Connected Vehicle Pilot Deployment Program Phase 1

Comprehensive Pilot Deployment Plan – Wyoming CV Pilot

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Notice

Version History

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1	08/19/2016	ICF-Wyoming	First version technically accepted by USDOT
2	10/31/2016	WYDOT	Updated version based on final Phase 1 Comprehensive Deployment Plan
3	05/10/2018	WYDOT	Updated version based on system architecture and design to date. Version at the end of Phase 2. This version includes minor changes to the CDP based on latest deployment approach. Summary of General changes: • All figure sources were updated to be WYDOT. Summary of specific changes: • Updated dates and text in Section 1.2. • Updated constraints and assumptions on Section 1.4. • Minor edits to the list of acronyms in Section 1.5. • Minor edits to the description of the deployment scope in Section 2.2. • Minor edits to the methodology to select the deployment location, described in Section 2.2.1. • Updated Figure 2-2. • Updated List of Partners on Section 2.2.3.4. • Updated period of performance for the advisory council in Section 2.2.3.6. • Updated Section 2.3 to match current architecture and performance measures. • Section 3.6 was updated to include latest amendments to the IRB and an update to the training efforts. • Updated Section 3.11 to match current performance measures. • Section 5 was updated with the latest schedule. • Section 6 was updated to provide a current list of personnel. • Section 7 was updated to present the most recent cost summary available.

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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 1 includes the planning for the CV pilot including the concept of operations development. Phase 2 is the design, development, and testing phase. Phase 3 includes a real-world demonstration of the applications developed as part of this pilot.

This document presents the Comprehensive Deployment Plan, which: i) summarizes the Phase 1 activities in a way that presents a cohesive and comprehensive Phase 2 and 3 approach – what is proposed and how it will be accomplished; and ii) describes how the WYDOT CV Pilot team will successfully deliver on the requirements defined in the Notice of Funding Opportunity (NOFO) by identifying and demonstrating that the partnership, the systems engineering, and the development approaches are apt for the tasks. Finally, this 2018 revised version is an update to an earlier version of the report, reflecting more thoroughly fleshed out concepts and insights gained by the site in Phase 2.

Furthermore, this version of the deployment plan includes updates based on the status and design of the system at the end of Phase 2.

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1 Introduction

1.1 Context

The State of Wyoming and the Wyoming Department of Transportation (WYDOT) present some unique opportunities for showcasing connected vehicle technologies on a high-priority corridor in a rural setting. Although the state is sparsely populated with an estimated 580,000 residents, it is positioned as an important freight corridor and is home to some unique recreational opportunities that attract a significant number of visitors.

Interstate 80 (I-80), which reaches its highest elevation in the United States at 8,640 feet in Wyoming, is a major corridor for east/west freight in the northwestern part of the country. Not only does I-80 reach its highest elevation, the roadway also is above 6,000 feet throughout the state (see Figure 1-1).

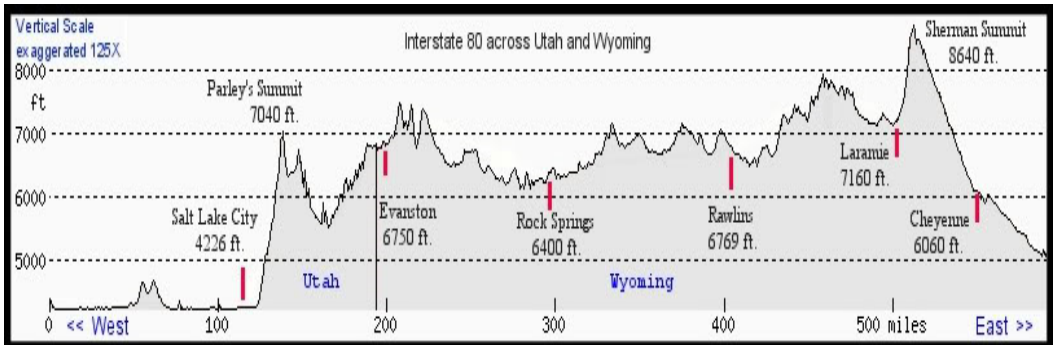

Figure 1-1. Profile of I-80 in Wyoming. Source: WYDOT.

Many commercial vehicle operators and tourists are unfamiliar with Wyoming's extreme weather conditions, resulting in weather-related crashes both in winter months, often caused by blowing snow events, and in the summer months, due to fog and high winds. Several high-profile, multiple-vehicle crashes have occurred along I-80 in Wyoming that have resulted in loss of life, extended closures, and direct impacts on the nation's economy. Although many states receive significant snowfall, Wyoming's notorious winds result in the nation's most severe blowing snow events and some of the greatest concentrations of vehicle blow overs in the country. Drivers on I-80 can experience high winds, heavy snow, blowing snow, and low visibility, which result in numerous closures each winter season. These conditions also directly contribute to higher than normal incident rates, often resulting in multivehicle crashes, especially during the winter months (see Figure 1-2).

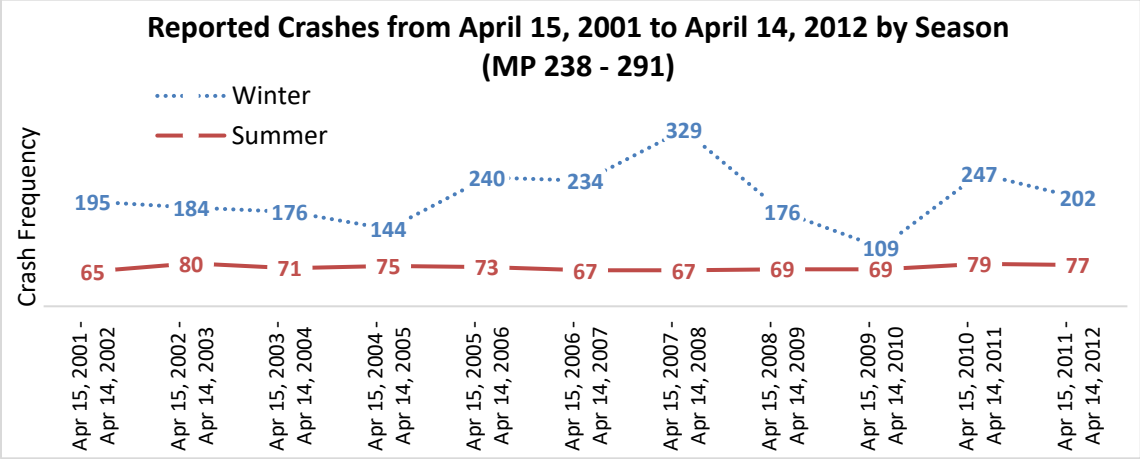

Figure 1-2. Elk Mountain Seasonal Variation of Crash Frequency 2001–2012. Source: University of Wyoming.

This interstate also is a primary freight corridor from the west coast to points east. Alternates are limited and can require significantly extra time to execute. This 402-mile corridor averages more than 32 million tons per year (at 16 tons per truck). The truck volume is 30–55% of the total annual traffic stream and comprises as much as 70% of the seasonal traffic stream. The mix of passenger vehicles and commercial vehicles can result in catastrophic crashes, the most recent of which resulted in a 65-vehicle pileup in 2015. In addition to large events, with a mix of commercial and passenger vehicles, drivers can face daily smaller challenges as well. For example, during elevation changes, slow-moving commercial vehicles can cause drivers of passenger vehicles to take risks they normally would not take—driving too closely, cutting off other vehicles to pass, or speeding to make up for lost time.

WYDOT has been advancing the use of intelligent transportation systems (ITS), especially for mitigating the impacts of adverse weather on its roadways and especially on I-80. Many of these initiatives are being replicated in other parts of the country. WYDOT continues to look for ways to improve its detection of conditions and improve dissemination to truckers and general travelers on I-80.

WYDOT continues to seek improvements in their operations along the corridor. One major limitation is the distances between the fixed environmental and speed detection, which creates significant gaps in determining road and weather conditions and reduces the effectiveness of strategies like variable speed limits. Secondly, the ability to communicate actionable information to travelers already on the roadway continues to be a challenge. Although dynamic message signs are available, WYDOT continues to look for ways to improve the efficacy and actionable nature of their traveler information systems. Mobile platforms that collect data and short-range communications that can communicate between vehicles and to the infrastructure are the logical avenues for WYDOT to explore as the next steps toward improving safety—leading to the interest and application for the Connected Vehicle (CV) Pilot.

1.2 The Connected Vehicle Pilot

Following a competitive procurement, WYDOT and the team were selected as one of the three efforts to demonstrate the real-world effectiveness of CV Technologies that showcase the use of Dedicated Short Range Communications (DSRC) and other communication methods to improve safety and

mobility of travelers. CV technologies enable new applications geared toward enabling collision avoidance, system optimization, and demand management, among other objectives.

The CV Pilot Demonstration Program is being delivered in three phases: Phase 1 – Planning, Phase 2 – System Design and Build, and Phase 3 – Demonstrate.

- Phase 1, completed on September 30, 2016. This report represents the culmination of the planning accomplishments in Phase 1. Through a collaborative effort with the U.S. Department of Transportation (USDOT) and the other pilot sites, artifacts from Phase 1 established the needs, developed concepts for the proposed system, developed performance criteria, and ensured the safety, security, and privacy of participants.
- Phases 2 and 3 will result in an operational CV system that generates meaningful travel alerts and advisories delivered with new communication techniques and have meaningful impacts on truck and passenger travel on the corridor of interest.

Phase 1 was a critical first step toward planning the CV Pilot systems that will be demonstrated. Several planning documents were prepared that documented the team's CV Pilot concept of operations and progress toward a systems architecture. Verifiable system requirements were developed, and performance measures were established. Additional plans were developed that define how the team will secure data, ensure safety, develop system applications, train participants, coordinate with partners, and provide outreach to interested groups. Although Phase 1 was led by ICF contractually, WYDOT was integral to the planning process and established a strong leadership role that will help the agency implement Phases 2 and 3.

1.3 Purpose of the Report

The deployment process of the Wyoming CV Pilot will happen in Phase 2, ending in April 2018, followed by an 18-month demonstration period—Phase 3, starting in May 2018.

The purpose of this document, ***WYDOT CV Pilot - Comprehensive Pilot Deployment Plan (CPDP)***, is two-fold.

1. Summarize the Phase 1 activities in a way that presents a cohesive and comprehensive Phase 2 and 3 approach – what is proposed and how it will be accomplished. The CPDP, a required deliverable under Task 12, serves as a capstone document that brings together the iterative, stakeholder-driven process used in Phase 1 to conceptualize the system.

2. Describe how the WYDOT CV Pilot team will successfully deliver on the requirements defined in the Notice of Funding Opportunity (NOFO). This document serves as our application for the NOFO and meets the requirement for Volume I–Part I identified in the NOFO. Through the CPDP, WYDOT seeks to articulate our ability to deliver on the plans in Phase 1 by identifying and demonstrating that the partnership, the systems engineering, and the development approaches are apt for the task.

It should be noted that selected deliverables from Phase 1 will be updated to reflect the Phase 1 end state as part of Task 2-B.

1.4 Constraints and Assumptions

The following constraints were also identified during the conceptualization of the system and will need to be addressed as part of the proposed system design:

- Vehicle to vehicle interactions are limited by the presence of connected vehicles in vicinity of each other during conditions of interest.
- Minimizing distraction to truck drivers is critical to any advisories and alerts issued by the system. Any in-vehicle advisory needs to be balanced with the demands of the driving tasks required of the truck driver during stressful conditions.
- Many important highway locations lack reliable, cost effective commercial power and communications services.
- The use of DSRC technology in the pilot will be guided by the IEEE 1609.2, 1609.3, and 1609.4 standards for Security, Network Services and Multi-Channel Operation (IEEE, 2016a, IEEE, 2016b; IEEE, 2016c), the SAE J2735 Message Set Dictionary (SAE, 2016b), and the recently released SAE J2945/1 Communication Minimum Performance Requirements standard (SAE, 2016a). As standards change and evolve, system requirements will continue to evolve.
- An important constraint to note is the dependency on external standards and WYDOT documents that are currently being developed or have not been published yet.

Some key assumptions are made in defining the features for the proposed system. The V2I requirements were built with SAE J3067 August 2014. The user needs were used with the operation scenarios from the Concept of Operations (Gopalakrishna et al., 2015) to identify and define the functional requirements from Section 3 onwards.

While some of the V2V requirements were used from J3067, in all cases where SAE J2945™/1 March 2016 had related V2V applications, the newer J2945/1 was used.

The current standard for basic safety messages within J2945/1 is for light vehicles and does not address heavy trucks or tractor-trailers. The CV pilot developers plan to extend the current specification to include trailer-related standards. For this, the CV pilot team will watch for an outcome in the form of a standard based on the NHTSA research project “V2V Basic Safety Message for Truck/CV Trailers.”

Additionally, SAE J2735™ March 2016 is used to update the outdated parts of the J3067 based on the new message set dictionary for DSRC. This document retains the original J3067’s system requirements numbers and descriptions in order to ensure compatibility with other CV projects and to provide clarity for future standards.

In cases where conflicting information is defined between the J2945/1, J2735, and J3067, J2945/1 will take initial precedence, followed by J2735 and finally J3067. The reason for this is J2945/1 is most specific and up to date for V2V safety communications and is there for most relevant to our pilot. J2735 is the second order of precedence because it has many updates to the message set that were not available when J3067 was written. J3067, while somewhat outdated is still relevant because it covers V2I communications and additional applications that are relevant to the Wyoming Pilot.

As J2945/2 and J2945/x become available the Wyoming Pilot will implement the standard interfaces and messages for Situation Awareness – Weather Condition Application, Situational Awareness Suboptimal Road Segment Conditions Applications and RWINFO for Freight Use Case if applicable and the pilot is not too far into implementation.

In summary, the key assumptions include the following:

- During the pilot design and demonstration, the number of connected vehicles is expected to be a fraction of the I-80 truck traffic. However, as the rate of connectivity grows, the system needs to be able to work with new on-board units on vehicles as they come on board. This necessitates a strong adherence to standards so that vehicles equipped with DSRC and on-board units are able to receive information from the infrastructure.
- Road weather forecasts by segment still will likely rely on a human meteorologist who is able to assimilate disparate datasets to generate a travel advisory. This does not apply for current observations or short-term alerts of impending conditions which may be based on reported conditions by connected vehicles directly.
- Cost-effective real-time monitoring of truck parking availability across the state of Wyoming can be accomplished through crowdsourcing interface in the WYDOT 511 App to support CV Pilot objectives. Due to budget constraints and project scope, equipping parking facilities with availability monitoring systems was not considered.
- USDOT-developed Security Certificate Management System (SCMS) can support secure communications as part of a larger security management framework developed for the proposed system. Evaluation is ongoing to select the PoC SCMS from CAMP or a commercial SCMS that will provide continued availability after the end of Phase 3.
- The USDOT developed ODE software is compatible with the 2016 version of J2735 and J2945/1 as well as the current version of the SCMS and the current version of the RSU specification. Additionally, the ODE is adequately scalable to support a 400-vehicle pilot.
- The USDOT developed Situational Data Clearinghouse is compatible with the 2016 version of J2735 and J2945/1 as well as the current version of the SCMS and the current version of the RSU specification. Additionally, the clearinghouse is adequately scalable to support the Wyoming pilot of about 400 additional vehicles.
- While CAN bus information is notoriously difficult to acquire due vehicle manufactures using different and proprietary codes sets, this pilot will attempt to use the standard CAN bus information on WYDOT snow plows to collect information on steering wheel angle, brake status, air bag deployment, traction control, antilock brake status and transmission status. If standard CAN bus messages are not being used for these features, manufactures will be asked to provide this information, but the pilot team does not plan for high success with getting cooperation from the manufactures. While this information is helpful it is not required to the overall operation of the pilot.

1.5 List of Acronyms, Terms Used

The acronyms used in this document are listed in Table 1-1.

Table 1-1. List of acronyms.

Acronym	Definition
AC	Actual Costs
ADP	Application Deployment Plan
ADS	Application Development Schedule
AOR	Agreement Officer's Representative
BSM	Basic Safety Messages

Acronym	Definition
CAN bus	Controller Area Network
CAP	Comprehensive Acquisition Plan
CIP	Comprehensive Installation Plan
CMOP	Comprehensive Maintenance and Operations Plan
ConOps	Concept of Operations
COR	Contract Officer's Representative
COTS	Commercial-off-the-shelf
CPI	Cost Performance Index
CV	Connected Vehicle
CVOP	Commercial Vehicle Operator Portal
DB	Data Broker
DMP	Data Management Plan
DMS	Dynamic Message Sing
DN	Distress Notification
DOP	Deployment Outreach Plan
DPP	Data Privacy Plan
DSRC	Dedicated Short Range Communications
DW	Data Warehouse
ESS	Environmental Sensor Stations
EV	Earned Value
FAQ	Frequently Asked Questions
FCW	Forward Collision Warning
FHWA	Federal Highway Administration
GIS	Geographic Information System
HMI	Human-Machine Interface
HSM	Hardware Secure Module
HUAS	Human Use Approval Summary
I-80	Interstate 80
I2V	Infrastructure to Vehicle
IE	Independent Evaluator
IORS	Installation and Operational Readiness Testing Schedule
IRB	Institutional Review Board
IT	Information Technology
ITE	Institute of Transportation Engineers
ITIS	Integrated Transport Information System
ITS	Intelligent Transportation Systems
MoU	Memorandums of Understanding
NCAR	National Center for Atmospheric Research
NWS	National Weather Service
OBU	On-Board Units
OCSP	Operational Capability Showcase Plan
ODE	Operational Data Environment
OIS	Outreach Implementation Schedule
ORP	Operational Readiness Plan
OSADP	Open Source Application Development Portal
PA	Pikalert System
PII	Personally Identifiable Information

Acronym	Definition
PIO	Public Information Office
PMESP	Performance Measurement and Evaluation Support Plan
PMESS	Performance Measurement and Evaluation Support Schedule
PMP	Program Management Plan
PTEP	Participant Training and Education Plan
PV	Planned Value
RCRS	Road Condition Reporting System
RSU	Roadside Units
RTM	Requirements Traceability Matrix
RWIS	Road Weather Information Systems
SAD	System Architecture Document
SCMS	Security Certificate Management System
SDD	System Design Document
SDO	Standards Development Organization
SDW	Situational Data Warehouse
SOMS	System Operations and Maintenance Schedule
SOP	Standard Operating Procedure
SP	Standards Plan
SPI	Schedule Performance Index
SV	Schedule Variance
SWIW	Spot Weather Impact Warning
SXSW	South by Southwest Interactive
SyRS	System Requirements Specification
T&E	Training and Education
TIM	Traveler Information Messages
TIS	Training Implementation Schedule
TMC	Transportation Management Center
TRAC	Transportation Reports and Action Console
TRB	Transportation Research Board
UAT	User Acceptance Testing
USDOT	U.S. Department of Transportation
UW	University of Wyoming
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
VSL	Variable Speed Limits
WBS	Work Breakdown Structure
WTI	Wyoming Traveler Information System
WYDOT	Wyoming Department of Transportation
WZW	Work Zone Warning

1.6 Organization of the Report

The remainder of this document is organized as follow:

- Section 2 describes the Wyoming CV Pilot, summarizing its objectives and deployment characteristics.
- Section 3 details the deployment approach for Phase 2, presenting information ranging from the program management plan of the project to the maintenance and operation plan.
- Section 4 details the deployment approach for Phase 3, presenting information ranging from the program management plan of the project to transition planning and standard development.
- Section 5 provides the deployment schedule, including supporting information on acquisition and installation of equipment.
- Section 6 presents the team organization and key personnel.
- Section 7 summarizes the projected cost estimates at a high-level of each task.
- Section 8 lists the references used in this document.

2 Deployment Concept

Section 2 documents the deployment scope, location, needs, partners and conceptualization of the system that will be built in Phase 2 and demonstrated in Phase 3.

2.1 Deployment Vision

The pilot will develop applications that use vehicle-to-vehicle (V2V) and infrastructure-to-vehicle[1] (I2V), connectivity to support a flexible range of services such as advisories, roadside alerts, and dynamic travel guidance. Information from these applications is made available directly to the equipped fleets or through WYDOT's existing traveler information sources.

Key to WYDOT's deployment vision is integration of CV technology with existing Transportation Management Center (TMC) operations. Data collected from the equipped vehicles not only support in-vehicle applications but also enable better traffic and incident management along the I-80 corridor. For example, conditions reported from connected vehicles will enable better setting of variable speed limits along the corridor. On the other hand, integration with existing TMC resources like construction, parking, and road condition reporting enable transmission of timely situational awareness alerts to the equipped vehicle.

By relying heavily on standards, especially in defining message sets, WYDOT's vision is focused on the future. As more and more vehicles equipped with DSRC connectivity become available, the true vision of WYDOT is that any connected vehicle on I-80 could benefit from the applications developed as part of the pilot, regardless of the make and model of the vehicle or the on-board unit.

2.2 Deployment Scope

WYDOT will develop systems that support the use of Connected Vehicle (CV) Technology along the 402 miles of Interstate 80 (I-80) in Wyoming. 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

[1] For this pilot, the terminology *Infrastructure to Vehicle* (I2V) takes into account its complementing direction of communication *Vehicle to Infrastructure* (V2I).

have the functionality to broadcast Basic Safety Messages (BSM) and will include a human-machine interface (HMI) to share alerts and advisories to drivers of these vehicles. A portion of the equipped vehicles will have additional capabilities, such as collecting environmental data through mobile weather sensors.

- **Develop several V2V 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.

In addition, the scope includes support for the performance management and evaluation, outreach, training, systems engineering and program management necessary for delivering the CV Pilot elements.

2.2.1 Deployment Location

The following sections summarize the location-specific details of the deployment.

2.2.1.1 Field Deployment

The pilot focuses on I-80. As such, RSUs will be installed at various locations along the interstate based in part on a statistically driven approach to identify hotspots and subsequently target RSU locations upstream of that location. It is anticipated that two RSUs will be placed at every selected location. Two reasons for this: 1) for the notification to be early enough in each direction; and 2) because I-80 is a divided highway with a very large distance between East and West bound at many places, which may not be covered by a single RSU.

Approach to identifying RSU locations.

- Perform a site analysis where various factors will be considered such as average daily traffic (ADT), Truck %, weather condition, roadway geometry, interchange/ramp density, existing ITS technologies (e.g., VSL and DMS)—some low speed locations will also be selected to provide more touch time with the vehicles.
- Once potential sites are identified, the RSU locations will be determined by the spatial and temporal implications of positioning the RSUs in advance of hazardous hotspot.

The selection of RSU locations is typically constrained by communications, power, and line-of-sight capabilities, amongst other project-needs factors. Other project needs include the need to collect data, perform OTA updates and might require RSU locations where vehicles congregate (snow plow garages, truck parking, port of entries, etc.).

I-80 contains significant ITS instrumentation along the corridor such as DMS signs, cameras, VSL signs and RWIS. All of them have adequate back-haul communications with WYDOT TMC. Therefore, WYDOT foresees no issues with identifying suitable locations. The cost of installation, however, might vary depending on what infrastructure is present at desired RSU sites.

In addition, RSU locations also include strategically identified locations such as the ports of entry to Wyoming, key interchanges on I-80, WYDOT vehicle barns, and in-service areas/parking locations.

2.2.1.2 Vehicle Locations

The approximately 400 equipped vehicles are based in a variety of locations. Specifically, WYDOT fleet vehicles are located along I-80 in various cities, with Cheyenne and Laramie being the cities of critical interest. Vehicles belonging to several of our fleet partners (identified in the Section 2.2.3) are based in Wyoming as well, but some vehicles from our fleet partners could be based in other states. Nonetheless, all vehicles involved in the pilot are frequent travelers of I-80 in Wyoming.

2.2.1.3 Back-Office Location

All back-office functionality and systems will be managed from WYDOT's Geographic Information System (GIS) and Intelligent Transportation System (ITS) Program (GIS/ITS), located in Cheyenne, Wyoming and co-located at the Transportation Management Center (TMC).

