 2011. [Cited: February 2, 2012.] <http://www.pnt.gov/interference/lightsquared>.

#### 4.11.1.2.3.3 Devices

Today, there are numerous devices that utilize GPS technology including personal navigation systems, many mobile phones, and some vehicles. Numerous GPS devices and/or subscriptions are available from many private companies such as NavCom Technologies, Inc., Trimble, Garmin, and JRC. One specific GPS-based service company called Skymeter Corp. focuses on road user fee applications, overseeing data collection and administrative processes.<sup>29</sup> Skymeter Corp. seeks to streamline and facilitate road user fee systems by ensuring reliability with their data verification process to prevent overcharging, alleviating privacy concerns, and minimizing costs to users and government agencies.<sup>29</sup>

All of these types of GPS devices have differing capabilities, and better performance generally translates to higher cost.<sup>20</sup> Characteristics that vary between devices include reduced accuracy in motion versus stationary readings, DGPS capabilities and the degree of reduced accuracy with increased distance from the base-station, the ability to compensate for multipath errors, and signal processing capabilities.<sup>20</sup> In a worst case scenario, these variations among devices could result in discrepancies among the devices' location readings by as much as 37.5 meters.<sup>20</sup>

GPS device manufacturer reports of accuracy are often for the most ideal conditions and should be taken cautiously.<sup>20</sup> A 2003 study by the University of Minnesota evaluated a set of GPS devices for comparative performance to gauge the level of quality versus their price.<sup>21,30</sup> GPS devices with a wide-range of costs and DGPS sources were compared in the study, as shown in Table 11. The intent of the evaluation was to focus on the performance specifications a road user fee application might require, not the specific brand or model of GPS device. It is important to note that even though a group of devices may use the same satellite signals, better software in the GPS device can improve accuracy and positioning information.<sup>30</sup>

**Table 11. Summary of GPS Devices Compared in a University of Minnesota Study<sup>21</sup>**

GPS Device	DGPS Type	Cost (in 2003)	Relative Quality	Accuracy with 99.73% Confidence
Trimble AgGPS 132	NDGPS	\$5000	High-end	6 feet
CSI GBX-12R	NDGPS	\$850	Mid-to-low end	14.5 feet
JRC DGPS 212	NDGPS	\$550	Low-end	16.1 feet
Garmin GPS 76	WAAS	\$200	-	20 feet
NavCom SF-2050M	StarFire	\$6000 + \$850/yr	Highest among global satellite-based DGPS	4 feet
Trimble MS-750	High Accuracy DGPS with RTK	\$12,000	Highest	1 - 3.3 feet

The Minnesota study<sup>21</sup> tested the GPS receivers at different speeds and in several environments: on highways and local streets, around Duluth and downtown Minneapolis, and in areas with large elevations changes. Study results showed that the accuracy of all GPS devices tested remained consistent across a range of vehicle speeds from 15 to 60 miles per hour. Likewise,

<sup>30</sup> Cheng, Pi-Ming, et al. *Evaluation of NDGPS for Assessing Road User Charges*. Washington, D.C. : Transportation Research Board, 2004.



GPS accuracy was unaffected by elevation changes, assuming there were enough satellites available to compute position information. The study notes that for a given road user fee application the highest accuracy GPS device is not necessarily the best alternative; a lane-specific application would likely require a more accurate and thus more expensive GPS device, but many other systems would not need such accuracy. Specifically, the Garmin device was noted as having the best price-to-performance ratio, costing \$200 and being able to distinguish two different roads only twenty feet apart with 99.73 percent accuracy, which would be sufficient for many road user fee applications. Finally, the study recommends for any road user fee application that a GPS device be selected based on higher standards, i.e., at least a 99.73 percent confidence level of accuracy versus a 95 percent confidence level to improve system reliability.

#### **4.11.1.2.4 Potential for Improvement in GPS Accuracy and Reliability**

Although existing GPS technologies alone may not meet the accuracy and reliability requirements of more demanding road user fee applications, numerous possibilities are under development to augment GPS capabilities. While some advancements are realistic for the short-term such as the development of more accurate digital maps, others involve a longer-term vision like the deployment of new GPS technologies. In other cases, it may be possible to merge GPS with other technologies like cellular communications infrastructure to increase accuracy and reliability.

##### ***4.11.1.2.4.1 Digital Maps***

When road user fees need to be associated with specific road segments, a digital map is used to match GPS positions with the correct roadway; the use of more accurate digital maps would greatly improve GPS capabilities.<sup>18</sup> Current digital maps have been shown to be largely insufficient for road user fee applications, and would cause inaccurate or unfair charges, particularly in areas with parallel roads or complex interchanges.<sup>19,21</sup> One study showed existing digital maps to provide incorrect matches 13-27 percent of the time, depending on road type.<sup>19</sup>

The next generation of digital maps, accurate to 20 cm and developed for moving vehicles, has been developed and is being used for safety applications, but is not yet available from either the public or private sectors.<sup>21,30</sup> While GPS analysis has shown that GPS technology is sufficiently accurate for road user fee applications, incorporating enhanced digital maps improves the viability of more precise road user fee applications, such as lane-specific pricing.<sup>21</sup> Using a combination of high accuracy digital maps and GPS devices, road user fee applications with quality lateral resolutions becomes a realistic, viable option.<sup>19,30</sup>

##### ***4.11.1.2.4.2 High Accuracy NDGPS***

A new generation of NDGPS, called High Accuracy NDGPS (HA-NDGPS), has been developed that is accurate to 4 inches for horizontal positioning with 95 percent confidence.<sup>25</sup> For full coverage, each current NDGPS site would need to be upgraded; as of 2008, three sites had already been retrofitted.

##### ***4.11.1.2.4.3 GPS Modernization***

Additionally, a GPS modernization program called GPS III has begun that will replace the previous GPS satellites, launching new satellites with increased capabilities that will provide

improved accuracy that is currently provided by other services like NDGPS or WAAS.<sup>25</sup> The signal used by the new system will facilitate use in currently impeded areas, e.g., around buildings or in forested areas.<sup>25</sup> It is anticipated that GPS III will match the accuracy and integrity of NDGPS, ultimately allowing it to be phased out of service and calling into question current investments into NDGPS.<sup>25</sup> Yet, the modernized GPS will require a transition period to phase in new equipment, software, procedures, and personnel training, is not expected to be fully operational until after 2021, and is already experiencing deployment delays.<sup>25</sup>

#### **4.11.1.2.4.4 Enhanced GPS**

Integrated navigation systems, also known as enhanced GPS, use other technologies such as a vehicle odometer, gyroscope, or accelerometer to increase performance of traditional GPS when signals are weak or unavailable, such as in urban, forested, or mountainous areas.<sup>19</sup> An example of this, GPS Deduced Reckoning or Dead Reckoning (GPS/DR), uses a deduced reckoning motion sensor like an odometer or gyroscope in areas where signals are weak or unavailable to keep track of the distance and direction traveled.<sup>20,31</sup> While this will retain information when GPS signals are unavailable, it requires interfacing with the vehicle and increased computing power.<sup>19</sup>

#### **4.11.1.2.4.5 Future Research**

As new GPS technologies and enhanced digital maps become available, it will be important to document improved capabilities versus the costs of the new system. In this way, decisions can be more readily made regarding the selection of GPS devices that provide the best value for the desired level of accuracy at the lowest cost. The use of more accurate digital maps may allow for a less accurate GPS device and thus be a cheaper option to implement a road user fee application, or vice versa. Before deployment of a road user fee system using GPS, combinations of the most-recent technologies need to be thoroughly researched in consideration of costs and accuracy, as well as future needs and expansion of the system.

#### **4.11.1.2.5 Discussion and Conclusions**

Given the wide variety of technologies available for any number of road user fee applications, GPS is not the only solution and may not be the best alternative depending on the objective of the road user fee system. Numerous factors determine the viability of GPS for a given road user fee application, including the specificity required by zone, road or lane; whether the area is heavily forested or a dense urban center; and the anticipated coverage area, e.g., a local or national scale. For almost any desired level of accuracy, technology sources are available to meet the need, comparing favorably to existing approaches to calculating the road usage.

Similarly, there are some acknowledged reliability issues with GPS, but these issues can be largely resolved currently with enhancements provided by added technologies. A natural concern then is that with increased accuracy provided by high-end GPS devices or other augmenting technology comes a higher price tag for the road user fee application. While it is generally accepted that the current price for GPS devices will decrease if deployed on a large scale, it is harder to estimate how much cheaper they will actually be.

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<sup>31</sup> Ochieng, W. Y.; North, R. J.; Quddus, M. A.; Noland, R. B., *Technologies to Measure Indicators for Variable Road User Charging*. Transportation Research Board, Annual Meeting, Washington, D.C., 2008.



The accuracy and reliability of GPS technology is only a first requirement for a given road user fee application. The same power that GPS technology has to collect and track such precise information of vehicle location over time for a road user fee application also generates public concerns over privacy. Issues regarding the type of information collected from GPS devices remain as general concerns, although public satisfaction with this was high with both the Oregon Road User Fee Pilot and Iowa Mileage-Based User Charge Evaluation. Other technological hurdles include the communication and management of data that the GPS device collects. Certainly these issues have been overcome in various aforementioned road user fee demonstrations and applications; however, road user fee applications have the potential to expand to increased levels of specificity and scale, and these challenges will have to be confronted.

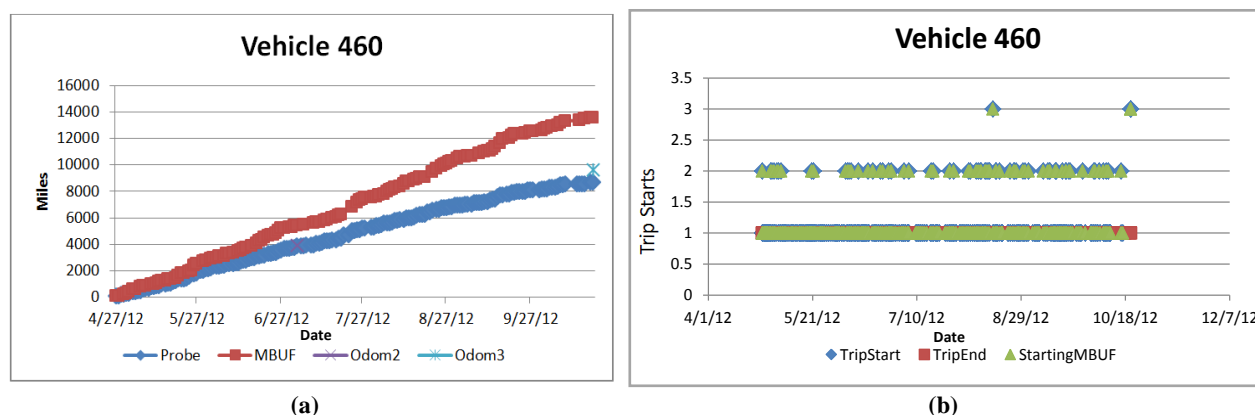
Even so, high accuracy is not always needed if it is purely a zone-based application. Evaluations in Oregon, Iowa, Minnesota, and Washington have successfully used various flavors of GPS as part of a zonal mileage-based road user fee demonstration. While GPS technological capabilities for lane-based applications are available, they have not been tested yet. In coming years, improvements to digital maps, upgrades to the NDGPS network, and modernization of the GPS satellites are all likely to increase accuracy and reliability for GPS technology, making it an increasingly viable option for road user fee applications.

#### **4.11.1.3 Mobile Data Connection Reliability**

In addition to GPS accuracy, an intermittent mobile data connection indirectly impacts the collection of MBUF data resulting in lower MBUF mileage reporting as compared to odometer mileage. As evidenced by 2.3 percent of participant service requests, field staff were unable to recover excessive MBUF mileage stored on the Smartphone due to intermittent mobile data connectivity. Mobile data connectivity was affected by both proximity to local cellular towers and Smartphone hardware issues. In the case of hardware, service staff found functionality within the Android Smartphone platform caused a permanent automatic shutdown of the mobile data connection when the phone transitioned into a low battery warning state to conserve battery power. If the participant was unaware of this condition it would lead to excessive amounts of data being stored on the Smartphone. When field staff identified the issue for an individual participant the amount of data was in excess of what could be uploaded over a mobile data connection without asking the participant to wait for an excessive amount of time. No other rapid means of recovering data from the Smartphone was available to the field staff.

#### **4.11.1.4 Instability of Power Source**

In cases where MBUF mileage exceeded odometer mileage, further analysis uncovered instability within the Android Smartphone platform when used in combination with on-board vehicle power to cue Smartphone application behavior (i.e. trip starts and stops). The case shown in Figure 62(a) and (b) illustrates behavior identified in 15 percent of all participant data. This behavior was evident across all MBUF application versions and participant groups. This behavior accounts for those points in Figure 58 where MBUF mileage exceeds odometer mileage, however, this phenomenon may also influence mileage of other participants that have MBUF mileage that does not exceed odometer mileage.



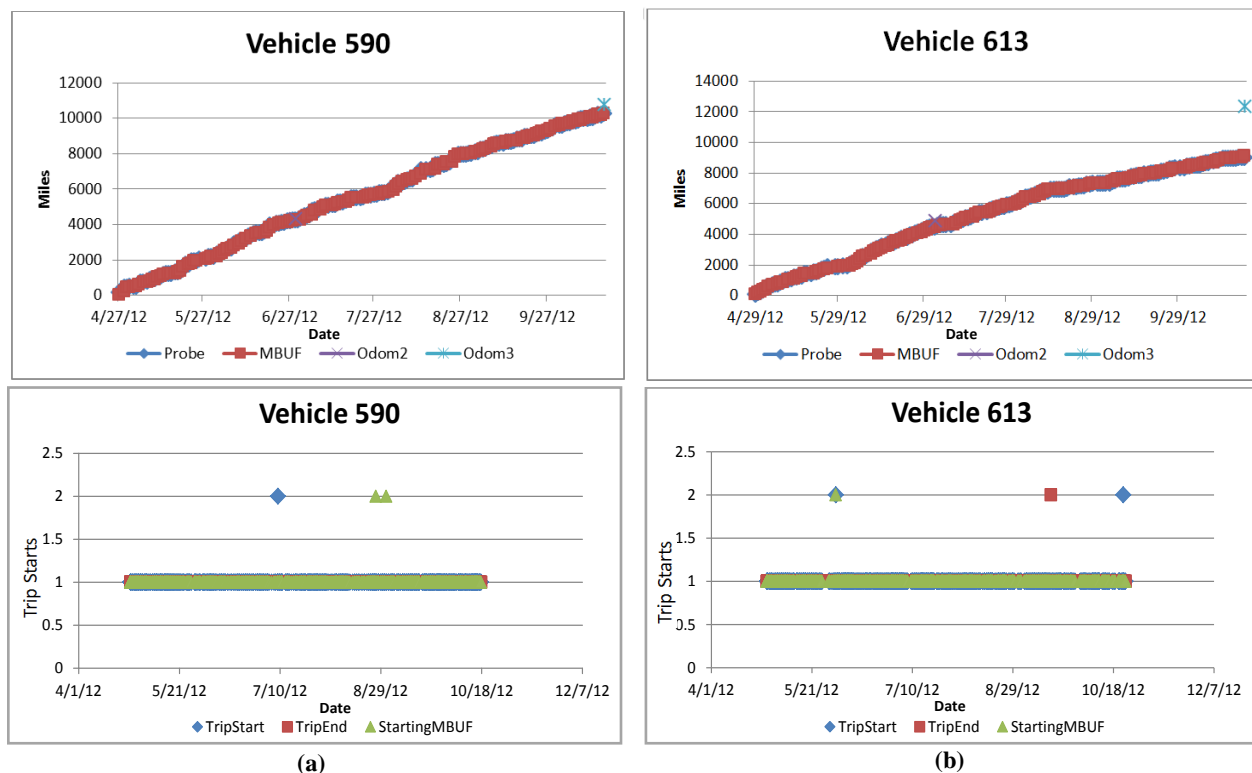
**Figure 62. (a) MBUF Mileage and Probe Data Over Time (b) Trip Starts by Trip ID**

As shown in Figure 62(a), MBUF mileage exceeds odometer mileage at the second odometer reading and the third odometer reading. MBUF mileage out-paces probe data calculated mileage throughout the period of use. Figure 62(b) is from the same participant and shows log entries indicating multiple trip starts for the same Trip ID which effectively doubled the MBUF mileage for that Trip ID due to the Android OS running multiple threads as described in more detail below. As a result, this participant reported a 141.2 percent usage rate as a ratio of MBUF mileage to odometer mileage, while the probe data captured more accurately tracked to the odometer captured mileage.

It is believed that the presence of multiple trip start/stop log entries indicates that stale threads might have been present resulting in incorrect mileage data collected by the application. The CVSMUF software was composed of one main application, which is visible to the user, and several “worker” threads that do all the calculations, communications, and data functions for the Probe, MBUF, and Signage portions of the application as discussed in Section 3.0 of this document. The CVSMUF software used the vehicle power to determine the start and end of a trip. The Android OS sent notification to the CVSMUF software when power was applied or removed from the micro-USB port of the smart phone. When the CVSMUF software received the power applied notification, the application performed several checks (already running, cleanup bad stop, cleanup bad start, etc.) before starting a new trip that then started a new set of threads for the CVSMUF software. There should have been only one instance of each thread running at a time. The trip continued to run until a power removed notification was received, and it was determined by the application that it was time to stop the trip. When the trip stops, the threads that were running and associated to that trip are stopped and removed. It appears that due to the poorly controlled and variable power supplied by the vehicle, the Android OS sent power applied and power removed notifications at times other than just when the ignition was turned on and off. This behavior has shown to produce odd behavior in the application where either multiple threads of the same type are started, or threads are not shut down properly.

In combination with the variability discussed earlier that contributes to reducing MBUF mileage, the net effect of these two influences had also skewed mileage collected for participants with less than 100 percent usage overall. A more reliable indication of consistent and reliable data collection can be seen by investigating those participants that show data collected uniformly over a period of use with a single trip start reported per Trip ID for nearly all trips as shown in

Figure 63. In both examples, the number of trip starts per Trip ID is one for nearly all recorded trips resulting in a consistent plot of usage over time. In example (b), the participant shows consistent usage and well performing trips (i.e. a single start per Trip ID) but still reports MBUF mileage that falls short of odometer mileage due to factors discussed earlier.

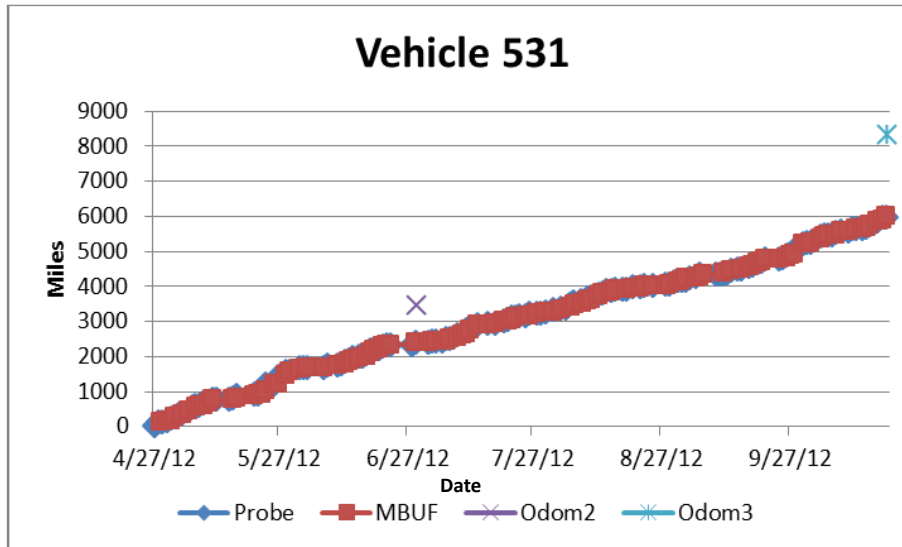


**Figure 63. Examples of Consistent Use and Single Trip Starts by Trip ID**

Identifying those participants that demonstrated the effectiveness of the overall system is accomplished by finding the correlation between trip starts and uniform MBUF and probe data over a period of use. This accounts for the nearly 60 percent of participants that have successfully demonstrated the system and is further supported by the analysis of probe data as compared to MBUF mileage.

#### 4.11.2 Probe Data vs. MBUF Recorded Mileage

Probe data was used by both Battelle and the Evaluation Contractor to further diagnose potential variability in the overall system. Further analysis of probe data as compared to MBUF recorded mileage supports those findings presented in the analysis of odometer mileage compared to MBUF recorded mileage. In particular, those cases where MBUF mileage trailed odometer readings a similar pattern of behavior is seen when analyzing probe data. For example, Figure 64 shows mileage trailing at odometer reading 2 and odometer reading 3 in the same manner for both probe data and MBUF recorded mileage. In this case, factors described in the previous section (e.g. participant use, GPS, etc.) may have contributed to this outcome.



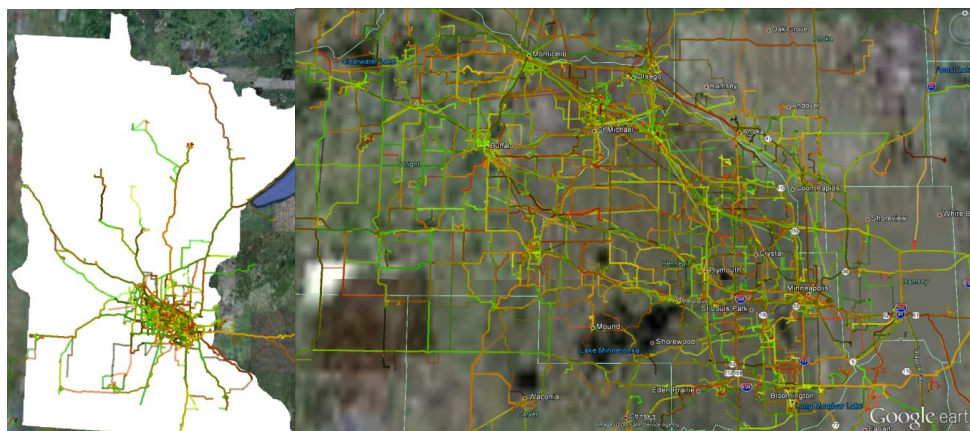
**Figure 64. Participant Usage as Recorded by Probe and MBUF**

In summary, MBUF mileage as compared to odometer mileage can be viewed in three distinct ranges; odometer mileage greater than MBUF mileage, MBUF mileage greater than odometer mileage, and MBUF mileage within a 10 percent margin of error as compared to odometer mileage. In all cases several independent factors influenced the collection of mileage including human factors, evolving mobile technologies, and instability and variability of in-vehicle power systems. Considering these factors, along with a more detailed analysis of usage and Trip IDs supported by probe data, it can be shown that for nearly 60 percent of all participants the use of off-the-shelf Smartphone technologies to collect mileage based user fees was effective within the context of this study.

## 5.0 TRAVEL TIME ANALYSIS

This section serves to illustrate the potential for understanding roadway conditions and aid in the calculation of travel times based on real-time position data (probe data) gathered anonymously from a Smartphone application deployed to 500 Minnesotans for 6 months over a 13-month period. The MRFT application collects position data once every second (probe snapshot) then packages 20 snapshots of probe data and sends that data in a probe message every 20 seconds to the Infrastructure support system via a cellular link. Given the expected latency times, probe data arriving for analysis will be generally no older than 39 seconds, but most data will be significantly younger. For each trip, a Trip ID is assigned as a globally unique ID (GUID). This GUID links all probe data for a given trip, but does not link the data to a particular user, vehicle, or Smartphone to ensure anonymity. By using the probe data, link times can be calculated based on trips happening in real time, or an analysis may be made of historical data.

Versus deploying classical or even emerging technology such as automated license readers or RFID sensors, or other traffic information technologies, significant coverage of the transportation system can be achieved with relatively few devices. During each day, the MRFT system collects, on average greater than 800,000 probe snapshots for every 150 users. Figure 65 shows a Google Earth image of the actual coverage of Minnesota (left) and Wright and Hennepin counties (right) by fewer than 150 devices in one month's time (November 2011) for the MRFT system.

