Phase 1 Systems Engineering Management Plan (SEMP)

Vehicle-to-Everything (V2X) Accelerator: Connecting the West – Utah Department of Transportation

www.its.dot.gov/index.htm

Final Report – April 9, 2025
FHWA-JPO-24-150

U.S. Department of Transportation

Produced by Saving Lives with Connectivity: Accelerating V2X Deployment Grant
U.S. Department of Transportation
Office of the Assistant Secretary for Research and Technology
U.S. Department of Transportation
Intelligent Transportation Systems Joint Program Office
Federal Highway Administration
Office of the Assistant Secretary for Research and Technology
Cover graphic source: U.S. Department of Transportation

Notice

Version History

#	Date	Author(s)	Comment
1	10/9/2024	CTW Team: D. Deeter J. Schroeder S. Zumpf T. English D. Weibler L. Cordova J. Amidon L. Preisen B. Leonard P. Castro	Initial draft
2	11/18/2024	CTW Team	Revised based on comments received from USDOT.
3	4/9/2025	CTW Team	Revised based on additional comments received from USDOT. Made additions to text and grammatical edits. Made the document Section 508-compliant.

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-JPO-24-150		

4. Title and Subtitle	5. Report Date
Phase 1 Systems Engineering Management Plan (SEMP) Vehicle-to-Everything (V2X) Accelerator: Connecting the West – Utah Department of Transportation	April 9, 2025
	6. Performing Organization Code
7. Author(s) D. Deeter, J. Schroeder, S. Zumpf, T. English, D. Weibler, L. Cordova, J. Amidon, L. Preisen, B. Leonard, and P. Castro	**8. Performing Organization Report No.**
9. Performing Organization Name and Address Utah Department of Transportation 2060 South 2760 West Salt Lake City, UT 84104	**10. Work Unit No. (TRAIS)** Proj No F-ST99(1014) **11. Contract or Grant No.** 693JJ324NF00003
12. Sponsoring Agency Name and Address U.S. Department of Transportation ITS Joint Program Office 1200 New Jersey Avenue, SE Washington, DC 20590	**13. Type of Report and Period Covered** Final **14. Sponsoring Agency Code** HOIT-1

15. Supplementary Notes

16. Abstract

The Systems Engineering Management Plan (SEMP) describes the systems engineering process, which include planning and systems engineering technical processes, that will occur over the course of the Connecting the West Program as well as the existing conditions in Utah, Colorado, and Wyoming. The SEMP supports the design and development of a system that is driven by user needs and built upon existing operational systems. The SEMP also identifies, at a high level, the items to be developed, delivered, integrated, installed, verified, and supported, which will be described in additional detail within subsequent documents in the systems engineering process for this effort. Through the systems engineering process, user needs are validated and verified across the deployment of complex systems over their life cycles.

17. Keywords	18. Distribution Statement
V2X; Vehicle-to-Everything; Accelerator; Deployment; Intelligent Transportation Systems	No restrictions. Document available from: National Technical Information Services, Alexandria, Virginia 22312

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	40	

Acknowledgements

The Connecting the West (CTW) team would like to thank the Federal Highway Administration (FHWA) and Noblis for their technical assistance throughout the review and editing process relating to the development of this document. The CTW team greatly appreciates the guidance and input that shaped this version of the Systems Engineering Management Plan (SEMP).

Table of Contents

List of Tables

List of Figures

List of Acronyms and Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
API	Application Programming Interface
ASN	Abstract Syntax Notation
ATMS	Advanced Traffic Management System
AWS	Amazon Web Services
BSM	Basic Safety Message
CAP	Comprehensive Acquisition Plan
CAV	Connected and Autonomous Vehicle
CCD	City and County of Denver
CDOT	Colorado Department of Transportation
CFR	Code of Federal Regulations
CI	Connected Intersection
CIMMS	Connected Intersection Message Monitoring System
CIP	Comprehensive Installation Plan
CIPT	Connected Intersection Preferential Treatment
CMOP	Comprehensive Maintenance and Operations Plan
ConOps	Concept of Operations
COTS	Commercial Off The Shelf
CSW	Curve Speed Warning
CTI	Connected Transportation Interoperability
CTIC	Connected Transportation Interoperability Committee
CTP	Comprehensive Transition Plan
CTW	Connecting the West
CV	Connected Vehicle
DMP	Data Management Plan
DOT	Department of Transportation
DPP	Data Privacy Plan
DSRC	Dedicated Short-Range Communication
ECLA	External Control Local Application
FCC	Federal Communications Commission
FHWA	Federal Highway Administration
GCP	Google Cloud Platform
GHz	Gigahertz
GM	General Motors
ICD	Interface Control Document
INCOSE	International Council on Systems Engineering
IOO	Infrastructure Owners and Operators

ISS	Integrity Security Services
ITE	Institute of Transportation Engineers
ITIS	International Traveler Information System
ITS	Intelligent Transportation Systems
JPO	Joint Program Office
JSON	JavaScript Object Notation
LiDAR	Light Detection and Ranging
LTE	Long-Term Evolution
ms	Millisecond
NEMA	National Electrical Manufacturers Association
NTRIP	Networked Transport of RTCM via Internet Protocol
NTP	Notice to Proceed
OBP	On-board Processor
OBU	On-board Unit
ODE	Operational Data Environment
OEM	Original Equipment Manufacturer
ORDP	Operational Readiness Demonstration Plan
ORDR	Operational Readiness Demonstration Report
ORP	Operational Readiness Plan
OTA	Over The Air
PFS	Pooled Fund Study
PII	Personally Identifiable Information
PMEP	Performance Measurement and Evaluation Plan
PMP	Project Management Plan
REST	Representational State Transfer
RLVW	Red Light Violation Warning
RSU	Roadside Unit
RTCM	Radio Technical Commission for Maritime Services
SAD	System Architecture Document
SCM	Signal Command Module
SCMS	Security Credential Management System
SDD	System Design Document
SDX	Situational Data Exchange
SEMP	Systems Engineering Management Plan
SEP	System Engineering Process
SNMP	Simple Network Management Protocol
SOMS	System Operations and Maintenance Schedule
SPaT	Signal Phase and Timing
SPII	Sensitive Personally Identifiable Information

SRM	Signal Request Message
SSM	Signal Status Message
STOL	Saxton Transportation Operations Laboratory
STP	System Test Plan
STRS	System Test Results Summary
SWIW	Spot Weather Impact Warning
SyRS	System Requirements Specification
TFHRC	Turner Fairbank Highway Research Center
TIM	Traveler Information Message
TMC	Traffic Management Center
TRAC	Transportation Reports and Action Console
TSP	Transit Signal Priority
UDOT	Utah Department of Transportation
USDOT	United States Department of Transportation
V2X	Vehicle-to-Everything
VM	Virtual Machines
VRU	Vulnerable Road User
VSL	Variable Speed Limit
WBS	Work Breakdown Structure
WYDOT	Wyoming Department of Transportation
WZDx	Work Zone Data Exchange

1. Introduction

Systems Engineering Management Plans (SEMPs) describe the people and methods used to manage the systems engineering processes. The SEMP supports the design and development of a system that is driven by user needs. Through the systems engineering process, user needs are validated and verified across the deployment of complex systems over their life cycles.

1.1. Document Purpose

The purpose of this SEMP is to describe the systems engineering processes for the Connecting the West (CTW) Program lifecycle. The lifecycle is comprised of four phases that align with the steps of systems engineering: (1) Planning and Design, (2) Materials and Equipment, (3) Installation and Integration, and (4) Operations and Maintenance. These phases are often depicted as part of a systems engineering “vee diagram” for the system lifecycle like that shown in Figure 1, with Planning and Design illustrated as a downward slope on the left side of the vee as the project begins, Materials and Equipment at the bottom of the vee as the project is being developed, the Installation and Integration on the upward slope on the right side of the vee as the project gets put into use, and the Operations and Maintenance outside of the vee on the top right due to it being ongoing.

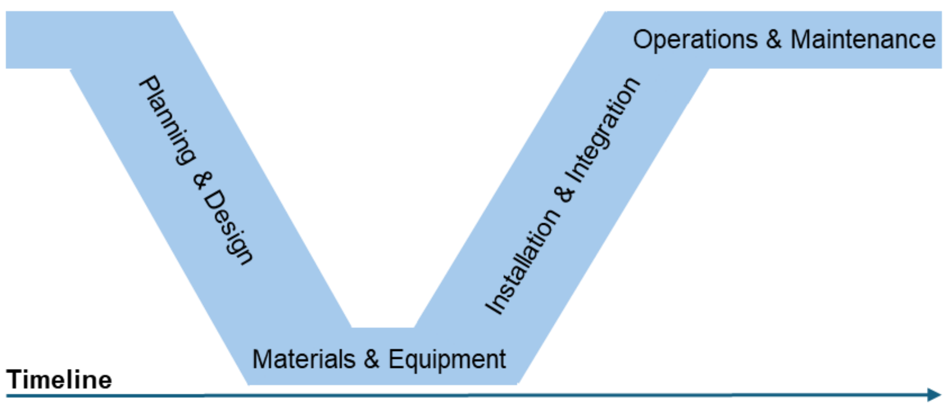

Figure 1. High-level “Vee Diagram” of the Systems Engineering Process Lifecycle
Source: Athey Creek Consultants, Nov. 18, 2024

The CTW systems engineering process illustrated at a high level in the vee diagram include the following:

- Planning and Design Phase
  - The **Planning** processes include high-level needs assessment, concept selection, and project planning that were conducted during the proposal stage. The CTW project is currently between the Planning processes and the Decomposition and Definition processes on the timeline.

  - The **Decomposition and Definition** processes will focus on documenting needs and an operational concept for the system to address needs in the Concept of Operations, deriving detailed requirements from the user needs to be documented in the System Requirements, and performing system architecture and design processes.
- Materials and Equipment Phase
  - The **Development and Implementation** processes will focus on materials and equipment procurement as well as configuration of existing software systems in place and expansion as needed.
- Installation and Integration Phase
  - The **Integration and Recomposition** processes will focus on materials and equipment installation and integration and implementation testing and acceptance.
- Operations and Maintenance Phase
  - The **Operations and Maintenance** processes will focus on ongoing operations and maintenance, changes and upgrades, and retirement/replacement of equipment and software systems.