2.2.2 Deployment Needs

The Concept of Operations (FHWA-JPO-16-287) defined specific user needs for various entities that will be involved in the corridor that have been used to drive requirements. The following graphic provides a high-level summary of the user needs that drive our CV Pilot (Figure 2-1).

Figure 2-1. Summary of Deployment User Needs. Source: WYDOT.

2.2.3 Deployment Team and Partners

WYDOT will lead the deployment team for Phase 2 and Phase 3. Our deployment team and partnerships are defined in Figure 2-2; they are distinguished by the nature of engagement that WYDOT expects to have with the entity for the pilot. Four types of partnership agreements are envisioned as part of the pilot:

- Intra-agency agreements that define various roles and responsibilities for WYDOT departments.
- Memorandums of Understanding (MoUs) with freight partners who will participate in the pilot.
- Contractual agreements to support the program development, systems integration and training needs.

- Vendor Purchase Agreements that will be initiated to procure equipment for the CV Pilot.

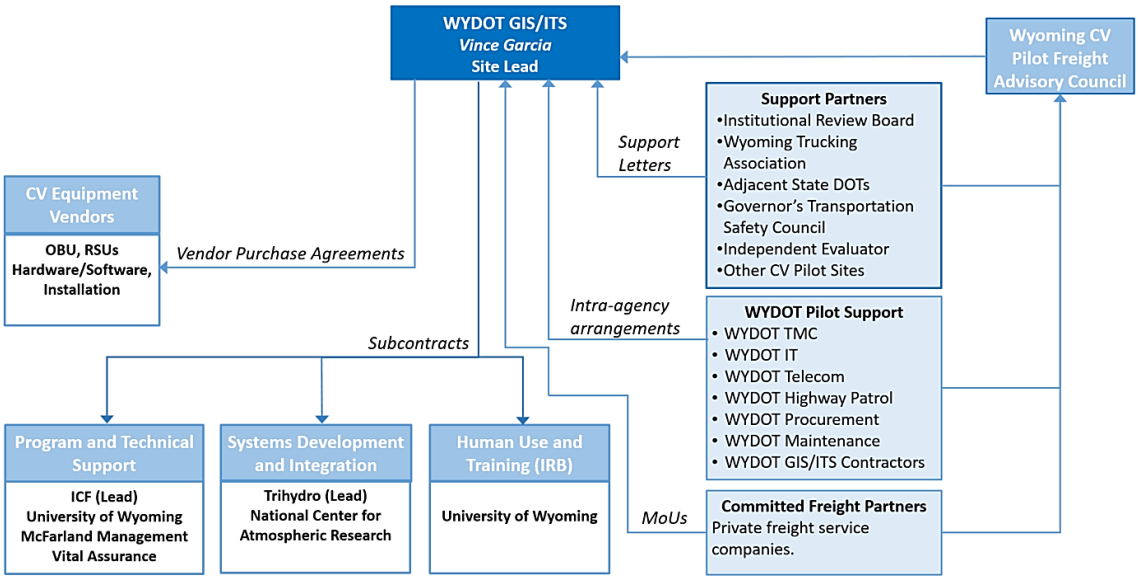

Figure 2-2. Deployment Partnership. Source: WYDOT.

2.2.3.1 WYDOT

Led by the WYDOT Geographic Information System (GIS) and ITS group, WYDOT expects several of their departments to be heavily involved in the pilot including:

- Traffic Management Center Personnel
- Telecommunications
- Highway Patrol
- Maintenance
- ITS Maintenance
- Information Technology (IT)
- Planning
- Contracts/Procurement
- GIS/ITS Contractors

2.2.3.2 Subcontractors

In addition, WYDOT has assembled the team that successfully completed Phase 1 and has added new members to the team to support the design, development, and demonstration phases. Details on staffing are provided in Volume 1–Part II of the application, but WYDOT plans to issue three contracts to support the pilot. Letters of commitment from each contractual lead are provided in the cost volume.

- **Program and Technical Support Contract** – Three contracts will be issued to a team led by ICF International, who led Phase 1 of the Pilot. ICF will provide overall program management support and support to various systems engineering tasks and lead the performance management, evaluation, and outreach activities. Program and Technical Support services in addition to ICF includes:

  - University of Wyoming (Directly Contracted with WYDOT, technical scope of work overseen by ICF)[2] – will support the performance management and evaluation of the CV Pilot system in Phase 2 and Phase 3.
  - McFarland Management (Directly Contracted with WYDOT, technical scope of work overseen by ICF) – will coordinate all performance management and evaluation activity for the pilot.
  - Vital Assurance (sub-contractor to ICF) – a new addition to the team. Vital Assurance is a group of consultants that includes Dr. Denny Stephens, a national expert in development, field deployment, testing and demonstration of connected vehicle technology in commercial vehicles and automobiles. Dr. Stephens will be instrumental in defining the system architecture, system design and testing approaches for the Phase 2 pilot.

- **Systems Development and Integration Lead –** WYDOT intends to issue a contract to Trihydro, a Phase 1 team member. Led by our systems integration lead, Trihydro staff will be responsible for system design, application development, testing during Phase 2 and monitoring of systems operations in Phase 3. Trihydro will include one additional firm:
  - National Center for Atmospheric Research (NCAR) – will help develop the weather-related application portions for the CV Pilot, including integrating the Pikalert® System with the overall CV Pilot.
- **Human Use and Training Lead –** WYDOT will maintain safety and security of all participants involved in the pilot and is committed to ensuring strict adherence to human use guidelines developed in Phase 1. WYDOT intends to contract directly with the University of Wyoming to support human use approvals and trainings. While UW will be a subcontractor to WYDOT (Lead Agency), who will supervise their work, UW will serve as the oversight agency of all Human Use activities (the IRB of record). Before dealing with human subjects, UW will ensure having agreements with all project partners. This, and all agreements, are discussed in the Partnership Status Summary document. This contract will include amendments to the Institutional Review Board (IRB) but also will support the testing and training of CV Pilot elements using the university truck and car simulators.

2.2.3.3 Vendors

In addition to these contracts, WYDOT intends to procure all the equipment necessary for the pilot. As part of the application, WYDOT has reached out to various vendors and used their initial estimates to build the cost model for the pilot. WYDOT expects the following equipment and technology to be procured through WYDOT procurement guidelines in Phase 2 of the pilot.

- On-Board Units – several types of units being procured from one or more vendors. OBU procurement also will include support costs and some installation costs; might also include costs for supporting equipment such as cabling, tablet interfaces, and antennas. OBU vendors are being requested to supply hardware and software with a three-year support contract. All custom software paid for by the pilot will be posted on the Open Source

[2] Both UoW and McFarland Management are directly contracted with WYDOT to minimize the overhead, fees and sub-admin costs that will arise out them being a subcontractor to ICF. UoW as a state entity has a lower indirect burden for public agencies allowing for cost efficiencies.

Application Development Portal (OSADP) using an Apache 2.0 license. Software included with the hardware will remain the intellectual property of the supplying vendor.

- Roadside Units – vendors are being requested to supply hardware and software with a three-year support contract. All custom software paid for by the pilot will be posted on the Open Source Application Development Portal (OSADP) using an Apache 2.0 license. Software included with the hardware will remain the intellectual property of the supplying vendor.
- Mobile Weather Sensors – vendors are being requested to supply hardware and software with a three-year support contract. All custom software paid for by the pilot will be posted on the Open Source Application Development Portal (OSADP) using an Apache 2.0 license. Software included with the hardware will remain the intellectual property of the supplying vendor.
- Support for Third-Party Integration –includes anticipated costs to support integration of CV Pilot data by external third parties (DriveWyze, Omnitracks, Inrix, etc.).
- Hardware/Software Development – to support back-office systems including data warehouses, databases.
- Installation Support Contracts – for installation of RSUs and OBUs.

2.2.3.4 Fleet Partners

Fleet participation is critical to the success of the project. Participation includes making vehicles available for on-board equipment installation, subscriptions to WYDOT's commercial vehicle operator portals, training, and participation in performance measurement activities.

With the IRB approval, WYDOT has made great progress in lining up fleet partners for the pilot. WYDOT is seeking a diversity of trucking firms to participate in the pilot starting with small local firms to large national carriers. The response from the trucking community with whom WYDOT has spoken about the pilot applications has been strong and positive. Currently, letters of support have been obtained from the Wyoming Trucking Association as well as from the several potential fleet partners. MoUs

- Dooley Oil Transport – A family owned and operated petroleum distributor based in Laramie, Wyoming. They will be installing the On-Board Units (OBUs) in up to 20 vehicles that are frequent users of I-80.
- Trihydro – In addition to their participation in the system development, Trihydro offers up to 15 small trucks that frequently travel the corridor for installation of OBUs.
- Double D Distribution – Specializes in transporting a variety of productions, including oil, potable water, magnesium and calcium chloride water, dry freight, refrigerated freight and other materials. They plan to install equipment on up to 10 vehicles that frequently travel on I-80.
- NorthPark Transportation – Provides overnight transportation services to more than 500 communities in Colorado, Wyoming, Utah, Montana, South Dakota and Nebraska. They plan to install equipment on up to 13 vehicles that frequently travel on I-80.

WYDOT fully anticipates that this list of fleet partners will grow. WYDOT continues to engage major freight distribution partners in the region including Lowes and Walmart. WYDOT expects to get letters of support from one or more national firms that will transition to MoUs very shortly. WYDOT has also received letters of support from the Wyoming Trucking Association and the Governor's Transportation Safety Council who will assist in outreach activities for the pilot. Together, WYDOT is confident that it can identify the 150 trucks that will be instrumented for this pilot. In addition, WYDOT's CVOP subscription base includes 800 firms and continues to grow.

2.2.3.5 Support Partners

The Wyoming CV Pilot will also interact with external entities. As explained in Section 1.4, the CV Pilot will interact with USDOT and other supporting contractors, which will play significant role in this project. USDOT participation incudes the provision of several USDOT-developed interfaces necessary for the deployment of the system's applications (e.g., ODE, SDW and SCMS). Additionally, USDOT will hire an Independent Evaluator who will be in charge of providing independent evaluation of the CV Pilot System. The Wyoming CV Pilot also seeking support from the University of Wyoming Institutional Review Board (IRB), adjacent State DOTs and trucking associations as part of the pilot.

2.2.3.6 Wyoming CV Pilot Freight Advisory Council

With an eye towards the post-pilot operations, Wyoming DOT is intending to set up a new freight advisory council to provide advisory support for the pilot. The freight advisory council consists of representatives from WYDOT, fleet partners who are participating in the pilot, local freight stakeholders who use CVOP, Transportation Safety Council, and the Wyoming Trucking Association (WTA). Wyoming DOT anticipates that the freight advisory council will meet quarterly starting in Phase 3. As the project progresses, the advisory council will support WYDOT in the post pilot transition planning assisting in setting priorities for application updates, and supporting growth in number of fleets that have access to this technology.

2.3 Deployment System Details

The following sections describe the system that will be developed as part of the CV Pilot.

2.3.1 Overview

The CV Pilot is considered a System of Systems, with two of interest: The *Vehicle System* and the *Wyoming CV System* (see Figure 2-3).

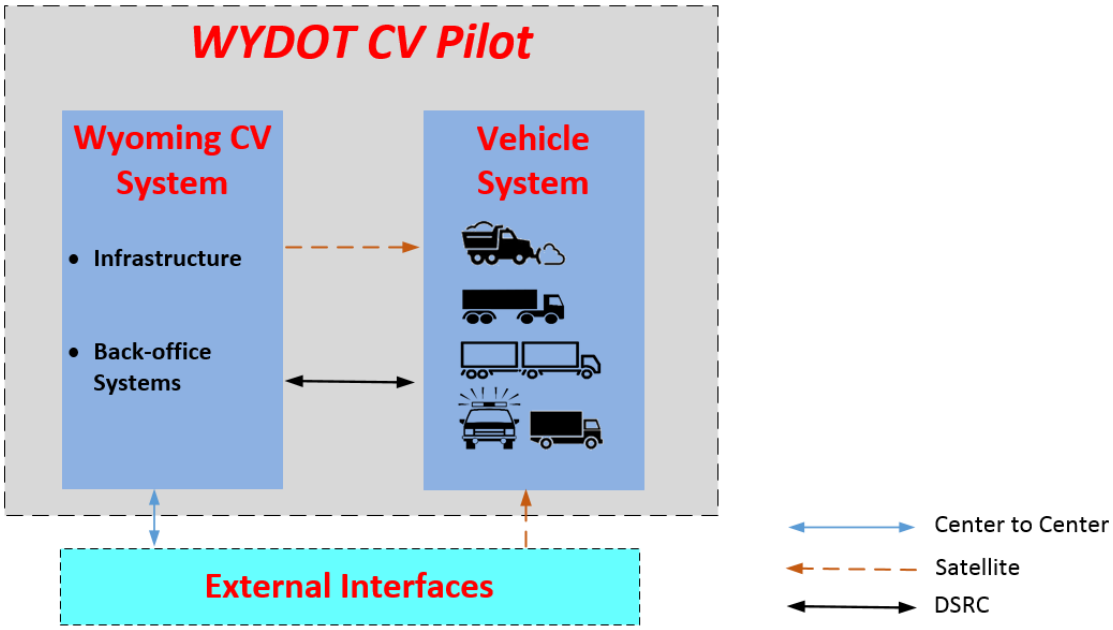

Figure 2-3 Wyoming CV Pilot System of Systems. Source: WYDOT.

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Intelligent Transportation Systems Joint Program Office

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 I2V applications. Both systems interface with external systems, including WYDOT, USDOT and the National Weather Service (NWS) systems.

The following sections describe each major system, the external interfaces, and the applications that will be developed as part of the pilot.

2.3.2 System Capabilities

This section describes functions to be performed by the *Vehicle System* and the *Wyoming CV System*. The *Vehicle System* will perform eight functions:

1. Collect CV Data – Connected vehicles wirelessly receive BSMs from other connected vehicles.
2. Collect TIMs – Wirelessly receives packets containing traveler information from the *Wyoming CV System* and distress information from other connected vehicles.
3. Manage and Process Information for Applications – Manages and processes information for the five on-board applications.
4. Provide In-Vehicle Application Alerts – Provides prioritized alerts and advisories for the Vehicle Operator.
5. Broadcast Vehicle Data – Broadcasts, at a predefined rate, vehicle information (BSMs and DNs) to other connected devices and to the *Wyoming CV System*.
6. Transmit Vehicle Data – Transmits vehicle data to the *Wyoming CV System*. The transmission includes event logs and DNs (including those of other connected vehicles).
7. Store Data – Locally stores selected data collected and generated (both from the field and the applications) until they are transferred to the *Wyoming CV System*.
8. OBU Management – Logs availability and operational capability, including validating and obtaining certificates, time and location accuracy, logging system information, and routine wellness check.

The Wyoming *CV System* performs six functions:

1. Collect CV Information – Collects data from the *Vehicle System*. Data collected includes BSMs Part I and Part II, event logs, other data (e.g., weather sensors), and distress messages.
2. Generate Road Weather Alerts and Advisories – Generates segment-level advisories and alerts of both current and forecast road and weather conditions based on customizable thresholds.
3. Support Information Brokerage – Distributes Road Weather Alerts and Advisories to the WYDOT's interfaces.
4. Distribute TIMs – Distributes the TIM to the *Vehicle System* and the Situational Data Warehouse.
5. Store Data – Data generated are stored by the system.

6. Manage and Maintain System – The WYDOT Maintenance team monitors the system for availability and operational capabilities.

In addition to on-board vehicle applications, information generated by the Wyoming CV System is expected to be used to support WYDOT traffic management and traveler information. WYDOT expects to use the information from the pilot for the following purposes:

- **Setting and removing VSL along the I-80 corridor –** VSLs will be managed through the Wyoming Traveler Information (WTI) interface. When segment-level alerts and advisories are received from the *Wyoming CV System* in WTI, the TMC operator will have the option to reduce speed according to the normal operation protocols. Similarly, when speed limits are reduced due to information available from the TMC, this information will be communicated with the *Wyoming CV System* and shared as part of the TIM. The VSL zones utilize changeable yet enforceable speed limits in 143 miles along four (4) segments – 23 miles around Evanston, 25 miles around Green River, 57 miles along Elk Mountain and 47 miles between Cheyenne and Laramie.
- **Supporting 511 and other traveler information** – Road weather collected by the Wyoming CV System will be ingested into and processed by the Pikalert system for dissemination to the public. In addition, incident information collected by the CV system will be used to directly update the WTI. The WTI system, upon database saves, has the integrated logic to automatically update the 511 systems (web, phone, email/text messages, app) in near real time.
- **Supporting road weather advisories and freight-specific travel guidance through CVOP** – Information from the *Wyoming CV System* will update the CVOP system to provide freight-specific information to subscribed fleet partners. Currently, more than 800 firms subscribe to CVOP.

The functional architecture view describes the abstract functional elements or processes and their logical interactions via data flows that satisfy the system requirements. Figure 2-4 depicts the functional diagram of the Systems of Interest along with the external interfaces that interact with the CV Systems. Section 2.3.4 describes in more detail the internal and external interactions of each system.

2.3.3 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
- Hardware Security Module (HSM)
- Pikalert System
- Data Broker (DB)
- Data Warehouse (DW)

2.3.3.1 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.

2.3.3.2 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.

2.3.3.3 Hardware Security Module

The Wyoming CV Pilot uses the IIS/GHS[3] rented, black box hardware security module (HSM) in the Cheyenne TMC. In essence, the HSM will manage the Wyoming CV System's certifications. It has a Representational State Transfer (RESTful)[4] endpoint that receives an unsigned TIM and outputs a signed TIM. The HSM also has a link to the ISS/GHS Certificate Management System (CMS) to get updated certifications. It should be noted that its internal workings are a black box that is proprietary code, and therefore WYDOT will not have access to it. WYDOT will physically have two 1U rack[5] units that each have dual power supplies and are fail over in capability. The units also have a gig Ethernet connection with IPv4 and IPv6.

2.3.3.4 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.

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[3] IIS/GHS is the company hosting the pilot's certificate management system (i.e., INTEGRITY Software Services/Green Hills Software).

[4] https://en.wikipedia.org/wiki/Representational_state_transfer

[5] Rack height unit 1.75" (https://en.wikipedia.org/wiki/Rack_unit)

2.3.3.5 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.

2.3.3.6 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.

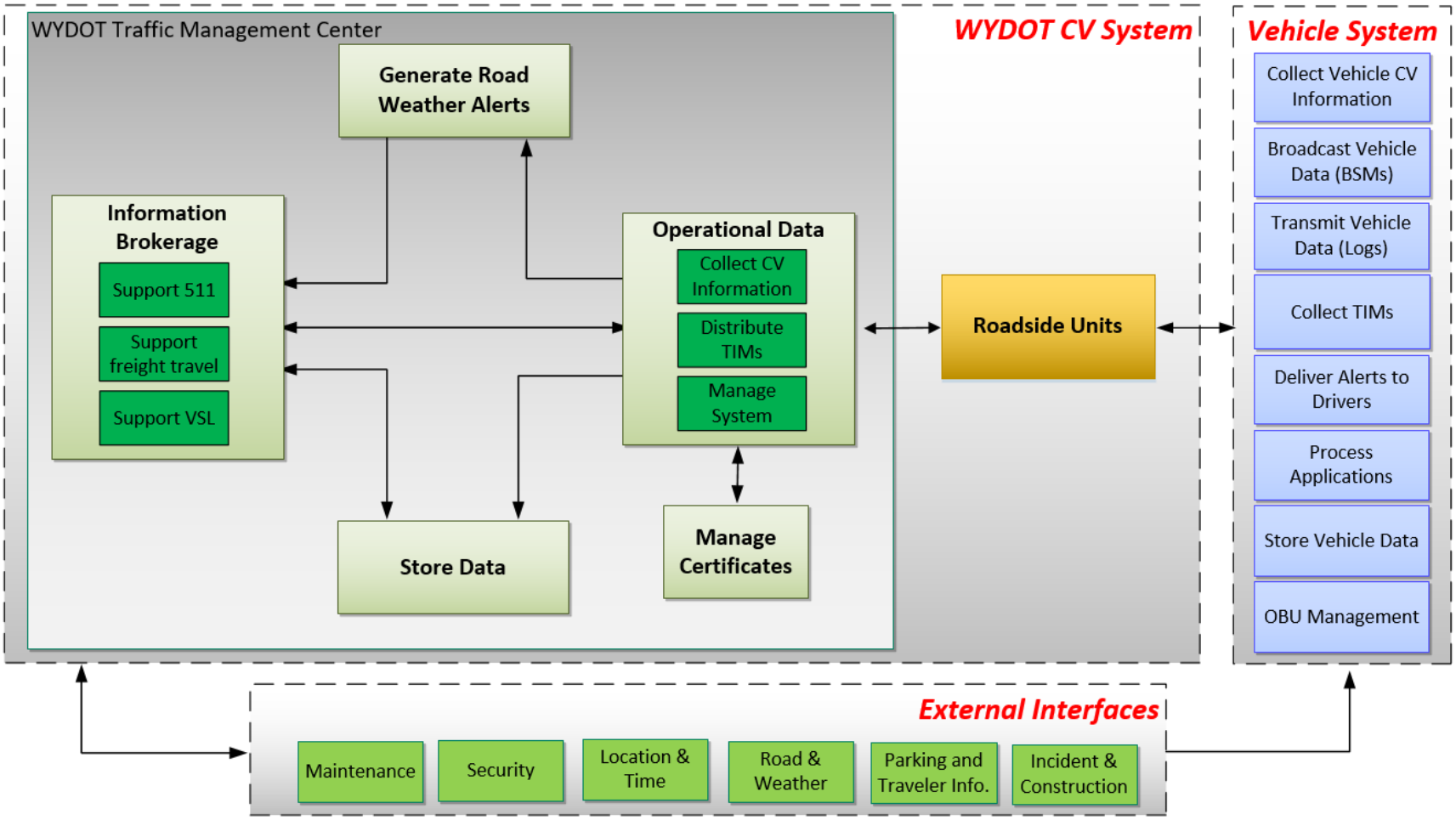


Figure 2-4. Functions of the Wyoming CV System and the Vehicle System. Source: WYDOT.