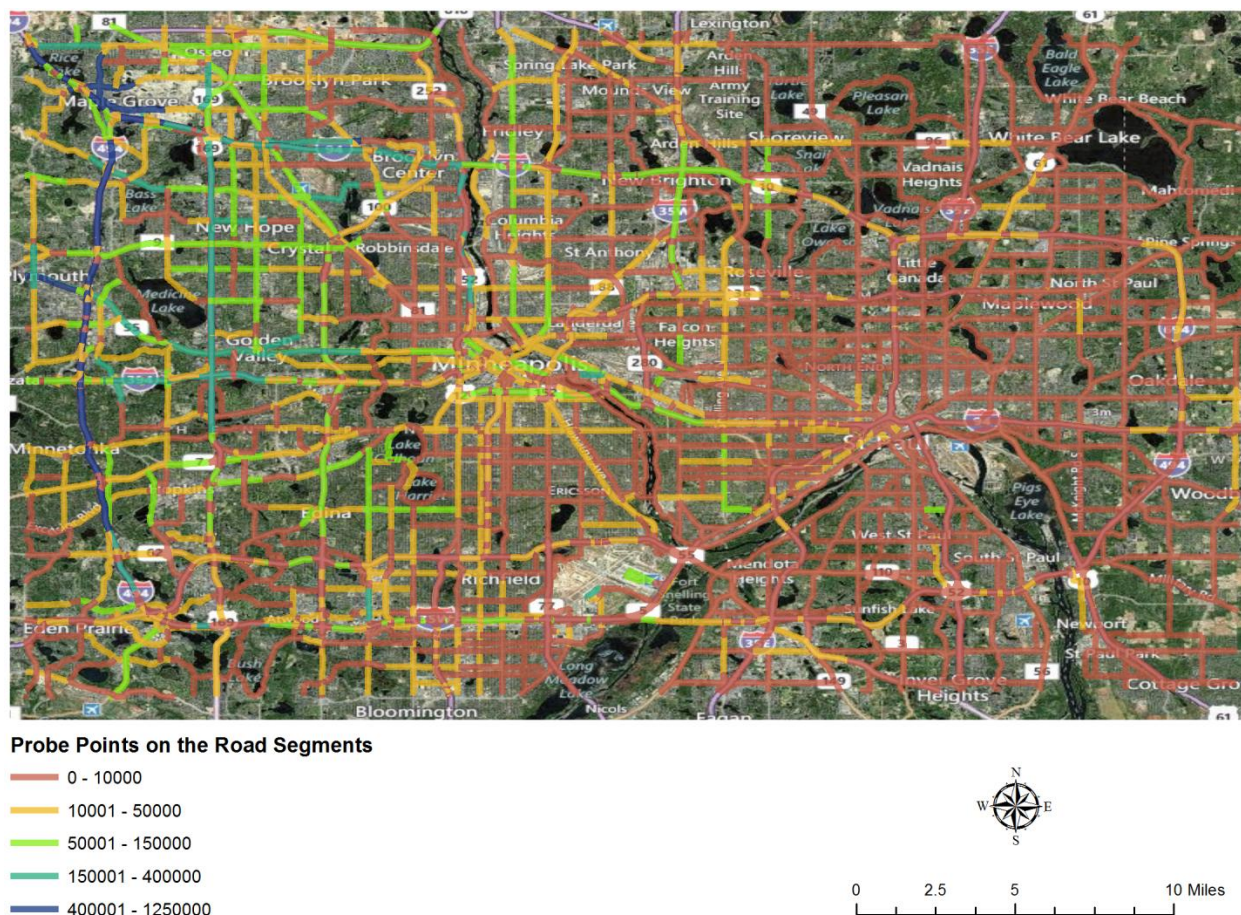


**Figure 65. Coverage for <150 Devices for November 2011**



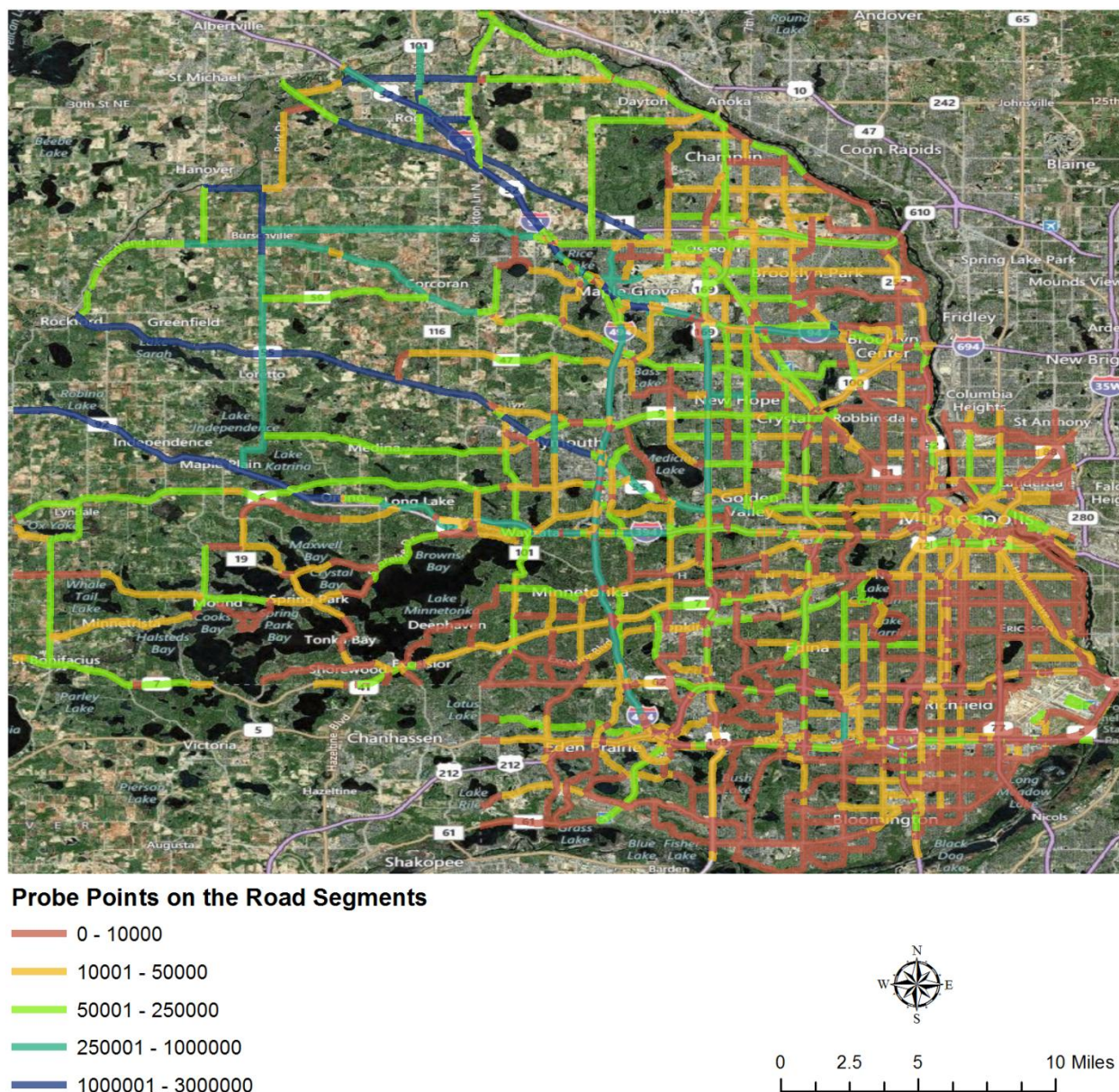
## Connected Vehicle for Safety, Mobility and User Fee Implementation Minnesota Road Fee Test Operations Report

As can be seen in Figure 66 and Figure 67 a significant amount of data was collected with just 500 vehicles operating for 6 months in the Twin Cities and Hennepin county.



**Figure 66. Probe Data Collected within the I-494/I-695 Beltway**





**Figure 67. Probe Data Collected in Hennepin County**

When the probe data are filtered based on location (specific roadway corridor), time (live or historical data) and directionality (eliminate cross-traffic), automatic analyses may be made on the trips transiting the zone.

During the course of the 13-month study, more than 660 million probe data snapshots were captured on 276,850 trips. These data were used to calculate the trip times for each of the three roadway corridors described above. Because of equipment malfunctions that were not evident during the study, some trips were not started and ended correctly (e.g., multiple trips were strung together into one trip). In order to prevent these trips from biasing the analysis, any trips that exceeded 10 minutes on a corridor segment were excluded from the summary statistics for that corridor segment (see following sections for description of corridor segments).



## 5.1 Freeway Road Corridor

An 8-mile corridor of I-94 was used for the freeway road corridor analysis (see Figure 68). As part of the analysis, this corridor was broken down into a series of 0.5-mile segments. Refer to Appendix Figures A-1 through A-16 for a graphical representation of how the corridor was split into the segments.

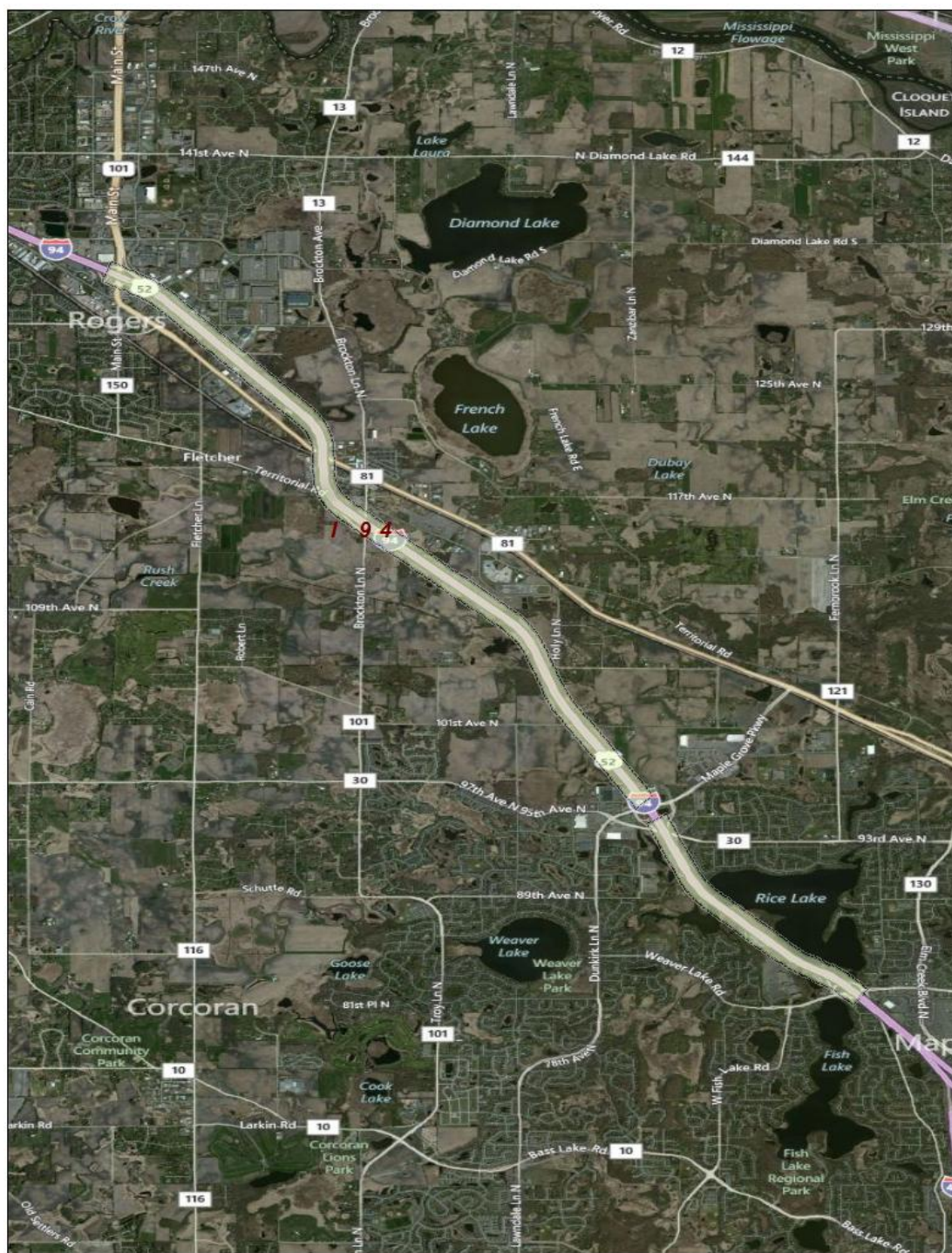


Figure 68. I-94 (Freeway Corridor)



Trips occurring on Tuesdays through Thursdays during morning rush (6:30 am - 8:30 am) and afternoon rush (3:00 pm - 6:00 pm) were analyzed to determine travel time statistics. Tables 12 through 15 present travel time statistics for each segment during the months with the highest travel in the eastbound and westbound directions for each rush period.

**Table 12. Travel Time Statistics for Eastbound Travel During AM Rush in May 2012**

Segment	Count of Trips	Average Travel Time (min)	Maximum Travel Time (min)	Minimum Travel Time (min)
1	103	0.75	9.22	0.37
2	146	0.44	0.83	0.35
3	151	0.46	1.95	0.33
4	153	0.48	2.02	0.37
5	155	0.57	3.35	0.35
6	162	0.62	2.33	0.33
7	163	0.58	2.13	0.35
8	167	0.64	2.55	0.32
9	171	0.68	2.57	0.37
10	172	0.66	2.85	0.35
11	170	0.73	2.87	0.33
12	170	0.66	5.00	0.28
13	167	0.99	7.08	0.35
14	195	0.74	1.90	0.37
15	197	0.69	2.52	0.38
16	173	0.72	3.43	0.38

**Table 13. Travel Time Statistics for Westbound Travel During AM Rush in December 2012**

Segment	Count of Trips	Average Travel Time (min)	Maximum Travel Time (min)	Minimum Travel Time (min)
1	4	0.43	0.48	0.42
2	5	0.45	0.52	0.40
3	5	0.45	0.53	0.42
4	5	0.42	0.43	0.40
5	5	0.43	0.48	0.40
6	5	0.44	0.48	0.42
7	5	0.44	0.47	0.42
8	6	0.44	0.47	0.43
9	6	0.41	0.42	0.40
10	6	0.41	0.43	0.40
11	5	0.43	0.45	0.40
12	5	0.36	0.38	0.33
13	5	0.43	0.47	0.40
14	5	0.44	0.47	0.42
15	5	0.45	0.47	0.42
16	5	0.44	0.47	0.42

**Table 14. Travel Time Statistics for Eastbound Travel During PM Rush in May 2012**

Segment	Count of Trips	Average Travel Time (min)	Maximum Travel Time (min)	Minimum Travel Time (min)
1	28	0.60	1.18	0.38
2	40	0.43	0.53	0.33
3	39	0.42	0.48	0.35
4	38	0.42	0.48	0.38
5	40	0.41	0.50	0.37
6	40	0.42	0.48	0.38
7	41	0.42	0.50	0.37
8	42	0.42	0.48	0.37
9	40	0.42	0.48	0.37
10	39	0.41	0.48	0.38
11	41	0.42	0.48	0.38
12	39	0.49	6.62	0.30
13	40	0.59	7.42	0.37
14	46	0.43	0.57	0.37
15	45	0.43	0.53	0.40
16	44	0.63	2.57	0.40

**Table 15. Travel Time Statistics for Westbound Travel During PM Rush in May 2012**

Segment	Count of Trips	Average Travel Time (min)	Maximum Travel Time (min)	Minimum Travel Time (min)
1	254	0.69	3.25	0.35
2	308	0.62	8.77	0.30
3	301	0.57	2.90	0.37
4	300	0.59	2.07	0.35
5	304	0.51	2.45	0.35
6	308	0.48	1.58	0.35
7	312	0.50	2.32	0.35
8	312	0.51	1.62	0.35
9	304	0.47	1.45	0.35
10	297	0.44	1.52	0.35
11	299	0.44	0.82	0.30
12	289	0.41	2.32	0.27
13	295	0.45	6.68	0.35
14	301	0.45	0.60	0.37
15	304	0.47	0.97	0.38
16	279	0.53	2.50	0.37

## 5.2 Low-speed Signalized Road Corridor (40 mph and below)

A 16-mile corridor of TH55 in Hennepin County was used for the low-speed signalized road corridor analysis (see Figure 69). As part of the analysis, this corridor was broken down into a series of segments separated at the interchanges to other roadways. Refer to Appendix Figures A-17 through A-70 for a graphical representation of how the corridor was split into the segments.

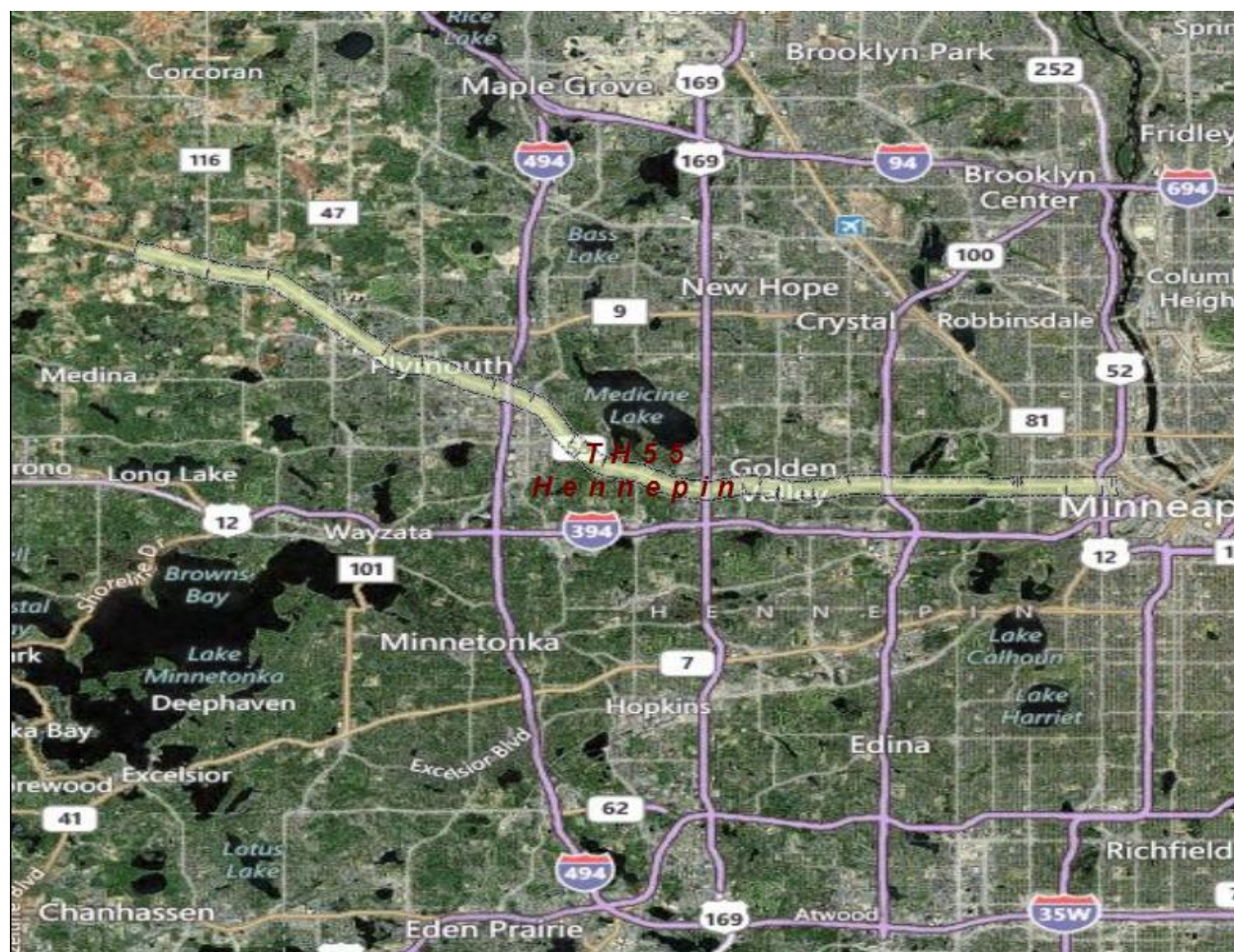


Figure 69. TH55 in Hennepin County (Low-Speed Signalized Corridor)

Trips occurring on Tuesdays through Thursdays during morning rush (6:00 am - 8:30 am) and afternoon rush (3:00 pm - 5:30 pm) were analyzed to determine travel time statistics. Tables 16 through 19 present travel time statistics for each segment with the highest travel in the eastbound and westbound directions for each rush period on the days with matching truth data from MnDOT. Segments for which no travel occurred are not shown in the tables.

**Table 16. Travel Time Statistics for Eastbound Travel During AM Rush on Feb. 29, 2012**

Segment	Count of Trips	Average Travel Time (min)	Maximum Travel Time (min)	Minimum Travel Time (min)
1	6	0.51	0.58	0.43
2	6	1.17	1.73	0.50
3	8	0.53	0.65	0.45
4	8	0.39	0.52	0.33
5	9	0.57	0.72	0.52
6	6	0.16	0.18	0.15
7	9	0.42	0.72	0.27
8	9	1.02	1.15	0.83
9	8	0.65	0.85	0.53
10	8	0.23	0.30	0.20
11	8	0.25	0.35	0.18
12	6	0.60	0.77	0.52
13	3	0.26	0.28	0.23
14	3	0.37	0.40	0.33
15	3	0.48	0.52	0.45
16	2	0.22	0.22	0.22
17	2	0.14	0.15	0.13
18	3	0.21	0.22	0.20
20	3	0.18	0.18	0.18
21	3	0.14	0.15	0.13
22	3	0.13	0.13	0.13
23	2	0.20	0.20	0.20
25	3	0.29	0.32	0.28
26	2	0.54	0.57	0.52
27	2	0.50	0.57	0.43
28	2	0.10	0.12	0.08
29	2	0.28	0.32	0.25
30	2	0.28	0.28	0.28
31	2	0.13	0.13	0.12
32	2	0.19	0.22	0.17
33	2	0.15	0.15	0.15
34	2	1.13	1.73	0.53
35	1	0.67	0.67	0.67

**Table 17. Travel Time Statistics for Westbound Travel During AM Rush on Feb. 29, 2012**

Segment	Count of Trips	Average Travel Time (min)	Maximum Travel Time (min)	Minimum Travel Time (min)
12	1	0.55	0.55	0.55
13	1	0.25	0.25	0.25
14	1	0.45	0.45	0.45
19	1	0.28	0.28	0.28
20	1	0.18	0.18	0.18
21	1	0.15	0.15	0.15
22	1	0.15	0.15	0.15
24	1	0.20	0.20	0.20
25	1	0.32	0.32	0.32
26	1	0.57	0.57	0.57
27	1	0.47	0.47	0.47
28	1	0.10	0.10	0.10
30	1	0.30	0.30	0.30
31	1	0.95	0.95	0.95
32	1	0.35	0.35	0.35
33	1	0.17	0.17	0.17
34	1	0.65	0.65	0.65
35	1	0.58	0.58	0.58
36	1	1.90	1.90	1.90
45	1	1.22	1.22	1.22
46	1	0.05	0.05	0.05
47	1	0.03	0.03	0.03
48	1	0.15	0.15	0.15
49	1	0.47	0.47	0.47
50	1	0.27	0.27	0.27
53	1	0.75	0.75	0.75

**Table 18. Travel Time Statistics for Eastbound Travel During PM Rush on March 15, 2012**

<b>Segment</b>	<b>Count of Trips</b>	<b>Average Travel Time (min)</b>	<b>Maximum Travel Time (min)</b>	<b>Minimum Travel Time (min)</b>
1	2	0.55	0.57	0.53
2	2	0.57	0.58	0.55
3	3	0.46	0.48	0.45
4	3	0.42	0.50	0.35
5	2	0.58	0.60	0.55
6	2	0.17	0.17	0.17
7	3	0.58	1.15	0.30
8	3	1.32	1.55	0.92
9	3	0.76	1.10	0.58
10	3	0.23	0.25	0.22
11	3	0.65	0.87	0.23
12	3	0.61	0.68	0.57
13	1	0.18	0.18	0.18

**Table 19. Travel Time Statistics for Westbound Travel During PM Rush on March 6, 2012**

Segment	Count of Trips	Average Travel Time (min)	Maximum Travel Time (min)	Minimum Travel Time (min)
1	2	0.47	0.48	0.47
2	3	0.51	0.53	0.50
3	7	0.47	0.53	0.40
4	6	0.33	0.37	0.30
5	5	0.70	1.33	0.50
6	7	0.14	0.15	0.13
7	7	0.27	0.28	0.25
8	7	0.85	0.97	0.58
9	8	0.55	0.63	0.48
10	6	0.38	1.10	0.20
11	6	0.21	0.27	0.12
12	7	0.55	0.63	0.48
13	5	0.46	0.80	0.22
14	3	0.51	0.67	0.37
15	2	0.58	0.70	0.47
16	2	0.21	0.22	0.20
17	1	0.13	0.13	0.13
18	2	0.17	0.17	0.17
20	2	0.17	0.17	0.17
21	2	0.13	0.13	0.12
22	2	0.13	0.13	0.12
23	1	0.22	0.22	0.22
25	2	0.42	0.52	0.32
26	3	0.88	1.08	0.77
27	3	0.44	0.48	0.40
28	2	0.13	0.13	0.12
29	2	1.11	1.45	0.77
30	2	0.35	0.43	0.27

### 5.3 High-speed Signalized Road Corridor (50 mph above)

A 1.6-mile corridor of TH55 in Wright County was used for the high-speed signalized road corridor analysis (see Figure 70). As part of the analysis, this corridor was broken down into a series of segments separated at the interchanges to other roadways. Refer to Appendix Figures A-71 through A-76 for a graphical representation of how the corridor was split into the segments.



