Connected Vehicle Pilot Deployment

Connected Vehicle Pilot Deployment Program Phase 1, Application Deployment Plan – ICF/Wyoming

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Notice

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16. Abstract

The Wyoming Department of Transportation's (WYDOT) Connected Vehicle (CV) Pilot Deployment Program is intended to develop a suite of applications that utilize vehicle to infrastructure (V2I) and vehicle to vehicle (V2V) communication technology to reduce the impact of adverse weather on truck travel in the I-80 corridor. These applications support a flexible range of services from advisories, roadside alerts, parking notifications and dynamic travel guidance. Information from these applications are made available directly to the equipped fleets or through data connections to fleet management centers (who will then communicate it to their trucks using their own systems). The pilot will be conducted in three Phases. Phase I includes the planning for the CV pilot including the concept of operations development. Phase II is the design, development, and testing phase. Phase III includes a real-world demonstration of the applications developed as part of this pilot. This document presents a breakdown of the various software elements that need to be developed as part of the pilot. Called "Applications", these elements include interfaces, services, testing tools and functionality that will be created, augmented for this pilot. This document is focused on defining the scope, schedule, and budget for all of the applications involved in the pilot project. This document references the System Requirements document when mapping application requirements to system requirements. Additionally, this document describes the software development, testing, and deployment strategy for all applications listed.

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Acknowledgements

Table of Contents

List of Figures

List of Tables

1 Introduction

1.1 Project Scope

Wyoming Department of Transportation (WYDOT) is one of the first wave of Connected Vehicle (CV) Pilot sites selected to showcase the value of and spur the adoption of Connected Vehicle Technology in the United States. Connected Vehicle Technology is a broad term to describe the applications and the systems that take advantage of vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) communications to improve safety, mobility and productivity of the users of the nation's transportation system.

As one of the three selected pilots, WYDOT is focusing on improving safety and mobility by creating new ways to communicate road and travel information to commercial truck drivers and fleet managers along the 402 miles of Interstate 80 (I-80 henceforth) in the State. For the pilot project, WYDOT will work in a planning phase through September 2016. The twenty-month deployment process will happen in the second phase (beginning in October 2016) followed by an eighteen-month demonstration period in the third phase.

Systems and applications developed in the pilot will enable connected drivers to have 360-degree awareness of hazards and situations they cannot even see. Specifically, WYDOT hopes to improve operations on the corridor especially during periods of adverse weather and when work zones are present. Through the anticipated outcomes of the pilot, fleet managers will be able to make better decisions regarding their freight operations on I-80, truckers will be made aware of downstream conditions and provided guidance on parking options as they travel the corridor, and automobile travelers will receive improved road condition and incident information through various existing and new information outlets.

1.2 Purpose

This document describes the list of various applications that will need to be created or augmented in order for the Connected Vehicle Pilot project to be built as intended. This document is focused on defining the scope, schedule, and budget for all of the applications involved in the pilot project. This document references the System Requirements document when mapping application requirements to system requirements. Additionally, this document describes the software development, testing, and deployment strategy for all applications listed.

Please note that the content within this document is a draft and that there are unknowns and assumptions being made that may change based on who is responsible for the development of the application, the hardware vendor(s), and if requirements are changed during the architectural design process.

1.3 System Overview

Wyoming Department of Transportation (WYDOT) is one of the first wave of Connected Vehicle (CV) Pilot sites selected to showcase the value of and spur the adoption of Connected Vehicle Technology in the United States. Connected Vehicle Technology is a broad term to describe the applications and the systems that take advantage of dedicated short-range communications (DSRC) between vehicle to vehicle (V2V), vehicle to infrastructure (V2I) and infrastructure to vehicle (I2V) to improve safety, mobility and productivity of the users of the nation's transportation system.

As one of the three selected pilots, WYDOT is focusing on improving safety and mobility by creating new ways to communicate road and travel information to commercial truck drivers and fleet managers along the 402 miles of Interstate 80 (I-80 henceforth) in the State. For the pilot project, WYDOT will work in a planning phase through September 2016. The deployment process will happen in the second phase (ending in April 2018) followed by an 18-month demonstration period in the third phase (starting in May 2018). At a very high level, the pilot scope includes the following implementation elements:

- **Deployment of about 75 roadside units (RSU)** that can receive and broadcast messages using DSRC along various sections on I-80.

- **Equip around 400 vehicles, a combination of fleet vehicles and commercial trucks, with on-board units (OBU).** Of the 400 vehicles, at least 150 would be heavy trucks. All vehicles are expected to be regular users of I-80. Several types of OBU are being procured as part of the pilot and differ based on their communication capabilities, ability to integrate with the in-vehicle network, and connectivity to ancillary devices and sensors. All OBUs will have the functionality to broadcast Basic Safety Messages (BSM) Part I and will include a human-machine interface (HMI) to share alerts and advisories to drivers of these vehicles.

- **Develop several V2V and V2I (and I2V) applications** that will enable communication with drivers for alerts and advisories regarding various road conditions. These applications include support for in-vehicle dissemination of advisories for collision avoidance, speed management, detours, parking, and presence of work zones and maintenance and emergency vehicles downstream of their current location.

- **Enable overall improvements in WYDOT's traffic management and traveler information practices** by using data collected from connected vehicles. Targeted improvements include better activation of variable speed limits (VSL) and improved road condition dissemination via 511, Dynamic Message Sings (DMS) and other WYDOT sources.

Systems and applications developed in the pilot will enable drivers of connected vehicles to have awareness of hazards and situations they cannot even see. The CV Pilot is considered a System of Systems, with two systems of interest: The *Vehicle System* and the *Wyoming CV System*, see Figure 1-1. The *Vehicle System* includes four Sub-Systems that represent the various vehicle and equipment types to be used in the pilot. These Sub-Systems vary in their data collection and sharing capabilities. The *Wyoming CV System* includes the infrastructure used in the pilot and back-office systems in charge of the various processes that lead to the generation and distribution of advisories and alerts. Together, the Vehicle and *Wyoming CV System*s support a variety of V2V and V2I applications. Both systems interface with external systems, including WYDOT, USDOT and the National Weather Service (NWS).

The CV Pilot Project will, at its core, provide key information to the drivers through five on-board applications: i) Forward Collision Warning (FCW); ii) I2V Situational Awareness (SA); iii) Distress

Notification (DN); iv) Work Zone Warning (WZW); and v) Spot Weather Impact Warning (SWIW). In addition, the CV Pilot project will support overall traffic management and traveler information services offered by WYDOT.

Through these applications and functions, WYDOT hopes to improve operations on the corridor especially during periods of adverse weather and when work zones are present. By means of the anticipated outcomes of the pilot, fleet managers will be able to make better decisions regarding their freight operations on I-80, truckers will be made aware of downstream conditions and provided guidance on parking options as they travel the corridor, and automobile travelers will receive improved road condition and incident information through various existing, improved and new information outlets.
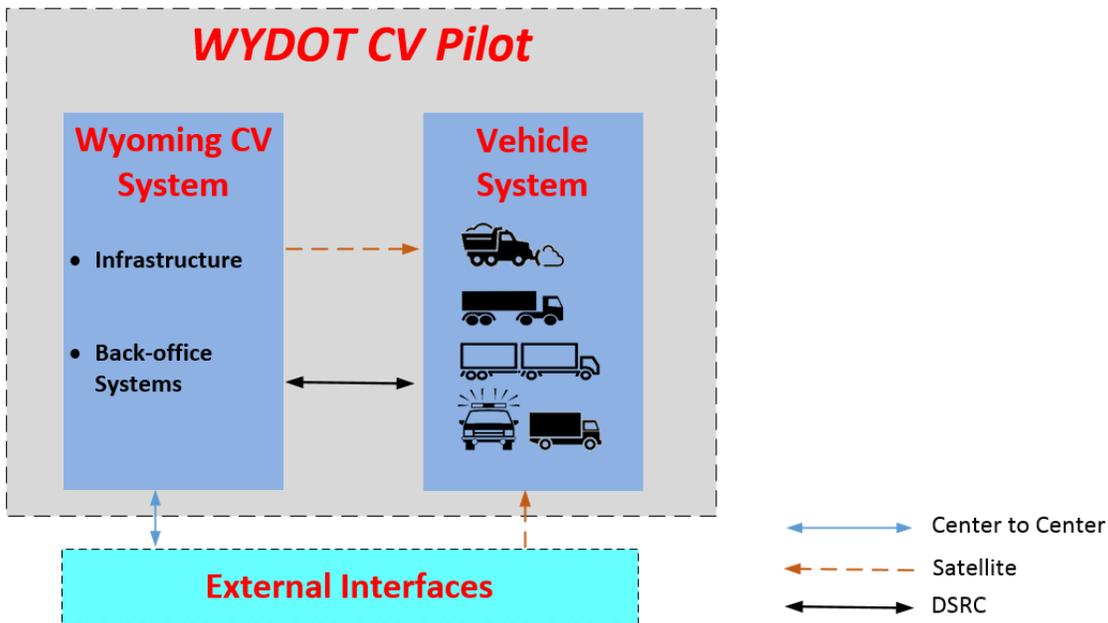
Figure 1-1 Wyoming CV Pilot System of Systems (Source: ICF/Wyoming)

The *Vehicle System* includes four subsystems that represent the various vehicle and equipment types to be used in the pilot. These subsystems vary in their data collection and sharing capabilities. The *Wyoming CV System* includes the infrastructure used in the pilot and back-office systems in charge of the various processes that lead to the generation and distribution of advisories and alerts. Together, the Vehicle and Wyoming CV Systems support a variety of V2V and V2I applications. Both systems interface with external systems, including WYDOT, USDOT and the National Weather Service (NWS) systems.

1.3.1 Wyoming System

The *Wyoming CV System* includes the infrastructure used in the pilot and the back-office systems in charge of the various processes that lead to the generation and distribution of advisories and alerts for CV Pilot vehicles. The *Wyoming CV System* will be located at the WYDOT TMC. Additionally, this system provides external interfaces to share the advisories and alerts with the public and commercial vehicle operators.

The *Wyoming CV System* is composed of five Sub-Systems:

- RSU
- ODE
- Pikalert System
- Data Broker (DB)
- Data Warehouse (DW)

1.3.1.1   *Roadside Units*

This Sub-System describes the physical units for deployment as part of the system along I-80. RSUs include DSRC connectivity, application support, data storage, and other support services to enable CV applications, such as necessary certificates. WYDOT RSUs can be either fixed or portable equipment depending on the use. In general, RSUs serve as a two-way communication portal between connected vehicles that provide information through DSRC and the ODE. About 75 RSUs are planned to be deployed in the pilot.

1.3.1.2   *Operational Data Environment*

The WYDOT ODE Sub-System receives information collected with connected devices, checks its quality, and then shares it with other Sub-Systems in charge of analyzing and distributing the information. The ODE also exports data to the SDW for USDOT-related activities. The ODE will be hosted at WYDOT TMC and uses the same codebase as the USDOT ODE. High-level requirements for the ODE are contained within the Task 4 ODE ConOps from the Southeast Michigan Test Bed Advanced Data Capture Field Testing. These include requirements for Validation, Integration, Sanitization, and Aggregation, which are combined in this document with the description of ODE processed data.

1.3.1.3   *Pikalert System*

The Pikalert System supports the integration and fusion of CV and non-CV weather data to develop alerts and advisories regarding adverse weather conditions along I-80. CV data are received from the ODE, while non-CV data derive from weather sources and the WYDOT DB. To generate the alerts and advisories, the Pikalert System assigns CV and non-CV data to 1-mile segments on I-80 every 5 minutes. The CV data is quality checked, then passed to the Road Weather Hazard module (RWH). The RWH uses these data to produce the alerts and advisories for adverse weather and for a 72-hour forecast of road weather conditions and hazards. The generated information is then shared with the DB for further distribution. Pikalert can also access historical data stored at the DW.

1.3.1.4   *WYDOT Data Broker*

WYDOT DB receives information from the ODE, Pikalert and some external systems, analyzes them, and shares them with the corresponding system or service including other sources. The DB supports the information brokerage of road weather alerts and advisories to WYDOT's Third-Party Interface (TPI), TRAC, WTI, Road Condition Reporting System (RCRS), and CVOP. Additionally, this system takes in incident information from the Incident Console (IC), work zone data from the Construction Administrator and parking availability information from the 511 Application. The DB also sends the

information back to the ODE to support the dissemination of TIM to the RSUs and can also access historical data stored at the DW if needed.

1.3.1.5 *WYDOT Data Warehouse*

The WYDOT DW stores various TMC- and CV-related data. The DW includes timestamped and geotagged logs of CV and non-CV data—information collected, generated and shared within the *Wyoming CV System*—that will be used for performance measurement.

1.3.2 Wyoming CV System External Interfaces

Figure 1-2 shows the physical architecture with interfaces numbered for reference and discussion here and in following sections. The Wyoming CV System includes the following external interfaces for exchanging data and information with external WYDOT and USDOT systems.[1]

- **I2V DSRC Communications Interface** (Interface WE1) Wireless DSRC interface provides communication between Wyoming CV System and Vehicle System through exchange of messages conforming to SAE J2735 and SAE J2945/1.

- **Location and Time Service (LTS)** (Interfaces WE2 and WE 3) – Provides location and time information, which is later used to geotag and timestamp all information produced by the systems of interest.[2]

- **NWS and RWIS** (Interface WE4) – NWS provides regional weather data shared through National Oceanic and Atmospheric Administration's Meteorological Assimilation Data Ingest System. **RWIS** provides atmospheric and pavement condition information collected through Environmental Sensor Stations (ESS) deployed as part of the WYDOT RWIS network in the field.

- **WYDOT 511 Application** (Interface WE5) – Provides information to the public regarding I-80's road weather and traffic conditions (e.g., road closure). The application is currently being updated to also share crowdsourced truck parking information with the CV Pilot.

- **WYDOT RCRS** (Interface WE6) – An Android tablet-based application that resides in WYDOT snow plows which enables field personnel (e.g., snowplow operators) to report weather and roadway pavement conditions following WYDOT's 8 Code (roadway condition), 9 Code (atmospheric) and 10 Code (other road condition) system.

- **WYDOT IC** (Interface WE7) – Provides timestamped and geotagged incident information on incidents along I-80 obtained from the WHP and other sources (e.g., maintenance).

- **WYDOT Construction Administration (CA)** (Interface WE8) – Provides timestamped and geotagged information of WYDOT's scheduled and unscheduled work-zone activities along I-80.

- **WTI** (Interface WE9) – Supports traveler information services to the public and to fleet management centers via various means (website, 511, 511 App, text, email, and alerts).

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[1] In the figure, WE refers to Wyoming CV System external interfaces, WI refers to Wyoming CV System internal interfaces, VE refers to Vehicle System external interfaces and VI refers to Vehicle System internal interfaces.
[2] The location is obtained from a GPS using WGS-84 coordinates system, and time is provided using UTC from GPS time.

- **WYDOT TPI** (Interface WE10) – A standardized interface based on the TMDD standard that can be used to support delivery of traveler information to external centers and information service providers.

- **WYDOT TRAC** (Interface WE11) – An operator console used in the TMC to monitor and manage planned, ongoing, and forecast events and actions on facilities monitored by the TMC. The TRAC provides a tabular list of currently ongoing events that require operator attention. These events may be entered manually and can be reported based on other systems like RCRS, radio communications with field personnel and citizen reports.

- **WYDOT CVOP** (Interface WE12) – A subscription-based website created by WYDOT for providing advanced notification of forecasted conditions to commercial travelers and fleet managers. Currently there are over 800 companies subscribed to the CVOP. As part of the CV Pilot System, the CVOP will be enhanced to include current weather information for segments on I-80.

- **WYDOT ITS Maintenance** (Interface WE13) – Provides a mechanism to report service outages and resumption of services of WYDOT's ITS equipment.

- **IE (Interface WE14) –** Provides WYDOT CV Pilot data to the IE for use in independent analysis and impact evaluation across multiple CV pilots.

- **USDOT SDW** (Interface WE15) – A service operated by USDOT that stores near real-time data and shares them with the remote users and developers for further distribution. As shown, this interface also supports communication of messages through **Satellite Service Provider (SSP)** satellites, allowing the system to transmit traveler-related information.

- **USDOT SCMS** (Interfaces WE16 and WE17) – Generates security certificates to manage messages securely from connected devices. As shown, this interface also supports communication of messages through **SSP** satellites, allowing the system to SCMS-related information.
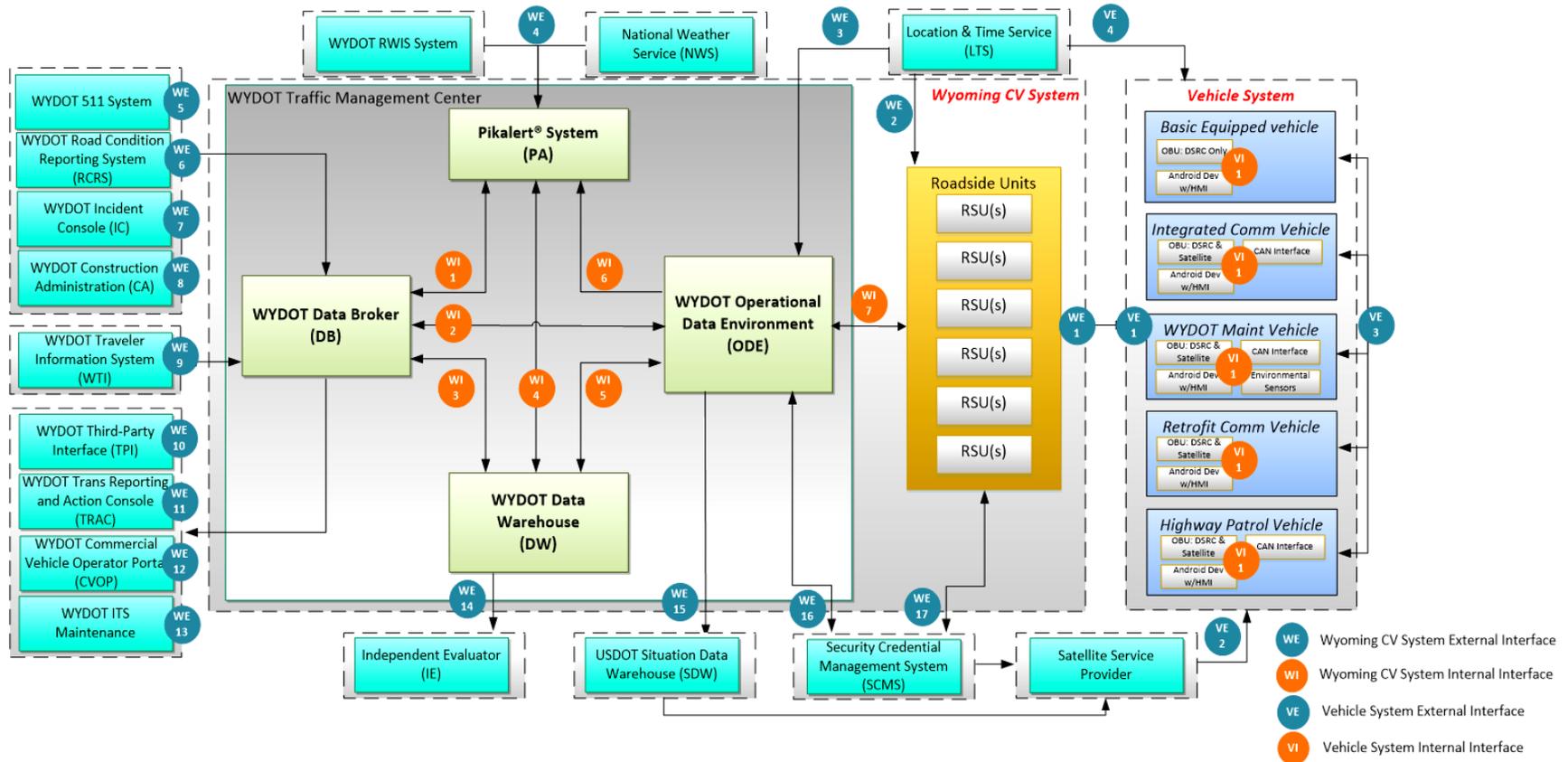
Figure 1-2. Physical View of WYDOT CV Pilot System Architecture with Numbered Interfaces. (Source: WYDOT)

1.3.3 Vehicle System

The *Vehicle System* represents the deployment of on-board equipment, sensors, and an HMI that will support CV applications. All vehicles that are part of the *Vehicle System* will have the following core capabilities:

- Ability to share and receive information via DSRC communication from other connected devices (vehicles and RSUs).
- Ability to broadcast BSM Part I.
- Ability to receive TIM.
- An HMI that allows alerts and advisories to be communicated with the driver.

