Unified Implementation of the Reference Architecture

Concept of Operations, Version 1

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16. Abstract

This document describes the Concept of Operations (ConOps) for the Unified Implementation of the Reference Architecture, located in Southeast Michigan, which supports connected vehicle research and development. This ConOps describes the current state of operations, establishes the reasons for change, and defines these operations in terms of the major functions/features provided and associated support operations.

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1.0	09/19/2016	James Marousek	Initial Published Version

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Scope

This document describes the Concept of Operations (ConOps) for the U.S. Department of Transportation's Unified Implementation of the Reference Architecture supporting connected vehicle research and development. This ConOps describes the current state of Unified Implementation of the Reference Architecture operations, establishes the reasons for change, and defines operations for the 2015 version of the Unified Implementation of the Reference Architecture in terms of functions and features and supporting operations.

The intended audience for this document includes:

- Unified Implementation of the Reference Architecture Project Engineering Team
- Intelligent Transportation Systems Joint Program Office (ITS JPO) Program Leads and Support Staff
- ITS JPO Program Engineering Teams
- Affiliated Test Bed Community
- Connected Vehicle Pilot Deployment Project Teams
- Early Deployment Project Teams
- Academic and Research Teams.

Please note that any hyperlinks provided throughout this document are accurate as of the date of publication.

Chapter 1. Current Situation

Background and Objectives

The U.S. Department of Transportation (USDOT) Connected Vehicle Test Bed in Southeast Michigan was implemented in 2007 to serve as the test facility for the proof of concept (POC) testing conducted by the USDOT and the auto industry to determine the feasibility and technical limitations of dedicated short-range communications (DSRC) operating at the 5.9 GHz bandwidth. Over the past few years, the USDOT Connected Vehicle Test Bed in Southeast Michigan has gone through numerous enhancements, including geographical expansion and technical and architectural updates, designed to support the connected vehicle industry's evolving needs for a test and development environment.

The following document is intended to describe the most recent updates to the Connected Vehicle Test Bed in Oakland County, Michigan. It is important to note that this document is just one instantiation, and efforts are underway to describe additional functionalities and align the capabilities of the Test Bed with user needs, additional tools, and compliance with the 2016 standards. Among the various planned, long-term transitions are the following current efforts—the introduction of the Operational Data Environment (ODE) platform as a locally owned and managed, optional gateway into the architecture; upgrades to the 2016 IEEE 1609 standards; and integration with the next generation Security Credential Management System (SCMS). The following Concept of Operations (ConOps) presents the starting point for these transitions and the foundation for the longer-term architecture. If you intend to use this ConOps for deployment or would like more information on the ongoing efforts and evolution of the Test Bed, beyond this document, please contact Ariel Gold, Data Program Manager at the Intelligent Transportation Systems Joint Program Office (ITS JPO), at: Ariel.Gold@dot.gov.

As evolution and transition in the Ted Bed is ongoing, the upgrades described in this document provide an enhanced platform for use in testing several new capabilities necessary for the more extensive Connected Vehicle Pilot Deployments occurring in 2016 and 2017, as well as for other future "early" deployments.

This document supersedes the 2014 ConOps, *Southeast Michigan Test Bed 2014 Concept of Operations*, with the following updates: additional upgrades and new functionality necessary to align the Connected Vehicle Test Bed with the ITS JPO's Connected Vehicle Reference Implementation Architecture (CVRIA) and serve as a reference implementation for numerous demonstrations conducted at the ITS World Congress in September of 2014. Collectively, the recent upgrades shape an evolution of the Southeast Michigan Connected Vehicle Test Bed toward a unified implementation of the USDOT's reference architecture (CVRIA), resulting in its rebranding as the "Unified Implementation of the Reference Architecture."

Description of Current Situation

The Connected Vehicle Test Bed in Oakland County, Michigan (now known as the Unified Implementation of the Reference Architecture), was implemented in 2007 to serve as the development and test facility for the POC engineering project conducted by the USDOT and the auto industry, to determine the feasibility and technical limitations of DSRC operating at the 5.9 GHz bandwidth. Over the past few years, the Unified Implementation of the Reference Architecture has gone through numerous enhancements, including geographical expansion and technical and architectural updates, designed to support the connected vehicle industry's evolving needs for a test and development environment.