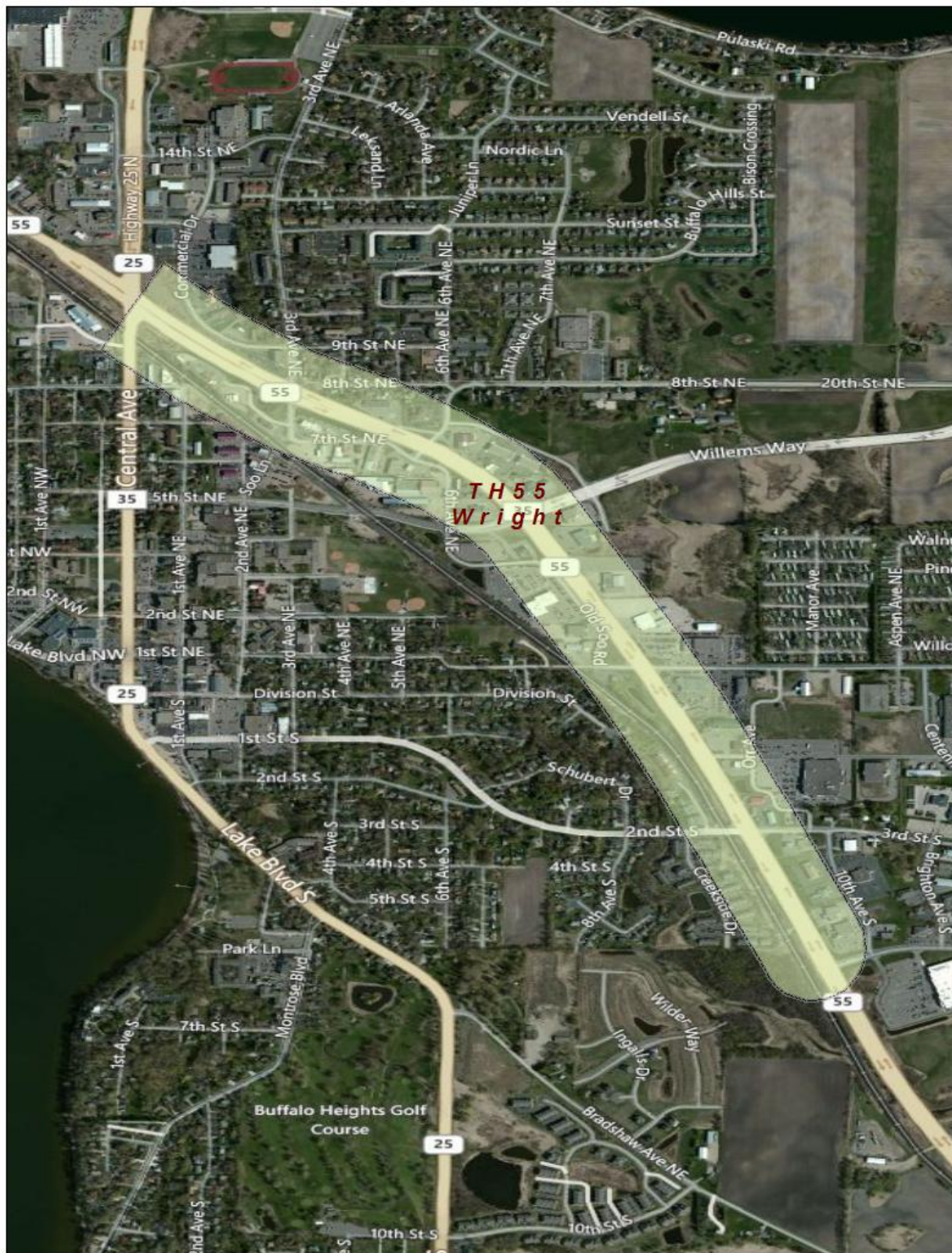


Figure 70. TH55 in Wright County (High-Speed Signalized Corridor)



Trips occurring on Tuesdays through Thursdays during morning rush (6:30 am - 8:30 am) and afternoon rush (3:00 pm - 6:00 pm) were analyzed to determine travel time statistics. Tables 20 through 23 present travel time statistics for each segment during the months with the highest travel in the eastbound and westbound directions for each rush period.

**Table 20. Travel Time Statistics for Eastbound Travel During AM Rush in May 2012**

Segment	Count of Trips	Average Travel Time (min)	Maximum Travel Time (min)	Minimum Travel Time (min)
1	35	0.66	6.28	0.25
2	31	0.39	5.15	0.17
3	14	0.38	1.02	0.17
4	18	0.43	1.33	0.27
5	17	0.49	2.00	0.28
6	20	0.29	1.87	0.15

**Table 21. Travel Time Statistics for Westbound Travel During AM Rush in May 2012**

Segment	Count of Trips	Average Travel Time (min)	Maximum Travel Time (min)	Minimum Travel Time (min)
1	13	0.47	1.42	0.22
2	16	0.81	9.17	0.20
3	3	0.22	0.27	0.20
4	11	0.46	0.82	0.33
5	9	0.44	1.02	0.33
6	7	0.20	0.22	0.17

**Table 22. Travel Time Statistics for Eastbound Travel During PM Rush in May 2012**

Segment	Count of Trips	Average Travel Time (min)	Maximum Travel Time (min)	Minimum Travel Time (min)
1	37	0.61	1.72	0.28
2	49	0.44	9.12	0.17
3	18	0.78	6.28	0.18
4	48	0.85	7.88	0.28
5	55	0.79	9.35	0.27
6	35	0.39	5.87	0.15

**Table 23. Travel Time Statistics for Westbound Travel During PM Rush in May 2012**

Segment	Count of Trips	Average Travel Time (min)	Maximum Travel Time (min)	Minimum Travel Time (min)
1	117	1.03	9.38	0.25
2	102	0.42	6.55	0.13
3	11	0.26	0.72	0.17
4	109	0.75	5.65	0.25
5	77	0.75	6.57	0.28
6	88	0.62	8.52	0.15

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## 6.0 ASSESSMENT AND RECOMMENDATIONS FOR IMPROVEMENT

The MRFT project provides a significant advancement in understanding the technological feasibility of implementing a road user fee through aftermarket devices, particularly a Smartphone. As with most research projects that seek to advance the boundary of known research, designing, developing, and implementing a robust, first-of-its-kind, system was an extraordinary endeavor. Was the MRFT project a success? Unequivocally, the answer must be “Yes.” More than 1 terabyte of data was successfully collected representing millions of miles traveled and hundreds of thousands of trips from 500 participants over a one year period without any significant adverse vehicle event such as a technology induced crash, vehicle battery failure, etc. Moreover, the project clearly demonstrated that the technology embedded within today’s Smartphone is more than sufficient to capture accurate and frequent GPS measurements (at one second intervals) as well as providing a viable mechanism for the delivery of other safety related applications such as dynamic signage. Finally, the MRFT project also demonstrated that such technology could be understood by the traveling public, is suitable for self-installation by the public, and can collect and process data through a cloud-based architecture securely and with complete transparency to the end-user.

1. A smart phone is a reasonable and viable platform for MBUF.
2. The quality of GPS signal is variable from phone-to-phone and is dependent upon placement of the device.
3. There will always be issues with smart phone operating systems that makes the ability to audit/post-process data critical and vital.
4. There is room for continued field support optimization.
5. Use of power-port (voltage) for trip start/stop is not reliable.
6. Statewide deployment will require provisions for providing significant help support.

**Figure 71. Critical Lessons Learned as Part of the Operational Deployment of the MRFT Project**

Among the most important aspects and findings of the MRFT project can be found through mining the data as well as the lessons learned during the field operations. These lessons can guide future research and deployment efforts to enhance the user experience, improve operational efficiency, and avoid technology-based limitations encountered during the project. A summary of the main lessons learned is provided in Figure 71 with additional detail in the text below, but the reader is encouraged not to infer from the detailed nature of these lessons that the project and technology deployment was anything but resoundingly successful.

### 6.1 A Smart Phone is a Reasonable and Viable Platform for MBUF

One of the most significant aspects of the test was to prove that low-cost, off-the-shelf consumer electronic navigation devices have sufficient abilities to both record and transmit a road user fee in a dynamic and real environment. Today, two years after the launch of the study, it seems obvious that Smartphones do have this capability along with many other capabilities. The same obvious statement could not be made in 2010, prior to this test. Through this project, many different nuances on designing and deploying an application for a mobile, smart phone based environment were learned ranging from deeply technical issues such as how Smartphones launch (and sometimes re-launch) software threads to more user oriented issues such as the brightness of the display and the ability for alerts to automatically disappear from the screen without user interaction. Ultimately, this project demonstrates that people are willing and comfortable with

Smartphone technology and the technology embedded in today's Smartphones is capable of capturing and processing second-by-second location and mileage information both accurately and consistently. There remain issues with GPS-based locations, as discussed in Section 4.11.1 of this document, common to all GPS receivers including Smartphones, particularly in dense urban canyons, but on the whole, when placed in the windshield the Smartphones were generally able to acquire a reliably accurate GPS fix.

## **6.2 The Quality of GPS Signal is Variable from Phone-to-Phone and is Dependent Upon Placement of the Device**

All Smartphones are not created equal. Even within the same type, producer, chipset, and embedded firmware there can be significant differences between two Smartphones regarding the ability to obtain and provide a GPS location. During the project, we identified several cases where the quality of the GPS signal on a daily commute could only be improved by replacing the device with an identical Smartphone. This does not mean that the original Smartphone was defective as it did provide location information. Rather, that the ability of the replacement Smartphone, mounted in the same location and driven along the same route at the same times of the day provided location information of a significantly higher quality. This suggests that future programs based upon COTS technology such as Smartphones cannot rely upon manufacturer make and model as a determiner of whether the device can provide high quality locations. Instead, each Smartphone or device should be independently tested and verified for accuracy prior to use in capturing a road user fee.

Location of the Smartphone had a significant impact on both the time it took to acquire a satellite based position fix as well as the quality of the location. Generally, Smartphones mounted on the windshield provided the best and quickest location fixes while Smartphones mounted in the air vents provided quicker and better location fixes than did Smartphones placed elsewhere in the vehicle.

## **6.3 There Will Always be Issues with Smartphone Operating Systems That Make the Ability to Audit/Post-Process Data Critical and Vital**

Although it seems that the current trend in Smartphone development is to narrow the gap between personal computers and hand-held, mobile devices, one of the lessons learned during this project is that Smartphones have a fundamentally different purpose than a desktop or laptop computer and this purpose can cause challenges when developing computationally intense software. In particular, the Smartphone operating system environment is dramatically more fluid than the desktop/laptop operating system environment with changes to the operating systems being deployed relatively frequently. During this year-long deployment, the Android OS underwent more than six distinct OS upgrades. With each upgrade, aspects of the OS are not necessarily maintained or further supported and backwards compatibility is not always provided. This can cause issues and the need for routine updates to be pushed to the end-user, occasionally with unforeseen issues arising during this process. One of the more significant OS changes to the Android OS occurred during the second wave (Wave B) of the study whereby the mechanism by which the Android OS open-and-closed files stored on the device was significantly changed. With a road-user-fee system that captures and transmits second-by-second location information and uses this information to update a local database on the Smartphone to aggregate distance; changes to the file handling mechanism caused the Smartphone to occasionally launch duplicate

threads of code. This resulted in an over accumulation of mileage in the local database and ultimately reporting of the mileage to the fee processing infrastructure and participant for payment.

The launching and closing of multiple threads was not readily visible to the software development team and was not a result of a code implementation; but rather, due to the OS functionality in combination with a variable power source as discussed in Section 4.11.1 of this document. However, this issue highlights the need for and the ability to have road-user-mileage and associated fees be audited using the more detailed GPS location points rather than only the total accumulated miles in each fee category. It was this very capability to audit the mileage accumulated by the MBUF application in comparison to the mileage recorded by the Probe application that allowed for the identification of this OS issue.

Although this issue is expected to be resolved in the next version of the Android OS and may in fact, have already been resolved, there will likely always be some type of processing issue that will require the ability to audit the mileage calculation on a trip-by-trip basis to ensure the correct assignment of fees.

## **6.4 There is Room for Continued Field Support Optimization**

Extraordinary efforts were made to provide detailed assistance to the participants of the Minnesota Road Fee Test. For example, at the first few odometer readings, one-on-one installation and operational instructions were provided for each participant. These sessions often included extended discussions and support. By the third wave, participants were briefed on the equipment in small groups and left to self-install the equipment in their own vehicle. Battelle believes that the initial briefing could also be eliminated as could some of the other procedures that were put into place to capture and record the vehicle's odometer.

One of the important findings is that participants were frequent users of the help support line and were very active in seeking assistance and information on the equipment, operation of the equipment, and their billing/invoicing. As part of the project experiment, the field location was established to be reflective of a small, licensing agency that processed licenses and/or other driver registrations and materials. There did not appear to be any significant issues with processing large numbers of vehicles in and out of the facility on a relatively short period. At the same time however, when examining the costs associated with the field operational support it is important to remember that the project field staff were instructed to provide as much support as needed, including installation support and one-on-one briefings of participants. This would likely not be representative of the type of service and user support that would be expected/needed for a larger deployment as much of this type of support would likely be performed by family and friends of the users rather than by paid staff.

## **6.5 Use of Power-Port (voltage) for Trip Start/Stop is Not Reliable**

Relying upon changes or fluctuations in the voltage crossing through the vehicle's power-port as an indication of whether or not the vehicle's engine is running is not a reliable mechanism. In some vehicles, changes in voltage as the vehicle's engine was engaged/disengaged resulted in a dip in the voltage as the vehicle transitioned to/from the battery power. However, this was not universal and certainly the dip in voltage was not consistent across make, model, and year. In some instances, transition to auxiliary power resulted in a spike in voltage rather than a drop in

voltage. This finding suggest that future deployments should utilize other means to identify a trip start/end such as an internal accelerometer or through accessing the vehicle's internal telematics through the On-Board Diagnostic port or through a direct connect to the vehicle CAN-bus.

## **6.6 Statewide Deployment Will Require Provisions for Providing Significant Help Support**

Providing help support to participants required a significant effort throughout the project. Although participants were encouraged to ask for assistance when needed, the level of calls to the "help desk" far exceeded what was anticipated based upon other help systems operated by Minnesota DOT as pointed out by a Department of Motor Vehicles representative during a Technical Advisory Board meeting. At this point, it is not clear that such an extreme level of help support would need to be maintained for a larger deployment, but it is clear that more support than a typical MnDOT program requires would be needed for a larger deployment.

## 7.0 PARTICIPANT-FACING MATERIAL

The following participant facing materials were generated over the course of the project in support of both operational and evaluation activities. Operational materials were centered on participant training, instruction, and system functionality; materials for the evaluation team were generated to support recruitment and participant orientation.

A full size representation of each document is provided in Appendix B of this document where practical.

### 7.1 In-Vehicle Installation Instructions with VIDM

Instructions were provided in every kit detailing the installation of in-vehicle equipment.

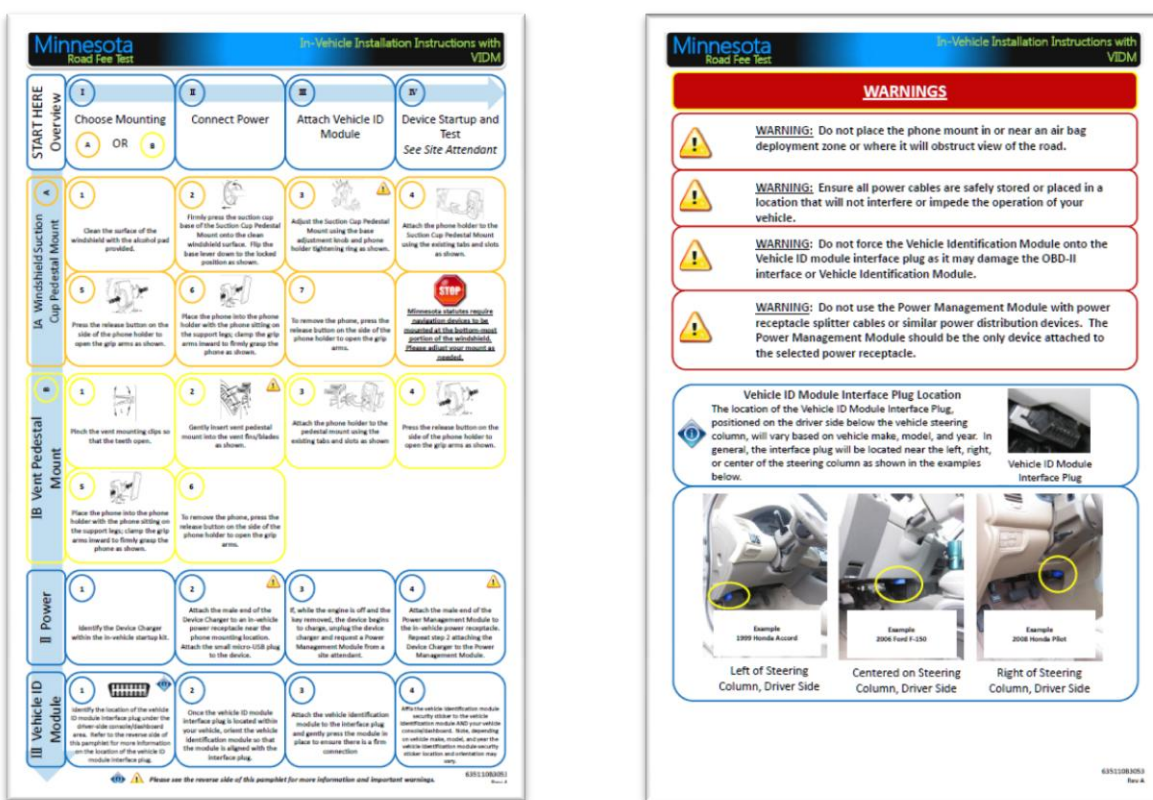


Figure 72. In-Vehicle Installation Instructions with VIDM

## 7.2 Device and Software Use Video (Odometer Reading #1)

A video titled “Welcome to the First Odometer Reading and Equipment Installation” was played continuously during the odometer reading #1 appointments demonstrating equipment installation and basic Smartphone operation.

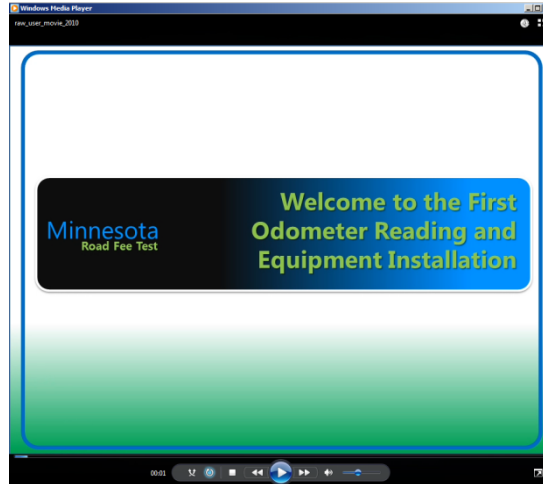


Figure 73. Device and Software Use Video

## 7.3 Device and Software Use Instructions (Odometer Reading #1)

This multipage document was provided during odometer reading #1 illustrating Smartphone use and basic MRFT application functionality.

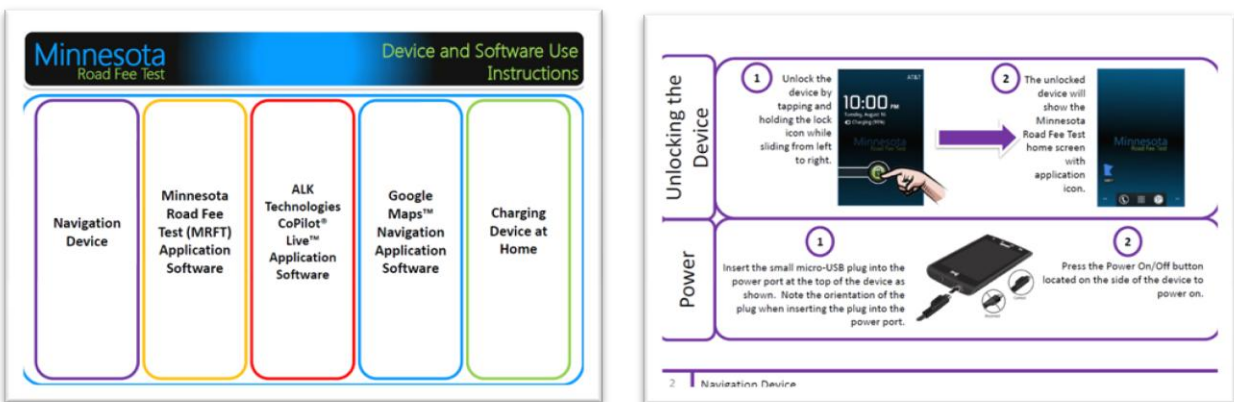


Figure 74. Device and Software Use Instructions



## 7.4 Device and Software Use Instructions Addendum (Odometer Reading #2)

This multipage document was provided during odometer reading #2 illustrating Smartphone use and updated MRFT application functionality.

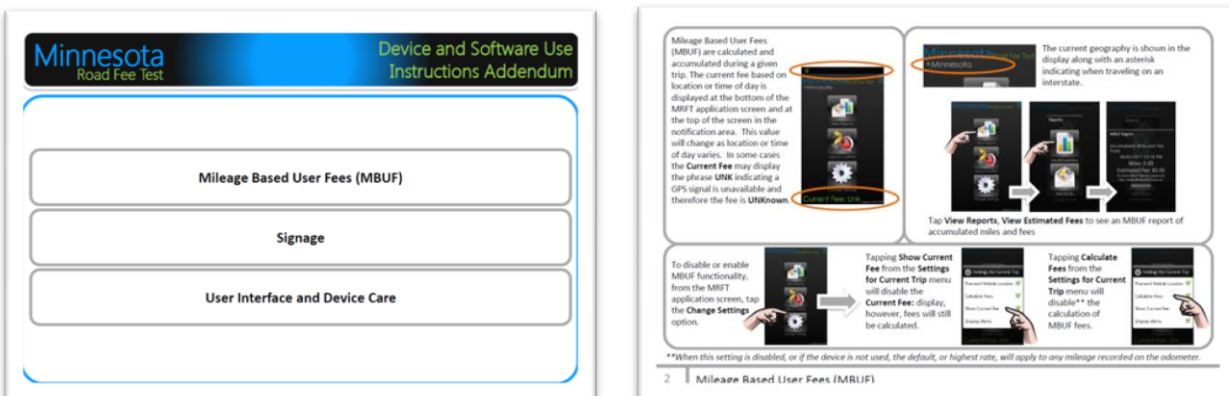


Figure 75. Device and Software Use Instructions Addendum

## 7.5 MBUF Pricing Table and Examples (Odometer Reading #2)

This document was provided during odometer reading #2 appointments illustrating the overall pricing concept in effect during the test period.

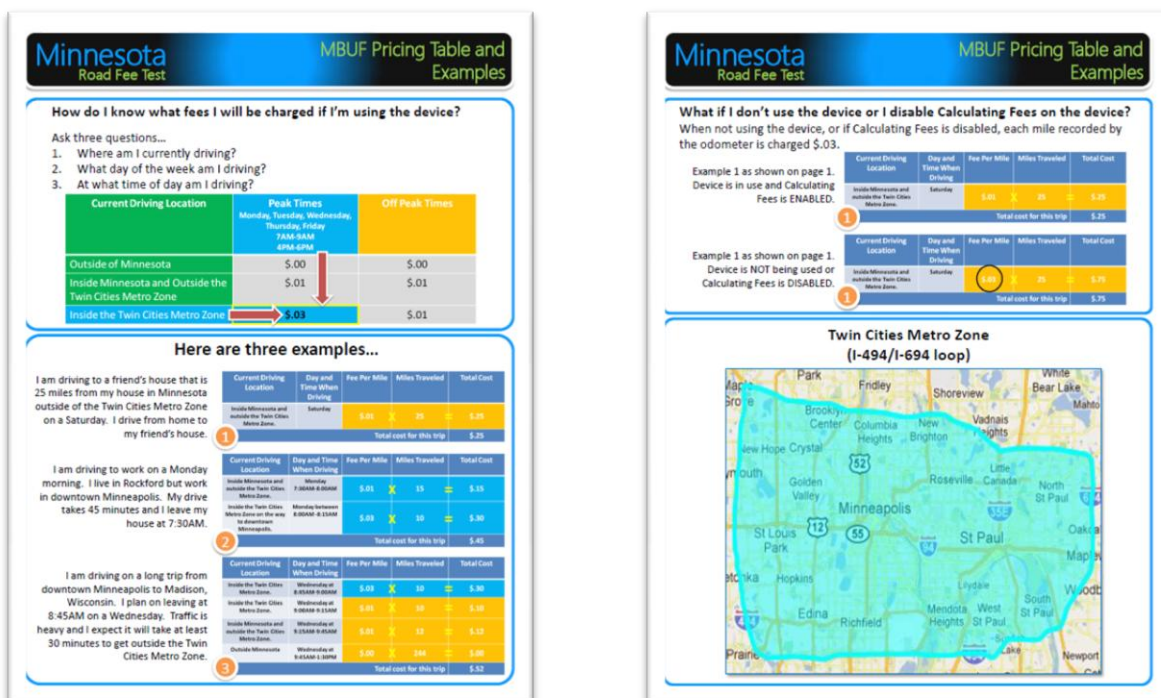


Figure 76. MBUF Pricing Table and Examples

## 7.6 Safety Signage Zones Overview (Odometer Reading #2)

This multipage document was provided during odometer reading #2 appointments showing areas where safety signage zones would appear if a participant drove through them.