Additionally, several vehicles that are part of the *Vehicle System* have further capability. Based on this, the *Vehicle System* is divided into five Sub-Systems, which define the various vehicle types for this pilot based on their data collection and communication capabilities. Each Sub-System and its rationale are described below.

1.3.3.1   *WYDOT Maintenance Vehicles*

This Sub-System represents the maintenance fleets operated by WYDOT. These include snow plow vehicles assigned to the I-80 corridor. These vehicles represent a set of vehicles over which WYDOT has full control as part of their operations. As such, the vehicles will be equipped with the full package of sensors and equipment necessary for the CV Pilot. Around 60 maintenance vehicles (snow plows) are expected to be part of this subsystem, which will have the ability to:

- Receive TIMs via DSRC and Satellite.
- Integrate with the vehicle network via a Controller Area Network (CAN bus) connection.
- Broadcast BSM Parts I and II.
- Collect weather sensor data.

1.3.3.2   *WYDOT Highway Patrol Vehicles*

This Sub-System represents the highway patrol fleet assigned to the I-80 corridor. While also operated by WYDOT, these vehicles represent a set over which WYDOT has less flexibility given the nature of their operations. Around 40 highway patrol vehicles are expected to be part of this subsystem, which will have the ability to:

- Receive TIMs via DSRC and Satellite.
- Integrate with the vehicle network via a CAN bus connection.
- Broadcast BSM Parts I and II.

1.3.3.3   *Integrated Commercial Vehicles*

This connected trucks Sub-System represents a subset of commercial trucks owned and operated by fleet partners involved in the pilot that can be integrated with the vehicle network. In contrast to the WYDOT Maintenance Vehicles, and similar to Highway Patrol Vehicles, no external weather sensor data will be collected from these systems (i.e., only data from the vehicle). To summarize, this Sub-System will include the abilities to:

- Receive TIMs via DSRC and Satellite (or other remote communication methods).
- Integrate with the vehicle network via a CAN bus connection.
- Broadcast BSM Parts I and II.

In essence, these vehicles represent the capability to use vehicle data collected from trucks in the pilot. WYDOT anticipates that about 200 trucks will have this functionality.

1.3.3.4   *Retrofit Commercial Vehicle*

This Sub-System is for trucks and other fleet vehicles that do not include integration with CAN bus data integration. This Sub-System is intended to simulate a commercial-off-the-shelf system that enables a vehicle to communicate data through DSRC to other connected devices and receive TIMs through DSRC or satellite. About 20–30 vehicles are expected in this category.

1.3.3.5   *Basic Equipped Vehicle*

This Sub-System includes vehicles equipped with just the core functionality for the *Vehicle System*, listed in the beginning of Section 1.3.3. About 100–150 vehicles are expected in this category. These vehicles enable WYDOT to equip vehicles inexpensively with the basic capability necessary to be part of the CV Pilot. All safety applications are supported by this Sub-System.

2 References

The following table lists the documents, sources and tools used to develop the concepts in this document.

Table 2-1 – References

#	Documents, Sources Referenced
1	SAE. (2014). J3067: Candidate Improvements to Dedicated Short Range Communications (DSRC) Message Set Dictionary [SAE J2735] Using Systems Engineering Methods. SAE International.
2	SAE. (2016). J2945/1: Dedicated Short Range Communication (DSRC) Minimum Performance Requirements. SAE International.
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3 Acronym List and Glossary of Terms

The following tables define selected project specific terms used throughout this Application Deployment document.

Table 3-1. Acronym List.

Acronym/Abbreviation	Definition
AAER	Automated Alerts for Emergency Responders
DN	Distress Notification
FCW	Forward Collision Warning
HMI	Human Machine Interface
I2V	Infrastructure to Vehicle
NWS	National Weather Service
OBU	On Board Unit
ODE	Operational Data Environment
ORDS	Object Registration and Discovery Service
OSADP	Open Source Application Development Portal
PII	Personally Identifiable Information
PM	Performance Management
PRL	Protocol Requirement List
RCR	Snow plow road condition reporting application
RDE	Research Data Exchange
REST	Representational State Transfer
RSU	Roadside Unit
RWAT	Road Weather Advisories for Trucks
SA	Safety Awareness
SCMS	Security Credential Management Service
SWIW	Spot Weather Impact Warning
VSL	Variable Speed Limit
WTIDB	Wyoming Travel Information Data Broker
WTI	Wyoming Travel Information
WZW	Work Zone Warnings

Table 3-2 Glossary of terms.

Term	Definition
Advanced Automatic Crash Notification Relay	An application that provides the capability for a vehicle to automatically transmit an emergency message when the vehicle has been involved in a crash or other distress situation.
Broadcast	Sharing unsigned data with no specific destination.
Commercial Vehicle Operator Portal	Provides forecasted road condition information on common commercial vehicle routes.
Safety Awareness	An application that determines if the road conditions measured by other vehicles represent a potential safety hazard for the vehicle containing the application.
Spot Weather Impact Warning	An application that will alert drivers to unsafe conditions or road closure at specific points on the downstream roadway as a result of weather-related impacts.
Transmit	Sharing signed and encrypted data directed to a specific receiver.
Transportation Management Center	Center that collects information and informs the public about changing travel conditions.
Wyoming Traveler Information (WTI)	Assembles information for various WYDOT traveler information resources. These resources include the 511App, 511 Phone System, website and text/email alert services.
WYDOT Data Broker (WTIDB)	WYDOT Data Broker is a sub-system that is responsible for interfacing with various WYDOT Transportation Management Center (TMC) systems gathering and distributing information on current traffic conditions, incidents, construction, operator actions and road conditions.
WYDOT Transportation Reporting and Action Console (TRAC)	An operator console used in the TMC to monitor and manage planned, ongoing, and forecast events and actions on facilities monitored by the TMC.

4 Overview of Applications

4.1 Physical Applications

This document gives details on each of the applications that will be created and deployed in order to support the connected vehicle pilot project ConOps applications. Applications within this document are separated into the platform and type of application that will be created. Note that the term "application" is broadly used to describe specific interfaces, services and software functionality that has to be created or augmented as part of this pilot.

These categories consist of Vehicle OBU applications, RSU applications, Service applications, Desktop/Web based applications, and Mobile applications. OBU Applications are applications that will be installed within on board unit installed in the connected vehicle. RSU applications are applications installed in roadside infrastructure that communicate with connected vehicles and the TMC. Service applications are applications that talk with OBU applications, RSU applications, third party information service providers, and mobile applications and provide a specific function such as data collection or emergency notification. Desktop and Web applications are applications built to interact with humans and provide functionality or information gathered from connected vehicles. Mobile applications are applications built for a phone or tablet that provide functionality or information to users of the device.

- OBU Applications
  - o OBU Spot Weather Impact Warning
  - o OBU Work Zone Warning
  - o OBU I2V Situational Awareness
  - o OBU Distress Notification
  - o OBU Forward Collision Warning
  - o OBU Vehicle Support Services
  - o OBU Vehicle Trust Management
- RSU Applications
  - o RSU Roadway Traffic Information Dissemination
  - o RSU Distress Notification
  - o RSU Basic Safety Monitoring
  - o RSU Support Services
  - o RSU Trust Management
- Service Applications
  - o Operational Data Environment (ODE)
  - o Pikalert
  - o TMC Data Broker (WTI DB extension)
  - o Service Monitor Device Management
  - o SCMS Provisioning
  - o SCMS Enrollment
  - o SCMS Authorization
  - o SCMS Misbehavior Reporting and Action
  - o SCMS Revocation
- Desktop/Web Applications
  - o CVOP Website Updates (CVOP extension)

- - o TMC Transportation Reports and Action Console (TRAC extension)
    - o TMC Wyoming Travel Information (WTI extension)
    - o WYOROAD.info (website extension)
    - o WYDOT Third Party Interface
    - o WYDOT Incident Console
    - o WYDOT Construction Administration
    - o OBU/RSU Management Application
    - o Participant Tracking Application
  - Mobile Applications
    - o WYDOT 511 (Android/iOS mobile application extension)
    - o Road Condition Reporting System (RCRS extension)
    - o Vehicle Human Machine Interface (HMI)

The plan recognizes that the development of applications may take various forms. In addition to new development by the team, some of these applications may be procured through vendors who may have the functionality built into their devices, others may be developed by WYDOT as part of their program, and other services may leverage USDOT activities like the SCMS and ODE. The purpose of the plan for the pilot team is to define all the software development activities that need to be undertaken.

4.2 Applications Defined in the Concept of Operations (ConOps)

The ConOps listed all of the applications that the overall system will support. This document will describe the physical applications that will be developed in order to support the applications listed below. Additionally, the physical application that each of these ConOps applications requires is also listed. Please note that all of the applications below require the following physical applications in order to function properly:

- OBU Vehicle Support Services
- OBU Vehicle Trust Management
- RSU Support Services
- RSU Trust Management
- Service Monitoring Device Management
- SCMS Provisioning
- SCMS Enrollment
- SCMS Authorization
- SCMS Misbehavior Reporting and Action
- SCMS Revocation
- OBU/RSU Management Application
- Participant Tracking Application
- Vehicle Human Machine Interface

4.2.1 Infrastructure-to-Vehicle (I2V) Situational Awareness

This application enables relevant downstream road condition information including weather alerts, speed restrictions, vehicle restrictions, road conditions, incidents, parking, and road closures to be broadcast from a roadside unit and received by the connected host vehicle. Such information is useful to connected host vehicles that are not fully equipped with weather sensors or to connected host vehicles in paths toward or entering areas with hazardous conditions. The Wyoming pilot will extend this application to use full coverage of

the I-80 corridor with satellite communications to send road condition information directly to selected connected vehicles. This step is important for mitigating the short range and sparse placement of RSUs along the corridor. This application will follow the description from J3067 August 2014 Section 2.9.3.6.

4.2.1.1 *Physical Application Mappings*

The following physical applications are required in order to implement the I2V Situational Awareness` application:

- OBU I2V Situational Awareness
- RSU Roadway Traffic Information Dissemination
- TMC WTI DB
- TMC WTI
- Operational Data Exchange
- Pikalert
- CVOP Website Updates
- WYDOT 511 App Integration
- WYOROAD.info
- WYDOT Third Party Interface

4.2.2 Distress Notification (DN)

This application enables connected vehicles to communicate a distress status defined as:
- When the vehicle's sensors an air bag deployment over the CAN Bus
- The vehicle's operator manually initiates a distress status with a selection from the Human Machine Interface (HMI)

The vehicle then generates and broadcasts a distress message (e.g., Mayday) to the nearest RSU. When an RSU is not within communication range, the message is received by connected vehicles that are in the vicinity and forwarded to an RSU that forwards it to the *Wyoming CV System*. The Distress Message will include the location, time of message, distress message explanation (e.g., air bag deployed, vehicle disabled, operator initiated), and vehicle type. Additionally, the distress notification received by nearby connected vehicles is broadcast to notify oncoming vehicles that a distressed vehicle is ahead. Although this application is loosely based on the Mayday application description from J3067 Section 3.5.9.2.1, it is built on a higher priority TIM communication using J2735 March 2016, Section 5.16, Part 3, Integrated Transport Information System (ITIS) advisory elements.

4.2.2.1 *Physical Application Mappings*

The following physical applications are required in order to implement the DN application:

- OBU Distress Notification
- RSU Distress Notification
- Operational Data Environment
- WYDOT TMC TRAC

4.2.3 Forward Collision Warning (FCW)

This application is a V2V communication-based safety feature that issues a warning to the driver of the connected host vehicle in case of an impending front-end collision with a connected vehicle ahead in traffic in the same lane and direction of travel on both straight and curved geometry roadways. FCW will help drivers

avoid or mitigate front-to-rear vehicle collisions in the forward path of travel. The system does not attempt to control the host vehicle to avoid an impending collision. This application will follow the description from J2945/1 March 2016 Section 4.2.4.

4.2.3.1 *Physical Application Mappings*

The following physical applications are required in order to implement the FCW application:

- OBU Forward Collision Warning
- RSU Basic Safety Monitoring
- Operational Data Environment

4.2.4 Spot Weather Impact Warning (SWIW)

Similar to situational awareness, this application enables relevant road condition information, such as fog or icy roads, to be broadcast from a roadside unit and received by the connected host vehicle. This application, however, is distinct from situational awareness in that it provides more localized information (i.e., at the segment level instead of area wide or region wide). This application will follow the TIM advisory content from part 3 defined in J2735 Section 6.142 for ITIS data elements 6.54 for weather conditions and 6.55 for winds defined in J2540_2. This application includes information on parking availability, when needed, as part of the advisory.

4.2.4.1 *Physical Application Mappings*

The following physical applications are required in order to implement the SWIW application:

- OBU Spot Weather Impact Warning Application
- RSU Roadway Traffic Information Dissemination
- Operation Data Environment
- Pikalert
- CVOP
- WYOROAD.info
- WYDOT Third Party Interface
- TMC WTI DB
- TMC WTI

4.2.5 Work Zone Warnings (WZW)

This application provides information about the conditions that exist in a work zone toward which the vehicle is approaching. This capability provides approaching vehicles with information about work zone activities that could present unsafe conditions for the vehicle, such as obstructions in the vehicle's travel lane, lane closures, lane shifts, speed reductions or vehicles entering/exiting the work zone. This application will follow the TIM work zone warning described in J2735 part 3 in Section 6.142.

4.2.5.1 *Physical Application Mappings*

The following physical applications are required in order to implement the WZW application:

- OBU Work Zone Warning
- RSU Roadway Traffic Information Dissemination
- Operation Data Environment

- CVOP
- WYOROAD.info
- WYDOT Third Party Interface
- TMC WTI DB
- WYDOT Construction Administration

5 Specific Application Information

This section goes into the details for each specific application. Details include a description of the application, the maturity level, development work needed for the application, detailed schedule for Phase 2 of development and deployment of the application. The applications are broken down into logical areas of development. Sections 5.1 and 5.2 are for field applications that reside on On-Board Unit (OBU) and Roadside Unit (RSU) devices. Section 5.3 applications are for services, both to ingest data from the field and to present to WYDOT applications as well as third party information service providers. Section 5.4 is for a set of applications that are for the staff at the TMC used for decision making and websites for presenting data to the public, these will be for ingesting traffic data, weather data, and vehicle data. The final section, 5.5, is a set of applications for smartphone/tablet, and HMI applications.

Maturity levels for each of the applications described below will use protocol requirement list (PRL) scale seen in Table 5-1. The PRL scale was derived by the National Transportation Communications for ITS Protocol standards.

Table 5-1. Maturity Level of the Application.

	PRL	Description
Basic/Exploratory/Policy Research	1	Basic principles and research
	2	Application formulated
	3	Proof of concept
Applied Research	4	Individual project components and requirements validated in a controlled test environment
	5	Integrated project components demonstrated in a controlled test environment
Development	6	Prototype demonstrated in realistic environment
	7	Prototype demonstrated in the intended operational environment
	8	Successful field test in end user environment
Implementation	9	Project results adopted in the intended user environment

Please note that additional information on application testing and testing types that will be used to evaluate each of the applications can be found in section 6.3.2.2. Additionally, each of the applications listed in this section references the System Requirements document when mapping application requirements to system requirements.

5.1 OBU Applications

OBU Applications are defined as software applications that are installed within the vehicles DSRC radio hardware and may interact with the vehicles CAN Bus and other installed sensors such as weather and road condition sensors installed within the vehicle.

5.1.1 OBU Spot Weather Impact Warning Application - SWIW

This application provides the capability for vehicles and drivers to receive information on upcoming weather hazards, based on the vehicles current location and direction of travel, from an RSU or satellite and display notices to the driver through the HMI.

5.1.1.1 *System Requirements*

5.1.1.1.1 Functional

This application shall wirelessly receive a packet containing traveler information from the *Wyoming CV System* in conformance with requirement VS-REQ-2.

This application shall ingest received TIMs to identify the applicable regions of use geographical path in conformance with requirement VS-REQ-14.

This application shall ingest received TIMs to identify advisories for wind and weather conditions in conformance with requirement VS-REQ-21.

This application shall follow all core architectural requirements defined in Appendix A.2 OBU Core Architecture Requirements of the SyRS document in conformance with requirement VS-REQ-52.

5.1.1.1.2 Interface

This application shall transmit over DSRC vehicle probe information to the *Wyoming CV System* when available from a vehicle Sub-System in conformance with requirement VS-REQ-36.

5.1.1.1.3 Performance

This application shall log local application availability to the local event logs by vehicle type. This will contain application restarts and availability based on application availability testing defined in FHWA-JPO-16-292 Connected Vehicle Pilot Deployment Program in conformance with requirement VS-REQ-49.

5.1.1.1.4 Data

This application shall store information generated by the host vehicle on local storage in conformance with requirement VS-REQ-39.

5.1.1.2 *Description of the Components of the Application*

This application will primarily be used for the collection and dissemination of weather and road condition data. This data will be made available to other vehicles and to the RSU's. The data will be collected from vehicles that have dedicated weather sensor packages in some cases, other vehicles that have CAN bus access through the OBU will gather weather related data from the CAN bus (like windshield wiper status, anti-lock brake activation, and other data that can be used as surrogate data to infer weather and road conditions).

Generic probe data will also be collected by this application for events to support performance management. Both environmental and performance based data set collection start/stop times, events, and rates of data collection will be defined by the TMC, made available to the RSU Support Services application from the ODE and collected by the OBU Vehicle Support Services.

Selected vehicles (snow plows, highway patrol, and WYDOT fleet vehicles) will be used for performance management and be identified with the probe data collected. This data will be sent to the TMC.

5.1.1.2.1 Maturity Level of the Application

This application has a PRL of 6 as it has been designed, built and used in realistic environments, but not with this pilot's vehicle types, sensor types and specific data collection requirements. The vendor that is chosen to supply the DSRC radios will help with the custom development for this application.

5.1.1.2.2 Required Development Work

This CV pilot will need to modify this application to work with the chosen weather sensor package and the OBU that is selected. Additionally, the application will need to be built to collect, store, and transmit data to infrastructure as needed. This application will need to have the ability to present configuration and status data on the HMI (e.g., local data size not sent to the TMC, application version, and environment sensor connection status and current value) and accept user input (e.g., to update application version, define collection event).