The focus of the USDOT's Connected Vehicle program over the last few years has been on research, development, and assessment of the efficacy of vehicle-to-vehicle (V2V) communications using Wireless Access in a Vehicular Environment (WAVE)/DSRC technologies to support connected vehicle safety applications. There has been some attempt to assess the viability of the generation and collection of probe data, both as defined in an older version of SAE J2735 and in the form of Basic Safety Messages (BSMs) defined in the current version of SAE J2735. The lynchpin of this research was the USDOT's Connected Vehicle Safety Pilot, which was conducted in Ann Arbor, Michigan, from 2012 through 2013, and will directly support the National Highway Transportation Safety Administration (NHTSA) rulemaking process regarding DSRC-based V2V safety mechanisms to be deployed in light-duty vehicles.

The Unified Implementation of the Reference Architecture has ITS roadside equipment located in Oakland County, Michigan, and interconnected back-office systems, located in Oak Ridge, Tennessee, that provide continuous real-time connectivity among users—enabling stakeholders to test prototype connected vehicle equipment, applications, and services. It currently covers 45 miles (194 km) comprising 75 linear miles (121 km) of roadways. The Unified Implementation of the Reference Architecture is currently operated and managed by a USDOT contractor team. For further information, please refer to the ITS JPO Connected Vehicle Test Bed portal.

A diverse range of ITS stakeholders use the Unified Implementation of the Reference Architecture for a variety of research and development activities including:

- RF engineering and protocol testing
- Safety, mobility, and environmental algorithm development
- Research data collection and analysis
- Positioning, navigation, and timing refinement
- Electronic signal phase and timing propagation
- Electronic map generation and propagation
- Product and service testing.

To better serve its role in supporting the USDOT's ITS Program goals, the Unified Implementation of the Reference Architecture required a number of functional upgrades and selected technology refreshes that were successfully deployed over the last several years.

Chapter 2. Justification for and Nature of Changes

The need for an evolving Unified Implementation of the Reference Architecture, as described in this ConOps, started with a set of planned minor updates and subsequently grew to include serving as a reference platform for staging demonstrations at ITS World Congress in September 2014. The upgraded Unified Implementation of the Reference Architecture may extend to other connected vehicle research test and development environments in Michigan if the prototype concepts and technologies introduced are successful. In the interim, the upgraded Unified Implementation of the Reference Architecture provides an enhanced platform for testing several new capabilities that will be necessary for more extensive pilot deployments in 2016 and 2017.

The following sections describe the rationale for refocusing the purpose and evolving the structure and functionality of the Unified Implementation of the Reference Architecture.

Support ITS Program Objectives

The recently published USDOT *ITS Strategic Plan, 2015-2019* defines two primary strategic priorities:

1. **Realizing Connected Vehicle Implementation:** Driven by the progress in engineering and planning for nationwide connected vehicle deployments
2. **Advancing Automation:** Focuses on research, development, and adoption of emerging automation-related technologies.

In addition, the *ITS Strategic Plan* identified five strategic themes that align with the strategic priorities and focus the attention of the ITS community on intended outcomes of new technologies and systems as they are developed, tested, and eventually adopted. These strategic themes include:

- Enable Safer Vehicles and Roadways
- Enhance Mobility
- Limit Environmental Impacts
- Promote Innovation
- Support Transportation System Information Sharing.

Collectively, the strategic priorities and themes provide the ITS Program's mission objectives and a structural frame. Within this framework, individual programs have been, and will be, established to perform the tasks necessary to achieve the goals of the ITS Program. Table 1 lists the *ITS Strategic Plan* program categories. For each category, there is a brief overview illustrating the relevance of the Unified Implementation of the Reference Architecture in supporting the programs within that category.

