

Phase 1 System Requirements Specification (SyRS)

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

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List of Acronyms and Abbreviations

ATMS	Advanced Traffic Management System
BSM	Basic Safety Message
C-V2X	Cellular V2X
CAN	Controller Area Network
CDOT	Colorado Department of Transportation
CI	Connected Intersection
CIMMS	Connected Intersection Message Monitoring System
CIPT	Connected Intersection Preferential Treatment
ConOps	Concept of Operations
COTS	Commercial Off the Shelf
CSW	Curve Speed Warning
CTI	Connected Transportation Interoperability
CTIC	Connected Transportation Interoperability Committee
CTW	Connecting the West
CV	Connected Vehicle
CV PFS	Connected Vehicle Pooled Fund Study
DOT	Department of Transportation
FHWA	Federal Highway Administration
GM	General Motors
GPS	Global Positioning System
HMI	Human Machine Interface
I-70	Interstate 70
IRC	Interstate and Rural Corridor
LIDAR	Light Detection and Ranging
MAP	Map Data Message
NTRIP	Networked Transport of RTCM via Internet Protocol
OBU	On-board Unit
ODE	Operational Data Environment
OEM	Original Equipment Manufacturer
ORP	Operational Readiness Plan
PMP	Project Management Plan
RLVW	Red Light Violation Warning
RSU	Roadside Unit
RTCM	Radio Technical Commission for Maritime Services
SCM	Signal Command Module
SCMS	Security Credential Management System
SDSM	Sensor Data Sharing Message

SDX	Situation Data Exchange
SI	Signalized Intersection
SMART	Strengthening Mobility and Revolutionizing Transportation
SOI	System of Interest
SPaT	Signal Phase and Timing
SRM	Signal Request Message
SSM	Signal Status Message
SWIW	Spot Weather Impact Warning
SyRS	System Requirements Specification
TIM	Traveler Information Message
TMC	Transportation Management Center
TOC	Traffic Operations Center
TSCBM	Traffic Signal Control Basic Message
TSP	Transit Signal Priority
UDOT	Utah Department of Transportation
UPER	Unaligned Packet Enabling Code
USDOT	United States Department of Transportation
UT	Utah
UTA	Utah Transit Authority
V2X	Vehicle-to-Everything
VRU	Vulnerable Road User
VSL	Variable Speed Limit
WTI	Wyoming Traveler Information System
WYDOT	Wyoming Department of Transportation
WZDx	Work Zone Data Exchange

1. Introduction

This document is the System Requirements Specification (SyRS) for the Connecting the West (CTW) Program. The CTW Program is part of the United States Department of Transportation's (USDOT) Saving Lives with Connectivity: Accelerating Vehicle-to-Everything (V2X) Deployment grant program (often referred to as the V2X Accelerator program) aiming to showcase interoperable, large-scale V2X benefits to drive Original Equipment Manufacturer (OEM) investment. This document outlines requirements specific to the systems that are anticipated to be deployed as part of the CTW Program. The CTW Program is led by the Utah Department of Transportation (UDOT) with partners Wyoming Department of Transportation (WYDOT) and Colorado Department of Transportation (CDOT). The CTW Program efforts will also include local agencies within each state, some of which will be partners in the process and others as participants. Each participating state has an existing connected vehicle ecosystem, and each state will expand and improve on this ecosystem through the CTW Program. However, as outlined below, these expansions and improvements are not uniform across all three states.

1.1. Purpose of the Document

The purpose of this document is to build upon the Concept of Operations (ConOps) to define system capabilities and requirements for the CTW system. More specifically, this SyRS includes functional, interface, performance, and data requirements that will inform the system architecture and system design phases of the CTW deployment. These requirements will also be the foundation for defining the testing and evaluation to be performed as documented in the Performance Management and Evaluation Plan, where validation criteria for the requirements will be managed. Finally, these requirements will feed into the Operational Readiness Plan (ORP), where test plans and procedures and verification and validation methods and criteria will be located and maintained to ensure the requirements are testable and achievable.

The systems engineering process 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. This document is completed as part of the Planning and Design phase of the systems engineering process lifecycle.

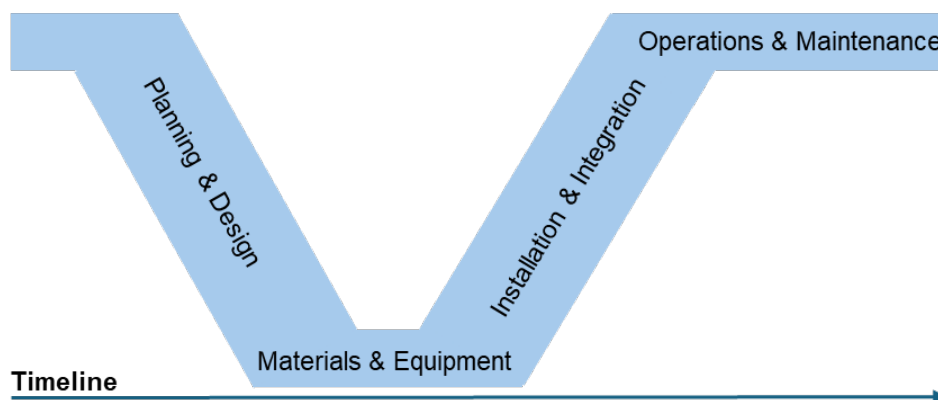


Figure 1. High-level “Vee Diagram” of the Systems Engineering Process Lifecycle
Source: Athey Creek Consultants, Nov. 18, 2024

1.2. Project Scope

The focus of the CTW Program is to expand the use of existing V2X applications in Utah, Wyoming, and Colorado and to share messages among the CTW States. The V2X applications that are anticipated to be deployed are:

- Connected Intersection Preferential Treatment (CIPT), including transit signal priority (TSP) and signal preemption for emergency vehicles and snowplows.
- Delivery of traveler information and driver alerts regarding curve speed warning (CSW), spot weather impact warning (SWIW), work zones, variable speed limits (VSLs), road closures, chain law restrictions, and disabled vehicle alerts.
- Detection of vulnerable road users (VRUs) at intersections coupled with in-vehicle and roadside alerts to drivers about VRU presence and intersection movements.

The scope of the CTW Program includes the following deployment activities:

- Install roadside units (RSUs) at signalized intersections (SIs) in Utah.
- Install RSUs at additional sites along corridors in Utah and Colorado.
- Equip additional intersections with VRU detection and warnings in Utah.
- Equip additional vehicles with On-Board Units (OBUs) and human machine interfaces (HMIs) where appropriate in Utah, including transit buses, snowplows, emergency vehicles (fire engines and ambulances), and general fleet vehicles including a General Motors (GM) test vehicle that will be driven by UDOT staff.
- Expand the coverage of all use cases currently being used in all CTW states.
- Establish the use of the Situation Data Exchange (SDX) across jurisdictions to make notifications uniform and interoperable across platforms in all CTW states.
- Expand the use of Connected Intersections (CI) Message Monitoring in Utah to monitor ongoing compliance with standards.

- Establish the use of security certificates and OBU certificate top off to facilitate interoperable communications in all CTW states.

The CTW Program will also:

- Perform rigorous testing to verify that CIs meet the Connected Transportation Interoperability (CTI) 4501 and other standards and transmit interoperable messages in Utah and Colorado.
- Document and broadly share the deployment and implementation approach to create a replicable model for others and to serve as a useful and meaningful reference implementation for interoperable connectivity.

The scope of this CTW Program is limited to the additional equipment, components, and functions that are expanding upon existing systems that are operating in Colorado, Utah, and Wyoming. The aforementioned activities are organized into seven projects, which are described below:

- **Project 1: Utah SI RSUs.** This project will install RSUs at state-owned SIs in Utah (i.e., over 300 SIs) and some local agency-owned intersections. Intersections will be enabled with appropriate messages and applications.
- **Project 2: Utah Interstate and Rural Corridors (IRC) RSUs.** This project will install RSUs along major Interstates in Utah at appropriate intervals and along some non-Interstate rural corridors to primarily support CSW and SWIW applications. Appropriate messages and applications will be enabled.
- **Project 3: Utah VRU Safety at Intersections.** This project will install Light Detection and Ranging (LiDAR)-based detection, Traveler Information Message (TIM) broadcasts, and electronic signs at urban intersections in Utah to issue warnings about VRU presence and collision risk.
- **Project 4: Colorado Interstate 70 (I-70) Expansion and Integration.** This project will install RSUs along the remaining portions of I-70 in Colorado to the Utah border without coverage. Appropriate messages and applications will be enabled.
- **Project 5: Application Integration and Interoperability Testing.** This project will bring 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.
- **Project 6: System Performance, Measurement, and Evaluation.** This project will include the evaluation efforts to assess the performance of the states' 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 the CTW systems to the end-user – the vehicle and its driver.
- **Project 7: Project Administration, Reporting, and Outreach.** This project will include all project management functions from the creation of the Project Management Plan (PMP) to the monthly reporting and participation in outreach and engagement efforts outlined in the Outreach and Engagement Plan.

1.3. Document Overview

The previously developed CTW ConOps document defined the user classes (i.e., stakeholders) and high-level user needs and described the capabilities that are being added or expanded in the CTW Program to address these needs. This SyRS document summarizes and reiterates these needs and capabilities and goes one step further by presenting details about the parts of the CTW system that is planned in each CTW agency state. More specifically, for each CTW state, this SyRS document defines:

- A description of the system to be deployed in each state.
- The capabilities specific to each state that will be added or expanded through the CTW Program. These capabilities are related to the CTW projects, as introduced above, to support the CTW project teams in understanding the capabilities that each project team will be delivering.
- The internal and external interfaces for each state's system.

This document also defines detailed system requirements to be met through the CTW system design in a tabular format that maps each requirement to the appropriate state(s), the user need, the capability, and the system (e.g., Central System, Field Equipment, and Vehicle System) related to the requirement. Further, each requirement is identified as one or more of the following: functional requirement, interface requirement, performance requirement, or data requirement.

The intended audience for this SyRS document is the USDOT FHWA; the CTW Program partners (UDOT, CDOT, WYDOT, City and County of Denver, Utah Transit Authority [UTA], Salt Lake City, and GM); and the consultants and contractors that are developing technical materials for the CTW Program.

This SyRS document contains the following sections:

- 2. General System Description
- 3. System Requirements

2. General System Description

This section provides a general description of the CTW system, including system context, capabilities, and expected components. In addition, the CTW system user classes (i.e., stakeholders) and user needs as defined in the CTW ConOps document are provided, and the system requirements detailed in subsequent sections of this SyRS document are mapped to the user needs. The CTW ConOps includes descriptions of operational scenarios for the CTW system, and readers are encouraged to review these as input to the system context of this document.

2.1. System Context

The proposed CTW system is a System of Systems, with a system of interest (SOI) that includes Central Systems, Field Equipment, and Vehicle Systems. UDOT, WYDOT, and CDOT will continue to operate their individual Central Systems and Field Equipment while also continuing to operate fleet vehicles equipped with Cellular V2X (C-V2X) technologies. WYDOT will also continue to operate fleet vehicles equipped with satellite-enabled V2X communications. In addition to the SOI, external systems will support the CTW SOI.

The functions of the proposed CTW system are described in terms of the functions that are anticipated to be performed by the following system component types:

- **Central Systems.** Central Systems are systems within the CTW SOI that are operated by each respective CTW agency and are typically housed within Department of Transportation (DOT) facilities or hosting centers.
- **Vehicle Systems.** Vehicle Systems include the OBUs and HMIs located in vehicles as well as a collective set of equipment and processing capabilities within vehicles that are equipped with V2X technology as part of the CTW SOI.
- **Field Equipment.** Field Equipment include roadside devices and equipment (often with built-in or supporting software and systems) that function as part of the CTW SOI.

As introduced originally in the CTW ConOps document, the following summary of capability changes describes the expansions and changes planned through the CTW Program.

The description of desired changes includes the following categories of changes:

1. Expansion of existing capabilities (e.g., existing capabilities that will be expanded with no change to the functionality).
2. Capability changes (e.g., changes to existing conditions in terms of enhanced system capabilities and expanded deployments).
3. Personnel changes (e.g., changes to roles and responsibilities of CTW agency staff).

Personnel changes were considered when developing the CTW ConOps, but it was determined that no personnel changes were needed. The following describes the anticipated changes within each category introduced above:

1. **Expansion of existing capabilities:** The following expansions of existing functions will be performed by the CTW Program:
 - a. *Expand preferential treatment at CIs.* Expand SI preferential treatment for transit and emergency vehicles and snowplows to additional intersections and vehicles in Utah.
 - b. *Expand CIs.* Expand the number of SIs in Utah that operate as CIs and meet the accuracy, reliability, and timeliness parameters needed to support in-vehicle safety applications to address the user needs to the extent possible.
 - c. *Expand the number of RSUs broadcasting and receiving messages.* Expand the deployments of RSUs to broadcast TIMs and receive Basic Safety Messages (BSMs) in Utah and Colorado.
 - d. *Expand VRU detection and alerts at intersections.* Deploy systems at a limited number of intersections in Utah to further test and demonstrate capabilities to detect VRUs crossing intersections and provide alerts to drivers about possible conflicts with the vehicles.
 - e. *Expand system monitoring and reporting.* Expand and enhance the collection, storage, and management of data describing the health of systems and messages exchanged with equipped vehicles.
 - f. *Expand security credentialing.* Expand the processes of attaching security credentials to messages exchanged by additional Field Equipment and Vehicle Systems.
 - g. *Demonstrate OEM vehicle interoperability.* Involve a C-V2X-enabled OEM vehicle with safety applications as a public agency-operated test vehicle with available safety applications and drive a predetermined, instrumented “loop” corridor within the three CTW states.
2. **Capability changes:** The proposed system will accomplish the following capability changes:
 - a. *Improve TIM consistency.* Modify the approaches used in CTW states for generating and managing TIMs to achieve consistency in message structure and content.
 - b. *Increase and improve TIM creation.* Expand the capability to create TIM messages (using the consistency approach agreed) that describe SWIW, CSW, alerts, and advisories by increasing the geographic coverage and expanding message content creation in Utah and Colorado.
 - c. *Improve consistency of Interstate exchange of event reports.* Modify event report creation in each state to a consistent approach and exchange event reports describing traveler information alerts among the CTW states using the SDX.
 - d. *Create new TIM exchanges.* Utilize the SDX such that each CTW state sends TIMs and receives TIMs from neighboring states.
 - e. *Demonstrate SCMS interoperability.* Conduct demonstrations to understand the extent to which Security Credential Management System (SCMS) certificates are interoperable between the CTW states and take steps to achieve interoperability as needed.
 - f. *Expand integration of connected vehicle (CV) data.* Expand the ingest, quality-check, and processing of data from CVs in Colorado and Utah as the number of RSU data collection sites expand.