The intended audience for this SEMP document is the United States Department of Transportation (USDOT) Federal Highway Administration (FHWA); the CTW Program partners, Utah Department of Transportation (UDOT), Colorado Department of Transportation (CDOT), Wyoming Department of Transportation (WYDOT), City and County of Denver (CCD), Utah Transit Authority, Salt Lake City, and General Motors (GM); the consultants and contractors that are developing technical materials for the CTW project; and future deployers of similar Vehicle-to-Everything (V2X) systems. Related, supporting documents that may be of interest to readers include the Project Management Plan (PMP) and subsequent systems engineering documents that are described in Section 1.3 below.

The SEMP is a living document that may be revised throughout the CTW Program. Discoveries and decisions made during the Planning and Design phase may impact and alter the Materials and Equipment Phase and the Installation and Integration Phase. As such, the SEMP will be revisited and updated after each system engineering deliverable and again after Phase 1 (as-built descriptions) to reflect the current systems engineering processes and expected products.

1.2. Connecting the West Program Overview

The CTW Program is part of a national initiative titled “Saving Lives with Connectivity: Accelerating Vehicle to Everything (V2X) Deployment” sponsored by USDOT and FHWA. This initiative consists of two phases as follows:

- Phase 1: Finalize Design, Build, and Test will result in an operational system that has been demonstrated and tested.
- Phase 2: Operate and Evaluate will begin after a go/no-go decision based on the outcomes of Phase 1.

The CTW Program is focused on saving lives and improving mobility using V2X technology in the 5.9 Gigahertz (GHz) “safety spectrum” along with some related communications platforms throughout Utah, Wyoming, and Colorado. The CTW team has deployed use cases in two major urban areas, in a rural community, along four major interstate corridors, and along unsignalized corridors in rural areas of the three states. The CTW team will leverage previous deployments, expand them to new areas, test and revise hardware and software to conform to the latest standards, and standardize the use of security credentials and data-sharing platforms. With this enlarged deployment operating in a uniform way, the program will demonstrate interoperable connectivity, measure the effectiveness of the technologies in the real world, and document this model as a national reference implementation.

The CTW Program will:

- Install Long-Term Evolution (LTE) V2X Roadside Units (RSUs) at signalized intersections in addition to existing equipped intersections (resulting in nearly every state-owned intersection in Utah being equipped with an RSU).
- Install LTE V2X RSUs along corridors in Utah and Colorado.
- Equip intersections in Utah with Vulnerable Road User (VRU) detection and warnings; UDOT is reviewing candidate locations as part of planning, and sites will be updated as known.
- Equip vehicles with On-board Units (OBUs) in Utah, specifically transit buses, snowplows, emergency vehicles, and state fleet vehicles operated by field supervisors. A GM vehicle with safety applications will also be operated by UDOT staff for testing and demonstrations.
- Expand the coverage of all of the use cases currently being used in Utah, Colorado, and Wyoming.
- Standardize the use of the Situational Data Exchange (SDX) across jurisdictions to make notifications uniform and interoperable across platforms.
- Perform rigorous testing in Utah and Colorado to verify that Connected Intersections (CIs) meet the appropriate Connected Transportation Interoperability (CTI) 4501 and other standards and transmit interoperable messages.
- Install CI Message Monitoring in Utah and Colorado to monitor ongoing compliance with standards.
- Establish standardized protocols for the issuance, management, and renewal of security certificates including OBU certificate top-offs to ensure secure and authenticated communication across all system components.
- Use field metrics to understand measurable improvements. Key metrics will be defined in the System Performance Measurement and Evaluation tasks.
- Document and broadly share to create a replicable model for others that will serve as a useful and meaningful reference implementation for interoperable connectivity.

The CTW Program consists of seven projects. Projects 1-4 will utilize existing software systems and add field infrastructure to what already exists in the participating states. Project 5 will focus on the integration and interoperability of applications both within the CTW Program and with external states and systems. Project 6 will focus on system performance measurement and evaluation. Project 7 includes the administration, reporting, systems engineering, and outreach activities.

Additional details of each of the seven projects are as follows:

- **Project 1: Utah Signalized Intersections RSUs**. *To be conducted by UDOT and their consulting team*. This effort will install RSUs at nearly every remaining, state-owned signalized intersection in Utah (i.e., over 300 signalized intersections) and some local agency-owned intersections. Intersections will be enabled with appropriate messages and applications.
- **Project 2: Utah Interstate and Rural Corridor RSUs.** *To be conducted by UDOT and their consulting team*. This effort will install RSUs along all major interstates in Utah at appropriate intervals and along some non-interstate rural corridors to primarily support Curve Speed Warning (CSW) and Spot Weather Impact Warning (SWIW) applications. Appropriate messages and applications will be enabled.
- **Project 3: Utah VRU Safety at Intersections.** *To be conducted by UDOT and their consulting team*. This project will install Light Detection and Ranging (LiDAR)-based detection, Traveler Information Message (TIM) broadcasts, and electronic signs at 20 urban intersections to issue warnings about VRU presence and collision risk.
- **Project 4: Colorado Interstate 70 Expansion and Integration.** *To be conducted by CDOT and their consulting team.* This project will install RSUs along the remaining portions of I-70 in Colorado to the Utah border.
- **Project 5: Application Integration and Interoperability Testing.** *To be conducted by collaboration of most of the consulting team.* This project brings all the agencies together to synthesize their applications, bring their applications into uniform compliance with standards and guidelines, integrate the data into the SDX, and perform detailed testing across all the jurisdictions to identify and overcome challenges and bring systems into conformance, making them interoperable. GM will engage during Project 5 to ensure that systems developed and data communicated conforms to their expectations, allowing their vehicles to successfully ingest and utilize data from within the CTW states.
- **Project 6: System Performance, Measurement, and Evaluation.** *To be conducted by UDOT, WYDOT, and CDOT with activities performed by the consultant team.* This project includes the evaluation efforts to assess the performance of our systems, report on those metrics, and account for confounding factors. A variety of testing methods and data analyses will be engaged, including using the purpose-built GM vehicle to confirm interoperability and produce data about the ultimate usefulness of our system to the end user – the vehicle and its driver.
- **Project 7: Project Administration, Reporting, and Outreach.** *To be led by UDOT with support from their consulting team.* This project includes all project management functions from the creation of the PMP to the monthly reporting and participating on outreach and engagement efforts outlined in the Outreach and Engagement Plan.

1.3. Summary of Systems Engineering Approach

This document represents one step of the systems engineering process within the CTW Program. Specifically, the systems engineering for the planning, design, deployment, integration, and operations activities described in Projects 1-5 above will be conducted as one overall process to describe the system of systems, with a single document for each of the following systems engineering elements:

- Concept of Operations (ConOps)
- System Requirements Specifications (SyRS)
- System Architecture Document (SAD)
- System Design Document (SDD)
- Operational Readiness Plan (ORP)
- Comprehensive Maintenance and Operations Plan (CMOP)
- Comprehensive Transition Plan (CTP)

Within these systems engineering documents, individual subsystems (including CTW team members' systems such as Panasonic's Cirrus and TriHydro's SDX) and field equipment will be defined with additional details. However, given a number of COTS software and hardware in this effort, the provided details will focus on the interfaces and configurations of COTS equipment and systems. Each CTW agency has their own program and may have existing documents. The CTW team will produce a single document that covers the work performed for this grant program and will include input from individual states.

In addition, the PMP and this SEMP represent two overarching documents that guide the entire program and systems engineering process. Additional details on aspects of the CTW Program related to the systems engineering process, such as milestones, decision points, and other additional context for the systems engineering process and CTW team within the broader program, can be found in the PMP. The timing of these documents within the systems engineering process over the course of the CTW Program are depicted in Figure 2. The system engineering documents for the CTW Program (and described in this document) cover system development, implementation and testing, operations and maintenance, and considerations beyond the program.

The systems engineering-related documents and activities for each of the four phases shown on the vee diagram include the following (see Figure 2):

- The PMP and SEMP are overarching documents that are developed early in the project and apply throughout the entire lifecycle of the four phases.
- During the project activities in the Planning and Design phase, five systems engineering documents will be developed:
    - Concept of Operations (ConOps)
    - System Requirement Specifications (SyRS)
    - System Architecture Document (SAD)
    - System Design Document (SDD)
    - Comprehensive Acquisition Plan (CAP)
    - Comprehensive Installation Plan (CIP)
    - Data Plan
- During the project activities in the Materials and Equipment phase, two systems engineering-related activities will be performed:

    - Procure equipment and systems
    - Build systems
- During the project activities in the Installation and Integration phase, one systems engineering document will be created and three systems engineering-related activities will be performed:
    - Systems engineering document:
        - Operations Readiness Plan
        - System Test Results Summary (STRS)
    - Systems engineering-related activities:
        - Install systems
        - Integrate systems
        - Test systems
- During the Operations and Maintenance Phase, two systems engineering documents will be developed:
    - Comprehensive Maintenance and Operations Plan
    - Comprehensive Transition Plan

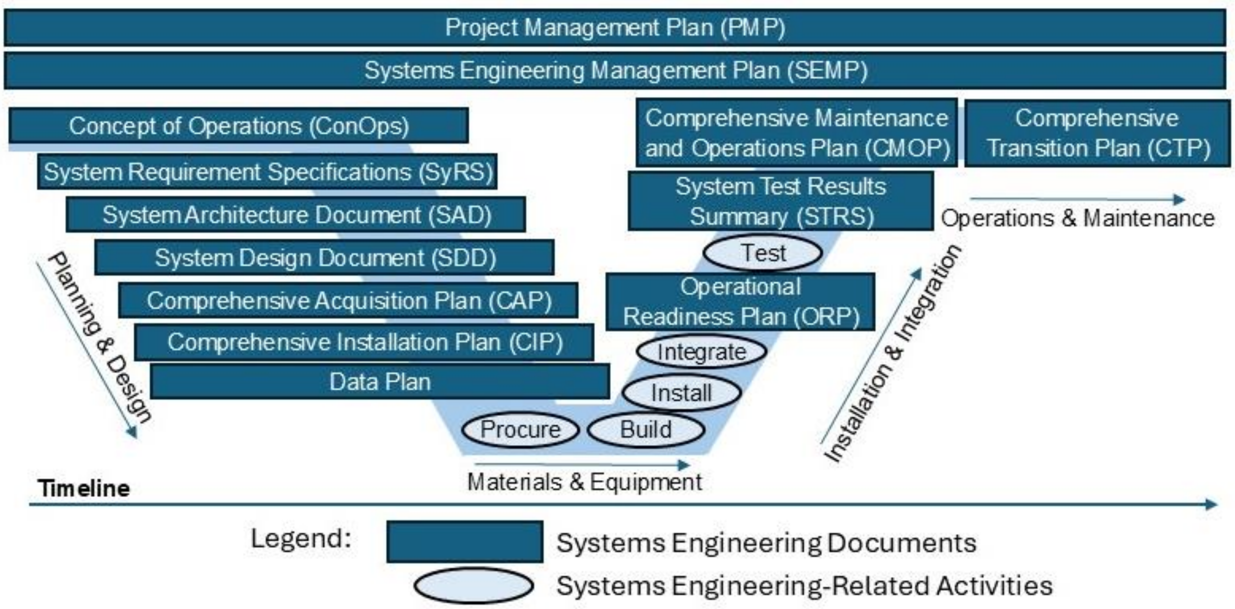

Figure 2. CTW Systems Engineering-Related Documents and Activities Over the Program Lifecycle

Source: Athey Creek Consultants, Nov. 18, 2024

1.4. Glossary of Key Terms

Table 1 defines key terms that are used in this SEMP.