2.3.4 Wyoming CV System External Interfaces

Figure 2-5 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.[6]

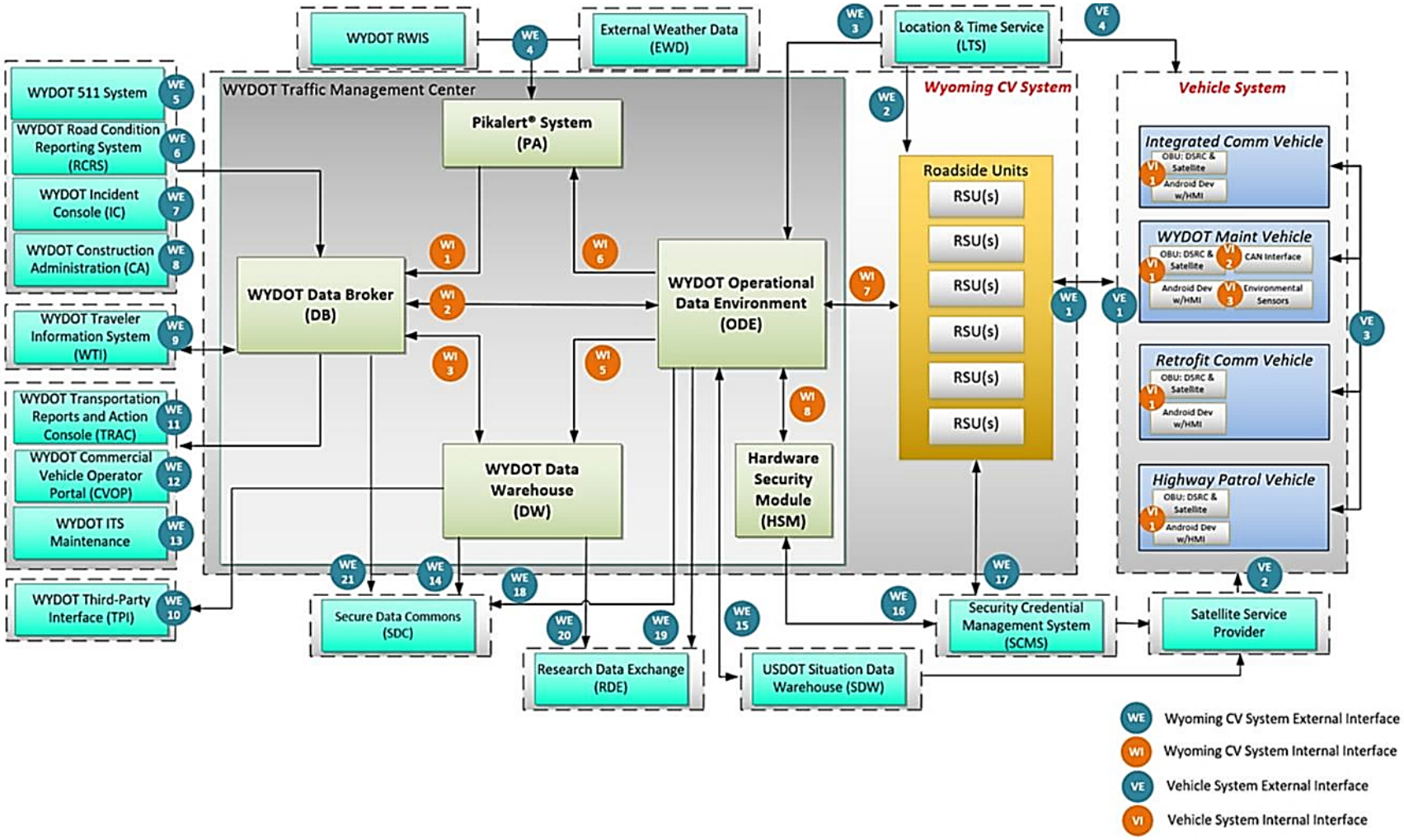
- **I2V DSRC Communications Interface** (Interface WE1) Wireless DSRC interface provides communication between Wyoming CV System and Vehicle System through exchange of messages conforming to SAE J2735 and SAE J2945/1.
- **Location and Time Service (LTS)** (Interfaces WE2 and WE 3) – Provides location and time information, which is later used to geotag and timestamp all information produced by the systems of interest.[7]
- **EWD and RWIS** (Interface WE4) – EWD provides regional weather data shared through data sources outside of WYDOT, such as the National Oceanic and Atmospheric Administration's Meteorological Assimilation Data Ingest System and USDOT. **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).
- **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

[6] 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.

[7] The location is obtained from a GPS using WGS-84 coordinates system, and time is provided using UTC from GPS time.

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.
- **Secure Data Commons (SDC) / Research Data Exchange (RDE)** (Interfaces WE14, WE18, WE19, WE20, and WE21) **–** Provides WYDOT CV Pilot data to the independent evaluators and the RDE 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.



NOTE: The Wyoming CV System Interface WI4 (PA→DW) was not implemented in the final system design.

Figure 2-5. Physical View of WYDOT CV Pilot System Architecture with Numbered Interfaces. Source: WYDOT.

2.3.5 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.
- 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 four Sub-Systems, which define the various vehicle types for this pilot based on their data collection, communication capabilities and fleet/vehicle type. Each Sub-System and its rationale are described below.

2.3.5.1 WYDOT Maintenance Vehicles

This Sub-System represents the maintenance fleets operated by WYDOT. This includes, but is not limited to, 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, some of the vehicles will be equipped with the full package of environmental sensors and equipment necessary to support the CV Pilot applications.

Around 95 vehicles are expected to be part of this sub-system, but not all with the same capabilities. Al vehicles will have the ability to:

- Receive TIMs via DSRC and Satellite.
- Broadcast BSM Parts I and II.

Whereas 50 of them are expected to be able to:

- Collect weather sensor data.

All vehicles within this subsystem will have the capability to integrate its network via a Controller Area Network (CAN bus) connection. Although it should be noted that the actual number of vehicles to have this connection is expected to be a limited and will be determined at a later stage of deployment.

2.3.5.2 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 35 highway patrol vehicles are expected to be part of this sub-system, which will have the ability to:

- Receive TIMs via DSRC.
- Broadcast BSM Parts I and II.

2.3.5.3 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. Similar to Highway Patrol Vehicles, no external weather sensor data will be collected from these systems (i.e., only data from the vehicle) and there is not CAN Bus integration. To summarize, this Sub-system will include the abilities to:

- Receive TIMs via DSRC and Satellite (or other remote communication methods).
- 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 250 trucks will have this functionality.

2.3.5.4 Retrofit Commercial Vehicle

This Sub-system is intended to simulate a commercial-off-the-shelf system—which is different from the one installed on the integrated commercial vehicles—that enables a vehicle to communicate data through DSRC to other connected devices and receive TIMs through DSRC or satellite. About 25 vehicles are expected in this category and their abilities include:

- Receive TIMs via DSRC and Satellite (or other remote communication methods).
- Broadcast BSM Parts I and II

2.3.6 Pilot On-Board Applications

The WYDOT CV Pilot will develop five on-board applications that will provide key information to the drivers of equipped vehicles. In addition to on-board applications, information generated by the *Wyoming CV System* is planned to support ongoing WYDOT traffic management and traveler information services. WYDOT expects to use the information from the pilot for:

- Setting and removing VSLs along the I-80 corridor.
- Supporting 511 and other traveler information.
- Supporting road weather advisories and freight-specific travel guidance through WYDOT's CVOP.

The following subsections provide a view of the applications to be developed as for this Pilot.

2.3.6.1 Forward Collision Warning (FCW)

FCW 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 as illustrated in Figure 2-6. FCW will help drivers avoid or mitigate front-to-rear vehicle collisions in the forward path of travel. This application is critically important for safety along I-80 in conditions when snow plows are moving slower than following traffic and/or when visibility may be limited due to adverse weather. The application does not attempt to control the host vehicle to avoid an impending collision. This application will follow the description from standard SAE J2945/1 March 2016 Section 4.2.4.

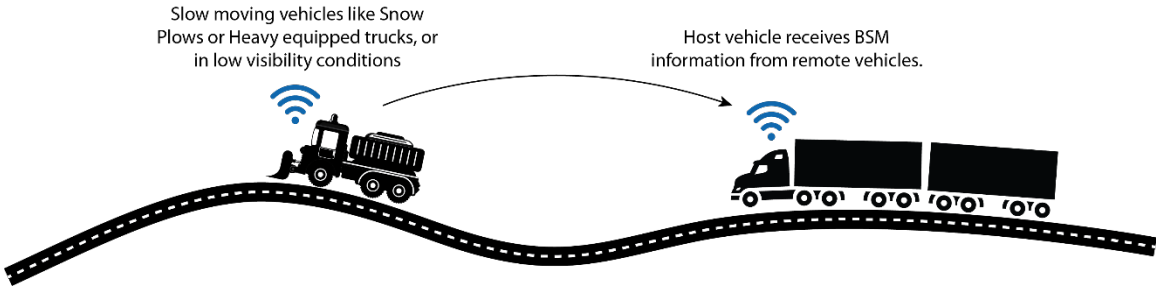


Figure 2-6. Forward Collision Warning Concept Diagram. Source: WYDOT.

2.3.6.2 Infrastructure-to-Vehicle (I2V) Situational Awareness

One of the important promises of Connected Vehicle technology is the delivery of up-to-date travel information to drivers that impact their safety and mobility. The WYDOT CV Pilot will implement an I2V Situational Awareness application that assembles important travel information from back-office systems and communications that directly to drivers through both DSRC and satellite communications. This application enables delivery of relevant downstream road condition information to drivers along I-80 in Wyoming, including: Weather alerts, Speed restrictions, Vehicle restrictions, Road conditions, Incidents ahead, Truck parking[8], and Road closures.

This information is expected to enhance both safety and traveler mobility along the corridor. The generic application is illustrated in Figure 2-7. It should be noted that the 402 miles of Wyoming I-80 is too long to provide cost effective DSRC communications coverage. Accordingly, the WYDOT CV Pilot will implement satellite-based communications to send situational awareness road condition information directly to satellite enabled connected vehicles along the entire length of Wyoming I-80, when out of range of DSRC communications. This application will follow the description from SAE J3067 August 2014 Section 2.9.3.6.

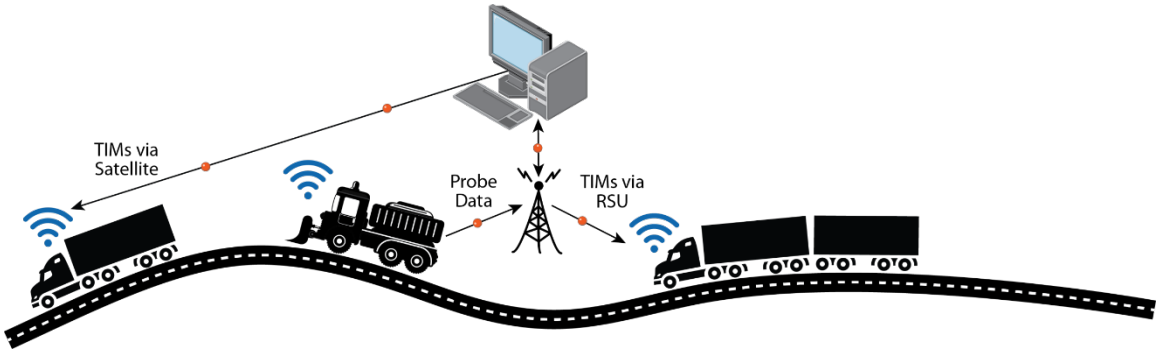


Figure 2-7. I2V Situational Awareness Concept Diagram. Source: WYDOT.

[8] As part of this project, the WYDOT CV Pilot team will update the WYDOT 511 Application for personal information devices (e.g. smartphones) to capture crowdsourced truck parking information and to share that with commercial vehicle drivers, particularly during inclement road weather conditions

2.3.6.3 Distress Notification (DN)

This application enables connected vehicles to communicate a distress status back to Wyoming CV System when the vehicle's sensors detect an event that might require assistance from others (e.g., air bag deployed, vehicle disabled) or the vehicle's operator manually initiates a distress status. The vehicle generates and broadcasts a DN (e.g., Mayday) to the nearest RSU. The DN will include the location, time of message, distress message explanation, and vehicle category. The RSU forwards it on to the *Wyoming CV System* for notification of system operators and first responders.

Recognizing that this CV Pilot cannot provide continuous coverage of I-80 by RSUs, this application includes a V2V relay of DNs, illustrated in Figure 2-8. When a distressed vehicle (#1) is not within communication range of an RSU, the message is received by nearby connected vehicles (#2) traveling in the same and/or in opposite directions. These vehicles relay the Notification to the nearest RSU, whether upstream or downstream, which forwards it on to the *Wyoming CV System*. The relay function also enables vehicles traveling the opposite direction (#2), to inform vehicles upstream (#3), traveling in the same direction as the distressed vehicle, of the need for caution ahead.

Although this application is loosely based on the Mayday application description from SAE J3067 Section 3.5.9.2.1, it is built on a higher priority TIM communication using SAE J2735 March 2016, Section 5.16, Part 3, Integrated Transport Information System (ITIS) advisory elements.

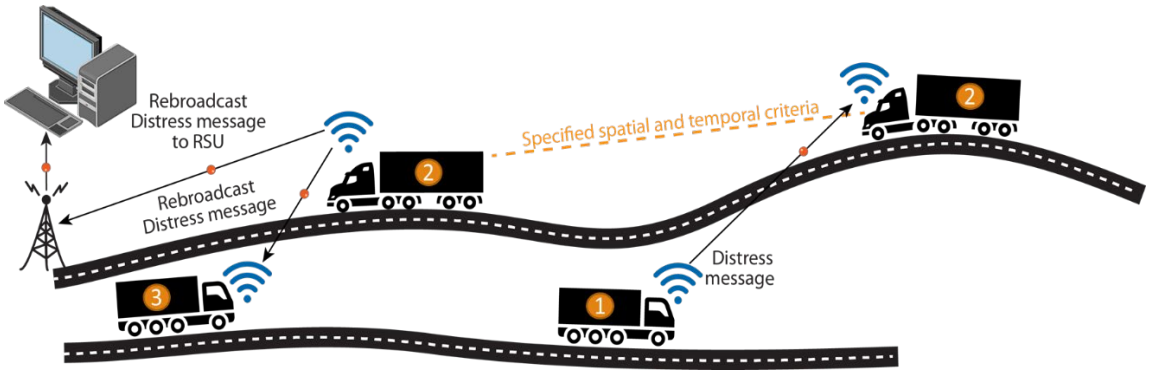


Figure 2-8 Distress Notification concept diagram. Source: WYDOT.

2.3.6.4 Work Zone Warning (WZW)

The WZW Application provides information about the conditions that exist in a work zone which the host vehicle is approaching (illustrated in Figure 2-9). This capability provides approaching vehicles with information about work zone activities that could present unsafe conditions for the workers or the host 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 WZW described in SAE J2735 March 2016 Part 3 in Section 6.142.

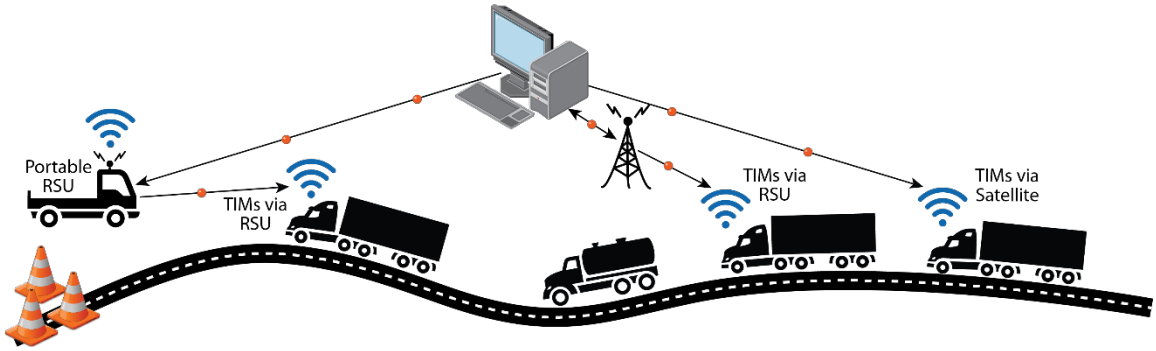


Figure 2-9. Work Zone Warning Concept Diagram. Source: WYDOT.

2.3.6.5 Spot Weather Impact Warning (SWIW)

SWIW is a special case of I2V Situational Awareness that enables hazardous road condition information due to weather, such as fog or icy roads, to be broadcast from a RSU and received by the connected host vehicles (see Figure 2-10). This application, however, is distinct from other I2V Situational Awareness applications 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 SAE J2735 Section 6.142 for ITIS data elements 6.54 for weather conditions and 6.55 for winds defined in SAE J2540_2.

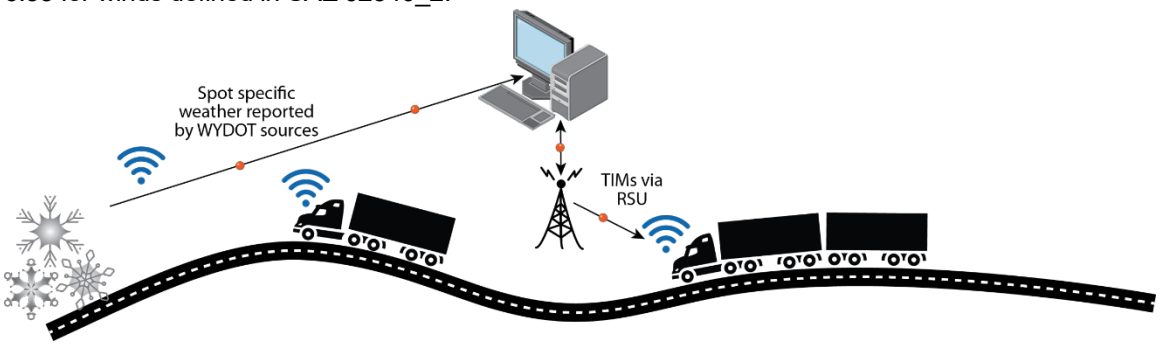


Figure 2-10 Spot Weather Impact Warning concept diagram. Source: WYDOT.

2.3.7 Expected Performance Improvements

To evaluate the Pilot, the Wyoming CV Pilot Team has identified 21 performance measures in eight (8) performance categories as shown in Figure 2-11. These eight performance categories focus on improvements to efficiency, safety, and mobility and represent the primary activities and outcomes of the Wyoming CV Pilot system, including data collection, information dissemination, alerts, and advisories shared between vehicles and roadside, improved speed adherence and reduced crash rates. The performance measures are detailed in Section 3.11.

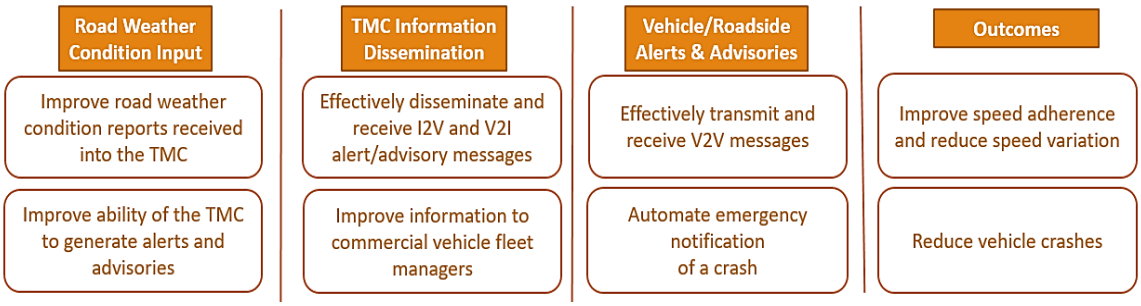


Figure 2-11. WYDOT CV Pilot Performance Measurement Categories. Source: WYDOT.

3 Deployment Approach for Phase 2

The following sections present our approach to the design and development of the CV Pilot. Our approach mirrors the task order and requirements specified in the NOFO.

3.1 Program Management – Task 2-A

Managing a multidisciplinary team of partners, engaging the broader list of stakeholders effectively, communicating, and reporting on progress with the Federal Highway Administration (FHWA), and maintaining the integrity and quality of the deployed pilot concept while adhering to scope, schedule, and cost are the primary requirements for WYDOT throughout Phases 2 and 3.

As the grant awardee, WYDOT will be responsible for successful oversight and program management throughout this task. WYDOT has experience deploying and managing projects that require development of new technology and roadside infrastructure. Most recently, FHWA awarded a Weather-Responsive Traffic Management grant for development of an app that enables snowplow operators to report road condition information directly to the public from a tablet computer mounted in snowplows. As part of the project, Wi-Fi hotspots were installed along the roadside to improve communication.

WYDOT also will rely on expertise from the team at ICF, a leading global professional services, multidisciplinary technology, policy, and management consulting firm that provides advisory and implementation services addressing today's most complex technology and policy challenges. ICF has successfully led a multidisciplinary team for Phase 1 that met USDOT technical, schedule and quality expectations.

Following Project Management Body of Knowledge guidance, WYDOT will create a Program Management Plan (PMP) for Phase 2 using the template developed in Phase 1 (Gopalakrishna, Garcia, et al. 2015). This version will describe, in each section, the sub-plans—Scope Management, Schedule Management, Communications Management, Cost Management, Quality Management, Configuration Management, and Risk Management—and the roles and responsibilities of all key individuals of the project team for Phase 2. Furthermore, the PMP will be a living document, one that will be updated quarterly throughout Phase 2, or sooner if needed.

Moving from Phase 1 to Phase 2, WYDOT recognizes the challenges involved in managing a dynamic project with an aggressive schedule to the application development and testing stages. To that end, WYDOT, supported by ICF, will ensure the team's focus on the following three key elements of the plan

- Managing Scope – As the project evolves, WYDOT and the project management lead will identify any impacts to scope early because of project activities, stakeholder needs or grant sponsor direction. The scope is controlled by the information presented in the grant award document. Modification of the scope of services can be authorized only by the USDOT Grant Officer. This authorization will be the only basis upon which scope and budget modifications are made, change orders are issued, and (if applicable) additional compensation claimed. All deliverable submissions will be sent to the ITS Projects mailbox (ITSProjects@dot.gov) in

addition to the Grant Officer's Representative. As the project progresses, USDOT will verify project deliverables against the Work Breakdown Structure (WBS) and deliverables list. USDOT will issue a written acceptance of the deliverable once they have verified that the deliverable meets the requirements defined in the project plan. All deliverables will be submitted as draft documents and reviewed by USDOT. Changes to drafts and comments will be provided in writing to the ICF Project Manager. WYDOT will revise the documents and provide a comment disposition matrix along with the final deliverable.

- Managing Schedules – The baseline schedule is included in this application. Schedule management activities include monitoring, analyzing, documenting, prioritizing, approving or rejecting, and publishing all schedule-related changes. WYDOT will create the project schedule using Microsoft Project 2013, starting with the activities identified in the project's WBS. Durations of activities and relationships among them will be estimated and assigned. WYDOT will be responsible for developing and maintaining the project schedule. Once approved, this schedule becomes the schedule baseline for the project. The resulting schedule then will be subject to control, requiring that any proposed major change be submitted for formal review and approval.
- Managing Workload and Resources – Staffing for the project is identified in the organization chart presented in Volume I, Part II. Staff requirements will be identified for each element in the WBS. By combining the hours listed in each project for staff members, utilization levels are tracked monthly allowing the ICF project manager to identify overloaded personnel on the project.
- Managing Quality – During quality planning, WYDOT identified a Quality Assurance / Quality Control (QA/QC) Lead for the project. With assistance from members of the Project Leadership team, the QA/QC Lead will identify relevant quality standards for the project and determine how to satisfy them. For this phase of the project, the quality planning standards that will be considered include, but are not restricted to, the following:
    - Documentation standards – Meeting ITS-JPO's documentation and publication guidelines including 508
    - Acceptance Standards – Meeting USDOT's acceptance criteria for all required deliverables
    - Schedule Standards – Ensuring on-time delivery of all project deliverables
    - Quality assurance review standards – Ensuring technical quality of deliverables
    - Testing standards
- Managing Cost – An Earned Value Management System (EVMS) will be used to monitor cost performance. The following four Earned Value metrics will be used to measure project cost performance consistent with Project Management Body of Knowledge guidelines:
    - Schedule Variance (SV)
    - Cost Variance
    - Schedule Performance Index (SPI)
    - Cost Performance Index (CPI)

  The SPI is defined as the ratio of Earned Value (EV) to the Planned Value (PV). EV is the total value of all project work completed to date. The CPI is defined as the ratio of EV to Actual Costs (AC). If the SPI or CPI has a variance between 10% and 20%, WYDOT will report the reason for the exception to USDOT. If the SPI or CPI has a variance greater than 20%, WYDOT will provide a detailed corrective plan to bring the project performance back to acceptable levels.

- Managing Configuration Control – WYDOT strongly believes in ensuring configuration control of all deliverables and activities produced under this task. Not only will all documents be configuration controlled through our online document sharing portals, a configuration management plan will be developed to ensure that application development occurs smoothly.
- Managing Risk – Effective risk planning involves a clear process for identifying risks, analyzing the impacts, and developing a response plan to mitigate the impact of the risk. WYDOT will follow the risk cycle rigorously throughout the project and proactively identify, analyze, plan and monitor risks.

For the entirety of Phase 2, WYDOT will maintain a high degree of communication throughout the project both internally with the project team and externally with FHWA. To kick off the Phase 2 activities, the team's key personnel will attend a kick-off meeting in Washington, DC, organized by the Agreement Officer's Representative (AOR).