- g. *Expand data storage.* Expand data storage processes to support additional RSU data collection sites.
- h. *Refine SCMS certificates without cellular service.* Refine and expand an approach to topping off SCMS certificates in Utah fleet vehicles that does not require cellular service.

In addition to these changes for the proposed CTW system, the internal interfaces among systems or subsystems and the interfaces to external systems are described for Colorado in Section 2.2.3, for Utah in Section 2.3.3, and for Wyoming in Section 2.4.3.

External systems are systems that support the CTW SOI and are needed for the overall CTW system functionality. For example, external systems will likely include traffic signal controllers, security certificate providers, and other similar systems. This also includes the SDX (identified as an “External Central System”) that all CTW systems will interface with.

Figure 2 shows a diagram of the CTW SOI and external systems. The SOI includes a Central System, Field Equipment, and Vehicle Systems. UDOT, WYDOT, and CDOT will continue to operate their individual Central Systems and Field Equipment while also continuing to operate fleet vehicles equipped with C-V2X technologies. WYDOT will also continue to operate fleet vehicles equipped with satellite-enabled V2X communications. In addition to the SOI, external systems will support the CTW SOI (e.g., traffic signal controllers and Traffic Operations Centers [TOCs]).

The data flows between portions of the CTW SOI will be the following:

- Cloud-based between the SOI Central System and both the SDX (identified as an External Central System) and various other external systems as well as between the SOI Field Equipment to various external systems.
- Center to center, center to field, and field to field between the SOI Central System and various external systems as well as between the SOI Central System and the SOI Field Equipment.
- C-V2X between the SOI Field Equipment and SOI Vehicle Systems.
- Satellite in Wyoming between the SOI Vehicle Systems and the external system Sirius XM.

Figure 2 shows the CTW SOI, external systems, and data flows.

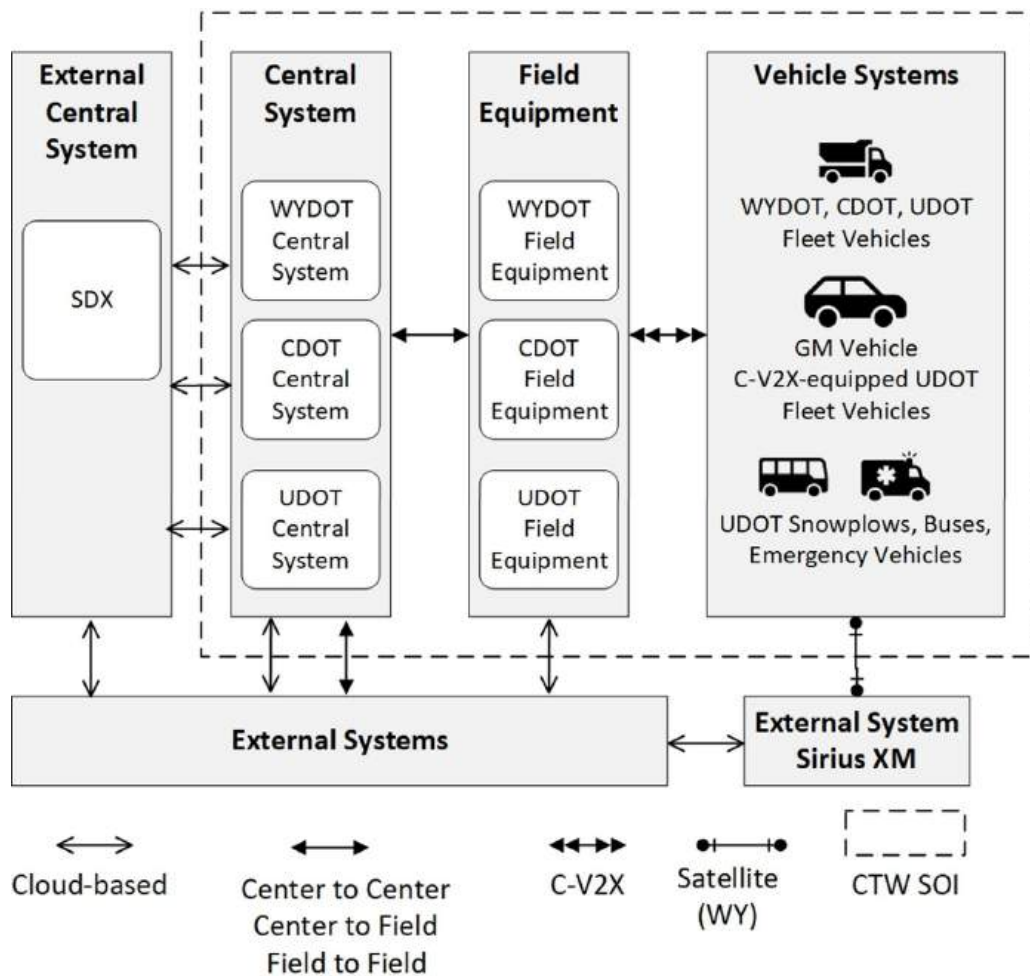


Figure 2. System Overview Diagram
 Source: Athey Creek Consultants, January 2025

2.2. Colorado System

This section provides a description of the overall Colorado system and describes the functions to be performed by individual systems within the Colorado system, including Central Systems, Vehicle Systems, Field Equipment, and interfaces to internal and external systems.

2.2.1. Colorado System Description

The Colorado system included in this CTW Program will support Connected Roadway applications through the addition of RSUs along I-70 and enhancements to Central Systems for event- and message-sharing. These RSUs will interface with Colorado's existing Central System and Vehicle Systems. The Referential Systems section of the CTW ConOps describes the functions of the current Colorado system

to support CIPT, and these will continue to operate. However, there are no plans for expansion or enhancements of CIPT activities at SIs in the CTW Program.

Table 1 shows the systems and subsystems included in the Colorado system.

Table 1. Colorado System and Subsystems
Source: Athey Creek Consultants, January 2025

System	Subsystems
Colorado Central Systems	• CDOT Operational Data Environment (ODE) • CDOT CV Manager • Connected Intersections Message Monitoring System (CIMMS)
Colorado Vehicle Systems	Fleet vehicles equipped with OBUs – no changes to existing fleets in the CTW activities
Colorado Field Equipment: Connected Roadway Systems	Field Equipment on Connected Roadways
Colorado Field Equipment: CI Systems	SIs in Denver, Colorado are equipped as CIs receiving preemption requests from CDOT snowplows
Colorado Interfaces to External Systems	• SDX • CDOT Advanced Traffic Management System (ATMS) • Third-party SCMS Provider • CDOT Work Zone Speed Reduction Reporting Forms

2.2.1.1. Colorado Central Systems

Colorado Central Systems are existing systems that will continue to operate throughout the CTW Program activities. It includes the systems that generate and distribute advisories and alerts and that store data collected from Field Equipment. The Colorado Central Systems also operate the CIMMS. The requirements in this document describe what the Central Systems in Colorado must do but do not describe how they will do it, nor do they identify which components of the Central Systems will perform the functions, as those will be identified in the architecture and design aspects.

The Colorado Central Systems will include the following sub-systems:

- **CDOT ODE.** The ODE will continue to operate as described in the CTW ConOpsReferential Systems section. CTW activities will expand the TIM distribution to the newly added RSUs.
- **CDOT CV Manager.** The Colorado CV Manager sub-system will continue to operate as described in the ConOps Referential Systems description. CTW activities will expand monitoring of health of RSUs to additional RSUs in the CTW Program.
- **CIMMS.** CIMMS will continue to monitor CIs as described in the ConOps Referential System description. No CTW changes will involve CIMMS in Colorado.

2.2.1.2. Colorado Vehicle Systems

The Colorado vehicle systems described in the Referential Systems section of the CTW ConOps include CDOT Region 1 fleet snowplows that request preemption at SIs as well as maintenance and other fleet vehicles serving as test vehicles along the I-70 corridor. Each of these vehicles are equipped with C-V2X capabilities.

There are no planned additional vehicle systems in Colorado as part of the CTW Program. The CTW enhancements in Colorado will not impact the Region 1 fleet snowplows. However, the CTW enhancements will impact the maintenance and other fleet vehicles that interact through C-V2X communications with the new Field Equipment to be deployed along I-70.

2.2.1.3. Colorado Field Equipment

The Colorado Field Equipment described in the ConOps Referential System section includes RSUs along I-70 with either fiber connectivity or cellular modems. There are plans to expand the number of RSUs along I-70 as part of the CTW Program, and new RSUs will perform the same functions as defined in the ConOps.

The Colorado Field Equipment will include:

- **Field Equipment on Connected Roadways.** Field Equipment on Connected Roadways are devices and supporting connections that broadcast and receive messages using C-V2X communications. This subsystem will receive messages from the Central Systems to be broadcast and will send messages received through over-the-air communications to the Central Systems. The primary device in this subsystem is the RSU with C-V2X capabilities.

2.2.2. Colorado System Functions

This section describes the functions to be performed by the Colorado system through the CTW Program. Specifically, it includes only those functions added, expanded, or enhanced by CTW activities, and for which requirements are described in this document.

Colorado Central Systems communicate with external systems and perform the following functions for the CTW Program:

1. **Collect Basic Safety Message (BSM) Data** – Colorado Central Systems will collect BSMs from the additional Field Equipment (e.g., RSUs) deployed and operated as part of the CTW Program. The BSMs will be received from C-V2X broadcasts of passing vehicles. This function supports Project 4: Colorado I-70 Expansion and Integration.
2. **Extract Event and Weather Data from BSMs** – Using the BSMs collected from additional RSUs deployed, Colorado Central Systems will extract data to be used to generate event reports and TIMs for sharing with other agencies and with drivers. This function supports Project 4: Colorado I-70 Expansion and Integration.

3. **Collect Event and Weather Data from External Systems** – Colorado Central Systems will collect data from external systems to help generate event reports and TIMs for sharing with other agencies and with drivers. This function supports Project 4: Colorado I-70 Expansion and Integration.
4. **Generate and Exchange Event Reports** – Colorado Central Systems will generate event reports describing atmospheric and pavement conditions, incidents, work zones, reduced speeds, reduced speed limits, and other events impacting travel and exchange these event reports with Utah and Wyoming Central Systems using a message structure and the SDX. Also, share the event reports with other CTW states using the SDX. This function supports Project 5: Application Integration and Interoperability Testing.
5. **Collect and Manage Health of System Data** – Colorado Central Systems will collect data and information from Field Equipment that provides insight into the health and operational status of Field Equipment. This general function supports multiple projects.
6. **Generate TIMs** – Colorado Central Systems will create, update, and expire TIMs that represent the event reports in accordance with agreed content and structure for TIMs as defined by the CTW Program. This function supports Project 4: Colorado I-70 Expansion and Integration.
7. **Distribute TIMs** – Colorado Central Systems will distribute TIMs to the appropriate Field Equipment, including the newly added RSUs (based on location) and to the Data Exchange. This function supports Project 4: Colorado I-70 Expansion and Integration.
8. **Exchange Data Using Network Communications** – Colorado Central Systems will distribute the TIMs through the SDX to subscribers that are expected to include third party traveler information systems, fleets, and other Central Systems. This function supports Project 5: Application Integration and Interoperability Testing.
9. **Store Data** – Colorado Central Systems will store the data generated by the Central Systems and data that is collected from the RSUs added through this CTW Program and provide access only to authorized users. This general function supports multiple projects.
10. **Perform Security Credential Management System (SCMS) Top-off to Fleet Vehicles** – Colorado Central Systems will send SCMS top-offs to fleet vehicles using an approach that does not require cellular connection by the vehicle. This general function supports multiple projects.
11. **Process Data for Performance Management (UDOT and CDOT)** – Colorado Central Systems will process data received from the expanded Field Equipment, calculate performance measures, and generate visual dashboards. This general function supports multiple projects.

Colorado Field Equipment functions for the CTW Program all support Project 4: Colorado I-70 Expansion and Integration and communicate with external systems. These functions include:

1. **Support Secure Data Exchanges** – Colorado Field Equipment will support secure data exchanges only accepting C-V2X messages with SCMS certificates that are verified by the Field Equipment and only broadcasting messages with SCMS certificates applied.
2. **Receive BSMS** – Colorado Field Equipment will receive BSMS that are broadcast by passing vehicles, check SCMS certificates, and communicate the BSMS to Central Systems.
3. **Receive and Broadcast TIMs** – Colorado Field Equipment will receive TIMs generated by Central Systems and broadcast the TIMs with necessary SCMS certificates.

4. **Communicate Messages and Data to Central Systems** – Colorado Field Equipment will send data and messages to Central Systems to support data storage, archive, analytics, and use of the data and/or messages for functions of the Central System.

For Colorado Vehicle System functions, no new vehicle systems are being added in Colorado as part of the CTW Program. Existing CDOT fleet vehicles will continue to broadcast BSMs and receive/display TIMs. These existing Vehicle Systems will interact with the Field Equipment added as part of the CTW Program.

These Colorado system functions are illustrated in Figure 3. The functions are separated by project to assist those working on individual projects to organize their functions, but there is no functional limitation across projects.