5.1.1.2.3 Specific Hardware and Software Needs

This application will rely on hardware for weather sensors, CAN bus interface, OBU and HMI. It will need software for the hardware defined, the SCMS for certificates, data management and business logic to define when messages need to be transmitted to other vehicles, the HMI or the TMC.

5.1.1.2.4 Required Interfaces, Inputs and Outputs

This application will need an HMI interface for driver input and notification. Additionally, it will have a DSRC interface for V2V and V2I data transmission, some vehicles will have backup communications capabilities via Wireless, and WYOLINK. It will also have an interface for the weather sensor package on some vehicle and a CAN bus interface on some vehicles.

5.1.1.3 *Intellectual Property Rights*

The vendor chosen for the OBU/RSU hardware has chosen to develop this application in-house outside of the funding provided for this pilot. Therefore all intellectual property right for this application will be kept by the OBU/RSU vendor.

5.1.1.4 *Application Safety Plan Considerations*

This application can operate in degraded states as described below to maintain safety for the driver and optimize data collection and dissemination.

If the OBU has multiple communication capabilities (DSRC/Wireless/WYOLINK) and one fails, the others may be used.

If the application fails, it will try to restart itself.

If all the communications fail, the OBU will report this to the driver and store the collected data locally.

If the application fails and communications are still available, the application will notify the TMC of the failure.

5.1.1.5 *Testing and Verification Requirements*

This application will be tested with other sensor data available from snow plows and RWIS to validate accuracy. The target level of accuracy for sensor data will be +/- 2 degrees for temperature readings, other environmental readings accuracy levels will be evaluated after a vendor has been chosen and the available information has been evaluated. Communications will be tested to the TMC and the data will be quality checked with RWIS and other data sources.

5.1.2 OBU Work Zone Warning - WZW

This application provides the capability for vehicles and drivers to receive information on upcoming work zones, based on the vehicles current location and direction of travel, from an RSU and display notices to the driver through the HMI.

5.1.2.1 *System Requirements:*

5.1.2.1.1 Functional

This application shall wirelessly receive a packet containing traveler information from the *Wyoming CV System* in conformance with requirement VS-REQ-2.

This application shall ingest received TIMs to identify the applicable regions of use geographical path in conformance with requirement VS-REQ-14.

This application shall ingest received TIMs to identify work zone warnings in conformance with requirement VS-REQ-19.

This application shall follow all core architectural requirements defined in Appendix A.2 OBU Core Architecture Requirements of the SyRS document in conformance with requirement VS-REQ-52.

5.1.2.1.2 Interface

This application shall transmit over DSRC vehicle probe information to the *Wyoming CV System* when available from a vehicle Sub-System in conformance with requirement VS-REQ-36.

5.1.2.1.3 Performance

This application shall log local application availability to the local event logs by vehicle type. This will contain application restarts and availability based on application availability testing defined in FHWA-JPO-16-292 Connected Vehicle Pilot Deployment Program in conformance with requirement VS-REQ-49.

5.1.2.1.4 Data

This application shall store information generated by the host vehicle on local storage in conformance with requirement VS-REQ-39.

5.1.2.2 *Description of the Components of the Application*

This application will primarily be used for work zone warnings.

Selected vehicles (snow plows, highway patrol, and WYDOT fleet vehicles) will be used for performance management and will collect WZW reception and driver responses to alerts. This data will be sent to the TMC. Other vehicles will receive the same message and data from event logs will be collected for performance purposes but PII will not be collected on those vehicles.

5.1.2.2.1   Maturity Level of the Application

This application has a PRL of 6 as it has been designed, built, and used in realistic environments, but not with this pilot's vehicle types and specific data collection requirements. The vendor that is chosen to supply the DSRC radios will help with the custom development for this application.

5.1.2.2.2   Required Development Work

This CV pilot will need to modify this application to work with the WYDOT data feeds for work zone warnings, the methodology of alerts with sound and HMI as well as the OBU that is selected. Additionally, the application will need to be modified to collect, store, and transmit data to the infrastructure as needed. Specific data transmitted may include TIM message and vehicle direction depending upon data availability.

5.1.2.2.3   Specific Hardware and Software Needs

This application will rely on hardware for OBU and HMI. It will need software for the hardware defined, it will use the SCMS for certificates, data management and business logic to define when messages need to be transmitted TMC.

5.1.2.2.4   Required Interfaces, Inputs and Outputs

This application will need an HMI interface for driver input and notification. Additionally, it will have an interface for V2I data transmitting.

5.1.2.3   *Intellectual Property Rights*

The vendor chosen for the OBU/RSU hardware has chosen to develop this application in-house outside of the funding provided for this pilot. Therefore all intellectual property right for this application will be kept by the OBU/RSU vendor.

5.1.2.4   *Application Safety Plan Considerations*

This application can operate in degraded states as described below to maintain safety for the driver and optimize data collection and dissemination.

If the OBU has multiple communication devices (DSRC/Wireless/WYOLINK) and one fails, the others may be used.

If all the communications fail, the OBU will report this to the driver and store the collected data locally.

If the application fails and communications are still available, the application will notify the TMC of the failure.

5.1.2.5 *Testing and Verification Requirements*

This application will be tested with location and heading data through work zones to validate accuracy. Communications will be tested to the TMC and the data will be quality checked. The target level of accuracy for receiving appropriate work zone warnings will be <5% of vehicles not receiving the appropriate WZW message for connected vehicles.

5.1.3 OBU I2V Situational Awareness – I2V

This application provides the capability for vehicles and drivers to receive general transportation information including weather alerts, speed restrictions, vehicle restrictions, road conditions, incidents, parking, and road closures from an RSU and display relevant notices to the driver through the HMI.

5.1.3.1 *System Requirements:*

5.1.3.1.1 Functional

This application shall wirelessly receive a packet containing traveler information from the *Wyoming CV System* in conformance with requirement VS-REQ-2.

This application shall ingest received TIMs to identify advisories in conformance with requirement VS-REQ-11.

This application shall ingest received TIMs to identify speed limits in conformance with requirement VS-REQ-12.

This application shall ingest received TIMs to identify Exit Services (Part III content choice exitService defined in J2735 section 6.142). This is used to provide parking information if necessary in conformance with requirement VS-REQ-13.

This application shall ingest received TIMs to identify the applicable regions of use geographical path in conformance with requirement VS-REQ-14.

This application shall ingest received TIMs to identify advisories for wind and weather conditions in conformance with requirement VS-REQ-21.

This application shall follow all core architectural requirements defined in Appendix A.2 OBU Core Architecture Requirements of the SyRS document in conformance with requirement VS-REQ-52.

5.1.3.1.2 Interface

This application shall transmit over DSRC vehicle probe information to the *Wyoming CV System* when available from a vehicle Sub-System in conformance with requirement VS-REQ-36.

5.1.3.1.3 Performance

This application shall log local application availability to the local event logs by vehicle type. This will contain application restarts and availability based on application availability testing defined in FHWA-JPO-16-292 Connected Vehicle Pilot Deployment Program in conformance with requirement VS-REQ-49.

5.1.3.1.4   Data

This application shall store information generated by the host vehicle on local storage in conformance with requirement VS-REQ-39.

5.1.3.2   *Description of the Components of the Application*

This application will primarily be used for driver notification of information from the TMC.

Selected vehicles (snow plows, highway patrol, and WYDOT fleet vehicles) will be used for performance management and will collect TIM reception and driver responses to alerts. This data will be sent to the TMC.

5.1.3.2.1   Maturity Level of the Application

This application has a PRL of 6 as it has been designed, built and used in realistic environments, but not with this pilot's vehicle types and specific data collection requirements. The vendor that is chosen to supply the DSRC radios will help with the custom development for this application.

5.1.3.2.2   Required Development Work

This CV pilot will need to modify this application to work with the data feeds from the TMC, the methodology and priority of information presentation to the driver with sound and HMI as well as integration with the OBU that is selected. Additionally, the application will need to be modified to collect, store, and transmit data to the infrastructure as needed.

5.1.3.2.3   Specific Hardware and Software Needs

This application will rely on hardware for OBU and HMI. It will need software for the hardware defined, the SCMS will be used for certificates, data management and business logic to define when messages need to be transmitted TMC. Additionally weather sensors will be added to the vehicle to collect weather and road condition data.

5.1.3.2.4   Required Interfaces, Inputs and Outputs

This application will need an HMI interface for driver input and notification. Additionally, it will have an interface for V2I data transmitting and DSRC communications.

5.1.3.3   *Intellectual Property Rights*

The vendor chosen for the OBU/RSU hardware has chosen to develop this application in-house outside of the funding provided for this pilot. Therefore all intellectual property right for this application will be kept by the OBU/RSU vendor.

5.1.3.4   *Application Safety Plan Considerations*

This application can operate in degraded states as described below to maintain safety for the driver and optimize data collection and dissemination.

If the OBU has multiple communication devices (DSRC/Wireless/WYOLINK) and one fails, the others may be used.

If all the communications fail, the OBU will report this to the driver and store the collected data locally.

If the application fails and communications are still available, the application will notify the TMC of the failure.

5.1.3.5   *Testing and Verification Requirements*

This application will be tested with multiple sets of information to verify priority and method of alert. Communications will be tested to the TMC and the data will be quality checked. For testing and verification purposes a log will be created whenever an information message is received and when the message is displayed to the driver. The level of accuracy this application is aiming for is 100% of all messages that are received are displayed for the driver.

5.1.4 OBU Distress Notification Application - DN

This application enables connected vehicles to communicate a distress status defined as:

- When the vehicle's sensors an air bag deployment over the CAN Bus
- The vehicle's operator manually initiates a distress status with a selection from the Human Machine Interface (HMI)

The vehicle then generates and broadcasts a distress message (e.g., Mayday) to the nearest RSU. When an RSU is not within communication range, the message is received by connected vehicles that are in the vicinity and forwarded to an RSU that forwards it to the *Wyoming CV System*. The Distress Message will include the location, time of message, distress message explanation (e.g., air bag deployed, vehicle disabled, operator initiated), and vehicle type. Additionally, the distress notification received by nearby connected vehicles is broadcast to notify oncoming vehicles that a distressed vehicle is ahead. Although this application is loosely based on the Mayday application description from J3067 Section 2.5.3.3, it is built on a higher priority TIM communication using J2735 March 2016, Section 5.16, Part 3, Integrated Transport Information System (ITIS) advisory elements.

5.1.4.1   *System Requirements:*

5.1.4.1.1   Functional

This application The *Vehicle System* shall wirelessly receive a packet containing distress information from other connected vehicles over DSRC in conformance with requirement VS-REQ-3.

This application shall identify received distress notifications in conformance with requirement VS-REQ-15 and all sub requirements.

This application shall have the ability to generate a distress notification in conformance with requirement VS-REQ-16 and all sub requirements.

This application shall ingest received TIMs to identify the applicable regions of use geographical path in conformance with requirement VS-REQ-17.

This application shall use a unique high priority Provider Service Identifier (PSID) for the distress notification application in conformance with requirement VS-REQ-18.

This application shall wirelessly broadcast distress messages to other connected devices in conformance with requirement VS-REQ-34 and all sub requirements.

This application (both the vehicle in distress, when in range of the Wyoming CV System, as well as the vehicle(s) that received the distress notification) shall transmit over DSRC received distress notifications to the *Wyoming CV System*. Distress information is a high priority messages loosely based on the mayday broadcast in conformance with requirement VS-REQ-38.

This application shall follow all core architectural requirements defined in Appendix A.2 OBU Core Architecture Requirements of the SyRS document in conformance with requirement VS-REQ-52.

5.1.4.1.2   Interface

This application shall transmit over DSRC TIM messages indicating distress notifications for other connected vehicles and road side units to receive.

5.1.4.1.3   Performance

This application shall log local application availability to the local event logs by vehicle type. This will contain application restarts and availability based on application availability testing defined in FHWA-JPO-16-292 Connected Vehicle Pilot Deployment Program in conformance with requirement VS-REQ-49.

5.1.4.1.4   Data

This application shall store information generated by the host vehicle on local storage in conformance with requirement VS-REQ-39.

5.1.4.2   *Description of the Components of the Application*

This application will primarily be used for emergency notification after a vehicle crash to the TMC.

Selected vehicles (snow plows, highway patrol, and WYDOT fleet vehicles) will be used for performance management based on OBU-REQ-3 and OBU-REQ-4. This data will be sent to the TMC.

5.1.4.2.1   Maturity Level of the Application

This application has a PRL of 1 as it has only the basic principles and research performed for it so far. Additional research will need to be performed along with formulating the application before the application development process will be able to begin. The vendor that is chosen to supply the DSRC radios will help with the custom development for this application.

5.1.4.2.2   Required Development Work

This CV pilot will need to modify the application to work with the data feeds from the CAN bus and information collection from the driver after a crash with the HMI as well as integration with the OBU that is selected. Additionally, the application will need to be modified to collect, store, and transmit data to the infrastructure as needed.

5.1.4.2.3   Specific Hardware and Software Needs

This application will rely on hardware for CAN bus interface, OBU and HMI. It will need software for the hardware defined, the SCMS will be used for certificates, data management and business logic to define when messages need to be transmitted TMC.

5.1.4.2.4   Required Interfaces, Inputs and Outputs

This application will need an HMI interface for driver input and notification. Additionally, it will have an interface for V2I data transmitting.

5.1.4.3   *Intellectual Property Rights*

The vendor chosen for the OBU/RSU hardware has chosen to develop this application in-house outside of the funding provided for this pilot. Therefore all intellectual property right for this application will be kept by the OBU/RSU vendor.

5.1.4.4   *Application Safety Plan Considerations*

This application can operate in degraded states as described below to maintain safety for the driver and optimize data collection and dissemination.

If the OBU has multiple communication devices (DSRC/Wireless/WYOLINK) and one fails, the others will be used.

If all the communications fail, the OBU will report this to the driver and store the collected data locally.

If the application fails and communications are still available, the application will notify the TMC of the failure.

5.1.4.5   *Testing and Verification Requirements*

This application will be tested with multiple vehicle types to ensure crash data is properly collected from the CAN bus. Communications will be tested to the TMC. The target level of accuracy for this application will be 100% of all emergency notifications that are received are displayed to the connected vehicle driver and relayed to other connected vehicles and infrastructure.

5.1.5 OBU Forward Collision Warning – FCW

This application exchanges current vehicle location and motion information with other vehicles in the vicinity, uses that information to calculate vehicle paths, and warns the driver when the potential for an impending collision is detected. Vehicle location and motion broadcasts are also received by the infrastructure and used by the infrastructure to support a wide range of roadside safety and mobility applications including variable speed limit support and situational awareness support. This application implements a broad range of features ranging from basic Vehicle Awareness where only vehicle location and speed are broadcast and provide no driver warnings to advanced integrated safety systems that may, in addition to warning the driver, provide collision warning information to support automated control functions that can support control intervention. The specific applications used will be based on vendor selection for OBU's, at a minimum all OBU's will support situational awareness.

5.1.5.1 *System Requirements:*

5.1.5.1.1 Functional

This application shall ingest BSM Parts I and II data received from remote vehicles to identify stopped remote vehicles directly ahead in the same lane and direction of travel in conformance with requirement VS-REQ-6.

This application shall ingest BSM Parts I and II data received from remote vehicles to identify decelerating or slower moving remote vehicles directly ahead in the same lane and direction of travel in conformance with requirement VS-REQ-7.

This application shall ingest BSM Parts I and II data received from remote vehicles to identify stopped and obstructed remote vehicles directly ahead in the same lane and direction of travel in conformance with requirement VS-REQ-8.

This application shall ingest BSM Parts I and II data received from remote vehicles to identify imminent danger of a rear-end crash with a remote vehicle lead vehicle in its lane of travel in straight roadway geometry in conformance with requirement VS-REQ-9.

This application shall ingest BSM Parts I and II data received from remote vehicles to identify imminent danger of a rear-end crash with a remote vehicle lead vehicle in its lane of travel in curved roadway geometry in conformance with requirement VS-REQ-10.

This application shall wirelessly broadcast over DSRC a basic safety message (BSM) to other connected devices in conformance with requirement VS-REQ-33.

This application shall follow all core architectural requirements defined in Appendix A.2 OBU Core Architecture Requirements of the SyRS document in conformance with requirement VS-REQ-52.

5.1.5.1.2 Interface

This application shall transmit over DSRC vehicle probe information to the *Wyoming CV System* when available from a vehicle Sub-System in conformance with requirement VS-REQ-36.

5.1.5.1.3 Performance

This application shall log local application availability to the local event logs by vehicle type. This will contain application restarts and availability based on application availability testing defined in FHWA-JPO-16-292 Connected Vehicle Pilot Deployment Program in conformance with requirement VS-REQ-49.

5.1.5.1.4 Data

This application shall store information generated by the host vehicle on local storage in conformance with requirement VS-REQ-39.

5.1.5.2 *Description of the Components of the Application*

This application will primarily be used for V2V situational awareness.

Selected vehicles (snow plows, highway patrol, and WYDOT fleet vehicles) will be used for performance management. This data will be sent to the TMC.

5.1.5.2.1   Maturity Level of the Application

This application has a PRL of 6 as it has been designed, built and used in realistic environments, but not with this pilot's vehicle types and specific data collection requirements. The vendor that is chosen to supply the DSRC radios will help with the custom development for this application.

5.1.5.2.2   Required Development Work

This CV pilot will need to modify this application to work with the Wyoming specific data feeds for location and telemetric data, modify the methodology of alerts using sound and the HMI when available, the code will also be updated to support the selected OBU. Additionally, the application will need to be modified to collect, store, and transmit data to the infrastructure as needed.

5.1.5.2.3   Specific Hardware and Software Needs

This application will rely on hardware for the OBU and HMI. It will need software for the hardware defined, the SCMS for certificates, data management and business logic to define when messages need to be transmitted TMC.

5.1.5.2.4   Required Interfaces, Inputs and Outputs

This application will need an HMI interface for driver input and notification. Additionally, it will have an interface for V2V and V2I data transmitting.

5.1.5.3   *Intellectual Property Rights*

The vendor chosen for the OBU/RSU hardware has chosen to develop this application in-house outside of the funding provided for this pilot. Therefore all intellectual property right for this application will be kept by the OBU/RSU vendor.

5.1.5.4   *Application Safety Plan Considerations*

This application can operate in degraded states as described below to maintain safety for the driver and optimize data collection and dissemination.

If the OBU has multiple communication devices (DSRC/Wireless/WYOLINK) and one fails, the others will be used.

If all the communications fail, the OBU will report this to the driver and store the collected data locally.

If the application fails and communications are still available, the application will notify the TMC of the failure.

5.1.5.5   *Testing and Verification Requirements*

This application will be tested with multiple vehicle situations to verify the alerts are appropriate for conditions. Communications will be spot tested for compliance with the standard in J2945/1. Please note that the pilot will only purchase devices that are certified by USDOT authorized testing facilities to be in compliance with SCMS and J2945/1.

5.1.6 OBU Vehicle Support Services

This application provides foundational functions that supports data collection, management, and distribution. It coordinates with Object Registration and Discovery to acquire necessary communications information and prioritization of data. It maintains the necessary security credentials, authorizations, and associated keys to support communications in the connected vehicle environment. This application also checks for updates of software (operating system, firmware, and applications) as well as configuration updates for existing application that change probe data collection frequency and event limits. Additionally, this application will be used for log file transfers of environmental probe data.