To support communications throughout the Phase, a communication management plan will be established to identify what and when information needs to be shared, who needs to be informed, when the information should be communicated and who is responsible for communicating the information. The plan will identify the best communication format (i.e., face-to-face meetings, phone calls, emails and newsletters) to share information with project team members, the USDOT AOR and AOR, equipment providers, partner fleet operators, key WYDOT internal players (Traffic, Telecom, Procurement, District personnel and Executive staff) and external stakeholders such as the Wyoming Trucking Association and interested parties.

The team will create a collaboration site where all project documents will be available at different levels of access to the entire team and FHWA. The platform for the site will be decided based on the kick-off discussion with options including SharePoint, DropBox, Box, Google Docs and OneDrive. Monthly progress reports will be submitted to FHWA that include all deliverables and deliverable status, narrative of month's accomplishments by task, project activities in the next quarterly period, an updated work breakdown structure, and narratives for schedule risk, technical risk, partnership risk, retrospective cost and project cost-to-complete.

Bi-weekly progress calls with FHWA will supplement the progress reports required as part of the contract. The project management lead will attend monthly all-site coordination teleconferences as part of the contract to support coordination and collaboration among the three deployment sites.

Deliverables:

- **Kick-off Meeting**
- **Project Management Plan (PMP)**
- **Revised PMP (as required)**
- **Project Schedules (updated monthly)**
- **Monthly Progress Reports**
- **Participation in site-specific bi-weekly coordination teleconferences**
- **Participation in monthly in all-site coordination teleconferences**

3.2 System Architecture and Design – Task 2-B

In this task, the WYDOT Team will develop detailed descriptions of the systems to be deployed during the remainder of the program in terms of the System Architecture Document (SAD) and System Design Document (SDD). The overall system architecture and design task will be led by Trihydro under the supervision of WYDOT.

3.2.1 Review and Update of Phase 1 Deliverables

As a first step in the System Architecture and Design process, the team will revisit the core deliverables developed in Phase 1 and update them based on the current scope and understanding of the pilot. These updates will include the following:

- Updated system description and proposed applications
- Consistency in terms, acronyms and references
- Updated references to standards.

Although not expected to be an extensive or resource-intensive subtask, this important step ensures consistency in documentation before moving forward with significant design and development efforts. These documents will be loaded onto the project collaboration site and will be controlled through the configuration management process.

3.2.2 Systems Architecture Development

The SAD and SDD documents will leverage prior work and prior CVRIA architecture and will be developed using the SET-IT tool. To develop these documents, Visio (and PowerPoint for presentation) will be used for high level representations of the Systems of Systems, Systems and in some cases for Sub Systems. SET-IT will be used for the more detailed interactions between Sub Systems, Components and Applications using Functional Architectures, Physical Architectures, and Communications Architectures. The objectives will be to establish a platform that supports and integrates with CVRIA and the National ITS Architecture, as well as all published and under-development ITS standards. The SAD document will follow the guidelines laid out in IEEE Standard 42010-2011 for format and content, and the SDD will follow the guidelines laid out in the IEEE1016-2009 recommended practice for SDD.

The SAD document will expand on the current system concepts defined in the Application Deployment Plan (Gopalakrishna, Garcia, et al. 2016) and System Requirements Specification (SyRS) (Gopalakrishna, Garcia, et al. 2016) documents created in Phase 1. This project will develop systems that make relevant information directly available to, and shared among, equipped fleets. Information is also shared through linkages with fleet management centers (who then will communicate it to their trucks using their own communication systems) and other external agencies and partners.

As previously mentioned, the main project objectives of the pilot to be accomplished and demonstrated are as follows:

- Deploy and operate a set of vehicles equipped with on-board units (OBU) with DSRC connectivity.
- Deploy roadside units (RSUs) with DSRC connectivity that can transmit advisories and alerts to equipped vehicles along I-80.
- Ensure adequate communications backhaul from the RSU to the WYDOT TMC
- Leverage the data provided from the equipped vehicles to develop and demonstrate a suite of V2V and V2I applications.

A detailed explanation of the Wyoming CV Pilot project can be found in *Connected Vehicle Pilot Deployment Program Phase 1, Concept of Operations (ConOps)* (Gopalakrishna, Garcia, et al. 2015).

The SAD will display multiple architecture views of the proposed system to describe the system fully for designers and stakeholders so they understand the intended system and implement it accurately. Each view describes and models the system by using block diagrams. The SAD is

expected to include the following architectural descriptions of the proposed system, which include CVRIA[9] and other descriptions the WYDOT team has found valuable from experience.

- **Enterprise Architecture View**, describing the relationships between organizations required to support the overall system architecture.
- **Functional Architecture View**, describing abstract functional elements (processes) and their logical interactions (data flows) that satisfy the system requirements.
- **Physical Architecture View**, describing the physical objects (systems and devices), their application objects, and the high-level interfaces between those physical objects. This is the most fundamental model of the architecture. Each block is a specific, tangible, physical entity in the system.
- **Communications Architecture View**, describing the communications protocols between system objects.
- **Message and Data Flow Architecture View**, describing the flow of messages (e.g., BSM and TIM) and data between elements of the system.
- **Computational Architectural View,** enumerating the computational components in the system, their location in the system, and the computational processes they perform. A computational component is a logically self-contained piece of software or process.

The approach to creating the SAD document will be to use as many pieces of the already-designed system architecture as possible. This includes reviewing and updating SET-IT diagrams created during Phase 1 to incorporate the updated System Requirements and the Application Deployment document information. These documents contain information on standards that will be used and application-specific requirements and design that will need to be incorporated into the overall system architecture design document.

A Standards Plan (SP) will be included as an attached document to the system architecture design. This SP will document all standards to be implemented and used during the pilot phase of the application development. Additionally, it will contain new and updated standards for areas where existing standards are deemed inadequate to address the pilots' technical needs/capabilities fully. Additional information on how proposed standards will be communicated/implemented is presented in the standards support task in this application.

A draft SAD document will be submitted to USDOT for review. This review will occur via a 1-day Systems Architecture Walkthrough following IEEE Standard 1028-2008 with the AOR and federal team members in the DC metro area. The review will include a Systems Architecture Workbook.

The pilot team will later update the document to address any issues raised. Once the SAD document has been finalized and accepted by USDOT, work will begin on the SDD. This document, which will be based on the SyRS document, will describe the full scope of the proposed system. Using elements from the SET-IT tool and the SAD document, detailed interfaces for hardware and software will be defined for each system component.

[9] CVRIA includes Enterprise, Functional, Physical, and Communications Views.

3.2.3 Systems Design Development

Following the completion of the SAD, the WYDOT Team will develop the System Design Document.[10] This SDD is a representation of the system and software design that will be used for capturing design information, addressing various design concerns, and communicating that information to the WYDOT CV Pilot Deployment stakeholders. The SDD will show how the hardware and software system will be structured to satisfy the requirements identified in the SyRS. It is a translation of requirements into a description of the structure and behavior of the system, the hardware and software components, the interfaces, and the data necessary for implementing the CV Pilot Deployment solution.

The SDD will provide detailed design descriptions of major system components, including

- Vehicles
- Roadside Infrastructure
- Centers
- Personnel interfaces
- Communications Infrastructure.

It will describe the internal system architecture and interfaces between system components and the external interfaces to components outside the system.

The SDD also will provide detailed design descriptions of each application identified in the pilot (see Section **Error! Reference source not found.**).

The overall approach to this SDD is based on the guidance described in IEEE Standard 1016-2009, the IEEE Standard for Information Technology – Systems Design – Software Design Description. After a draft SDD has been created and submitted to USDOT for review, the Wyoming Pilot Team will conduct a 2-day system design walkthrough following IEEE Standard 1028-2008 with the AOR and federal team members in Cheyenne Wyoming. A walkthrough workbook also will be provided to expedite the process. A revised SDD document will be created based on comments and feedback received both orally during the walkthrough and written prior to the walkthrough. This final SDD will be submitted to USDOT for verification with an accompanying comment resolution report.

Following the submission and acceptance of the final SDD, the updates to the Phase 1 Deliverables will be revisited to reflect the final SAD and final SDD, including the Concept of Operations, Systems Requirements Specifications, and Comprehensive Pilot Deployment Plan.

Deliverables:

- **Draft Systems Architecture Document (SAD)**
- **Systems Architecture Walkthrough and Workbook (DC metro area)**
- **Revised SAD with Comment Resolution Report**
- **Final Systems Architecture Document**
- **Draft Systems Design Document (SDD)**
- **Systems Design Walkthrough and Workbook (deployment site)**
- **Revised SDD with Comment Resolution Report**
- **Final Systems Design Document**

[10] The system, as currently envisioned, is described in the document *Connected Vehicle Pilot Deployment Program Phase 1, Concept of Operations (ConOps)*, ICF/Wyoming.

- **Updated Phase 1 Deliverables, at a minimum**
    - **Revised Concept of Operations**
    - **Revised Systems Requirements**
    - **Revised Comprehensive Deployment Plan**

3.3 Data Management Planning – Task 2-C

During Phase I, the WYDOT CV Pilot Team carefully considered how data would be collected, secured, and managed during Phases 2 and 3 to support performance measurement. Planning documents were prepared that define our approach; specifically, the Performance Measurement and Evaluation Support Plan (PMESP), Security Management Plan, and Human Use Plan. Other planning documents such as our Concept of Operations and Application Deployment Plan are also foundational and supportive of data collection and management approaches. Task 2C will further refine these approaches to support the development of methods and procedures, test initial systems, and implement a final set of systems that will effectively collect, secure, manage, and share the project data.

The Wyoming Team acknowledges that large amounts of varying types of data will be generated during Phases 2 and 3 activities including geolocated and timestamped vehicle and weather probe data. These data are considered a strategic asset and will be used to facilitate system performance measurement, support independent evaluation, and encourage future innovation. The handling, management, and sharing of these data are essential to the project.

Data will be collected, managed and shared utilizing the various WYDOT CV Pilot systems as illustrated previously in Figure 2-5. The appropriate data will be shared with the Independent Evaluator through the Research Data Exchange. The WYDOT team is not planning to share real-time data externally during Phases 2 and 3, but rather will provide data periodically as defined in the PMESP. The majority of the evaluation data shared will be from the WYDOT Data Warehouse which will contain a complete set of data from all other systems.

This task will develop the following three documents to guide our approach to data privacy, management, and sharing:

- Data Privacy Plan
- Data Management Plan
- Data Sharing Framework

3.3.1 Data Privacy Plan

The Wyoming CV Pilot has developed a Security Management Operating Concept (Gopalakrishna, Garcia, et al. 2015) that has been accepted by USDOT in Phase 1. This document will be used as a starting point to develop a Data Privacy Plan (DPP) in Phase 2. The DPP will contain the following sections:

- Introduction – purpose and content of document
- Approach – proposed methods to manage data and maintain privacy where needed
- Controls – technical, policy, standards, and physical controls that will be used
- Compliance – documented assurances that all team members and project participants will comply with the Privacy Management Plan
- Resources – proposed sufficient resources to ensure compliance.

The Wyoming CV Pilot will follow the USDOT guidelines in designing a system structured with Privacy by Design. With this philosophy, individual vehicles will not be tracked or identified. The WYDOT and Trihydro fleet will be an exception to this rule and will be individually identifiable for more specific needs of testing and development. They also will be equipped with environmental sensors. These two fleets also will be used for testing the systems and applications, which requires vehicle identification.

Although not part of this contract, a Privacy Management Plan will be developed by the Wyoming CV Pilot, in accordance with Wyoming State and any local laws. WYDOT is working closely with the State of Wyoming on emerging guidance and policy on privacy. These state guidelines, if ready, will inform the privacy plan. Before the DPP is finalized, the Privacy Management Plan will be completed, and the Wyoming CV Pilot will submit to USDOT a one-page Notice of Privacy.

The DPP will be initially submitted in draft form to USDOT and will be revised based on comments from USDOT into a final version for review and approval.

3.3.2 Data Management Plan

The Wyoming Team will develop a Data Management Plan (DMP). This Plan will define the data collection procedures, sources, destinations, content, and flow. Additionally, the DMP will define how the data will be protected, stored, and shared (see data framework below). The data types will include:

- System data – Data collected from the CV Pilot system, including all messages sent and received (i.e., all BSM and TIM) by each component, and respective logs, of the CV Pilot System across each communications interface.
- Non-System data – Data collected from external systems and databases necessary to support performance measurement.
- Modeling and Simulation data – Any data collected or generated by modeling/simulation for the purpose of performance measurement and system analysis.
- Survey Data – Any data collected through surveys of travelers and truck drivers for the purpose of performance measurement and system analysis.
- Interview Data – Qualitative data may be collected at various points to support the previously identified performance measures, including lessons learned and institutional issues gathered through interviews with involved personnel.

Where appropriate and defined in the Performance Measurement and Evaluation Support Plan (Kitchener, et al. 2016), data will be collected both before (baseline) and after CV technology deployment. Table 3-1 summarizes the elements of each data type listed above.

Table 3-1. Data Types and Respective Elements

Data Type	Elements
System	BSMs, alerts/advisories, RSU logs, OBU logs, Pikalert logs, TMC logs, WTI updates, crash notifications, partner fleet manager data, security breaches, mobile road weather observations, other connected vehicle alerts
Non-System	Traffic data, crash records, road closures, RWIS data, DMS logs, Construction and maintenance event logs
Modeling and Simulation	VISSIM simulation model results, UW driver simulator analysis results
Survey and Interview	Stakeholder and participant survey and interview results before and after deployment

To provide further insight into the system performance measures, modeling and simulation of the corridor will be performed as feasible within the budget limitations of the project and data availability. Driver behavior data such as speed selection, car following, and lane changing behavior will be collected from connected vehicles and driver simulator studies of connected vehicles where feasible within the scope of the project. The data will be analyzed and the results used to adjust behavior model parameters within traffic simulation software to account for connected vehicles within the simulation environment to allow for the investigation into the impacts of widespread connected vehicle deployment in the project corridor. Simulation modeling output data will be part of the data management of the project. In addition to model outputs, the developed models will also be made available.

All data referred to in Table 3-1 will be stored in the *Wyoming CV System* Data Warehouse and made available, as appropriate, to project partners and others who need access including the Independent Evaluators (after completing all IRB-required training). The Data Warehouse currently exists, but will be enhanced and expanded to address the new CV Pilot data. The DMP will provide clear operational procedures consistent with the related Phase 1 deliverables. The frequency of data collection, processing, and sharing also will be defined in the DMP.

A draft (for review) and final DMP will be provided to USDOT in Phase 2 for their approval and use in Phase 3.

3.3.3 Data Sharing Framework

The DMP will define how the Wyoming CV Pilot data will be shared with the public, USDOT and Independent Evaluator, and other interested parties. Procedures to ensure the proper handling of protected intellectual property rights and personal privacy also will be defined. A data-sharing framework will be established and documented in the DMP. This framework will be used during Phases 2 and 3 to share the data collected.

The data shared with the public will be in two forms. First, the Wyoming road weather conditions, alerts, and advisories will be provided to the motoring public and commercial vehicle fleet managers/drivers through their traveler information and ITS device sources. Second, project data will be shared through the USDOT Research Data Exchange (RDE), which will be publicly available.

Additional data to be shared with USDOT and the Independent Evaluator (and documented in the framework) will focus on system performance and evaluation activities. The content, frequency, dissemination methods, and destination of the data will be defined in the framework and documented in the DMP. USDOT is currently working to define the database destination options and enhance the capabilities of those databases with the goal of efficient, timely, and cost-effective CV Pilot project collection and sharing. The Wyoming Pilot Team will design this data-sharing framework in Phase 2 in accordance with the most current methods available from USDOT. Special care with Personally Identifiable Information (PII) will be taken to ensure personal security is safeguarded in accordance with Phase 1 planning documents approved by USDOT.

Deliverables:

- **Draft Data Privacy Plan (DPP)**
- **Revised DPP with Comment Resolution Report**
- **Final Data Privacy Plan (DPP)**
- **Notice of Privacy Management Consistency**
- **Draft Data Management Plan (DMP)**
- **Revised DMP with Comment Resolution Report**
- **Final Data Management Plan (DMP)**

3.4 Acquisition and Installation Planning – Task 2-D

The acquisition and installation planning task will be driven by the Comprehensive Acquisition Plan (CAP) and the Comprehensive Installation Plan (CIP) documents that will be developed by Trihydro team under WYDOT's supervision.

WYDOT will be responsible for procuring all the equipment necessary for the CV-Pilot. WYDOT has a procurement process that allows the acquisition and tracking of equipment and software for client contracts. The procurement and accounting processes include the following staffing resources: legal/contracts, accounts receivable, accounts payable, inventory tracking, and reporting, and the process involves a subject matter expert to provide the product specifications. WYDOT will create a procurement team that includes WYDOT staff and Trihydro. The procurement team will manage the connected vehicle equipment and software acquisitions. The Trihydro team will assist WYDOT on equipment and software acquisition and installations. WYDOT will make the acquisitions and Trihydro will write the specifications for software and hardware. The Trihydro team has former experience with scoping out the specifications, configuring equipment and then installing the equipment on behalf of WYDOT.

The CAP and CIP will be reviewed by the procurement team members to understand the goals and expectations of the Connect Vehicle Pilot. Using the CAP and CIP as guidance, the team will be able to work directly with the vendors to acquire the equipment and track the inventory. The tracking of the equipment will be key in understanding warranties and available maintenance for the purchased equipment. Trihydro will create an inventory tracking system that will capture this information and be able to report this to the WYDOT. Part of the team's responsibility will be to revisit the cost and negotiate the best possible cost for purchase and ongoing maintenance of the equipment.

These documents will be developed in tandem based on the selection and evaluation of hardware and software vendors. Vendor evaluation was started during Phase 1 and will be completed prior to the design and development of the CAP and CIP documents. This task will cover the acquisition, configuration, and installation of all devices, equipment, and software-based capabilities. The CAP will identify the type and number of each item acquired during the development of the designed system. In detail, the CAP will include sections for:

- Vehicles and In-Vehicle Equipment
- Roadside Equipment
- Mobile Devices
- Management Center Equipment/Capabilities
- Other Equipment and Supporting Capabilities.

The acquisition of the equipment will be handled by WYDOT. The procurement of equipment will be guided by CAP and the deployment schedule and will comply with the procurement policies of the State of Wyoming. Procurement of the equipment will be handled by a purchasing officer within the team; the purchasing officer will be responsible for following the procurement process laid out within the CAP. The procurement process will follow these steps:

1. Evaluation of the purchase request by the team including any sole source justifications if necessary
2. Submittal of a purchase order to the vendor based on the agreed-upon purchase price of the equipment and quantities required
3. Tracking of the order confirmation and delivery schedule provided by the vendor
4. Receipt and inventory of the delivery to compare the purchase order and equipment received.

The WYDOT purchasing office will be responsible for tracking and reporting on the equipment budget to the management team. The CAP will be submitted in draft form for review and comments by the team. A revised CAP will be delivered after receipt of comments from USDOT along with a comment resolution report. The final CAP will be delivered for acceptance.

The CIP will provide direction for the team to implement the devices, equipment, and software-based capabilities that were acquired under the CAP. The CIP will be developed based on the equipment and software specifications provided by the potential vendors and compliant with the SyRS of the CV Pilot. The CIP will contain an overview of the supplier best practices defined during vendor evaluations. The team will provide a plan for inventory and configuration management describing the procedures for tracking inventory and the configuration process, which will be followed during the deployment of inventory. The installation schedule will be developed within the CIP based on the overall project schedule. An assessment of the procurement timeframe with each potential vendor will help the team meet the installation schedule deadlines. Installation plans will be developed to cover each specific system within the CIP. The RSU installation locations will be identified with a statistical approach including data from a number of crashes, detailing their location, severity (loss of life, injuries or property damage), high frequency of road and atmospheric conditions that contribute to crashes and then possibility of finding an upstream location within a few miles that has power and backhaul capabilities. The installation plans will contain at a minimum the following:

- Wiring, fiber optic splicing (if applicable) and interconnects
- Rack mount elevation of communications devices and the Control Center
- Electrical and power interface diagram (including grounding and transient voltage surge suppression)
- Infrastructure hardware mounting details
- In-vehicle hardware mounting details.

In addition, for each identified type of equipment, the CIP shall identify:

- Supplier(s)
- Inventory control method(s)
- Required configuration or pre-installation modifications
- Pre- and post-installation inspection procedures
- Detailed installation procedures
- QA/QC processes (with identified responsible parties)
- A preliminary, high-level installation schedule
- Hardware/software configuration control processes
- Spare parts/warranty contingency plans.

The CIP will be submitted in draft form for review and comment by the USDOT team. A revised CIP will be delivered after receipt of comments from USDOT along with a comment resolution report. The final CIP will be delivered for acceptance.

Deliverables:

- **Draft Comprehensive Acquisition Plan (CAP)**
- **Revised CAP with Comment Resolution Report**
- **Final Comprehensive Acquisition Plan**
- **Draft Comprehensive Installation Plan (CIP)**
- **Revised CIP with Comment Resolution Report**
- **Final Comprehensive Installation Plan**

3.5 Application Development – Task 2-E

Prior to the beginning of any application development, the Phase 1 Application Deployment Plan (ADP) (Gopalakrishna, Garcia, et al. 2016) will be revisited and revised based on updates made during the System Architecture and Design tasks. Once this document has been completed and submitted to the USDOT, work will begin on creating the Application Development Schedule (ADS).

3.5.1 Application Development Schedule

An ADS will be developed by the Wyoming CV Pilot Team using the following criteria: application development team resource availability, a critical path analysis, and application testing considerations. Application development teams for the Wyoming CV Pilot are described in Section 3.5.1.2 along with the preliminary set of applications that each team will be responsible for. The critical path analysis that will be performed will be based on initial estimates of each applications development time—that is, the ADS will be developed based on application dependencies and development schedules. The ability to test applications in real world environments and with hardware that will be used in the field will also be used as a consideration when building the ADS. Applications that are dependent on certain hardware for testing purposes will be scheduled such that the hardware is available for testing purposes during development.

Applications that are determined to be core applications in order for the system to function correctly or play a key role in the success of the project will be prioritized accordingly in the development schedule. An example of this is the ODE application. This application plays a key role in acquiring, processing, storing, and disseminating CV data to a wide array of applications. A preliminary analysis of applications to be developed by priority and by vendor is listed in Section 3.5.1.1. As application development begins, the ADS will be updated with the current status and progress of each application and revised after each 2-week iteration in the development phase. Updates to the ADS and the ADP will be submitted to USDOT for progress updates and feedback. This method will help identify and mitigate risks with technical, schedule, and cost issues as early as possible in the development process.

3.5.1.1 Preliminary Development Schedule

Below is a sample list of the first three applications that are currently scheduled to be developed or updated for the WYDOT CV pilot project.

- Application Name: ODE
  Development Priority: 1
  Justification for Priority: The ODE application is responsible for processing incoming CV data and distributing the CV data to subscribing sources such as the Situational Data Warehouse, Pikalert application, WYDOT 511 application, etc. As such this application will play a central role in the development of all other applications for the Wyoming CV Pilot project and will need to be integrated into the system early in the process.

- Application Name: Distress Notification Application
  Development Priority: 2
  Justification for Priority: This application will be developed by the vendor that will provide the hardware for the DSRC radios. The vendor will have all of the development resources, requirements, and hardware necessary to develop this application in parallel with the development efforts for the ODE.

- Application Name: WYDOT 511 App updates for crowd source parking
  Development Priority: 3
  Justification for Priority: A new feature within the existing WYDOT 511 App that shall allow app users to report on parking availability throughout the I-80 corridor. This application is independent of the ODE and OBU Distress Notification Applications development and will allow this application to be developed in parallel by the WYDOT development team.

3.5.1.2 Application Development Teams

Although all application development will be coordinated through Trihydro there will be four distinct development teams that will be working on applications for the Wyoming CV Pilot project. The teams along with the applications that each team is tentatively responsible for are outlined below. Please note that each of the teams described below may have enough resources to work on multiple applications at a time. For instance, the WYDOT development team will have enough development resources to work on 2 application development projects in parallel with 2 distinct development teams.

- **WYDOT Development Team**

  The WYDOT Development team will primarily be responsible for application development related to updating existing WYDOT applications to integrate newly available CV data.