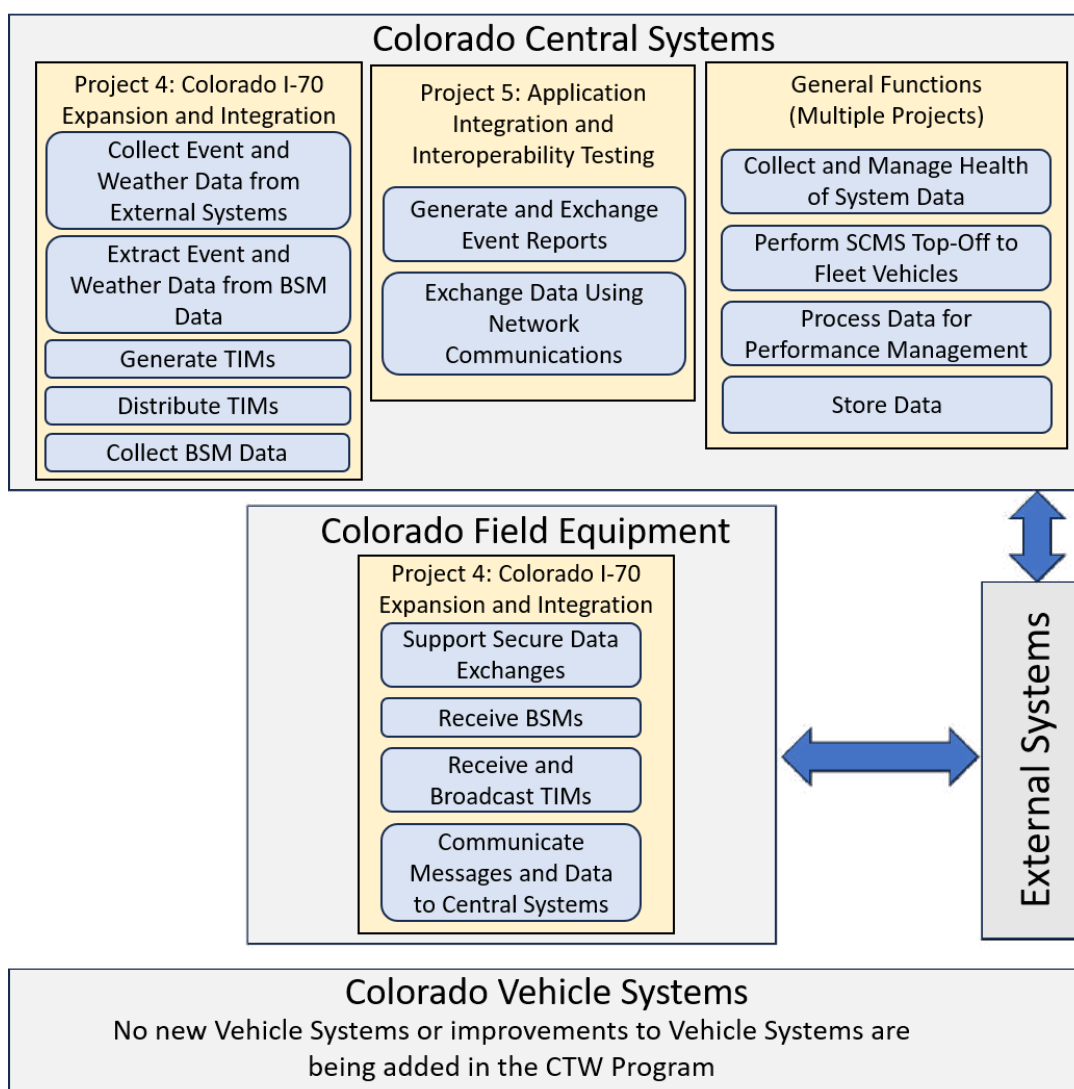


Figure 3. Colorado System Functions
 Source: Athey Creek Consultants, January 2025

2.2.3. Colorado System Interfaces (Internal and External)

The internal and external interfaces to Colorado system are illustrated in Figure 4, with descriptions of these interfaces provided in Section 2.2.3.1 and Section 2.2.3.2.

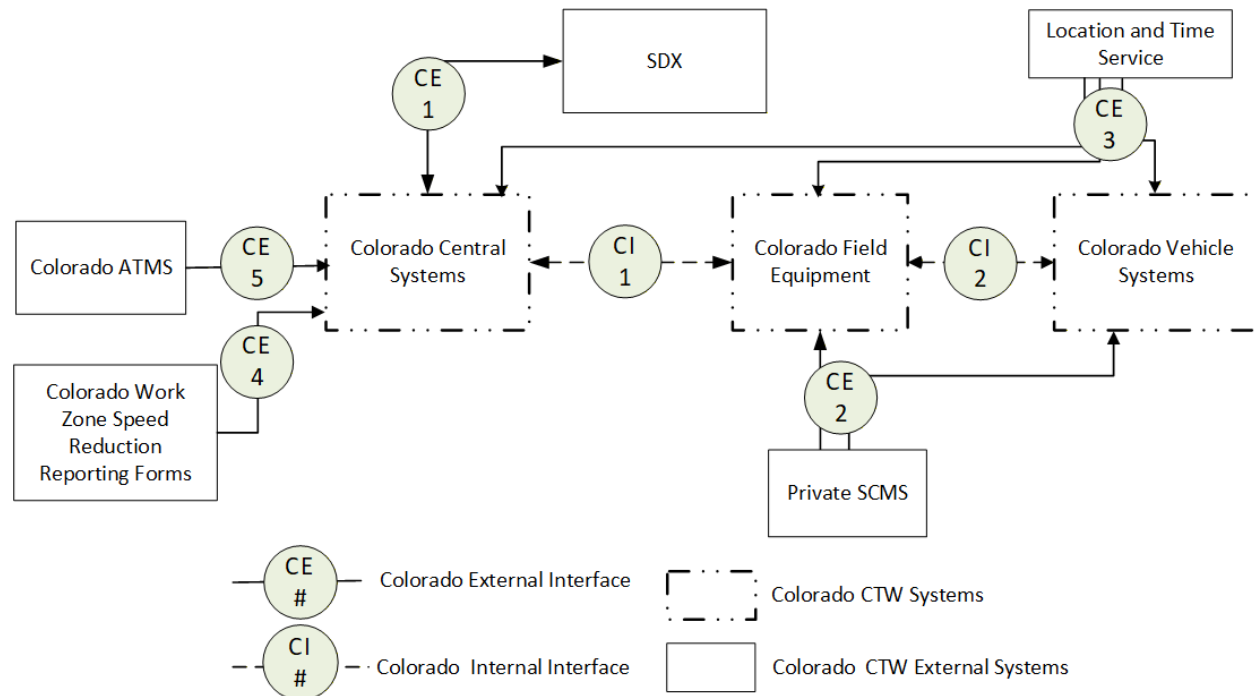


Figure 4. Colorado System Interfaces (Internal and External)

Source: Athey Creek Consultants, January 2025

2.2.3.1. Colorado Internal System Interfaces

The internal interfaces for the Colorado system will include those interfaces between the Central System, Field Equipment, and Vehicle Systems. The Colorado internal interfaces include:

- **Central Systems to Field Equipment (Interface CI-1).** Supports a two-way exchange of messages. The Central System sends TIMs to the Field Equipment for broadcast, and the Field Equipment sends BSM messages to the Central System.
- **Field Equipment to Vehicle Systems (Interface CI-2).** Supports a two-way exchange of messages. The Field Equipment broadcast TIMs that are received by Vehicle Systems, and the Vehicle Systems broadcast BSMs that are received by Field Equipment.

2.2.3.2. Colorado External System Interfaces

Several external systems are accessed by the Colorado system, as described in the ConOps. The requirements in this SyRS document describe the requirements for the Colorado system to perform to interface with these systems. The interfaces to external systems in Colorado include:

- **Interface to SDX (Interface CE-1).** Center-to-center communications between Colorado's Central Systems and the SDX to send event reports and TIMs as well as to receive event reports and TIMs from other CTW states. By sharing TIMs to the SDX, CDOT accomplishes network communications sharing of TIMs to subscribers to the SDX.
- **Interface to a private third-party SCMS provider (Interface CE-2).** The Colorado Field Equipment and Vehicle Systems will each interface to the third-party SCMS provider to receive security credentials and top-offs as needed.
 - OBUs will use the third-party SCMS provider to attach certificates to messages broadcast.
 - RSUs will use the third-party SCMS provider to attach certificates to messages broadcast.
 - SDX will use the third-party SCMS provider to attach certificates to messages shared to subscribers.
- **Interface to receive location and time services (Interface CE-3).** The Colorado Central Systems, Field Equipment, and Vehicle Systems will interface with a source for location and time to receive location and time data.
- **CDOT Work Zone (WZ) Speed Reduction Reporting Forms (Interface CE-4).** The Colorado Central Systems will interface with a data file that contains speed reduction information (or the Work Zone Data Exchange [WZDx] messages generated from this file) to gather supplemental information describing the work zones. An enhancement as part of the CTW Program will be for the Colorado Central Systems to access content on work zone report forms to be used when generating TIMs for both existing and newly added RSUs.
- **Interface to CDOT's Advanced Transportation Management System (ATMS) (Interface CE-5).** The Colorado Central Systems will interface with the ATMS to receive TIMs to be distributed to the Field Equipment. In order to support the expanded number of RSUs, the interface to the ATMS will retrieve TIMs for an expanded geographic area. The ATMS will continue to generate work zone TIMs with supporting information about where they should be distributed.

2.3. Utah System

This section provides a description of the Utah CTW system and describes the functions to be performed by Central Systems, Vehicle Systems, Field Equipment, and interfaces to internal and external systems.

2.3.1. Utah System Description

The Utah system included in this CTW Program will support CIs, Connected Roadways, and VRU Safety Systems applications. The ConOps Referential Systems section describes the functions of existing Utah system. As the existing Utah systems continue to operate, plans for expansion and enhancements of these systems under the CTW Program will be consistent with existing systems.

Table 2 shows the systems and subsystems that comprise the Utah CTW system.

Table 2. Utah System and Subsystems
Source: Athey Creek Consultants, January 2025

System	Subsystems
Utah Central Systems	• C-V2X Central System • CIMMS
Utah Vehicle Systems	• Fleet vehicles (including V2X-equipped Utah transit vehicles and UDOT snowplows requesting CIPT) • GM C-V2X-equipped UDOT fleet vehicle
Utah Field Equipment: CIs	Field Equipment at CIs
Utah Field Equipment: Connected Roadway Systems	Field Equipment on Connected Roadways
Utah Field Equipment: VRU Safety Systems	• LiDAR VRU detection • Blank-out signs • Existing Field Equipment at CIs
Utah Interfaces to External Systems	• Third-party SCMS provider • Radio Technical Commission for Maritime Services (RTCM) data communicated using Networked Transport of RTCM via Internet Protocol (NTRIP) • UDOT ATMS • Traffic signal controllers

2.3.1.1. Utah Central Systems

The Utah Central Systems are existing systems that will continue to operate throughout the CTW Program activities. It includes the systems that generate and distribute advisories and alerts and that store data collected from Field Equipment. Utah Central Systems also operate the CIMMS. The requirements in this document describe what the Central Systems in Utah must do but do not describe how they will do it, nor do they identify which components of the Central Systems will perform the functions, as those will be identified in the architecture and design aspects.

The Utah Central Systems will include the following sub-systems:

- **C-V2X Central System.** UDOT used the Cirrus platform developed by Panasonic up through late 2025 and will replace that system with the iNET platform developed by Parsons and Taplane in early 2026. These two platforms provide very similar capabilities; the transition does not represent any significant changes. This new system will be known as “Connected Utah.” Although iNET has many Advanced Traffic Management System (ATMS) functions, UDOT will be leveraging only the V2X-related modules in iNET. While Cirrus was referenced in earlier versions of this SyRS, most of those references now reflect a more generic term: the UDOT V2X Maintenance Management System (V2X MMS), which includes both Cirrus and iNET / Connected Utah.
- **CIMMS.** CIMMS will continue to monitor CIs as described in the ConOps Referential Systems section. Utah use of CIMMS use may be expanded in CTW, but no changes will be made to the CIMMS use in Utah.

2.3.1.2. Utah Vehicle Systems

The Utah Vehicle Systems described in the ConOps Referential Systems section include public agency vehicles, specifically snowplows, transit vehicles, emergency vehicles, and UDOT fleet vehicles equipped with OBUs. The CTW enhancements to the Utah Vehicle Systems will include additional Vehicle Systems in snowplows and transit vehicles. A special Vehicle System operated as a UDOT fleet vehicle will be a GM vehicle equipped to broadcast BSMs and to operate a variety of on-board applications.

The Utah Vehicle Systems will include the following:

- **Fleet Vehicle Systems equipped with OBUs.** This term will be used to describe requirements for the Utah fleet vehicles that interact with the Field Equipment deployed by CTW activities. Fleet Vehicle Systems equipped with OBUs include the OBU that sends and receives messages using C-V2X communications as well as the HMI that presents the information to the vehicle operator (although the Vehicle Systems opt out of including an HMI). Fleet Vehicle Systems will be deployed on Utah transit vehicles, UDOT snowplows, and Utah emergency vehicles, primarily to leverage CIPT.

2.3.1.3. Utah Field Equipment

The Utah Field Equipment described in the ConOps Referential System section includes C-V2X RSUs at CIs and along IRCs and VRU detection at selected intersections. In addition to the RSUs, the Field Equipment at CIs include fiber switches and Signal Command Modules (SCMs), and Field Equipment on IRCs include fiber switches. There are plans to expand the number of RSUs at CIs and Connected Roadways as part of the CTW Program, and new RSUs will perform the same functions as defined in the ConOps and will rely upon power at the site, as indicated in the ConOps. Solar power equipment may be used in rare situations where line-power is not available at the site.

The Utah Field Equipment will include:

- **Field Equipment at CIs.** This refers to the Field Equipment deployed at SIs operating as CIs.
- **Field Equipment on Connected Roadways.** This refers to the Field Equipment deployed on IRCs.

2.3.1.4. Utah Vulnerable Road User Safety Systems

The Utah VRU Safety Systems described in the ConOps Referential Systems section include LiDAR VRU Detection Systems, Blank-Out Signs, and Existing CI Field Equipment as described in the Referential Systems section of the ConOps. There are plans to expand the number of Utah VRU Safety Systems as part of the CTW Program, and new systems will perform the same functions as defined in the ConOps.

The Utah VRU Safety Systems will include:

- **LiDAR-Based VRU Detection Systems.** These systems are comprised of a pole-mounted LiDAR unit (or units) at an intersection to detect and classify both VRUs and vehicles. A processing unit in an edge computer (located in a nearby cabinet) operates software that creates messages with real-time information about VRUs. An interface to existing SI systems is used to broadcast these messages and activate blank-out signs, as appropriate.