Table 1. Relevance of the Unified Implementation of the Reference Architecture to the ITS Program Categories

ITS Program Category	Relevance of the Unified Implementation of the Reference Architecture
Connected Vehicles	With the second phase of the Safety Pilot Model Deployment well underway, the USDOT Connected Vehicle Research Program is increasing its focus on development of dynamic mobility and environmental applications, as well as additional vehicle-to-infrastructure (V2I) safety applications. Over the last decade, the Unified Implementation of the Reference Architecture has been, and will continue to be, one of the cornerstones for connected vehicle research, which focused initially on DSRC technology for both V2V and V2I communications. Over the years, it has expanded to support a number of alternative communications technologies and to provide essential data distribution and support services that enable it to support a wide range of connected vehicle and automated vehicle deployments and operations.
Automation	Automated or autonomous vehicles will be an integral part of the wider connected vehicle operational environment, requiring the same supporting services provided by the Unified Implementation of the Reference Architecture.
Emerging Capabilities	As current technologies that enable both connected and automated vehicle operations continue to evolve and new relevant technologies emerge, the Unified Implementation of the Reference Architecture provides a set of core services (security credentialing, object discovery, and data distribution) that will facilitate the research, prototype development, test and evaluation of technologies, standards, devices, and systems that incorporate these advanced or alternative technologies. This can be exemplified by the integration of satellite-based and radio-based technologies that now augment the Unified Implementation of the Reference Architecture's data distribution operations.
Enterprise Data	***Enhanced Data Distribution Services*** – Brokered data distribution services based on a "publish and subscribe" paradigm were introduced. As developed, this is best characterized as data warehousing, where deposits (of data) are made to the warehouse by willing data providers; and deliveries (of data) are made by the warehouse to interested consumers. These deposits and deliveries are orthogonal, and the data providers and consumers are unaware of each other, and therefore of the source of any data they consume or the destination of any data they provide. The Unified Implementation of the Reference Architecture has two functionally distinct data warehouses—the USDOT Situation Data Warehouse and the USDOT Situation Data Clearinghouse, which will be defined and described later in this document: • Supports data collection and exchange with different automated and connected vehicles (automobiles, transit, and commercial vehicles), mobile devices, and infrastructure object. • Supports aggregation and integration of data collected from multiple sources • Supports data provisioning through the Operational Data Environment to a wide and diverse community, including the USDOT Research Data Exchange, of data consumers • Supports extensible and flexibly defined data constructs • Supports efficient data distribution through data "bundling."
Interoperability	One of the most significant benefits provided by the Unified Implementation of the Reference Architecture is the set of core services (security credentialing, object

ITS Program Category	Relevance of the Unified Implementation of the Reference Architecture
	discovery and data distribution) that inherently promote interoperability. More specifically, this is facilitated through the introduction of the following features: • Uniform time, location, and geographic references and data context definitions • An adaptable Data Exchange (Information Flow) Dialog Pattern that promotes interoperability by enabling connected and automated vehicle objects (vehicles, personal devices, infrastructure objects, and associated applications) to effectively communicate with other objects as needed, regardless of where and by whom they were built and where or when they are used.
Accelerating Deployment	As current and emerging technologies, devices, and systems evolve into market-ready products, the Unified Implementation of the Reference Architecture will provide guidance and address concerns associated with deployment into operational environments. In addition to providing ongoing support for the USDOT Safety Pilot, it will also provide this same support across all USDOT Connected Vehicle Pilot Deployments. Additionally, the maturation of the Unified Implementation of the Reference Architecture, which provides increased capabilities for supporting research, development, and evaluation of connected and automated vehicle technologies, devices, and systems, has generated significant and accelerating interest from a wide variety of stakeholders focused not only on its inherent services and features, but also on exploring opportunities for collaboration. The Affiliated Test Beds initiative enhances this opportunity by encouraging and facilitating participation by road operators, certification entities, and research organizations that would otherwise be unable to fully use the Unified Implementation of the Reference Architecture.

Support ITS Architecture and Standards Program Goals

As stated earlier in this document, the Unified Implementation of the Reference Architecture was built on the foundation established by ITS JPO's CVRIA. The CVRIA establishes a framework for integrating connected vehicle technologies and identifies those interfaces that should be standardized to better facilitate interoperability and ease of deployment. The CVRIA will be integrated into the ITS National Architecture in the near future

The Unified Implementation of the Reference Architecture has adapted to align with the functions, interfaces, standards, and terminology specified within the CVRIA and to use the Systems Engineering Tool for Intelligent Transportation (SET-IT) developed by the ITS JPO National Architecture Team. It will continue to do so as the CVRIA and SET-IT evolve. This is vital given the key role that the Unified Implementation will play in providing essential data distribution and support services for a significant number of ITS Connected Vehicle and Automated Vehicle Programs, as well as planned and future deployments.