5.1.6.1   *System Requirements:*

5.1.6.1.1   Functional

This application shall store information generated by the host vehicle on local storage in conformance with requirement VS-REQ-39.

This application shall maintain rolling logs for in vehicle generated CV data in conformance with requirement VS-REQ-40.

This application shall use the USDOT SCMS POC certificates to encrypt probe vehicle data stored locally using the Public Key Encryption in conformance with requirement VS-REQ-48.

This application shall log local application availability to the local event logs by vehicle type in conformance with requirement VS-REQ-49.

This application shall follow all core architectural requirements defined in Appendix A.2 OBU Core Architecture Requirements of the SyRS document in conformance with requirement VS-REQ-52.

This application shall follow all core safety communication requirements defined in Appendix A.3 V2V Core Safety Communication Requirements of this SyRS document in conformance with requirement VS-REQ-53.

5.1.6.1.2   Performance

This application shall log local application availability to the local event logs by vehicle type. This will contain application restarts and availability based on application availability testing defined in FHWA-JPO-16-292 Connected Vehicle Pilot Deployment Program in conformance with requirement VS-REQ-49.

5.1.6.1.3   Data

This application shall collect additional environmental sensor data from host vehicles equipped with external environmental sensors in conformance with requirement VS-REQ-5.

This application shall have the capability to collect vehicle status information from the host vehicle in conformance with requirement VS-REQ-4.

This application will collect information messages from the RSU that is used for configurations of locally installed applications. Additionally, it will announce the OBU's current configurations (e.g. firmware version, operating system version, application version, performance management/environmental probe data collection configuration) and heartbeat information to the TMC and look for updated applications, firmware and operating system upgrades. The updates for the applications, firmware and operating system will need to be done over wireless links for a selected subset of vehicle used by WYDOT when the vehicles are at home base.

5.1.6.2 *Description of the Components of the Application*

This application will primarily be used for the collection of configuration and security information. Additionally, it will provide a method of application management and OBU management.

5.1.6.2.1 Maturity Level of the Application

This application has a PRL of 3 as parts of it have been built, but much of the OBU management has not been designed or built. The vendor that is chosen to supply the DSRC radios will help with the custom development for this application.

5.1.6.2.2 Required Development Work

This CV pilot will need to modify parts of the existing vendor's application, but most the application will need to be built including the interface with the ORDS system and the updates needed to properly support communications within the CV environment. The CV pilot will need to design and build the application management components.

5.1.6.2.3 Specific Hardware and Software Needs

This application will rely on hardware for the OBU and HMI. It will need software for the hardware defined, the SCMS for certificates, data management and business logic to define when messages need to be transmitted to other vehicles or the TMC.

5.1.6.2.4 Required Interfaces, Inputs and Outputs

This application will need an HMI interface for driver input and notification. Additionally, it will have an interface for V2I data communication via DSRC and selected vehicles will have Wireless, or WYOLINK access.

5.1.6.3 *Intellectual Property Rights*

The vendor chosen for the OBU/RSU hardware has chosen to develop this application in-house outside of the funding provided for this pilot. Therefore all intellectual property right for this application will be kept by the OBU/RSU vendor.

5.1.6.4 *Application Safety Plan Considerations*

This application can operate in degraded states as described below to maintain safety for the driver and optimize data collection and dissemination.

If the OBU has multiple communication devices (DSRC/Wireless/WYOLINK) and one fails, the others will be used.

If all the communications fail, the OBU will report this to the driver and store the collected data locally.

If the application fails and communications are still available, the application will notify the TMC of the failure.

5.1.6.5 *Testing and Verification Requirements*

This application will be tested with application upgrades and simulated failures of applications and sensors. Communications will be tested to the TMC.

5.1.7 OBU Vehicle Trust Management

This application manages the certificates and associated keys that are used to sign, encrypt, decrypt, and authenticate messages. It communicates with the Security and Credentials Management System through the RSU Trust Management application or directly with the Operation Data Environment via Satellite communications to maintain a current, valid set of security certificates and identifies, logs, and reports events that may indicate a threat to the Connected Vehicle Environment security.

5.1.7.1 *System Requirements:*

5.1.7.1.1 Functional

This application shall use the USDOT SCMS POC certificates in accordance with the security and privacy requirements in conformance with requirement VS-REQ-43.

This application shall use the USDOT SCMS POC certificates to sign and encrypt messages transmitted in conformance with requirement VS-REQ-44.

This application shall use the USDOT SCMS POC certificates to sign, but not encrypt, all broadcasted messages in conformance with requirement VS-REQ-45.

This application shall use the USDOT SCMS POC certificates to encrypt log files stored locally in conformance with requirement VS-REQ-46.

This application shall use the USDOT SCMS POC certificates to sign log files stored locally in conformance with requirement VS-REQ-47.

This application shall use the USDOT SCMS POC certificates to encrypt probe vehicle data stored locally using the Public Key Encryption defined in the USDOT SCMS POC section 2.1.5 in conformance with requirement VS-REQ-48.

5.1.7.1.2 Data

This application will collect SCMS information messages through the RSU that is used for configurations, downloads and installation of certificates and security information including certificate revocation lists.

5.1.7.2 *Description of the Components of the Application*

This application will primarily be used for SCMS communications and certificate management.

5.1.7.2.1 Maturity Level of the Application

This application has a PRL of 6 as it has been designed, built and used in realistic environments, but not with this pilot's vehicle types and specific requirements. The vendor that is chosen to supply the DSRC radios will help with the custom development for this application.

5.1.7.2.2   Required Development Work

This CV pilot will need to modify parts of this application, but most of it will be supplied by the OBU vendor.

5.1.7.2.3   Specific Hardware and Software Needs

This application will rely on hardware for the OBU and HMI. It will need software for the hardware defined and the SCMS communications.

5.1.7.2.4   Required Interfaces, Inputs and Outputs

This application will need an HMI interface for driver input and notification. Additionally, it will have an interface for V2I data communication.

5.1.7.3   *Intellectual Property Rights*

The vendor chosen for the OBU/RSU hardware has chosen to develop this application in-house outside of the funding provided for this pilot. Therefore all intellectual property right for this application will be kept by the OBU/RSU vendor.

5.1.7.4   *Application Safety Plan Considerations*

This application can operate in degraded states as described below to maintain safety for the driver and optimize data collection and dissemination.

If the OBU has multiple communication devices (DSRC/Wireless/WYOLINK) and one fails, the others will be used.

If all the communications fail, the OBU will report this to the driver and store the collected data locally.

If the application fails and communications are still available, the application will notify the TMC of the failure.

5.1.7.5   *Testing and Verification Requirements*

This application will be tested with certificate installation and top off of certificates as well as testing for certificates on revocation lists.

5.2 RSU Applications

5.2.1 RSU Roadway Traffic Information Dissemination – I2V, SWIW, WZW

This application includes dissemination of information to vehicles and drivers, including traffic and road conditions, incident information, work zone information, parking information, weather information and broadcast alerts within a defined radius. Traffic Information Messages (TIM) dispersal notifications are received from the ODE.

5.2.1.1 *System Requirements:*

5.2.1.1.1   Functional

This application shall follow all core architectural requirements in conformance with requirement RSU-REQ-5.

This application shall follow all core safety communication requirements in conformance with requirements RSU-REQ-6.

This application shall broadcast information following all requirements in conformance with requirement RSU-REQ-7.

This application shall transmit information in conformance with requirements RSU-REQ-8.

5.2.1.1.2   Performance

This application shall manage the policy for data collection and performance data in conformance with requirement RSU-REQ-10.

5.2.1.1.3   Data

This application shall distribute TIMs, received from the ODE, to the *Vehicle System*, in conformance with requirement RSU-REQ-2.

5.2.1.2 *Description of the Components of the Application*

This application will primarily be used for the transmitting of traffic information to equipped vehicles.

5.2.1.2.1   Maturity Level of the Application

This application has a PRL of 6 as it has been designed, built and used in realistic environments, but not with this pilot's vehicle types and specific data collection requirements. The vendor that is chosen to supply the DSRC radios will help with the custom development for this application.

5.2.1.2.2   Required Development Work

This CV pilot will need to modify this application to work with the ODE to get data for traveler information and make that data available to equipped vehicles.

5.2.1.2.3   Specific Hardware and Software Needs

This application will rely on hardware selected for the RSU. It will need software for interfacing with the SCMS as well as data management and business logic to define when messages need to be transmitted to equipped vehicles.

5.2.1.2.4   Required Interfaces, Inputs and Outputs

This application will have an interface for V2I data communication and an interface through the WYDOT backhaul to the ODE.

5.2.1.3   *Intellectual Property Rights*

The vendor chosen for the OBU/RSU hardware has chosen to develop this application in-house outside of the funding provided for this pilot. Therefore all intellectual property right for this application will be kept by the OBU/RSU vendor.

5.2.1.4   *Application Safety Plan Considerations*

This application can operate in degraded states as described below.

The RSU will have active monitoring of its applications and notify the TMC for failures as well as try to restart the failed application.

If the communications fail to the TMC the RSU will continue to communicate relevant information to the OBU's and store information destined for the TMC on local storage to send when communications are restored.

5.2.1.5   *Testing and Verification Requirements*

This application will be tested with communicating to the TMC and in simulated failure modes.

5.2.2 RSU Distress Notification Application - DN

This application will be installed on RSU's. Emergency broadcasts received will be prioritized and sent to the TMC through the ODE where the WYDOT TMC Emergency Notifications Support application will handle the incoming signal and alert staff to an emergency situation through the TRAC system. This application works in conjunction with the OBU Vehicle Emergency Notification Application to relay emergency notifications received to the ODE for aggregation and dissemination.

5.2.2.1   *System Requirements:*

5.2.2.1.1   Functional

This application shall follow all core architectural requirements in conformance with requirement RSU-REQ-5.

This application shall follow all core safety communication requirements in conformance with requirements RSU-REQ-6.

This application shall broadcast information following all requirements in conformance with requirement RSU-REQ-7.

This application shall transmit information in conformance with requirements RSU-REQ-8.

5.2.2.1.2   Performance

This application shall manage the policy for data collection and performance data in conformance with requirement RSU-REQ-10.

5.2.2.1.3   Data

This application shall receive broadcast information in conformance with requirement RSU-REQ-9.

This application shall transmit all collected information to the Operational Data Environment in conformance with requirement RSU-REQ-11.

5.2.2.2 *Description of the Components of the Application*

This application will primarily be used for receiving DN requests from equipped vehicles and sending this information to the TMC to alert dispatch.

5.2.2.2.1 Maturity Level of the Application

This application has a PRL of 6 as it has been designed, built and used in realistic environments, but not with this pilot's vehicle types and specific data collection requirements. The vendor that is chosen to supply the DSRC radios will help with the custom development for this application.

5.2.2.2.2 Required Development Work

This CV pilot will need to modify this application to work with the ODE to send data for DN.

5.2.2.2.3 Specific Hardware and Software Needs

This application will rely on hardware selected for the RSU. It will need software for the hardware defined, use the SCMS for certificates, data management and business logic to define when messages need to be received from equipped vehicles.

5.2.2.2.4 Required Interfaces, Inputs and Outputs

This application will have an interface for V2I data communication and to communicate with the TMC.

5.2.2.3 *Intellectual Property Rights*

The vendor chosen for the OBU/RSU hardware has chosen to develop this application in-house outside of the funding provided for this pilot. Therefore all intellectual property right for this application will be kept by the OBU/RSU vendor.

5.2.2.4 *Application Safety Plan Considerations*

This application can operate in degraded states as described below.

The RSU will have active monitoring of its applications and notify the TMC for failures as well as try to restart the failed application.

If the communications fail to the TMC the RSU will continue to communicate relevant information to the OBU's and store information destined for the TMC on local storage to send when communications are restored.

5.2.2.5 *Testing and Verification Requirements*

This application will be tested with communicating to the TMC and in simulated failure modes.

5.2.3 RSU Basic Safety Monitoring

This application monitors the basic safety messages that are broadcast from connected vehicles and filters this data into traffic flow measures that can be used to manage the network in combination with or in lieu of traffic data collected by infrastructure-based sensors. As connected vehicle penetration rates increase, the measures provided by this application can expand beyond vehicle speeds that are directly reported by vehicles to include estimated volume, occupancy, and other measures.

5.2.3.1 *System Requirements:*

5.2.3.1.1 Functional

This application shall interface with the LTS in conformance with requirement RSU-REQ-4.

This application shall follow all core architectural requirements in conformance with requirement RSU-REQ-5.

This application shall follow all core safety communication requirements in conformance with requirement RSU-REQ-6.

This application shall broadcast information following all requirements in conformance with requirement RSU-REQ-7.

This application shall transmit information in conformance with requirement RSU-REQ-8.

5.2.3.1.2 Performance

This application shall manage the policy for data collection and performance data in conformance with requirement RSU-REQ-10.

5.2.3.1.3 Data

This application shall collect data from the *Vehicle System* in conformance with requirement RSU-REQ-1.

This application shall receive broadcast information in conformance with requirement RSU-REQ-9.

This application shall transmit all collected information to the Operational Data Environment in conformance with requirement RSU-REQ-11.

5.2.3.2 *Description of the Components of the Application*

This application will primarily be used for the receiving of BSM messages from equipped vehicles within DSRC range of the RSU and forwarding these messages to the ODE.

5.2.3.2.1 Maturity Level of the Application

This application has a PRL of 6 as it has been designed, built and used in realistic environments, but not with this pilot's vehicle types and specific data collection requirements. The vendor that is chosen to supply the DSRC radios will help with the custom development for this application.

5.2.3.2.2   Required Development Work

This CV pilot will need to modify this application to work with the chosen alerts and events for BSM's, V2V situational awareness and RSU that is selected. Additionally, the application will need to be modified to collect, store, and transmit data to the TMC ODE.

5.2.3.2.3   Specific Hardware and Software Needs

This application will rely on RSU hardware. It will need software for the RSU hardware selected, the SCMS for certificates, data management and business logic to define when messages need to be transmitted to the TMC.

5.2.3.2.4   Required Interfaces, Inputs and Outputs

This application will have an interface for V2I data communications and from the RSU to the TMC ODE.

5.2.3.3   *Intellectual Property Rights*

The vendor chosen for the OBU/RSU hardware has chosen to develop this application in-house outside of the funding provided for this pilot. Therefore all intellectual property right for this application will be kept by the OBU/RSU vendor.

5.2.3.4   *Application Safety Plan Considerations*

This application can operate in degraded states as described below.

The RSU will have active monitoring of its applications and notify the TMC for failures as well as try to restart the failed application.

If the communications fail to the TMC the RSU will continue to communicate relevant information to the OBU's and store information destined for the TMC on local storage to send when communications are restored.

5.2.3.5   *Testing and Verification Requirements*

This application will be tested with communicating with the TMC and in simulated failure modes.

5.2.4 RSU Support Services

This application provides foundational functions that supports data collection, management, and distribution. It coordinates with Object Registration and Discovery to maintain its registration with respect to location/geographic scope and credentialing information. It maintains the necessary security credentials, authorizations, and associated keys to support communications in the connected vehicle environment. This application also checks for configuration updates for existing application that change probe data collection frequency and event limits. Additionally, this application can track the location the RSU first and last communicated with OBU's to ensure the RF range is correct and report back to the TMC through the ODE.

5.2.4.1 *System Requirements:*

5.2.4.1.1   Functional

This application shall interface with the LTS in conformance with requirement RSU-REQ-4.

This application shall follow all core architectural requirements in conformance with requirement RSU-REQ-5.

This application shall follow all core safety communication requirements in conformance with requirement RSU-REQ-6.

This application shall broadcast information following all requirements in conformance with requirement RSU-REQ-7.

This application shall transmit information in conformance with requirement RSU-REQ-8.

5.2.4.1.2   Performance

This application shall manage the policy for data collection and performance data in conformance with requirement RSU-REQ-10.

5.2.4.1.3   Data

This application shall collect data from the *Vehicle System* in conformance with requirement RSU-REQ-1.

This application shall receive broadcast information in conformance with requirement RSU-REQ-9.

This application shall transmit all collected information to the Operational Data Environment in conformance with requirement RSU-REQ-11.

5.2.4.2 *Description of the Components of the Application*

This application will primarily be used for communicating configuration data to the OBUs, making available updates to the OBU's configuration files for probe data collection and receiving heartbeat information from the OBUs. Additionally, it will communicate with the TMC via the ODE for OBU updates, heartbeat information and configuration information.

5.2.4.2.1   Maturity Level of the Application

This application has a PRL of 3 as parts of it have been built, but much of the RSU application for OBU management has not been designed or built. The vendor that is chosen to supply the DSRC radios will help with the custom development for this application.

5.2.4.2.2   Required Development Work

This CV pilot will be able to use parts of the vendor's current application, but the majority of the application will need to be built. The CV pilot will need to design and build the application management components as well as the ORDS interface and credentialing information.

5.2.4.2.3   Specific Hardware and Software Needs

This application will rely on RSU hardware. It will need software for the RSU hardware selected, the SCMS for certificates, data management and business logic to define when messages need to be transmitted to vehicles and the TMC.

5.2.4.2.4   Required Interfaces, Inputs and Outputs

This application will have an interface for V2I data communications and from the RSU to the TMC ODE.

5.2.4.3   Intellectual Property Rights

The vendor chosen for the OBU/RSU hardware has chosen to develop this application in-house outside of the funding provided for this pilot. Therefore all intellectual property right for this application will be kept by the OBU/RSU vendor.

5.2.4.4   Application Safety Plan Considerations

This application can operate in degraded states as described below.

The RSU will have active monitoring of its applications and notify the TMC for failures as well as try to restart the failed application.

If the communications fail to the TMC the RSU will continue to communicate relevant information to the OBU's and store information destined for the TMC on local storage to send when communications are restored.

5.2.4.5   Testing and Verification Requirements

This application will be tested with communicating with the TMC and in simulated failure modes.

5.2.5 RSU Trust Management

This application manages the certificates and associated keys that are used to sign, encrypt, decrypt, and authenticate messages. It communicates with the Security and Credentials Management System to maintain a current, valid set of security certificates and keys and identifies, logs, and reports events that may indicate a threat to Connected Vehicle Environment security. This application is also used to verify communications from the TMC and is a CVRIA application.

5.2.5.1   System Requirements:

5.2.5.1.1   Functional

This application shall interface with the USDOT SCMS in conformance with requirement RSU-REQ-3.

This application shall interface with the LTS in conformance with requirement RSU-REQ-4.

This application shall follow all core architectural requirements in conformance with requirement RSU-REQ-5.

This application shall follow all core safety communication requirements in conformance with requirement RSU-REQ-6.

This application shall broadcast information following all requirements in conformance with requirement RSU-REQ-7.

5.2.5.1.2   Performance

This application shall manage the policy for data collection and performance data in conformance with requirement RSU-REQ-10.

5.2.5.1.3   Data

This application shall transmit all collected information to the Operational Data Environment in conformance with requirement RSU-REQ-11.

5.2.5.2   *Description of the Components of the Application*

This application will primarily be used for communicating with the SCMS to update and manage certificates. Additionally, it will communicate with the TMC via the ODE.

5.2.5.2.1   Maturity Level of the Application

This application has a PRL of 6 as it has been designed, built and used in realistic environments, but not with this pilot's vehicle types and specific requirements. The vendor that is chosen to supply the DSRC radios will help with the custom development for this application.

5.2.5.2.2   Required Development Work

This CV pilot will need to modify parts of this application, but most of it will be supplied by the OBU vendor.