  - WYDOT 511 Application
  - WYDOT Third Part Interface
  - WYDOT Transportation Reports and Action Console (TRAC)
  - WYDOT Road Condition Reporting (RCRS)
  - WYDOT Wyoming Traveler Information (WTI)
  - WYDOT Wyoming Data Broker (WTIDB)
  - WYDOT Commercial Vehicle Operator Portal (CVOP)
  - WYDOT Incident Console (IC)
  - WYDOT Construction Administration (CA)

- **Trihydro Development Team**

  The Trihydro application development team will be responsible for application development related to new applications created specifically for the CV project as well as updating and integrating USDOT CV applications already initially created by the USDOT such as the ODE. Additionally, the Trihydro development team will be responsible for creating ad hoc testing applications to test the system integration and subsystem functionality and development oversight from other development teams.

  - Operational Data Environment
  - Participant Tracking Application
  - OBU/RSU Management Application

- **NCAR Development Team**

  The NCAR development team will be responsible for all development related to the Pikalert system.

  - Pikalert ®

- **OBU/RSU Vendor**

The OBU/RSU application vendor development team will be responsible for application development related to new or updated applications created specifically for the OBUs and RSUs. Additionally, this development team will also be responsible for creating related testing applications to test the system integration and subsystem functionality.

- Forward Collision Warning
- Infrastructure-to-Vehicle (I2V) Situational Awareness
- Distress Notification
- Work Zone Warning
- Spot Weather Impact Warning

3.5.1.3 Application Integration and Coordination

Application development efforts will be coordinated through Trihydro. Each application within the system will be developed by a team that includes a business analyst, developer(s), and tester(s). In cases where applications are interdependent the teams will work together through Trihydro to coordinate application requirements and testing/verification. When needed, coordination standup meetings between teams will be scheduled and held on a daily basis in order to help stimulate communication between dependent application development teams.

3.5.2 *Agile* Development Process

The applications software will be developed using an *Agile* software development process. This process calls for short iterations and allows requirements to be flexible during development. This will also enable USDOT to see the software progress and allow them to evaluate it early in the development process, enabling changes to be made more efficiently. Each application will be assigned to a development team and a development lead. Application teams will work closely with one another when dependencies between applications are identified. The process for an individual application development is detailed below.

An application will have an initial set of requirements defined by the System Requirements that must be met for the application to be deemed complete. As many design level requirements as possible will be identified during the initial application design. The next step will be to analyze all identified requirements and to begin the technical design of the application. A software architect will be assigned to create an architectural design document detailing the proposed design of the application. This document will detail the architectural representation, constraints, application layers, and physical deployment plan and identify the schedule. After this document has been created, the development team will perform an architectural design review, and their comments will be incorporated in the architectural design document. The architectural design document, which will be a living document, 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 on the cost and schedule of the application.

After the architectural design of the application is completed and accepted as complete by USDOT, the schedule for the development of the application will be finalized and development of the project will begin. Application development will occur in iterations (or sprints). Each iteration will begin with a planning meeting that will involve the entire development team. The iteration planning meeting's 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 can vary based on the number of requirements identified, but will be no longer than three weeks. Additional requirements might be

found during the development process; these requirements will be documented and analyzed to determine the effect on the cost and schedule of the application.

During the development within an iteration, the team will meet daily (standups) to discuss each developer's progress. These standups will enable the team to identify the tasks they have worked on the previous day, their plan for the current day, and any issues or roadblocks they might need assistance in overcoming. The standup is also a forum for the developers to raise concerns with the current development schedule or technical issues they have encountered. These meetings enable the technical lead to 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 Quality Assurance (QA) team to test the newly developed features. Testing will be covered in the quality management section below. After testing is completed and the iteration has ended, the team will hold an iteration retrospective meeting. This meeting will enable team members to discuss what went well and what did not, and what can be done to improve the process. This meeting could be combined with the iteration planning meeting to streamline the development process.

When projects rely on other project development, the technical lead for the affected project or the dependent project will be invited to these retrospective and planning meetings. This approach will facilitate better communication among development teams that are interdependent. Relevant code will be uploaded to the Open Source Application Development Portal (OSADP) with required associated files.

There will be instances where private vendors elect to build software on behalf of the WYDOT project. Some of these vendors will chose to build the software using their own resources and methods with the understanding that the code base will belong to them. In the event this happens, WYDOT will fully evaluate the software for conformance with the requirements traceability matrix (Section 3.5.3.1) and mandate that any procured/licensed software will be placed in escrow. In the event the company will not or cannot support the product into the future, an escrow clause will be employed by WYDOT to access the code for on-going support. Further, any contracts with such vendors will clearly state the cost and maximum escalation rate for license of software into the future.

3.5.3 Quality Management

3.5.3.1 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 by 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.

3.5.3.2 Testing

Several levels of testing will be used to verify application functionality, usability, correctness, and performance. Test Management will be accomplishing using a software development management system such as Microsoft Team Foundation Server, but the specific management system will be determined later. Testing for the Wyoming CV Pilot Project will vary in size and scope depending on the stage of application development. The various testing for each application is outlined below along with the stage in the application development in which the testing will be done.

The WYDOT Team appreciates the need for quality software and the role that testing plays in ensuring quality. The WYDOT team will apply industry best practices in developing and testing its

software. Upon award of the NOFO, the WYDOT Team will review IEEE 829 and ISO/IEC/IEEE 29119 and incorporate those processes and techniques which are applicable and are consistent with its *Agile* software development process and which can be supported with available resources.

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. Unit tests will be built to test small verifiable parts of applications to verify certain code blocks are operating as intended.

Regression Testing: Unit testing will be followed by extensive system testing by internal testing professionals to ensure complete testing coverage. This will be accomplished by testers who will create and run test cases and document the test cases and scripts within the development management software. Regression testing will be used extensively to ensure that applications still function correctly as they are integrated into the CV system starting at the component level all the way to the system level.

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 set up 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 then will be set up to simulate high load periods and to determine application performance under these conditions. This testing method will help to determine if an application runs at acceptable performance levels on a component level to a system level. Performance and load testing will be performed on the system as a whole as well as at an individual application level.

User Acceptance Testing (UAT): As application functionality successfully passes prior testing levels, the application will be deployed to the WYDOT testing environment for additional functional and load testing. Although the goal of testing ultimately will be 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 enable users to become familiar with new features and provide feedback. UAT testing is documented through test cases that are written for each application and are only passed when the test cases written to verify the requirement are passed. Requirements for the WYDOT system are likewise tested as the different Wyoming Pilot applications are integrated together.

Additional testing for integrating systems together will also be performed. Integration testing from component level to system level is further described in Section 3.7.1.

Operational Readiness Testing: Operational Readiness will be tracked from the beginning of the development process through deployment and through operations, maintenance, and data collection. Operational Readiness will be tracked for each system component of the Wyoming CV Pilot Program and for the integration and testing of the system. Operational Readiness testing activities will be performed at the system level to demonstrate that the deployed system operates as designed in a safe and secure manner. Operational readiness testing will be performed after integration testing has passed and the entire system is in place and ready to deploy. Operational Readiness Testing at this level will focus on component level testing, failover, functional stability, supportability, operations support (monitoring), interoperability, reliability, and recovery.

3.5.3.3 Standards

All development for the Connected Vehicle project (except for products licensed for this project from third party developers) will be completed using the Apache Portal coding standards (found here: https://portals.apache.org/development/code-standards.html). These standards 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 and compliance with the written standards.

3.5.3.4 Source Control

All software development will be maintained through a GitHub source code repository. Each application will be maintained in the same repository as separate applications. Each team will be granted access to the repository for the application(s) that they are in charge of developing. The GitHub access will be overseen and maintained by the technical lead and the software development lead.

Configuration Management practices that will be put in place in order to work within the agile development process include versioning code sets that are checked in, adding build automation for each project, automating deployment and unit tests, and continuous integration.

Versioning Code: Developers will be encouraged to check in working code on a regular basis (at least once a day) in order to minimize code loss and to help incorporate continuous integration with other systems that are being developed simultaneously. Each check-in to GitHub will version the code being checked in. Additionally, versioning will also be placed on build scripts and test scripts. This will allow the team (if necessary) to roll back the code to a known good version.

Build automation: Automated build will be setup for each project within GitHub using a tool such as the Jenkins plugin or Docker. The exact tool will be determined and put in place prior to beginning development work

Automating Deployment/Unit Tests: Automating deployments will be tightly integrated with the automated builds. Deployments will be automated for all pushes to the test and production environments in order to reduce deployment mistakes from developers when deploying applications. Additionally, unit tests that are written for each application will be run after each build to ensure that all code is functioning as intended. Any unit tests that fail will be reported to the developers responsible as well as the project manager and technical lead.

Continuous Integration: Continuous integration encompasses versioning, proper code check in, and automating builds and deployments. This practice will incorporate running grabbing the latest version of all code related to the CV system, building all of the ode, running unit tests and deploying to a set environment. This practice should encourage developers to check in working code that will not negatively affect the entire system. Code that does break the system is typically caught early in the process when incorporating continuous integration practices into the system.

3.5.4 Open Source submissions

Applications that are expressly developed and paid for under the Connected Vehicle Pilots project will be uploaded to the Open Source Application Development Portal (OSADP) using the guidelines at the following webpage (http://www.itsforge.net/index.php/community/faq/technical-faq/155-upload-to-osadp). Technical leads for each project will be responsible for uploading to the OSADP site all code related to the application and for updating the code. The applications defined in Section 2.3.6 will be developed and relevant code uploaded to the OSADP, along with required associated files.

Deliverables:

- **Revised Application Deployment Plan**
- **Initial Application Development Schedule (ADS)**
- **ADS Update with Progress/Risk Summary (bi-weekly)**
- **Open Source Software and Supporting Documentation (per the ADP and ADS)**

3.6 Participant and Staff Training – Task 2-F

A Participant Training and Education Plan (PTEP) (Ahmed, Gopalakrishna, et al. 2016) was developed during Phase 1. The plan identified all stakeholders of Wyoming's CV Pilot Project that will need to be trained and educated to ensure the correct deployment, operation and maintenance of the system. The main stakeholder groups identified for training and education are:

1. Training Instructors
2. CV-Pilot Participants
   a. Drivers of Equipped Vehicles
   b. WYDOT TMC and Highway Patrol (WHP) Dispatch Personnel
   c. WYDOT Operational and Support Personnel
   d. Fleet Management Center Personnel (CVOP Users)
3. Public (Third-Party Interface Users)

The PTEP (and the overall project) follows Federal regulations and the Institutional Review Board (IRB) application and approval processes to protect human participants in the pilot. A Human Use Summary (HUAS) (Ahmed, Gopalakrishna, et al. 2016) was developed to document and explain the IRB application, obtaining participants' consent, review process, and how the WYDOT addressed the IRB comments and secured the IRB approval for Phases 2 and 3.

WYDOT will efficiently use different methodologies to train system users (e.g., snowplow, WHP, truck drivers), system managers and staff (e.g., TMC operators, technicians), and instructors. These methodologies are categorized into (1) in-person/ online instructional clinics and (2) live demonstrations and test drives. Having an array of options will ensure the plan is accessible to all stakeholder participants in the project. The development of the PTEP will be conducted in consultation with the heads of the various departments involved in the pilot at the local and State levels. In addition, coordination with the appropriate office manager(s) will occur with the partnering truck companies to ensure active participation of the trainees. Table 3-2 provides a summary matrix that specifies the methodologies that will be available to the instructors, drivers, and operational staff.

Table 3-2. Summary Training Matrix

User	Hands-On			Lecturing	
	Driving Simulator	E-Training	Field Demonstrations	Workshop T&E	Online T&E
	Instructors				
Instructors for Drivers	X	X	X	X	X
Instructors for Operational Staff				X	X
	Equipped Drivers				
Snowplow	X	X	X	X	X
Connected Trucks	X	X	X	X	X

User	Hands-On			Lecturing	
	Driving Simulator	E-Training	Field Demonstrations	Workshop T&E	Online T&E
Connected WHP Vehicles	X	X	X	X	X
Fleet Vehicles	X	X	X	X	X
	Operational Staff				
TMC Operators				X	X
WHP Dispatchers				X	X
ITS and Telecom Technician Staff				X	X
Maintenance Supervisors				X	X
WYDOT Supervisory and Support Staff				X	X
WYDOT Development Staff				X	X
	Fleet Management Centers				
CVOP Users					X
	Public				
Third Party Interface Users					X

Specific training products will be developed for each of the five training methodologies. WYDOT understands that training and education are continuous, and no final list of products can be defined, as the needs could evolve and change over time. Following is a preliminary list of products that will be developed:

1. E-Training Module for All Drivers: All drivers need to take and pass this module. Furthermore, this module will help in obtaining the necessary informed consent from the participating drivers. This module will be tailored to each type of driver through extensions of the existing training provided to them, namely:
   a. Snowplow Driver Training Module Extension, which will address any unique issues/questions pertaining to snowplow drivers (for example, use of the RCRS system in conjunction with the pilot)
   b. Highway Patrol Training Module Extension
   c. Commercial Vehicle Training Module Extension
   d. Fleet Vehicle Training Module Extension
2. Driver Simulation Training Module: This will provide the drivers with a simulated environment where they can practice the tasks they will be performing as part of the CV-Pilot, see Figure 3-1. Given its capacity and logistic limitations, this module is expected to be used by fewer participants who can travel to the UW campus.
3. CVOP Training Module: This module is an animated slideshow within the CVOP explaining the CV-Pilot project and the new features of the upgrade portal.

Figure 3-1. Driving Simulator at UW. Source: University of Wyoming.

4. WYDOT Third-Party Interface Training Module: This module is a set of resources (e.g., technical specifications, FAQs, troubleshooting) explaining the CV-Pilot project and the new features of the new/upgrade interfaces.
5. Field Demonstrations: This module primarily will be available for WYDOT and other fleet drivers of the CVs but might be conducted at specific locations of partnering fleet agencies. The goal is to provide in-the-field demonstration of the systems, better explaining the capabilities and limitations.
6. Operator Training Module: This module includes lectures, slides, and hands-on experience. This module will be tailored to each type of operator through extensions, namely:
   a. TMC Operators Training Module Extension
   b. Highway Patrol Dispatch Training Module Extension
7. Operation and Maintenance Training Module: This module will target field staff having maintenance responsibilities, providing them with the expertise to operate and maintain the system in regular and emergency situations.
8. General Education Modules: This module provides general information of the CV-Pilot, describing its components and explaining its scope and objectives. This is targeted primarily toward WYDOT Management, such as maintenance supervisors and other supervisory staff, and to WYDOT Support Staff, including meteorologists. This module also will be used to orient motor vehicle enforcement personnel.

To ensure optimum training outcomes, tailored evaluations will be performed for the different training methodologies, as explained in the PTEP. The training and education activities, lasting 20 months, are set to start at the beginning of Phase 2 of the CV-Pilot Project—that is, month 1 of the Training and Education Plan coincides with month 1 of Phase 2. A review team will be assigned to ensure consistency of the training materials. After the internal approval of the PTEP by the reviewer team, this document will be submitted to USDOT for review and approval.

The PTEP team will work closely with the ADP team to identify and mitigate risks as early as possible in the development process. As illustrated in the initial Training Implementation Schedule (TIS) in the PTEP, the Institutional Review Board (IRB) proposal was officially approved on May 23rd, 2016 for 1 year. An IRB amendment was submitted on February 14th, 2017 and was approved on March 6th, 2017. Another amendment was submitted on September 21st, 2017 to support Performance Measurements and Evaluation activities. The amendment included the following updates:

- Personally Identifiable Information (PII) will be only collected from WYDOT's fleet vehicles where necessary for some of the performance measurements to demonstrate the effectiveness of CV during the pilot phase. Measures to protect the privacy and identity of participants were provided in the updated Data Privacy Plan and Data Management Plan.
- Independent Evaluators (IE) assigned by the USDOT, the sponsor of the pilot, may collect additional data via survey questionnaires. The IE will use their own IRB.
- Independent Evaluators (IE) assigned by the USDOT will have access to the entire data. A limited subset of the data, PII free, will be available to the general public via the Research Data Exchange portal maintained by the USDOT.

The amendment was approved on December 1st, 2017. The University of Wyoming (UW), as the IRB of record, will be in close contact with the university's Office of Research and Economic Development to amend and maintain the Human Use Approval as needed.
The WYDOT team had all Training Materials/ Modules ready on October 1st, 2017. Hands-on training started in November, 2017; five drivers participated in the first field demonstration received their training utilizing UW driving simulator and E-training module. To date, 23 drivers received hands-on training, i.e., 19 WYDOT snow plow drivers and 4 light vehicle drivers from Trihydro. Training WYDOT, Trihydro, and other fleet partners will continue through phase 2 and 3.

Deliverables:

- **Initial Training Implementation Schedule (TIS)**
- **Training Materials (Initial and Updates, as specified in the PTSEP and TIS)**
- **Updated TIS with Progress/Risk Summary (monthly)**
- **Human Use Approval Confirmation Materials (per the HUAS)**

3.7 Operational Readiness Test and Demonstration Planning – Task 2-G

The objective of this task is to establish the Operational Readiness Plan (ORP) to verify and demonstrate to USDOT and other stakeholders that the WYDOT Connected Vehicle Pilot Deployment (CVPD) meets performance requirements, is operational, and will be reliable, available, maintainable, and safe.

Operational readiness planning and tracking will begin upon initiation of Phase 2 with the development of a first draft Operational Readiness Checklist and Schedule. This Checklist and Schedule will be part of the ORP and will be updated regularly throughout Phase 2 with any new elements that must be tracked and with status of each element on the checklist.

This section describes operational readiness from the following perspectives:

- Integrated System Engineering and *Agile* Development, Integration, and Testing
- Reliability, Availability, Maintainability, and Pre-Deployment Shakedown Testing
- Readiness Demonstration Planning
- Institutional, Staff, and Financial Resource Readiness
- Procedures, Documentation, and Training Readiness.

An Operational Readiness Concept Briefing will be conducted after completion of the Draft System Architecture Document, described in Task 2-B.

3.7.1 Integrated System Engineering Waterfall and Agile Development, Integration and Testing

Operational Readiness will be tracked from the beginning of the development process through deployment and through operations, maintenance, and data collection. Operational Readiness will be tracked for each system component of the Wyoming CV Pilot Program and for the integration and testing of the system. The major phases of development, integration, and testing that will be tracked include

- Component Development, Requirements Verification, and Acceptance Testing
- Laboratory and Benchtop Integration, Requirements Verification, and Acceptance Testing
- Vehicle Integration, Requirements Verification, and Acceptance Testing
- Controlled Environment and/or Track Testing Integration, Requirements Verification, and Acceptance Testing
- Infrastructure Integration, Requirements Verification, and Acceptance Testing
- On-Road Vehicle-Infrastructure Integration, Requirements Verification, and Acceptance Testing
- System Operational Readiness Demonstration
- Pre-deployment System Shakedown Testing
- System Production Deployment.

3.7.1.1 Agile Development, Integration and Testing

The WYDOT Team will develop and implement the CVPD system through the integration of the principles of *Agile* development and conventional Waterfall System Integration. A key feature and benefit of the *Agile* development process is that end-to-end functionality is developed and tested from the earliest possible development iteration (sprint), rather than waiting until all components and subsystems are developed and integrated. In this case, basic communications and messages (at least at the rudimentary level) from vehicles-to-back office and databases and from back office-to-vehicles will be demonstrated, very early in the development process. Once basic system functions are developed, new features are added and tested at each subsequent *Agile* sprint.

Early development and readiness planning will include allocation of system requirements to each phase of the development and implementation process identified above and to each *Agile* sprint. With each sprint, additional requirements are implemented, and inspection, testing, analysis, and demonstration are conducted to verify requirements for each development phase and each Sprint are met. Through this integrated methodology, the requirements satisfied during each sprint could be component level, subsystem level, system level, or all three. All requirements for each phase of development are satisfied at the conclusion of the final sprint.

Since the *Agile* development process includes a rapidly changing development process Continuous Integration will be incorporated into the development process in order to address issues that may arise with *Agile* Development such as code changes breaking system functionality, updates not getting integrated with the overall system in a timely manner, and testing for the entire system not being run prior to system deployments. The Continuous Integration process that will be followed is further described in Section 3.5.3.4.

3.7.2 Reliability, Availability, Maintainability and Pre-Deployment Shakedown Testing

Connected Vehicle Pilot Deployments represent the second major deployment of CV technology, following the first in the Connected Vehicle Safety Pilot, and the first major deployment of V2I technology. Commercial-off-the-shelf (COTS) hardware and software are marginally past their prototype implementations and are not necessarily field hardened. All suppliers will be expected to demonstrate the reliability, availability, and maintainability of their hardware and software. Purchase specifications will include requirements that vendors provide documentation of their reliability and availability testing and results. Vendors also will be required to demonstrate features that ensure the ease of diagnosing and repairing equipment problems. Software systems and software configurations must be updated over-the-air easily (and securely).

Reliability and maintainability also will be verified through a shakedown test of each major component and subsystem prior to full deployment. All key components will be installed in a shakedown test fleet during the latter sprint of *Agile* development to verify performance in the field and to demonstrate maintainability through updates, repair, and replacement of software and hardware components.

3.7.3 WYDOT CV System Readiness Demonstration Planning

Upon completion of the On-Road Vehicle-Infrastructure Integration, Requirements Verification, and Acceptance, the WYDOT team will provide a comprehensive demonstration for USDOT and invited stakeholders of the system components, capabilities, and functions in accordance with the Operational Readiness Plan. The WYDOT team will review the system engineering-based development and testing process, the test results, and the refinements made to establish the system.

Follow-up briefings will be provided following Pre-Deployment System Shakedown Testing and periodically throughout the Production System Deployment. Please note that the WYDOT team demonstrations may be both virtual and physical in nature. The demonstrations shall allow users to view data through a secure mapping application that shows both the vehicle on the road and the data interaction with the system that the vehicle has. This will allow the WYDOT team to remotely demonstrate features to the USDOT leading up to the on-site operational readiness demonstrations.

The ORP will include demonstrations, requirements verification, and acceptance test results for each major system component, including:

- Vehicles
- Roadside Infrastructure
- Centers
- Personnel
- Communications Infrastructure.

The ORP will include demonstrations, requirements verification, and acceptance test results for each major system function, including:

- Collect Road and Weather Data
- Collect Work Zone Information
- Collect Dynamic Travel Information
- Share Integrated and Fused Advisories
- Provide Dynamic Travel Information
- Share Safety and Road Condition Messages
- Collect Messages from Other Connected Vehicles
- Collect Messages from Infrastructure
- Generate Emergency Message.

The ORP will include demonstrations, requirements verification, and acceptance test results for each of the applications, including:

- Forward Collision Warning
- Situational Awareness
- Distress Notification
- Work Zone Warnings
- Spot Weather Impact Warning.

Finally, the ORP will include demonstrations, requirements verification, and acceptance test results for key operational scenarios, such as:

- Corridor Monitoring and Operations Support
  - V2I Road Weather Data Collection
  - Data Fusion and Segment Advisories
  - Weather Responsive Traffic Management
  - Adjacent State DOT coordination
- Truck Advisories
  - I2V Advisory
  - Wide Area Advisory
  - V2V Advisory
- Truck Warning
  - I2V Warning – General

- V2I Warning – Custom
- V2V Warning

The ORP will include documentation plans for demonstrations, including:

- Demonstration Descriptions
- Demonstration Procedures
- Demonstration Data
- Demonstration Results.

The ORP will include documentation plans for key requirements verification and acceptance tests will be provided and reviewed, including:

- Test Descriptions
- Test Cases
- Test Procedures
- Test Data
- Test Results
- Test Failure Remediation
- Requirements-to-test procedure matrix.

As noted in the USDOT NOFO, other ORP elements will include:

- Safety-Focused Readiness Elements
- Security-Focused Readiness Elements
- Privacy-Focused Readiness Elements
- Performance Measurement and Evaluation Support Readiness Elements.