Figure 77. Safety Signage Zones Overview

## 7.7 Technology Flyer (Evaluation Team)

This document was provided to the evaluation team for distribution to participant prior to arriving for the odometer reading #1 appointment. Participants were provided with a basic overview of the MRFT system design and technology.



Figure 78. Technology Flyer

## 7.8 Third (Final) Odometer Reading Notice (Insert)

This document was included as an insert prior to scheduling odometer reading #3 notifying participants of the odometer reading #3 milestone objectives and what materials to bring.

The form is titled "Minnesota Road Fee Test" and "Third (Final) Odometer Reading Notice". It is addressed to "Dear Minnesota Road Fee Test Participant," and thanks them for being an active participant. It explains that they need to complete the third (final) odometer reading for the study and complete the process of reconciliation of the invoices and the mileage identified on their odometer. Once they have completed this process, they will be restoring the device back to its factory settings and giving it to them as a reward for completing the study. To summarize, the objectives of the third odometer reading are as follows:

1. Final odometer reading and report.
2. Reconciliation of all invoices.

All invoices must be reconciled including charges for:

- Unpaid invoices
- Mileage collected during March, and
- The difference in mileage between the device and your odometer charged at the default rate.

It is important to note, charges will never exceed the start up funds you were provided. Payment for outstanding charges can be made using PayPal or by cash or check.

3. The device will be restored to factory settings, instructions for contacting a compatible service provider will be provided, and the device will be given to you as a reward for your participation once all previous steps have been completed.

Please bring the following items to the odometer reading:

- ✓ Driver's License with your current address (Note: If the address on your Driver's License is not your current address, please also bring two bills with matching addresses.)
- ✓ Registration or valid insurance card indicating that you are the owner of the car
- ✓ The vehicle that you brought to the second odometer reading
- ✓ All Minnesota Road Fee Test equipment including:
  - Device
  - Charging Cable(s)
  - Vehicle Identification Module
  - Vehicle Mount(s)
- ✓ Your Travel diary (please write your name and phone number on the first page)

To schedule a third (final) odometer reading please contact the Minnesota Road Fee Test support team.

(612) 708-7288  
[support@mnroadfeetest.com](mailto:support@mnroadfeetest.com)  
<http://www.mnroadfeetest.com>

DRAFT

Figure 79. Third (Final) Odometer Reading Notice

## 7.9 Third (Final) Odometer Reading Close Out (Odometer Reading #3)

This multipage document was provided during odometer reading #3 summarizing the steps involved in completing the third and final odometer reading appointment.

The image shows a digital document titled "Minnesota Road Fee Test" and "Third (Final) Odometer Reading Close Out". It begins with a thank-you message and a list of six numbered steps for participants to follow. Step 1 involves vehicle verification and odometer recording. Step 2 is about verifying address and contact info. Step 3 requires signing a participant diary. Step 4 is about returning equipment. Step 5 is about paying outstanding invoices. Step 6 is about receiving an exit survey and stipend. At the bottom, contact information is provided: (320) 365-1084 and myMNpoints@saic.com.

**Minnesota Road Fee Test** Third (Final) Odometer Reading Close Out

Thank you for participating in the Minnesota Road Fee Test!

- 1 Field staff will verify your vehicle, check the vehicle ID module, and record the odometer reading.
- 2 Field staff will verify your address and contact information as reported in the participant portal.
- 3 On the first page of the participant diary, please sign and print your name along with a phone number for the Evaluation Team to contact you with questions.
- 4 Please return all equipment including the vehicle ID module, power chargers, and device mount.  
**As a token of our appreciation the Minnesota Road Fee Test project team would like to present you with the Smartphone as a gift. The phone has been restored to factory settings; please contact a compatible service provider for more information on activation.**
- 5 Pay all outstanding invoices including February, March, and close out. Payment can be made via cash, check, or PayPal.
- 6 The Evaluation Team will contact you with information regarding exit survey and receiving your stipend. All questions with regard to stipend should be directed to the Evaluation Team by phone or e-mail.

(320) 365-1084  
myMNpoints@saic.com

Figure 80. Third (Final) Odometer Reading Close Out



## 7.10 Critical Software Update (Insert)

This document was included as a special insert to participants instructing them on how to apply a critical update identified after the Wave B participant group had completed the odometer reading #2 milestone.

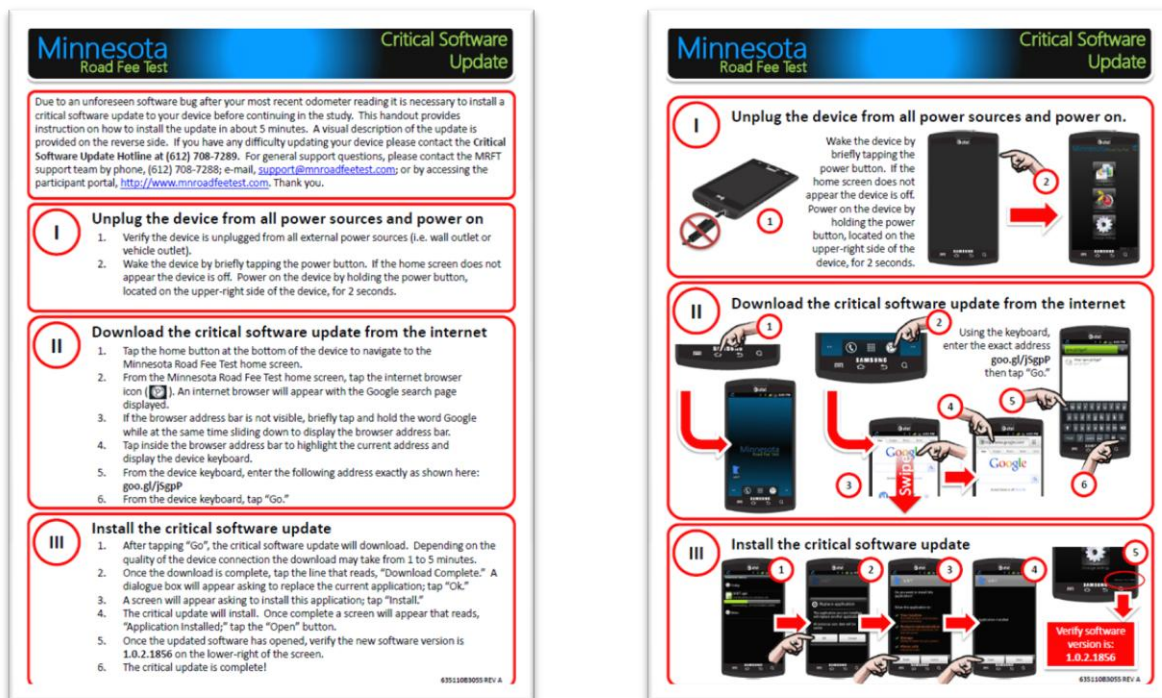


Figure 81. Critical Software Update

## 7.11 Field Office Posters

Posters displayed in the office for participant reference during odometer reading appointments.

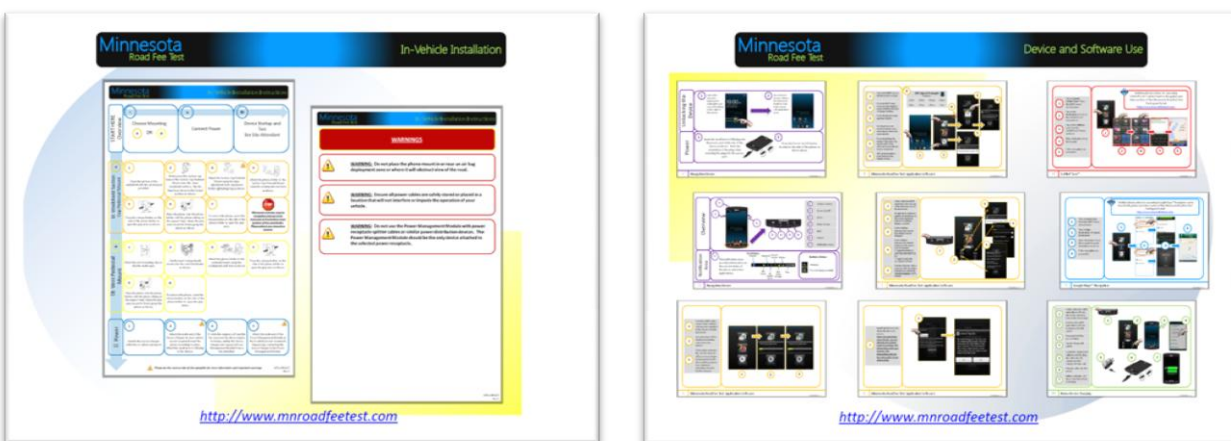


Figure 82. Field Office Posters

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## 8.0 CONFIGURATION MANAGEMENT RECORD

During the course of the program the documentation contributing specifically to the design, and configuration control of the deployed equipment was submitted to and controlled by a Configuration management system within Battelle. This system allowed for the documentation, routing for approval and control of any electronic documentation for key hardware or software deliverables. The configuration control documentation is presented in table from (including all revisions) in Table 24.

Additionally, project working documents were housed on a SharePoint Team Server hosted by Battelle which contained all of the working documents shared amongst the team during the course of the project. Those documents were posted to a list and associated with one of five categories including:

1. Weekly Project Management Meetings
2. Evaluation Documents
3. Draft Deliverables
4. Final Deliverables
5. Working Documents

The final contents of that document repository is shown in Table 25 through Table 29.

**Table 24. Configuration Management Record**

Document No	Revision	Name	Release Date	Next Assembly	Title
635110B0020	A	1006.xml	2010-07-09	FINAL	ISMUFI CONCEPT OF OPERATIONS
635110B0030	A	1009.xml	2010-08-06	FINAL	ISMUFI STAKEHOLDER REQUIREMENTS DOCUMENT
635110B0030	B	1010.xml	2010-09-10	FINAL	ISMUFI STAKEHOLDER REQUIREMENTS DOCUMENT
635110B0040	A	1011.xml	2010-10-13	FINAL	ISMUFI SYSTEM REQUIREMENTS DOCUMENT
635110B0040	B	1012.xml	2010-10-13	FINAL	ISMUFI SYSTEM REQUIREMENTS DOCUMENT
635110B0040	B1	1068.xml	2011-01-14	635110B0000	ISMUFI SYSTEM REQUIREMENTS DOCUMENT
635110B0040	B2	1069.xml	2011-01-11	635110B0000	ISMUFI SYSTEM REQUIREMENTS DOCUMENT
635110B0040	B3	1072.xml	2011-02-02	635110B0000	ISMUFI SYSTEM REQUIREMENTS DOCUMENT
635110B0040	B4	1106.xml	2011-03-21	635110B0000	ISMUFI SYSTEM REQUIREMENTS DOCUMENT
635110B0040	C	1118.xml	2011-03-21	635110B0000	ISMUFI SYSTEM REQUIREMENTS DOCUMENT
635110B0050	A	1013.xml	2010-11-23	FINAL	ISMUFI SYSTEM ARCHITECTURE DOCUMENT
635110B0050	B	1039.xml	2010-11-24	635110B0000	ISMUFI SYSTEM ARCHITECTURE DOCUMENT
635110B0050	C	1050.xml	2011-01-06	635110B0000	ISMUFI SYSTEM ARCHITECTURE DOCUMENT
635110B0050	D	1073.xml	2011-02-04	635110B0000	ISMUFI SYSTEM ARCHITECTURE DOCUMENT
635110B0060	A	1051.xml	2011-01-06	635110B0000	ISMUFI SYSTEM DESIGN OVERVIEW DOCUMENT
635110B0060	B	1099.xml	2011-02-04	635110B0000	ISMUFI SYSTEM DESIGN OVERVIEW DOCUMENT
635110B0070	A	1041.xml	2010-11-24	635110B0000	ISMUF MESSAGE SET DICTIONARY
635110B0070	B	1042.xml	2011-01-06	635110B0000	ISMUF MESSAGE SET DICTIONARY
635110B0070	C	1098.xml	2011-02-04	635110B0000	ISMUF MESSAGE SET DICTIONARY
635110B0100	A	1052.xml	2011-01-06	635110B0000, 635110B1030	CICAS-SSA DATA PROCESSING SDD
635110B0100	B	1074.xml	2011-02-04	635110B0000, 635110B1030	CICAS-SSA DATA PROCESSING SDD
635110B0101	A	1021.xml	2010-11-24	635110B0000, 635110B1010	ISMUF SOFTWARE SDD
635110B0101	B	1043.xml	2011-01-06	635110B0000, 635110B1010	ISMUF SOFTWARE SDD
635110B0101	C	1091.xml	2011-02-04	635110B0000, 635110B1010	ISMUF SOFTWARE SDD
635110B0101	C1	1107.xml	2011-04-20	635110B0000, 635110B1010	ISMUF SOFTWARE SDD
635110B0102	A	1023.xml	2010-11-24	635110B0000, 635110B1010	INITIALIZATION SOFTWARE SDD



**Table 24. Configuration Management Record (Continued)**

Document No	Revision	Name	Release Date	Next Assembly	Title
635110B0102	A1	1071.xml	2011-02-02	635110B0000, 635110B1010	INITIALIZATION SOFTWARE SDD
635110B0103	A	1024.xml	2010-11-24	635110B0000, 635110B1010	LOGGING SOFTWARE SDD
635110B0103	B	1044.xml	2011-01-06	635110B0000, 635110B1010	LOGGING SOFTWARE SDD
635110B0103	C	1076.xml	2011-02-04	635110B0000, 635110B1010	LOGGING SOFTWARE SDD
635110B0104	A	1025.xml	2010-11-24	635110B0000, 635110B1010	POSITIONING SOFTWARE SDD
635110B0104	B	1045.xml	2011-01-06	635110B0000, 635110B1010	POSITIONING SOFTWARE SDD
635110B0104	C	1075.xml	2011-02-04	635110B0000, 635110B1010	POSITIONING SOFTWARE SDD
635110B0105	A	1026.xml	2010-11-24	635110B0000, 635110B1010	SIGNAGE SOFTWARE SDD
635110B0105	B	1049.xml	2011-01-06	635110B0000, 635110B1010	SIGNAGE SOFTWARE SDD
635110B0105	C	1088.xml	2011-02-04	635110B0000, 635110B1010	SIGNAGE SOFTWARE SDD
635110B0106	A	1027.xml	2010-11-24	635110B0000, 635110B1010	MILEAGE-BASED USER FEE (MBUF) COLLECTION SOFTWARE SDD
635110B0106	B	1048.xml	2011-01-06	635110B0000, 635110B1010	MILEAGE-BASED USER FEE (MBUF) COLLECTION SOFTWARE SDD
635110B0106	C	1089.xml	2011-02-04	635110B0000, 635110B1010	MILEAGE-BASED USER FEE (MBUF) COLLECTION SOFTWARE SDD
635110B0106	C1	1108.xml	2011-04-20	635110B0000, 635110B1010	MILEAGE-BASED USER FEE (MBUF) COLLECTION SOFTWARE SDD
635110B0107	A	1028.xml	2010-11-24	635110B0000, 635110B1010	PROBE DATA COLLECTION SOFTWARE SDD
635110B0107	B	1047.xml	2011-01-06	635110B0000, 635110B1010	PROBE DATA COLLECTION SOFTWARE SDD
635110B0107	C	1090.xml	2011-02-04	635110B0000, 635110B1010	PROBE DATA COLLECTION SOFTWARE SDD

**Table 24. Configuration Management Record (Continued)**

Document No	Revision	Name	Release Date	Next Assembly	Title
635110B0107	C1	1109.xml	2011-04-20	635110B0000, 635110B1010	PROBE DATA COLLECTION SOFTWARE SDD
635110B0108	A	1029.xml	2010-11-24	635110B0000, 635110B1010	VEHICLE COMMUNICATIONS SUPPORT SOFTWARE SDD
635110B0108	B	1046.xml	2011-01-06	635110B0000, 635110B1010	VEHICLE COMMUNICATIONS SUPPORT SOFTWARE SDD
635110B0108	C	1077.xml	2011-02-04	635110B0000, 635110B1010	VEHICLE COMMUNICATIONS SUPPORT SOFTWARE SDD
635110B0108	C1	1110.xml	2011-04-20	635110B0000, 635110B1010	VEHICLE COMMUNICATIONS SUPPORT SOFTWARE SDD
635110B0200	A	1030.xml	2010-11-24	635110B0000	STORAGE ACCOUNT, SDD
635110B0200	B	1053.xml	2011-01-06	635110B0000	STORAGE ACCOUNT, SDD
635110B0200	C	1078.xml	2011-02-04	635110B0000	STORAGE ACCOUNT, SDD
635110B0200	C1	1111.xml	2011-03-21	635110B0000	STORAGE ACCOUNT, SDD
635110B0201	A	1054.xml	2011-01-06	635110B0000	CVSMUF WINDOWS AZURE PROJECT, SDD
635110B0201	B	1079.xml	2011-02-04	635110B0000	CVSMUF WINDOWS AZURE PROJECT, SDD
635110B0210	A	1020.xml	2010-11-24	635110B0000	VEHICLE COMMUNICATIONS WEB ROLE, SDD
635110B0210	B	1055.xml	2011-01-06	635110B0000	VEHICLE COMMUNICATIONS WEB ROLE, SDD
635110B0210	C	1085.xml	2011-02-04	635110B0000	VEHICLE COMMUNICATIONS WEB ROLE, SDD
635110B0210	C1	1112.xml	2011-03-15	635110B0000	VEHICLE COMMUNICATIONS WEB ROLE, SDD
635110B0211	A	1031.xml	2010-11-24	635110B0000	PARTICIPANT PORTAL WEB ROLE, SDD
635110B0211	B	1056.xml	2011-01-06	635110B0000	PARTICIPANT PORTAL WEB ROLE, SDD
635110B0211	C	1086.xml	2011-02-04	635110B0000	PARTICIPANT PORTAL WEB ROLE, SDD
635110B0212	A	1032.xml	2010-11-24	635110B0000	ADMIN PORTAL WEB ROLE, SDD
635110B0212	B	1057.xml	2011-01-06	635110B0000	ADMIN PORTAL WEB ROLE, SDD
635110B0212	C	1087.xml	2011-02-04	635110B0000	ADMIN PORTAL WEB ROLE, SDD
635110B0212	C1	1113.xml	2011-03-15	635110B0000	ADMIN PORTAL WEB ROLE, SDD
635110B0213	A	1033.xml	2010-11-24	635110B0000	BUSINESS LOGIC WEB ROLE, SDD
635110B0213	B	1058.xml	2011-01-06	635110B0000	BUSINESS LOGIC WEB ROLE, SDD
635110B0213	C	1080.xml	2011-02-04	635110B0000	BUSINESS LOGIC LIBRARY, SDD
635110B0213	C1	1114.xml	2011-03-15	635110B0000	BUSINESS LOGIC LIBRARY, SDD
635110B0220	A	1034.xml	2010-11-24	635110B0000	VEHICLE PAYLOAD PROCESSING WORKER ROLE, SDD
635110B0220	B	1059.xml	2011-01-06	635110B0000	VEHICLE PAYLOAD PROCESSING WORKER ROLE, SDD

**Table 24. Configuration Management Record (Continued)**

Document No	Revision	Name	Release Date	Next Assembly	Title
635110B0220	C	1081.xml	2011-02-04	635110B0000	VEHICLE PAYLOAD PROCESSING WORKER ROLE, SDD
635110B0223	A	1035.xml	2010-11-24	635110B0000	REPORT GENERATION WORKER ROLE, SDD
635110B0223	B	1070.xml	2011-01-14	635110B0000	REPORT GENERATION WORKER ROLE, SDD
635110B0223	C	1082.xml	2011-02-04	635110B0000	REPORT GENERATION WORKER ROLE, SDD
635110B0223	C1	1115.xml	2011-03-21	635110B0000	REPORT GENERATION WORKER ROLE, SDD
635110B0230	A	1036.xml	2010-11-24	635110B0000	DATA REPOSITORY DATABASE, SDD
635110B0230	B	1060.xml	2011-01-06	635110B0000	DATA REPOSITORY DATABASE, SDD
635110B0230	C	1083.xml	2011-02-04	635110B0000	DATA REPOSITORY DATABASE, SDD
635110B0230	C1	1116.xml	2011-03-15	635110B0000	DATA REPOSITORY DATABASE, SDD
635110B0231	A	1037.xml	2010-11-24	635110B0000	PROBE AND LOG DATABASE, SDD
635110B0231	B	1061.xml	2011-01-06	635110B0000	PROBE AND LOG DATABASE, SDD
635110B0231	C	1084.xml	2011-02-04	635110B0000	PROBE AND LOG DATABASE, SDD
635110B1001	A	1014.xml	2010-11-23	635110B1010	NAVIGATION SOFTWARE, VICD
635110B1001	B	1062.xml	2011-01-06	635110B1010	NAVIGATION SOFTWARE, VICD
635110B1001	C	1092.xml	2011-02-04	635110B1010	NAVIGATION SOFTWARE, VICD
635110B1011	A	1015.xml	2010-11-24	635110B1010	COMPUTING MODULE, VICD
635110B1011	B	1063.xml	2011-01-06	635110B1010	COMPUTING MODULE, VICD
635110B1011	C	1093.xml	2011-02-04	635110B1010	COMPUTING MODULE, VICD
635110B1011	C1	1117.xml	2011-03-15	635110B1010	COMPUTING MODULE, VICD
635110B1020	A	1016.xml	2010-11-23	635110B1000	POWER MANAGEMENT MODULE, VICD
635110B1020	B	1064.xml	2011-01-06	635110B1000	POWER MANAGEMENT MODULE, VICD
635110B1020	C	1094.xml	2011-02-04	635110B1000	POWER MANAGEMENT MODULE, VICD
635110B1020	D	1158.xml	2011-08-01	635110B1000	POWER MANAGEMENT MODULE, VICD
635110B1030	A	1017.xml	2010-11-23	635110B1000	DSRC MODULE, VICD
635110B1030	B	1065.xml	2011-01-06	635110B1000	OBV COMPUTING PLATFORM AND API, VICD
635110B1030	C	1095.xml	2011-02-04	635110B1000	OBV COMPUTING PLATFORM AND API, VICD
635110B1040	A	1018.xml	2010-11-23	635110B1000	VEHICLE IDENTIFICATION MODULE, VICD
635110B1040	B	1066.xml	2011-01-06	635110B1000	VEHICLE IDENTIFICATION MODULE, VICD
635110B1040	C	1096.xml	2011-02-04	635110B1000	VEHICLE IDENTIFICATION MODULE, VICD
635110B1050	A	1019.xml	2010-11-23	635110B1000	NAVIGATION DEVICE VEHICLE MOUNT, VICD
635110B1050	B	1067.xml	2011-01-06	635110B1000	NAVIGATION DEVICE VEHICLE MOUNT, VICD
635110B1050	C	1097.xml	2011-02-04	635110B1000	AFTERMARKET NAVIGATION DEVICE VEHICLE MOUNT, VICD

**Table 24. Configuration Management Record (Continued)**

Document No	Revision	Name	Release Date	Next Assembly	Title
635110B2001	A	1040.xml	2010-11-24	635110B0000	CLOUD COMPUTING PROJECT SETUP INSTRUCTIONS
635110B3001	A	1121.xml	2011-06-09	635110B0000	ADMINISTERING A LOST OR STOLEN DEVICE
635110B3001	B	1178.xml	2011-09-12	635110B0000	ADMINISTERING A LOST OR STOLEN DEVICE
635110B3002	A	1138.xml	2011-08-01	635110B0000	DEVICE REPORTED AS MALFUNCTIONING
635110B3003	A	1139.xml	2011-08-01	635110B0000	PARTICIPANT VOLUNTARILY ENDS INVOLVEMENT
635110B3003	B	1185.xml	2011-09-12	635110B0000	PARTICIPANT VOLUNTARILY ENDS INVOLVEMENT
635110B3004	A	1140.xml	2011-08-01	635110B0000	ADDRESSING COMPUTER NETWORK (WEBHOSTING) DOWNTIME
635110B3005	A	1141.xml	2011-08-01	635110B0000	PARTICIPANT IN ACCIDENT WITH DEVICE INSTALLED
635110B3006	A	1142.xml	2011-08-01	635110B0000	PARTICIPANT VEHICLE CHANGE
635110B3008	A	1143.xml	2011-08-01	635110B0000	KITTING PROCEDURES
635110B3008	B	1179.xml	2011-09-12	635110B0000	KITTING PROCEDURES
635110B3010	A	1144.xml	2011-08-01	635110B0000	PROCESSING CHANGES IN WAVE SETTINGS
635110B3011	A	1145.xml	2011-08-01	635110B0000	PROCESSING CHANGES IN SIGNAGE ZONES
635110B3013	A	1146.xml	2011-08-01	635110B0000	RECEIVING A RETURNED DEVICE
635110B3013	B	1181.xml	2011-09-12	635110B0000	RECEIVING A RETURNED DEVICE
635110B3015	A	1147.xml	2011-07-07	635110B0000	HOW TO HANDLE DISPUTES WITH AN INVOICE
635110B3015	B	1192.xml	2011-09-12	635110B0000	HOW TO HANDLE DISPUTES WITH AN INVOICE
635110B3016	A	1123.xml	2011-08-15	635110B0000	WHAT HAPPENS WHEN AN INVOICE IS NOT PAID
635110B3017	A	1125.xml	2011-08-01	635110B0000	HOW TO HANDLE A CALL OR INQUIRY FROM THE MEDIA
635110B3017	B	1182.xml	2011-09-12	635110B0000	HOW TO HANDLE A CALL OR INQUIRY FROM THE MEDIA
635110B3018	A	1148.xml	2011-08-01	635110B0000	VIEWING ROUTE INFORMATION
635110B3019	A	1120.xml	2011-08-01	635110B0000	PROCESSING LEGAL REQUEST FOR MRFT SYSTEM DATA
635110B3020	A	1150.xml	2011-08-01	635110B0000	PROCESSING A SERVICE REQUEST
635110B3021	A	1151.xml	2011-08-01	635110B0000	REINSTATE DISABLED ACCOUNT
635110B3021	B	1186.xml	2011-09-12	635110B0000	REINSTATE DISABLED ACCOUNT
635110B3022	A	1152.xml	2011-08-01	635110B0000	CUSTOMER SUPPORT RECORD: LOGGING AND REPORTING REQUIREMENTS
635110B3022	B	1187.xml	2011-09-12	635110B0000	CUSTOMER SUPPORT RECORD: LOGGING AND REPORTING REQUIREMENTS
635110B3023	A	1153.xml	2011-08-01	635110B0000	HOW TO PROCESS A CASH OR CHECK PAYMENT
635110B3024	A	1133.xml	2011-08-01	635110B0000	HOW TO SCHEDULE ODOMETER READING/IN-PERSON SUPPORT
635110B3024	B	1177.xml	2011-09-12	635110B0000	HOW TO SCHEDULE ODOMETER READING/IN-PERSON SUPPORT