As the Connected Vehicle Pilot Deployments ramp up, each system should have a fully specified system architecture based on the CVRIA. In addition to addressing the respective stakeholder concerns, each

CVRIA-based system architecture will be able to leverage the common language definition and early deployment concepts provided by the CVRIA and used by the Unified Implementation of the Reference Architecture. The CVRIA and its associated SET-IT tool enable initial deployments and integration activities, specifically with the Unified Implementation of the Reference Architecture by providing the framework for how they all interconnect.

The CVRIA framework consists of four distinct viewpoints—Physical, Functional, Communications, and Enterprise, of which two (Physical and Enterprise) are included for the Unified Implementation in this ConOps.

Concepts Supporting Program Goals and Future Deployments

The central mission of the Unified Implementation of the Reference Architecture is to support research and development of concepts, technologies, services, and applications for connected vehicle deployments. To that end, the following concepts were selected as foundational and have been incorporated into recent and planned system upgrades.

Time and Location Reference

It is essential that all Unified Implementation of the Reference Architecture objects operate with a common understanding and framework for both time and location. It is assumed that every object that is part of, or uses the services of the Unified Implementation of the Reference Architecture, has a common understanding of time, based on Coordinated Universal Time (UTC) as defined by the "International Telecommunications Union Recommendation TF.460-6," to within 1 millisecond absolute to UTC.

It is also assumed that every object that is part of, or uses the services of the Unified Implementation of the Reference Architecture, has a common understanding of location, using the DE_Longitude, DE_Latitude and DE_Elevation units as specified in the "SAE J2735 – Dedicated Short-Range Communications (DSRC) Message Set Dictionary."

Geographic Reference

As with many warehouse-based distribution systems, each Situation Data Warehouse or Situation Data Clearinghouse will have an exclusive (non-overlapping) geographic region for which it will accept or provide goods (e.g., Enhanced Vehicle Situation Data Type Bundles). These geographic regions will be defined and bounded in units of degrees. The initial USDOT Situation Data Warehouse and Clearinghouse will be located in the Unified Implementation of the Reference Architecture and will serve the 2-degree-by-3-degree geographic region shown below. The region will be divided into a geographic grid of "tiles," each of which will be a 10 millidegree square. This will yield 60,000 tiles. Geographic reference points used to exercise the functions described in this ConOps should be expressed with 10 millidegree precision to align with this "tiled" grid overlay. Please note that while the initial service area will be constrained to the Novi, Michigan area, the relatively large geographic boundary was selected to allow for expansion into the surrounding areas in the near future.

As more data providers come online, the Unified Implementation of the Reference Architecture service area could be further divided into three discrete 2x1 rectangles or six discrete 1x1 degree squares to

support the greater granularity needed for the increased data volumes. This process of subdivision could be iterated to scale as necessary to support continually increasing data volumes as more and more vehicles become equipped and more applications are deployed.

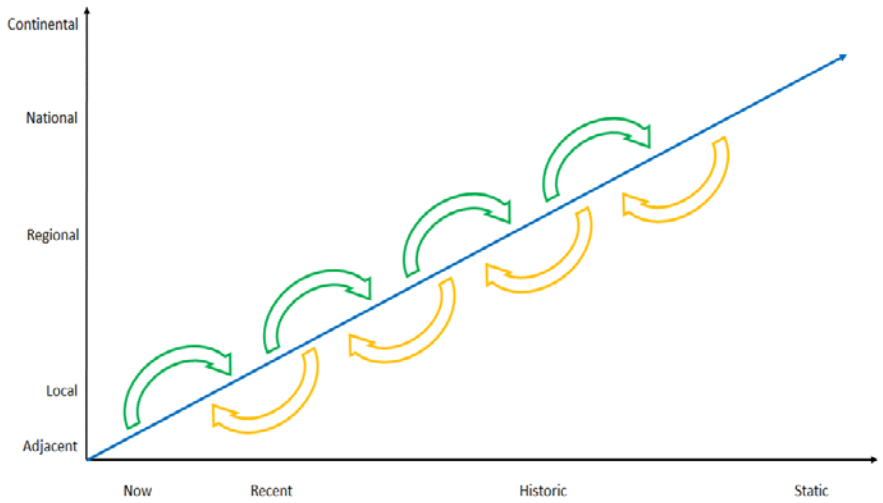
Photo Source: Google Earth

Figure 1. Unified Implementation of the Reference Architecture Geographic Boundary

As affiliated test beds and early deployments come online, additional situation data warehouses and clearinghouses could be created with respective defined geographic regions. Each associated geographic region could, in turn, have its respective boundaries divided or subsequently subdivided to scale with increased data volumes.