3.7.4 Institutional, Staff, and Financial Resource Readiness

Partner institutions will need to establish new communications interfaces and will share data and make decisions based on their and other data. Doing so will require written agreements or MoUs (or both) between parties. This activity will be prioritized because experience has shown that establishing interagency agreements could require as much calendar time as completing the technical developments.

The ORP will identify the agreements required between each involved institution. Responsibility for advancing these agreements will be assigned, and the status will be regularly updated for all participants.

In addition to interagency agreements, each involved institution will need to allocate the financial, staff, vehicle, maintenance, and other resources necessary to ensure the successful deployment and maintenance of the system. Participating institutions will be expected to allocate the necessary budgets, staff time for training, operations, and maintenance of the deployment. This effort could require allocating time of existing staff, or, in some cases, dedicating staff to this deployment. Examples of other required resources include vehicles, IT equipment, ITS equipment, and network communication bandwidth and associated budgets. Readiness planning will include working with each agency to determine the resources needed and their schedule for participation. These resource needs will be incorporated in the ORP.

3.7.5 Procedures, Documentation, and Training Readiness

In moving from experiments to deployment, installation, operation, and maintenance of all CV-related components and systems, all actions must be standardized and documented. Training materials and courses are necessary to ensure consistency and reliability in their deployment and maintenance. All procedures, particularly installation and maintenance procedures, must include post-installation or maintenance quality control tests to verify proper implementation. Readiness planning will include identification of the procedures, training, and documentation materials required for successful implementation and deployment of the pilot. These will be incorporated in the ORP. Readiness tracking will include tracking the successful completion of installation, operation, and maintenance training by staff supporting the pilot.

3.7.6 ORP Walkthrough, Revision, and Finalization

After a draft ORP has been created and submitted to USDOT for review, WYDOT will conduct a 2-day readiness walkthrough following IEEE Standard 1028-2008 with the AOR and federal team members in Washington DC. A walkthrough workbook also will be provided to expedite the walkthrough process. A revised ORP document will be created based on comments and feedback received both orally during the walkthrough and written prior to the walkthrough. This final ORP will be submitted to USDOT for verification with an accompanying comment resolution report.

Deliverables:

- **Operational Readiness Concept Briefing (DC metro area)**
- **Draft Operational Readiness Plan (ORP)**
- **ORP Walkthrough and Workbook (DC metro area)**
- **Revised ORP with Comment Resolution Report**
- **Final Operational Readiness Plan (ORP)**

3.8 Installation and Operational Readiness Testing – Task 2-H

The objective of this task is to implement the plans from Task 2-G to verify and to demonstrate to USDOT and other stakeholders that the pilot meets performance requirements and is fully operational and will be reliable, available, maintainable, and safe.

After the CIP and the ORP have been finalized and approved by the USDOT team, work will update and refine the Installation and Operational Readiness Checklist and Schedule (IORS). Tasks defined in the CIP and ORP will be disaggregated and mapped in a dependency graph. The dependency graph will enable the team to analyze the best way to map the order in which the tasks should be completed to implement the CIP and ORP properly.

Installation and testing progress will be tracked according to the milestones of initiation: 20% complete, 50% complete, 80% complete, and completed. The proposed OBU/RSU management application will be able to track installation progress for all DSRC radios. This application will be used to generate an appendix for the IORS weekly updates that lists the status of all DSRC-equipped devices, the vehicle or location of the device installation, the current software version installed, and any issues/special circumstances associated with the device. Device types will be tracked within the OBU/RSU management application.

As technical risks and issues arise, they will be tracked in a document defined by the IORS, and all current risks and issues will be attached to the weekly updates sent to USDOT.

All tests performed for operational readiness will be documented with the results of the tests. Test results will be made available to USDOT and stakeholders via the weekly updates. Once the system is deemed ready for operation according to the ORP demonstrations for operational readiness, a meeting will be scheduled with all stakeholders and the AOR and key federal staff. All demonstrations then will be documented according to the ORP.

Deliverables:

- **Installation and Operational Readiness Testing Schedule (IORS)**
- **Updated IORS with Progress/Risk Summary (weekly)**
- **Test Results Summary Documentation (per the ORP)**
- **Operational Readiness Demonstration (per the ORP)**

3.9 Maintenance and Operations Planning – Task 2-I

Once the ORP and all needed equipment have been finalized and defined, work will begin on a Comprehensive Maintenance and Operations Plan (CMOP). The type and number of each piece of equipment required to be maintained during the Pilot phase of the operation and beyond will be recorded as part of the CMOP. For each equipment type identified in the CMOP, a corresponding plan to maintain and operate that type of equipment will be included. Also included in this plan will be information on the manufacturer's operating manual and corresponding manufacturer information regarding maintenance and warranty information.

The CMOP will be divided into sections that correspond to Operations and Maintenance broken down into subsections as defined by USDOT (vehicles and in-vehicle equipment, roadside units, etc.). As a baseline for maintaining and operating all equipment, the project will default to the manufacturer's recommended approach. When a maintenance or operational issue arise that is not covered under the manufacturer's guidelines, the manufacturer will be contacted for guidance to resolve the issue. Resolutions will be documented and added to the CMOP section(s) corresponding to the associated equipment.

The Operations section of the CMOP will list operating tasks and schedules. An example of this is the following text: [*In-Vehicle DSRC: 60 DSRC Radios were installed in WYDOT snowplows for use in the I-80 corridor. The DSRC radios broadcast at a range of 300 meters and operate continuously while the vehicle is in use. The DSRC radios will operate at all times and under all conditions, except when undergoing repair or replacement.*] Operations will be updated based on the manufacturer's specifications and on the current operating environment of the connected vehicles.

In the maintenance section of the document, each equipment type will be listed with its maintenance schedule. Information provided within the maintenance section will include, at a minimum, the following information: routine maintenance requirements/schedules, inspection procedures, maintenance/replacement procedures, QA/QC processes, hardware/software configuration control processes, recall processes, and spare parts/warranty contingency plans.

Additionally, all maintenance performed will follow a standard operating procedure (SOP) that will be created and appended to the CMOP. The SOP will contain the following information: purpose, health and safety precautions, equipment, and task procedure. The section content for each of these items is defined below:

- Purpose: Explains the purpose of the SOP and why it has been written for this task.
- Health and Safety: Contains general safety procedures and concerns regarding the task and specific safety training requirements needed to perform the task.
- Equipment: Contains an itemized list of all equipment required to perform this task.
- Task Procedure: Details the procedure to follow in performing maintenance for the equipment. The procedure should include sections for preparation, task activity, and post-activity steps.

Deliverables:

- **Draft Comprehensive Maintenance and Operations Plan (CMOP)**
- **Revised CMOP with Comment Resolution Report**
- **Final CMOP**

3.10 Stakeholder Outreach – Task 2-J

In Phase 2, WYDOT will be focused primarily on preparing and informing stakeholders and the public about the Installation and Operational Readiness Testing activities. In this task, ICF will lead the outreach activities under WYDOT supervision. The Team's partnerships with fleets will be leveraged to garner further buy-in or support by other fleet companies and others in the freight and transportation industry. The Wyoming Team will conduct outreach activities, in close coordination with WYDOT's Public Information Office (PIO) and USDOT.

The Wyoming Team will update the Outreach Plan developed in Phase 1 (Gopalakrishna, Garcia, et al. 2016) and will continue to update it, as needed throughout the phase. From this update, an Outreach Implementation Schedule (OIS) will be developed, which will identify the precise schedule of development for the Phase 2 outreach collateral and the outreach channels, from the planning stage through the printing or implementation stage. The OIS also will identify the schedule of development, planning, and implementation of the outreach channels. Each month, the OIS will be updated showing the progress of each item, track the progress against the plan, and identify any risks and mitigation activities (which will be the Lessons Learned Logbook).

The outreach materials to be developed during Phase 2 are:

- Pilot site logo and style guide
- Elevator pitch and talking points
- Initial PowerPoint Presentation slides, flyer and brochure for trade shows/conferences
- Two infographics and the first promotion video.

The message in the outreach materials will focus on discussing the purpose of and efforts leading up to and through the installation and operational readiness testing.

To engage the public, the Wyoming Team will create an online microsite for this pilot and develop the initial web content that will populate the site, including an initial project background, first set of frequently asked questions (FAQs), and a project schedule. All new outreach materials will be added to the microsite as they are developed throughout the phase. The team will develop the monthly social media content calendar that covers the 20 months of this phase. The social media content calendar will provide a schedule for when content will be published to WYDOT's Facebook, Twitter, and YouTube channels, based on the outreach materials development schedule or anticipated schedule of the various outreach activities. The Wyoming Team will participate in two community/local events that provide information before and after the Operational Readiness Testing.

During Phase 2, the Wyoming Team will engage the media by conducting two press conferences and developing two press releases.

To engage with industry partners, academia, and researchers, the Wyoming Team expects to hold and schedule as many requested site visits as possible. During Phase 2, the Wyoming Team will participate in three trade shows/conferences: The Transportation Research Board (TRB) Annual Meeting in January 2017, South by Southwest Interactive (SXSW) Festival in March 2017, and the Institute of Transportation Engineers (ITE) Annual Meeting in August 2017. Every trade show/conference will be accompanied by a roadshow presentation packet with information outreach materials for interested trade show/conference attendees. When scheduled by USDOT, the Wyoming Team will also participate in up to three USDOT-organized webinars. The webinar topics will be set by USDOT, but they are expected to relate to: 1) System Architecture/Design, 2) Application Development and Deployment Progress, and 3) Operational Readiness/Baseline Data Collection Plan. The Wyoming Team will prepare talking points that highlight the pilot's focus on safety, weather, involvement of the freight industry, and integration into WYDOT's fleet, including snow plows and other maintenance or safety vehicles.

As USDOT coordinates with international partners who are also leading the way in connected vehicles and research, the Wyoming Team will support any collaboration efforts that furthers the collective knowledge about the opportunities for connected vehicles. International partners may be particularly interested in: i) the experience of the fleet partners and the impacts of the use of OBUs on their operations and on their drivers' safety; ii) the experience of the retrofit or commercial vehicle subsystems; and/or iii) the application that collects weather data to develop alerts and advisories regarding adverse weather conditions. International partners may also wish to learn about the WYDOT Data Broker and how it analyzes and distributes the data being collected from the ODE, Pikalert and other external systems. As needed, the Wyoming Team will provide site visits to interested international partners. If international partners express interest in developing complementary deployment activities or performance measures to support their research efforts, the Wyoming Team will work with the international partners to develop these complementary elements within the pilot.

Deliverables:

- **Revised Deployment Outreach Plan (DOP)**
- **Initial Outreach Implementation Schedule (OIS)**
- **Outreach materials (as specified in the DOP and OIS)**
- **Updated OIS with Progress/Risk Summary (monthly)**
- **Updated Deployment Outreach Plan (minimum one update)**

3.11 Performance Measurement and Independent Evaluation Support – Task 2-K

The Wyoming Team prepared a Performance Measurement and Evaluation Support Plan (PMESP) (Kitchener, et al. 2016) during the Phase 1 activities, which was accepted by USDOT. This document will guide the performance measurement and support to the Independent Evaluator (IE) during Phases 2 and 3. The PMESP identifies 21 distinct performance measures (with targets) within eight (8) categories, illustrated in Figure 2-11, and defines specific evaluation designs to analyze each. The quantitative and qualitative data that will be needed to support these analyses is also identified for each PM. Table 3-3 summarizes the proposed performance measures that will guide the evaluation of the Wyoming CV Pilot project. These PMs were developed during several iterations by the team to

carefully identify the key outputs and outcomes of the WYDOT CV Pilot, clearly understand the expected benefits, and reflect the stakeholder expressed needs.

Task 2-K will refine the PMESP to reflect current system designs, document baseline conditions which will be used for comparison purposes during performance measurement activities, prepare a detailed schedule of PM activities and track it against actual accomplishments, and also refine data collection, management, and sharing procedures.

Table 3-3. Wyoming CV Pilot Performance Measures

No.	Performance Measure
Improved Road Weather Condition Reports Received into the TMC	
1	Number of road weather condition reports per road section/day pre and post CV Pilot (quantity)
2	Number of road sections with at least one reported road condition per hour pre and post CV Pilot (coverage)
3	Average refresh time of road condition reports in each section pre and post CV Pilot (latency)
Improved Ability of the TMC to Generate Alerts and Advisories	
4	Pikalert™ generated Motorists Alert Warnings (MAWs) that were accepted by TMC operators
Effectively Disseminate and Receive I2V and V2I Alert/Advisory Messages from the TMC	
5	Number of messages sent from the TMC that are received by the RSU.
6	Number of messages sent and received between the RSU and WYDOT fleet vehicle's OBU (when vehicles are in the vicinity of a RSU)
7	Connected vehicles that likely took action following receipt of an alert: Parked, Reduced speed, Came to a stop safely, or Exited.
Improved Information to Commercial Vehicle Fleet Managers	
8	Number of operational changes made by fleet managers due to information from TMC (compare before and after the CV Pilot)
9	Commercial vehicle managers are satisfied with information provided by the TMC (compare before and after the CV Pilot)
10	Commercial vehicle driver's experienced benefits due to CV technology during major incidents and events on I-80.
Effectively Transmitted and Received V2V Messages	
11	Number of V2V messages properly received in surrounding vehicles from sending vehicle (WYDOT fleet vehicles in vicinity of each other)
12	Connected vehicles that took action following receipt of a V2V alert
Automated Emergency Notifications of a Crash	
13	Number of emergency notifications that are first received in the TMC from connected vehicles (compared to alternate traditional methods, such as 911 caller)
Improved Speed Adherence and Reduced Speed Variation	
14	Total vehicles traveling at no more than 5 mph over the posted speed (compare before and after CV Pilot)
15	Total vehicles traveling within +/- 10 mph of 85th percentile speed (compare before and after CV Pilot)
16	Speed of applicable connected vehicles are closer to posted speed when compared to non-connected vehicles
Reduced Vehicle Crashes	
17	Number of connected vehicles involved in a crash
18	Reduction of the number of vehicles involved in a crash (compare a 5-year average before Pilot to CV Pilot data) ● Track connected versus non-connected vehicles
19	Reduction of total and truck crash rates within a work zone area (compare a 5-year average before Pilot to CV Pilot data) ● Track connected versus non-connected vehicles
20	Reduction of total and rates of truck crash along the corridor (compare a 5-year average before Pilot to CV Pilot data) ● Track connected versus non-connected vehicles

No.	Performance Measure
21	Reduction of critical (fatal or incapacitating) total and truck crash rates in the corridor (compare a 5-year average before Pilot to CV Pilot data) ● Track connected versus non-connected vehicles

The focus of this task is to define how the PMESP process will be managed, describe in more detail data collection and processing activities, document the baseline conditions (before CV Pilot deployment), and coordinate efforts with the Independent Evaluator. Specifically, the Wyoming Team will:

- Establish a Performance Measurement and Evaluation Support Schedule (PMESS) and provide weekly progress updates.
- Document pre-deployment performance conditions, including data, log books, analytical models and other supporting information.
- Provide system performance reports.
- Update the PMESP.
- Support Independent Evaluator activities.

3.11.1 Performance Measurement and Evaluation Support Schedule (PMESS)

The Wyoming Team will prepare the PMESS, which will define a work breakdown structure required to implement the PMESP and measure/evaluate the performance of the Wyoming CV Pilot components and overall system. The PMESS will guide the performance measurement and evaluation support activities and be used as a guide to provide USDOT weekly progress reports.

The schedule will include:

- Major PMESP activities and their timeframe
- Key milestones and dates to implement the PMESP successfully
- PMESP deliverables with dates (including performance-related data)
- PMESP dry-run demonstration and the key elements leading up to the demonstration
- Technical issues and risks affecting the execution of the PMESP (as a supplement).

Weekly updates of the PMESS will be provided to USDOT documenting PMESP progress, including percent completion estimates for all major milestones and deliverables. The PMESS will be updated as necessary during the course of Phase 2 and updates shown in the weekly progress reports. Also included with the weekly updates will be narrative, describing activities underway, progress made since the last update, and all technical issues or risks and mitigation actions taken.

3.11.2 Pre-Deployment Performance Conditions

A key task in Phase 2 will be establishing the baseline performance conditions—pre-deployment of the CV Pilot technologies and systems. Many performance measures identified in the PMESP require a before/after analysis to be conducted during the evaluation to quantify the results (see Table 3-4). This evaluation method can be performed only if a valid baseline is established prior to any CV technology deployment. The Wyoming Team plans to establish a performance baseline during the Phase 2 activities and document the results in the updated PMESP. Specific baseline condition elements that will be documented include, but are not limited to:

- Traffic characteristics, including truck and private vehicle speeds under various conditions and speed variance results
- Weather events and categorization: type, severity, roadway impacts, etc.
- Number of road weather reports received at the TMC using traditional methods
- I-80 coverage (percentage of total) with road weather reports during severe weather events and identification of any gaps in coverage
- Average refresh time of road condition reports in each designated segment
- Current time for TMC operators to disseminate broad area traveler information
- Number of operational changes (routing, timing, cancelled trips) by commercial vehicle managers from road weather condition information provided by the TMC
- Baseline surveys/interviews of TMC operators, connected vehicle drivers, and commercial vehicle fleet managers. Qualitative data collected will include institutional and organizational aspects
- Vehicle speeds, speed variations, and posted speeds for various road weather conditions
- 5-year history of crash and injury data
- Location, extent, cause, and duration of I-80 closures over past 5 years.

Additionally, and in coordination with the establishment of the baseline conditions, Phase 2 activities will include data collection to support calibration of the simulation model that will be used in Phase 3 to support PM activities. The various evaluation approaches to be used are presented in Table 3-4 (see the Performance Measurement and Evaluation Support Plan (Gopalakrishna et al., 2016) for a more detailed explanation of each approach and the data needed).

The results and related data collected during the establishment of the performance baseline conditions will be documented in the PMESP update report.

3.11.3 System Performance Reports

In addition to documenting the baseline conditions, Phase 2 efforts will define end-to-end data collection and processing capabilities and procedures to support Phase 3 performance measurement activities. These capabilities will be demonstrated during a dry-run exercise to ensure all necessary data can be collected and processed prior to Phase 3 commencement.

The Wyoming Team will deliver to USDOT periodic system performance reports in accordance with the PMESS. The system performance reports will include data, logs, analysis results, model results, and other supporting information related to the baseline condition establishment and dry-run data collection and processing procedures. System performance reports are anticipated to be provided as the information becomes available, but at least twice during the course of the Phase 2 activities.

3.11.4 Performance Measurement and Evaluation Support Plan (PMESP) Update

The Wyoming Team plans to update the PMESP once, near the end of Phase 2. The Plan revisions will include, but not be limited to:

- Documentation of baseline conditions (pre-deployment)
- Updates/changes to the performance measures or evaluation designs, analytical models, and algorithmic methodologies to reflect system design decisions
- Updates to the performance confounding factors and mitigation approaches that reflect the most current understanding and approaches

- Detailed performance data and data management approaches (in coordination with the Data Management Plan – Task 2-C)
- Results of the performance measurement dry-run demonstration.

A review draft and final versions of the PMESP will be provided to USDOT.

Table 3-4. Approach for Evaluation of Selected Performance Measures

PM No.	Evaluation Approach					Data Need
	Before-After	With-Without	System Performance	Behavior Assessment	Qualitative Assessment	
						Improved Road Weather Condition Reports Received into the TMC
1	X					• Number of road weather condition reports coming to TMC operators through the Pikalert system (post deployment) • Number of WYDOT snowplow road weather condition reports submitted (baseline and post deployment) • Pikalert system logs (post deployment) • RSU logs (post deployment) • OBU logs (post deployment)
2	X					• Number of road weather condition reports coming to TMC operators through the Pikalert system (post deployment) • Number of WYDOT snowplow road weather condition reports submitted (baseline and post deployment) • Pikalert system logs (post deployment) • RSU logs (post deployment) • OBU logs (post deployment)
3	X					• Number of road weather condition reports coming to TMC operators through the Pikalert system (post deployment) • Number of WYDOT snowplow road weather condition reports submitted (baseline and post deployment) • Pikalert system logs (post deployment) • RSU logs (post deployment) • OBU logs (post deployment)
						Improved Ability of the TMC to Generate Alerts and Advisories
4			X			• Pikalert system logs of recommended alerts and advisories (post deployment) • TMC logs of those Pikalert system recommendations being accepted by TMC operators and disseminated (post deployment)

PM No.	Evaluation Approach					Data Need
	Before-After	With-Without	System Performance	Behavior Assessment	Qualitative Assessment	
						Effectively Disseminated and Received I2V and V2I Alert/Advisory Messages from the TMC
5			X			• TMC logs (post deployment) • RSU logs (post deployment)
6			X			• RSU logs (post deployment) • OBU logs (post deployment)
7				X		• TMC logs (post deployment) • OBU logs (post deployment) • Temporal and spatial data of all connected vehicles (post deployment) • Information regarding connected vehicle's involvement in any incident (post deployment)
						Improved Information to Commercial Vehicle Fleet Managers
8	X					• TMC logs indicating information provided to commercial vehicle fleet managers (baseline and post deployment) • Fleet manager survey responses of operational changes made (type and timing) based on input from the TMC (before and after CV Pilot)
9					X	• Commercial vehicle fleet manager survey responses of satisfaction levels with TMC information (before and after CV Pilot)
10					X	• Commercial vehicle driver survey responses
						Effectively Transmitted and Received V2V Messages
11			X			• OBU logs recording sent and received V2V messages from other connected vehicles (post deployment) • RSU logs that recorded V2V messages being transmitted to other connected vehicles (post deployment)
12				X		• OBU logs regarding sent and received V2V messages (post deployment) • Temporal and spatial data of all connected vehicles (post deployment) • Information regarding connected vehicles' involvement in any type of incident (post deployment)

PM No.	Evaluation Approach					Data Need
	Before-After	With-Without	System Performance	Behavior Assessment	Qualitative Assessment	
						Automated Emergency Notifications of a Crash
13			X			• Number of emergency notifications from connected vehicles (post deployment) • Total number of emergency notifications from all sources (post deployment)
						Improved Speed Adherence and Reduced Speed Variation
14 15 16	X X	 X				• Time-stamped speed of individual vehicles from roadside speed radar equipment at locations in the VSL corridors including vehicle length (for classification of vehicles into passenger cars and trucks) (before and after deployment) • VSL event logs indicating changes to VSL speed limit signs. (before and after deployment) • OBU logs from CV equipped vehicles including vehicle speeds (post deployment)
						Reduced Vehicle Crashes
17			X			• Data from CV equipped vehicles regarding involvement in crashes on project corridor (post deployment)
18	X					• Crash data from WYDOT-maintained crash database for the project corridor starting 5-years prior to and continuing through CV demonstration period. Coordination with Wyoming Highway Patrol may be required depending on lag time from crash incident to inclusion in database for crash events that occur during the demonstration period (before and after deployment)

PM No.	Evaluation Approach					Data Need
	Before-After	With-Without	System Performance	Behavior Assessment	Qualitative Assessment	
						• Traffic volume data from existing roadside traffic monitoring equipment (before and after deployment) • Weather data from the corridor's Road Weather Information System (RWIS) sensors covering same time period as crash data (before and after deployment) • Data from CV equipped vehicles regarding involvement in crashes on project corridor (before and after deployment)
19	X					• Crash data from WYDOT-maintained crash database for the project corridor starting 5-years prior to and continuing through CV demonstration period. Coordination with Wyoming Highway Patrol may be required depending on lag time from crash incident to inclusion in database for crash events that occur during the demonstration period (before and after deployment) • Traffic volume data from existing roadside traffic monitoring equipment (before and after deployment) • Weather data from the corridor's Road Weather Information System (RWIS) sensors covering same time period as crash data (before and after deployment) • Location and Duration of Work Zones in Project Corridor starting 5-years prior to beginning of CV demonstration period (before and after deployment) • Data from CV equipped vehicles regarding involvements in crashes on project corridor (post deployment)
20	X					• Crash data from WYDOT-maintained crash database for the project corridor starting 5-years prior to and continuing through CV demonstration period. Coordination with Wyoming Highway Patrol may be required depending on lag time from crash incident to inclusion in database for crash events that occur during the demonstration period (before and after deployment)

PM No.	Evaluation Approach					Data Need
	Before-After	With-Without	System Performance	Behavior Assessment	Qualitative Assessment	
						• Traffic volume data from existing roadside traffic monitoring equipment (before and after deployment) • Weather data from the corridor's Road Weather Information System (RWIS) sensors covering same time period as crash data (before and after deployment) • Data from CV equipped vehicles regarding involvement in crashes on project corridor (before and after deployment)
21	X					• Crash data from WYDOT-maintained crash database for the project corridor starting 5-years prior to and continuing through CV demonstration period. • Traffic volume data from existing roadside traffic monitoring equipment. • Weather data from the corridor's Road Weather Information System (RWIS) sensors covering same time period as crash data. • Data from CV equipped vehicles regarding involvements in crashes on project corridor.