**Table 24. Configuration Management Record (Continued)**

Document No	Revision	Name	Release Date	Next Assembly	Title
635110B3026	A	1122.xml	2011-06-09	635110B0000	HOW TO DISABLE A DEVICE
635110B3026	B	1188.xml	2011-09-14	635110B0000	HOW TO DISABLE A DEVICE
635110B3027	A	1124.xml	2011-06-15	635110B0000	IN-VEHICLE INSTALLATION INSTRUCTIONS
635110B3027	B	1193.xml	2011-08-31	635110B0000	IN-VEHICLE INSTALLATION INSTRUCTIONS
635110B3027	C	1194.xml	2011-09-12	635110B0000	IN-VEHICLE INSTALLATION INSTRUCTIONS
635110B3028	A	1135.xml	2011-08-01	635110B0000	HOW TO PREPARE A DEVICE FOR A PARTICIPANT
635110B3028	B	1183.xml	2011-09-14	635110B3041	HOW TO PREPARE A DEVICE FOR A PARTICIPANT
635110B3029	A	1154.xml	2011-08-01	635110B0000	PARTICIPANT IS NOT COMPLIANT WITH TERMS OF AGREEMENT
635110B3029	B	1191.xml	2011-09-14	635110B0000	PARTICIPANT IS NOT COMPLIANT WITH TERMS OF AGREEMENT
635110B3030	A	1126.xml	2011-06-09	635110B0000	HOW A PARTICIPANT BEGINS INVOLVEMENT IN MRFT
635110B3030	B	1189.xml	2011-09-12	635110B0000	HOW A PARTICIPANT BEGINS INVOLVEMENT IN MRFT
635110B3032	A	1134.xml	2011-08-01	635110B3041	HOW TO PERFORM A DEVICE INSTALLATION CHECK
635110B3032	B	1190.xml	2011-09-14	635110B3041	HOW TO PERFORM A DEVICE INSTALLATION CHECK
635110B3034	A	1164.xml	2011-08-15	635110B0000	CANCELLING AT&T SERVICE FOR LOST OR STOLEN PHONE
635110B3034	B	1197.xml	2011-09-27	635110B0000	CANCELLING AT&T SERVICE FOR LOST OR STOLEN PHONE
635110B3036	A	1156.xml	2011-08-01	635110B3041	END USER LICENSE AGREEMENTS (EULAs) FOR MINNESOTA ROAD FEE TEST (MRFT)
635110B3036	B	1165.xml	2011-08-15	635110B3041	END USER LICENSE AGREEMENTS (EULAs) FOR MINNESOTA ROAD FEE TEST (MRFT)
635110B3036	C	1176.xml	2011-08-31	635110B3041	END USER LICENSE AGREEMENTS (EULAs) FOR MINNESOTA ROAD FEE TEST (MRFT)
635110B3037	A	1163.xml	2011-08-16	635110B0000	IN-VEHICLE IDENTIFICATION MODULE SECURITY STICKER SHOWS "VOID"
635110B3038	A	1167.xml	2011-08-16	635110B3042, 635110B3043	HOW TO FORCE SENDING OF AN MBUF REPORT
635110B3038	B	1198.xml	2011-09-27	635110B3042	HOW TO FORCE SENDING OF AN MBUF REPORT
635110B3039	A	1171.xml	2011-09-27	635110B3024	CONTENT FOR MESSAGES SENT TO PARTICIPANTS
635110B3040	A	1173.xml	2011-09-12	635110B3043	HOW TO RESTORE PHONE TO STOCK IMAGE
635110B3041	A	1128.xml	2011-07-26	635110B0000	HOW TO CONDUCT FIRST ODOMETER READING
635110B3041	B	1169.xml	2011-09-08	635110B0000	HOW TO CONDUCT FIRST ODOMETER READING
635110B3041	C	1195.xml	2011-09-14	635110B0000	HOW TO CONDUCT FIRST ODOMETER READING
635110B3042	A	1160.xml	2011-08-16	635110B0000	HOW TO CONDUCT SECOND ODOMETER READING
635110B3043	A	1159.xml	2011-07-26	635110B0000	HOW TO CONDUCT THIRD (FINAL) ODOMETER READING
635110B3043	B	1161.xml	2011-08-01	635110B0000	HOW TO CONDUCT THIRD (FINAL) ODOMETER READING

**Table 24. Configuration Management Record (Continued)**

Document No	Revision	Name	Release Date	Next Assembly	Title
635110B3043	C	1168.xml	2011-09-12	635110B0000	HOW TO CONDUCT THIRD (FINAL) ODOMETER READING
635110B3044	A	1137.xml	2011-06-15	635110B0000	DEVICE AND SOFTWARE USE INSTRUCTIONS
635110B3044	B	1201.xml	2011-11-16	635110B0000	DEVICE AND SOFTWARE USE INSTRUCTIONS
635110B3044	C	1215.xml	2011-12-16	635110B0000	DEVICE AND SOFTWARE USE INSTRUCTIONS
635110B3045	A	1196.xml	2011-11-16	635110B0000	WAVE SETTINGS
635110B3045	B	1212.xml	2011-12-16	635110B0000	WAVE SETTINGS
635110B3045	C	1216.xml	2012-07-30	635110B0000	WAVE SETTINGS
635110B3046	A	1175.xml	2011-08-31	635110B0000	TECHNOLOGY FLYER
635110B3047	A	1205.xml	2011-11-16	635110B0000	DEVICE AND SOFTWARE USE INSTRUCTIONS ADDENDUM
635110B3048	A	1199.xml	2011-09-27	635110B0000	MILEAGE BASED USER FEE VIP WAVE A RATES
635110B3049	A	1200.xml	2011-09-27	635110B0000	SAFETY SIGNAGE ZONES OVERVIEW
635110B3049	B	1206.xml	2011-11-16	635110B0000	SAFETY SIGNAGE ZONES OVERVIEW
635110B3051	A	1208.xml	2011-11-16	635110B0000	MBUF PRICING TABLE AND EXAMPLES
635110B3052	A	1209.xml	2011-11-16	635110B3042	SOFTWARE UPGRADE PROCEDURE FOR WAVE A ODOMETER READING #2

**Table 25. Weekly Project Management Meetings**

ID	Name	Modified
2	Project Review Meeting 06_30_2010.pptx	6/30/2010 14:02
7	Project Review Meeting 07_7_2010.pptx	7/7/2010 10:48
12	Project Review Meeting 07_14_2010.pptx	7/14/2010 10:55
23	Project Review Meeting 07_28_2010.pptx	7/28/2010 12:36
35	Project Review Meeting 8_4_2010.pptx	8/4/2010 14:24
51	Project Review Meeting 8_11_2010.pptx	8/13/2010 12:02
54	Project Review Meeting 8_18_2010.pptx	8/18/2010 11:24
59	Project Review Meeting 8_24_2010.pptx	8/30/2010 11:03
64	Project Review Meeting 8_30_2010.pptx	9/1/2010 9:39
66	Project Review Meeting 9_7_2010.pptx	9/8/2010 9:22
75	Project Review Meeting 9_14_2010.pptx	9/15/2010 9:38
81	Project Review Meeting 9_22_2010.pptx	9/22/2010 10:50
90	Project Review Meeting 10_6_2010.pptx	10/6/2010 10:51
102	CVSMUF October 20, 2010 Action Items Summary.pptx	10/25/2010 9:37
109	Project Review Meeting 11_3_2010.pptx	11/4/2010 9:12
110	Project Review Meeting 11_10_2010.pptx	11/10/2010 14:03
111	Project Review Meeting 11_17_2010.pptx	11/17/2010 10:49
119	Project Review Meeting 12_15_2010.pptx	1/18/2011 16:39
120	Project Review Meeting 12_1_2010.pptx	1/5/2011 9:03
133	Project Review Meeting 1_12_2011.pptx	1/18/2011 16:39
134	Project Review Meeting 1_5_2011.pptx	1/18/2011 16:39
139	Project Review Meeting 2_16_2011.pptx	2/16/2011 11:05
140	Operational Procedures_Presentation_2011_02_23.pptx	2/28/2011 16:52
141	Overview of MBUF Evaluation_2011_02_23.ppt	2/28/2011 16:52
142	Project Review Meeting_2011_02_23.pptx	2/28/2011 16:52
143	System_Design_Presentation_2011_02_23.pptx	2/28/2011 16:52
144	Test Plan_Feb24_Final.pptx	3/2/2011 16:41
145	Project Review Meeting 3_9_2011.pptx	3/9/2011 13:44
146	Project Review Meeting 3_1_2011.pptx	3/14/2011 14:03
155	Project Review Meeting 3_21_2011.pptx	3/29/2011 22:17
156	Project Review Meeting 3_30_2011v3.pptx	4/4/2011 14:19
157	Project Review Meeting 4_6_2011v1.pptx	4/8/2011 12:45
169	May 10 2011 MRFT Tech Adv Meeting Slides.pptx	5/23/2011 13:08
170	May 11 2011 MRFT Tech Adv Meeting Slides.pptx	5/23/2011 13:08
176	Project Review Meeting 5_25_2011.pptx	7/5/2011 16:28
177	Project Review Meeting 5_4_2011.pptx	7/5/2011 16:28
178	Project Review Meeting 6_1_2011_v3.pptx	7/5/2011 16:28
179	Project Review Meeting 6_29_2011.pptx	7/5/2011 17:27
180	Project Review Meeting 6_8_2011.pptx	7/5/2011 17:27
182	Project Review Meeting 7_28_2011 v4.pptx	8/2/2011 13:05
185	Project Review Meeting 8_2_2011 v1.pptx	8/9/2011 21:51
188	Project Review Meeting 8_10_2011 v3.pptx	8/17/2011 9:09
189	Project Review Meeting 8_17_2011.pptx	8/17/2011 16:37
196	Project Review Meeting 8_31_2011-v1.pptx	9/7/2011 10:37
197	Project Review Meeting 9_07_2011-v1.pptx	9/7/2011 10:37



**Table 25. Weekly Project Management Meetings (Continued)**

ID	Name	Modified
204	Project Review Meeting 9_28_2011.pptx	9/28/2011 11:17
207	Project Review Meeting 10_5_2011.pptx	10/12/2011 8:38
210	Project Review Meeting 11_09_2011.pptx	11/9/2011 11:38
215	Project Review Meeting 11_30_2011.pptx	11/30/2011 10:59
219	Project Review Meeting 2_2_2011.pptx	12/9/2011 11:15
220	Project Review Meeting 4_13_2011v1.pptx	12/9/2011 11:16
221	Project Review Meeting 4_21_2011v1.pptx	12/9/2011 11:16
222	Project Review Meeting 9_14_2011-v0.pptx	12/9/2011 11:20
223	Project Review Meeting 10_12_2011.pptx	12/9/2011 11:21
224	Project Review Meeting 10_26_2011.pptx	12/9/2011 11:21
225	Project Review Meeting 11_2_2011.pptx	12/9/2011 11:21
226	Project Review Meeting 11_16_2011.pptx	12/9/2011 11:21
227	Project Review Meeting 12_07_2011.pptx	12/9/2011 11:22
230	Project Review Meeting 12_21_2011 v1.pptx	12/21/2011 10:55
231	Project Review Meeting 1_4_2012.pptx	1/4/2012 11:37
235	Project Review Meeting 2_1_2012.pptx	2/28/2012 13:12
236	Project Review Meeting 2_15_2012.pptx	2/28/2012 13:12
237	minnesota_road_fee_test_status_meeting_feb_29_2012_Final.pptx	3/1/2012 10:07
238	Evaluation Update_2012 02 29 Meeting.pptx	3/1/2012 10:09
239	Signage Analysis_2012 02 28.docx	3/1/2012 10:09
242	Project Review Meeting 03_21_2012.pptx	4/4/2012 10:59
243	Project Review Meeting 04_04_2012-20120404_0957.pptx	4/4/2012 10:59
247	biren1_ODO2_20120703.pdf	7/6/2012 12:53
248	Project Review Meeting 04_18_2012.pptx	8/7/2012 14:34
249	Project Review Meeting 05_23_2012.pptx	8/7/2012 14:34
250	Project Review Meeting 06_27_2012.pptx	8/7/2012 14:34
251	Project Review Meeting 07_11_2012.pptx	8/7/2012 14:34
252	Project Review Meeting 07_25_2012.pptx	8/7/2012 14:34
253	Project Review Meeting 08_08_12v2.pptx	8/8/2012 11:15
256	mrft_tab_meeting20120820_FINAL.pptx	8/21/2012 10:51
257	Team Meeting - Evaluation Update 20AUG2012.pptx	8/21/2012 10:58
258	20120820 - Attendee list.docx	8/21/2012 10:58
260	Project Review Meeting 09_05_12.pptx	10/17/2012 15:51
261	Project Review Meeting 09_19_12_update.pptx	10/17/2012 15:52
262	Project Review Meeting 10_03_12.pptx	10/17/2012 15:53
263	Project Review Meeting 10_17_12.pptx	10/17/2012 15:53
268	Project Review Meeting 10_31_12.pptx	12/14/2012 12:56
269	Project Review Meeting 12_12_12.pptx	12/14/2012 12:56
270	Project Review Meeting 11_14_12.pptx	12/14/2012 12:56



**Table 26. Evaluation Documents**

ID	Name	Modified
1	2009-06-30 - Task 3 3 - Final Preliminary Evaluation Plan.pdf	6/30/2010 14:01
84	2010-09-16 Meeting_Evaluation Plan Slides.ppt	9/23/2010 16:54
85	2010-08-04 Considerations for a Participant Payment Scheme.ppt	9/23/2010 16:56
86	2010-09-24 - Draft Final Evaluation Plan.pdf	9/24/2010 19:59
108	2010-10-29 - Final Evaluation Plan.docx	11/1/2010 15:22
147	CICAS approach 169 from east 6.JPG	3/15/2011 13:13
148	CICAS approach Rt11 from north 2.JPG	3/15/2011 13:20
149	CICAS approach Rt11 from south 3.JPG	3/15/2011 13:19
158	2011-04-08 - Draft Test Plans for Minnesota Road Fee Test Evaluation.docx	4/8/2011 19:21
187	sensitive_MnDOT Participant Data_1-96_2011 08 16_delivered.xlsx	8/16/2011 11:05
192	sensitive_MnDOT Participant Data_97-151_2011 08 29_delivered.xlsx	8/29/2011 17:09
194	sensitive_MnDOT Participant Data_UPDATE_2011 08 30_delivered.xlsx	8/30/2011 15:19
195	sensitive_MnDOT Participant Data_UPDATE_2011 09 02_delivered.xlsx	9/2/2011 15:52
198	sensitive_MnDOT Participant Data_UPDATE_2011 09 07_delivered.xlsx	9/7/2011 15:37
199	sensitive_MnDOT Participant Data_UPDATE_2011 09 08_delivered.xlsx	9/9/2011 7:37
200	sensitive_MnDOT Participant Data_UPDATE_2011 09 12_delivered.xlsx	9/12/2011 15:13
202	sensitive_MnDOT Participant Data_UPDATE_2011 09 15_delivered.xlsx	9/15/2011 14:52
203	sensitive_MnDOT Participant Data_UPDATE_2011 09 19_delivered.xlsx	9/19/2011 22:38
205	MRFT Database Report-Wave A Active Participants updated 8_19_2011 and after.xlsx	9/28/2011 14:30
206	Minnesota Road Fee Test Welcome Packet.pdf	9/29/2011 14:05
211	sensitive_MnDOT Participant Data_Wave B UPDATE_2011 11 11_delivered.xlsx	11/11/2011 15:34
212	sensitive_MnDOT Participant Data_UPDATE_2011 17 11_Delivered.xlsx	11/17/2011 8:35
213	sensitive_MnDOT Participant Data_UPDATE_2011 22 11_delivered.xlsx	11/22/2011 11:20
216	Participant Stipend Groups - Wave A_2011 11 08.xlsx	12/2/2011 15:11
228	sensitive_MnDOT Participant Data_UPDATE_2011 09 12.xlsx	12/9/2011 15:59
229	sensitive_MnDOT Participant Data_UPDATE_2011 12 09_delivered.xlsx	12/21/2011 10:55
234	Participant Stipend Groups - Wave B_2011 01 26.xlsx	1/26/2012 13:40
240	sensitive_MnDOT Participant Data to Battelle 20MAR2012.xlsx	3/20/2012 19:13
241	sensitive_MnDOT Participant Data to Battelle 29MAR2012 - FINAL.xlsx	3/29/2012 8:00
259	Task Force Meeting_2012 08 21.pptx	9/5/2012 15:59

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**Table 27. Draft Deliverables**

ID	Name	Modified
4	Initial ConOps Meeting 6_16_2010.pdf	7/7/2010 8:16
5	MnDOT Kickoff Meeting 6_16_2010.pdf	7/7/2010 8:16
8	635110B0020A - ISMUF ConOps RevA Comment Form (YourInitialsHere).xls	9/20/2010 13:31
9	635110B0020A - ISMUF Concept of Ops Document.docx	9/20/2010 13:30
11	ISMUF Project Management Plan R00 7_9_2010.docx	7/9/2010 16:31
37	635110B0030A - ISMUF Stakeholder Req Comment Form (YourInitialsHere).xls	9/20/2010 13:30
38	635110B0030A - ISMUF Stakeholder Req Document.docx	9/20/2010 13:29
39	635110B0030A - ISMUF Stakeholder Req Trace Matrix.pdf	9/20/2010 13:29
56	ISMUF Project Management Plan R02 8_20_2010.docx	8/20/2010 16:10
57	IntelliDriveMeetingMinutes_20100701.doc	8/20/2010 16:23
77	635110B0040A - ISMUF System Req Comment Form (YourInitialsHere).xlsx	9/21/2010 10:28
78	635110B0040A - ISMUF System Req Trace Matrix.pdf	9/21/2010 10:28
79	635110B0040A - ISMUF System Requirements Document.docx	9/21/2010 10:28
83	Quarterly Update June_August 2010 Deliverable 1_5.pdf	9/23/2010 11:19
106	635110B0050A - ISMUF System Arch Comment Form (YourInitialsHere).xlsx	10/27/2010 9:37
107	635110B0050A - ISMUF System Architecture Document DRAFT.docx	10/27/2010 9:37
112	Draft System Test Plan_20101124.docx	11/24/2010 10:21
113	Deliverable 11 - ISMUF System Design Comment Form (YourInitialsHere).xlsx	11/24/2010 13:40
116	Deliverable 11 - Draft Design2.zip	11/29/2010 15:27
117	ISMUF Deliverable 11_1 System Design Document Draft 12_24_2010.zip	12/24/2010 11:00
118	635110B0050C - ISMUF System Architecture Document.pdf	12/24/2010 11:05
125	635110B-ECP001A-Draft.docx	1/17/2011 19:54
126	635110B-ECP003A-Draft.docx	1/17/2011 19:55
127	635110B-ECP004A-Draft.docx	1/17/2011 19:55
128	635110B-ECP005A-Draft.docx	1/17/2011 19:55
129	635110B-ECP006B-Draft.docx	3/8/2011 15:27
135	Quarterly Update September_January 2011 Deliverable 1_9 Submitted 2_1_2011.docx	2/1/2011 16:49
150	Draft System Test Plan_V2.3 Appendix A.pdf	3/17/2011 15:42
151	Draft System Test Plan_V2.3 Appendix B.pdf	3/17/2011 15:42
152	Draft System Test Plan_V2.3 Appendix C.pdf	3/17/2011 15:42
153	Draft System Test Plan_V2.3 Appendix D.pdf	3/17/2011 15:42
154	Draft System Test Plan_V2.3.docx	3/17/2011 15:41
163	ISMUF Test Plan Comment Form_Dispositions_051711.xls	5/18/2011 11:34
171	Minnesota_Site_Visit_Trip_Report-April_28_2011.docx	5/23/2011 15:01
214	635110B3045B-Wave Settings Pre-Release Draft.docx	11/29/2011 11:44
254	Quarterly Update Apr_June 2012 Deliverable 1_12.docx	8/8/2012 13:38
255	Quarterly Update Jan_March 2012 Deliverable 1_11.docx	8/8/2012 13:38
266	Quarterly Update July_Sept 2012 Deliverable 1_13.pdf	11/14/2012 16:09

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**Table 28. Final Deliverables**

ID	Name	Modified
18	Final Kickoff Meeting Minutes Deliverable 1_3.pdf	7/23/2010 11:45
19	ISMUF Project Management Plan R01 7_22_2010.pdf	7/23/2010 11:45
26	Stakeholder Requirements Meeting Notes-Final.pdf	8/2/2010 16:25
27	Stakeholder Requirements Meeting Notes-Final.docx	8/2/2010 16:26
36	Final Initial ConOps Meeting Minutes Deliverable 1_4.pdf	8/4/2010 14:36
62	ISMUF_CICAS Requirements Meeting Notes_081810.docx	12/6/2011 11:29
63	ISMUF_CICAS Requirements Meeting Notes_082410_v2.docx	12/6/2011 11:30
73	635110B0030B - ISMUF Stakeholder Req Trace Matrix.pdf	9/20/2010 13:28
74	635110B0030B - ISMUF Stakeholder Requirements Document Rev B.docx	9/20/2010 13:28
99	635110B0040B - ISMUF System Req Trace Matrix.pdf	10/14/2010 10:17
100	635110B0040B - ISMUF System Requirements Document Rev B.pdf	10/14/2010 10:16
103	Project Review Meeting October 20_2010 Version FINAL.pptx	12/6/2011 15:37
104	635110B0020B - ISMUF ConOps_Changes 102510.docx	10/26/2010 11:11
105	635110B0020B-ISMUF ConOps Disposition of Comments on REVA.xls	10/26/2010 11:26
114	635110B0050B - ISMUF System Architecture Document.pdf	11/24/2010 13:41
121	ISMUF Project Management Plan R03 1_07_2011.docx	1/10/2011 11:39
131	DCN_1068-635110B0040B1.pdf	1/18/2011 16:18
132	DCN_1069-635110B0040B2.pdf	1/18/2011 16:18
136	DCN_1072-635110B0040B3.pdf	2/4/2011 17:02
137	635110B0050D - ISMUF System Architecture Document.pdf	2/4/2011 17:10
138	ISMUF Deliverable 12 System Design Document Final.zip	2/4/2011 17:12
159	635110B0040C - ISMUF System Requirements Document Rev C.pdf	4/20/2011 11:03
160	DCN_1106-635110B0040B4.pdf	4/20/2011 12:15
161	ISMUF Technical Advisory Board Meeting Notes Feb23 2011.docx	5/9/2011 17:35
164	System Test Plan_ver2.0_051611.pdf	5/18/2011 11:36
166	Test Plan Appendix C.pdf	5/18/2011 11:39
167	Test Plan Appendix A.pdf	5/18/2011 11:40
168	Test Plan Appendix B.pdf	5/18/2011 11:41
184	635110B3046A - Tech Flyer.pdf	8/5/2011 9:49
186	635110B3046B - Tech Flyer.pdf	8/9/2011 22:26
190	635110B3036C-EULAs.pdf	8/22/2011 11:22
217	MnDOT IRB Application-Approval of Human Subjects Research Protocol Request 4_23_2011 rev3.docx	12/6/2011 16:56
218	HSRE 0150 Pierce Zimmer MnDOT IntelliDrive April 2011.pdf	12/6/2011 16:56
264	MRFT Travel Time Report.pdf	11/13/2012 17:17
265	Travel Time Data by Segment.xlsx	11/13/2012 17:16
267	MRFT Travel Time Report.docx	12/5/2012 10:35