Table 1. Glossary of Terms
Source: Athey Creek Consultants, April 2025

Term	Definition
Connected Intersection Message Monitoring System (CIMMS)	Developed by the Connected Vehicle (CV) Pooled Fund Study (PFS) to monitor the operation of CIs by comparing vehicle movements through the intersection with the active Signal Phase and Timing (SPaT) and MAP messages to identify inconsistencies. This open-source tool gives the unprecedented capability to assess real-time operations of intersections.
Cirrus	A scalable and cloud-based V2X and CV platform offered by Panasonic that helps agencies manage the broader CV ecosystem.
Operational Data Environment (ODE)	The ODE is an open-source set of tools used for backend systems in Colorado and Wyoming that support the encoding and decoding of Abstract Syntax Notation One (ASN.1), RSU management, privacy protection, and interfacing with third-party systems.
Situational Data Exchange (SDX)	A centralized data retention and distribution source by TriHydro for connected and autonomous vehicle (CAV) information, such as TIMs.
Subsystem	Subsystems refer to the self-contained software and/or hardware solutions that comprise the overall CTW system. The subsystems can operate independently but will be interconnected and interdependent with the other CTW subsystems to collectively comprise the entire system. CTW subsystems are expected to include (as a minimum) the Panasonic Cirrus System, the TriHydro SDX, the TriHydro ODE, the Helix Innovations Signal Command Module (SCM), and the Helix Innovations On-board Processors (OBPs).
Systems Engineering	A methodical interdisciplinary approach for the planning, design, implementation, technical management, operations, and retirement of a system.
Traffic Management Center (TMC)	Agency-owned center that collects traffic information, monitors and operates transportation networks and systems, and informs the public about changing travel conditions.

2. Existing Conditions

This section describes the existing V2X technologies and applications within Utah, Colorado, and Wyoming followed by individual descriptions of the key existing subsystems in place that form the basis from which the broader CTW system will be implemented. These existing subsystems in different states underscore the need for integration, an approach to define the data exchanges between them, and the common use of messaging including the TIMs and event message exchanges.

In addition to existing V2X technologies and applications described in Section 2.1, Table 2 summarizes the existing operational systems that are described in subsequent sections that will be leveraged for each CTW project.

Table 2. Summary of Existing Operational Systems That will be Leveraged for Each CTW Project
Source: Athey Creek Consultants, April 2025

Existing Subsystem	Project 1	Project 2	Project 3	Project 4	Project 5
TriHydro SDX	No	Yes	No	Yes	Yes
CIMMS	Yes	No	No	Yes	No
Panasonic Cirrus Cloud-based V2X Platform	Yes	Yes	Yes	No	Yes
SCM	Yes	No	No	No	No
OBPs	Yes	No	Yes	No	Yes
RSUs	Yes	Yes	Yes	Yes	Yes
OBUs	Yes	Yes	Yes	Yes	Yes
ODE	No	No	No	Yes	Yes
CV Manager	No	No	No	Yes	Yes

2.1. Existing V2X Technologies and Applications

Overall, the state agencies involved in CTW have an existing 5.9 GHz LTE V2X footprint that includes RSUs at 493 CIs and 535 non-signalized corridors and 483 vehicles with OBUs. The breakdown of these installations is summarized in Table 3 and Table 4 below.

Table 3. Summary of Current RSU Installations Across Deployment Area
Source: Athey Creek Consultants, April 2025

Current RSU Location	UDOT	WYDOT	CDOT	CCD	Total
At Signalized Intersections	360	0	26	107	**493**
Along Roadway Corridors	97	72	366	0	**535**
Total RSUs	**457**	**72**	**392**	**107**	**1,028**

Table 4. Summary of Current OBU Installations Across Deployment Area
Source: Athey Creek Consultants, April 2025

UDOT	WYDOT	CDOT	CCD	Total
327	10	98	48	**483**

As shown in Table 4, WYDOT currently only has 10 vehicles with LTE V2X RSUs. They previously had about 400 vehicles with Dedicated Short-Range Communication (DSRC) OBUs, but those vehicles are now capable of satellite reception only.

Additionally, existing applications that will be used in this effort include:

- **Connected Intersection Preferential Treatment (CIPT) –** CIPT includes transit signal priority (TSP) and emergency vehicle and snowplow preemption, to allow for improved mobility of equipped fleet vehicles at signalized intersections with LTE V2X technologies.
- **VRU Technologies –** UDOT has conducted research, early testing, and prototyping of LiDAR-based detection systems to detect VRUs at intersections that are being coupled with in-vehicle applications and roadside signs to alert drivers about pedestrian presence and intersection movements.[1]
- **CV Safety Applications –** These include CSW, SWIW, and alerts related to work zones, variable speed limits (VSLs), road closures, chain law restrictions, emergency vehicles, and disabled vehicles.

In addition to this brief summary of existing conditions, the ConOps document will define existing conditions as part of the derivation of objectives and user needs.

[1] Panasonic. (n.d.). Concept for System Capabilities, Vulnerable Road User Safety System. Prepared exclusively for the Utah Department of Transportation.

2.2. Existing Operational Systems Supporting Multiple Connecting the West States

2.2.1. Situational Data Exchange (SDX)

The SDX is a centralized exchange platform for public agencies to share data and messages from many data sources and provide a single data feed to various consumers (e.g., third-party consumers and ultimately to CVs). Currently, the SDX receives and distributes information formatted according to the SAE J2735 TIM standard and the Work Zone Data Exchange (WZDx) specification. The SDX can either receive messages with CV security credentials or apply security credentials. Third-party consumers then subscribe, at no cost, to consume event reports from the SDX. As part of CTW, UDOT, CDOT, and WYDOT anticipate developing a process for creating and sharing TIMs and various event reports via the SDX.

2.2.2. Connected Intersection Message Monitoring System

CIMMS was developed by the CV PFS to monitor the operation of CIs. CIMMS accomplishes this by analyzing vehicle movements, derived from generated Basic Safety Messages (BSMs) that are in relation to the active SPaT and MAP messages, and identifying any inconsistencies. Additionally, the tool assesses MAP and SPaT messages based on requirements outlined by the CTI Implementation Guide. CIMMS generates alerts for Traffic Management Center (TMC) operators detailing compliance issues, message counts, and overall intersection performance reports. This open-source tool gives the unprecedented capability to assess real-time operations of intersections. CIMMS is currently in use with UDOT and CDOT. While updates are expected over the term of this project for both states, they are separately funded by a PFS grant.

2.3. Existing Operational Systems – Utah V2X Highway Installations and Connected Intersections

2.3.1. Panasonic Cirrus Cloud-based V2X Platform

Cirrus is a cloud-based V2X platform that is a paid service used by UDOT to manage the broader CV ecosystem, connecting data from vehicles to the roadway infrastructure to improve safety and efficiency. Using Cirrus, UDOT can scale hardware deployments through a system of data collection, remote device monitoring/management, safety application support, and efficacy reporting. Cirrus provides comprehensive monitoring and operational support for CIPT and for the V2X Connected Roadway Systems.

Additionally, because V2X datasets are designed for anonymity with rotating IDs that do not persist, origin-destination of vehicle journeys is not collected by design. RSUs are secured and therefore only forward messages to Cirrus if the messages have valid security credentials attached by the OBUs that broadcast the message. Further, the RSUs are connected to the UDOT network, which allows traffic to and from the Cirrus network via firewall configurations. The data is secured in industry standard cloud-based solutions through Amazon Web Services (AWS). User roles are designed to allow data access to individuals based on approved account permissions, with logging and monitoring of all user activities.

2.3.2. Signal Command Module (SCM)

SCM is an external control local application (ECLA) device from Helix Innovations that sends MAP, SPaT, and Radio Technical Commission for Maritime Services (RTCM) messages to the RSU to be broadcast. SPaT messages are generated from information received from the traffic signal controller every 100 milliseconds (ms). RTCM messages are generated from either the SCM or by using a Networked Transport of RTCM via Internet Protocol (NTRIP) server. The device also consumes signal request messages (SRMs) to implement TSP and preemption for the traffic signal controller. As necessary, it reports ongoing TSP and preemption requests it has received by generating and sending signal status messages (SSMs) to the RSU to broadcast.

2.3.3. On-board Processors (OBP)

The OBP is a device from Helix Innovations that generates and sends BSM and SRM messages to the OBU to be broadcast. In addition, the device is capable of running a selectable algorithm that determines whether an SRM should be sent to request TSP or preemption. These algorithms use vehicle position, MAP matching, and data from external sources to determine whether it is necessary to request TSP or preemption for a given vehicle type. External data sources include transit bus onboard data, voltage input, or cloud data indicating schedule adherence for a given transit bus.

2.3.4. Roadside Units (RSUs)

RSUs In Utah are LTE V2X wireless radios from vendors, including Kapsch or Commsignia, that broadcast and receive SAE J2735 messages.