- **Blank-Out Signs.** Blank-out signs located at the intersection receive an activation trigger message via an interface with the LiDAR-Based VRU Detection System to prompt the display of a predetermined warning message to approaching vehicles.
- **Existing CI Field Equipment.** VRU Safety Systems are installed at intersections already equipped to operate as CIs.

2.3.2. Utah System Functions

This section describes the functions to be performed by the Utah system through the CTW Program. Specifically, it includes only those functions added, expanded, or enhanced by CTW activities, and for which requirements are described in this document.

Utah Central Systems communicate with external systems and perform the following functions for the CTW Program:

1. **Collect BSM Data** – Collect BSMs from Field Equipment (e.g., RSUs) that were received from C-V2X broadcasts of passing CVs. This general function supports multiple projects.
2. **Collect Signal Phase and Timing (SPaT), Map Data Message (MAP), and RTCM Messages.** Collect the messages broadcast by Field Equipment at SIs, including SPaT, MAP, and RTSM messages. This function supports Project 1: Utah SI RSUs.
3. **Extract Event and Weather Data from BSMs** – Using the BSMs, extract data to be used to generate event reports and TIMs for sharing with other agencies and with drivers. This function supports Project 2: Utah IRC RSUs.
4. **Collect Event and Weather Data from External Systems** – Collect event descriptions and/or data from external systems accessed by the Utah Central System. This function supports Project 2: Utah IRC RSUs.
5. **Generate and Exchange Event Reports** - Generate event reports describing atmospheric and pavement conditions, incidents, work zones, reduced speeds, reduced speed limits, and other events impacting travel. Also, share the event reports with other CTW states using the SDX. This function supports Project 5: Application Integration and Interoperability Testing.
6. **Collect Messages and Data from VRU Safety Systems** - Collect messages (i.e., Sensor Data Sharing Messages [SDSMs]) and additional data from Field Equipment supporting VRU Safety Systems. This function supports Project 3: Utah VRU Safety at Intersections.
7. **Collect and Manage Health of System Data** – Collect data and information from Field Equipment that provides insight into the health and operational status of Field Equipment. This general function supports multiple projects.
8. **Generate TIMs** – Create, update, and expire TIMs that represent the event reports in accordance with agreed-upon content and structure for TIMs as defined by the CTW Program. This function supports Project 2: Utah IRC RSUs.
9. **Distribute TIMs** – Distribute TIMs to the appropriate Field Equipment (based on location) and to the SDX. This function supports Project 2: Utah IRC RSUs.

10. **Exchange Data Using Network Communications** – Distribute the TIMs through the SDX to subscribers that are expected to include third-party traveler information systems, fleets, and other Central Systems. This function supports Project 5: Application Integration and Interoperability Testing.
11. **Store Data** – Store the data generated by the Central Systems and collected from Vehicle Systems and provide access only to authorized users. This general function supports multiple projects.
12. **Perform SCMS Top-off to Fleet Vehicles (UDOT only)** – Send SCMS top-offs to fleet vehicles using an approach that does not require cellular connection by the vehicle. This general function supports multiple projects.
13. **Process Data for Performance Management (UDOT and CDOT)** – Process data received from Field Equipment, calculate performance measures, and generate visual dashboards. This general function supports multiple projects.

Utah Vehicle Systems communicate with external systems and perform the following functions for the CTW Program:

1. **Generate and Broadcast Partial BSMs** – Vehicle Systems will generate partial BSM messages using data available from the OBU (i.e., no access to the vehicle Controller Area Network [CAN] bus), attach SCMS certificates, and broadcast the BSMs using C-V2X communications. This function supports all Utah Vehicle Systems.
2. **Generate and Broadcast Full BSMs** – The GM vehicle that will be operated as a UDOT fleet vehicle will generate full Part 1 BSM messages, attach SCMS certificates, and broadcast the BSMs using C-V2X communications. This function supports all Utah Vehicle Systems.
3. **Receive TIMs** – Utah Vehicle Systems will receive TIMs broadcast by the Field Equipment. This function supports Project 2: Utah IRC RSUs.
4. **Receive and Process CI messages** – Vehicle Systems will receive and process the messages broadcast by CIs (i.e., SPaT, MAP, RTCM, and TIMs) to support in-vehicle applications such as Red Light Violation Warning (RLVW) and CIPT. The GM vehicle operated as a UDOT fleet vehicle will demonstrate this. This function supports all Utah Vehicle Systems.
5. **Provide In-Vehicle Application Alerts** – Utah Vehicle Systems that include an HMI will deliver alerts to the drivers that are received as TIMs. Alerts will be selected and prioritized for the vehicle location and direction of travel. This function supports Project 2: Utah IRC RSUs.
6. **Generate and Broadcast TSP Signal Request Messages (SRMs)** – Vehicle Systems in Utah that meet requirements to submit TSP requests will collect data from the vehicle to determine if the vehicle is eligible for TSP. When eligible, the Vehicle System will create and broadcast SRMs using C-V2X communications, updating and eventually expiring the SRMs. This function supports Project 1: Utah SI RSUs and will be used in Utah transit vehicle systems.
7. **Generate and Broadcast Vehicle Preemption SRMs** – Selected Vehicle Systems in Utah will determine when preemption requests are authorized, generate SRMs requesting preemption, and broadcast the SRMs using C-V2X communications. This function supports Project 1: Utah SI RSUs and will be used for snowplows and emergency vehicle systems.

8. **Receive SDSMs and Deliver Alerts (Utah only)** – Selected UDOT fleet vehicles will be equipped with OBUs that receive and process SDSMs that are broadcast using C-V2X communications. These OBUs will process the SDSMs and determine if the vehicle trajectory is at risk of conflict with the VRU and deliver HMI alerts to the driver when appropriate. This function supports Project 3: Utah VRU Safety at Intersections.

Utah Field Equipment communicate with external systems and perform the following functions for the CTW Program for the CTW Program include:

1. **Support Secure Data Exchanges** – Field equipment will support secure data exchanges only accepting C-V2X messages with SCMS certificates that are verified by the Field Equipment and only broadcasting messages with SCMS certificates applied. This function supports all Utah Field Equipment and includes Project 2: Utah IRC RSUs.
2. **Receive BSM Data** – Field Equipment will receive BSMS that are broadcast by passing vehicles, check SCMS certificates, and communicate the BSMS to Central Systems. This function supports all Utah Field Equipment and includes Project 2: Utah IRC RSUs.
3. **Receive and Broadcast TIMs** – Field Equipment will receive TIMs generated by Central Systems and broadcast the TIMs with necessary SCMS certificates. This function supports all Utah Field Equipment and includes Project 2: Utah IRC RSUs.
4. **Receive and Process SRMs** – Field Equipment will receive SRMs for priority or preemption, confirm SCMS certificates, and communicate with the local traffic signal controller to submit, update, and expire the priority or preemption request, as appropriate. This function supports Project 1: Utah SI RSUs.
5. **Broadcast Signal Status Message (SSM)** – Field Equipment will generate and broadcast SSMs confirming the receipt of the SRM. This function supports Project 1: Utah SI RSUs.
6. **Assemble and Broadcast SPaT, MAP, and RTCM Messages** – Field Equipment at SIs will collect data or messages and use them to assemble and broadcast SPaT, MAP, and RTCM messages that have been validated in accordance with national standards. This function supports Project 1: Utah SI RSUs.
7. **Detect VRUs and Generate SDSMs** – Field Equipment at intersections equipped with VRU Safety Systems will detect VRUs in selected intersection crosswalks and create SDSMs describing the location and movement of the VRUs. This function supports Project 3: Utah VRU Safety at Intersections.
8. **Broadcast SDSMs**. Field Equipment will broadcast SDSMs generated at intersections equipped with VRU warning technologies. This function supports Project 3: Utah VRU Safety at Intersections.
9. **Determine Possible VRU-Vehicle Conflicts and Activate Signs**. Field Equipment will detect vehicle movements and combine them with VRU locations and movement to determine when predesignated blank-out warning signs should be activated to alert drivers of vehicles equipped or not equipped for C-V2X communications. This function supports Project 3: Utah VRU Safety at Intersections.
10. **Communicate Messages and Data to Central Systems**. Field Equipment will send data and messages to Central Systems to support data storage, archive, analytics, and use of the data and/or messages for functions of the Central System. This function supports all Utah Field Equipment and includes Project 2: Utah IRC RSUs.

The Utah system functions are illustrated in Figure 5 below. As noted above, the functions are separated by project to assist those working on individual projects to organize their functions. but there is no functional limitation across projects.

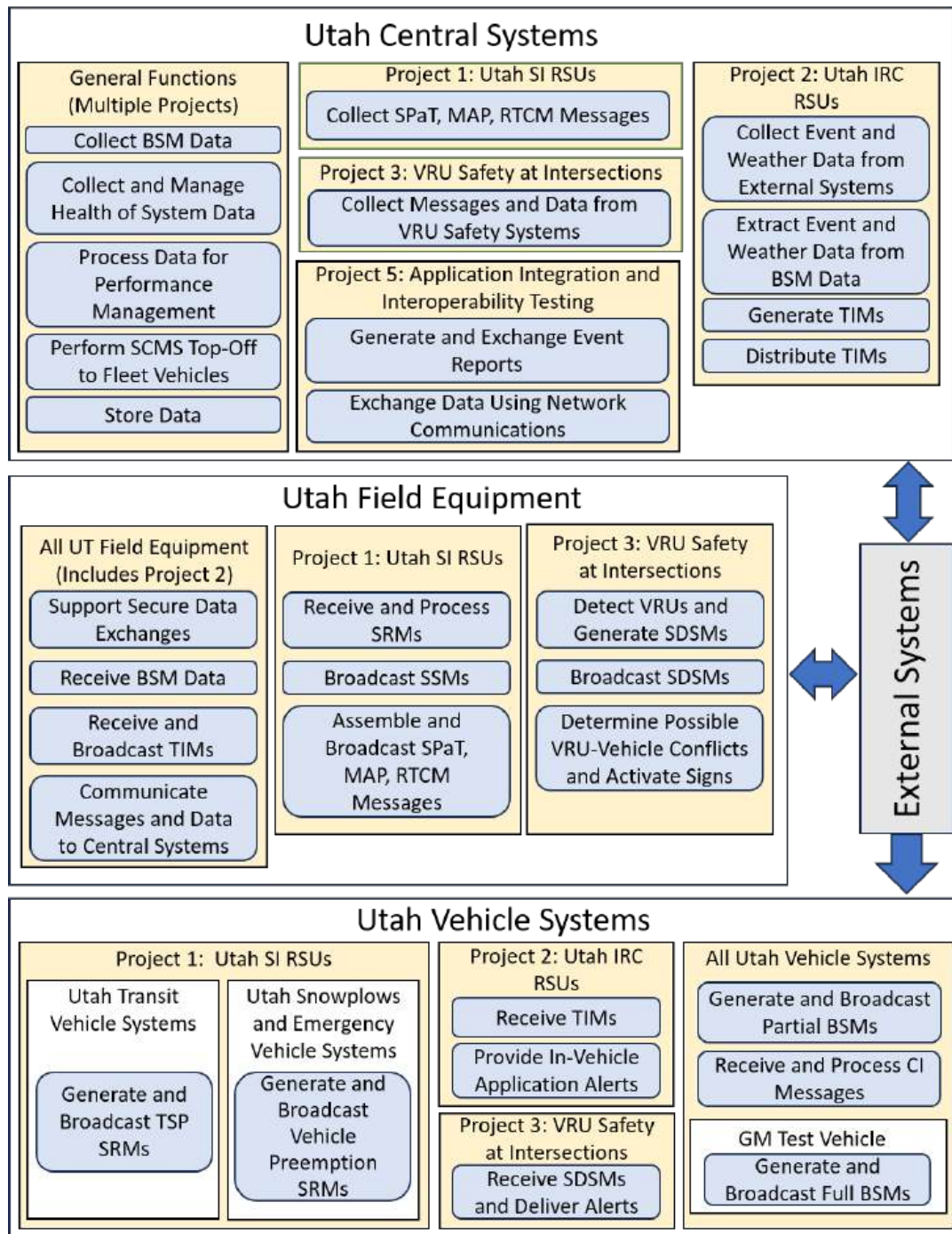


Figure 5. Utah System Functions
Source: Athey Creek Consultants, January 2025

2.3.3. Utah System Interfaces (Internal and External)

The internal and external interfaces to Utah systems are illustrated in Figure 6, with descriptions of each interface provided in Section 2.3.3.1 and Section 2.3.3.2.