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**Table 29. Working Documents**

ID	Name	Modified
3	intellidrive-02.wmv	7/6/2010 15:06
6	Regional Meeting - Rev version 2.ppt	7/7/2010 10:41
13	635110B0020A-ISMUF ConOps RevA-Comment Form-(MCG).xls	7/29/2010 12:00
14	BKP Slides for Requirements Gathering Meeting 7_15_2010.pptx	7/20/2010 10:34
16	REZ StakeholderReqMeeting-v7_7-15-2010.pptx	7/20/2010 10:39
17	PMP ver1 comments Cory.xls	7/20/2010 11:54
21	635110B0020A-ISMUF ConOps RevA-Comment Form-MHI.xls	7/23/2010 12:34
22	635110B0020A-ISMUF ConOps RevA-Comment Form-CJJ.xls	7/23/2010 12:35
24	635110B0020A-ISMUF ConOps RevA-Comment Form-(RAS).xls	9/20/2010 13:31
31	Intersection Collision Warning Sign Scenario.doc	8/4/2010 9:54
32	White Paper CICAS Interface_073010.doc	8/4/2010 9:55
33	White Paper Thoughts MBUF Rates_072210.doc	8/4/2010 9:55
34	Participants flow payments.doc	8/4/2010 9:56
40	Data Latency between Vehicle and Back Office Services Analysis.doc	9/8/2010 9:41
41	Parasitic Drain of Vehicle Batteries.doc	9/8/2010 9:40
42	CICAS_SSA Architecture.docx	8/10/2010 17:27
43	CICAS-SSA ConOps FINAL 3-18-08_508.doc	8/10/2010 17:31
44	CICAS-SSA Requirements Spec 3_21_08.doc	8/10/2010 17:33
45	State Map Report V5.docx	8/10/2010 17:34
46	635110B0030A_ISMUF_Stakeholder_Req-Comment Form (MCG).xls	8/11/2010 16:12
49	Data Latency between Vehicle and Back Office Services Analysis_MCG_Comments.docx	8/13/2010 11:42
50	Parasitic Drain of Vehicle Batteries_MCG_Comments.docx	8/13/2010 11:43
52	635110B0030A - ISMUF Stakeholder Req Comment Form (MHI).xls	9/20/2010 13:33
53	Cannon Falls WB.wmv	8/17/2010 17:18
55	Preliminary Technology Survey Summary submitted 8_20_2010.docx	8/20/2010 15:43
58	Operational Reports.doc	8/26/2010 14:15
65	Reporting Table BKP 9_2_2010.docx	9/2/2010 9:23
67	Parasitic Drain of Vehicle Batteries-v2.docx	9/8/2010 9:40
68	Probe Data Latency between Vehicle and Back Office Services Analysis-v2.docx	9/8/2010 9:40
69	20100823_MnDOT_Battelle_2011 World Congress Demonstration Storyboard.doc	9/8/2010 10:36
70	Parasitic Drain of Vehicle Batteries-v3.docx	9/8/2010 16:50
71	Probe Data Latency between Vehicle and Back Office Services Analysis-v3.docx	9/8/2010 16:51
72	635110B0030A - ISMUF Stakeholder Req Comment Resolution Report.pdf	9/20/2010 13:32
76	Quarterly Update Example.doc	9/15/2010 10:26
80	ITS GA 2010 MBUF Battelle Presentation.pptx	9/22/2010 8:48
82	Technology Survey Criteria List Draft 9_22_2010.docx	9/22/2010 17:39
87	MBUF Concept for Demonstration_092410_clean.doc	9/28/2010 14:37
88	635110B0040A - ISMUF System Req Comment Form MnDOT total.xlsx	9/29/2010 15:13
89	635110B0040A - ISMUF System Req Comment Form MHI.xls	10/1/2010 15:28
92	Cut of Scenario i BKP.wmv	10/6/2010 12:30
93	Cut of Scenario j BKP.wmv	10/6/2010 12:31
94	Cut of Scenario K_END_ BKP.wmv	10/6/2010 12:31
95	Cut of Scenario K_START_ BKP.wmv	10/6/2010 12:32
96	intellidrive-scenario-k-02_1.wmv	10/6/2010 12:34
97	Platform Selection Scorecard 20101006 -Criteria With Weights.xlsx	10/6/2010 12:42
98	635110B0040A - ISMUF System Req Comment Resolution Report.pdf	10/14/2010 10:17
122	Review of COTS PND for MBUF.docx	1/17/2011 16:13
123	System Architecture and Design for ISMUF.docx	1/17/2011 16:13
124	Thick or Thin the Minnesota MBUF Solution.docx	1/17/2011 16:14
130	DSRC Evaluation December_1.pptx	1/18/2011 10:41
172	20110525_0830-Battelle ISMUF System Deployment Schedule.pdf	5/25/2011 9:03
173	20110527_2319-Battelle ISMUF System Deployment Schedule-2 week delay contingency.pdf	5/27/2011 23:51
174	20110630_0002-Battelle ISMUF System Deployment Schedule.mpp	6/30/2011 0:11

*Use/disclosure of data appearing on this sheet is subject to restrictions set forth on the revision history page of this document.*

**Table 29. Working Documents (Continued)**

ID	Name	Modified
175	20110630_0002-Battelle ISMUF System Deployment Schedule.pdf	6/30/2011 0:11
181	20110726_0925-Battelle MRFT System Deployment Schedule-Sept12 start.pdf	7/26/2011 14:55
183	20110802_2130-Battelle MRFT System Deployment Schedule-Sept12 start.pdf	8/2/2011 21:59
208	20111103_1519-Battelle MRFT System Deployment Schedule.mpp	11/3/2011 15:27
209	20111103_1519-Battelle MRFT System Deployment Schedule.pdf	11/3/2011 15:28
232	20120119_1333-Battelle MRFT System Deployment Schedule.mpp	1/25/2012 10:34
233	20120119_1333-Battelle MRFT System Deployment Schedule.pdf	1/25/2012 10:34
244	M2U00216-CICAS Intersection WB.wmv	4/19/2012 15:01
245	M2U00217-CICAS Intersection EB.wmv	4/19/2012 14:59
246	M2U00213-Safety Signage.wmv	4/19/2012 15:13

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## Appendix A: Definitions, Acronyms and Initialisms

Term	Definition
ASCII	American Standard Code for Information Interchange
Alert	Alerts are audible only, with no visual component that might distract the driver from the view of roadway conditions.
CICAS	Cooperative Intersection Collision Avoidance System
CICAS-SSA	Cooperative Intersection Collision Avoidance System for Stop Sign Assist
CICAS-SSA Alert	This condition indicates a lag where a conscious decision to proceed is needed, but that safe passage is likely based on gap rejection statistics and drivers' preferred safety margins. At the Minnesota Research Intersection, alerts will be issued when the lag is less than 11 seconds, but greater than 7 seconds. A CICAS-SSA Alert may or may not have a visual component associated with it, contrast Alert which is audible only.
CICAS-SSA Warning	This condition indicates a lag that is based on statistical models and preferred safety margins that would be considered by most drivers to be unsafe. The information conveyed by the driver interface would be to recommend a driver not proceed with either crossing or entering the traffic stream. At the Minnesota Research Intersection, warnings will be issued when the lag is less than or equal to 7 seconds.
DC	Direct Current
DSRC	Dedicated Short Range Communications
GMT	Greenwich Mean Time
GPS	Global Positioning System
IEEE	Institute of Electrical and Electronics Engineers
CVSMUF	Minnesota DOT Connected Vehicle for Safety Mobility and User Fee System
MBUF	Mileage-Based User Fees
MBUF Pricing Zone	A geo-located zone associated with a (set of) MBUF price(s).
MBUF Rate Scheme	A data item which relates MBUF prices with each of the MBUF Pricing Zones.
MN/DOT	Minnesota Department of Transportation
MUTCD	Manual on Uniform Traffic Control Devices

Term	Definition
PII	Personally Identifiable Information
Participant ID	A Participant ID is assigned to each participant in the CVSMUF demonstration. An instance of an in-vehicle subsystem will be assigned to one Participant ID at a time.
Probe Data Snapshot	A Probe Data Snapshot is an encapsulation of vehicle probe data at a single position and time.
SAE	Society of Automotive Engineers
Trip	The time between a vehicle ignition on event and a vehicle ignition off event.
Trip ID	A Trip ID is a globally unique ID within the CVSMUF demonstration assigned to a set of probe data which links all probe data elements within a given trip taken by a participant.
USDOT	United States Department of Transportation
UTC	Coordinated Universal Time
VIN	Vehicle Identification Number
Vehicle ID	A Vehicle ID is assigned to each vehicle participating in the CVSMUF demonstration. An instance of an in-vehicle subsystem will be assigned to one Vehicle ID at a time.



## Appendix B: Full Size Participant-facing Material

**Minnesota**  
Road Fee Test
**In-Vehicle Installation Instructions with VIDM**

START HERE Overview	I Choose Mounting <span style="background-color: yellow; border: 1px solid black; border-radius: 50%; padding: 2px;">A</span> OR <span style="background-color: yellow; border: 1px solid black; border-radius: 50%; padding: 2px;">B</span>		II Connect Power		III Attach Vehicle ID Module		IV Device Startup and Test <i>See Site Attendant</i>	
	<b>IA Windshield Suction Cup Pedestal Mount</b>	<b>1</b> Clean the surface of the windshield with the alcohol pad provided.	<b>2</b>  Firmly press the suction cup base of the Suction Cup Pedestal Mount onto the clean windshield surface. Flip the base lever down to the locked position as shown.	<b>3</b>  Adjust the Suction Cup Pedestal Mount using the base adjustment knob and phone holder tightening ring as shown.	<b>4</b>  Attach the phone holder to the Suction Cup Pedestal Mount using the existing tabs and slots as shown.			
<b>5</b>  Press the release button on the side of the phone holder to open the grip arms as shown.		<b>6</b>  Place the phone into the phone holder with the phone sitting on the support legs; clamp the grip arms inward to firmly grasp the phone as shown.	<b>7</b> To remove the phone, press the release button on the side of the phone holder to open the grip arms.	 <u>Minnesota statutes require navigation devices to be mounted at the bottom-most portion of the windshield. Please adjust your mount as needed.</u>				
							<b>IB Vent Pedestal Mount</b>	
<b>1</b>  Pinch the vent mounting clips so that the teeth open.		<b>2</b>  Gently insert vent pedestal mount into the vent fins/blades as shown.	<b>3</b>  Attach the phone holder to the pedestal mount using the existing tabs and slots as shown.	<b>4</b>  Press the release button on the side of the phone holder to open the grip arms as shown.				
<b>5</b>  Place the phone into the phone holder with the phone sitting on the support legs; clamp the grip arms inward to firmly grasp the phone as shown.		<b>6</b> To remove the phone, press the release button on the side of the phone holder to open the grip arms.						
<b>II Power</b>	<b>1</b> Identify the Device Charger within the in-vehicle startup kit.	<b>2</b> Attach the male end of the Device Charger to an in-vehicle power receptacle near the phone mounting location. Attach the small micro-USB plug to the device.	<b>3</b> If, while the engine is off and the key removed, the device begins to charge, unplug the device charger and request a Power Management Module from a site attendant.	<b>4</b> Attach the male end of the Power Management Module to the in-vehicle power receptacle. Repeat step 2 attaching the Device Charger to the Power Management Module.				
<b>III Vehicle ID Module</b>	<b>1</b>  Identify the location of the vehicle ID module interface plug under the driver-side console/dashboard area. Refer to the reverse side of this pamphlet for more information on the location of the vehicle ID module interface plug.	<b>2</b> Once the vehicle ID module interface plug is located within your vehicle, orient the vehicle identification module so that the module is aligned with the interface plug.	<b>3</b> Attach the vehicle identification module to the interface plug and gently press the module in place to ensure there is a firm connection.	<b>4</b> Affix the vehicle identification module security sticker to the vehicle identification module AND your vehicle console/dashboard. Note, depending on vehicle make, model, and year the vehicle identification module security sticker location and orientation may vary.				

Please see the reverse side of this pamphlet for more information and important warnings.

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Rev A

## WARNINGS



**WARNING:** Do not place the phone mount in or near an air bag deployment zone or where it will obstruct view of the road.



**WARNING:** Ensure all power cables are safely stored or placed in a location that will not interfere or impede the operation of your vehicle.



**WARNING:** Do not force the Vehicle Identification Module onto the Vehicle ID module interface plug as it may damage the OBD-II interface or Vehicle Identification Module.



**WARNING:** Do not use the Power Management Module with power receptacle splitter cables or similar power distribution devices. The Power Management Module should be the only device attached to the selected power receptacle.



### Vehicle ID Module Interface Plug Location

The location of the Vehicle ID Module Interface Plug, positioned on the driver side below the vehicle steering column, will vary based on vehicle make, model, and year. In general, the interface plug will be located near the left, right, or center of the steering column as shown in the examples below.



Vehicle ID Module  
Interface Plug



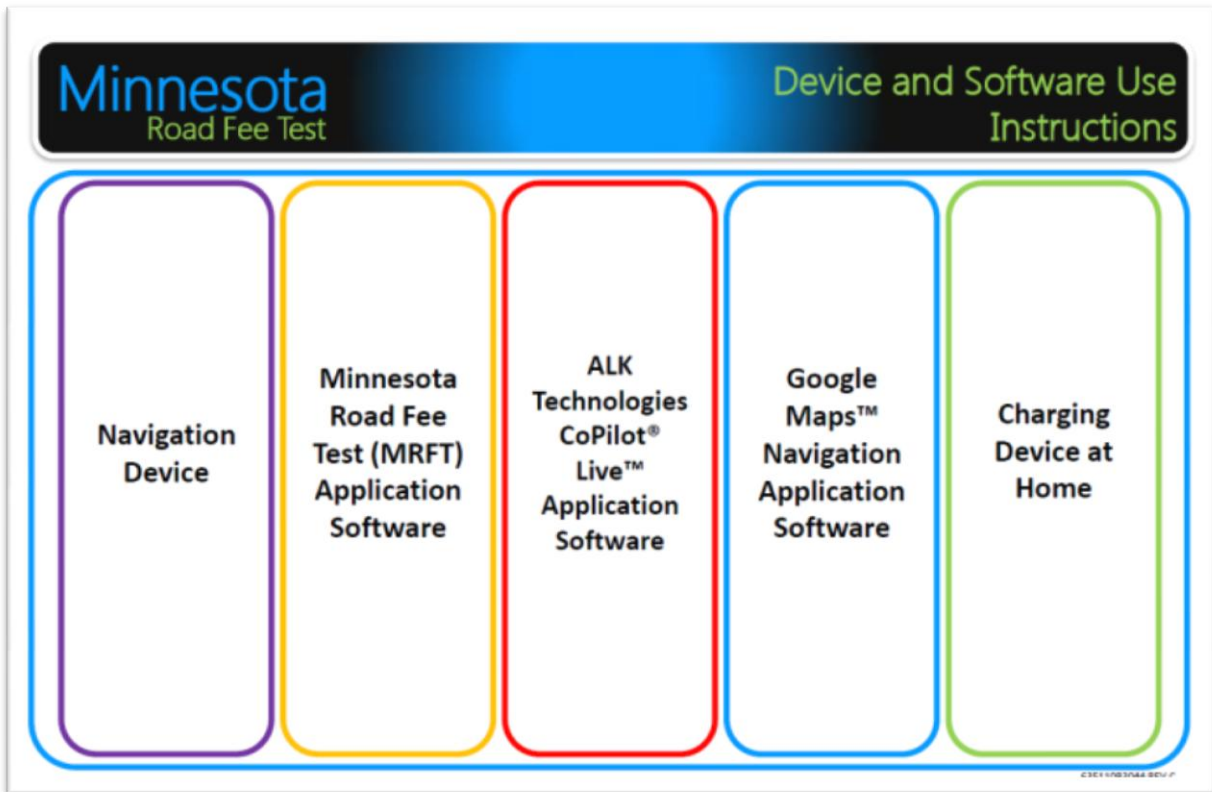
Example  
1999 Honda Accord  
Left of Steering  
Column, Driver Side



Example  
2006 Ford F-150  
Centered on Steering  
Column, Driver Side



Example  
2008 Honda Pilot  
Right of Steering  
Column, Driver Side





Overview

1	Volume Control
2	Power On/Off
3	Submenu
4	Home Screen
5	Back
6	Search
7	Notification Area

Notification Area

7 The notification area provides information on the current status of the device and active applications.

**Battery Status**

Charging

90 Percent Charge Available

3

Navigation Device

1

Tap on the MRFT icon on the device home screen

2

From the MRFT main menu, tap **View Reports, Launch (CoPilot OR Nav), or Change Settings**

3

From the Reports menu, tap **View Trip IDs**

4

Typically, the **Trip ID List** will be blank as trip information will be sent automatically

5

From the **Settings for Current Trip** menu, the functionality of the software may be altered for the current trip

6

GPS signal strength is shown by the number of bars displayed

6

**GPS Signal Strength**

Accuracy

1 Bar	2 Bars	3 Bars	4 Bars
25 m	15 m	10 m	5 m

4

Minnesota Road Fee Test Application Software

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B-4

<p>1</p>	<p>From the MRFT main menu a trip is started when power is applied to the device (vehicle turned on)</p>	
<p>2</p>	<p>A progress bar is displayed indicating when a trip has started</p>	
<p>3</p>	<p>When the vehicle is turned off, power is no longer supplied to the device and a progress bar is displayed indicating when the trip has stopped</p>	

1

2

3

5 | Minnesota Road Fee Test Application Software

<p>1</p>	<p>Send Trip IDs from the View Trip IDs home screen. <b>Note: By submitting your trip IDs, you are allowing the project team to associate this information with your invoices. The information will not be made public to any other entity.</b></p>	
----------	---	--

6 | Minnesota Road Fee Test Application Software

1	While within the MRFT application software, tap on the submenu icon on the device face
2	An application submenu appears at the bottom of the screen displaying buttons for <b>Settings</b> , <b>Options</b> , and <b>Info</b>
3	On the <b>Settings</b> submenu, the current trip settings may be changed
4	On the <b>Options</b> submenu, the default behavior of the device may be changed: <ul style="list-style-type: none"> <li>• Toggle the ability to Auto Save and Send Trip IDs</li> <li>• Toggle Google Nav. (i.e. replace CoPilot)</li> </ul>
5	The <b>Info</b> submenu allows access to software status indicators as well as the <b>Technical Support</b> phone number

7 | Minnesota Road Fee Test Application Software

1	Tap on <b>Launch CoPilot®Live™</b> from the MRFT home screen menu
2	Tap on the <b>Destination</b> icon from the CoPilot®Live™ menu shown
3	Tap on the <b>Address</b> icon from the CoPilot®Live™ menu as shown
4	Enter destination from the keypad
5	Follow navigation as presented

Additional instructions for operating CoPilot®Live™ can be found in the guides and video section of the Minnesota Road Fee Test Participant Portal  
<http://www.mnroadfeetest.com/>

8 | CoPilot®Live™

1	Tap on <b>Launch Nav</b> from the MRFT home screen menu
2	Tap on <b>Type Destination</b> OR <b>Speak Destination</b>
3	Enter destination from the keypad OR speak destination as shown
4	Follow navigation as presented

**i** Additional instructions for operating Google Maps™ Navigation can be found in the guides and video section of the Minnesota Road Fee Test Participant Portal  
<http://www.mnroadfeetest.com/>

9
Google Maps™ Navigation

1	While within the MRFT application software, tap on the submenu icon on the device face
2	Exit from the MRFT application software by tapping the <b>Exit</b> option
3	Verify MRFT is closed by checking that there is no state of Minnesota icon in the notification bar
4	Locate the charger and cable in your kit; plug the cable into the charger and the charger into the wall
5	Plug the cable into the phone
6	The battery indicator shows when the phone is charging

10
Charging Device at Home



## Minnesota Road Fee Test

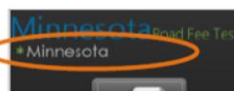
## Device and Software Use Instructions Addendum

### Mileage Based User Fees (MBUF)

### Signage

### User Interface and Device Care

Mileage Based User Fees (MBUF) are calculated and accumulated during a given trip. The current fee based on location or time of day is displayed at the bottom of the MRFT application screen and at the top of the screen in the notification area. This value will change as location or time of day varies. In some cases the **Current Fee** may display the phrase **UNK** indicating a GPS signal is unavailable and therefore the fee is **UNKNOWN**.



The current geography is shown in the display along with an asterisk indicating when traveling on an interstate.

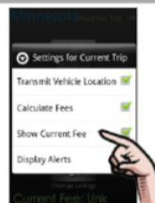


Tap **View Reports**, **View Estimated Fees** to see an MBUF report of accumulated miles and fees

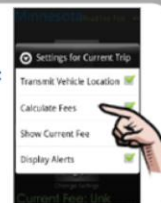
To disable or enable MBUF functionality, from the MRFT application screen, tap the **Change Settings** option.



Tapping **Show Current Fee** from the **Settings for Current Trip** menu will disable the **Current Fee** display, however, fees will still be calculated.



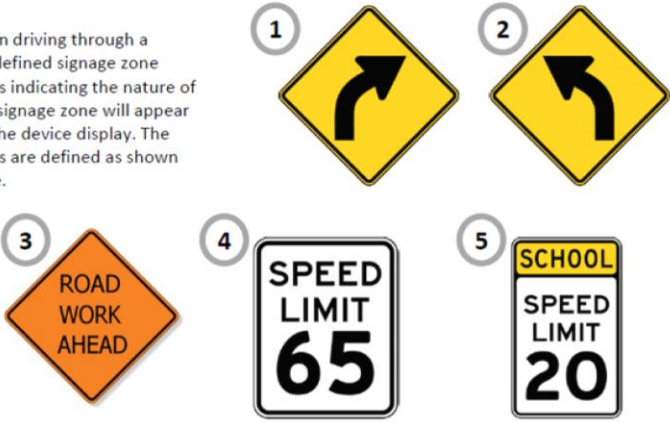

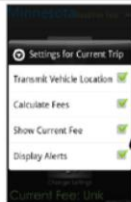
Tapping **Calculate Fees** from the **Settings for Current Trip** menu will disable\*\* the calculation of MBUF fees.



\*\*When this setting is disabled, or if the device is not used, the default, or highest rate, will apply to any mileage recorded on the odometer.

## 2 Mileage Based User Fees (MBUF)

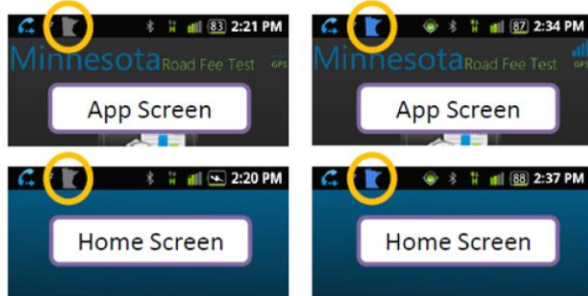


1	Right curve ahead; the device will beep if more than 5 miles over the set limit	<p>Upon driving through a predefined signage zone icons indicating the nature of the signage zone will appear on the device display. The icons are defined as shown here.</p> 
2	Left curve ahead; the device will beep if more than 5 miles over the set limit	
3	Road work ahead; the device will beep if more than 5 miles over the set limit	
4	The current speed limit is 65 mph; the device will beep if more than 5 miles over the set limit	
5	A school zone has been entered; the current speed limit is 20 mph; the device will beep if more than 5 miles over the set limit	<p>To disable the signage functionality, from the MRFT application screen, tap the <b>Change Settings</b> option.</p>  <p>The signage feature can be disabled by toggling the check mark beside <b>Display Alerts</b> within the <b>Setting for Current Trip</b> menu.</p> 


3 | Signage

### User Interface

A grey Minnesota icon in the notification area indicates the MBUF software is running, however, the device is not recording a trip. This icon will be displayed from the app screen or the home screen. This icon will still appear despite the **Show Current Fee** option is unchecked as shown on page 2, MBUF.



A blue Minnesota icon in the notification area indicates the MBUF software is running and the device is recording a trip but the **Show Current Fee** option is unchecked. If the **Show Current Fee** option is checked, the current fee will appear instead of the Minnesota icon as discussed on page 2, MBUF.



### Extreme Temperatures May Affect The Operation Of This Device

Please note, extreme cold or hot may affect the operation of this device. Due to extreme temperatures the device may take longer to turn on or load. Battery life and performance may be affected when the device is left in extreme temperatures for extended periods of time.

It is recommended that the device be removed from the vehicle and taken indoors, when not in operation, if the temperature in the vehicle is expected to fall below 32°F (0°C) or exceed 113°F (45°C).

4 | User Interface and Device Care

## Minnesota Road Fee Test

## MBUF Pricing Table and Examples

### How do I know what fees I will be charged if I'm using the device?

Ask three questions...