2.3.5. On-board Units (OBUs)

OBUs are LTE V2X wireless radios from vendors, including Ficosa or Commsignia, that broadcast and receive SAE J2735 messages.

2.4. Existing Operational Systems – Colorado V2X Highway Installations and Connected Intersections

CDOT’s CV deployments encompass LTE V2X RSUs and CIs. Integrity Security Services (ISS) Security Credential Management System (SCMS) enrolled RSUs are installed on most of the major highways in Colorado, including I-25, I-70, I-225, and I-270. These units are primarily used to transmit TIMs to OBUs and receive BSMs. There are currently 26 CIs that exist within Colorado under CDOT’s jurisdiction. The CIs are located along Region 1’s Arapahoe Road and Wadsworth Boulevard. Region 1 fleet snowplows are equipped with ISS SCMS-enrolled OBUs that interact with the CIs to request TSP and preemption. CDOT has an additional 40 state vehicles equipped with ISS SCMS-enrolled OBUs without TSP or preemption capabilities. All RSUs are configured to forward transmitted and received SAE J2735 messages to a backend ODE hosted in Google Cloud Platform (GCP). CDOT also supports Over the Air (OTA) updates for OBUs via Wi-Fi through select RSUs.

2.4.1. Functionality and Configurations

Supplementary data and data processing systems such as Zabbix, WZDx, the ODE, the CIMMS Conflict Monitor, and the CV Manager are also utilized by CDOT. The WZDx is a public dashboard and Application Programming Interface (API) for accessing ongoing and upcoming work zones across the state of Colorado. The information is utilized to generate traveler information messages deployed to geo-relevant RSUs. The ODE is hosted in GCP and used to process all received SAE J2735 messages from RSUs or log files sent from OBUs and deploy TIMs to RSUs. All processed SAE J2735 messages are decoded, converted into processed JavaScript Object Notation (JSON) format, and stored in MongoDB and GCP BigQuery for data analysis. The CV Manager is hosted in GCP and provides a portal view of the health of RSUs and allows for various CV data visualizations. The CV Manager has full integration with the CIMMS Conflict Monitor and Conflict Visualizer API to display CIs and associated events. CV Manager also supports RSU management and RSU upgrades for firmware.

2.4.2. Key Features

- RSUs provide OBUs with TIMs along major highways for work zones and safety conditions.
- CIs allow for TSP/preemption of CDOT Region 1 fleet snowplows.
- Use of the CV Manager allows streamlined CV architecture management and data analysis.

2.4.3. Users

- State employees driving vehicles with OBUs installed.
- State employees driving Region 1 fleet snowplows with OBUs installed.
- Intelligent transportation systems (ITS) department employees managing RSUs and creating tickets for site repairs.
- CDOT data analysts.

2.4.4. Interoperability and Data Sharing

Regarding interoperability with other systems, all SAE J2735 data generated by the CDOT CV system is forwarded to the CDOT GCP environment where the data is processed and used for visualization and analysis. The GCP environment is primarily composed of open-source technologies developed for the USDOT Joint Program Office (JPO) JPO-ODE GitHub repository. This includes services such as the jpo-ode, asn1_codec, jpo-geojsonconverter, jpo-conflictmonitor, and jpo-cvmanager. All SAE J2735 messages are processed using these publicly available solutions, and resulting JSON formats attempt to closely resemble the SAE J2735 standard. MAP messages and BSMs are also simplified into standard geoJSON for visualization. If there are any concerns or questions regarding the data within any of the processed messages, the original ASN.1 is maintained within the metadata.

Additionally, CDOT interoperability is also facilitated through the SDX. The CDOT system generates TIM messages that are forwarded by the ODE to the SDX. These alerts are publicly shared through the SDX. The SDX shares this data through a web portal that visualizes the current active TIMs and through a Representational State Transfer (REST) interface for more detailed information.

2.4.5. Summary

CDOT existing systems that are subsystems of the broader CTW Program are:

- ODE
- CIMMS Conflict Monitor
- CV Manager
- SDX
- Interfaces with the SDX

2.5. Existing Operational Systems – Wyoming Roadside Units (RSUs) and Sirius XM Satellite Communication Systems

WYDOT’s CV deployment involves LTE V2X RSUs installed along the I-80 corridor. All LTE V2X devices in the deployment are enrolled with production ISS SCMS certificates. Currently, there are 72 RSUs deployed along the corridor, along with 10 OBUs installed in state vehicles.

2.5.1. Functionality and Configurations

The RSUs are configured to forward transmitted and received SAE J2735 messages to a backend system, known as the ODE. This system is hosted internally on WYDOT's virtual machines (VMs). WYDOT also supports OTA updates and V2X message log file offloading for OBUs via Wi-Fi through selected RSUs. OBUs are configured to receive TIMs from both RSUs and Sirius XM satellites, which are managed by the SDX. TIMs are generated by the TMC using the Wyoming Traveler Information system. The Wyoming Traveler Information system calls into a Wyoming Data Broker REST service that in turn receives the data and builds a message with all information needed to properly build a TIM along with additional information on which RSUs to add the TIM to. These messages are then sent to the ODE, which distributes them to the identified RSUs as well as the SDX, which then updates Sirius XM broadcasted TIMs.

All data processing for WYDOT’s CV deployment is handled internally via locally hosted VMs. These VMs host the ODE, CV Manager, and database clusters. The ODE receives messages from RSUs either through a User Datagram Protocol connection or via Rsync offloaded V2X log files. These messages are then converted into JSON format, following the SAE J2735 standard, and stored in a MongoDB database for further analysis. Compressed log files are also archived to support misbehavior detection. The CV Manager application provides management and monitoring of the deployed RSUs, including reporting on their health through ping statistics and the status of SCMS certificates. It also offers a web portal to configure RSU firmware updates and manage Simple Network Management Protocol (SNMP) forwarding rules.

2.5.2. Key Features

- RSUs and Sirius XM satellites provide OBUs with TIMs along I-80 for chain law status, weather alerts, and vehicle blow-over restrictions.
- OBU V2X log offloading accommodates areas of I-80 without RSU connectivity.
- Use of the CV Manager allows streamlined CV architecture management and data analysis.

2.5.3. Users

- State employees driving vehicles with OBUs installed.
- TMC operators supply information about current conditions from WYDOT field personnel.
- WYDOT data analysts.

2.5.4. Interoperability and Data Sharing

Regarding interoperability with other systems, the WYDOT interoperability interface is primarily facilitated through the SDX. Road conditions and other alerts supported by the ODE are forwarded from the TMC. These alerts are converted to TIMs and are publicly shared through the SDX. The SDX shares this data through a web portal that visualizes the current active TIMs and through a REST interface for more detailed information. Other assorted SAE J2735 messages are also stored in a query supportive JSON format in a MongoDB database. Processed GeoJSON messages are also available and stored for BSM and MAP message types. WYDOT has extensive interface control document (ICD) documentation that outlines interfaces for most applications in the CV message pipeline.

2.5.5. Summary

WYDOT existing systems that will be included as subsystems of the broader CTW Program are:

- ODE
- CV Manager
- Interface with the SDX

2.6. Existing Operational Systems – City and County of Denver

The CCD has a V2X deployment that includes LTE V2X RSUs operating at 107 CIs. These RSUs support TSP and snowplow preemption. There are 48 CCD vehicles that have LTE V2X OBUs installed. Details of CCD's involvement in the CTW Program are still being defined; anticipated activities include validation of CIs to demonstrate interoperability.

2.6.1. Functionality and Configurations

Since the level of participation of CCD in the CTW Program is still being defined, details on the functionality of their V2X system is not yet determined.

2.6.2. Key Features

- CIs allow for TSP/preemption of transit buses and CCD fleet snowplows.

2.6.3. Users

- CCD employees driving snowplows with OBUs installed.
- CCD employees managing RSUs.
- CCD employees using data for systems analysis.

2.6.4. Interoperability and Data Sharing

Since the level of participation of CCD in the CTW Program is still being defined, details on interoperability and data sharing are not yet determined.

2.6.5. Summary

There are no CCD existing systems that are known subsystems of the broader CTW Program.

3. Planned System

3.1. System Overview

CTW will not build a new system from the ground up; it will extend and enhance the proven systems as described in the existing conditions section above and knit them into a cohesive, interoperable network across the three-state deployment site (Utah, Colorado, and Wyoming). The importance of this interoperability and connection between the three CTW state infrastructure owners and operators (IOOs) is emphasized by the activities of Project 5: Application Integration and Interoperability Testing. Figure 3 provides a high-level context diagram for the system. The subsystems and equipment referenced in the diagram will be described and defined in detail through the systems engineering process.

Figure 3 illustrates the system of interest as three subsystems and relevant external systems. The three subsystems are the central systems, field equipment and systems, and vehicle systems. The dashed line around these three boxes illustrates that everything outside of these three are external systems.

Central systems include:

- Wyoming's central systems are:
  - WYDOT Data Broker
  - Event Processor/Transportation Reports and Action Console (TRAC) System
  - Operational Data Environment
- Utah's central systems are:
  - Panasonic's Cirrus Platform
  - CIMMS
  - Utah Advanced Traffic Management System (ATMS)
- Colorado's central systems are:
  - CDOT ATMS
  - Event Processor
  - Operational Data Environment
  - CIMMS
- A central system represented and not tied to any state is the SDX:
  - SDX Hub
  - TIM Repository

Field equipment and systems include:

- VRU and vehicle detection
- Blank-out signs
- Work zone data detection
- RSUs and supporting equipment

Vehicle systems include:

- OBUs
- In-vehicle applications
- Human machine interfaces
- Mobile devices
- Signal request generators

External systems include:

- Traffic signal controllers
- VSL control systems
- Third-party traveler information systems

Note that this project leverages the open-source ITS JPO GitHub hosted ODE and CIMMS solutions. All updates made to these systems will be peer reviewed by the Turner Fairbank Highway Research Center (TFHRC) Saxton Transportation Operations Laboratory (STOL) team and updated quarterly on GitHub. Likewise, any performance management and test results data from this project can be shared with the DataHub with a bulk upload.