5.2.5.2.3   Specific Hardware and Software Needs

This application will rely on RSU hardware. It will need software for the RSU hardware selected and the SCMS, data management and business logic to define when messages need to be transmitted the TMC.

5.2.5.2.4   Required Interfaces, Inputs and Outputs

This application will have an interface for communications to the SCMS and from the RSU to the TMC ODE.

5.2.5.3   *Intellectual Property Rights*

The vendor chosen for the OBU/RSU hardware has chosen to develop this application in-house outside of the funding provided for this pilot. Therefore all intellectual property right for this application will be kept by the OBU/RSU vendor.

5.2.5.4   *Application Safety Plan Considerations*

This application can operate in degraded states as described below.

The RSU will have active monitoring of its applications and notify the TMC for failures as well as try to restart the failed application.

If the communications fail to the TMC the RSU will continue to communicate relevant information to the OBU's and store information destined for the TMC on local storage to send when communications are restored.

5.2.5.5   *Testing and Verification Requirements*

This application will be tested with certificate installation and top off of certificates.

5.3 Services Applications

5.3.1 Operational Data Environment (ODE) – I2V, SA, PM, DN

The USDOT Operational Data Environment (ODE) Sub-System receives information collected with connected devices, checks its quality, and then shares it with other Sub-Systems in charge of analyzing and distributing the information. The ODE also exports data to the Situational Data Warehouse for USDOT-related activities. The ODE will be hosted at WYDOT TMC and uses the same codebase as the USDOT ODE.

5.3.1.1   *System Requirements:*

5.3.1.1.1   Functional

This application shall ingest CV-data from connected devices in conformance with requirement ODE-REQ-1.

This application shall provide the "VISA" functions of Validation, Integration, Sanitization (De-identification), and Aggregation of CV Data in conformance with requirement ODE-REQ-2 with all sub requirements.

This application shall distribute processed CV information to other systems and sub-systems in conformance with requirement ODE-REQ-3 with all sub requirements.

5.3.1.1.2   Interface

This application shall interface with the USDOT SCMS based on the current requirements of the SCMS proof-of-concept implementation in conformance with requirement ODE-REQ-4 with all sub requirements.

This application shall interface with the Location and Time Service (LTS) using in conformance with requirement ODE-REQ-4.

5.3.1.1.3   Performance

The Operational Data Environment shall distribute TIMs to the Situational Data Warehouse in conformance with requirement ODE-REQ-3.2.

The ODE shall be able to scale to input from 400 vehicles with no noticeable performance degradation.

5.3.1.1.4   Data

This application shall provide the "VISA" functions of Validation, Integration, Sanitization (De-identification), and Aggregation of CV Data in conformance with requirement ODE-REQ-2 with all sub requirements.

5.3.1.2   *Description of the Components of the Application*

This application will primarily be used for ingesting data from RSU's and OBU's. The ODE will be responsible for validating incoming messages through the SCMS and providing incoming data to subscribed permitted applications. Applications that are currently expected to subscribe to data feeds include the Pikalert, Data Broker, and Data Warehouse applications. Additionally, it will be capable to packaging TIM messages and notifying RSU's of new messages that need to be distributed.

5.3.1.2.1   Maturity Level of the Application

This application has a PRL of 3 as it has been designed, built and used in realistic environments, but not with this pilot's vehicle types and specific requirements. WYDOT will obtain the source code for the current ODE application from the Southeast Michigan project. WYDOT will work with the ODE development team of Booz Allen (BAH) to request and identify updates necessary for this application for use in WYDOT's environment. The pilot assumes BAH will update the ODE to support the 2016 standards for J2735 messages, SCMS updates, and has a logic flow that support data going from the RSU/OBU to the ODE.

5.3.1.2.2   Required Development Work

This CV pilot will need to extend and modify the existing ODE application in order to ingrate the pilot project data.

5.3.1.2.3   Specific Hardware and Software Needs

This application will rely on existing hardware and software.

5.3.1.2.4   Required Interfaces, Inputs and Outputs

This application will have a REST interface for all communications.

5.3.1.3   *Intellectual Property Rights*

All code customized and built for this pilot application will be posted on the Open Source Application Development Portal (OSADP) with Apache 2.0 licensing.

5.3.1.4   *Application Safety Plan Considerations*

Since this is a REST service application an active IP monitor will be setup to continuously monitor the application and notify an administrative group when the application fails. Additionally, this application will be setup using a cloud service that will allow for replication among many servers. If one server

goes down the others in the server farm will handle the additional load. In cases where all servers go down and the service is unavailable the RSU software will detect the communication failure and store the data locally until the service is once again available.

5.3.1.5 *Development Team*

The development team in Table 5-2 will be responsible for the design and development of the ODE application:

Table 5-2. ODE application development team

Team Member	Role
Shane Zumpf	Architect
Kim Perry	Developer
TBD	Developer
Brian Peel	Database Administrator

5.3.1.6 *Testing and Verification Requirements*

This application will have multiple layers of testing including, load testing, performance testing, and unit testing that will target the services ability to ingest data from RSUs and OBUs quickly and efficiently. Testing policies and procedures are further described in the Software Development Process/Quality Management section of this document.

5.3.2 Pikalert System

The Pikalert System was developed over several years with funding from the Federal Highway Administration (FHWA) and is currently available on the Open Source Application Development Portal (OSADP). It will serve as the main data processing application for the pilot's connected vehicle data and to generate weather-based hazard advisories and warnings. To be integrated successfully into the pilot, beyond its current capabilities the Pikalert system will be installed in a cloud computing environment for use by WYDOT, set up to run over the I-80 corridor, connected vehicle pilot data and weather data ingests set up, display localized over Wyoming, and a high wind/blowover hazard algorithm developed and added to the existing Road Weather Hazard module algorithms.

5.3.2.1 *System Requirements:*

5.3.2.1.1 Functional

This application shall receive atmospheric information collected from the RCRS following the 9 Code System in conformance with requirement RCRS-REQ-1.2. The 9 Code includes:

- 9-1 Favorable
- 9-2 Snowing
- 9-3 Raining
- 9-4 Strong Winds
- 9-5 Fog
- 9-6 Blowing Snow
- 9-7 Reduced Visibility

This application shall receive weather information collected from external sources within the *Wyoming CV System* in conformance with requirement WI-REQ-1. The external weather information may consist of one or more of the following sources:

- NWS watches and warnings, including county-based and polygon-based data.
- NWS storm reports, including hail, wind, and tornado data.
- NWS radar data.
- Weather model data
    - Global Forecast System (GFS),
    - North American Mesoscale Forecast System (NAM)
    - High-Resolution Rapid Refresh (HRRR).
- NOAA remote sensing data.
- NOAA single polarization radar data.
- NOAA satellite data.
- USDOT Weather Data Environment

This application shall receive shall receive road weather information system (RWIS) data from the WYDOT RWIS Server in conformance with requirement WI-REQ-2.

This application shall receive weather information from external weather sources in conformance with requirement PA-REQ-1.

This application shall receive CV weather information from other Wyoming CV Sub-Systems including the ODE and DB in conformance with requirement PA-REQ-2 with all sub requirements.

This application shall generate alerts and advisories in conformance with requirement PA-REQ-3.

This application shall distribute alerts and advisories in conformance with requirement PA-REQ-4 with all sub requirements.

5.3.2.1.2 Interface

This application shall have an interface to ingest connected vehicle and weather data in conformance with PA-REQ-1.

This application shall have a web-based display to provide a visual representation of incoming connected vehicle data and generated advisories, warnings, and weather forecasts to project and WYDOT personnel.

5.3.2.1.3 Performance

This application shall support performance measurement and management in conformance with requirement MMP-REQ-1.

5.3.2.1.4 Data

This application shall provide quality checked connected vehicle data, weather data, and weather advisories and warnings to the WYDOT data warehouse.

5.3.2.2 *Description of the Components of the Application*

This application will primarily be used to ingest connected vehicle data and weather data, quality check the connected vehicle data, and fuse the data to generate advisories and warnings of adverse

weather and forecasts of road weather conditions. The core capabilities of the application are already developed. It will be extended for use over I-80 in Wyoming in a cloud computing environment, which includes setting up a Wyoming-based cloud instance of the Pikalert system, setting up a data ingest of WYDOT connected vehicle data, and developing a high wind/blowover hazard algorithm.

5.3.2.2.1 Maturity Level of the Application

This application has been used in a research environment in real-time by the Michigan, Minnesota, Nevada, Colorado, and Alaska state DOTs. It has not been used with this pilot's specific connected vehicle data formats and data types, nor has it been used to issue operational alerts that have passed the Pikalert output outside a TMC. NCAR currently maintains the source code for this application and will perform the development work. Installing the Pikalert system in a cloud computing environment will allow WYDOT to have 24/7 support for keeping the application running operationally, which NCAR does not provide. NCAR will provide support during standard business hours.

5.3.2.2.2 Required Development Work

This CV pilot will need to extend and modify the existing Pikalert system in order to have the system installed in the cloud, run over I-80 in Wyoming using the pilot's CV data, and include a high wind/blowover hazard algorithm that is important to the pilot's weather advisory and warning objectives.

5.3.2.2.3 Specific Hardware and Software Needs

This application will rely on existing hardware and software, though additional software will need to be developed to install the Pikalert system in the cloud and add the high wind/blowover hazard algorithm, as well as allow ingest of the pilot-specific vehicle data.

5.3.2.2.4 Required Interfaces, Inputs and Outputs

This application will have an interface with incoming connected vehicle and weather data as well as an interface with the WYDOT data warehouse and a web-based display.

5.3.2.3 *Intellectual Property Rights*

This application in its current state is already available on the OSADP with a GPL and an Apache 2.0 license. It will be extended using the pilot funds, and all updates will likewise be posted to the OSADP under the same licensing structure.

5.3.2.4 *Application Safety Plan Considerations*

This application will be setup using a cloud service that will allow for replication among many servers. If one server goes down the others in the server farm will handle the additional load.

5.3.2.5 *Development Team*

Table 5-3 lists the development team responsible for the design and development of the Pikalert application:

Table 5-3. Pikalert application development team

Team Member	Role
Amanda Anderson	Project Manager
Gerry Wiener	Engineering Lead
William Petzke	Application Engineer
Seth Linden	Application Engineer
James Cowie	Application Engineer
Padhrig McCarthy	Display Engineer
Jared Lee	Science Support
Thomas Brummet	Application Engineer
Brian Peel	Database Administrator

5.3.2.6 *Testing and Verification Requirements*

This application will have multiple layers of testing including, load testing, performance testing, and unit testing that will target application functionality, performance, and usability.

5.3.3 TMC Data Brokerage (WTIDB) – I2V, SA, PM, DN

As the WYDOT existing system data broker, this system already receives, transmits and archives many data feeds. With the addition of the connected vehicle pilot, the WTIDB will additionally handle data inputs for mayday alerts from the ODE, data inputs for weather alerts and advisories from Pikalert and support new data exports to keep the CVOP current and the ODE for TIMs. The details for these data processing systems are defined below.

5.3.3.1 *System Requirements:*

5.3.3.1.1 Functional

This application shall receive information from external interfaces in conformance with requirement DB-REQ-1.

This application shall distribute information to external interfaces in conformance with requirement DB-REQ-2.

This application shall generate traveler information messages (TIMs) in conformance with requirement DB-REQ-3.

This application shall transmit road condition information to the Pikalert application in conformance with requirement DB-REQ-4

This application shall receive information from the Pikalert system in conformance with requirement DB-REQ-5.

This application shall transmit TIM information from the WYDOT ODE in conformance with requirement DB-REQ-6.

This application shall receive information from the WYDOT ODE in conformance with requirement DB-REQ-7.

This application shall transmit information to the Data Warehouse in conformance with requirement DB-REQ-8.

This application shall receive information from the Data Warehouse in conformance with requirement DB-REQ-9.

5.3.3.1.2   Interface

This application shall have an interface to process and distribute CV data through a REST service endpoint.

5.3.3.1.3   Performance

This application shall support performance measurement and management.

5.3.3.1.4   Data

This application shall provide weather, TIM message, road condition, and incident information stored in the Data Warehouse and provided from the WYDOT ODE.

5.3.3.2   *Description of the Components of the Application*

This application will primarily be extended for use in ingesting data from the ODE and Pikalert and providing TIMs to the ODE and the CVOP. It will maintain existing capabilities to store data in the data warehouse and interact with existing WYDOT systems (e.g., TRAC, RCRS, Third Party interfaces, and WTI).

5.3.3.2.1   Maturity Level of the Application

This application has a PRL of 6 as it has been designed, built and used in realistic environments, but not with this pilot's vehicle types and specific requirements nor with the volume of data that will be expected for this project. WYDOT currently maintains the source code for this application and will perform the development work.

5.3.3.2.2   Required Development Work

This CV pilot will need to extend and modify the existing WTIDB application in order to ingrate the pilot project data.

5.3.3.2.3   Specific Hardware and Software Needs

This application will rely on existing hardware and software.

5.3.3.2.4   Required Interfaces, Inputs and Outputs

This application will have a REST interface for all communications.

5.3.3.3 *Intellectual Property Rights*

This application will be extended using funds outside of the pilot funds. As such, WYDOT will obtain the intellectual property rights and this application will not be posted to the OSADP.

5.3.3.4 *Application Safety Plan Considerations*

Since this is a REST service application an active IP monitor will be setup to continuously monitor the application and notify an administrative group when the application fails. Additionally, this application will be setup using an internal cloud service that will allow for replication among many servers. If one server goes down the others in the server farm will handle the additional load.

5.3.3.5 *Development Team*

Table 5-4 lists the development team responsible for the design and development of the Data Broker application.

Table 5-4. Data Broker application development team

Team Member	Role
Ivan Yourshaw	Lead Developer
Tim Frye	Project Manager

5.3.3.6 *Testing and Verification Requirements*

This application will have multiple layers of testing including, load testing, performance testing, and unit testing that will target the services ability to ingest data from the ODE and Pikalert quickly and efficiently.

5.3.4 WYDOT Third Party Interface (TPI)

The application communicates with the WYDOT Data Broker to receive a broad range of data including traffic and road conditions, emergency information and advisories, weather data, special event information, traveler services, and parking. This application primarily shares data with other information centers (like Waze, DriveWyze and neighboring state TMC's) through standard ITS data descriptors (e.g., TMDD).

5.3.4.1 *System Requirements:*

5.3.4.1.1 Functional

This application shall transmit traffic condition information based on the Traffic Management Data Dictionary (TMDD) in conformance with requirement TPI-REQ-1.

5.3.4.1.2 Interface

This application shall have an interface to directly ingest data through a REST service.

5.3.4.1.3   Data

This application will collect transportation related data from a broad range of providers including weather providers, emergency service providers, special events, parking, and traveler services. This data is quality checked and provided to authorized users in a consistent format.

5.3.4.2   Description of the Components of the Application

This application will primarily be used to collect, and export traveler data stored in the data warehouse.

5.3.4.2.1   Maturity Level of the Application

This application has a PRL of 1 as it has only the basic principles and research performed for it so far. Additional research will need to be performed along with formulating the application before the application development process will be able to begin. WYDOT will perform the development for this application.

5.3.4.2.2   Required Development Work

The CV pilot will need to design and develop a new REST service application.

5.3.4.2.3   Specific Hardware and Software Needs

This application will rely on existing hardware and software.

5.3.4.2.4   Required Interfaces, Inputs and Outputs

This application will have a REST interface for all communications.

5.3.4.3   Intellectual Property Rights

All code built for this pilot application will be posted on the Open Source Application Development Portal (OSADP) with Apache 2.0 licensing.

5.3.4.4   Application Safety Plan Considerations

Since this is a REST service application an active IP monitor will be setup to continuously monitor the application and notify an administrative group when the application fails. Additionally, this application will be setup using a cloud service that will allow for replication among many servers. If one server goes down the others in the server farm will handle the additional load.

5.3.4.5   Development Team

Table 5-5 lists the development team responsible for the design and development of the TPI application.

Table 5-5. TPI application development team

Team Member	Role
Suzie Roseberry	Lead Developer
Tony English	Support

5.3.4.6   *Testing and Verification Requirements*

This application will have multiple layers of testing including, load testing, performance testing, and unit testing that will target the services ability to ingest data from the WTIDB quickly and efficiently.

5.3.5 Service Monitor Device Management

This application provides the functions necessary to manage devices, including network management, operational status monitoring, and application performance monitoring. Devices managed will include RSU's and OBU's.

5.3.5.1   *System Requirements:*

5.3.5.1.1   Functional

This application shall monitor performance for applications within the CV environment and report performance problems to the WYDOT TMC.

This application shall manage device maintenance.

5.3.5.1.2   Interface

This application shall have an interface to directly ingest data through a REST service.

5.3.5.1.3   Performance

This application shall collect, store and transmit data to the performance monitoring data to the data warehouse.

5.3.5.1.4   Data

This application will transmit data related to performance monitoring and management among CV related equipment.

5.3.5.2   *Description of the Components of the Application*

This application will primarily be responsible for managing devices, including network management, operational status monitoring, and application performance monitoring for CV related services.

5.3.5.2.1   Maturity Level of the Application

This application has a PRL of 1 as it has only the basic principles and research performed for it so far. Additional research will need to be performed along with formulating the application before the application development process will be able to begin. WYDOT will perform the development work for this application.

5.3.5.2.2   Required Development Work

The CV pilot will need to design and develop a new REST service application.

5.3.5.2.3   Specific Hardware and Software Needs

This application will rely on existing hardware and software.

5.3.5.2.4   Required Interfaces, Inputs and Outputs

This application will have a REST interface for all communications.

5.3.5.3   *Intellectual Property Rights*

All code built for this pilot application will be posted on the Open Source Application Development Portal (OSADP) with Apache 2.0 licensing.

5.3.5.4   *Application Safety Plan Considerations*

Since this is a REST service application an active IP monitor will be setup to continuously monitor the application and notify an administrative group when the application fails. Additionally, this application will be setup using a cloud service that will allow for replication among many servers. If one server goes down the others in the server farm will handle the additional load.

5.3.5.5   *Development Team*

The design and development of this application will be the responsibility of the OBU/RSU vendor chosen for this project. After a vendor is chosen this document will be updated to include the vendor name.

5.3.5.6   *Testing and Verification Requirements*

This application will have multiple layers of testing including, load testing, performance testing, and unit testing that will target the services ability to ingest data quickly and efficiently.

5.3.6 SCMS Provisioning

This application provides the end entity with material that allows it to enter the 'Unenrolled' state. This consists of root certificates and the crypto material that allows it to communicate securely with the Enrollment components. This function ensures the requesting entity meets requirements for provisioning and provides the certificates and relevant policy information to entities that meet the requirements. This application will be a USDOT application and it is included in this application development plan for completeness.

5.3.6.1   *System Requirements:*

5.3.6.1.1   Functional

This application shall provide security certificates and provisioning information based on the requirements in the current version of the Security Credential Management System Proof-of-Concept Implementation EE Requirements and Specifications Supporting SCMS Software (version 1.1 as of May 2016).

5.3.6.1.2   Interface

This application will have a service interface defined by the USDOT.

5.3.6.1.3   Performance

Performance requirements for this application shall be defined by the USDOT.

5.3.6.1.4   Data

This application shall transmit data related to security certificates and provisioning profiles.

5.3.6.2   *Description of the Components of the Application*

This application will primarily be used to ensure the requesting entity meets requirements for provisioning and provides the certificates and relevant policy information to entities that meet the requirements.