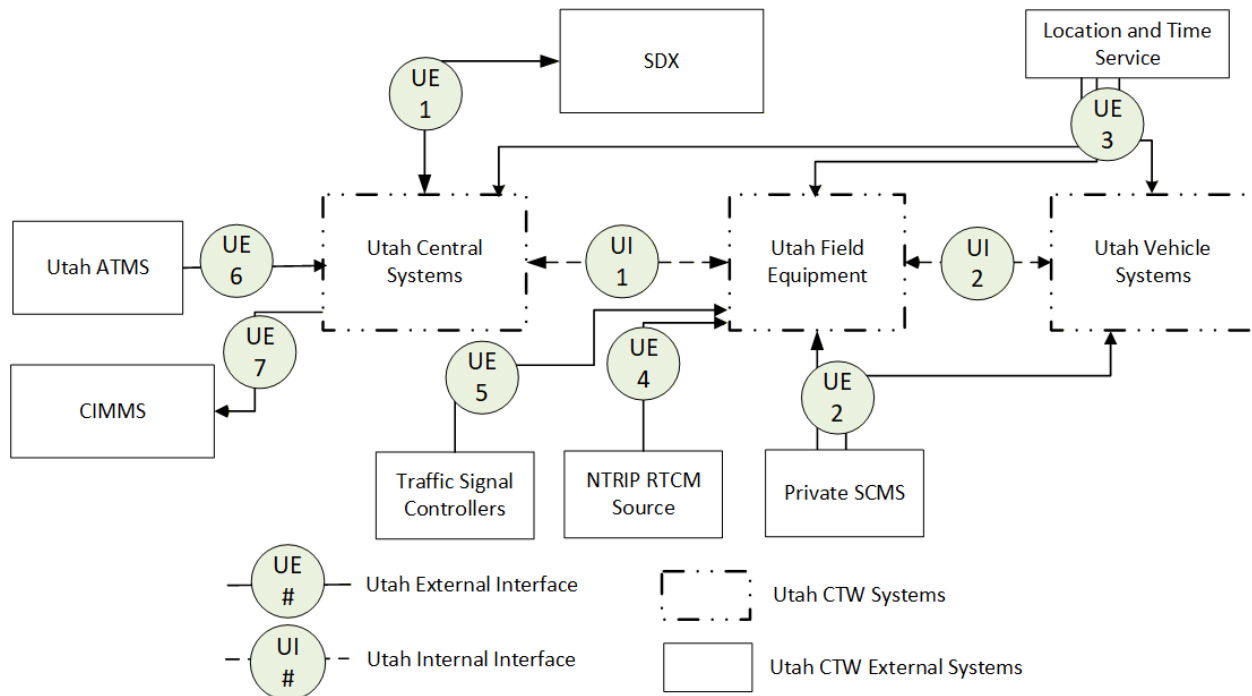


Figure 6. Utah System Interfaces (Internal and External)

Source: Athey Creek Consultants, January 2025

2.3.3.1. Utah Internal System Interfaces

The internal interfaces for the Utah system will include those interfaces between the Central System, Field Equipment, and Vehicle Systems. The Utah internal interfaces include:

- Central Systems to Field Equipment (Interface UI-1).** Supports a two-way exchange of messages. The Central Systems send TIMs to the Field Equipment for broadcast, and the Field Equipment sends BSM messages to the Central Systems. There is no change planned for this interface in the CTW Program.
- Field Equipment to Vehicle Systems (Interface UI-2).** Supports a two-way exchange of messages. The Field Equipment broadcasts TIMs that are received by Vehicle Systems, and the Vehicle Systems broadcast BSMs that are received by Field Equipment. There is no change planned for this interface in the CTW Program.

2.3.3.2. Utah External System Interfaces

Several external systems are accessed by the Utah system, as described in the ConOps. The requirements in this document describe the requirements for Utah Central Systems to perform to interface with these systems. The interfaces to external systems in Utah include:

- **Interface to SDX (Interface UE-1).** Center-to-center communications between Utah's Central Systems and the SDX to send event reports and TIMs as well as to receive event reports and TIMs from other CTW states. By sharing TIMs to the SDX, UDOT accomplishes network communications-sharing of TIMs to subscribers to the SDX.
- **Interface to private SCMS Service Provider (Interface UE-2).** Utah Field Equipment and Vehicle Systems interface with a private third-party SCMS provider to receive security credentials and top-offs, as needed.
- **Interface to receive location and time services (Interface UE-3).** Utah Field Equipment, Vehicle Systems, and Central Systems interface with a source to receive location and time data.
- **The NTRIP RTCM Source (Interface UE-4).** Utah subsystems will interface with an NTRIP server for RTCM messages, as needed.
- **Interface to Traffic Signal Controllers (Interface UE-5).** Utah subsystems interface with the traffic signal controller at each CI for outputs of the current status of the signal controller (i.e., which signal groups are in green, yellow, and red phases and the time to the next phase change) using the Traffic Signal Control Basic Message (TSCBM). The signal controller maintains a time clock, and the TSCBM describes signal status in relation to this time clock. The signal controller also grants priority or preemption.
- **Interface to UDOT's ATMS (Interface UE-6).** Utah Central Systems may interface with UDOT's ATMS as a data source for generating TIMs, given it includes reports of traffic incidents, work zones, work zone-related delays, and travel times. The ATMS is an existing external system being considered for CTW.
- **Interface to UDOT's CIMMS (Interface UE-7).** Utah Central Systems interface to CIMMS software to share SPaT, MAP, and BSM data for analyses and testing of message accuracy.

2.4. Wyoming System

This section provides a description of the Wyoming CTW system and describes the functions and interfaces to internal and external systems.

2.4.1. Wyoming System Description

The Wyoming system included in the CTW Program will expand features and functions of the existing Connected Roadway deployments in Wyoming that are described in more detail in the CTW ConOps Referential Systems section. There are no plans for additional Field Equipment or Vehicle Systems as part of Wyoming's involvement in the CTW Program. CTW improvements to the Wyoming system will focus on the integration and interoperability of messages and event reports to ensure that messages delivered by WYDOT's existing Field Equipment, Central Systems, and external systems are compatible and interoperable with those in Utah and Colorado.

Table 3 summarizes the systems and subsystems that comprise the Wyoming CTW system.

Table 3. Wyoming System and Sub-systems
Source: Athey Creek Consultants, January 2025

System	Subsystems
Wyoming Central Systems	- Wyoming Traveler Information System (WTI) - Wyoming ODE - Wyoming CV Manager
Wyoming Vehicle Systems	WYDOT fleet vehicles equipped with C-V2X OBUs WYDOT fleet vehicles equipped with C-V2X OBUs and Sirius XM antennas
Wyoming Field Equipment	Field Equipment on Connected Roadways
Wyoming Interfaces to External Systems	- Third-party SCMS provider - Location and time service provider - SDX - Private satellite service provider - Traffic signal controllers

2.4.1.1. Wyoming Central Systems

The Wyoming Central Systems are existing systems that will continue to operate throughout the CTW Program activities. It includes the systems that generate and distribute advisories and alerts and that store data collected from Field Equipment. The requirements in this document describe the changes or enhancements to the Wyoming Central Systems.

The Wyoming Central Systems will include the following subsystems:

- **The WTI.** The WTI subsystem will continue to operate as described in the ConOps Referential Systems section. CTW activities will expand the TIM creation activities for new types of events.
- **The Wyoming ODE.** The ODE will continue to operate as described in the ConOps Referential Systems section. CTW activities are expected to increase the number of TIMs and distribution through the ODE.
- **The Wyoming CV Manager.** The ODE will continue to operate as described in the ConOps Referential Systems section. CTW activities will expand the TIM creation and event creation, and sharing may involve the CV Manager.

2.4.1.2. Wyoming Vehicle Systems

The Wyoming Vehicle Systems described in the ConOps Referential Systems section include public agency vehicles, specifically snowplows, maintenance supervisor vehicles, and other vehicles operating in the area. In addition, any vehicle passing by Field Equipment may receive the broadcasts and/or may be broadcasting the BSM. There are no planned additional Vehicle Systems in Wyoming as part of the CTW Program. The CTW enhancements will not impact the deployed Vehicle Systems in Wyoming.

2.4.1.3. Wyoming Field Equipment

The Wyoming Field Equipment described in the CTW ConOps Referential Systems section includes RSUs along IRCs that broadcast TIMs and receive BSMs. There are no plans to expand the number of RSUs in Wyoming as part of the CTW Program.

2.4.2. Wyoming System Functions

This section describes the functions to be performed by the Wyoming system and subsystems. Specifically, it includes only those functions added, expanded, or enhanced by CTW activities. The requirements defined for the Wyoming aspects of the CTW Program will be based on these functions, and therefore requirements are described in this document.

Wyoming Central Systems communicate with external systems and perform the following functions for the CTW Program:

1. **Generate and Exchange Event Reports** – Wyoming Central Systems will generate event reports describing atmospheric and pavement conditions, incidents, work zones, reduced speeds, reduced speed limits, and other events impacting travel and exchange these event reports with Utah and Colorado Central Systems using a commonly agreed-upon message structure and the SDX. This function supports Project 5: Application Integration and Interoperability Testing.
2. **Generate TIMs** – Wyoming Central Systems will create, update, and expire TIMs that represent the event reports in accordance with agreed-upon content and structure for TIMs as defined by the CTW Program. This function supports Project 5: Application Integration and Interoperability Testing.
3. **Distribute TIMs** – Wyoming Central Systems will distribute TIMs to the appropriate Field Equipment (based on location) and to the SDX. This function supports Project 5: Application Integration and Interoperability Testing.
4. **Exchange Data Using Network Communications** – Wyoming Central Systems will distribute the TIMs through the SDX to subscribers that are expected to include third-party traveler information systems, fleets, and other Central Systems. This function supports Project 5: Application Integration and Interoperability Testing.
5. **Process Data for Performance Management** – Wyoming Central Systems will store the data generated by the Central Systems and data that is collected from the RSUs added through this CTW Program and provide access only to authorized users. This is a general function.
6. **Perform SCMS Top-off to Fleet Vehicles** – Wyoming Central Systems will send SCMS top-offs to fleet vehicles using an approach that does not require cellular connection by the vehicle. This is a general function.
7. **Distribute TIMs to Sirius XM** – The Wyoming Central Systems will send TIMs to Sirius XM for over-the-air delivery to OBUs connected to in-vehicle Sirius XM antennas. This function supports Project 5: Application Integration and Interoperability Testing.

For Wyoming Field Equipment functions, no new Field Equipment are being added in Wyoming as part of the CTW Program. Existing Wyoming Field Equipment will continue to operate to receive and broadcast TIMs and to receive BSMs and communicate them to the Wyoming Central System. However, requirements are not included in this document for Wyoming Field Equipment.

For Wyoming Vehicle System functions, no new Vehicle Systems are being added in Wyoming as part of the CTW Program. Existing WYDOT fleet vehicles will continue to operate broadcasting BSMs and receiving/displaying TIMs. These existing Vehicle Systems will interact with the Field Equipment added as part of the CTW Program.

The Wyoming system functions are illustrated in Figure 7.

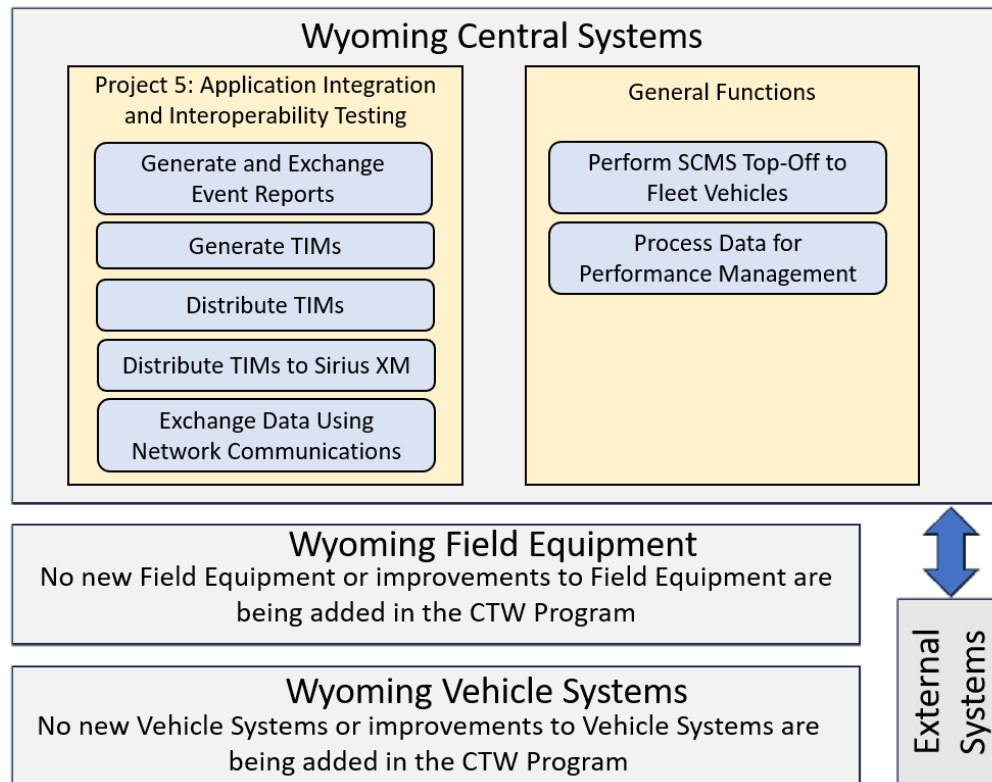


Figure 7. Wyoming System Functions
 Source: Athey Creek Consultants, January 2025

2.4.3. Wyoming System Interfaces (Internal and External)

The internal and external interfaces to Wyoming system are illustrated in Figure 8, with descriptions of each interface provided in Section 2.4.3.1 and 2.4.3.2.

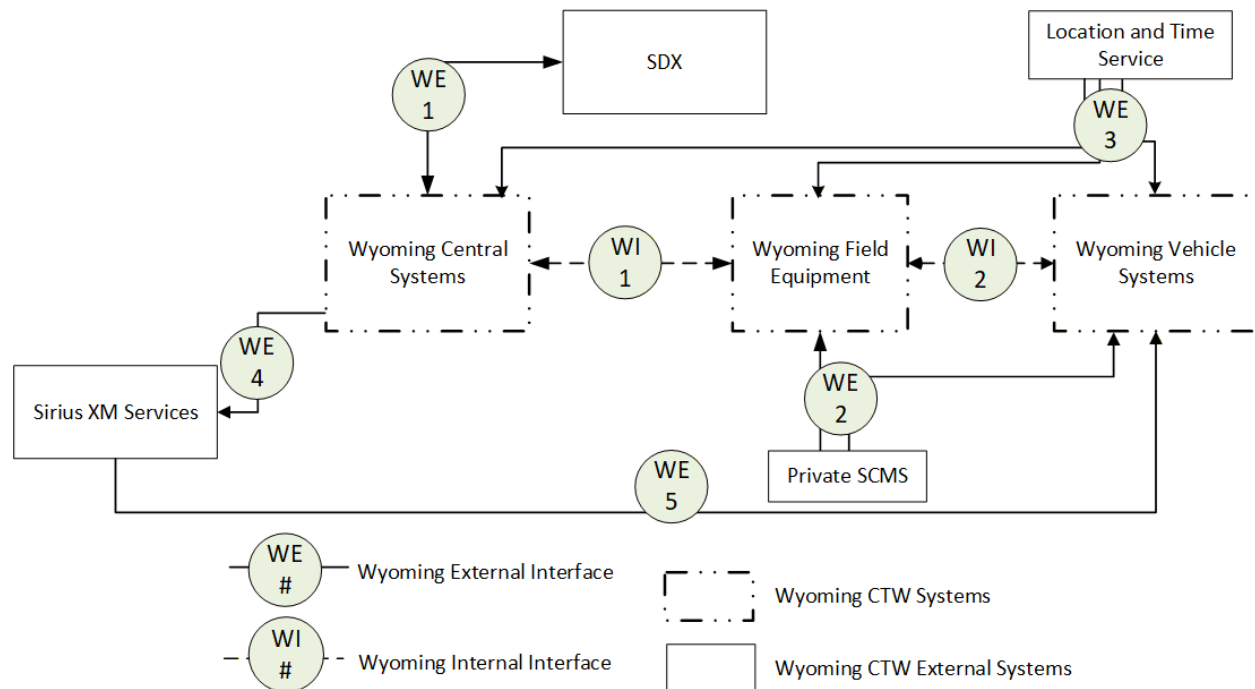


Figure 8. Wyoming System Interfaces (Internal and External)

Source: Athey Creek Consultants, January 2025

2.4.3.1. Wyoming Internal System Interfaces

The internal interfaces for the Wyoming System will include those interfaces between the Central System, Field Equipment, and Vehicle Systems. The Wyoming internal interfaces include:

- Central Systems to Field Equipment (Interface WI-1).** Supports a two-way exchange of messages. The Central Systems send TIMs to the Field Equipment for broadcast, and the Field Equipment sends BSM messages to the Central Systems. There is no change planned for this interface in the CTW Program.
- Field Equipment to Vehicle Systems (Interface WI-2).** Supports a two-way exchange of messages. The Field Equipment broadcast TIMs that are received by Vehicle Systems, and the Vehicle Systems broadcast BSMs that are received by Field Equipment. There is no change planned for this interface in the CTW Program.