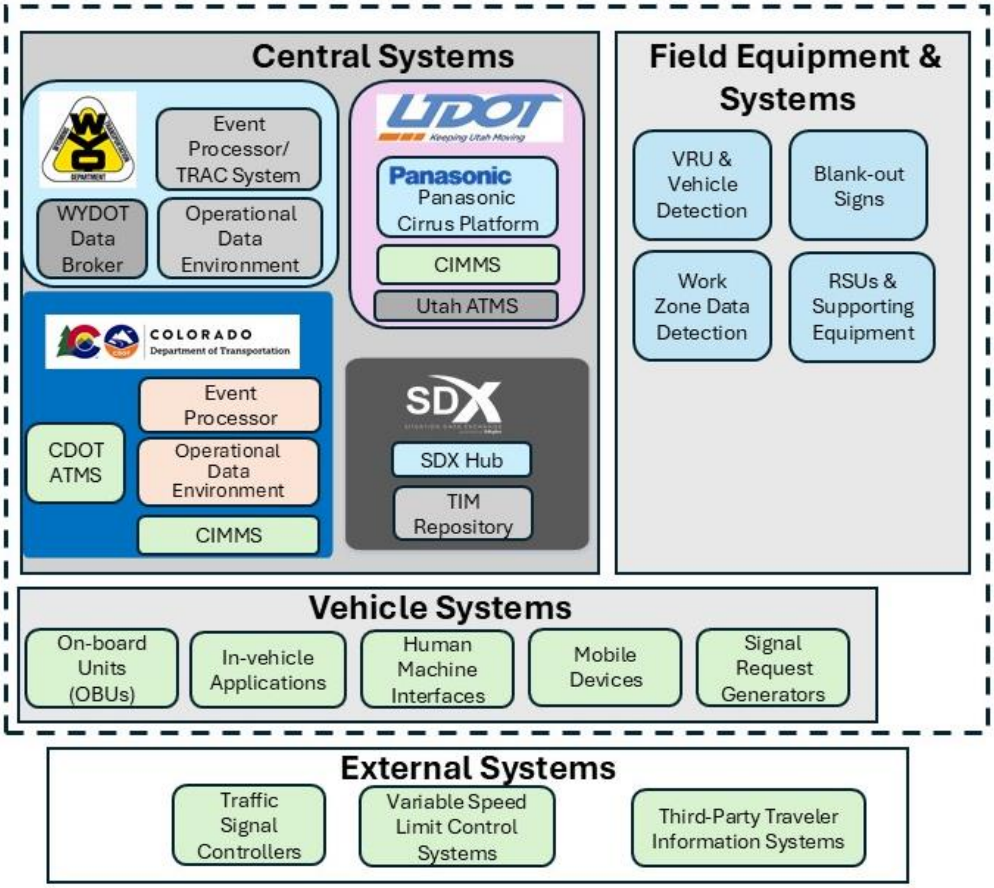

Figure 3. CTW High-Level Context Diagram

Source: TriHydro, modified by Athey Creek Consultants, Nov. 18, 2024

3.2. System Constraints

CTW will develop a system that communicates information to CVs via in-band (e.g., 5.9 GHz LTE-V2X RSUs that will conform to Federal Communications Commission [FCC] rules for the use of the 5.9 GHz band) and out-of-band network communications (e.g., network cellular and Sirus XM satellite radio) across Colorado, Utah, and Wyoming. To do so, it will deploy technology to ensure consistent and secure messaging to vehicles and utilize a data exchange that supports all three states and their travelers. The CTW Program will demonstrate the potential for interconnectivity and interoperability through a standard data exchange. CTW will also interface with the Maricopa County and Texas Accelerating V2X Deployment sites to demonstrate interoperability and scalability.

One constraint is that the system will utilize existing software solutions (e.g., Cirrus, SDX, and ODE) that are already in use. The CTW Program is building on the use of existing software packages currently in use by UDOT, CDOT, and WYDOT. Some of those are commercial products (e.g., Cirrus and SDX). Modifications will likely be necessary to these systems to advance the applications being used and to enable interoperability across state lines. Modifications may be constrained by the mature nature of these commercial products and their established architectures. Since these modifications are within commercial products, the new software cannot be open-source, as required by the grant agreement. Because of this, any needed modifications will be paid for with other sources of funding, not funds from this grant. New software or new solutions are not being added as part of this program.

Another potential constraint may be in the widespread deployment of RSUs. While the three participating states have committed to their use for this program, their adoption at a national level is limited. This may result in limited future development and maturation of RSUs with the CV industry potentially moving to cellular or other mediums for data exchange.

A related constraint involves the limitations of existing RSU, OBU, and signal controller vendors. Since CTW is a Commercial Off the Shelf (COTS) deployment at a time when adoption of RSUs and OBUs at a national level is limited, this program is limited by what those vendors have available. Similarly, existing signal controllers continue to have limitations interfacing with RSUs to seamlessly support CI applications.

Some technical risks related to the constraints are summarized as follows:

- **Crash Prevention at Signalized Intersections –** The proposed CIs will have the potential to support Red Light Violation Warning (RLVW) applications that warn drivers who are about to run red lights. However, these benefits will be limited by the number of RLVW applications deployed to vehicles. But the number of intersections validated to meet minimum requirements for RLVW and the trust from original equipment manufacturers (OEMs) and impacts on their decisions to deploy production vehicle applications can be measured.
- **VRU-Related Crash Preventions –** While the deployments of VRU safety systems at intersections hold great promise to reduce vehicle and VRU collisions, there is also the potential information overload to drivers. Monitoring vehicle movements will help to evaluate the impacts that the system has on driver behavior, and this will be a critical surrogate because it is impossible to accurately estimate the number of collisions avoided.
- **Crash Prevention Along Interstates and Rural Corridors –** The proposed system may not avoid an initial crash, but the system capabilities should be able to limit the extent of the crash (number of vehicles involved), related secondary crashes, and the severity of the crash (injuries/fatalities). These items are expected to be explored and reported in the Performance Measurement and Evaluation Plan (PMEP).
- **Information Overload –** System capabilities are limited by how much information can realistically be given to drivers. There is a multitude of possible information that could be provided including speed limits, warnings, incidents ahead, detours, parking opportunities, etc. Measuring the effectiveness of the eventual system will be a challenge and will be a topic during the development of the PMEP.
- **Technology Penetration –** The evaluation aspects of CTW during the FHWA-defined program's Phase 2 (Operate and Evaluate) will be challenged by the relatively few numbers of vehicles that will be capable of receiving direct information from the infrastructure or other vehicles – especially in comparison to the number of total vehicles operating in the project sites. The technology can be shown to work; however, measuring the benefits with such a small sample size will be limiting, although the coupled capabilities to also share messages with Third-party Traveler Information Applications will increase the number of drivers receiving alerts, albeit with increased latency.

3.3. System Milestones and Decision Gates

Projects 1-5, as defined in Section 1.2, are where the proposed system will be planned, designed, procured, and installed. Each of these five projects has common stages as identified by the work breakdown structure (WBS) Level 2. These stages include:

- **Planning/Design –** Where a number of key decisions will be reached, examples of these decisions include locations of deployment, equipment to be installed in the field, and designs of planned implementations. Preliminary and Final Design Reviews (as needed) are expected to be in this stage. The completion of the Planning/Design stage for each project will be a key milestone as the individual project teams will move on to the next stage.
- **Materials/Equipment –** Where decisions will be reached about the assets that need to be acquired will be made and documented in Project 6 as part of the CAP. Once acquisitions are defined, this stage will also procure and assemble the equipment. The completion of the Materials/Equipment stage will be a key milestone as the individual project teams will move on to the next set of tasks.
- **Installation/Integration –** Activities at this stage of each of the five projects will focus on providing input to the Comprehensive Installation Plan developed in Project 6 and will install and integrate the equipment and materials purchased. This stage will correlate with Project 5 activities, and this is where initial operational compatibility will be achieved. The completion of Installation/Integration will be a key milestone as the individual project teams will move on to the next set of tasks. At the conclusion of the activities in this stage, FHWA will reach a go/no-go decision regarding the CTW Program advancing to Phase 2 of the FHWA “Saving Lives with Connectivity: Accelerating Vehicle to Everything (V2X) Deployment” initiative.
- **Operations/Maintenance –** Activities at this stage will operate and maintain the systems deployed as part of Phase 2 of the FHWA initiative.

The common use of these milestones throughout the five deployment-focused projects represents the transitions from planning through operations and maintenance. The five projects are not planned to progress at the same rates; however, all will be completed in time for the performance measurement and evaluation activities. The overall CTW Program schedule, that is updated monthly, reflects the planned completions of each of these milestone areas. The initially planned schedule for each milestone by project is shown in Table 5 below.

Table 5. CTW High-Level Schedule of Milestones for Projects 1-4
Source: Athey Creek Consultants, April 2025

Task Name	Duration	Start Date	Finish Date
Phase 1 (Finalized Design, Build, and Test)	400 days	September 18, 2024	March 31, 2026
Project 1: Utah Signalized Intersections RSUs	474 days	August 29, 2024	June 23, 2026
Project 1: Planning/Design	164 days	August 29, 2024	April 15, 2025
Project 1 - Materials/Equipment	100 days	December 11, 2024	April 29, 2025
Project 1 - Installation/Integration	261.5 days	December 11, 2024	December 11, 2025
Project 1 – Operations/Maintenance	200 days	September 17, 2025	June 23, 2026
Project 2: Utah Interstate and Rural Corridor RSUs	412 days	September 1, 2024	March 31, 2026
Project 2 - Planning/Design	132 days	September 1, 2024	March 4, 2025
Project 2 - Materials/Equipment	100 days	December 11, 2024	April 29, 2025
Project 2 - Installation/Integration	321.5 days	September 18, 2024	December 11, 2025
Project 2 – Operations/Maintenance	160 days	August 20, 2025	March 31, 2026
Project 3: Utah VRU Safety at Intersections	390 days	September 18, 2024	March 17, 2026
Project 3: Planning/Design	150 days	September 18, 2024	April 15, 2025
Project 3 - Materials/Equipment	60 days	February 19, 2025	May 13, 2025
Project 3 - Installation/Integration	201.5 days	March 5, 2025	December 11, 2025
Project 3 – Operations/Maintenance	200 days	June 11, 2025	March 17, 2026
Project 4: Colorado Interstate 70 Expansion and Integration	390 days	September 18, 2024	March 17, 2026
Project 4: Planning/Design	160 days	September 18, 2024	April 30, 2025
Project 4 - Materials/Equipment	80 days	January 22, 2025	May 13, 2025
Project 4 - Installation/Integration	231.5 days	January 22, 2025	December 11, 2025
Project 4 - Maintenance/Operations	220 days	May 14, 2025	March 17, 2026

Project 5 is also a deployment-related project, albeit focused on achieving interoperability and compatibility in the systems deployed in Projects 1-4. For Project 5, a different set of stages have been defined. These include:

- **Planning/Design –** Where decisions will be reached about how consistency in messages and data exchanges can be achieved (e.g., what TIMs are used, what optional elements are mandatory, and how are the TIMs configured).
- **Develop Test Processes and Tools (Operational Readiness) –** Where preparations are made to transition Projects 1-4 into operational readiness testing. This stage is where full operational compatibility will be achieved.
- **Interoperability Testing –** Where the testing of interoperability among states is conducted.
- **Documentation and Reporting –** Where the testing of the proposed system is conducted.