1. Where am I currently driving?
2. What day of the week am I driving?
3. At what time of day am I driving?

Current Driving Location	Peak Times Monday, Tuesday, Wednesday, Thursday, Friday 7AM-9AM 4PM-6PM	Off Peak Times
Outside of Minnesota	\$ .00	\$ .00
Inside Minnesota and Outside the Twin Cities Metro Zone	\$ .01	\$ .01
Inside the Twin Cities Metro Zone	\$ .03	\$ .01

### Here are three examples...

I am driving to a friend's house that is 25 miles from my house in Minnesota outside of the Twin Cities Metro Zone on a Saturday. I drive from home to my friend's house.

Current Driving Location	Day and Time When Driving	Fee Per Mile	Miles Traveled	Total Cost
Inside Minnesota and outside the Twin Cities Metro Zone.	Saturday	\$ .01	25	\$ .25
Total cost for this trip				\$ .25

I am driving to work on a Monday morning. I live in Rockford but work in downtown Minneapolis. My drive takes 45 minutes and I leave my house at 7:30AM.

Current Driving Location	Day and Time When Driving	Fee Per Mile	Miles Traveled	Total Cost
Inside Minnesota and outside the Twin Cities Metro Zone.	Monday 7:30AM-8:00AM	\$ .01	15	\$ .15
Inside the Twin Cities Metro Zone on the way to downtown Minneapolis.	Monday between 8:00AM-8:15AM	\$ .03	10	\$ .30
Total cost for this trip				\$ .45

I am driving on a long trip from downtown Minneapolis to Madison, Wisconsin. I plan on leaving at 8:45AM on a Wednesday. Traffic is heavy and I expect it will take at least 30 minutes to get outside the Twin Cities Metro Zone.

Current Driving Location	Day and Time When Driving	Fee Per Mile	Miles Traveled	Total Cost
Inside the Twin Cities Metro Zone.	Wednesday at 8:45AM-9:00AM	\$ .03	10	\$ .30
Inside the Twin Cities Metro Zone.	Wednesday at 9:00AM-9:15AM	\$ .01	10	\$ .10
Inside Minnesota and outside the Twin Cities Metro Zone.	Wednesday at 9:15AM-9:45AM	\$ .01	12	\$ .12
Outside Minnesota	Wednesday at 9:45AM-1:30PM	\$ .00	244	\$ .00
Total cost for this trip				\$ .52

## Minnesota Road Fee Test

## MBUF Pricing Table and Examples

### What if I don't use the device or I disable Calculating Fees on the device?

When not using the device, or if Calculating Fees is disabled, each mile recorded by the odometer is charged \$.03.

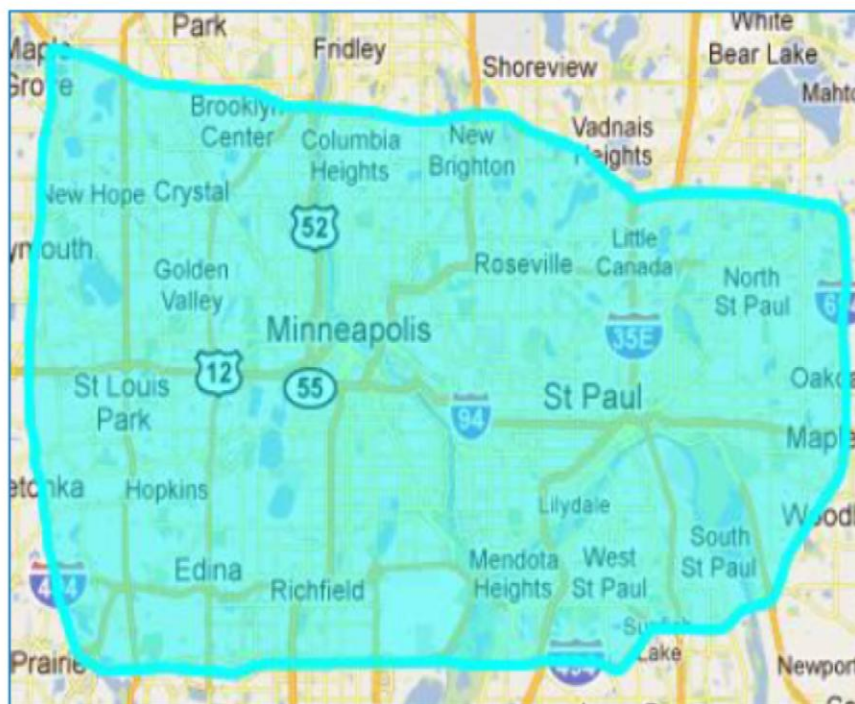
Example 1 as shown on page 1.  
Device is in use and Calculating  
Fees is ENABLED.

Current Driving Location	Day and Time When Driving	Fee Per Mile	Miles Traveled	Total Cost
Inside Minnesota and outside the Twin Cities Metro Zone.	Saturday	\$.01	25	\$ .25
Total cost for this trip				\$ .25

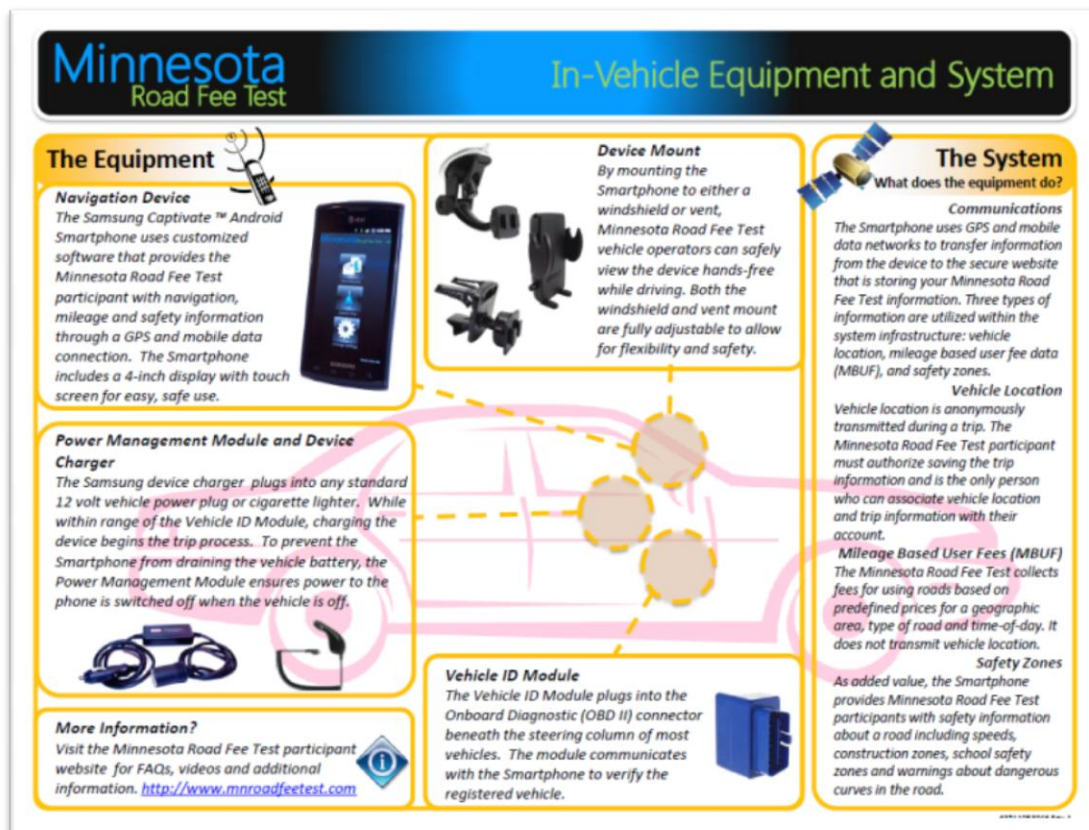
Example 1 as shown on page 1.  
Device is NOT being used or  
Calculating Fees is DISABLED.

Current Driving Location	Day and Time When Driving	Fee Per Mile	Miles Traveled	Total Cost
Inside Minnesota and outside the Twin Cities Metro Zone.	Saturday	\$.03	25	\$ .75
Total cost for this trip				\$ .75

### Twin Cities Metro Zone (I-494/I-694 loop)







## Minnesota Road Fee Test

## Third (Final) Odometer Reading Notice

Dear Minnesota Road Fee Test Participant,

Thank you for being an active Participant in the Minnesota Road Fee Test. As an active Participant, we require your assistance to complete the third (final) odometer reading for the study and complete the process of reconciliation of the invoices and the mileage identified on your odometer. Once you have completed this process, we will be restoring the device back to its factory settings and giving it to you as a reward for completing the study. To summarize, the objectives of the third odometer reading are as follows.

1. Final odometer reading and report.
2. Reconciliation of all invoices.

All invoices must be reconciled including charges for:

- Unpaid invoices
- Mileage collected during March, and
- The difference in mileage between the device and your odometer charged at the default rate.

It is important to note, charges will never exceed the start up funds you were provided. Payment for outstanding charges can be made using PayPal or by cash or check.

3. The device will be restored to factory settings, instructions for contacting a compatible service provider will be provided, and the device will be given to you as a reward for your participation once all previous steps have been completed.

Please bring the following items to the odometer reading:

- ✓ Driver's License with your current address (Note: If the address on your Driver's License is not your current address, please also bring two bills with matching addresses.)
- ✓ Registration or valid insurance card indicating that you are the owner of the car
- ✓ The vehicle that you brought to the second odometer reading
- ✓ All Minnesota Road Fee Test equipment including:
  - Device
  - Charging Cable(s)
  - Vehicle Identification Module
  - Vehicle Mount(s)
- ✓ Your Travel diary (please write your name and phone number on the first page)

To schedule a third (final) odometer reading please contact the Minnesota Road Fee Test support team.

(612) 708-7288

[support@mnroadfeetest.com](mailto:support@mnroadfeetest.com)

<http://www.mnroadfeetest.com>

DRAFT



## Minnesota Road Fee Test

## Third (Final) Odometer Reading Close Out

Thank you for participating in the Minnesota Road Fee Test!

1

Field staff will verify your vehicle, check the vehicle ID module, and record the odometer reading.

2

Field staff will verify your address and contact information as reported in the participant portal.

3

On the first page of the participant diary, please sign and print your name along with a phone number for the Evaluation Team to contact you with questions.

4

Please return all equipment including the vehicle ID module, power chargers, and device mount.

**As a token of our appreciation the Minnesota Road Fee Test project team would like to present you with the Smartphone as a gift. The phone has been restored to factory settings; please contact a compatible service provider for more information on activation.**

5

Pay all outstanding invoices including February, March, and close out. Payment can be made via cash, check, or PayPal.

6

The Evaluation Team will contact you with information regarding exit survey and receiving your stipend. All questions with regard to stipend should be directed to the Evaluation Team by phone or e-mail.

**(320) 365-1084**  
**myMNpoints@saic.com**

## Minnesota Road Fee Test

## Critical Software Update

Due to an unforeseen software bug after your most recent odometer reading it is necessary to install a critical software update to your device before continuing in the study. This handout provides instruction on how to install the update in about 5 minutes. A visual description of the update is provided on the reverse side. If you have any difficulty updating your device please contact the Critical Software Update Hotline at (612) 708-7289. For general support questions, please contact the MRFT support team by phone, (612) 708-7288; e-mail, [support@mnroadfeetest.com](mailto:support@mnroadfeetest.com); or by accessing the participant portal, <http://www.mnroadfeetest.com>. Thank you.


### I

#### Unplug the device from all power sources and power on

1. Verify the device is unplugged from all external power sources (i.e. wall outlet or vehicle outlet).
2. Wake the device by briefly tapping the power button. If the home screen does not appear the device is off. Power on the device by holding the power button, located on the upper-right side of the device, for 2 seconds.

### II

#### Download the critical software update from the internet

1. Tap the home button at the bottom of the device to navigate to the Minnesota Road Fee Test home screen.
2. From the Minnesota Road Fee Test home screen, tap the internet browser icon (  ). An internet browser will appear with the Google search page displayed.
3. If the browser address bar is not visible, briefly tap and hold the word Google while at the same time sliding down to display the browser address bar.
4. Tap inside the browser address bar to highlight the current address and display the device keyboard.
5. From the device keyboard, enter the following address exactly as shown here: [goo.gl/jSgpP](http://goo.gl/jSgpP)
6. From the device keyboard, tap "Go."

### III

#### Install the critical software update

1. After tapping "Go", the critical software update will download. Depending on the quality of the device connection the download may take from 1 to 5 minutes.
2. Once the download is complete, tap the line that reads, "Download Complete." A dialogue box will appear asking to replace the current application; tap "Ok."
3. A screen will appear asking to install this application; tap "Install."
4. The critical update will install. Once complete a screen will appear that reads, "Application Installed;" tap the "Open" button.
5. Once the updated software has opened, verify the new software version is 1.0.2.1856 on the lower-right of the screen.
6. The critical update is complete!

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# Minnesota Road Fee Test

## Critical Software Update

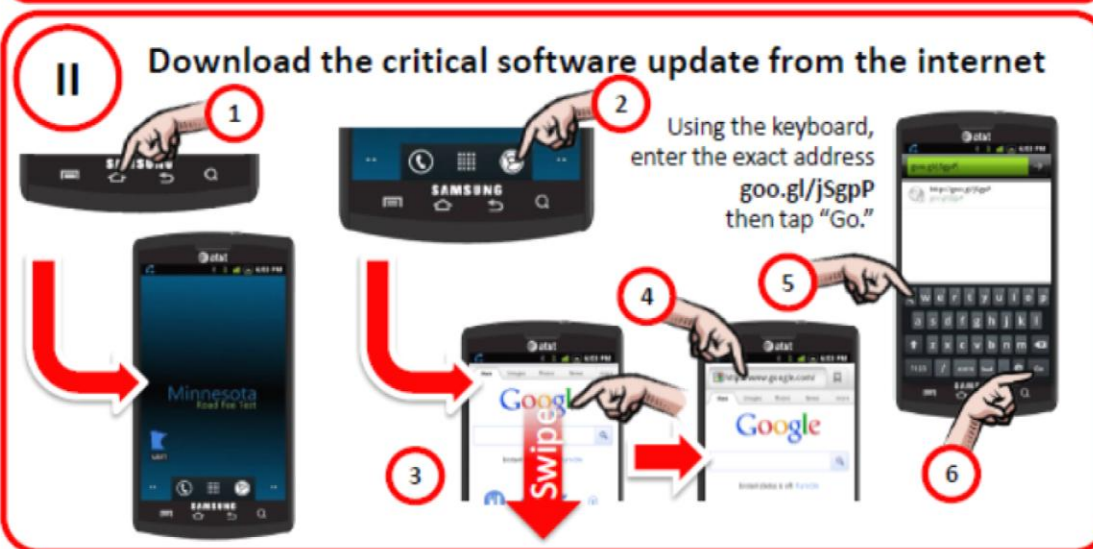
### I Unplug the device from all power sources and power on.

Wake the device by briefly tapping the power button. If the home screen does not appear the device is off. Power on the device by holding the power button, located on the upper-right side of the device, for 2 seconds.




### II Download the critical software update from the internet

Using the keyboard, enter the exact address [goo.gl/jSgpP](http://goo.gl/jSgpP) then tap "Go."



### III Install the critical software update

Verify software version is: 1.0.2.1856



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## **Appendix C: End User License Agreement**

### **Minnesota Road Fee Test (MRFT)**

# **End User License Agreements (EULAs) for Minnesota Road Fee Test (MRFT)**

**Document Number: 635110B3036**

**Revision: C**

## Revision History

Revision	Date	Change Description	Affected Sections/Pages
A	2011-06-07	INITIAL RELEASE	
B	2011-08-03	UPDATED CROSS REF TABLE ADDED SUMMARY PAGE REFORMATTED APPENDICES D AND E	PAGE 1 PAGE 2-3 APPENDICES D AND E
C	2011-08-19	REORDERED APPENDICES AND UPDATED CONTENT OF NEW IDENTIFIERS A, B, AND C.  ADDED 635110B3019 AND 635110B3030 TO LIST OF PROCEDURES REFERENCING THIS PROCEDURE.	ENTIRE DOCUMENT

## Cross References

This operational procedure is explicitly referenced by the following operational procedures:

Operational Procedure Number	Title
635110B3019	Processing a Legal Request for MRFT System Data
635110B3030	How a Participant Begins Involvement in MRFT
635110B3041	How to Conduct First Odometer Reading

This operational procedure specifically references the following operational procedures:

Operational Procedure Number	Title
Not Applicable	Not Applicable

## Content

The following appendices include the End User License Agreements that are applicable to this program. Participant signatures are required in three places: at the end of Appendix A, end of Appendix B, and end of Appendix C. A brief summary of each of the agreements is included on the following page.

## **Summary of each End User License Agreement (EULA)**

As a Participant in this study, you are required to sign three (3) separate agreements, one of which references terms for two (2) software navigation programs you may use during the study. A brief summary of each agreement is included in the paragraphs below. For a complete description of each agreement, please refer to the referenced Appendix in this document.

### **Appendix A: MBUF Tennesen Warning**

By signing this agreement, you acknowledge that you have read, understand, and agree to allow MnDOT to collect Participants' names, home contact information, vehicle identification data, and financial data to enroll volunteers into the study and to install the smart phone device into the participants' vehicle. The data will also be used to track payments made by participants and to pay volunteers for their participation in the study. If you refuse to supply the requested data, Mn/DOT cannot enroll you as a participant in the study and cannot have you install the smart phone into your vehicle.

Minnesota Statutes Chapter 13 (Minnesota Government Data Practices Act) governs the public availability of data created and collected during the study. In anticipation of the study, Mn/DOT sought and received a temporary classification from the Minnesota Department of Administration (Minn. Stat. §13.06). Participant names, vehicle identification data, financial account data and road usage data are classified as not public data. The temporary classification will expire on August 1, 2013.

### **Appendix B: Informed Consent Form from SAIC**

By signing this appendix, you acknowledge your participation will last approximately 6 months during which time you will use this device everyday in your own personal vehicle, schedule and bring your vehicle to three (3) odometer reading appointments, and pay all monthly invoices using the start-up funds provided to you during the test (there is no out-of-pocket cost to you).

Upon completion of this test, you will be paid a stipend for your participation in this study. This stipend will be based on the number of activities you complete during the test, which will not be more than \$375.

### **Appendix C: Battelle Minnesota Road Fee Test Participant Agreement**

By signing this appendix, you agree that you have read and understand the EULA in this Appendix for Battelle, in Appendix D for Co-Pilot and in Appendix E for Google Navigation; and are willing to adhere to these agreements for the duration of your participation in the study.

In addition, the telephone and SMS features of the cellular phone have been disabled, and you will not attempt to circumvent this disabling. You will be responsible for the devices and hardware while participating in the study, and you agree to specifically avoid interacting with the device (e.g., typing or setting a navigation destination) while your vehicle is in motion.

### **Appendix D: EULA for CoPilot Software and Appendix E: Google© Terms of Service**

By signing Appendix C, Battelle Minnesota Road Fee Test Participant Agreement, you are also agreeing to the EULA For CoPilot Software from ALK Technologies, Inc., detailed in Appendix D and to the Google© Terms of Service detailed in Appendix E. These are the same terms to which you would agree whenever you use the same software for personal use.

## **Appendix A**

# **Data Deemed to be Private Under the Minnesota Data Practices Act (also known as MBUF Tennessen Warning)**

The following is considered to be classified as private data under the Minnesota Data Practices Act.

- Participant's residential address and telephone number;
- Personal travel information, unless the participant has voluntarily provided this information as part of the demonstration through the submission of trip identifiers.
- Monthly invoice for road user fees.

The Mileage Based User Fee Tennessen Warning content is included in the following pages of this appendix.

### Explanation of Your Rights

Before you give the Minnesota Department of Transportation (MnDOT) permission to collect and/or release private or confidential data about you, MnDOT encourages you to review the information listed on this Tennessee Warning (also called a Data Privacy Notice). MnDOT must inform you of:

- The purpose and intended use of the requested data within MnDOT.
- Whether you may refuse or are legally required to supply the requested data.
- Any known consequences arising from supplying or refusing to the requested data.
- The identity of other persons or entities authorized by state or federal law to receive the requested data.

If you have a question about anything on this form, or would like more explanation, please contact MnDOT's Office of Chief Counsel before you sign it:

Barbara Forsland  
Data Practices Compliance Officer  
Office of Chief Counsel  
Minnesota Department of Transportation  
395 John Ireland Blvd. MS 140  
St. Paul, MN 55155  
651-366-4822  
[Barbara.forsland@state.mn.us](mailto:Barbara.forsland@state.mn.us)

Peter Zuniga  
Staff Attorney, Data Practices Unit  
Office of Chief Counsel  
Minnesota Department of Transportation  
395 John Ireland Blvd. MS 140  
St. Paul, MN 55155  
651-366-4837  
[Peter.zuniga@state.mn.us](mailto:Peter.zuniga@state.mn.us)

The Minnesota Department of Transportation's Minnesota Road Fee Test (study) will test technology that could be used in the future to collect a mileage-based user fee that could replace the gas tax. The mileage-based user fee would tax individuals for the miles they drive instead of the amount of gas they buy. MnDOT has contracted with outside vendors and consultants Battelle Memorial Institute, Science Applications International Corporation (SAIC), Mixon/Hill, Incorporated, and the University of Minnesota, Office of Sponsored Projects Administration, to administer the Minnesota Road Fee Test (collectively MnDOT).

This Tennessee Warning or Data Privacy Notice 1) identifies the data MnDOT is collecting; 2) informs you why MnDOT is collecting the data; 3) informs you whether you may refuse or are legally required to supply the data; 4) informs you of the consequences of supplying or not supplying the data; and 5) identifies persons or entities who will have access to your data.

1) Participants will install a smart phone with a GPS application into their vehicle and MnDOT will collect the following data:

- Participant's names;
- Home contact information;
- Vehicle identification data, including make, model, year, and vehicle identification number;
- Financial information, including a credit card number and bank account information; MnDOT has designed the system and the operational procedures so that financial information will not be retained.
- Miles driven;
- Travel Routes; and
- Days and times of trips;

2) The purpose and intended use of the requested data within MnDOT.

- Participants' names, home contact information, vehicle identification data, and financial data will be used to enroll volunteers into the study and to install the smart phone device into the participants' vehicle. The data will also be used to track payments made by participants and to pay volunteers for their participation in the study.
- Miles driven, travel routes, and days and times of trips will be used to determine whether the technology can be used to collect a mileage-based user fee and whether the device effectively communicates real-time information about work zones, crashes, congestion, and road hazards that could improve driver safety.
- MnDOT will use road usage data and types of vehicles used in the study to produce summary reports.



- 3) Whether you may refuse or are legally required to supply the requested data.
  - You are not legally required to supply the requested data and you may refuse to supply the requested data.
  - You may temporarily suspend your participation in the study at any time.
  - You may end participation in the study at any time.
- 4) Any known consequences arising from supplying or refusing to supply the requested data.
  - If you refuse to supply the requested data, MnDOT cannot enroll you as a participant in the study and cannot have you install the smart phone into your vehicle.
  - Once enrolled as a participant in the study, you may refuse to supply the requested data. However, if you refuse to supply the requested data, your participation in the study will be terminated.
- 5) The identity of other persons or entities authorized by state or federal law to receive the requested data. It is likely the following people or entities will have access to the requested information:
  - Cory Johnson, MnDOT Project Manager
  - MnDOT, Battelle, SAIC, Mixon/Hill, and the University of Minnesota staff whose work reasonably requires access to the data, for example: to prepare reports, contact participants with surveys, or handle questions or problems with equipment, etc.
  - MnDOT will not produce the not public data to any other government entity
  - MnDOT will only produce the not public data to federal, state, and local law enforcement authorities acting pursuant to a valid search warrant

Minnesota Statutes Chapter 13 (Minnesota Government Data Practices Act) governs the public availability of data created and collected during the study. In anticipation of the study, MnDOT sought and received a temporary classification from the Minnesota Department of Administration (Minn. Stat. §13.06). Participant names, vehicle identification data, financial account data and road usage data are classified as not public data. The temporary classification will expire on August 1, 2013.

MnDOT pursued legislation in the 87<sup>th</sup> Legislature, 2011-2012 session, to permanently classify the data as private data on individuals. The legislature did not pass a permanent classification of the data. MnDOT will pursue legislation in the 88<sup>th</sup> Legislature, 2012 – 2013 session to permanently classify the data as private data on individuals. If the Legislature does not pass a permanent classification in the 2012 -2013 session, the data will become public after August 1, 2013. MnDOT will not store your financial information, but if the data are classified as public, MnDOT will continue to protect any of your financial information as security information under Minnesota Statute §13.37.

**Connected Vehicle for Safety, Mobility and User Fee Implementation  
Minnesota Road Fee Test Operations Report**

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Summary reports created from the collected data and payments made to participants are public as long as the participants' identities or any other characteristic that could uniquely identify participants are not ascertainable.

I have read, understand, and agree to allow MnDOT to collect data as part of my participation in the Minnesota Road Fee Test. I understand the collected data are governed by the MGDPA and applicable state and federal laws and MnDOT will manage the data consistent with those laws and this Tennessen Warning.