2.4.3.2. Wyoming External System Interfaces

Several external systems are accessed by the Wyoming system. The interfaces to external systems in Wyoming include:

- Interface to SDX (Interface WE-1).** Center-to-center communications between Wyoming's Central Systems and the SDX to send event reports and TIMs as well as to receive event reports and TIMs from other CTW states. By sharing TIMs to the SDX, WYDOT accomplishes network communications-sharing of TIMs to subscribers to the SDX.

- **Interface to a third-party SCMS service provider (Interface WE-2).** The Wyoming subsystems will interface to the third-party SCMS provider to receive security credentials and top-offs as needed.
- **Interface to receive location and time services (Interface WE-3).** Wyoming Field Equipment, Vehicle Systems, and Central Systems interface with a source to receive location and time data.
- **Central Systems to Sirius XM Services (Interface WE-4).** Wyoming Central Systems interface using Center-to-center communications Sirius XM to deliver TIMs for broadcast to Sirius XM.
- **Sirius XM Services to Vehicle Systems (Interface WE-5).** Over-the-air communications between Sirius XM and Vehicle Systems to deliver TIMs to Sirius XM antennas and vehicle OBU HMLs in WYDOT Vehicle Systems.

2.5. External Systems

As described in the sections above, there are interfaces to external systems. This section provides brief descriptions of the external systems that CTW systems will interface with.

- **SDX.** A service operated by Tri-Hydro that stores near real-time data and messages and shares them with remote users for further distribution.
- **Private SCMS Provider.** Generates security certificates to ensure secure message management from connected devices.
- **CDOT's ATMS** A Colorado system primarily supporting transportation management functions that, in Colorado, performs the function of creating work zone-related TIMs to be distributed by Field Equipment.
- **CDOT Work Zone Speed Reduction Reporting Forms.** Report forms that contain information about work zones that may be accessed in the creation of work zone-related TIMs.
- **NTRIP RTCM Source.** A service that provides global positioning system (GPS) position correction data in the RTCM format over the internet using the NTRIP protocol.
- **UDOT's ATMS.** A Utah system primarily supporting traffic management functions that contain event information that may be accessed by the Utah Central Systems when creating TIMs.
- **Utah Traffic Signal Controllers.** Devices located at SIs that are responsible for managing and coordinating the timing and operation of traffic lights.
- **Sirius XM Services.** Commercial satellite communications services that can deliver data to in-vehicle antennas over wide areas.

2.6. Major System Constraints

The following constraints were identified by one or more of the following activities:

- **Needed Decisions or Actions.** Constraints identified during the user needs discussion and conceptualization of the system as items that are not CTW system requirements but need to be addressed for the system to function as intended.

- **Limitations to CTW Benefits.** Constraints to the benefits possible through operation of CTW systems outside control of the system.
- **Extracted from CTW Existing Systems Documentation.** Constraints extracted while documenting the existing systems that will remain operational.
- **External Influences.** Constraints that were identified based on national products or services available.

Some of these constraints have been factors in the requirements development and others will either need to be addressed as part of either the proposed system architecture or the design aspects of the CTW Program.

Constraints based on needed decisions or actions include:

- Success metrics and data to evaluate success will need to be defined for all deployed CTW systems.
- A public outreach campaign is needed to educate stakeholders in each CTW state about system benefits and to address any privacy concerns.
- A nationally accepted and trusted series of processes and procedures with supporting tools is needed by agencies operating CIs to support safety applications to determine if CIs are validated to ensure the trust of OEMs. (A solution for this constraint is being developed through the UDOT Verifying Connected Intersections project as part of the USDOT Strengthening Mobility and Revolutionizing Transportation [SMART] Grants program.)
- A nationally accepted, common approach is needed to define how CIs validated to meet Connected Transportation Interoperability Committee (CTIC) requirements will be monitored to detect when the intersection data is not meeting “validated” status. (A solution for this constraint is being developed through the UDOT Verifying Connected Intersections project as part of the USDOT SMART Grants program.)
- There is a need for universal and consistent guidance on planning, design, and deployment of CIs to guide consistent deployments that are interoperable with SCMS providers, OBUs, and RLVW applications. (This constraint is met through the Connected Intersections Guidance Document developed through the [Connected Vehicle Pooled Fund Study \[CV PFS\]](#)). Resulting constraints from this include:
 - Requirements for CTW systems supporting CIs are constrained by CTIC requirements, and as these are still evolving, the requirements defined in the CTIC will be referenced but not recreated in the CTW SyRS.
 - All CTW CI messages will be SAE J2735 messages.
- Each agency performing CIPT must have policies that define what vehicles are authorized to send CIPT requests and under what operating conditions they are authorized to request CIPT (e.g., bus occupancy, schedule adherence, and plowing in progress).
- Anticipated uses of data collected from CVs will need to be defined so CTW agencies can conduct useful performance management activities.
- Each agency will need to have defined and documented data retention policies to support data requests and uses of data to support CTW agency performance management.

Constraints causing limitations to CTW benefits include:

- The safety benefits that can be achieved through CI safety applications for SIs (e.g., RLVW applications) are constrained by the number of CIs that are currently deployed nationally, as the number of CIs influences the OEMs' business decisions to release safety applications and the number of intersections for which warnings may be issued.
- The safety benefits of RLVW applications deployed by CTW are further constrained by the number of privately owned vehicles equipped with the capability to receive SPaT, MAP, and RTCM messages to support RLVW applications.
- The safety benefits that can be achieved through safety applications on V2X Connected Roadways (e.g., to provide alerts and warnings pertaining to road weather conditions, work zones, curves, incidents, lane closures, and speed reductions) are constrained by the number of TIMs containing timely, accurate, and consistent information about hazards or events that are able to be generated and disseminated.
- The safety benefits of V2X Connected Roadways are further constrained by the number of public and privately owned vehicles equipped with the capabilities to generate and broadcast BSMs and receive TIMs.
- The safety benefits of the VRU Safety Systems are constrained by the number of privately owned vehicles equipped with the capability to receive data describing trajectories of VRUs and to warn drivers of possible conflicts. This reflects the early status of deployment of these systems. This constraint will be minimized by the fact that the blank-out signs will provide a visual warning to drivers regardless of whether they are operating in-vehicle applications.

Constraints based on information extracted from CTW existing systems documentation include:

- Any TIMs generated in the CTW Program will be constrained by existing data sources and data collected from BSMs broadcast in the vicinity of CTW agency operated RSUs. No additional data sources or field collection of data are being added through CTW. This will constrain the types of TIMs that can be generated. Examples of these constraints include:
 - TIMs describing the presence of workers in work zones are constrained to existing agency approaches for determining if workers are present.
 - Local state Central Systems that issue and administer VSLs will be an external system and is needed for the CTW agency to disseminate VSL messages. Any CTW agency that provides TIMs describing VSLs through the proposed CTW system will need to operate their local state Central Systems that are capable of calculating and authoritatively issuing VSLs based on approved business processes and making these VSLs available for the CTW Central Systems to access.
- CIs added in Utah to support CIPT will utilize the same approach where Vehicle Systems determine if they are authorized to request preferential treatment and only broadcast SRMs when appropriate.
- The distribution of TIMs to third-party traveler information system providers will be constrained by the successful implementation of the SDX in Wyoming. The SDX has an established (and growing) list of subscribers and a proven track record. This does not preclude any CTW agency from pursuing additional data exchanges, but CTW Program efforts to exchange data to these third parties will use the SDX.

- The C-V2X communication to vehicles over wide areas (i.e., beyond the range of RSU broadcasts) in Wyoming will continue to be performed using Sirius XM radio, as this is a proven approach.

Constraints based on external influences include:

- The messages generated and broadcast by CTW subsystems to communicate alerts and traveler information is constrained by industry-available OBUs that currently support TIMs. Therefore, TIMs are designated as the SAE J2735 standard for communicating these messages.
- Long-term success of delivering TIMS to Commercial Off the Shelf (COTS) OBUs is constrained by the need for nationally consistent definitions of what, how, and when to create TIMs. (The CTW Program is initiating the solution to this by facilitating discussions with additional states around common TIMs.)
- CTW mechanisms for securing V2X messages are constrained to use a nationally available SCMS..

2.7. User Classes and User Needs

This section describes the user classes (i.e., stakeholders) for the CTW system, followed by user needs that are specific to the anticipated CTW system deployments.

2.7.1. User Classes

The user classes and other involved personnel that will interact with the CTW system represent key stakeholders involved in the CTW Program. The CTW Program user classes (i.e., stakeholders) are defined in Table 4.

Table 4. CTW User Classes
Source: Athey Creek Consultants, January 2025

User Class	Definition
All CTW States	CDOT, UDOT, WYDOT, and other CTW partner entities that will deploy or benefit from one or more of the proposed CTW systems.
CDOT	A CTW agency in Colorado that will deploy one or more of the proposed CTW systems, with a focus on CIs and Connected Roadways to deliver in-vehicle traveler information.
UDOT	A CTW agency in Utah that will deploy one or more of the proposed CTW systems, including CIs, Connected Roadways, and VRU Safety Systems.
WYDOT	A CTW agency in Wyoming that will deploy one or more of the proposed CTW systems, with a focus on Connected Roadways to deliver in-vehicle traveler information.
Public Agencies in Utah that Operate SIs	UDOT and other public agencies (e.g., cities and counties) in Utah that operate SIs and are anticipated to deploy CTW systems at additional SIs.

User Class	Definition
Public Agencies in Colorado that Operate SIs	CDOT and other public agencies (e.g., cities and counties) in Colorado that operate SIs which are expected to continue to operate throughout the CTW Program.
UTA	A CTW partner agency that operates a limited number of transit vehicles equipped to receive preferential treatment at CIs in Utah. UTA will equip additional transit vehicles with V2X technology to receive preferential treatment through the CTW Program.
Traffic Operations Centers (TOCs)/Transportation Management Centers (TMCs) in CTW States	The TOC at UDOT and TMCs at CDOT and WYDOT that monitor and manage traffic conditions and will interact with one or more of the proposed CTW systems.
Drivers	Drivers of vehicles that are equipped to receive messages from CTW systems, including drivers of CTW agency fleet vehicles, transit vehicle operators, emergency vehicle operators, snowplow operators, and commercial vehicle operators.

2.7.2. User Needs

The CTW user needs were developed through targeted stakeholder outreach and describe what the stakeholders want from the proposed system. It is important to note that the CTW Program is expanding existing systems with available funding. As such, some of the user needs call out only one or two of the CTW states. This is because those needs are not identified as needs to be addressed by all CTW sites as part of this CTW Program. Table 5 provides the CTW user needs.

Table 5. CTW User Needs
Source: CTW ConOps, April 2025

User Need ID and Title	User Need
CTW-1: Need expanded SI preferential treatment.	UDOT, UTA, and local agencies in Utah that operate SIs, as well as drivers, need SI preferential treatment to expand to additional intersections and vehicles. <i>Note: Expansion of SI preferential treatment was not identified as a need for CDOT or WYDOT in the CTW Program.</i>
CTW-2: Need additional CIs.	To encourage RLVW applications, public agencies in Utah that operate SIs need to expand the number of SIs that operate as CIs that broadcast messages for in-vehicle safety applications. <i>Note: This need was not identified as a need for CDOT or WYDOT in the CTW Program.</i>
CTW-3: Need accurate, reliable, and timely data broadcasts at CIs.	Public agencies in Utah and Colorado that operate SIs and drivers need their existing CIs or additional CIs added through the CTW Program to deliver accurate, reliable, and timely data. <i>Note: This need was not identified as a need for WYDOT in the CTW Program.</i>

User Need ID and Title	User Need
CTW-4: Need to expand the creation of SWIW messages.	All CTW states and drivers need to increase the creation of messages to support SWIW to equipped vehicles (i.e., vehicles equipped with V2X technology).
CTW-5: Need to expand the creation of CSW messages.	All CTW states and drivers need to increase the creation of messages to support CSWs to equipped vehicles at selected locations.
CTW-6: Need to increase the creation of traveler information alerts and situational awareness notifications.	All CTW states and drivers need to increase notifications of events and activities such as work zones, incidents, VSLs, high wind warnings, over height warnings, truck parking availability, and road or lane closures to be distributed to equipped vehicles.
CTW-7: Need to continue and expand, as appropriate, the distribution of TIMs to equipped vehicles	All CTW states need to continue to support (and expand as needed) the distribution of warnings, alerts, and situational awareness notifications (i.e., those warnings, alerts, and notifications created by addressing needs CTW-4, CTW-5, and CTW-6).
CTW-8: Need to inform third-party traveler information systems.	All CTW states need a common mechanism to share alerts and warnings on IRCs with third-party traveler information systems.
CTW-9: Need event-sharing between CTW states.	TOCs in CTW states need access to timely and accurate event reports affecting key routes in states adjacent to their jurisdiction.
CTW-10: Need to expand locations where data is collected from equipped vehicles.	UDOT and CDOT need to expand the locations where they receive BSM data from equipped vehicles to supplement information about vehicle movements, weather, and pavement conditions. <i>Note: Additional coverage of RSUs in Wyoming was not identified as a need for the CTW Program.</i>
CTW-11: Need to secure devices and data.	All CTW states need to secure the physical devices and messages communicated as part of the proposed CTW system.
CTW-12: Need to expand the capability to alert drivers to possible conflicts with VRUs.	UDOT and drivers need to expand the capability to detect VRUs at SIs and alert drivers as appropriate. <i>Note: This need was not identified as a need for CDOT or WYDOT in the CTW Program.</i>
CTW-13: Need interoperability and consistency in messages delivered.	All CTW states and drivers (i.e., system end-users) need systems to be deployed and operated in a consistent, interoperable, and secure manner to ensure trust.
CTW-14: Need to expand the collection, storage, and management of data for analytics to support CTW expansions.	All CTW states need the capability to collect, store, and manage data in order to understand the impacts of deployed systems in the CTW Program.