5.3.6.2.1   Maturity Level of the Application

This application has a PRL of 6 and is currently in development at the USDOT to expand the system for use in the pilot projects.

5.3.6.2.2   Required Development Work

The USDOT is currently developing this application, no development work on this application is expected once the USDOT development is complete.

5.3.6.2.3   Specific Hardware and Software Needs

The USDOT will provide all necessary hardware and software for this application.

5.3.6.2.4   Required Interfaces, Inputs and Outputs

This application will need to have an application interface for interactions with the pilot connected vehicle pilot projects.

5.3.6.3   *Intellectual Property Rights*

This application is being built by the USDOT and all intellectual property rights will be decided by the USDOT.

5.3.6.4   *Application Safety Plan Considerations*

This application must be available in order for provisioning to be handled correctly. The USDOT will be responsible for the application safety plan considerations.

5.3.6.5 *Testing and Verification Requirements*

The USDOT will handle the bulk of the testing for this application. To ensure the application is working correctly and to eliminate potential troubleshooting issues with the SCMS system a unit test application will be built to test correct functionality.

5.3.7 SCMS Enrollment

This application provides enrollment credentials to end entities. The end entity applies for and obtains enrollment credentials that can be used to communicate with other SCMS components, entering the "Unauthorized" state. SCMS Enrollment components also participate in de-registration processes through interaction with SCMS Revocation components. This application will be a USDOT application and it is included in this application development plan for completeness.

5.3.7.1 *System Requirements:*

5.3.7.1.1 Functional

This application shall provide security enrollment information based on the requirements in the current version of the Security Credential Management System Proof-of-Concept Implementation EE Requirements and Specifications Supporting SCMS Software (version 1.1 as of May 2016).

5.3.7.1.2 Interface

This application will have a service interface defined by the USDOT.

5.3.7.1.3 Performance

Performance requirements for this application shall be defined by the USDOT.

5.3.7.1.4 Data

This application shall transmit data related to security credentials.

5.3.7.2 *Description of the Components of the Application*

This application will primarily be used to provide enrollment credentials to end entities.

5.3.7.2.1 Maturity Level of the Application

This application has a PRL of 6 and is currently in development at the USDOT to expand the system for use in the pilot projects.

5.3.7.2.2 Required Development Work

The USDOT is currently developing this application, no development work on this application is expected once the USDOT development is complete.

5.3.7.2.3 Specific Hardware and Software Needs

The USDOT will provide all necessary hardware and software for this application.

5.3.7.2.4   Required Interfaces, Inputs and Outputs

This application will need to have an application interface for interactions with the pilot connected vehicle pilot projects.

5.3.7.3   *Intellectual Property Rights*

This application is being built by the USDOT and all intellectual property rights will be decided by the USDOT.

5.3.7.4   *Application Safety Plan Considerations*

This application must be available in order for provisioning to be handled correctly. The USDOT will be responsible for the application safety plan considerations.

5.3.7.5   *Testing and Verification Requirements*

The USDOT will handle the bulk of the testing for this application. To ensure the application is working correctly and to eliminate potential troubleshooting issues with the SCMS system a unit test application will be built to test correct functionality.

5.3.8 SCMS Authorization

This application provides authorization credentials (e.g., pseudonym certificates) to end entities. The end entity applies for and obtains authorization credentials, enabling the end entity to enter the "Operational" state. This function requires an interactive dialog, including at minimum a Certificate Request from the end entity desiring certificates. This request will be checked for validity, with the embedded enrollment certificate checked against an internal blacklist. If all checks are passed, this function will distribute a bundle of linked pseudonym certificates suitable for use by the requesting end entity, with the characteristics and usage rules of those certificates dependent on the operational policies of the SCMS. It also provides the secure provisioning of a given object's Decryption Key in response to an authorized request from that object. The retrieved Decryption Key will be used by the receiving object to decrypt the "next valid" batch within the set of previously retrieved Security Credential batches. This application will be a USDOT application and it is included in this application development plan for completeness.

5.3.8.1   *System Requirements:*

5.3.8.1.1   Functional

This application shall provide security authorization credentials based on the requirements in the current version of the Security Credential Management System Proof-of-Concept Implementation EE Requirements and Specifications Supporting SCMS Software (version 1.1 as of May 2016).

5.3.8.1.2   Interface

This application will have a service interface defined by the USDOT.

5.3.8.1.3   Performance

Performance requirements for this application shall be defined by the USDOT.

5.3.8.1.4   Data

This application shall transmit data related to security authorization credentials.

5.3.8.2   *Description of the Components of the Application*

This application will primarily be used to provide authorization credentials to entities involved within the CV system.

5.3.8.2.1   Maturity Level of the Application

This application has a PRL of 6 and is currently in development at the USDOT to expand the system for use in the pilot projects.

5.3.8.2.2   Required Development Work

The USDOT is currently developing this application, no development work on this application is expected once the USDOT development is complete.

5.3.8.2.3   Specific Hardware and Software Needs

The USDOT will provide all necessary hardware and software for this application.

5.3.8.2.4   Required Interfaces, Inputs and Outputs

This application will need to have an application interface for interactions with the pilot connected vehicle pilot projects.

5.3.8.3   *Intellectual Property Rights*

This application is being built by the USDOT and all intellectual property rights will be decided by the USDOT.

5.3.8.4   *Application Safety Plan Considerations*

This application must be available in order for provisioning to be handled correctly. The USDOT will be responsible for the application safety plan considerations.

5.3.8.5   *Testing and Verification Requirements*

The USDOT will handle the bulk of the testing for this application. To ensure the application is working correctly and to eliminate potential troubleshooting issues with the SCMS system a unit test application will be built to test correct functionality.

5.3.9 SCMS Misbehavior Reporting and Action

This application processes misbehavior reports from end entities. Misbehavior reports are analyzed and investigated if warranted. Investigated misbehavior reports are correlated with end entities and systemic issues are identified. If revocation is warranted, this component provides information to Authorization or Revocation components to initiate revocation and/or blacklisting, as appropriate. This application will be a USDOT application and it is included in this application development plan for completeness.

5.3.9.1 *System Requirements:*

5.3.9.1.1 Functional

This application shall provide security misbehavior report information based on the requirements in the current version of the Security Credential Management System Proof-of-Concept Implementation EE Requirements and Specifications Supporting SCMS Software (version 1.1 as of May 2016).

5.3.9.1.2 Interface

This application will have a service interface defined by the USDOT.

5.3.9.1.3 Performance

Performance requirements for this application shall be defined by the USDOT.

5.3.9.1.4 Data

This application shall transmit data related to security misbehavior reports.

5.3.9.2 *Description of the Components of the Application*

This application will primarily be used to process misbehavior reports related to entities among the CV environment.

5.3.9.2.1 Maturity Level of the Application

This application has a PRL of 1 and is currently in the research and design phase at the USDOT. This application is scheduled to be available for the pilot studies in the later part of 2017 for use in the pilot projects.

5.3.9.2.2 Required Development Work

The USDOT is currently developing this application, no development work on this application is expected once the USDOT development is complete.

5.3.9.2.3 Specific Hardware and Software Needs

The USDOT will provide all necessary hardware and software for this application.

5.3.9.2.4 Required Interfaces, Inputs and Outputs

This application will need to have an application interface for interactions with the pilot connected vehicle pilot projects.

5.3.9.3 *Intellectual Property Rights*

This application is being built by the USDOT and all intellectual property rights will be decided by the USDOT.

5.3.9.4 *Application Safety Plan Considerations*

This application must be available in order for provisioning to be handled correctly. The USDOT will be responsible for the application safety plan considerations.

5.3.9.5 *Testing and Verification Requirements*

The USDOT will handle the bulk of the testing for this application. To ensure the application is working correctly and to eliminate potential troubleshooting issues with the SCMS system a unit test application will be built to test correct functionality.

5.3.10 SCMS Revocation

This application generates the internal blacklist and Certificate Revocation List (CRL) and distribute them to other SCMS components and end entities. Once placed on the CRL, an end entity is in the unauthorized state. Once placed on the blacklist, an end entity is in the unenrolled state. This application will be a USDOT application and it is included in this application development plan for completeness.

5.3.10.1 *System Requirements:*

5.3.10.1.1 Functional

This application shall provide information on entities that have been revoked based on the requirements in the current version of the Security Credential Management System Proof-of-Concept Implementation EE Requirements and Specifications Supporting SCMS Software (version 1.1 as of May 2016).

5.3.10.1.2 Interface

This application will have a service interface defined by the USDOT.

5.3.10.1.3 Performance

Performance requirements for this application shall be defined by the USDOT.

5.3.10.1.4 Data

This application shall transmit data related to revoked entities in the CV environment.

5.3.10.2 *Description of the Components of the Application*

This application will primarily be used to generate and distribute certificate revocation lists related to entities among the CV environment.

5.3.10.2.1   Maturity Level of the Application

This application has a PRL of 1 and is currently in the research and design phase at the USDOT. This application is scheduled to be available for the pilot studies in the later part of 2017 for use in the pilot projects.

5.3.10.2.2   Required Development Work

The USDOT is currently developing this application, no development work on this application is expected once the USDOT development is complete.

5.3.10.2.3   Specific Hardware and Software Needs

The USDOT will provide all necessary hardware and software for this application.

5.3.10.2.4   Required Interfaces, Inputs and Outputs

This application will need to have an application interface for interactions with the pilot connected vehicle pilot projects.

5.3.10.3   *Intellectual Property Rights*

This application is being built by the USDOT and all intellectual property rights will be decided by the USDOT.

5.3.10.4   *Application Safety Plan Considerations*

This application must be available in order for provisioning to be handled correctly. The USDOT will be responsible for the application safety plan considerations.

5.3.10.5   *Testing and Verification Requirements*

The USDOT will handle the bulk of the testing for this application. To ensure the application is working correctly and to eliminate potential troubleshooting issues with the SCMS system a unit test application will be built to test correct functionality.

5.4 Website/Desktop Applications

5.4.1 CVOP Website updates (Extension & Interface) – I2V

This application is responsible for extending the current CVOP site to allow for updating content based on the TMC Road Weather Advisories and Warnings service. Updates to the CVOP site will include a section where current conditions by road segment will be available and the site will include updates for responsive web design making the website more user friendly on mobile devices.

5.4.1.1   *System Requirements:*

5.4.1.1.1   Functional

This application shall receive current information from the Wyoming CV System in conformance with requirement CVOP-REQ-1 with all sub requirements.

This application shall receive segment-specific alerts generated by the Wyoming CV System in conformance with requirement CVOP-REQ-1.1 with all sub requirements.

This application shall receive forecasted segment-specific alerts information from the WTIDB in conformance with requirement CVOP-REQ-1.2 with all sub requirements.

This application shall display alert and forecast information received from the Wyoming CV System.

This application shall display truck parking information received from the Wyoming CV System.

5.4.1.1.2   Interface

This application shall provide a responsive web interface for commercial vehicle drivers and operators with access to the site. The application shall adjust the screen layout and viewable area based on the device screen size being used.

5.4.1.1.3   Performance

This application shall create a dashboard within the CVOP allowing personnel to quickly view road information.

5.4.1.1.4   Data

This application shall provide data related to freight specific travel planning.

5.4.1.2   *Description of the Components of the Application*

This application's primary purpose will be to display travel planning and information for commercial vehicle operators.

5.4.1.2.1   Maturity Level of the Application

This application has a PRL of 3 as it has been designed, built and used in realistic environments, but not with this pilot's connected vehicle data input or the parking components. WYDOT will perform all updates needed for this application.

5.4.1.2.2   Required Development Work

This CV pilot will need to extend and modify the existing CVOP website in order to integrate the pilot project data.

5.4.1.2.3   Specific Hardware and Software Needs

This application will rely on existing hardware and software.

5.4.1.2.4   Required Interfaces, Inputs and Outputs

This application will require an interface that allows users to select website preferences for the modifiable dashboard.

This application will require a responsive web design to allow multiple device types to access the site and view data in a modified layout.

5.4.1.3   *Intellectual Property Rights*

This application will be extended using funds outside of the pilot funds. As such, WYDOT will obtain the intellectual property rights and this application will not be posted to the OSADP.

5.4.1.4   *Application Safety Plan Considerations*

Since this is a web-based application an active IP monitor will be setup to continuously monitor the application and notify an administrative group if/when the application fails. Additionally, this application will be setup using a cloud service that will allow for replication among many servers. If one server goes down the others in the server farm will handle the additional load.

5.4.1.5   *Development Team*

Table 5-6 lists the development team responsible for the design and development of the CVOP website updates.

Table 5-6. CVOP updates development team

Team Member	Role
David Rush	Lead Developer
TBD	Developer

5.4.1.6   *Testing and Verification Requirements*

This application will have multiple layers of testing including, load testing, performance testing, and unit testing that will target the application functionality, performance, and usability.

5.4.2 WYDOT Transportation Reports and Action Console (TRAC) - DN

The TRAC is an operator console used in the TMC to monitor and manage planned, ongoing, and forecast events and actions on facilities monitored by the TMC. The TRAC provides a tabular list of actions that require operator attention. As events progress, operators mark actions as complete. The TRAC receives information from various sources available to the TMC (e.g., citizen reports, 511 App, RCRS, field reports) but can also include operator inputs. The TRAC interface is the primary interface for communicating information to the operators in the TMC. Additionally, the CV Pilot will use the TRAC system for events to directly influence the traveler information that is being provided.

5.4.2.1 *System Requirements:*

5.4.2.1.1   Functional

This application shall receive CV-pilot events from the Wyoming CV System. CV-events include those generated by the Wyoming CV System that require operator attention in conformance with requirement TRAC-REQ-1 with all sub requirements.

This application shall provide the ability for TMC staff to assign a CV-Pilot event to an individual TMC operator.

This application shall provide non-CV event data to the WYDOT Data Broker.

This application shall disseminate information from the WTIDB about weather, road conditions, and incident data.

5.4.2.1.2   Interface

This application shall allow users to interact with a desktop application that will give them the ability view new incident information.

5.4.2.1.3   Performance

This application shall provide a dashboard within the TRAC system where new emergency notifications would be displayed and TRAC systems users would need to acknowledge them before any other functionality of the application is enabled - allowing personnel to quickly view incident information.

5.4.2.1.4   Data

This application shall provide non-CV event data to the WYDOT data broker including closure speed limit, and restriction data.

5.4.2.2   *Description of the Components of the Application*

This application's primary purpose is to allow TMC operators to view new incident notifications and to allow them the ability to notify the highway patrol of new incidents.

5.4.2.2.1   Maturity Level of the Application

This application has a PRL of 6 as it has been designed, built and used in realistic environments, but not with this pilot's connected vehicle data input for automated incident information. WYDOT will perform all updates needed for this application.

5.4.2.2.2   Required Development Work

This CV pilot will need to extend and modify the existing TRAC system in order to integrate the pilot project data.

5.4.2.2.3   Specific Hardware and Software Needs

This application will rely on existing hardware and software.

5.4.2.2.4   Required Interfaces, Inputs and Outputs

This application will require an interface that allows users to view new incidents detected within the system.

This application will require an interface to notify highway patrol of new incident information.

5.4.2.3   *Intellectual Property Rights*

This application will be extended using funds outside of the pilot funds. As such, WYDOT will obtain the intellectual property rights and this application will not be posted to the OSADP.

5.4.2.4   *Application Safety Plan Considerations*

Since this is a desktop application an active monitor will be built into the application to continuously monitor the online status of the application and will notify the TMC administrator if/when the application fails.

5.4.2.5   *Development Team*

Table 5-7 lists the development team responsible for the design and development of the TRAC application.

Table 5-7. TRAC application development team

Team Member	Role
David Rush	Developer
Paul Maxim	Developer
Ivan Yourshaw	Developer

5.4.2.6   *Testing and Verification Requirements*

This application will have multiple layers of testing including, load testing, performance testing, and unit testing that will target the application functionality, performance, and usability.

5.4.3 WYDOT Wyoming Traveler Information (WTI) – FCW, SWIW

This application provides center monitoring and control of variable speed limits systems. It monitors data on traffic and environmental conditions collected from sensors along the roadway. Based on the measured data, it calculates and sets suitable speed limits. It controls equipment that posts the current speed limits and displays additional information such as basic safety rules and current traffic information to drivers. This will be an extension of the WTI system.

5.4.3.1   *System Requirements:*

5.4.3.1.1   Functional

This application shall allow users to view operator-suggested traffic changes for speed and DMS (i.e., snow plows and highway patrol drivers' suggestions).

This application shall receive current segment-specific alerts from the Wyoming CV System in conformance with requirement WTI-REQ-1.1 with all sub requirements.

This application shall receive forecasted segment-specific alerts from the Wyoming CV System in conformance with requirement WT-REQ-1.2 with all sub requirements.

This application shall transmit current information for corridor roadway segments available to the Wyoming CV System in conformance with requirements WTI-REQ-2 with all sub requirements.

5.4.3.1.2   Interface

This application shall provide an interface for TMC operators to view connected vehicle information relevant to changing variable speed limits.

5.4.3.1.3   Performance

This application shall create a dashboard allowing personnel to quickly view suggested FCW updates.

5.4.3.1.4   Data

This application shall provide information related to weather, speeds, and historic speed limit data.

5.4.3.2   *Description of the Components of the Application*

The primary purpose of this application is to allow TMC operators to view current connected vehicle speed recommendations, view historic weather related information, and allow operators to update speed limits for segments along the I-80 corridor.

5.4.3.2.1   Maturity Level of the Application

This application has a PRL of 6 as it has been designed, built and used in realistic environments, but not with this pilot's connected vehicle data input. WYDOT will perform all updates needed for this application.

5.4.3.2.2   Required Development Work

This CV pilot will need to extend and modify the existing WTI system in order to integrate the pilot project data.

5.4.3.2.3   Specific Hardware and Software Needs

This application will rely on existing hardware and software.

5.4.3.2.4   Required Interfaces, Inputs and Outputs

This application will require an interface that allows users to view all current speed limits for FCW's within the system.

This application will require an interface to view connected vehicle recommendations and to update FCW's within the system.

5.4.3.3 *Intellectual Property Rights*

This application will be extended using funds outside of the pilot funds. As such, WYDOT will obtain the intellectual property rights and this application will not be posted to the OSADP.

5.4.3.4 *Application Safety Plan Considerations*

Since this is a desktop application an active monitor will be built into the application to continuously monitor the online status of the application and notify will notify the TMC administrator if/when the application fails.

5.4.3.5 *Development Team*

Table 5-8 lists the development team responsible for the design and development of the WTI application.

Table 5-8. WTI application development team

Team Member	Role
Ivan Yourshaw	Developer

5.4.3.6 *Testing and Verification Requirements*

This application will have multiple layers of testing including, load testing, performance testing, and unit testing that will target the application functionality, performance, and usability.

5.4.4 WYDOT Construction Administration (CA) - WZW

This application coordinates work plans with maintenance systems (ConAdmin) so that work zones are established that have minimum traffic impact. Traffic control strategies are implemented to further mitigate traffic impacts associated with work zones that are established, providing work zone information to driver information systems such as dynamic message signs.

5.4.4.1 *System Requirements:*

5.4.4.1.1 Functional

This application shall share timestamped work zone information with the Wyoming CV System in conformance with requirement CA-REQ-1.

This application shall transmit work zone information, based on HTTP protocol, to the Wyoming CV System in conformance with requirement CA-REQ-2.