Characterizing Data Context

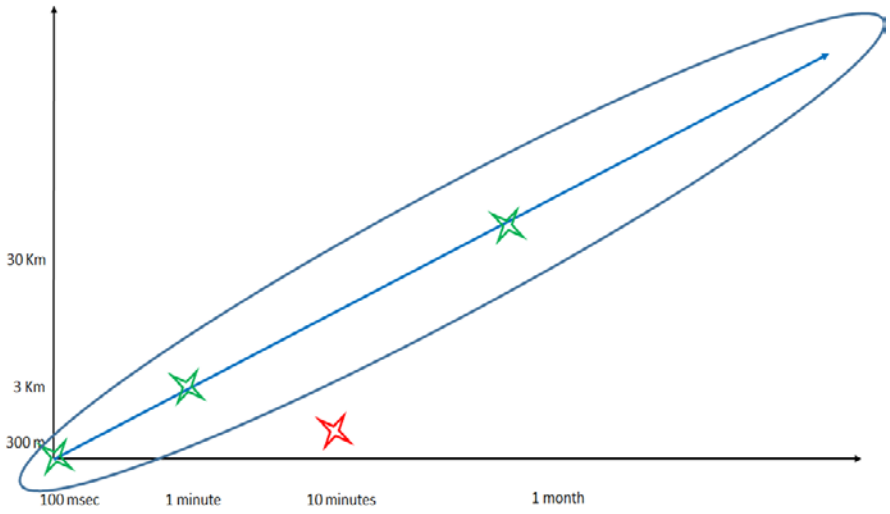
One of the fundamental concepts underpinning the Unified Implementation of the Reference Architecture is that data and/or information generated, situational or otherwise, is characterized by two key state elements—its time context and space context. These two characterizations determine the relevance of the data/information to the recipient based on the recipient's proximity (in time and/or space) to the source of the data. All data/information that is generated within the Unified Implementation of the Reference Architecture will accordingly be both time and location stamped at creation. This allows each data recipient to respectively adjudicate the relevance and value of the data. Figure 2 illustrates this concept.



Source: USDOT

Figure 2. Space and Time Context of Data/Information

Figure 3 provides an illustrative scale identifying the respective values for the labels defined in the previous diagram.



Source: USDOT

Figure 3. Targeted Space and Time Context of Data/Information

Security/Privacy by Design

A fundamental concept that will pervade the design and development of the Unified Implementation of the Reference Architecture is “Security/Privacy by Design.” This means, the Unified Implementation will be designed to protect the privacy of the users to the highest possible degree, while simultaneously

protecting Unified Implementation assets and operations from cyber threats. This is especially challenging in a multi-application setting, because the user (mobile or fixed) may have higher privacy requirements than a specific application requires. There is an additional threat to the privacy of the user from correlations between applications. This is further complicated in that some connected vehicle applications, by their nature, will have to reveal sensitive or user-specific information (e.g., BSMs reveal vehicle location). This makes it all the more important to ensure that:

- The Unified Implementation of the Reference Architecture does not require applications to reveal this type of information unless it is absolutely necessary.
- Unified Implementation of the Reference Architecture applications do not reveal this type of information unless it is absolutely necessary, as revealing the information within application A will allow it to be correlated with information from application B.

Further discussion of privacy and security for the multi-application setting can be found in EU-US ITS Task Force Standards Harmonization Working Group Harmonization Task Group 1 Report 1-1, "Current Status of Security Standards," Section 14 and Annex C.

The "Security/Privacy by Design" principle is limited to cyber security and does not consider the ancillary need for device physical security. It also does not address data protection at endpoints (e.g., encryption of databases). *It is assumed that* ***endpoints that store Personal Identifiable Information (PII) shall take appropriate measures to protect all PII***.