User Need ID and Title	User Need
CTW-15: Need to expand the capability to monitor C-V2X devices' health and status to support additional devices.	All CTW states need to understand the status of deployed systems at any given time.
CTW-16: Need Interstate interoperability in SCMS certificates.	All CTW states need the SCMS certificates broadcast to be interoperable with other states, enabling vehicles to successfully exchange messages with all three sites.
CTW-17: Need to refine and implement SCMS certificate top-off.	UDOT needs to refine and implement a non-cellular approach to top off security certificates in fleet vehicles. <i>Note: This need was not identified as a need for CDOT or WYDOT in the CTW Program.</i>
CTW-18: Need to adhere to standards and to documented best practices.	All CTW states and system end-users need systems to be deployed and operated using standards and documented best practices for interpreting and applying standards to facilitate interoperability with other states and systems nationally.

3. System Requirements

This CTW Program is expanding legacy systems (by deploying additional legacy systems) and expanding capabilities to achieve new interoperability among in-place systems and the newly expanded systems. The functionality of the CTW legacy systems is not the focus of this systems engineering effort, as these legacy systems were defined and deployed under previous efforts. Therefore, this SyRs document does not include system requirements that have been defined through previous deployments of legacy systems. Rather, this SyRS document contains only system requirements that are needed to support the expansion of legacy systems and the associated new interoperability of these systems. The details associated with delivering the CTW Program activities to support overall functionality of the CTW system will be detailed in the Comprehensive Acquisition Plan and the Comprehensive Installation Plan.

The system requirements for the CTW Program are presented in Table 6. Note that traceability to user needs and capabilities are included in this table in lieu of a separate traceability section. Table 6 is organized to include the following information in each column:

- ID: A unique identifier for each requirement that is notated XX-YY-ZZ, where the initial “XX” digits reference the system of interest (i.e., Central Systems = CS, FE = Field Equipment, VS = Vehicle Systems, or G = General), the middle “YY” digits are the parent requirement number, and the final “ZZ” digits are child requirements of the parent requirement.
- Type of Requirement: Parent requirements are the main requirements, with child requirements being more detailed subsets of the parent requirements.
- Requirement: The system requirement specification.
- Performance Requirement: Indicates whether or not it is a performance requirement.
- Interface Requirement: Indicates whether or not it is an interface requirement.
- Functional Requirement: Indicates whether or not it is a functional requirement.
- Data Requirement: Indicates whether or not it is a data requirement.
- Verification Method: Identifies how each requirement will be verified:
 - Demonstration: A requirement that the system can demonstrate without external test equipment (e.g., a Central Systems demonstrating that event reports are created).
 - Test: A requirement that requires some external piece of test equipment (e.g. an OBU to receive messages).
 - Analyze: A requirement that is met indirectly through a logical conclusion or mathematical analysis of a result (e.g., comparing the timestamp of message creation and receipt by another system or analyzing the pedestrian crash rate at an intersection compared to the statewide average crash rate per intersection).
 - Inspection: A verification through a visual comparison (e.g., inspecting the location where Field Equipment are deployed to determine if they are along transit routes).

- User Need: Provides traceability for each child requirement back to the user need identified in the CTW ConOps.
- Utah: Indicates whether or not the requirement pertains to CTW efforts in Utah.
- Colorado: Indicates whether or not the requirement pertains to CTW efforts in Colorado.
- Wyoming: Indicates whether or not the requirement pertains to CTW efforts in Wyoming.
- System: Identifies whether the requirement pertains to Central Systems, Field Equipment, or Vehicle Systems.
- Capability or Change: Identifies the relevant capability that the requirement pertains to.

Table 6. CTW System Requirements
Source: Athey Creek Consultants, April 2025

ID	Type of Requirement	Requirement	Performance Requirement	Interface Requirement	Functional Requirement	Data Requirement	Verification Method	User Need	Utah	Colorado	Wyoming	System	Capability or Change
CS-1	Parent	Create event reports. Central Systems shall create event reports.	No	No	Yes	Yes	Demonstration	CTW-13	Yes	Yes	Yes	Central Systems	Improve TIM consistency
CS-1.1	Child	<i>Event report content.</i> Central Systems shall create event reports that describe current roadway conditions or activities on the road that are expected to impact drivers. Final decisions on thresholds will be at each state's discretion.	No	No	Yes	Yes	Demonstration	CTW-13	Yes	Yes	Yes	Central Systems	Improve TIM consistency
CS-1.2	Child	<i>Event report sources.</i> Central Systems in each CTW state shall acquire data or other content from local sources to generate event reports.	No	No	Yes	Yes	Demonstration	CTW-13	Yes	Yes	Yes	Central Systems	Improve TIM consistency
CS-1.3	Child	<i>Event report timing.</i> Central Systems shall acquire and process local data and content to create or update event reports at a frequency that is determined by each state and may vary based on the type of event.	No	No	Yes	Yes	Demonstration	CTW-13	Yes	Yes	Yes	Central Systems	Improve TIM consistency
CS-1.4	Child	<i>Event report structure.</i> Central Systems shall create event reports that follow the CTW agreed-upon structure developed during the design process.	No	No	Yes	Yes	Demonstration	CTW-13	Yes	Yes	Yes	Central Systems	Improve TIM consistency
CS-2	Parent	Interstate event exchange. Central Systems shall send event reports to the SDX.	Yes	Yes	Yes	No	Demonstration	CTW-13	Yes	Yes	Yes	Central Systems	Improve TIM consistency
CS-2.1	Child	<i>Timing of Interstate event exchange.</i> Central Systems shall initiate the process to send event reports to the SDX within 1 minute of the event report being created.	Yes	Yes	Yes	No	Analyze and Demonstration	CTW-13	Yes	Yes	Yes	Central Systems	Improve TIM consistency
CS-2.2	Child	<i>Confirmation of Interstate event exchange.</i> Central Systems shall continue the process of attempting to send event reports to the SDX until the event exchange is confirmed.	Yes	Yes	Yes	No	Demonstration	CTW-13	Yes	Yes	Yes	Central Systems	Improve TIM consistency
CS-3	Parent	Update events. Central Systems shall update event reports as data or content from the sources are updated.	Yes	Yes	Yes	No	Demonstration	CTW-9	Yes	Yes	Yes	Central Systems	Improve consistency of Interstate exchange of event reports

ID	Type of Requirement	Requirement	Performance Requirement	Interface Requirement	Functional Requirement	Data Requirement	Verification Method	User Need	Utah	Colorado	Wyoming	System	Capability or Change
CS-3.1	Child	<i>Share updates of events.</i> Central Systems shall send event report updates to the SDX within 1 minute after the event is updated, following the same process as the initial send.	Yes	Yes	Yes	No	Analyze	CTW-9	Yes	Yes	Yes	Central Systems	Improve consistency of Interstate exchange of event reports
CS-3.2	Child	<i>Share updates of events.</i> Central Systems shall send event report expirations of events with the SDX within 1 minute after the event is determined to be expired.	Yes	Yes	Yes	No	Analyze	CTW-9	Yes	Yes	Yes	Central Systems	Improve consistency of Interstate exchange of event reports
CS-4	Parent	Send TIMs to SDX. Central Systems shall send all TIMs generated to the SDX as fully-formed ASN.1 Unaligned Packet-Enabling Code (UPER)-encoded TIMs.	Yes	No	Yes	No	Inspection	CTW-8	Yes	Yes	Yes	Central Systems	Create new TIM exchanges
CS-4.1	Child	<i>Timing of TIM Exchanges.</i> Central Systems shall send TIMs to the SDX within 1 minute after the fully-formed, ASN.1 UPER-encoded TIM is generated.	Yes	No	Yes	No	Analyze	CTW-8	Yes	Yes	Yes	Central Systems	Create new TIM exchanges
CS-4.2	Child	<i>Confirmation of TIM exchanges.</i> Central Systems shall continue the process of sending TIMs to the SDX until the TIM exchange is confirmed.	Yes	No	Yes	No	Demonstration	CTW-8	Yes	Yes	Yes	Central Systems	Create new TIM exchanges
CS-5	Parent	Update TIMs in SDX. Central Systems shall send updated TIMs to the SDX within 1 minute after the TIM is updated, following the same process the initial TIM send.	Yes	Yes	Yes	No	Analyze	CTW-8	Yes	Yes	Yes	Central Systems	Create new TIM exchanges
CS-6	Parent	Expire TIMs in SDX. Central Systems shall send TIM expirations to the SDX within 1 minute after the TIM expiration is determined by the Central System, following the same process as when sending the initial TIM.	Yes	Yes	Yes	No	Analyze	CTW-8	Yes	Yes	Yes	Central Systems	Create new TIM exchanges
CS-7	Parent	Compatible SAE J2735 versions. When continuing message exchanges that are currently operational in each CTW state, the Central Systems shall exchange messages as defined in SAE J2735 standards.	No	Yes	Yes	Yes	Inspection	CTW-13	Yes	Yes	Yes	Central Systems	Demonstrate OEM vehicle interoperability
CS-7.1	Child	<i>Central Systems receive J2735 messages.</i> Central Systems shall be capable of receiving and processing messages as defined in J2735 standards in all of the following versions: 2016, 2020, and 2024.	No	Yes	Yes	Yes	Demonstration	CTW-13	Yes	Yes	Yes	Central Systems	Demonstrate OEM vehicle interoperability

ID	Type of Requirement	Requirement	Performance Requirement	Interface Requirement	Functional Requirement	Data Requirement	Verification Method	User Need	Utah	Colorado	Wyoming	System	Capability or Change
CS-7.2	Child	<i>Central Systems send J2735 messages.</i> Central Systems shall generate all messages to be exchanged using C-V2X communications as defined by J2735 according to one of the following versions: 2016, 2020, or 2024.	No	Yes	Yes	Yes	Inspection and Demonstration	CTW-13	Yes	Yes	Yes	Central Systems	Demonstrate OEM vehicle interoperability
CS-8	Parent	Expand ingest of SWIW-related data. Central Systems shall be capable of receiving, processing, and storing BSMs received from additional RSUs deployed in the CTW project.	No	Yes	Yes	Yes	Inspection and Demonstration	CTW-4	Yes	Yes	Yes	Central Systems	Increase and improve TIM creation
CS-9	Parent	Expand locations supported by CSW messages. Central Systems shall increase creation of CSW messages to include messages for curves near expansion RSUs.	No	No	Yes	Yes	Demonstration	CTW-5	Yes	Yes	Yes	Central Systems	Increase and improve TIM creation
CS-10	Parent	Expand TIM creation. Central Systems shall expand the type and number of TIMs created.	No	No	Yes	Yes	Demonstration	CTW-6	Yes	Yes	Yes	Central Systems	Increase and improve TIM creation
CS-10.1	Child	<i>Expand TIM locations to include additional RSU locations.</i> Central Systems shall create TIMs, when appropriate, that describe conditions downstream of the additional RSUs added in this project and identify the appropriate RSU for broadcast. Determination of what is appropriate is to be defined by each state and is expected to vary by TIM.	No	No	Yes	Yes	Demonstration	CTW-6	Yes	Yes	No	Central Systems	Increase and improve TIM creation
CS-10.2	Child	<i>Expand TIM locations to include all areas of the state.</i> Central Systems shall create TIMs, when appropriate, that describe conditions anywhere in the state to be shared through the SDX. Determination of what is appropriate is to be defined by each state and is expected to vary by TIM.	No	No	Yes	Yes	Demonstration	CTW-6	Yes	Yes	Yes	Central Systems	Increase and improve TIM creation
CS-10.3	Child	<i>Expand TIM locations to include other states.</i> Central Systems shall consider TIMs and Event Reports received from adjacent states and create TIMs, when appropriate, that communicate the information to travelers heading in the direction of the adjacent states' events. Determination of what is appropriate is to be defined by each state and is expected to vary by TIM.	No	No	Yes	Yes	Demonstration	CTW-6	Yes	Yes	Yes	Central Systems	Increase and improve TIM creation