This application shall transmit work zone information to the Wyoming CV System in conformance with requirement CA-REQ-3 consisting of one or more of the following:

- Work zone type
- Location
- Scheduled and unscheduled time of work
- Return to normal notification
- Number of lanes closed (including shoulder)

This application shall transmit Work Zone data to the Wyoming CV System within thirty minutes of generation in conformance with requirement CA-REQ-4.

5.4.4.1.2   Interface

This application shall extend the ConAdmin application to integrate work zone warning with the new connected vehicle data and communications.

5.4.4.1.3   Performance

This application shall create a dashboard to allow TMC personnel to view work zone information within the ConAdmin application.

5.4.4.1.4   Data

This application shall provide information related to current and upcoming work zones including work zone type, location, schedule/unscheduled time of work, and number of lanes closed.

5.4.4.2   *Description of the Components of the Application*

The primary purpose of this application is to allow TMC operators to manage work zones for segments along the I-80 corridor.

5.4.4.2.1   Maturity Level of the Application

This application has a PRL of 1 as it has only the basic principles and research performed for it so far. Additional research will need to be performed along with formulating the application before the application development process will be able to begin. WYDOT will perform all updates needed for this application.

5.4.4.2.2   Required Development Work

This CV pilot will need to create a new application for TMC operational personnel that allows them to manage work zones along the I-80 corridor.

5.4.4.2.3   Specific Hardware and Software Needs

This application will rely on existing hardware and software.

5.4.4.2.4   Required Interfaces, Inputs and Outputs

This application will require an interface that allows users to manage Work Zones within the system.

5.4.4.3   *Intellectual Property Rights*

All code built for this pilot application will be posted on the Open Source Application Development Portal (OSADP) with Apache 2.0 licensing.

5.4.4.4 *Application Safety Plan Considerations*

An active monitor will be built into the application to continuously monitor the online status of the application and notify will notify the TMC administrator if/when the application fails.

5.4.4.5 *Development Team*

Table 5-9 lists the development team responsible for the design and development of the CA application.

Table 5-9 CA application development team

Team Member	Role
Suzie Roseberry	Developer
David Rush	Developer

5.4.4.6 *Testing and Verification Requirements*

This application will have multiple layers of testing including, load testing, performance testing, and unit testing that will target the application functionality, performance, and usability.

5.4.5 WYOROAD.INFO Website (Extension & Interface)

This application will extend the current WYOROAD.INFO website to include improved data from the CV pilot including data from work zone warnings, SPOT weather information, situational data, and incident information. It will get information for updates from the WTIDB services engine and from WTI.

5.4.5.1 *System Requirements:*

5.4.5.1.1 Functional

This application shall provide work zone warning information based on information provided by the WTI application.

This application shall provide integrated SPOT weather information from the TMC to the WYOROAD.info website.

This application shall provide incident information to the WYOROAD.info website based on information provided by the WTI application.

This application shall provide situational data from connected vehicles to the WYOROAD.info website.

This application shall provide weather data and road conditions gathered from connected vehicles with weather sensors.

5.4.5.1.2 Interface

This application shall provide a web based interface to view road condition information.

5.4.5.1.3 Performance

This application shall handle high volumes of traffic to the website.

5.4.5.1.4   Data

This application shall provide data on work zone warnings, SPOT weather information, situational data, and incident information to drivers.

5.4.5.2   *Description of the Components of the Application*

This application's primary purpose will be to disseminate traveler information from the connected vehicle environment to drivers without connected vehicles.

5.4.5.2.1   Maturity Level of the Application

This application has a PRL of 6 as it has been designed, built and used in realistic environments, but not with connected vehicle data integrated. WYDOT will perform all updates needed for this application.

5.4.5.2.2   Required Development Work

This CV pilot will need to extend and modify the existing WYOROAD.info website in order to integrate the pilot project data.

5.4.5.2.3   Specific Hardware and Software Needs

This application will rely on existing hardware and software.

5.4.5.2.4   Required Interfaces, Inputs and Outputs

This application will require an interface that allows users to view information including work zone warnings, SPOT weather information, situational data, and incident information.

5.4.5.3   *Intellectual Property Rights*

This application will be extended using funds outside of the pilot funds. As such, WYDOT will obtain the intellectual property rights and this application will not be posted to the OSADP.

5.4.5.4   *Application Safety Plan Considerations*

Since this is a web-based application an active IP monitor will be setup to continuously monitor the application and notify an administrative group if/when the application fails. Additionally, this application will be setup within the WYDOT server farm or a cloud-hosted system that will allow for replication among many servers. If one server goes down the others in the server farm will handle the additional load.

5.4.5.5   *Development Team*

Table 5-10 lists the development team responsible for the design and development of the WYOROAD.info website updates.

Table 5-10. WYROAD.info updates development team

Team Member	Role
Suzie Roseberry	Developer
Liane Terrill	Developer
Ben Saunders	Developer
Trenton Rawlinson	Developer

5.4.5.6 *Testing and Verification Requirements*

This application will have multiple layers of testing including, load testing, performance testing, and unit testing that will target the website functionality, performance, and usability.

5.4.6 OBU/RSU Management Application

This application will allow CV developers to test and manage applications for vehicle on board unit and roadside unit. It will be also allowing CV developers to query current equipment inventory and add new equipment for connected vehicle inventory management. Additionally, this application will allow CV developers to track, monitor, and perform updates (applications, firmware, and operating systems) for OBU and RSU software. For OBU's it will be a pull based system as we will not have direct access to OBU's.

5.4.6.1 *System Requirements:*

5.4.6.1.1   Functional

This application shall provide the capability to update RSU and OBU software.

This application shall provide the capability to manage RSU and OBU hardware and software.

5.4.6.1.2   Interface

This application shall provide a web based interface to allow CV developers to manage RSU and OBU hardware/software.

5.4.6.1.3   Performance

This application shall create a dashboard within the OBU/RSU management application that will allow personnel to quickly view RSU/OBU inventory data.

5.4.6.1.4   Data

This application shall help manage RSU/OBU hardware inventory and software.

5.4.6.2 *Description of the Components of the Application*

This application will focus on the management of all RSU and OBU hardware and software that will be used for the pilot project.

5.4.6.2.1   Maturity Level of the Application

This application has a PRL of 1 for the OBU as it has only the basic principles and research performed for it so far. This application has a PRL of 6 for the RSU as it has been designed, built and used in realistic environments, but not with this pilot's vehicle types and specific data collection requirements. Additional research will need to be performed along with formulating the application before the application development process will be able to begin. WYDOT will perform all updates needed for this application.

5.4.6.2.2   Required Development Work

This CV pilot will need to modify the RSU application for pilot operations personnel with authorization to integrate CV software into the application and management of that software. Additionally, the OBU software management piece will need to be created to allow management of authorized users to deploy OBU software updates available for connected vehicle OBUs.

5.4.6.2.3   Specific Hardware and Software Needs

This application will rely on existing hardware and software.

5.4.6.2.4   Required Interfaces, Inputs and Outputs

This application will require an interface that allows users to manage RSU/OBU hardware and software.

5.4.6.3   *Intellectual Property Rights*

All code built for this pilot application will be posted on the Open Source Application Development Portal (OSADP) with Apache 2.0 licensing.

5.4.6.4   *Application Safety Plan Considerations*

Since this is a web-based application an active IP monitor will be setup to continuously monitor the application and notify an administrative group if/when the application fails. Additionally, this application will be setup within the WYDOT server farm that will allow for replication among many servers. If one server goes down the others in the server farm will handle the additional load. If this application does go down, there should not be a direct immediate impact on the pilot vehicles safety in the short term.

5.4.6.5   *Development Team*

The vendor chosen for the OBU/RSU hardware will be responsible for the design and development of the OBU/RSU management application:

5.4.6.6   *Testing and Verification Requirements*

This application will have multiple layers of testing including, load testing, performance testing, and unit testing that will target the application functionality, performance, and usability.

5.4.7 Participant Tracking Application

This application will track the training, vehicle, and driver information for all participants of the connected vehicle program. The system will allow new participants to be added and participants to be removed from the system.

5.4.7.1 *System Requirements:*

5.4.7.1.1 Functional

This application shall encrypt all participant information associated with the pilot project.

This application shall require security credentials in order to access participant information.

This application shall provide the ability to manage participant, vehicle and device information in the pilot project.

5.4.7.1.2 Interface

This application shall provide an interface to allow CV administrators to manage (add/edit/delete) participants, devices and vehicles associated with the pilot project.

5.4.7.1.3 Performance

This application shall provide response times that are no longer than 5 seconds in duration.

5.4.7.1.4 Data

This application shall manage the encryption of participants, vehicles, and devices used in the CV pilot project.

This application shall operate over an SSL connection.

This application shall encrypt all participant information for storage in the database.

5.4.7.2 *Description of the Components of the Application*

The primary purpose of this application will be to manage participants within the connected vehicle pilot project.

5.4.7.2.1 Maturity Level of the Application

This application has a PRL of 1 as it has only the basic principles and research performed for it so far. Additional research will need to be performed along with formulating the application before the application development process will be able to begin. WYDOT will perform all updates needed for this application.

5.4.7.2.2 Required Development Work

This CV pilot will need to create a new application for pilot operations personnel with authorization to allow tracking and management of CV participants.

5.4.7.2.3   Specific Hardware and Software Needs

This application will rely on existing hardware and software.

5.4.7.2.4   Required Interfaces, Inputs and Outputs

This application will require an interface that allows users to manage information regarding participants, vehicles, and devices used within the CV pilot project.

5.4.7.3   *Intellectual Property Rights*

All code built for this pilot application will be posted on the Open Source Application Development Portal (OSADP) with Apache 2.0 licensing.

5.4.7.4   *Application Safety Plan Considerations*

Since this is a web-based application an active IP monitor will be setup to continuously monitor the application and notify an administrative group if/when the application fails. Additionally, this application will be setup using a cloud service that will allow for replication among many servers. If one server goes down the others in the server farm will handle the additional load. If this application does go down there will not be an impact on the pilot vehicles safety in the short term.

5.4.7.5   *Development Team*

Table 5-11 lists the development team responsible for the design and development of the Participant Tracking application.

Table 5-11. Parking Tracking application development team

Team Member	Role
Shane Zumpf	Project Manager
Kim Perry	Developer
TBD	Developer

5.4.7.6   *Testing and Verification Requirements*

This application will have multiple layers of testing including, load testing, performance testing, and unit testing that will target the application functionality, performance, and usability.

5.5 Mobile Applications

5.5.1 WYDOT 511 integration (Android & iOS) - I2V

This application provides drivers with personalized traveler information including traffic and road conditions, transit information, maintenance and construction information, multimodal information, event information, and weather information. The provided information is tailored based on driver requests. Both one-time requests for information and on-going information streams based on a submitted traveler profile and preferences are supported. This application will be extended to support

updated data feeds available from the CV project such as work zone warnings, road weather advisories, SPOT Weather impacts, and parking availability. Users of the application will be able to subscribe to these data feeds based on their location. Additionally, the app will be updated to allow for users to submit information on truck parking availability for parking locations.

5.5.1.1   *System Requirements:*

5.5.1.1.1   Functional

This application shall transmit parking data to the Wyoming CV System for facilities along I-80 reported by users of the App in conformance with requirement 511-REQ-1 with all sub requirements. Information transmitted shall include the following:

- Categorized parking availability in conformance with requirement 511-REQ-1.1
- Availability shall default to available in conformance in conformance with requirement 511-REQ-1.2
- Timestamp of submission date/time in conformance with requirement 511-REQ-1.3
- Parking facility location in conformance with requirement 511-REQ-1.4
- Parking schema information defined by WYDOT in conformance with requirement 511-REQ-1.6

This application shall transmit all information to the Wyoming CV System using the HTTP protocol in conformance with requirement 511-REQ-1.5

This application shall pull data from the WTIDB service for connected vehicle information.

This application shall make notifications available to users when they enter a road segment with new advisories and warning that the user is subscribed to receive.

5.5.1.1.2   Interface

This application shall provide an interface for users to receive push notifications that they have subscribed to.

This application shall allow users to set preferences within the WYDOT 511 app.

5.5.1.1.3   Performance

This application shall push notifications to users entering areas where warnings and advisories are posted.

5.5.1.1.4   Data

This application shall push notifications related to work zone warnings, road weather advisories, SPOT Weather impacts, and parking availability.

5.5.1.2   *Description of the Components of the Application*

This applications will primarily be responsible for pushing notifications to users for advisories and warnings associated with connected vehicle environment inputs.

5.5.1.2.1   Maturity Level of the Application

This application has a PRL of 8 as it has been designed, built and is currently deployed to a production environment, but not with connected vehicle data integrated. WYDOT will perform all updates needed for this application.

5.5.1.2.2   Required Development Work

This CV pilot will need to extend and modify the existing WYDOT 511 mobile app in order to integrate the pilot project data.

5.5.1.2.3   Specific Hardware and Software Needs

This application will rely on existing hardware and software.

5.5.1.2.4   Required Interfaces, Inputs and Outputs

This application will require an interface that allows users to set preferences related to connected vehicle advisories.

This application shall allow users to receive push notifications for information including work zone warnings, road weather advisories, SPOT Weather impacts, and parking availability.

5.5.1.3   *Intellectual Property Rights*

This application will be extended using funds outside of the pilot funds. As such, WYDOT will obtain the intellectual property rights and this application will not be posted to the OSADP.

5.5.1.4   *Application Safety Plan Considerations*

The WYDOT 511 application shall monitor the current internal state. If the state is found to be nonresponsive the application shall attempt to restart itself (if possible).

5.5.1.5   *Development Team*

The WYDOT team is currently looking into vendors for the development team to update the 511 app. Once a vendor is chosen this section will be updated with the development team information.

5.5.1.6   *Testing and Verification Requirements*

This application will have multiple layers of testing including, load testing, performance testing, and unit testing that will target the app functionality, performance, and usability.

5.5.2 Vehicle Messaging Display/Interface

This application will provide a hands-free and eye-free interface setting for drivers to display information related to an upcoming warning. The exact specifics of the interface will be determined by available products that comply with the hands-free and eyes-free requirements. This application will be capable of audio and visual alerts as well as displaying different messages to drivers including hazardous weather advisories, local variable speed limits, incidents, SPOT weather advisories, road closures, and other information deemed necessary for drivers to consider while driving through the I-

80 corridor. Though this application will be deployed in pilot vehicles it will be built using a mobile development platform.

5.5.2.1 *System Requirements:*

5.5.2.1.1 Functional

This application shall provide an interface for drivers to receive prioritized in-vehicle based in conformance with requirement VS-REQ-23.

This application shall provide three levels of alert in conformance with requirement VS-REQ-24.

This application shall provide only the highest level of alert to the vehicle operator when more than one alert is currently active in conformance with requirement VS-REQ-25.

This application shall alert the vehicle operator for forward collision warning in conformance with requirement VS-REQ-26

This application shall alert the vehicle operator for a distress message when the direction of travel of the host vehicle moving toward the distressed vehicle and is within five miles of the location of a distressed vehicle using an inform message in conformance with requirement VS-REQ-27.

This application shall alert the vehicle operator for a situational awareness advisory in conformance with requirement VS-REQ-28.

This application shall inform the vehicle operator of the current speed limit of the variable speed limit zone the vehicle is within in conformance with requirement VS-REQ-29.

This application shall alert the vehicle operator of a spot weather incident when the host vehicle is traveling toward and within five miles of the incident's location using an inform message in conformance with requirement VS-REQ-30

This application shall alert the vehicle operator of a work zone in conformance with requirement VS-REQ-31.

5.5.2.1.2 Interface

This application shall minimize the 'eyes off the road' time when presenting information in conformance with requirement VS-REQ-32.2.

This application shall provide messages that can be read from the driver's normal seating position in conformance with requirement VS-REQ-32.3.

This application shall include both a visual and auditory interface for sharing traveler information in conformance with requirement VS-REQ-32.4 and all sub requirements.

This application shall be customizable to reflect driver preferences in conformance with requirement VS-REQ-32.5.

This application shall provide system status information to drivers in conformance with requirement VS-REQ-32.6 and all sub requirements.

This application shall include a distress button to allow a driver to notify the Vehicle System that the driver has initiated a distress condition in conformance with requirement VS-REQ-32.7

5.5.2.1.3   Performance

This application shall present emergency notifications in less than .1 second from the time the message has been received from an OBU.

5.5.2.1.4   Data

This application will present data considered current that is received from other connected vehicles and RSUs that contains information that is determined to be critical information the driver needs to view based on OBU application business rules.

5.5.2.2   *Description of the Components of the Application*

This applications primary purpose will be to display information sent from the TMC and other connected vehicles that is determined to be useful for the driver to know or to display alerts immediately to the driver of a connected vehicle. It will also be used for maintenance activities (e.g. application updates) and status information (e.g. certificate status)

5.5.2.2.1   Maturity Level of the Application

This application has a PRL of 6 as it has only the basic principles and research performed for it so far. Additional research will need to be performed along with formulating the application before the application development process will be able to begin. WYDOT will perform all updates needed for this application.

5.5.2.2.2   Required Development Work

This CV pilot will need to design and develop a new mobile application that integrates with the DSRC radio and will be used to display vehicle and driver alerts.

5.5.2.2.3   Specific Hardware and Software Needs

This application will be built on an Android platform. The application shall be built on the native Java platform and communicate with the DSRC radio to receive alerts and messages. An Android tablet/device will need to be used for the hardware.

5.5.2.2.4   Required Interfaces, Inputs and Outputs

This application shall provide an interface that allows users to set user preferences including text size, contrast, hands-free and eyes-free operation, and brightness.

This application shall provide feedback to application users for alerts.

5.5.2.3   *Intellectual Property Rights*

This application will be built by the OBU/RSU hardware vendor with funds outside of the scope of this project. As such the vendor, will retain all intellectual property rights for the application.

5.5.2.4 *Application Safety Plan Considerations*

The messaging display application shall monitor the current internal state. If the state is found to be nonresponsive the application shall attempt to restart itself and notify the user (if possible).

5.5.2.5 *Development Team*

The design and development of this application will be the responsibility of the OBU/RSU vendor chosen for this project. After a vendor is chosen this document will be updated to include the vendor name.

5.5.2.6 *Testing and Verification Requirements*

This application will have multiple layers of testing including, load testing, performance testing, and unit testing that will target the app functionality, performance, and usability.

6 Overall Plan Information

This section will give details for the applications as a group, including the required use of the SCMS, the overall software development process and uploading to the OSADP and RDE.

6.1 Cross-Cutting Development Effort

In order to reduce the overall cost, increase system maintainability, and simplify the connected vehicle application environment a number of applications and development libraries will be developed and used by multiple applications within the connected vehicle pilot project. Some of the development that will affect multiple applications will include the creation of services applications and the development for the human machine interface (HMI) to be used within vehicles.

Code that may be used across multiple applications will be abstracted out into reusable libraries and shared among applications. This will also reduce the time to fix bugs located in the common code as one update will resolve the bug for every application that is using the library. Please note that the cost savings associated with the reusable libraries has been factored into the costs for the OBU and RSU applications.

6.1.1 Services Applications

Application functionality that may be used by more than one other application will be created as a Representational State Transfer (REST) service. Each of these services has specific functionality that is made available to all other applications. For instance, the field data collection application will be created as a service that's purpose is to collect from RSU applications and store that information in the WYDOT data warehouse. This service will also provide functionality to process the incoming data and notify TMC applications when emergency alerts are detected. Each service described in the services applications section will affect many applications. Please see the definition of each application in section 5.3 for more information.