Beyond these stages, milestones, and transitions, the CTW team has not yet defined additional details of milestones, but these will be updated as these decisions are reached.

3.4. Standardized Processes and Standards

The CTW Program is built upon existing and proven technologies that are currently in use. The primary efforts of the program will be expansion of these technologies and integration of their use among agencies. In order to do this, the program will adhere to the systems engineering process from planning through operation.

The systems engineering standards will follow the guidance in the FHWA Systems Engineering for ITS guide and be in compliance with 23 Code of Federal Regulations (CFR) Parts 655 and 940, the Final Rule on Architecture and Standards Conformity.

In complying with the Final Rule, the CTW team will reference systems engineering standards, including the International Council on Systems Engineering (INCOSE) Systems Engineering Handbook. It is noted that while these standards are referenced, there may be modest variations in individual projects.

Additionally, the rapid development of the CTW Program in conformance with the Accelerating V2X Deployment Grant program will not allow edits to existing ITS Architectures. In preparation for the program, the CTW team members reviewed available Regional ITS Architectures of member states and related materials and found no conflicts with existing architectures.

Because CTW utilizes mature systems, software development and modification will be minimal. However, any software modification and configurations are expected to use Agile methodologies. Specifically, open-source updates for the CIMMS and ODE code are the only open-source developments expected in the program. These will support updated reporting for CIs and automated events publishing for TIMs that support cross-board events. As the systems engineering tasks progress, there is a potential that additional new software creation will be identified. If new software is created, it will also be developed as open-source software and follow an Agile methodology.

CTW leadership and participating agencies are familiar with and have been involved in the various CTI activities and will leverage and make use of the standards and implementation guides, including:

- CTI 4001 v01.01 – Roadside Unit (RSU) Standard.
- CTI 4501 v01.01 – Connected Intersections Implementation Guide
- CTI 4501 v2.0 – Connected Intersections Implementation Guide (currently a Work in Progress)
- CTI 5001 – On-board Unit Standard for Connected Vehicles (currently a Work in Progress)

Standards for data exchange to be adhered to include:

- SAE J2735 V2X Communications Message Set Dictionary – This standard specifies a message set, and its data frames and data elements, for use by applications that use V2X communications systems. Specifically, the TIM is described within the SAE J2735 standard. The TIM is used to send various types of information (advisory and road sign types) to equipped devices, using International Traveler Information Systems (ITIS) codes.
- SAE J2540/2: International Traveler Information Systems (ITIS) Phrase Lists – This standard provides textual messages meeting the requirements for expressing ITIS phrases commonly used in the ITS industry. The codes within this standard are used in TIMs to communicate specific details about road conditions and events, for example.
- USDOT WZDx Specification – The WZDx specification enables IOOs to make harmonized work zone data available for third party use. The objective is to make travel on public roads safer and more efficient through ubiquitous access to data on work zone activity. While this specification is currently used by Utah, Wyoming, and Colorado Departments of Transportation (DOTs), it is being superseded by the Connected Work Zones Implementation Guidance Standard, which is based on the WZDx and is being developed by the Institute of Transportation Engineers (ITE), American Association of State Highway and Transportation Officials (AASHTO), National Electrical Manufacturers Association (NEMA), and SAE with funding provided by the USDOT.

3.5. Defect Discrepancy Processes

The CTW Program has the benefit that it is building upon existing systems already in place. Each system is already responsible for managing defects and discrepancies inherent to the system. This will continue and no new specific tool is proposed to be used to track defects and discrepancies. Any defects or discrepancies identified will be reported to the administrator of the respective system.

4. Systems Engineering Process Plan

A Systems Engineering Process (SEP) will be used to guide CTW deployment efforts across the three partner states. This section provides a plan for this process, specifically defining:

- What – The systems engineering deliverables that will be developed in this effort.
- Who – The CTW team members' roles and responsibilities in the systems engineering process.
- When – The overall schedule for the SEP.

As described above, CTW builds upon previous deployments and infrastructure. The program largely expands and integrates the use and impact of existing technologies. Hardware will largely be COTS devices and equipment. It is expected there will be limited software development, but any development required will follow Agile methodologies.

4.1. Project Team Organization

The CTW team is described and illustrated in the Program's PMP, Section 2.2. Team members' roles in regard to the systems engineering process are described in Section 4.3 below.

4.2. Systems Engineering Deliverables

Table 6 summarizes CTW's systems engineering-related deliverables.

Table 6. Summary of Systems Engineering-Related Deliverables
Source: Athey Creek Consultants, April 2025

Systems Engineering Deliverable	Purpose
Project Management Plan (PMP)	This document was created as the initial step in the CTW effort and will be maintained through the program. The PMP is accompanied by the master schedule that will track planned and actual program progress through the entire program. This document references the SEMP as the mechanism for managing the systems engineering portion of the program.
Systems Engineering Management Plan (SEMP)	The role of the SEMP is to describe the management approach to completing the systems engineering tasks and deliverables.

Systems Engineering Deliverable	Purpose
Concept of Operations (ConOps)	The ConOps will define the overall objectives of the program, stakeholders, stakeholder needs, the system concept from the perspective of stakeholders, and operational scenarios while considering cybersecurity/resilience and security threats. This document captures needs and operational concepts that are key inputs to the System Requirements.
System Requirements Specifications (SyRS)	The SyRS will define functional and performance requirements that the overall CTW system needs to perform to accomplish the objectives. The requirements included in the SyRS will map to the user needs in the ConOps to ensure that all needs are addressed by one or more requirements. The SyRS will not describe how these requirements will be met, but rather serve as a key input to the SAD and SDD to follow it.
System Architecture Document (SAD)	The SAD will build upon the requirements defined in the SyRS and identify which subsystem(s) will be responsible for accomplishing the requirements and how the different subsystems will interact to accomplish the requirements. This document will be the basis for understanding how existing systems will work together to accomplish the requirements and to identify additional hardware, systems, functionalities, or configurations of existing systems that may be needed. The SAD will also define the data flows between subsystems that are needed to accomplish the requirements.
System Design Document (SDD)	After the SAD has assigned each requirement to one or more subsystems and defined the data flows between subsystems, the SDD will describe the subsystem technologies (e.g., Panasonic's Cirrus, TriHydro's SDX, individual vendors' RSUs, vendors' OBUs, and signal control equipment) that collectively comprise the overall CTW system as well as the interfaces between the subsystems that will accomplish all requirements and address all stated user needs. The SDD will also build upon the data flows defined in the SAD to include an ICD to define the interfaces between systems.
Comprehensive Acquisition Plan (CAP)	Developed simultaneously with the SDD and leveraging information from the SDD and SyRS, the CAP will provide a detailed plan for procurement of equipment or services to accomplish the SDD. The CAP will identify the type and number of devices, equipment, and software-based capabilities to be acquired. The CAP will provide an overview of the proposed acquisition approach and a plan to equitably engage and inform prospective vendors over time in case of changes to requirements, quantities, and delivery timelines. As was noted in the PMP, much of the equipment to be purchased are COTS with little or no variations in products offered and that UDOT and CDOT have vendors under contract to provide. While the CAP will document and describe these, purchases for equipment will not wait until the full CAP is developed or approved, especially as these sometimes require a long lead time for procurement.

Systems Engineering Deliverable	Purpose
Comprehensive Installation Plan (CIP)	The CIP will incorporate the CAP and further identify the types and number of equipment required to be configured and installed. The CIP will provide an overview of the supplier base and procurement methods, a high-level plan for inventory and configuration management, a high-level initial installation schedule, and high-level installation plans.
Data Plan	The CTW Data Plan will include a Data Management Plan (DMP) and a Data Privacy Plan (DPP). The DMP will describe how data will be collected, integrated, managed, and disseminated in this program (e.g., data sources and destinations, volume of data flow, contents of data flow, communications mediums involved, and long-term storage plans). The DMP is therefore related to the systems engineering process as it will clarify how multiple requirements and needs are met and is a key aspect of design. It will also allow any variances identified from the requirements to be identified and discussed in CTW Technical Meetings. The Data Plan will also include a one-page letter on the Notice of Privacy Management Consistency. The intent of the letter will be to indicate that Privacy Management Plans have been created for the CTW member states.
Operational Readiness Plan (ORP)	The ORP will be a comprehensive plan that includes a System Test Plan (STP) and an Operational Readiness Demonstration Plan (ORDP). The STP is related to the systems engineering process in that it will be the plan for tests to be performed on the system components to verify the system meets proposed system requirements and is ready for launch. The testing will include, but will not be limited to, functional testing, performance testing, security testing, and end user tests. The STP will include a Requirements Traceability Matrix that shows traceability between requirements, the test verification method (e.g., inspection, demonstration, analysis, or test), and the specific test cases where the testing will occur. The ORDP is also related to systems engineering as it will describe the demonstration process to show that the system performs as expected in key use cases/scenarios.
System Test Results Summary (STRS)	The STRS will summarize the test results for all tests in the STP and will therefore include results of the testing of each requirement defined in the SyRS. The STRS will note any defects (e.g., where requirements are not met), the severity or impact of the defect, and the plan for addressing the defect.
Comprehensive Maintenance and Operations Plan (CMOP)	The CMOP will define the types and number of equipment that need to be maintained and operated as well as the operational methods to be implemented.
Comprehensive Transition Plan (CTP)	The CTP will describe the organizational and management process by which the system components will be transferred to a long-term operational and maintenance plan beyond Phase 2 of this program and that does not rely on federal funding.