ID	Type of Requirement	Requirement	Performance Requirement	Interface Requirement	Functional Requirement	Data Requirement	Verification Method	User Need	Utah	Colorado	Wyoming	System	Capability or Change
CS-11	Parent	Central Systems support storage of data for expansion sites and services. Central Systems shall provide capacity to store the additional data added by expansion systems.	No	No	Yes	No	Demonstration	CTW-14	Yes	Yes	No	Central Systems	Expand integration of CV data; expand data storage
CS-11.1	Child	<i>Support storage for additional BSM data.</i> Central Systems shall provide capacity to store BSM messages collected by RSUs added by the CTW Program to meet the retention policies of each CTW state.	No	No	Yes	No	Demonstration	CTW-14	Yes	Yes	No	Central Systems	Expand integration of CV data; expand data storage
CS-11.2	Child	<i>Support storage for additional TIMs.</i> Central Systems shall provide capacity to store the additional TIMs created by the expanded functions in CTW, to meet the retention policies of each CTW state.	No	No	Yes	No	Demonstration	CTW-14	Yes	Yes	No	Central Systems	Expand integration of CV data; expand data storage
CS-11.3	Child	<i>Support storage for additional SRMs and SSMS.</i> Central Systems shall provide capacity to store the additional SRMs and SSMS created and exchanged for the expanded CIs supporting CIPT, to meet the retention policies of each CTW state.	No	No	Yes	No	Demonstration	CTW-14	Yes	Yes	No	Central Systems	Expand integration of CV data; expand data storage
CS-11.4	Child	<i>Support storage for additional CI data.</i> Central Systems shall provide capacity to store the additional SPaT, MAP, and RTCM messages and associated data created and exchanged for the expanded CIs, to meet the retention policies of the CTW state adding CIs.	No	No	Yes	No	Demonstration	CTW-14	Yes	No	No	Central Systems	Expand integration of CV data; expand data storage
CS-11.5	Child	<i>Support storage for SDSM messages.</i> Central Systems shall provide capacity to store the SDSM messages created and exchanged in support of the VRU Safety Systems added in Utah to meet the retention policies of the state of Utah.	No	No	Yes	No	Demonstration	CTW-14	Yes	No	No	Central Systems	Expand integration of CV data; expand data storage
CS-12	Parent	Central Systems monitor expansion sites. Central Systems shall monitor health of additional Field Equipment deployed in each state, as documented in the ConOps Sections 3.2.1.2, 3.2.2.2, 3.3.1.2, and 3.4.1.2.	No	No	Yes	No	Demonstration	CTW-15	Yes	Yes	No	Central Systems	Expand system monitoring and reporting

ID	Type of Requirement	Requirement	Performance Requirement	Interface Requirement	Functional Requirement	Data Requirement	Verification Method	User Need	Utah	Colorado	Wyoming	System	Capability or Change
CS-13	Parent	<i>TIMs' adherence to documented best practices.</i> Central Systems shall generate the content and structure of TIMs in a way that adheres to CTW-agreed TIM guidance and best practices documented in the design process.	No	No	Yes	Yes	Demonstration	CTW-18	Yes	Yes	Yes	Central Systems	Improve TIM consistency
CS-14	Parent	<i>SDX Functionality.</i> Existing SDX functions should be able to exchange the additional number of TIMs generated from expanded CTW locations.	No	Yes	Yes	No	Demonstration	CTW-8	Yes	Yes	Yes	Central Systems	Create new TIM exchanges
CS-15	Parent	<i>Acquire events from other CTW states.</i> Central Systems shall acquire event reports from the SDX.	No	Yes	Yes	No	Demonstration	CTW-6	Yes	Yes	Yes	Central Systems	Create new TIM exchanges
CS-15.1	Child	<i>Frequency of acquiring Event Reports from SDX.</i> Central Systems shall acquire event reports from the SDX at a frequency defined locally by each CTW state.	No	Yes	Yes	No	Demonstration	CTW-6	Yes	Yes	Yes	Central Systems	Create new TIM exchanges
CS-15.2	Child	<i>Parameters of Event Report Queries from SDX.</i> Central Systems shall query the SDX for event reports within a geographic boundary set by the Central Systems and defined locally by each CTW state.	No	Yes	Yes	No	Demonstration	CTW-6	Yes	Yes	Yes	Central Systems	Create new TIM exchanges
CS-16	Parent	<i>Create TIMs based on other states' event reports.</i> Central Systems should create TIMs based on the Event Reports received from other CTW states.	No	No	Yes	No	Demonstration	CTW-6	Yes	Yes	Yes	Central Systems	Create new TIM exchanges
CS-17	Parent	<i>Acquire TIMs from other CTW states.</i> Central Systems may acquire TIMs from the SDX.	No	Yes	Yes	No	Demonstration	CTW-6	Yes	Yes	Yes	Central Systems	Create new TIM exchanges
CS-17.1	Child	<i>Location-based query of SDX TIMs.</i> Central Systems may query the SDX for active TIMs within a geographic boundary set by the Central Systems and defined locally by each CTW state.	No	Yes	Yes	No	Demonstration	CTW-6	Yes	Yes	Yes	Central Systems	Create new TIM exchanges
CS-17.2	Child	<i>Acquire TIMs from other CTW states.</i> Central Systems may acquire TIMs from the SDX at a frequency determined by each site.	No	Yes	Yes	No	Demonstration	CTW-6	Yes	Yes	Yes	Central Systems	Create new TIM exchanges
CS-18	Parent	<i>Distribute TIMs received from other states.</i> Central Systems may distribute TIMs that were acquired from the SDX to RSUs for broadcast if the TIM valid region is within a defined distance (to be defined individually by each state) downstream of the RSU location.	No	No	Yes	No	Demonstration	CTW-6	Yes	Yes	Yes	Central Systems	Create new TIM exchanges

ID	Type of Requirement	Requirement	Performance Requirement	Interface Requirement	Functional Requirement	Data Requirement	Verification Method	User Need	Utah	Colorado	Wyoming	System	Capability or Change
FE-1	Parent	Field Equipment-compatible SAE J2735 versions. All CTW Field Equipment added through this effort shall send and receive messages as defined in SAE J2735 standards.	No	Yes	Yes	Yes	Inspection and Demonstration	CTW-13	Yes	Yes	No	Field Equipment	Demonstrate OEM vehicle interoperability
FE-1.1	Child	<i>Field Equipment receive messages in compatible SAE J2735 versions. All CTW Field Equipment added through this effort shall be capable of receiving and processing messages as defined in J2735 standards in all of the following versions: 2016, 2020, and 2024.</i>	No	Yes	Yes	Yes	Demonstration	CTW-13	Yes	Yes	No	Field Equipment	Demonstrate OEM vehicle interoperability
FE-1.2	Child	<i>Field Equipment send messages in compatible SAE J2735 versions. CTW Field Equipment added through this effort that generate messages shall generate and send messages as defined in SAE J2735 according to one of the following versions: 2016, 2020, 2024.</i>	No	Yes	Yes	Yes	Inspection	CTW-13	Yes	Yes	No	Field Equipment	Demonstrate OEM vehicle interoperability
FE-2	Parent	Expansion sites adhere to earlier qualifications. Expansion sites for CIPT shall be identified that meet location qualifications defined in earlier deployments.	No	No	Yes	No	Inspection	CTW-1	Yes	No	No	Field Equipment	Expand preferential treatment at CIs
FE-2.1	Child	<i>Expansion sites support transit use. Expansion sites for CIPT shall include intersections along core transit routes that would benefit from improved schedule adherence.</i>	No	No	Yes	No	Inspection	CTW-1	Yes	No	No	Field Equipment	Expand preferential treatment at CIs
FE-2.2	Child	<i>Expansion sites support snowplow use. Expansion sites for CIPT shall include intersections along UDOT snowplow routes and where snowplows are (or planned to be) equipped to send CIPT requests.</i>	No	No	Yes	No	Inspection	CTW-1	Yes	No	No	Field Equipment	Expand preferential treatment at CIs
FE-2.3	Child	<i>Expansion sites support emergency vehicle use. Expansion sites for CIPT shall include intersections used by emergency vehicles that are (or planned to be) equipped to send CIPT requests.</i>	No	No	Yes	No	Inspection	CTW-1	Yes	No	No	Field Equipment	Expand preferential treatment at CIs
FE-3	Parent	CI expansion sites to address needs. CI expansion sites supporting CIPT shall be in locations where there is existing or planned vehicular traffic that will be equipped to submit priority requests.	No	No	Yes	No	Inspection	CTW-2	Yes	No	No	Field Equipment	Expand CIs

ID	Type of Requirement	Requirement	Performance Requirement	Interface Requirement	Functional Requirement	Data Requirement	Verification Method	User Need	Utah	Colorado	Wyoming	System	Capability or Change
FE-4	Parent	CI expansion sites shall continue adherence to CTI 4501/1. CI expansion sites shall follow CTI 4501/1 to the extent possible considering legacy systems involved (e.g., traffic signal controllers) as of April 2025 and as determined in the design process.	Yes	No	Yes	Yes	Inspection and Demonstration	CTW-3	Yes	No	No	Field Equipment	Expand CIs
FE-5	Parent	Connected Roadway expansion sites to address needs. RSUs deployed at Connected Roadway expansion sites shall be in locations where there is current or planned vehicular traffic that will be equipped to receive messages.	No	No	Yes	No	Inspection	CTW-7	Yes	Yes	No	Field Equipment	Expand the number of RSUs broadcasting and receiving messages
FE-6	Parent	Connected Roadway expansion sites interoperable with legacy Central Systems. RSUs deployed at Connected Roadway expansion sites shall be interoperable with legacy Central Systems deployed in Utah and Colorado as described in the CTW ConOps Sections 3.2.2 (Utah) and 3.4.2 (Colorado).	No	Yes	Yes	No	Inspection and Demonstration	CTW-7	Yes	Yes	No	Field Equipment	Expand the number of RSUs broadcasting and receiving messages
FE-7	Parent	Connected Roadway expansion sites to address needs. Connected Roadway expansion sites that receive BSMs broadcast by passing vehicles shall be in locations where existing or planned equipped vehicles travel.	No	No	Yes	No	Inspection	CTW-10	Yes	Yes	No	Field Equipment	Expand the number of RSUs broadcasting and receiving messages
FE-8	Parent	SCMS credentialing interoperability Connected Roadway expansions. SCMS credentialing on Connected Roadway and CI expansion sites shall be interoperable with credentialling performed for existing CTW systems, as defined in the CTW ConOps Sections 3.2 and 3.4.	No	Yes	Yes	No		CTW-11	Yes	Yes	No	Field Equipment	Expand security credentialing
FE-9	Parent	VRU Safety System expansion sites adhere to earlier qualifications. Expansion sites for VRU Safety Systems shall be identified that meet location qualifications defined in existing deployments.	No	No	Yes	No	Inspection	CTW-12	Yes	No	No	Field Equipment	Expand VRU detection and alerts at intersections

ID	Type of Requirement	Requirement	Performance Requirement	Interface Requirement	Functional Requirement	Data Requirement	Verification Method	User Need	Utah	Colorado	Wyoming	System	Capability or Change
FE-9.1	Child	<i>VRU Safety System expansion sites at sites with consistent pedestrian traffic.</i> Expansion sites for VRU Safety Systems shall be identified that have pedestrian crash rates that are above the average number of pedestrian crashes per intersection over a 10-year period (currently 3.2 crashes/year) at SIs.	No	No	Yes	No	Inspection	CTW-12	Yes	No	No	Field Equipment	Expand VRU detection and alerts at intersections
FE-10	Parent	<i>SDSM messages interoperable to legacy systems. SDSM messages broadcast by VRU Safety Systems in expansion sites shall be as defined in SAE J3224.</i>	No	Yes	Yes	Yes	Test	CTW-12	Yes	No	No	Field Equipment	Expand VRU detection and alerts at intersections
FE-11	Parent	<i>Process SCMS certificates from external agency fleet vehicles.</i> RSUs in CTW states shall have the capability to validate SCMS certificates that accompany messages broadcast by fleet vehicles owned by other CTW sites.	No	No	Yes	No	Test	CTW-16	Yes	Yes	Yes	Field Equipment	Demonstrate SCMS interoperability
FE-12	Parent	<i>Enable fleet vehicles to receive SCMS top-offs without cellular connection.</i> Selected sites shall include the capability to enable C-V2X-equipped fleet vehicles without cellular connectivity to connect to the Internet through Wi-Fi to enable the fleet vehicles to download SCMS top-offs from the contracted SCMS provider.	No	No	Yes	No	Test	CTW-17	Yes	Yes	No	Field Equipment	Refine SCMS certificates without cellular service
VS-1	Parent	<i>Vehicle Systems-compatible SAE J2735 versions.</i> All CTW Vehicle Systems added through this effort shall send and receive messages as defined in SAE J2735 standards.	No	Yes	Yes	Yes	Inspection and Demonstration	CTW-13	Yes	No	No	Vehicle Systems	Demonstrate OEM vehicle interoperability
VS-1.1	Child	<i>Vehicle Systems receive in compatible SAE J2735 versions.</i> All CTW Vehicle Systems added through this effort shall be capable of receiving and processing messages as defined in J2735 standards in all of the following versions: 2016, 2020, and 2024.	No	Yes	Yes	Yes	Demonstration	CTW-13	Yes	No	No	Vehicle Systems	Demonstrate OEM vehicle interoperability
VS-1.2	Child	<i>Vehicle Systems send in compatible SAE J2735 versions.</i> All CTW Vehicle Systems added through this effort shall generate and send messages as defined in SAE J2735 according to one of the following versions: 2016, 2020, or 2024	No	Yes	Yes	Yes	Inspection	CTW-13	Yes	No	No	Vehicle Systems	Demonstrate OEM vehicle interoperability

ID	Type of Requirement	Requirement	Performance Requirement	Interface Requirement	Functional Requirement	Data Requirement	Verification Method	User Need	Utah	Colorado	Wyoming	System	Capability or Change
VS-2	Parent	SRM messages interoperable to legacy systems. SRM messages broadcast by Vehicle Systems deployed in the CTW project that are CIPT-participating vehicles shall be interoperable with legacy CIPT Field Equipment.	No	Yes	Yes	Yes	Test	CTW-1	Yes	No	No	Vehicle Systems	Expand preferential treatment at CIs
VS-3	Parent	Process SCMS certificates from external agency RSUs. Vehicle Systems operated by CTW agencies shall have the capability to validate SCMS certificates that accompany messages broadcast from RSUs operated by other CTW sites.	No	No	Yes	No	Test	CTW-16	Yes	Yes	Yes	Vehicle Systems	Demonstrate SCMS interoperability
VS-4	Parent	Receive Wi-Fi top-offs of SCMS certificates. Vehicle Systems without cellular communications shall include the capability to establish internet connection through Wi-Fi to receive top-offs of SCMS certificates directly from contracted SCMS providers.	No	No	Yes	No	Test	CTW-17	Yes	No	No	Vehicle Systems	Refine SCMS certificates without cellular service

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