3.11.5 Independent Evaluator Activities

The focus of the Wyoming Team's evaluation will be to understand what worked, what did not, and how to improve the system and determine future enhancements. Additionally, the Project Team's evaluation will measure the impacts on the trucking industry, Wyoming residents, and other users of the I-80 corridor and seek ways to expand on the identified benefits.

USDOT plans to contract with an Independent Evaluator (IE) to support the Wyoming CV Pilot project evaluation. The IE will not duplicate or appraise the Wyoming team's evaluation activities, but rather broaden the project evaluation to focus on measures not covered by the Wyoming team's evaluation, impacts of larger scale CV deployments, and national programmatic aspects of this CV Pilot project, combined with other similar projects being conducted. The IE team will strive to understand how the project outcomes can contribute to the future of the Connected Vehicle Program nationally.

Toward this end, the Wyoming Team will work collaboratively to ensure a comprehensive and successful evaluation is completed and documented in such a way to benefit Wyoming, other interested states, and the national CV Program. Specifically, the Wyoming Team will:

- Work closely with the IE to ensure a complete understanding of the Wyoming CV Pilot project, and assist in preparing a complementary evaluation plan and approach
- Provide the mutually agreed-upon data needed for the IE to conduct evaluation activities. The Wyoming team anticipates that the selected IE will produce their own evaluation plan possibly identifying data needs not yet discussed. We will work with the IE to update and finalize the list of data to be collected/provided. Additionally, the IE's data needs may require them to collect specific data not provided by Wyoming. In this case, the Wyoming team will coordinate with them to facilitate their efforts.
- Provide Wyoming PM-based analysis procedures, analytical tools, and models to be used during the Phase 3 evaluation activities
- Facilitate IE access to Wyoming Team staff and relevant stakeholders as needed to support the evaluation plan and activities
- Assist the IE in identifying and recruiting participants related to the evaluation plan and activities.

Deliverables:

- **Draft Performance Measurement and Evaluation Support Schedule (PMESS)**
- **Updated PMESS with Progress/Risk Summary (weekly)**
- **Pre-Deployment Performance Data, logbooks, analytical models, and other support information (per the PMESS)**
- **System Performance Reports (per the PMESS)**
- **Updated PMESP (minimum one update)**

3.12 Participation in Standards Development – Task 2-L

After the System Architecture Document (SAD) and accompanying Standards Plan is completed and finalized by USDOT, the Technical Lead for the pilot project (Tony English) will participate in related Standards Development Organization (SDO) working group/committee meetings. As applications are developed and modified standards might need to be modified for the system to operate or to operate more efficiently. In such cases, the System Lead will document the proposed standards updates/new standards that should be created and add them to the SAD standards plan. Additionally, the proposed

updates/new standards will be communicated to the appropriate SDOs in the specified SDO-specific technical memoranda defined in the Standards Plan.

In addition to proposing modified/new standards based on the Wyoming Pilot study, other pilot programs/SDOs could have related standards that need to be updated/created. In such cases, the technical lead will participate in all SDO discussions and coordinate the implementation of new or updated standards into the pilot program as needed. In these cases, the Standards Plan in the SAD also will be updated to reflect the new/modified standards that were agreed upon in the SDO.

The Wyoming Pilot will work on two new applications that could be considered for review. First, the Distress Notification application based on TIM messaging with an increased priority PSID. This will be used to develop an application similar to Mayday forwarding and opposite-direction notification of an incident. Second, the implementation of TIM distribution by DSRC through RSUs and satellite. The second application will need to define how duplicated messages are received by the OBU and processed for the driver.

Participation in SDOs is critical to the overall success of the pilot programs as is the need to create a standard repeatable solution for implementation at other locations without having to create custom solutions that work only under specific conditions. Therefore, a technical expert working closely with the technical lead will be designated as a backup to attend SDOs when the technical lead might be unable to attend and participate. This approach will enable a representative from the Wyoming pilot study to participate consistently in all relevant SDOs. This process will include giving feedback on USDOT architectures and tools.

Deliverables:

- **SDO-specific Technical Memoranda (as defined in the Standards Plan)**
- **Participation in SDO working group or committee meetings/activities (as required)**

4 Deployment Approach for Phase 3

The following sections describe the deployment approach for Phase 3 and describe the methods to demonstrate the pilot applications in a real-world setting and collect data on the performance and impact.

4.1 Program Management – Task 3-A

WYDOT is experienced in ensuring the ongoing operation of deployed infrastructure and in maintaining software systems. Using the expertise of staff developers and project team members like Trihydro and NCAR, WYDOT will be able to modify existing service-level agreements and governing policies to ensure the ongoing operation of devices and applications needed for the success of the pilot project. Continuing from Phase 2, the project management team will update the PMP and project schedule. WYDOT and key personnel will attend a Phase 3 kick-off meeting in Washington, D.C. WYDOT will continue to support the Monthly Progress Reports, site-specific meetings, and monthly all-site coordination elements including roundtables.

Deliverables:

- **Kick-off Meeting**
- **Project Management Plan (PMP)**
- **Revised PMP (as required)**
- **Project Schedules (updated monthly)**
- **Monthly Progress Reports**
- **Participation in site-specific bi-weekly coordination teleconferences**
- **Participation in monthly all-site coordination teleconferences**

4.2 Systems Operations and Maintenance – Task 3-B

After the CMOP has been completed and Phase 3 has begun, work will begin on creating a System Operations and Maintenance Schedule (SOMS). As part of the SOMS, the OBU/RSU management application will be used to maintain information related to DSRC equipment and associated information, including device type and current installation status.

The OBU/RSU management application will be used with spreadsheet tracking (or other best in breed tool) for other equipment related to the project to help generate monthly reports to USDOT. These reports will contain a status report for all equipment associated with the pilot project. Additional information for inclusion in the report will be:

- Current Operational Status
- Associated Asset(s)
- Last Inspection Date
- Inspection History

- Last Maintenance Date
- Maintenance History.

Note that there are limitations due to the security and privacy concepts on figuring out whether specific OBUs are alive or not. However, aggregate statistics on OBU presence on I-80 can be monitored and reported. Logs will also be maintained for predictive failures by location and mean time between failures as described by the manufacture and through empirical data.

To verify that regular maintenance and inspections for equipment have been completed, as defined in the SOMS, a maintenance/inspection logbook will be created and audited at regular intervals for all equipment types. When the equipment is installed on vehicles outside of the control of the pilot project or cannot be inspected or maintained regularly, the equipment will be documented and noted as exempt from the inspection/maintenance schedule. This inspection/maintenance log will be made available to USDOT as part of the monthly SOMS update.

As technical issues and risks arise during Phase 3 of the pilot program, they will be documented and provided as an addendum to the monthly SOMS report provided to USDOT. Monthly SOMS reports format and content will be modified based on USDOT comments and comments on current risks and issues.

Deliverables:

- **Initial System Operations and Maintenance Schedule (SOMS)**
- **Updated SOMS with Progress/Risk Summary (monthly)**

4.3 Stakeholder Outreach – Task 3-C

In Phase 3, the Wyoming Team will focus primarily on preparing and informing stakeholders and the public about the Demonstration activities. In this task, the Wyoming Team will conduct the following outreach activities, in close coordination with WYDOT's Public Information Office (PIO) and USDOT. The Freight Advisory Council (FAC) will start their quarterly meetings in Phase 3, were past outreach activities will be analyzed and future ones discussed.

The Wyoming Team will continue to update the Outreach Plan as needed throughout the phase. From this update, an Outreach Implementation Schedule (OIS) will be developed, which will identify the precise schedule of development for the Phase 3 outreach collateral and the outreach channels, from the planning phase through the printing or implementation phase. The OIS also will identify the schedule of development, planning, and implementation of the outreach channels. Each month, the OIS will be updated showing the progress of each item, track the progress against the plan, and identify any risks and mitigation activities (which will be the Lessons Learned Logbook).

The outreach materials developed during Phase 3 will be updated elevator pitch, updated talking points, updated PowerPoint Presentation slides, updated flyer for trade shows/conferences, updated brochure, one new infographic, and two new promotion videos. The message in the outreach materials will focus on discussing operational maintenance of the system and the performance measurement analyses.

The Wyoming Team will continue to update the content for the online microsite for this pilot with an updated schedule, updated FAQs, and any updated outreach materials. The team will develop the monthly social media content calendar that covers the 18 months of this phase. The social media content calendar will provide a schedule of when content will be published to WYDOT's Facebook, Twitter, and YouTube channels, based on the outreach materials development schedule or anticipated

schedule of the various outreach activities. The Wyoming Team will participate in two community/local events.

During this phase, to engage the media, the Wyoming Team will hold two press conferences and, develop two press releases. The Wyoming Team also will develop, in close coordination with USDOT, an Operational Capability Showcase (OCS) for interested media participants. This showcase is currently anticipated for March 2019, when the Operational Readiness Testing and Installation and Systems Maintenance efforts are completed. This showcase will take place along I-80, after an OBU from one of the other pilots is installed into a WYDOT vehicle. The showcase will demonstrate to the media how the OBU from one of the other pilots interacts with the Wyoming pilot's RSU and System, to demonstrate universal applicability and interoperability. A further test of interoperability is this pilot's use of the XM OBU, which will be use "out-of-the-box", with no customizations applied, and will run for the entire length of the pilot testing. An Operational Capability Showcase Plan (OCSP) will be drafted, reviewed by USDOT, and finalized, and any work items will be appended to the OIS. During the OCS, video, pictures, and notes will be taken, which will be used to integrate the results of the OCS with existing outreach materials, such as the PowerPoint Presentation and promotional video. Following the OCS, the Wyoming Team will document the results and products of the OCS in an Operational Capability Showcase Summary (OCSS), which will document exactly how the results from the OCS will be integrated with the outreach materials.

When scheduled by USDOT, the Wyoming Team will also participate in up to three USDOT-organized webinars. The webinar topics will be set by USDOT, but may be: 1) Results of the Readiness Test and Baseline Performance, 2) Highlights of the Operational Capability Showcase, and 3) Performance Measurement/Transition Plan. The Wyoming Team will prepare talking points that highlight the pilot's impacts on safety improvements, on the freight industry, and on the operations of WYDOT's fleet, including snow plows and other maintenance or safety vehicles. To engage with industry partners, academia, and researchers, the Wyoming Team will offer to schedule and conduct any requested site visits.

As USDOT coordinates with international partners who are also leading the way in connected vehicles and research, the Wyoming Team will support any collaboration efforts that furthers the collective knowledge about the opportunities for connected vehicles. During Phase 3, international partners may be interested in how the performance measurement is conducted and how the pilot plans to maintain and continue CV operations. As needed, the Wyoming Team will provide site visits to interested international partners. If international partners express interest in developing complementary deployment activities or performance measures to support their research efforts, the Wyoming Team will work with the international partners to develop these complementary elements within the pilot.

Deliverables:

- **Initial Outreach Implementation Schedule (OIS)**
- **Outreach Materials (as specified in the DOP and OIS)**
- **Updated OIS with Progress/Risk Summary (monthly)**
- **Draft Operational Capability Showcase Plan (OCSP)**
- **Revised OCSP with Comment Resolution Summary**
- **Final Operational Capability Showcase Plan (OCSP)**
- **Operational Capability Showcase (OCS)**
- **Draft Operational Capability Showcase Summary (OCSS)**
- **Revised OCSS with Comment Resolution Report**
- **Final Operational Capability Showcase Summary**

4.4 Performance Measurement and Independent Evaluation Support – Task 3-D

During the Wyoming CV Pilot Project Phase 3 activities, the CV technologies will be demonstrated in a real-world environment and the performance documented. The updated PMESP prepared during the Phase 2 activities will guide the performance measurement efforts.

The focus of this task is to define how the PMESP will be executed, report to USDOT the data and performance measurement results, and coordinate efforts with the Independent Evaluator. Specifically, the Wyoming Team will:

- Provide weekly updates to the PMESS
- Deliver post-deployment performance materials and reports, including data, log books, analytical models and other supporting information
- Update the PMESP and corresponding DMP
- Support Independent Evaluator Activities.

4.4.1 Performance Measurement and Evaluation Support Schedule (PMESS)

During Phase 2, the PMESS will have been established and updates provided weekly. During Phase 3, this process will continue. The schedule will focus on Phase 3 activities, with more detail included and an expanded work breakdown structure to guide the measurement and evaluation of the Wyoming CV Pilot components and overall system throughout the demonstration.

The schedule will include:

- Major PMESP activities (Phase 3) and their timeframe
- Key milestones and dates to implement the PMESP successfully
- PMESP deliverables with dates (including performance-related data and results)
- Technical issues and risks affecting the execution of the PMESP (as a supplement)

Weekly updates of the PMESS will be provided to USDOT documenting the PMESP progress, including percentage completion estimates for all major milestones and deliverables. The PMESS will be updated as necessary during the course of Phase 3 and updates shown in the weekly progress reports. Also included with the weekly updates will be a narrative describing activities underway, progress made since the last update, any technical issues/risks that have arisen, and mitigation actions taken.

4.4.2 Post-Deployment Performance Data and Reporting

Phase 3 performance measurement activities will execute the PMESP by collecting and analyzing data during the Wyoming CV Pilot demonstration. Each performance measure identified in the updated PMESP will be addressed according to the evaluation design defined in the Plan. Extensive data will be collected to support the evaluation efforts.

This task periodically will deliver to USDOT and the IE the collected data, logs, analysis results, model results, system performance reports, and other supporting information. Additionally, the available performance measurement results will be delivered in accordance with the PMESS timelines and the final PMESP and DMP.

Performance data will be defined in the DMP prepared in Phase 2. Some of the performance measures will be evaluated using a "with-without" design evaluation method in which comparisons will be made between vehicles with the CV technology and vehicle without the CV technology. These data and performance results will be included in the materials provided to USDOT.

4.4.3 Performance Measurement and Evaluation Support Plan (PMESP) and Data Management Plan

The Wyoming Team plans to update the PMESP twice. The first update will occur following the first winter season (2017–2018) of data collection and analysis in Phase 2. The second update will be delivered near the end of Phase 3. These updates will include any revisions to the PMs or evaluation designs and the performance measurement results to date. Specifically, the Plan revisions will include, but not be limited to:

- Updates to the performance measures or evaluation designs, analytical models, and algorithmic methodologies to reflect, most accurately, the Wyoming CV Pilot systems deployed
- Updates to the performance confounding factors and mitigation approaches that reflect the most current understanding and approaches
- Results to date of the performance-measurement Phase 3 activities, including data collected and analyses conducted.

The DMP also will be updated twice in Phase 3 as will the PMESP. This document will include the data collected and other supporting information to support the PMESP activities and the management approaches employed to secure, store and share the appropriate data.

A review draft and final versions of the PMESP and DMP will be provided to USDOT.

4.4.4 Independent Evaluator Activities

The Wyoming Team will continue to work collaboratively to ensure a comprehensive and successful evaluation is completed and documented to benefit the state of Wyoming, other interested states, and the national CV Program. During Phase 3, the Wyoming Team will continue to work closely with the IE to provide assistance, data, access to stakeholders, and general support to help the IE achieve their goals and objectives (defined in their Evaluation Plan – Phase 2 deliverable). Additionally, the Wyoming team will provide the analysis procedures, analytical tools, and models used during Wyoming's Phase 3 evaluation efforts in support of the IE's evaluation activities.

Deliverables:

- **Draft Performance Measurement and Evaluation Support Schedule (PMESS)**
- **Updated PMESS with Progress/Risk Summary (weekly)**
- **Post-Deployment Performance Data, logbooks, analytical models and other supporting information (per the PMESS)**
- **System Performance Reports (per the PMESS)**
- **Updated PMESP and DMP documents (as required)**

4.5 Post-Pilot Deployment Transition Planning – Task 3-E

WYDOT fully expects the CV Pilot to result in an operational system that will continue to be used beyond Phase 3. As part of Phase 1 ConOps and system planning, WYDOT has carefully considered

the financial and partnership requirements beyond the pilot demonstration. Throughout the transition period, WYDOT will work in close collaboration with the Freight Advisory Council (FAC) to analyze all aspects of the project in order to ensure continuous operation and potential growth of the CV network. The following elements are critical to WYDOT's transition concept:

- A significant population of WYDOT-owned fleets are part of the CV-Pilot
- The CV-Pilot system is conceived to be fully integrated with WYDOT TMC operations
- A reliance on standards and protocols to ensure that applications are broadly available to a diversity of on-board units

The following sub-sections present WYDOT's current thinking on the transition plan. However, as Phase 2 and Phase 3 progress, the topic of transition will be revisited before the conclusion of the pilot. The information presented in this section should be treated as preliminary considerations on this topic.

At the conclusion of Phase 3, WYDOT would have around 400 vehicles with DSRC technology coupled with about 75 roadside units. Five on-board applications would have been successfully demonstrated as part of Phase 3. CV Pilot elements would be effectively integrated to support WYDOT traffic and traveler information services.

WYDOT will continue to maintain and operate connected vehicle equipment on their fleets (about 100) including expanding as appropriate to other corridors in the State. WYDOT, as part of their normal ITS program, will maintain the roadside units and the back-office system necessary to support the I2V applications demonstrated in the pilot. Private fleet partners will be encouraged to continue to support the on-board units for the pilot but it is likely that they would have to take ownership of maintenance and support. Ultimately, the partnering private fleet carriers will have to make a business decision based on the utility of the applications to the driver.

WYDOT would not be able procure additional on-board units for private fleets post Phase 3. As such, the penetration on DSRC-enabled onboard devices in passenger vehicles or trucks is outside the control of WYDOT. Growth in DSRC equipped vehicles is dependent on factors like DOT rule-making, adoption of such technology by OEMs (and especially truck OEMs). As more and more vehicles become available, the value of the V2I applications become more evident.

With DSRC adoption timelines still in question, WYDOT will continue to maximize the utility of the existing CV technology in their fleets. WYDOT will focus in the near-term on expanding the ability to push the traveler information to as many on-road vehicles and fleet managers as possible. This will primarily be accomplished through:

- Supporting and encouraging the integration of the third-party interface created as part of WYDOT. The third party interface is intended to support private vendors who can use WYDOT data to provide value-added information to their consumers.
- Encouraging the delivery of TIMs through Satellite and other wide-area communication methods.
- Growing the subscriber base for CVOP which currently includes about 800 freight stakeholders.
- Actively using data from connected fleets for traffic management on I-80.

WYDOT is committed to the national growth of CV Technology and will continue to actively engage with Standards Development Organization (SDOs) and AASHTO V2I Deployment Coalition. WYDOT I-80 will serve as an important test bed for DSRC technology and testing of CV applications with a focus on adverse weather mitigation.

A Comprehensive Transition Plan will be written to provide a framework for ongoing project activity. It will describe project successes to be continued and unsuccessful operations to be discontinued, with rationale for each. Additionally, possible areas of improvement for consideration by WYDOT for future enhancements will be documented.

Deliverables:

- **Draft Comprehensive Transition Plan (CTP)**
- **Revised CTP with Comment Resolution Report**
- **Final Comprehensive Transition Plan (CTP)**

4.6 Participation in Standards Development – Task 3-F

During Phase 3 of the project, the Technical Lead for the pilot project will participate in related SDO working group/committee meetings. As applications are load tested in actual working environments, standards might need to be modified for the system to operate more efficiently. In such cases, the WYDOT team will document the proposed standards updates and new standards that should be created and add them to the SAD standards plan. Additionally, the proposed updates/new standards will be communicated to the appropriate SDOs in the specified SDO-specific technical memoranda defined in the Standards Plan.

In addition to proposing modified and new standards based on the Wyoming Pilot study, other pilot programs/SDOs could have related standards that require updating or creation. In such cases, the Technical Lead will participate in all SDO discussions and coordinate the implementation of updated or new standards into the pilot program, as needed. The Standards Plan in the SAD also will be updated to reflect the modified/new standards agreed upon in the SDO.

Participation in SDOs is critical to the overall success of the pilot programs and to creating a standardized, repeatable solution for implementation at other locations without creating custom solutions that work only under certain conditions. Therefore, a technical expert working closely with the Technical Lead will be designated as a backup to attend SDOs when the Technical Lead might be unable to attend and participate. This approach will enable a representative from the Wyoming pilot study to participate in all relevant SDOs consistently.

Deliverables:

- **SDO-specific Technical Memoranda (as defined in the Standards Plan)**
- **Participation in SDO working group or committee meetings/activities (as required)**

5 Deployment Schedule

The following sections provide a high-level schedule for Phases 2 and 3. Section 5.2 provides a high-level summary of our acquisition plan.

5.1 Schedule Description

This section presents a tabular presentation of the task dependencies by Phase, spanning their period of performance. Table 5-1 presents the WBS of the Wyoming CV Pilot, with specific duration and start/finish dates. Figure 5-1 provides information on the dependencies. However, the schedule will be updated as part of Task 2-A. A schedule baseline will be created as part of the program management plan upon grant award. A Microsoft Project schedule will also be created and updated throughout the duration of Phase 2 and Phase 3.

Table 5-1. Wyoming CV Pilot Work Breakdown Structure.