Assessing Communications Characteristics

One of the fundamental objectives for the Unified Implementation of the Reference Architecture is the assessment of communications performance and determination of their inherent suitability for supporting various connected vehicle applications. One of the key communications media supported in the Unified Implementation of the Reference Architecture will be the 5.9 GHz DSRC band, using the IEEE 1609 - WAVE protocol suite. Interested readers are referred to those standards for more information. It is intended that all seven DSRC channels be exercised within the Unified Implementation of the Reference Architecture and that the following (at a minimum) communication characteristics be assessed:

- Congestion
- Interference (e.g., multipath, cross-channel)
- Performance (e.g., range)
- Data throughput
- Relative endpoint velocity.

There are two types of communication patterns that support data exchanges between connected vehicle application objects (otherwise known as applications) in the Unified Implementation of the Reference Architecture—broadcast and unicast (transactional, peer to peer).

Broadcast Communications

Typically sent as unencrypted messages with unencrypted data, broadcast communications are intended to be "heard" by any receiver in the vicinity. These broadcast communications are sent without concern

for how many (if any) receivers are actually in the vicinity, nor if the receivers are interested in the contents of the broadcast. It is up to the receiving device as to whether it wishes to interpret or act upon the received message. Well-known data structures are defined to facilitate broadcast communications between objects that do not have a pre-established relationship. The Unified Implementation of the Reference Architecture will use the IEEE 1609.3 WAVE Short Message Protocol (WSMP) to broadcast WAVE Short Messages (WSM) encapsulating these pre-defined data structures. For the Unified Implementation of the Reference Architecture's DSRC-based communications, these pre-defined data structures will be adopted, adapted, or developed based on the structures defined in the SAE J2735 Data Dictionary.

Examples of broadcast communications are SAE J2735 BSMs broadcast V2V over DSRC and SAE J2735 Signal Phase and Timing (SPaT) messages broadcast infrastructure to vehicle over DSRC. Please note that in the Unified Implementation of the Reference Architecture, all broadcast messages will be digitally signed immediately by the transmitting device. In other words, if an informational message originates at a center-based service provider and is sent to roadside equipment (RSE) for broadcast, it will be signed by the RSE as part of the complete transmission.

Unicast (Transactional) Communications

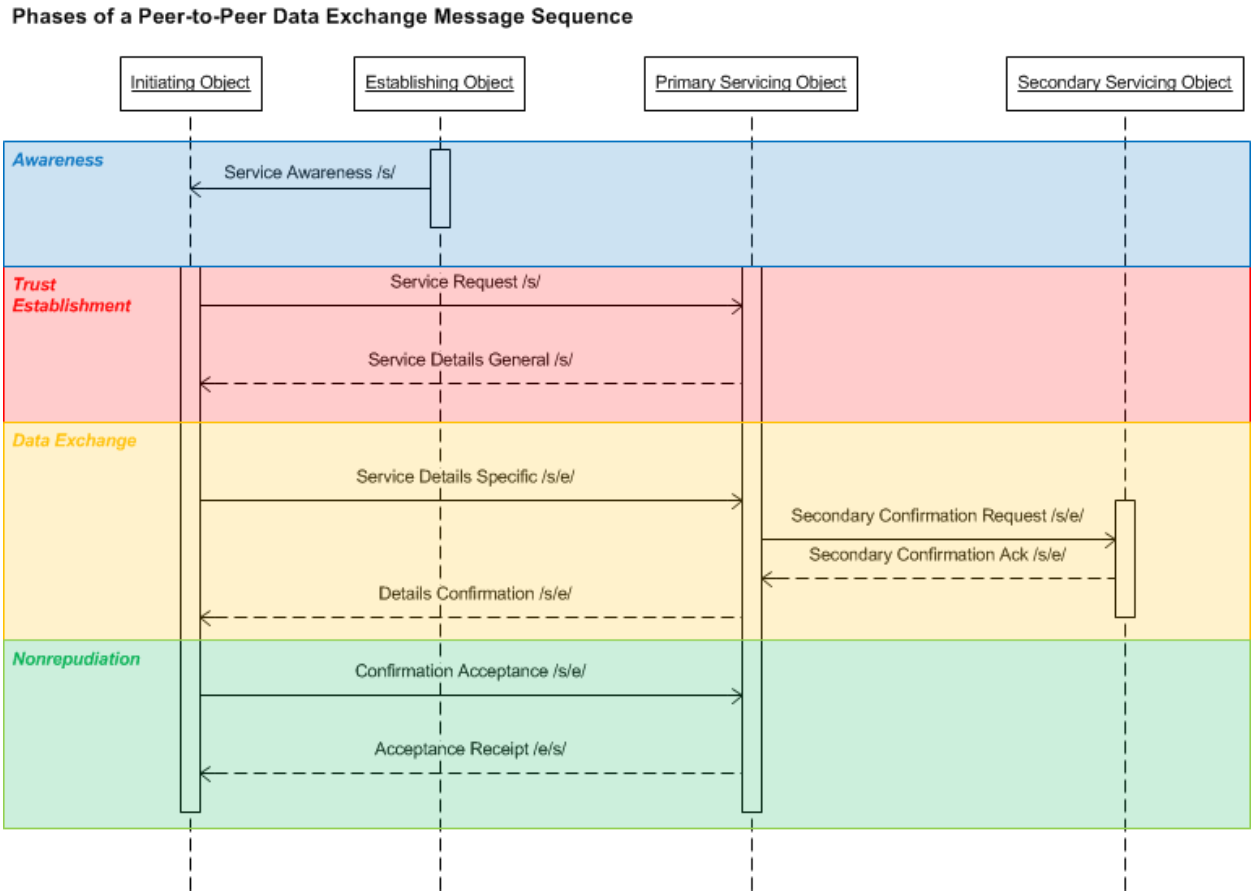
Unicast communications are typically exchanged between two Unified Implementation of the Reference Architecture objects to enact a transactional data exchange. It is intended that any IP-based communications path (e.g., 3G, 4G, Wi-Fi, WiMAX) can be used, provided both Unified Implementation of the Reference Architecture objects are accordingly configured. IEEE WAVE over DSRC communications can be used as the sole hop between the two Unified Implementation of the Reference Architecture objects (for all V2V and some V2I), or it can be used as the first/last hop in a multi-hop routed communications path between two Unified Implementation of the Reference Architecture objects using IP-based communications.