\_\_\_\_\_  
Name

\_\_\_\_\_  
Date

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**Appendix B**

**Informed Consent Form**

**from**

**Science Applications International Corporation**  
**(SAIC)**

## **SAIC INDEPENDENT STUDY OF THE MINNESOTA ROAD FEE TEST**

### **RECORD OF INFORMED CONSENT**

In accordance with 45 C.F.R., Section 46.116, relating to the Protection of Human Subjects in Research, your informed consent for participation in the Science Applications International Corporation (SAIC) Evaluation of the Minnesota Road Fee Test is required.

The following information is the data management and protection practices approved by SAIC Institutional Review Board. These practices may be superseded by Minnesota state laws. Further information about this can be found in the Minnesota Department of Transportation's "Explanation of Your Rights" which will also be provided to you. SAIC will retain data for a minimum length of time consistent with the policies of the SAIC Institutional Review Board and the state of Minnesota.

Please consider the following elements of information in reaching your decision whether or not to consent:

#### **Section I. General:**

We are asking for your voluntary participation as a paid subject in an evaluation of driver use and opinions of an in-vehicle device which will calculate a mileage-based road fee, provide warnings when you are in a safety zone, and collect data for estimating travel times. Your participation will last approximately 6 months during which time you will use this device in your own personal vehicle. Your participation will require you to meet several requirements and perform a number of activities.

#### **Section II. Study Procedures:**

You must have a valid driver's license in order to participate. You will receive detailed instructions during the test regarding project activities, and you will receive frequent reminders.

In summary, these activities are:

- Bring and turn-on the test device every time you drive your vehicle during the 6-month test period.
- Schedule and bring your vehicle to three (3) odometer reading appointments.
- Pay all monthly invoices using the start-up funds provided to you during the test. If your invoices exceed the start-up funds provided, you will not be required to pay any additional fees.
- Respond to three (3) surveys which will each take approximately thirty (30) minutes of your time.
- Participate in at least one (1) telephone interview at the conclusion of the test which will take approximately thirty (30) minutes of your time.

- Record your thoughts, comments, and concerns in a diary (journal) provided to you at the first odometer reading.
- Regularly send your stored Trip ID information to the SAIC study team.

You may also have the option of participating in small focus group meetings occasionally during the test. Each meeting will take approximately two (2) hours of your time.

The results of this research will be useful to traffic engineers, policy researchers, research psychologists, and others concerned with improving the Minnesota and national transportation system.

Upon completion of this test, you will be paid a stipend for your participation in this study. This stipend will be based on the number of activities (listed above) you complete during the test. For each activity that you complete, you will earn points. At the end of the test, these points will be converted into a dollar amount which will be not more than \$375. You must complete the study in its entirety to receive full remuneration, except as indicated in the sections below. You may stop at any time for any reason. Additionally, you may be asked to leave the study by the study team at any time for any reason.

### Section III. Risks:

The study team will collect and store your personal contact information for the purposes of scheduling and follow-up. The study team will also collect other data during the test in the form of surveys, interviews, focus groups, and road usage (i.e., trip) information. This data will be assigned a randomly generated participant identification number (Participant ID) for the purposes of analysis. A limited number of SAIC staff will know which Participant ID is assigned to your data.

### Section IV. Risk Reduction:

All contact information will be stored on a password-protected and encrypted computer in a locked office. The contact information will only be viewable by a limited number of SAIC staff for use in contacting you during the project (except as it may be shared with the state of Minnesota as specified in the introduction to this Consent).

Road usage (i.e., trip) data will remain anonymous until you send your Trip IDs to the SAIC study team. At that point, the research team will remove your name and assign a random Participant ID to your data. Surveys, interviews, and any other data and communications will also be assigned this Participant ID number. The assignment of Participant IDs will only be known by a limited number of SAIC staff (except as it may be shared with the state of Minnesota as specified in the introduction to this Consent). This information will be stored on a password protected and encrypted hard drive in a locked office.

During the analysis of data, all data will also be stored on a password-protected and encrypted hard drive in a locked office. The data will only be viewable by a limited number of SAIC study team staff (except as it may be shared with the state of Minnesota as specified in the introduction

to this Consent). Data findings will only be reported in the aggregate or summary form and no data will be personally identifiable. Published reports of findings will not indicate an individual's identity.

**Section V. Withdrawal of Consent:**

You are free to decline consent or to withdraw consent and discontinue participation in the study session at any time without penalty or loss of benefits to which you would have been entitled had you not participated at all. You will receive a stipend payment prorated based the number of activities in which you participated. Thus, your final payment will be based on the number of activities you actually completed and not on full study participation.

**Section VI. For Further Information:**

If you have additional questions pertinent to this research, your rights as a subject, or any injury you believe to be related to this research, please contact:

Sheryl Miller, Primary Investigator (SAIC Study Team)  
Transportation Solutions Division  
Science Applications International Corporation (SAIC)  
8301 Greensboro Drive  
McLean, Virginia 22102  
(703) 676-4501

OR

Nicholas Owens, Human Protections Administrator  
Transportation Research Division  
Science Applications International Corporation (SAIC)  
8301 Greensboro Drive McLean, Virginia 22102  
(703) 676-2408

**The foregoing information has been presented and clearly understood by me, and I hereby voluntarily consent to participate as a subject in this study.**

**NAME** (Please print): \_\_\_\_\_

**SIGNATURE:** \_\_\_\_\_

**DATE:** \_\_\_\_\_



## **Appendix C**

# **Battelle End User License Agreement For Use of Minnesota Road Fee Test Device and Software**

## **Battelle Minnesota Road Fee Test Participant Agreement**

**Version 8/18/2011**

By signing below, you agree that you have read and understand the End User License (EULA) Agreements contained in this package and are willing to adhere to these agreements for the duration of your participation in the study. Failure to follow these agreements will result in your removal from the study.

Your signature indicates your specific agreement to the following documents and provisions:

### **Documents:**

1. Battelle End-User-License Agreements
2. Co-Pilot License Agreement
3. Google Navigation License Agreement

### **Additional Provisions:**

As part of participating in this research project, you will be receiving a Samsung Galaxy S Smart Phone, with the associated mounts and power cables for use in your personal automobile. Additional hardware such as an On-Board Diagnostic Port Bluetooth reader will also be provided. You are agreeing to the following provisions regarding the use of this hardware in addition to those provisions provided in the aforementioned documents:

1. You will be responsible for the devices and hardware while participating in the study.
2. You agree to specifically avoid interacting with the device (e.g., typing or setting a navigation destination) while your vehicle is in motion.
3. The telephone and SMS features of the cellular phone have been disabled. You will not attempt to circumvent this disabling. Should there be charges accrued on the device beyond the data charges included as part of your participation, you will be responsible for those charges.

**I have read, understand, and agree to abide by the terms and conditions of this Participant Agreement and its associated End User License Agreements.**

**NAME** (Please print): \_\_\_\_\_

**SIGNATURE:** \_\_\_\_\_

**DATE:** \_\_\_\_\_

**Appendix D**

**End User License Agreement**

**For**

**CoPilot Software**

**From**

**ALK Technologies, Inc.**

The content of this appendix was copied from the website referenced below and was verified to be current as of the release date for this appendix. The content has been reformatted to improve legibility. In the event of a conflict, the content in this appendix takes precedence.

<http://www.alk.eu.com/copilotlive/legal/>

## End User Licence Agreement for ALK Technologies

### EULA

Last revised on: 31 March 2011

In order to use the enclosed ALK Technologies, Inc ('ALK') CoPilot Software (the "Software"), you must first agree to the End User Licence Agreement ('EULA') below. You may not use the Software if you do not accept the EULA. You can accept the EULA by: i) clicking to accept or agree to the EULA, where this option is made available to you by ALK in the Software; or ii) installing or actually using the Software. In so doing, you understand and agree that ALK will treat your use of the Software as acceptance of the EULA from that point onwards. You may not use the Software and may not accept the EULA if: i) You are not of legal age to form a binding contract with ALK, or ii) You are a person barred from receiving the Software under the laws of the United States or other countries including the country in which you reside or from which you access the Software.

By agreeing to the EULA, you acknowledge that i) ALK is not responsible for any Third Party content ii) the Software may collect and use data for which ALK respects privacy rules, iii) for some features of the Software, you will need to have wireless internet and data connection enabled on your mobile device. Using wireless internet may result in data charges from your mobile service provider for which ALK is not responsible, iv) ALK uses different Third Party map data suppliers; to check which Map Data EULA applies to your Product, please refer to the "About Screen" of your Software and v) your use of this real time route guidance application is at your sole risk. Location data may not be accurate.

When possible ALK has provided for your information a translation of the EULA. You agree that the translations are provided for your convenience only and that the English Language shall prevail and always be binding in case of conflict. ALK's terms and conditions on ALK's website and any of ALK's associated pages are hereby incorporated by reference to the EULA and therefore form a binding agreement. We regularly update the EULA and the website and encourage you to visit those pages.

### END-USER LICENCE AGREEMENT FOR COPILOT® SOFTWARE

Please read the following agreement ("Licence") carefully.

Acceptance: Installation or use of the enclosed Software on your device constitutes your acceptance of these terms. If you do not agree to the Terms of Use, you must immediately delete the Software from your device and destroy any copies you made of the Software and of any written materials relating to the Software, and promptly return the Software and, if bought as part of a package, any associated devices to your retailer for a refund.

Licence: ALK grants you, as an individual, a non-exclusive, non-transferable right and licence to install and use one copy of the Software on a single device at a time. If your Software includes CoPilot Central™, you may install and use the CoPilot Central™ portion on a different device than the CoPilot navigation portion. Your licence to use the Software is subject to you complying with the terms of this Licence. A licence is required for each installation of the Software, unless

the Software is (i) installed temporarily on a computer during the repair or maintenance of the device on which the Software is normally installed and (ii) is immediately deleted from such device as soon as those repairs or maintenance are complete. You may make one copy of the Software for backup purposes only.

Transfer: You are allowed to move your Software from one device to another only if a) the Software is installed on only one device at a time and b) the second device is running the same operating system as the original one. To Transfer your Software from one device to another, follow the deactivation method described on the Help Page at <http://activate.alk.com/>. If for repair purposes or Read Only Memory ('ROM') changes, you are not able to follow the deactivation method, you will most likely encounter the Anti Piracy Protection implemented by ALK at your next Activation.

Anti-Piracy Protection: the Software may include product activation and other technology to prevent unauthorized use and copying. When provided with a Product Key Code, Google order number, or any other similar mechanism, you will need to activate your Software with the associated method in order to use it. If you try to activate an excessive number of times, the anti Piracy Protection may cause your Software to lock and prevent you from further activating your Software. Refer to our Help Page at <http://activate.alk.com> for more information about our Product Activation and Anti Piracy Protection.

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Limited Warranty: ALK warrants that the Software will perform substantially in accordance with the applicable documentation for a period of 30 days from the date of purchase. Any implied warranties relating to the Software are limited to such 30 day period provided that limitation is permitted by applicable law.

End-User Remedies: If the Software does not conform to the "Limited Warranty" above, ALK's entire liability and your sole and exclusive remedy will be, at ALK's option, either to (i) correct the error, or (ii) help you work around the error, or (iii) accept a return and issue a refund through your retailer. The Limited Warranty is void if failure of the Software has resulted from your fault, abuse, or misapplication. If we correct an error in the Software for you, then the

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**Privacy:** We take your privacy very seriously and will not share your details or personal information with any outside agency without your permission. For information about ALK's data protection practices, please read ALK's privacy policy at <http://www.alk.com/privacy.asp>. This policy explains how ALK treats your personal information and protects your privacy, when you use the Software. You agree to the use of your data in accordance with ALK's privacy policies.

**Warning:** The Software is only a help for navigation. You must respect locally applicable traffic rules and regulations and use the Software with common sense. The reality observed on the road, and the traffic rules and regulations, always take precedence over the information provided by the Software. You must always control your vehicle, and your speed. You must be able to react properly and execute every appropriate maneuver. You must adopt at all times a prudent and respectful behavior with respect to other vehicles and pedestrians. ALK shall not be held responsible for any information provided by the Software including, any map data or any route calculation.

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Date: This EULA was last updated on February 7th, 2011. Visit [www.copilotlive.com/legal](http://www.copilotlive.com/legal) for regular updates.

## **END USER LICENSE FOR SPEECH PLAYBACK**

This license applies to the speech playback function included in your Software, if any.

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<http://www.apache.org/licenses/LICENSE-2.0>



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## **FOR SOFTWARE DOWNLOADED FROM APPLE APP STORE**

All the Terms of the above EULA apply. In addition specific terms for the iOS Products apply below

Scope of Licence: The license granted to You for the Software is limited to a non-transferable licence to use the Software on any iOS Product that You own or control and as permitted by the Usage Rules set forth in the App Store Terms of Service. Please refer to the App Store Terms of Service for more information.

Maintenance and Support: ALK is solely responsible for providing maintenance and support services with respect of the Software as required under applicable law. Apple has no obligation to furnish any maintenance and supports services with respect to the Software

Warranty: The above warranties apply. In the event of any failure of the Software to conform to the above applicable warranty, You may notify Apple and Apple will refund You the purchase price for the Software, to the maximum extent permitted by applicable law. ALK will not refund the Software. Apple will have no other warranty obligation whatsoever with respect to the Software and any other claims, liabilities, damages, costs or expenses attributable to any failure to conform to the warranty shall be ALK's sole responsibility.

Product Claims: You acknowledge that ALK, not Apple, is responsible for addressing any of Your or any Third Party claims relating to the Software possession or use, including but not limited to i) product liability claim, ii) any claim that the Software fails to conform to any applicable legal or regulatory requirement, and iii) claims arising under consumer protection or similar legislation.

Legal compliance: You represent and warrant that i) You are not located in a country subject to a U.S Government embargo, or that has been designated by the U.S Government as a "terrorist supporting" country and ii) You are not listed on any U.S Government list of prohibited or restricted parties.

Intellectual Property Rights: You acknowledge that in the event of any claim that the Software or your possession and use of the Software infringes any Third Party Intellectual Property Rights ALK and not Apple shall be solely responsible for the investigation, defense, settlement and discharge of such Intellectual Property Infringement claim.

Third Party Beneficiary: ALK and You acknowledge and agree that Apple, and Apple's subsidiaries, are third party beneficiaries of the E.U.L.A. upon Your acceptance of the terms and conditions of this E.U.L.A. Apple will have the right to enforce the E.U.L.A. against You as a third party beneficiary thereof.

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## Appendix E

### Google<sup>®</sup> Terms of Service

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<http://www.google.com/accounts/TOS>

## 8.1.1 Google Terms of Service

### Welcome to Google!

#### 1. Your relationship with Google

1.1 Your use of Google's products, software, services and web sites (referred to collectively as the "Services" in this document and excluding any services provided to you by Google under a separate written agreement) is subject to the terms of a legal agreement between you and Google. "Google" means Google Inc., whose principal place of business is at 1600 Amphitheatre Parkway, Mountain View, CA 94043, United States. This document explains how the agreement is made up, and sets out some of the terms of that agreement.

1.2 Unless otherwise agreed in writing with Google, your agreement with Google will always include, at a minimum, the terms and conditions set out in this document. These are referred to below as the "Universal Terms".

1.3 Your agreement with Google will also include the terms of any Legal Notices applicable to the Services, in addition to the Universal Terms. All of these are referred to below as the "Additional Terms". Where Additional Terms apply to a Service, these will be accessible for you to read either within, or through your use of, that Service.

1.4 The Universal Terms, together with the Additional Terms, form a legally binding agreement between you and Google in relation to your use of the Services. It is important that you take the time to read them carefully. Collectively, this legal agreement is referred to below as the "Terms".

1.5 If there is any contradiction between what the Additional Terms say and what the Universal Terms say, then the Additional Terms shall take precedence in relation to that Service.

#### 2. Accepting the Terms

2.1 In order to use the Services, you must first agree to the Terms. You may not use the Services if you do not accept the Terms.

2.2 You can accept the Terms by:

(A) clicking to accept or agree to the Terms, where this option is made available to you by Google in the user interface for any Service; or

(B) by actually using the Services. In this case, you understand and agree that Google will treat your use of the Services as acceptance of the Terms from that point onwards.

2.3 You may not use the Services and may not accept the Terms if (a) you are not of legal age to form a binding contract with Google, or (b) you are a person barred from receiving the Services under the laws of the United States or other countries including the country in which you are resident or from which you use the Services.

2.4 Before you continue, you should print off or save a local copy of the Universal Terms for your records.



### **3. Language of the Terms**

3.1 Where Google has provided you with a translation of the English language version of the Terms, then you agree that the translation is provided for your convenience only and that the English language versions of the Terms will govern your relationship with Google.

3.2 If there is any contradiction between what the English language version of the Terms says and what a translation says, then the English language version shall take precedence.

### **4. Provision of the Services by Google**

4.1 Google has subsidiaries and affiliated legal entities around the world (“Subsidiaries and Affiliates”). Sometimes, these companies will be providing the Services to you on behalf of Google itself. You acknowledge and agree that Subsidiaries and Affiliates will be entitled to provide the Services to you.

4.2 Google is constantly innovating in order to provide the best possible experience for its users. You acknowledge and agree that the form and nature of the Services which Google provides may change from time to time without prior notice to you.

4.3 As part of this continuing innovation, you acknowledge and agree that Google may stop (permanently or temporarily) providing the Services (or any features within the Services) to you or to users generally at Google’s sole discretion, without prior notice to you. You may stop using the Services at any time. You do not need to specifically inform Google when you stop using the Services.

4.4 You acknowledge and agree that if Google disables access to your account, you may be prevented from accessing the Services, your account details or any files or other content which is contained in your account.

4.5 You acknowledge and agree that while Google may not currently have set a fixed upper limit on the number of transmissions you may send or receive through the Services or on the amount of storage space used for the provision of any Service, such fixed upper limits may be set by Google at any time, at Google’s discretion.

### **5. Use of the Services by you**

5.1 In order to access certain Services, you may be required to provide information about yourself (such as identification or contact details) as part of the registration process for the Service, or as part of your continued use of the Services. You agree that any registration information you give to Google will always be accurate, correct and up to date.

5.2 You agree to use the Services only for purposes that are permitted by (a) the Terms and (b) any applicable law, regulation or generally accepted practices or guidelines in the relevant jurisdictions (including any laws regarding the export of data or software to and from the United States or other relevant countries).

5.3 You agree not to access (or attempt to access) any of the Services by any means other than through the interface that is provided by Google, unless you have been specifically allowed to do so in a separate agreement with Google. You specifically agree not to access (or attempt to access) any of the Services

through any automated means (including use of scripts or web crawlers) and shall ensure that you comply with the instructions set out in any robots.txt file present on the Services.

5.4 You agree that you will not engage in any activity that interferes with or disrupts the Services (or the servers and networks which are connected to the Services).

5.5 Unless you have been specifically permitted to do so in a separate agreement with Google, you agree that you will not reproduce, duplicate, copy, sell, trade or resell the Services for any purpose.

5.6 You agree that you are solely responsible for (and that Google has no responsibility to you or to any third party for) any breach of your obligations under the Terms and for the consequences (including any loss or damage which Google may suffer) of any such breach.

## **6. Your passwords and account security**

6.1 You agree and understand that you are responsible for maintaining the confidentiality of passwords associated with any account you use to access the Services.

6.2 Accordingly, you agree that you will be solely responsible to Google for all activities that occur under your account.

6.3 If you become aware of any unauthorized use of your password or of your account, you agree to notify Google immediately at <http://www.google.com/support/accounts/bin/answer.py?answer=58585>.

## **7. Privacy and your personal information**

7.1 For information about Google's data protection practices, please read Google's privacy policy at <http://www.google.com/privacy.html>. This policy explains how Google treats your personal information, and protects your privacy, when you use the Services.

7.2 You agree to the use of your data in accordance with Google's privacy policies.

## **8. Content in the Services**

8.1 You understand that all information (such as data files, written text, computer software, music, audio files or other sounds, photographs, videos or other images) which you may have access to as part of, or through your use of, the Services are the sole responsibility of the person from which such content originated. All such information is referred to below as the "Content".

8.2 You should be aware that Content presented to you as part of the Services, including but not limited to advertisements in the Services and sponsored Content within the Services may be protected by intellectual property rights which are owned by the sponsors or advertisers who provide that Content to Google (or by other persons or companies on their behalf). You may not modify, rent, lease, loan, sell, distribute or create derivative works based on this Content (either in whole or in part) unless you have been specifically told that you may do so by Google or by the owners of that Content, in a separate agreement.

8.3 Google reserves the right (but shall have no obligation) to pre-screen, review, flag, filter, modify, refuse or remove any or all Content from any Service. For some of the Services, Google may provide tools to filter out explicit sexual content. These tools include the SafeSearch preference settings (see

<http://www.google.com/help/customize.html#safe>). In addition, there are commercially available services and software to limit access to material that you may find objectionable.

8.4 You understand that by using the Services you may be exposed to Content that you may find offensive, indecent or objectionable and that, in this respect, you use the Services at your own risk.

8.5 You agree that you are solely responsible for (and that Google has no responsibility to you or to any third party for) any Content that you create, transmit or display while using the Services and for the consequences of your actions (including any loss or damage which Google may suffer) by doing so.

## **9. Proprietary rights**

9.1 You acknowledge and agree that Google (or Google's licensors) own all legal right, title and interest in and to the Services, including any intellectual property rights which subsist in the Services (whether those rights happen to be registered or not, and wherever in the world those rights may exist). You further acknowledge that the Services may contain information which is designated confidential by Google and that you shall not disclose such information without Google's prior written consent.

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9.3 If you have been given an explicit right to use any of these brand features in a separate written agreement with Google, then you agree that your use of such features shall be in compliance with that agreement, any applicable provisions of the Terms, and Google's brand feature use guidelines as updated from time to time. These guidelines can be viewed online at <http://www.google.com/permissions/guidelines.html> (or such other URL as Google may provide for this purpose from time to time).

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12.1 The Software which you use may automatically download and install updates from time to time from Google. These updates are designed to improve, enhance and further develop the Services and may take the form of bug fixes, enhanced functions, new software modules and completely new versions. You agree to receive such updates (and permit Google to deliver these to you) as part of your use of the Services.

## **13. Ending your relationship with Google**

13.1 The Terms will continue to apply until terminated by either you or Google as set out below.

13.2 If you want to terminate your legal agreement with Google, you may do so by (a) notifying Google at any time and (b) closing your accounts for all of the Services which you use, where Google has made

this option available to you. Your notice should be sent, in writing, to Google's address which is set out at the beginning of these Terms.

13.3 Google may at any time, terminate its legal agreement with you if:

(A) you have breached any provision of the Terms (or have acted in manner which clearly shows that you do not intend to, or are unable to comply with the provisions of the Terms); or

(B) Google is required to do so by law (for example, where the provision of the Services to you is, or becomes, unlawful); or

(C) the partner with whom Google offered the Services to you has terminated its relationship with Google or ceased to offer the Services to you; or

(D) Google is transitioning to no longer providing the Services to users in the country in which you are resident or from which you use the service; or

(E) the provision of the Services to you by Google is, in Google's opinion, no longer commercially viable.

13.4 Nothing in this Section shall affect Google's rights regarding provision of Services under Section 4 of the Terms.

13.5 When these Terms come to an end, all of the legal rights, obligations and liabilities that you and Google have benefited from, been subject to (or which have accrued over time whilst the Terms have been in force) or which are expressed to continue indefinitely, shall be unaffected by this cessation, and the provisions of paragraph 20.7 shall continue to apply to such rights, obligations and liabilities indefinitely.

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(B) ANY LOSS OR DAMAGE WHICH MAY BE INCURRED BY YOU, INCLUDING BUT NOT LIMITED TO LOSS OR DAMAGE AS A RESULT OF:

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19.2 You understand and agree that if you use the Services after the date on which the Universal Terms or Additional Terms have changed, Google will treat your use as acceptance of the updated Universal Terms or Additional Terms.

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20.2 The Terms constitute the whole legal agreement between you and Google and govern your use of the Services (but excluding any services which Google may provide to you under a separate written agreement), and completely replace any prior agreements between you and Google in relation to the Services.

20.3 You agree that Google may provide you with notices, including those regarding changes to the Terms, by email, regular mail, or postings on the Services.

20.4 You agree that if Google does not exercise or enforce any legal right or remedy which is contained in the Terms (or which Google has the benefit of under any applicable law), this will not be taken to be a formal waiver of Google's rights and that those rights or remedies will still be available to Google.

20.5 If any court of law, having the jurisdiction to decide on this matter, rules that any provision of these Terms is invalid, then that provision will be removed from the Terms without affecting the rest of the Terms. The remaining provisions of the Terms will continue to be valid and enforceable.

20.6 You acknowledge and agree that each member of the group of companies of which Google is the parent shall be third party beneficiaries to the Terms and that such other companies shall be entitled to directly enforce, and rely upon, any provision of the Terms which confers a benefit on (or rights in favor of) them. Other than this, no other person or company shall be third party beneficiaries to the Terms.

20.7 The Terms, and your relationship with Google under the Terms, shall be governed by the laws of the State of California without regard to its conflict of laws provisions. You and Google agree to submit to the exclusive jurisdiction of the courts located within the county of Santa Clara, California to resolve any legal matter arising from the Terms. Notwithstanding this, you agree that Google shall still be allowed to apply for injunctive remedies (or an equivalent type of urgent legal relief) in any jurisdiction.

April 16, 2007