WBS	Task Name	Duration	Start	Finish
2	**Phase 2**	**499 days**	**Thu 9/1/16**	**Tue 7/31/18**
2.A	Program Management	499 days	Thu 9/1/16	Tue 7/31/18
2.B	System Architecture and Design	260 days	Thu 9/1/16	Wed 8/30/17
2.C	Data Management Planning	150 days	Thu 12/1/16	Wed 6/28/17
2.D	Acquisition and Installation Planning	283 days	Sat 10/1/16	Tue 10/31/17
2.E	Application Development	304 days	Mon 10/3/16	Thu 11/30/17
2.F	Participant and Staff Training	215 days	Tue 1/3/17	Mon 10/30/17
2.G	Operation Readiness Testing and Demo Planning	282 days	Thu 12/1/16	Fri 12/29/17
2.H	Installation and Operation Readiness Testing	370 days	Mon 4/3/17	Tue 7/31/18
2.I	Maintenance and Operations Planning	176 days	Thu 6/1/17	Thu 2/1/18
2.J	Stakeholder Outreach	482 days	Thu 9/1/16	Tue 7/31/18
2.K	Performance Measurement and Indep. Eval. Support	435 days	Thu 12/1/16	Tue 7/31/18
2.L	Participation in Standards Development	195 days	Wed 11/1/17	Tue 7/31/18
3	**Phase 3**	**416 days**	**Sun 7/1/18**	**Fri 1/31/20**
3.A	Program Management	416 days	Sun 7/1/18	Fri 1/31/20
3.B	System Operations and Maintenance	416 days	Sun 7/1/18	Fri 1/31/20
3.C	Stakeholder Outreach	416 days	Sun 7/1/18	Fri 1/31/20
3.D	Performance. Measurement and Indep. Eval Support	416 days	Sun 7/1/18	Fri 1/31/20
3.E	Post-Pilot Deployment Transition Planning	368 days	Tue 9/5/18	Fri 1/31/20
3.F	Participation in Standards Development	327 days	Thu 11/1/18	Fri 1/31/20

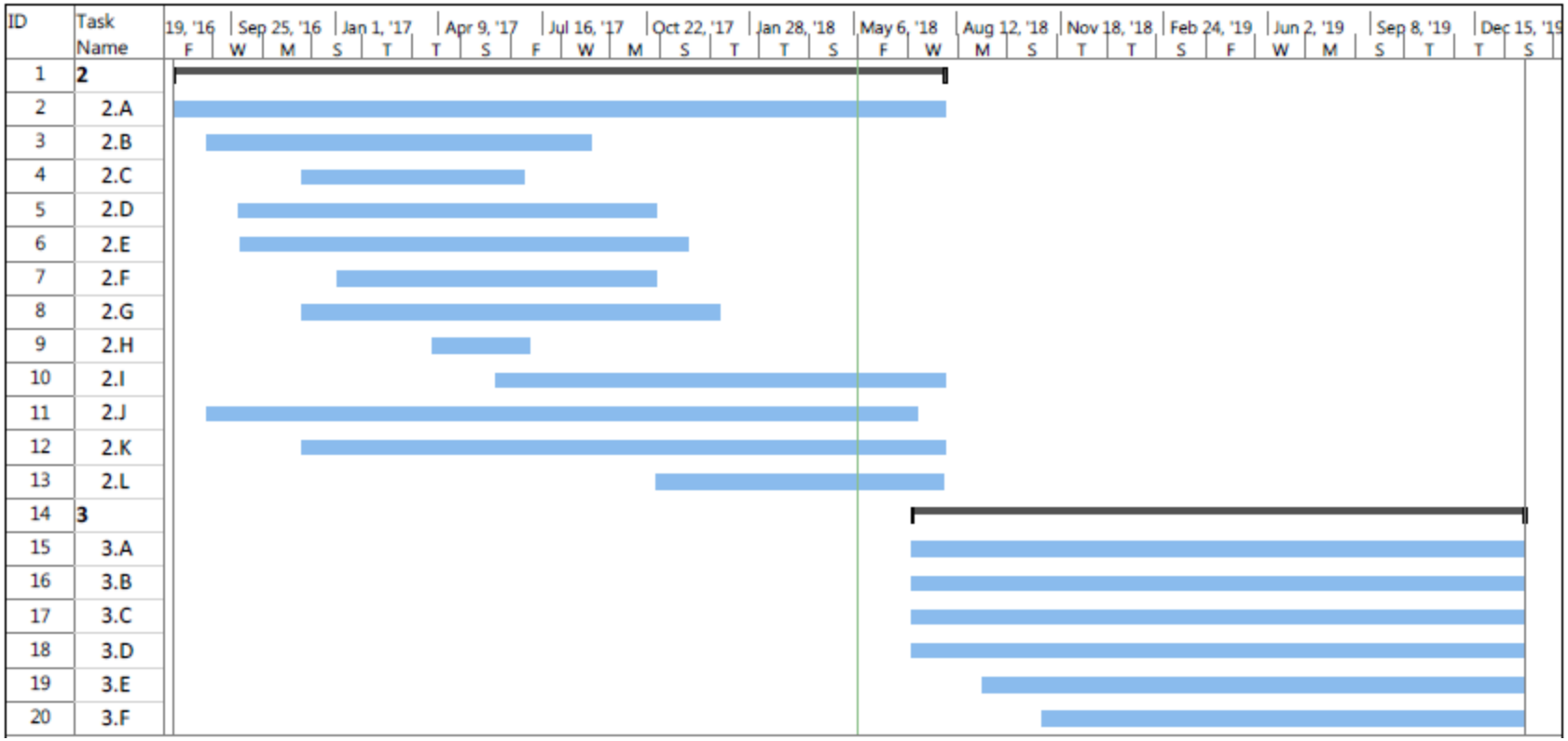


Figure 5-1. Schedule of Phases 2 and 3 of the CV Pilot Project. Source: WYDOT.

5.2 Supporting Information on Current Acquisition and Installation Planning

The Wyoming Pilot will acquire one type of infrastructure RSU, three mobile types of OBUs, and one type of mobile weather sensor. This section describes the status of the type of element development, production, and schedule.

The Wyoming Pilot plans to install around 75 RSUs on I-80 and in WYDOT fleet maintenance areas. Additionally, a few will be installed in areas for testing. Only RSUs that have passed USDOT-approved certification will be considered for acquisition. Currently, the pilot is obtaining proposals from vendors to provide turnkey solutions for certified hardware, software, installation support, and warranty support coverage for the roadside and on board hardware and software for the pilot's duration.

WYDOT will be responsible for procuring the RSUs. The goal is to identify successful vendors in November 2016 and purchase an initial set of 10 devices for testing and installation documentation in December 2016, with the fulfillment of devices in April 2017. The plan is to have all devices installed and tested with initial applications by November 2017 and final, production-tested applications by May 2018.

The Wyoming Pilot plans to acquire around 25 commercial off-the-shelf OBU devices, capable of DSRC bidirectional communication and receiving TIMs via satellite. Only OBUs that have passed USDOT-approved certification will be considered for acquisition. Currently, the pilot is requesting proposals for a complete commercial-off-the-shelf system with an HMI, antennas, and cabling. This request includes hardware, software, and installation support for the duration of the pilot, and a limited amount of custom software development is required. The device would be used for the basic V2V and V2I applications for the pilot, but would not support CAN Bus integration or environmental sensors. The purchase of five devices is planned for December 2016, with the remaining being procured in in April 2017.

The Wyoming Pilot plans to acquire between 200 and 250 full-featured OBU devices capable of DSRC bidirectional communications and receiving TIMs via satellite. Only OBUs that have passed USDOT-approved certification will be considered for acquisition. Currently the pilot is requesting a proposal from different vendors for these devices. This request includes hardware, software, and installation support for the duration of the pilot, and custom software development is required. This device would be used for the V2V and V2I applications for the pilot and would support CAN Bus and environmental sensors. The purchase of 10 devices is planned for December 2016, and an additional 80 devices for April 2017, with completion in November 2017.

The Wyoming Pilot plans to acquire around 125 basic OBU devices capable of DSRC bidirectional communications with no satellite capabilities. Only OBUs that have passed USDOT-approved certification will be considered for acquisition. Currently, the pilot is requesting a proposal from several vendors for these devices. The request includes hardware, software, and installation support for the duration of the pilot, and custom software development would be required. This device would be used for the V2V and V2I applications for the pilot and would not support CAN Bus or environmental sensors. The purchase of 10 devices is planned for December 2016, an additional 40 devices in April 2017, with completion in November 2017.

The Wyoming Pilot plans to acquire around 50 mobile weather sensors. Currently, the pilot is requesting a proposal from vendors for these devices. This request includes hardware, software, and installation support for the duration of the pilot, and custom software development is required. The

purchase of 10 devices is planned for December 2016, an additional 20 devices in April 2017, with completion in November 2017.

A summary table of planned equipment purchases is provided in Table 5-2.

Table 5-2. Wyoming CV Pilot's Planned Equipment Purchases

Item	Quantity	Schedule
RSUs	78	Initial set of 10 devices: December 2016. Fulfillment of devices (75 total devices): July 2017
OBU devices capable of bidirectional DSRC communications and receiving Traveler Information Messages (TIM) via satellite – no CAN Bus or environmental sensor support	28	Initial five devices: June 2017. Remaining devices: Sept 2017.
OBU devices capable of bidirectional DSRC communications and receiving TIMs via satellite – CAN Bus or environmental sensor would be supported	346	Set of devices will be purchased between December 2016 and April 2018.
OBU devices capable of bidirectional DSRC communications and receiving Traveler Information Messages (TIM) via satellite – no CAN Bus or environmental sensor support	35	Initial 10 devices: December 2016. Additional devices: Sept 2017. Remaining devices: April 2018.
Mobile weather sensors	53	Initial 10 devices: January 2017. Remaining devices: Sept 2017.

6 Team Organizational Summary

The following sections present the team organization for Phase 2 and 3.

6.1 Project Team

The team for Phase 2 and 3 is composed of staff from the following organizations:

- **Wyoming Department of Transportation (WYDOT)** – WYDOT is the United States DOT (USDOT) Connected Vehicle (CV) Pilot Grant Recipient for Phase 2 and Phase 3 of this project. WYDOT is a strong committed State DOT partner that is a leader in rural intelligent transportation systems (ITS) and CVs. Led by the WYDOT geographic information system (GIS)/ITS group, WYDOT expects several of their departments to be heavily involved in the pilot including:
    - WYDOT Traffic Management Center Personnel
    - WYDOT Telecommunications
    - Wyoming Highway Patrol
    - WYDOT Maintenance
    - WYDOT GIS/ITS
    - WYDOT IT
    - WYDOT Contracts/Procurement
    - WYDOT Public Affairs Office

  WYDOT staff includes State employees and existing GIS/ITS Contractors who currently support various systems development activities.
- **ICF** – ICF's staff bring deep expertise in road weather management, systems engineering, application development, and stakeholder outreach and coordination for this effort. ICF will provide overall program management support, support to various systems engineering tasks, lead the performance management, evaluation, and outreach activities. The ICF team includes the firms:
    - **Vital Assurance** - A new addition to the team, Vital Assurance is a group of consultants that includes Dr. Denny Stephens, a national expert in systems development for connected vehicle deployment and a strong truck technology background. Dr. Stephens will play an important role in adequately defining the system architecture, system design and testing approaches for the pilot in Phase 2.
- **Trihydro** – Leads the systems engineering and integration work for the Pilot. An engineering and systems development firm based in Wyoming, with a 118-vehicle fleet that supports WYDOT as well as the oil and gas industry in Wyoming. Trihydro staff, led by our systems integration lead will be responsible for system design, application development, testing during Phase 2 and monitoring the operations of the system in Phase 3. Trihydro's team will include one additional firm:
    - **National Center for Atmospheric Research (NCAR)** – NCAR will help develop the weather-related application portions for the CV Pilot including integration of the Pikalert® system with the overall CV pilot.

- **University of Wyoming (UW)** – A research institution that brings a fully-equipped driving simulator and sophisticated modeling expertise in the areas of road weather management. UW will act as the Institutional Review Board (IRB) of record and will support continued human use approvals and trainings, including amendments to the IRB and support the testing and training of CV pilot elements using the university truck and car simulators. The university will also support the performance management and evaluation of the CV Pilot system in Phase 2 and Phase 3.
- **McFarland Management** - will coordinate all performance management and evaluation activity for the pilot.

From a contractual standpoint, WYDOT is the grant recipient and ICF, Trihydro, McFarland Management and UW have separate contracts with WYDOT.

6.2 Project Organizational Chart

This project requires expertise in a broad range of subject matters and a strong management team to guide the development, deployment, testing, maintenance, and performance measurement of this pilot. To accomplish Phase 2 and 3 within 38 months, the teams on this pilot are organized under one site leader and three main management leads. The Project Site Lead is the main pilot site project lead and is supported by the three other management leads – Project Management Lead, Systems Development Lead, and Human Use and Training Lead. Figure 6-1 shows the organization of this leadership structure.

The top tier leadership structure (the five leads) are supported by a strong team of key supporting technical area leads with experience on a variety of topics. These key supporting technical area leads will coordinate closely with the leadership structure and will provide guidance to the broader team. Figure 6-1 lists each of the key supporting technical area leads and their specific area(s) of support during this pilot. Bios are provided for all the leadership staff and the key supporting staff leads identified in the organizational chart and the table below. Not all Procurement Services Support Staff and Project Administrative Support Staff are listed in the table.

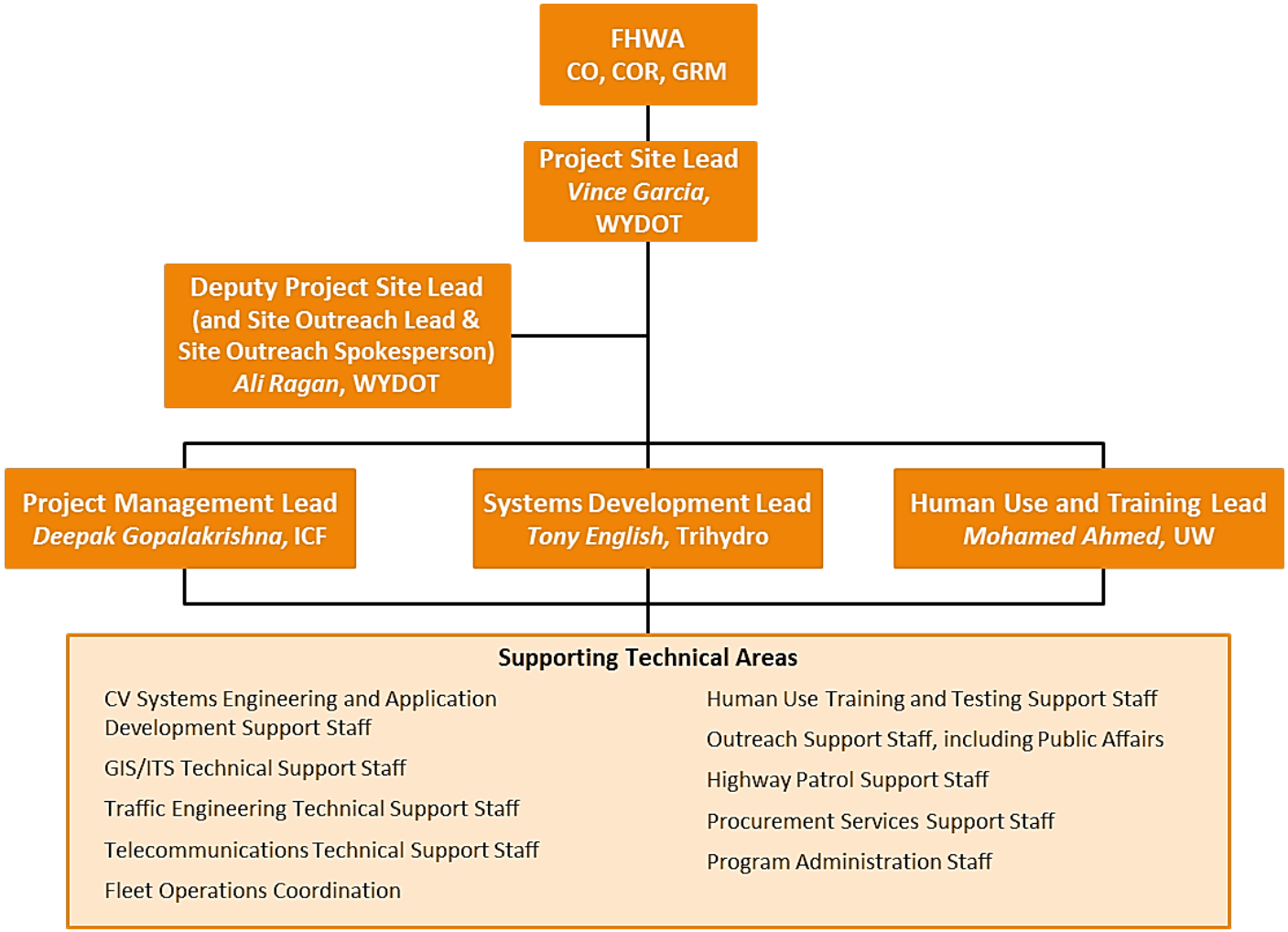


Figure 6-1. Project Organization Chart. Source: WYDOT.

Table 6-1. Key Supporting Technical Area Leads

Key Supporting Technical Area Leads		
CV Systems Engineering and Application Development Support Leads • Denny Stephens, Vital Assurance – Engineering Lead • Josh Dorrell, Trihydro – Technology Services and Solutions Lead • Shane Zumpf, Trihydro – Software Development Lead • Ivan Yourshaw, WYDOT GIS/ITS Contractor, Neaera Consulting – User Experience Development Lead **Weather and CV Leads** • Amanda Anderson, NCAR • Gerry Weiner, NCAR **GIS/ITS Technical Support Leads** • Jim Vanderweide, Trihydro – GIS Lead • Brian Peel, WYDOT – WYDOT GIS Lead • David Rush, WYDOT GIS/ITS Contractor, DAR Consulting – Technical Integration Lead	**Traffic Engineering Technical Support Leads** • Joel Meena, WYDOT – Traffic Engineering Integration Lead **Telecommunications Technical Support Leads** • Larry Sheridan, WYDOT – Telecommunications Integration Lead **Fleet Operations Coordination** • Tony English • Ali Ragan **Performance Management Leads** • Fred Kitchener, McFarland Management – Evaluation Lead • Rhonda Young, UW – Safety Analysis Lead	**Human Use Training and Testing Support Leads** • Dr. Mohamed Ahmed, University of Wyoming • Dr. Nayel Urena Serulle, ICF – Technical User Training Integration Lead • Eva Hsu, ICF – User Testing Development Lead **Outreach Support Leads** • Ali Ragan, WYDOT - Site Outreach Lead and Site Outreach Spokesperson • Eva Hsu, ICF – Outreach Activities Lead **Program Administration Leads** • Cindy Peck, ICF, Program Management Reporting

6.3 Project Leadership

Project Site Lead, Vince Garcia, WYDOT: Mr. Vince Garcia is a graduate of the UW with a degree in civil engineering and has worked for the WYDOT in various capacities for more than 30 years. He began his career as a road designer and then transitioned to a bridge design engineer for 8 years. Between 1995 and 2003, he led WYDOT's Information Technology (IT) program and was involved with numerous network and software development projects. Since 2003, he has managed WYDOT's GIS/ITS Program where he has worked with a team to build a statewide Transportation Management Center (TMC) and to deploy numerous intelligent transportation pre-trip and roadside systems. Mr. Garcia has been at the forefront of advancing traffic management for rural applications and especially for the State of Wyoming. As one of the leaders in this area, he has initiated several projects that move WYDOT closer to a CV world. Some of the innovations in Wyoming include a successful weather-based variable speed limit, an automated road condition reporting system, a citizen reporting system, and freight portals for trucker-specific information. As a trusted partner to FHWA, he has been involved in various FHWA RWMP research activities including the integration of weather information in TMCs and the latest Wx-TINFO project where he was able to take a FHWA ConOps and translate that into an implemented project with their maintenance fleets.

Project Management Lead, Deepak Gopalakrishna, ICF: Mr. Deepak Gopalakrishna brings proven program management skills on large and high-visibility FHWA projects. In his previous employment at Battelle, he has served the program manager for FHWA Office of Operations IDIQ, leading a team of

over 20 consultants in delivery of a diverse task portfolio for the entire office. A skilled facilitator and team builder, his leadership of activities in the road weather management program and planning for operations have resulted in real-world benefits to State DOTs. His expertise is in systems planning and concept development. For example, he led the development of five Concepts of Operations for Weather Responsive Traffic Management for FHWA, three of which have been successfully implemented in the real-world (Wx-ATM, Wx-TINFO, and Wx-ATM). Similarly, he led a team to develop five concept of operations for exploring national road user charging options for FHWA. As part of this effort, he worked with FHWA Office of Policy, Operations, and the OST-R to draft five feasible approaches for consideration.

Systems Development lead, Tony English, Trihydro: Mr. Tony English has over 20 years of experience leading and managing IT projects and is a Mechanical Engineer and Microsoft Certified System Engineer with experience in managing technical programming and infrastructure projects. Mr. English's primary area of expertise is in the architecture of Internet security systems, data-driven portals, programming, and robotics. He also has extensive experience with web-portal based programming projects with an emphasis in document management and workflow in secure environments. This experience includes working on a number of transportation-related projects including, but not limited to, installing and managing roadside unit security firewalls and VPN's for Remote Weather Information Systems (RWIS), Variable Speed Limit (VSL) signs, Dynamic Message Signs (DMS), and other Intelligent Traffic Systems, as well as developing and maintaining an ASP.Net and Java-based information system to manage remote data to relay critical travel data to citizens via the Internet, 511, email, and texting for road conditions and closures.

Human Use and Training Lead, Mohamed Ahmed, University of Wyoming: Dr. Mohamed M. Ahmed is an Assistant Professor in the Department of Civil and Architectural Engineering at UW and is the director of the Driving Simulator Lab (WYOSIM) at UW. Dr. Ahmed has over 15 years of practical and research experiences in the field of transportation and traffic engineering with a focus on traffic safety. He has a wide experience in conducting safety studies, statistical analyses, human factors studies, utilizing Big Data collected from Naturalistic and Simulated Driving Studies in safety research. Recently, Dr. Ahmed was involved in a research study sponsored by Colorado DOT to incorporate safety in VSL systems on Interstate 70 in Colorado. Dr. Ahmed was involved in developing a novel mobile visibility detection system for fog and smoke for the Florida DOT to reduce traffic injuries and fatalities on Florida roadways. Dr. Ahmed has sufficient experience with the preparation of protocols necessary for performing research involving human subjects and obtaining IRB approvals.

Deputy Project Site Lead, Site Outreach Lead, and Site Outreach Spokesperson, Ali Ragan, WYDOT: Ms. Ali Ragan is a project manager for the Wyoming Department of Transportation's GIS/ITS program. She joined WYDOT in 2013 and has served as project manager on number of projects including an FHWA-funded Weather Responsive Traffic Management project. She has a bachelor's degree from Colorado State University-Pueblo in mass communications and previously worked as a journalist.

7 Cost Summary

The following tables summarize the cost for the CV Pilot program. The overall cost of the pilot is **$6,165,003** with a federal share of **$4,720,258** and a WYDOT match of **$1,444,745** ($1,275,723 cash over the three years and $122,604 in-kind through state-funded overheads of staff). This translates to a 23% match for the project.

Tables 7-1 and 7-2 summarize the overall cost and the funding source to match the cost.

Table 7-1. Summary of Pilot Cost.

Summary of Cost	Phase 2	Phase 3	Total
Labor	$ 147,008	$ 21,677	$ 168,685
ODCs	$ 1,692,890		$ 1,692,890
Travel	$ 10,000	$ 10,000	$ 20,000
Subcontractors	$ 2,870,360	$ 1,413,068	$ 4,283,428
Total	**$ 4,720,258**	**$ 1,444,745**	**$ 6,165,003**

Table 7-2. Summary of Cost by Funding Source

Cost Element	Total	Federal Share	Cost Share	
			Cash	In-Kind
Direct Labor	$ 96,408	$ 26,335		$ 70,073
Indirect Costs	$ 72,277	$ 19,744		$ 52,533
ODCs	$ 1,692,890	$ 437,377	$ 1,255,513	
Travel	$ 20,000	$ 20,000		
Subcontractors	$ 4,283,428	$ 4,263,218	$ 20,210	
Total	**$ 6,165,003**	**$ 4,766,674**	**$ 1,275,723**	**$ 122,606**
% of Total	**100%**	**77%**	**21%**	**2%**

This budget is broken into the tasks identified in the scope of work as shown in Table 7-3.

Table 7-3. Budget by task.

Task	Total	Percent of Phase
Phase 2	**$ 4,720,258**	**100%**
2-A. Program Management	$ 181,634	4%
2-B. System Architecture and Design	$ 574,128	12%
2-C. Data Management Planning	$ 108,585	2%
2-D. Acquisition and Installation Planning	$ 1,611,587	34%
2-E. Application Development	$ 901,075	20%

Task	Total	Percent of Phase
2-F. Participant and Staff Training	$ 186,678	4%
2-G. Operational Readiness Test and Demonstration Planning	$ 201,638	4%
2-H. Installation and Operational Readiness Testing	$ 326,079	7%
2-I. Maintenance and Operations Planning	$ 154,664	3%
2-J. Stakeholder Outreach	$ 169,699	4%
2-K. Performance Measurement and Independent Eval Support	$ 253,056	5%
2-L. Participation in Standards Development	$ 51,436	1%
Phase 3	**$ 1,444,745**	**100%**
3-A. Program Management	$ 150,009	10%
3-B. System Operations and Maintenance	$ 447,823	31%
3-C. Stakeholder Outreach	$ 157,371	11%
3-D. Performance Measurement and Independent Eval Support	$ 447,754	31%
3-E. Post-Pilot Deployment Transition Planning	$ 115,815	8%
3-F. Participation in Standards Development	$ 125,973	9%
Total	**$ 6,165,003**	

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U.S. Department of Transportation
ITS Joint Program Office-HOIT
1200 New Jersey Avenue, SE
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