4.3. Team Members Responsible for the Systems Engineering Process

It is important that each CTW team member understands their roles and responsibilities in the systems engineering process to ensure successful completion of all documents and supporting materials. These roles are as follows:

- **CDOT, UDOT, and WYDOT –** Each agency is responsible for the infrastructure and the various subsystems and field equipment that are deployed within their jurisdiction as part of this program. In most cases, each agency oversees a consultant team that will provide each agency support for developing, installing, and managing those subsystems. Each agency will provide input and approval for each step of the systems engineering process, with an emphasis on the needs definition in the ConOps and in the development of the CMOP as it relates to the operations that each agency will be responsible for at the conclusion of this effort.
- **Panasonic, TriHydro, and Narwhal –** Each of these entities have developed systems that are currently used by one or more of the CTW agencies, and these systems are all planned subsystems in the program. Each of these entities will provide input and feedback to the systems engineering process, as follows:
    - As deployers of systems supporting the CTW states, these entities will bring knowledge to ConOps and SyRS developments.
    - As the systems engineering process transitions to the SAD, these entities will provide critical information about their systems that will support the assigning of requirements to their systems and to the definition of data flows in and out of their systems that are needed to accomplish the requirements (essentially defining what data their systems can contribute to and what data their systems must consume from other subsystems).
    - As the systems engineering process transitions into the SDD, these entities will support the development of the overall ICD by describing the interfaces to accomplish the flows defined in the SAD. Additionally, each system owner will design the configurations needed to their systems, any supporting inputs (e.g., standardized messages such as the SAE J2735 TIM), and any system upgrades needed.
    - As the SEP transitions beyond the systems engineering document development and into procuring, installing, deploying, and configuring, these entities will be responsible for performing enhancements or configurations to their systems as needed.
- **Neaera Consulting –** Since Neaera works with both CDOT and WYDOT to support integrating systems and brings extensive experience in systems integration, Neaera will support the needs definition of the ConOps and the requirements definition of the SyRS and play a key role in the SAD and SDD development, leading the development of the ICDs needed to achieve the integration of systems.
- **Athey Creek Consultants –** Athey Creek Consultants will support UDOT in providing oversight for the overall systems engineering process. Additionally, Athey Creek will lead the development of systems engineering documentation, gathering input and feedback from relevant CTW team members, as needed. As part of this process, Athey Creek will compile information about all relevant projects and subsystems in order to develop singular, comprehensive systems engineering

documents (e.g., a single CTW Concept of Operations) for each step of the process that comprehensively describe the broader context of the CTW system.

- **GM –** As a consumer of CTW data, GM will provide a vehicle with on-board applications to make use of the data. GM will provide input to the requirements and overall design from the perspective of ensuring the data supports the applications they have created.

4.4. System Analysis

As the requirements are mapped to the individual systems that will perform the functions to accomplish the requirements, the expectations (based on existing deployments) are that the existing systems will be able to meet the requirements with additional configurations and that minimal new design or development of the systems will be needed. However, should design and development be needed, the trade-offs of key decisions will be handled as follows:

- The CTW team member responsible for their own systems will make the initial design and/or development decisions, reflecting the users of their system are likely to include other agencies outside the CTW states (e.g., there are other users of CIMMS, ODE, SDX, etc.).
- During CTW Technical Meetings, the CTW team member will share design or development changes, either by circulating documentation or presenting changes, together with anticipated benefits and drawbacks to the CTW system. The other team members involved in the Technical Meetings will react and discuss decisions and plan for any impacts to other CTW systems.
- The FHWA team will be updated on the next CTW FHWA Coordination Meeting, which always follows the CTW Technical Meetings by one week.
- The primary goal of these discussions and inclusion of input from CTW team members is to minimize risks to the overall CTW Program and risks that changes to one system may impact performance of other systems.

4.5. Timeline and Schedule of the Systems Engineering Process

A high-level schedule containing due dates for select draft and final systems engineering-related deliverables is shown in Table 7. Note that this table is not a comprehensive list of all systems engineering-related deliverables and walkthroughs and that actual due dates may vary and will be updated, as needed, as part of revisions to the PMP.

Table 7. CTW Due Dates of Systems Engineering Deliverables
Source: FHWA, Condensed by Athey Creek Consultants, Sept. 16, 2024

Deliverable	Due Date
Final PMP	Award
Final SEMP (508)	Award + 3 months
Final ConOps (508)	Award + 4 months
Final SyRS (508)	Award + 5.5 months
Final SAD (508)	Award + 7 months
Final SDD (508)	Award + 8.5 months
Final Data Plan (508)	Award + 10 months
Final CAP	Award + 10 months
Final CIP (508)	Award + 11.5 months
Final CMOP (508)	Award + 13 months
Final ORP (508)	Award + 13 months
Final STRS (508)	Per the ORP
Final CTP (508)	NTP + 12 months

5. System Engineering Technical Processes

This section defines details of the technical approach to the systems engineering activities outlined above. The goal is to include enough detail such that CTW Program team members understand the approach, their role in the approach, and the intended outcome of each step in the process.

Considerations of Configuration Management and Risk Management are critical for any systems engineering process. As such, the CTW Program approaches to Configuration Management and Risk Management have been respectively incorporated into Sections 9 and 10 of the overarching PMP document.

5.1. User Needs Processes

User needs will be gathered during the development of the ConOps. Preliminary needs will be developed at a high level through a review of literature and knowledge of the current operations of the technologies to be used in this program.

Following a general understanding of needs, stakeholders (i.e., program partners defined above that were instrumental in designing and implementing the existing systems operational today) will be interviewed through virtual workshops to understand their expectations on how end users will interact with the system and the needs of these end users. The outcome will be a set of user needs that will form the basis for the remainder of the effort.

The process to identify the user needs will be:

1. Define challenges to be addressed by this program.
2. Identify the proven and emerging solutions that address the challenges.
3. Establish the CTW objectives.
4. Work with users to identify their needs to achieve the objectives.

User needs will be identified for the following functional groups:

- Signalized intersections (Project 1)
- Interstates and rural corridors (Projects 2 and 4)
- VRUs (Project 3)
- Interoperability and compatibility (Projects 1-5)

Note that Projects 6 and 7 do not have users of the end systems, as these projects are dedicated to reporting and evaluation activities.

User needs will be documented in the ConOps. The ConOps will establish a matrix (or series of matrices) that documents all user needs and maps them to the associated user and functional area. The ConOps will provide the foundation for defining system requirements and guiding the design process. It will document the desired operational outcomes and scenarios from users' perspectives and then be translated into system requirements that define what the system must do.

The ConOps will also include operational scenarios that describe the planned actions of the CTW system from the perspective of users. Several scenarios will be developed that reflect a range of scenarios for each of the four functional groups defined above.

5.2. Requirements Process

System requirements will be developed to define a series of "shall" statements that describe what the overall CTW system must do to address the needs defined in the ConOps. The requirements will stop short of defining how the requirements will be met or what CTW subsystem will address each requirement. Each requirement will map to one or more needs, with the goal that only those requirements that address needs are included.

The process of defining requirements will be iterative and begin with a review of each need documented in the ConOps and a review of existing systems already operational in the member states. Any identified gaps will be used to define a preliminary draft set of system requirements with the purpose to serve as a basis for discussion and refinement.

The preliminary system requirements will be provided to CTW partner stakeholders for review, followed by stakeholder workshops to discuss and refine them. Based on feedback, the system requirements will be revised as a draft.

The draft will be reviewed by CTW stakeholders and their input will be incorporated into the final SyRS. Final system requirements will be mapped to user needs from the ConOps and to the specific projects to which they apply to demonstrate how and where each need is addressed. The relationship of needs to requirements will not be one-to-one, as some needs may be addressed by a set of requirements while other requirements may address multiple needs.

5.3. Architecture and Interface Development Process

Once the ConOps is created, the next step in the systems engineering process will be the development of the SAD.

5.3.1. Summary of the Connecting the West SAD – "The What"

The architecture and interface development process will be iterative and result in the SAD that describes the overall system architecture that will accomplish the requirements defined in the SyRS. It is expected that the SAD will be organized around the four functional areas that were the basis for the ConOps and SyRS, as follows:

- Signalized intersections (Project 1)
- Interstates and rural corridors (Projects 2 and 4)
- VRUs (Project 3)
- Interoperability and compatibility (Projects 1-5)

The SAD will define the subsystems that collectively will accomplish the requirements defined in the SyRS and the data flows between subsystems.

5.3.1.1. Connecting the West Approach to the SAD – "The How"

For each of the four focus areas identified above, the system architecture process will examine requirements defined in the SyRS and perform a mapping that assigns each requirement to one or more individual subsystems of the overall system. This will be done in conjunction with the partners responsible for each individual system. For example, some requirements will be accomplished by Cirrus, some by the SDX, and others by the actions of agency staff.

Due to the following key points, the SAD will be the first time that these requirements (which all map to needs) will be assigned to either existing CTW subsystems or identify for new systems that must be created:

- The ConOps will have focused only on defining what needs will be addressed (not how).
- The SyRS will have focused only on what requirements must be met (not how they are to be met).

The SAD will also define the required data interfaces for both data exchanges between individual CTW subsystems and data exchanges with external data sources. Where needed, the SAD will define the need for ICDs to be developed in the design phase as part of the SDD. Additionally, the content of the SAD will ensure secure data flows, encrypted communication channels, and isolated environments for sensitive components.

5.4. Design Processes

Upon completion of the SAD, the requirements will be mapped to individual CTW subsystems that either exist today or will be developed as part of the program. As each CTW subsystem will now have been assigned requirements it must meet, there will be increased need to define the data exchanges between subsystems and external data sources. In other words, **individual subsystems will need to rely on specific data in specific formats from other subsystems in order to meet their requirements. Defining these interfaces is a key aspect of the SDD for the overall CTW Program.** In particular, Project 5: Application Integration and Interoperability Testing will be considered as a part of this process given the need to ensure interoperability.