6.1.2 HMI messaging development

Building a common vehicle interface for all OBU vehicle applications using one development effort. After the messaging interface has been determined a common application interface (api) will be built and used by all OBU applications to access and interface with vehicle drivers. This development effort will affect the following OBU applications: OBU Vehicle Speed Management, OBU Vehicle Traveler Information Reception, OBU Vehicle Emergency Notification Application, and the OBU Vehicle Basic Safety application. The cross-cutting development effort here is not in the development of the HMI mobile app described in Section 5.5.2, but in the interface that the OBU applications will use to communicate with the HMI application.

The HMI application will also be responsible for interfacing with the weather cloud application. The HMI app will periodically poll data and create a log file for all weather data. This data will then be read from the DSRC radio and pushed to the ODE through the DSRC probe data application. Allowing the HMI application to perform this functionality will save time and effort since the capabilities for the

software from the HMI application are more compatible with the weather cloud application than the software development effort is from the DSRC radio to communicate with the weather cloud application.

6.2 Security Credential Management System

It is understood that the USDOT is currently developing the Security Management Credential System (SCMS) and will be made available for use to the Wyoming CV pilot project by the time pilot application development begins. SCMS applications built by the USDOT are listed in this document but understood to be under the management of the USDOT. Applications using the USDOT SCMS application and how they will be using it are described below.

- *OBU Basic Safety Message:* The OBU Basic Safety Message application will use the SCMS in order to verify basic safety messages (BSMs) from both infrastructure and from other vehicles. BSM data coming from the vehicle will also be signed with an SCMS certificate in order to verify the validity of the current vehicle.
- *OBU Vehicle Probe Data:* The OBU Vehicle Probe Data Application will use the SCMS to sign data messages containing vehicle probe data. This data must be verified as authentic from the infrastructure and center since it may contain actionable information that may affect the safety of other vehicles on the road.
- *OBU Vehicle Speed Management:* The OBU Vehicle Speed Management application will use the SCMS application to verify the sender for messages involving FCW updates and current speeds from both infrastructure and other vehicle transmissions. This application will also use the SCMS application to sign messages sent to other vehicles for FCW updates.
- *OBU Vehicle Traveler Information Reception:* This application will use the SCMS to validate traveler information sent from infrastructure and other vehicles. This application will also use the SCMS application to sign messages sent to other vehicles for traveler information updates.
- *OBU Vehicle Emergency Notification Application:* This application will use SCMS system to validate emergency notification information sent from other vehicles and to rebroadcast emergency notification messages sent to other vehicles and infrastructure.
- *OBU Vehicle Support Services:* This application will work in conjunction with the SCMS system by maintaining necessary security credentials, authorizations, and associated keys to properly validate messages sent from a vehicle to other vehicles and infrastructure.
- *OBU Vehicle Trust:* This application will communicate with the SCMS to maintain a current, valid set of security certificates and identifies, logs, and reports events that may indicate a threat to the Connected Vehicle Environment security. This application is also responsible for managing certificates and associated keys received from the SCMS.
- *RSU Probe Data Application:* The RSU Probe Data Application will use the SCMS to verify data messages containing vehicle probe data.
- *RSU Speed Management:* The RSU Speed Management will use the SCMS to sign messages to vehicles for Speed Management notifications.
- *RSU Roadway Traffic Information Dissemination:* This application will use the SCMS to sign messages to vehicles and drivers that may include traffic and road conditions, incident information, work zone information, parking information, weather information and broadcast alerts.
- *RSU Emergency Signal Application:* This application will use the SCMS to verify emergency notifications received from connected vehicles.

- *RSU Basic Safety Monitoring:* This application will use the SCMS to sign and verify all basic safety messages sent and received from connected vehicles.
- *RSU Support Services:* This application works with the SCMS by maintaining the necessary security credentials, authorizations, and associated keys to support communications in the connected vehicle environment.
- *RSU Trust Management:* This application communicates with the SCMS to maintain a current, valid set of security certificates and keys and identifies, logs, and reports events that may indicate a threat to Connected Vehicle Environment security.
- *Operational Data Exchange (ODE):* This application communicates with the SCMS to maintain a current, valid set of security certificates and keys and identifies, logs, and reports events that may indicate a threat to Connected Vehicle Environment security.

6.3 Software Development Process

In order to determine the priority of applications in the development process a critical path analysis has been performed. This critical path analysis (seen in Figure 6-1) gives a bigger view of all the different applications that will be created and the order in which they will be worked on. Each application within the project will follow the application development process defined below.

6.3.1 Application Development Approach

The overall software development approach for the applications in section 3 will be done using an agile software development process. This process calls for short iterations and allows for requirements to be flexible during the development process. This will also allow WYDOT to see the software progress being made and allow WYDOT to evaluate software at early stages in the development process and allow changes to be made in a less costly manner. Applications will each be assigned a development team and a development lead. Application teams will need to work closely with one another when dependencies between applications are identified. The process for an individual application development is detailed below.

6.3.1.1 Application Lifecycle Management System

The application lifecycle management system that has been chosen to help store documentation, plan development, and track progress of application development is Atlassian's JIRA Software in conjunction with Confluence. Confluence will be used for document management and collaboration for software architecture documents, test plans, test results, and other related application development documents. Separate projects will be setup within JIRA Software for each application that will be developed. Projects will be setup using the JIRA Agile template. All requirements will be added to the appropriate project in a User Story format. The requirements will be stored in a backlog until they are chosen to be implemented within a Sprint (see Section 6.3.1.4 for more information).

6.3.1.2 Architectural Design

An application will have an initial set of requirements defined by the System requirements that must be met in order for the application to be called complete. As many requirements will be identified as possible during the initial application design. The next step will be to analyze all of the identified requirements and to begin the technical design of the application. A software architect will then be assigned to create an architectural design document detailing the proposed design of the application.

The applications architectural design document will detail the architectural representation, constraints, application layers, physical deployment plan, and identify the cost and schedule associated to the design. All of this information will be found within the System Design Document (SDD). After the SDD document has been created the development team will perform an architectural design review. Comments from the team will be incorporated into the SDD. The SDD will be a living document that will evolve during the application development and as other requirements are identified during the development phase of the application. Newly identified requirements will be documented and analyzed to determine the effect to the cost and schedule of the application as they are identified.

6.3.1.3   *Requirements Definition*

In addition to the requirements defined in this document applications will have technical as well as further functional requirements defined within the architectural design document. All of the requirements that are found will be placed into JIRA Software as User Stories and stored in the backlog. All requirements will be reviewed by the project manager or scrum master as well as the development team to ensure that they are well written and understood by the entire team. If more information is needed on a User Story the project manager or scrum master will be tasked with updating the User Story with the required information.

User Stories shall be written as short, simple descriptions of a feature from the point of view of the stakeholder requesting the desired functionality. Conditions should be added to the end of the users stories that will help developers know when a User Story has been met. Once all conditions within the User Story are satisfied the User Story can then be closed out.

6.3.1.4   *Sprint Development Process*

After the architectural design of the application is completed and accepted as complete by WYDOT the schedule for the development of the application will be finalized and development on the project will begin. Application development will take place in sprints (or iterations). Each sprint will begin with a planning meeting that will involve the entire development team. The sprint planning meetings main goal will be to identify a list of requirements that the team will be able to develop, test, and deploy to a test environment within the given iteration timeframe. This timeframe may vary based on the number of requirements identified but will be no longer than 3 weeks in length. Additional requirements may be found during the development process and these requirements will be documented and analyzed to determine the effect to the cost and schedule of the application as they are identified.

During the sprint the team will hold daily meetings (standups) to discuss each developer's progress. These standups will allow the team to identify what tasks they have worked on the previous day what their plan is for the current day and if there are any issues or roadblocks that they may need assistance in overcoming. This is also a forum for the developers to raise concerns with the current development schedule or technical issues they have run into. All concerns raised will be documented and added to the list of risks for the project. These meetings shall allow the technical lead to step in and resolve issues early in the development process. At the end of an iteration the development team will deploy the current iteration software to a test or staging site to allow the QA team to test the newly developed features. Testing will be covered in the quality management section below. After testing is completed any testing issues that have been found will be documented. Developers will work to resolve these issues and follow the same deploy/test methodology until the QA team has verified the functionality of all requirements as being completed.

After all requirements are validated and the iteration has ended the team will hold an iteration retrospective meeting. This meeting will allow team members to discuss what went well, what didn't go so well, and what may be done to improve the process in future iterations. This meeting may be combined with the iteration planning meeting in order to streamline the development process. Retrospective feedback will be documented by the Scrum Master and made available for all project teams to review on the associated Confluence project site.

In cases where projects are reliant on other project development the technical lead for the affected project or dependent project will be invited to these retrospective and planning meetings. This will facilitate a better communication amongst development teams that are interdependent.

6.3.2 Quality Management

6.3.2.1 *Traceability*

Requirements traceability is essential to ensure that all system requirements have been met and exist in the newly developed system. Traceability of a requirement life cycle and between related requirements will be achieved through developing and maintaining a requirements traceability matrix (RTM). The RTM will be created and maintained through the life of the application development by the project manager or scrum master.

6.3.2.2 *Testing*

Several levels of testing will be used to verify application functionality, usability, correctness, and performance. Test Management will be done through a software development management system such as Microsoft Team Foundation Server but the specific management system will be determined later. The different testing that will be performed on each of the applications being developed are outlined below.

Unit Testing: Developers will write unit tests for any new code developed to limit the number of defects introduced into the application. Unit tests will be written in a separate solution and built to test code in the primary solution. This allows developers to run unit tests before any code is deployed and allows bugs to be caught early in the development process.

Regression Testing: Unit testing will be followed by extensive system testing by internal testing professionals to ensure complete testing coverage. This will be accomplished through testers creating and running test cases and documenting the test cases and scripts within the development management software.

User Testing: The standard software development life cycle testing methods mentioned above will be supplemented through in-house testing by subject matter experts.

Performance/Load Testing: Performance testing will be performed early in the development process and incorporated into the unit tests. This will allow performance issues to be identified early in the development process and continue to be monitored as development progresses. The performance tests will be setup based on the maximum load of the application and metrics will be determined for acceptable performance of the system under heavy load periods. Automated tests will then be setup to simulate high load periods and determine the performance of the application under these conditions.

User Acceptance Testing (UAT): As application functionality successfully passes prior testing levels, it will be deployed to the WYDOT testing environment for additional functional and load testing. While

the end goal of testing will ultimately be formal acceptance of developed requirements in the form of Deliverable Acceptance Requests, system development will be deployed to the WYDOT testing environment as often as possible to allow users to become familiar with new features and provide feedback.

6.3.2.3   *Testing Documentation*

Testing shall be documented according to the IEEE 29119-3 test documentation standards for Agile development. The following documents shall be created to encompass all of the development projects:

- Test Policy
- Organizational Test Strategy

Once these documents have been created and shared with the development team, individual projects will then create a test plan for their specific application. After the test plan is completed the following documentation will be completed for each sprint within the development process:

- Test Specification
- Test Requirement
- Test Readiness
- Test Execution
- Test Completion Report

These documents will be lightweight and outlines will be provided to help fill in areas to avoid unnecessarily burdensome documentation. Documentation examples will be posted to the Confluence site. All filled in testing documents will also be stored within the corresponding applications Confluence development site.

6.3.2.4   *Standards*

All development for the Connected Vehicle project will be done using the Apache Portal coding standards (found here: https://portals.apache.org/development/code-standards.html). This standard will be submitted to the Open Source Initiative for formal acceptance and then used as the standard for all development work once approved. All code will be peer reviewed for maintainability as well as compliance for the written standards. WYDOT has additional internal standards for programming projects that will additionally adhered followed.

6.3.2.5   *Source Control*

All software development will be maintained through BitBucket source code repositories. Each application will be assigned a separate repository.

6.4 Plan for Uploading Relevant Materials to OSADP and RDE

6.4.1 Open Source submissions

Applications paid for under the Connected Vehicle Pilots project will be uploaded to the OSADP using the guidelines that the OSADP details at the following webpage

(http://www.itsforge.net/index.php/community/faq/technical-faq/155-upload-to-osadp). Technical leads for each of the projects will be responsible for uploading and updating all code related to the application to the OSADP site. The following applications defined in section 3 will be developed and relevant code uploaded to the OSADP along with required associated files for upload.

Table 6-1. Application's code uploaded to the OSADP.

Application Name	Application Type	Licenses uploaded under
Operational Data Environment	Service	Apache 2.0
Participant Tracking Application	Desktop/Website	Apache 2.0
OBU/RSU management	Desktop/Website	Apache 2.0
Vehicle Messaging/Display	Mobile	Apache 2.0

6.4.2 Research Data Exchange Submissions

As part of the USDOT pilots program the Wyoming connected vehicle pilot project will publish data gathered from the pilot project to the Research Data Exchange (RDE). The process that will be followed when publishing research data is described below.

Data will be gathered during the Connected Vehicle Pilots project. Initially, all data identified through the performance plan and system requirements document will be stored in WYDOT's data warehouse. Since there are extremely large amounts of data that will be generated from the connected vehicle project not all data deemed necessary to the success of the program is stored for practical and budgetary reasons. During the pilot's phase data that is stored in the WYDOT warehouse may contain Personally Identifiable Information (PII). In cases where PII is present the PII specific data will be filtered out and the remaining data will be made available to the RDE.

The TMC Data Collection and Application sharing application will contain functionality allowing authorized users to export data from the WYDOT data warehouse for purposes of pushing the data to the RDE. Data generated from this application for publication will then be reviewed by authorized WYDOT personnel to review and verify that no PII is contained in the data that will be published to the RDE. After the verification has been made the publication to the RDE will be performed.

6.5 Overall Schedule

The overall schedule has been determined based on the high level estimates given for each of the different applications in the application overview sections above. The overall schedule in the format of a critical path analysis is presented in Figure 6-1 and overall costs are given in Table 5-3 and Table 5-4 for CV and Non-CV funded applications, respectively. Please note the orange applications in the critical path analysis are applications that are considered to be in the critical path. The critical path is defined as the path that will take the least time to develop the end product based on estimated development efforts for each application and related dependencies. Blue applications are applications that need to be developed for the system to work correctly but the development schedule for these applications may be more flexible based on dependencies and estimated development effort.
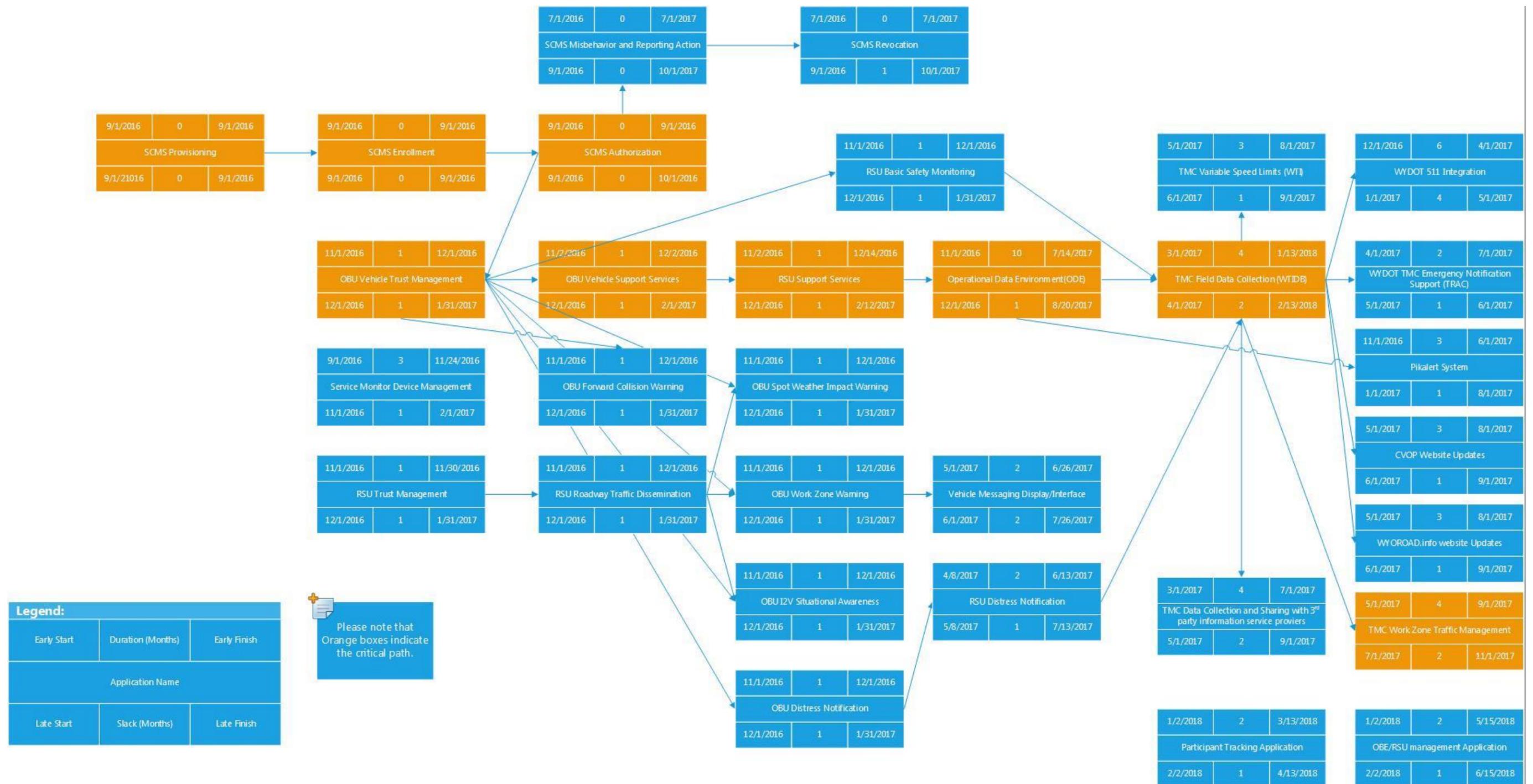
Figure 6-1. Critical Path Analysis (Source: ICF/Wyoming)

6.6 Assumptions and Risks

The following are assumptions and risks associated with the level of effort and scope of the applications described in this document. Please note that these assumptions and risks will be tracked through the course of phase 2 and phase 3 of the application development.

6.6.1 Assumptions

The following assumptions are being made for the applications

- The USDOT Clearinghouse is compliant with the 2016 version of J2735 standards.
- The USDOT Clearinghouse is compliant with the 2016 version of J2945-1 standards.
- The ODE is compliant with the 2016 version of J2735 standards.
- The ODE is compliant with the 2016 version of J2945-1 standards.
- The ODE is fully compliant with the new TIM, probe, and BSM standards.
- The ODE software current state of performance can support scaling to a 400 vehicle pilot.
- The new version of SCMS is published and compliant with the latest 2016 standards for J2735 and J2945-1.

6.6.2 Risks

The following risks may affect the overall budget, schedule, or scope of the applications described in this document.

- The USDOT Clearinghouse does not support the 2016 version of J2735 or J2945-1 standards.
- The ODE is not compliant with the 2016 version of J2735 or J2945-1 standards.
- The ODE is not compliant with supporting either TIM, probe, or BSM messages.
- The ODE does not support the latest version of the TIM, probe, or BSM standards.
- The new version of the SCMS is not published on time.
- The new version of the SCMS is not compliant with the 2016 version of the J2735 or J2945-1 standards

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