5.4.1. Summary of the Connecting the West SDD – "The What"

The SDD will describe the subsystem technologies (e.g., Panasonic's Cirrus, TriHydro's SDX, individual vendors' RSUs, vendors' OBUs, and signal control equipment) that collectively comprise the overall CTW system as well as the interfaces between the subsystems that will accomplish all requirements and address all stated user needs.

The key emphasis of the SDD will be on designs of an overall ICD or possibly multiple ICDs that describe how each subsystem interacts with each other and the interfaces each commits to and relies upon.

5.4.2. Connecting the West Approach to the SDD – "The How"

The SDD will advance the systems engineering process from where the SAD concluded by facilitating a process where the vendor or public agency responsible for each CTW subsystem examines the requirements to be met by their subsystem, examines the architecture flows and data exchanges that other subsystems are looking to their subsystem to deliver, and ultimately defines the processes and activities of their subsystem that will accomplish these requirements. This will include:

- Specific inputs and outputs of individual subsystems that are needed to accomplish the requirements defined in the system requirements specification.
- One or multiple ICDs, as needed, that define the data exchanges between individual systems to ensure these inputs are available to individual systems that need them.
- Specific capabilities of each individual subsystem that either exist today or will exist through modifications or configurations to meet the requirements and support the needed data exchanges from other systems.
- Which of the needed capabilities are already inherent to the existing subsystems already operational in CTW.
- Which capabilities need to be designed and added to the individual systems to support the overall System of System functionality (e.g., those not supported in the existing software systems).
- Which capabilities inherent to the existing software systems require configuration in order to meet the specific requirements.

It is expected that individual project or subsystem designs will be developed as part of the SDD. As much of the equipment will be COTS products, detailed designs of components such as RSU, OBUs, modems, and signal controllers will not be included, but rather their role in the overall design will be included – much in the way that an intersection design would incorporate COTS lighting. However, the SDD will refer to and acknowledge the standards, requirements, and designs developed by the Connected Transportation Interoperability Committee (CTIC). Additionally, the content of the SDD will ensure secure data flows, encrypted communication channels, and isolated environments for sensitive components.

To accomplish the SDD, an overall lead author of the SDD will examine the requirements and SAD outcomes and then work with the representative of each individual system to address the questions above and develop an overall design.

5.4.3. Traceability

The process of tracking requirements through the architecture and design activities is critical to ensure that all requirements are met and/or that any requirements not able to be met are understood and an action plan to minimize impacts is developed. This traceability will be initiated in the requirements stage and carried through the SAD and SDD development processes. It will be determined later whether one overall expansion of the requirements traceability matrix is used or whether the requirements are "decomposed" into design traceability matrices in each project's design, but the concept will be that the information will be readily available as to how each requirement is addressed (e.g., existing system feature, system configuration and use of existing feature, new feature, etc.). At this stage, each project team is expected to be meeting regularly with the active participants involved in discussions around their projects of interest. These team members will collectively reach the decisions and populate these tables, with regular updates during the CTW Technical Meetings for consideration by the broader CTW team as well.

5.5. Development Processes

CTW will be developed primarily using existing hardware and software, and there will be minimal software development with its focus on integration and interoperability.

Similarly, CTW will utilize existing and proven hardware, including RSUs and OBUs, that are functionally the same as units deployed in the three states.

However, the existing hardware and software systems (and additional field equipment purchased) will require configuration and may require creation of message templates or other inputs to function. These forms of development will have been defined in the SDD development and will be performed in this stage.

Additionally, after the designs are described as part of the SDD, a process for developing any additional needed software will be defined with the parties responsible for software development of each individual system. Security considerations will also be made during the development process, including secure data flows, encrypted communication channels, and isolated environments for sensitive components.

5.6. Implementation, Integration, and Verification Processes

The implementation, integration, and verification processes will be specific to each of the projects:

- Project 1: Utah Signalized Intersections RSUs
- Project 2: Utah Interstate and Rural Corridor RSUs
- Project 3: Utah VRU Safety at Intersections
- Project 4: Colorado Interstate 70 Expansion and Integration.
- Project 5: Application Integration and Interoperability Testing.

Implementation, integration, and verification as well as considerations for security, will be conducted independently within each project following the development processes identified above, with the exception of Project 5, which will require readiness of Projects 1-4.

STPs will be developed for each project. The test plans will describe the process to verify operational readiness of each component. The STP will be used during the validation process described below.

The Operations Readiness Plans (ORPs) will be developed following the STPs and will document the readiness for operations, including elements that are neither hardware nor software but represent support and other institutional considerations. The ORPs will provide a description of the validation process and the tests to be run. The tests are described in more detail under Section 5.7.

5.7. Validation Process

The validation process for each project will follow the process defined in the ORP, and the resulting test documentation will be incorporated into the ORP. Validation will consist of testing each system and validating the functions and security, as required.

Test scripts will be developed for each project that are similar to the operational scenarios defined in the ConOps. The scripts will be comprised of steps, with each step mapped to the relevant system requirements that are being demonstrated and validated. The test scripts will identify the expected successful outcome of each step as the design fulfillment statements. When the expected outcome is not achieved, it may be noted during testing that the requirement was not fulfilled.

The program will track the status of each requirement through testing to identify issues and deficiencies that will require addressing and retesting before the system can be validated.

5.8. Operations and Maintenance Processes

Each project in CTW will be operated and maintained independently but will adhere to a common set of standard operating procedures to ensure that each subsystem works independently and as an integrated part of the system.

A CMOP will be developed that documents the standard operating procedures and describes specifically how each subsystem will conduct those procedures. The CMOP will describe the following topics for CTW Projects 1-5:

- Change management
- System maintenance
- Maintenance of project documents
- Data management
- Staff roles and responsibilities
- Technical support

5.9. Data Management and Planning Processes

Data management will be a key aspect of the CTW Program. The process of data management will begin early in the effort, and the DMP will be the key deliverable. The DMP will describe how data will be collected, integrated, managed, and disseminated in this program (e.g., data sources and destinations, volume of data flow, contents of data flow, communications mediums involved, and long-term storage plans). The DMP will include a section that describes the DPP. The section on the DPP will describe the privacy controls to mitigate the risk of harm through improper handling or disclosure of PII or sensitive personally identifiable information (SPII).

As outlined in the program schedule, the approach to data management planning will be a process of individual member state DOTs (i.e., UDOT, CDOT, and WYDOT) all contributing input to the data management planning process based on their existing data management procedures and the planned changes to their systems through the CTW Program. This input will include both handling of PII and SPII as well as data storage, access, and availability. In addition to the input from member state DOTs, this process will include input from systems developers/operators of aggregated systems (e.g., those used across agencies) such as the ODE and SDX. This input will describe their systems' ability to support data management, experiences to date, and local configurations needed.

Based on the facilitated process for input, the overall Data Plan (including both the DMP and DPP) will be developed and reviewed in the CTW Technical Meetings.

5.10. Post-Phase 2 Processes

CTW will be built to continue to operate and provide its intended benefits beyond the program schedule. Funding for “Past Phase 2” has not been identified but continued operation is required for at least five years. Similarly, ownership and responsibilities beyond the program schedule will need to be defined.

The following considerations and the strategy for ongoing operations and maintenance will be documented in a Comprehensive Transition Plan (CTP):

- Plans for funding
- Ownership of individual components
- Long-term operational agreements
- Data and service hosting
- Data ownership
- Long-term maintenance and operations responsibilities
- Plans for continually updating and improving the system
- Evaluating the system to determine lifecycle and retirement plans

5.11. Risk Management

Risk management is covered in Chapter 10 of the PMP, and to avoid redundancy or conflicting definitions it is not defined here. However, the need to identify and manage risks, especially at key transitions and milestones of the CTW Program, is recognized. The monthly reporting to FHWA includes a monthly update to the Risk Register, and the Technical Working Group that meets bi-weekly will be discussing and identifying risks. As these risks are identified, they will be organized into the appropriate project and stage and tied to milestones whenever possible.

6. Agile Process Application

6.1. Systems, Subsystems, and Components Using Agile Development

This section identifies those parts of the proposed system that will use the Agile development process.

6.1.1. Cirrus Cloud-based V2X Platform

Cirrus is an existing system operated and maintained by Panasonic, with an existing internal process for managing the software and systems. No changes to this software system are planned through this program; rather, configurations of the system will be done as needed. If any enhancements are identified, these will be considered by Panasonic and implemented as part of their internal product development process. No Agile development planned as part of this project.

6.1.2. Connected Intersection Message Monitoring System (CIMMS)

The CIMMS tool is in active development and testing within the CV PFS and is an open-source tool. This development uses existing processes for Agile workflows and validation testing and is separate from this program. Any new additions to the CIMMS tool, from planned quarterly releases, will be deployed and integrated at existing CIMMS deployment sites. No Agile development is planned for the CIMMS tool as part of this program.

6.1.3. Situational Data Exchange (SDX)

The SDX is an existing system operated and maintained by TriHydro, with an existing internal process for managing the software and systems. No changes to this software system are planned through this program; rather, configurations of the system will be done as needed. If any enhancements are identified, these will be considered by TriHydro and implemented as part of their internal product development process. No Agile development planned as part of this program.

6.1.4. Operational Data Environment (ODE)

The ODE project will use an Agile development approach to enable the efficient transfer of TIMs across state borders. This process will involve a Scrum-based methodology, with tasks assigned to team members in two-week sprints to maintain a steady workflow. Daily Scrum meetings will enable team members to report on their progress, highlight any blockers, and discuss key updates. A Scrum Master will oversee these discussions, facilitate sprint planning sessions, and ensure that the team adheres to Agile principles. Additionally, all new code features will undergo a peer review process through Pull Requests, enabling early identification of potential bugs and performance issues before deployment to production. This process helps maintain high code quality and ensures smoother system integration.

6.2. Systems Engineering Agile Integration, Roles, Planning, and Tools

Given that the CTW Program is a fusion and expansion of existing systems, very limited software development is planned (as outlined in Section 6.1 above). The Agile process will be managed by each contractor responsible for their products and in relation to the agencies using their systems.

U.S. Department of Transportation
ITS Joint Program Office – HOIT
1200 New Jersey Avenue, SE
Washington, DC 20590

Toll-Free "Help Line" 866-367-7487

www.its.dot.gov

FHWA-JPO-24-150

U.S. Department of Transportation