For Unified Implementation of the Reference Architecture objects, these transactions are usually small data transfers (up to approximately 10 Kbytes). However, depending on operational circumstances and available communication paths, larger data transfers are possible. For unicast transactions conducted over DSRC/WAVE communications, it is strongly recommended that small size transactions be the norm, as there is no communication mechanism for maintaining transactions using adjacent RSE communication facilities. There is no functional support for anycast, multicast, or groupcast communications. In addition to the fundamental assumption that each unicast transaction will be digitally signed, it is also assumed that virtually all unicast transactions will also be digitally encrypted. To that extent, the pictorial representations of the various transaction dialogs will have illustrative tags ("/s/" for signed and "/e/" for encrypted) for each transaction within the dialog. Solid lines indicate a request, and dashed lines indicate the corresponding response.

Data Exchange (Information Flow) Dialog Pattern

There will be a significant number of information flows between various Unified Implementation of the Reference Architecture objects that are characterized as "peer-to-peer" data exchanges. Each information flow will be comprised of one or more information flow dialogs. All such information flow dialogs should be developed, to the extent feasible, using the following data exchange pattern as their basis.

It is anticipated that there will be additional “peer-to-peer” information flow dialogs between third-party objects operating as part of the Unified Implementation of the Reference Architecture. In addition, it is anticipated and strongly encouraged that these third-party application dialogs are developed using the “Peer-to-Peer” Data Exchange Pattern described below. Their specific usage and functionality is outside the scope of this document.



Source: USDOT

Figure 4. Peer-to-Peer Data Exchange Sequence

The Information Flow dialog pattern has four distinct phases as described below.

Phase 1: Service Awareness

As additional objects are introduced (e.g., connected vehicle entering the Unified Implementation of the Reference Architecture area) into the Unified Implementation of the Reference Architecture, they will need to become aware of other Unified Implementation of the Reference Architecture objects with which they might wish to exchange data. This awareness must include sufficient information to allow the “interested” Unified Implementation of the Reference Architecture object to determine where and when to reach out to for services that are currently or will be available. This awareness can be accomplished by several means:

1. The interested Unified Implementation of the Reference Architecture object can have “a priori” knowledge, typically by hardcoding “well known” information or via a static or dynamic configuration mechanism.
2. The interested Unified Implementation of the Reference Architecture object can request (“pull”) the information from one or more “well known” service information repositories, which for the Unified Implementation of the Reference Architecture will be the Object Registration and Discovery Service (ORDS). This obviously implies that all Unified Implementation of the Reference Architecture objects wishing to be “advertised” need to register and maintain their service information with the ORDS and also need to have a “well known” identifier that can be used to query the ORDS.
3. The interested Unified Implementation of the Reference Architecture object can receive (“push”) the needed information from one or more service announcements provided by other Unified Implementation of the Reference Architecture objects that have received the information either “a priori” or from the ORDS. With respect to the Unified Implementation of the Reference Architecture, these service advertisements will be provided by the Unified Implementation of the Reference Architecture RSE. It should be noted that the “interested” Unified Implementation of the Reference Architecture object must contain internal logic sufficient to determine whether to act on the service advertisement.

It should be noted that “a priori” awareness can be minimized to just that for the ORDS. With that service awareness, all additional service awareness information can be obtained.

Phase 2: Trust Establishment

Trust Establishment is based on the premise that both parties participating in a “peer-to-peer” data exchange must trust the communications received from the corresponding Unified Implementation of the Reference Architecture object and must be able to provide “trusted” communications in return. For the Unified Implementation of the Reference Architecture, this is based on the foundation that all participating Unified Implementation of the Reference Architecture objects shall have valid Security Credential Management System (SCMS) security credentials installed as necessary to support Unified Implementation of the Reference Architecture operations in general and “peer-to-peer” data exchanges specifically. It is also based on the premise that the “initiating” Unified Implementation of the Reference Architecture object has already established service “awareness” of the corresponding Unified Implementation of the Reference Architecture object to the extent that it is able to initiate the “peer-to-peer” data exchange.

The “initiating” Unified Implementation of the Reference Architecture object shall initiate the communications dialog when logic dictates that this is the correct choice. To affect this data exchange, the “initiating” Unified Implementation of the Reference Architecture object will format, construct, and transmit a secure “Service Request” message in which it will both identify itself and declare its intent to initiate a “peer-to-peer” data exchange. This “Service Request” message will include sufficient security credential information to allow the corresponding Unified Implementation of the Reference Architecture object to verify that the “initiating” Unified Implementation of the Reference Architecture object is currently authorized to participate in Unified Implementation of the Reference Architecture operations in general and to enter this specific “peer-to-peer” data exchange operation specifically.

Upon receipt of the “Service Request” message, the corresponding Unified Implementation of the Reference Architecture object will verify that the “initiating” Unified Implementation of the Reference Architecture is currently authorized to participate in the specific “peer-to-peer” data exchange. Upon this verification, the corresponding Unified Implementation of the Reference Architecture object will format, construct, and transmit a secure “Service Response” message in which it will both confirm its identity and declare its agreement to participate in the specific “peer-to-peer” data exchange. This “Service Response” message will include sufficient security credential information so as to allow the “initiating” Unified Implementation of the Reference Architecture object to verify that the corresponding Unified Implementation of the Reference Architecture object is indeed the Unified Implementation of the Reference Architecture object indicated in the service information obtained during the service awareness phase. It is possible that the “Service Response” message could also include informational elements that are relevant to the configuration of the specific data exchange session, configuration of all data exchanges with the correspondent object, or even system-wide configuration elements.

At this point, either both Unified Implementation of the Reference Architecture objects have respectively confirmed the validity of the other Unified Implementation of the Reference Architecture object, in which case, trust has been established; or the “peer-to-peer” data exchange is effectively cancelled.

Phase 3: Data Exchange

The respective messages within the Data Exchange phase will, by necessity, be specific to each dialog of each information flow dialog. The respective data exchange phases of all information flow dialogs with or between Unified Implementation of the Reference Architecture objects will be defined in a separate design document.

As mentioned previously, it is anticipated that there will be additional “peer-to-peer” information flow dialogs between third-party objects operating as part of the Unified Implementation of the Reference Architecture. The specific usage and functionality of the data exchange phase of these dialogs is outside the scope of this document.

That being said, the following list of common concepts should be applied to each dialog:

1. Each Unified Implementation of the Reference Architecture object participating in the dialog must use appropriate SCMS security credentials to send “sensitive information” using signed/encrypted communications.
2. The dialog will terminate upon expiration of the security credentials of either participant.

Phase 4: Nonrepudiation

The Nonrepudiation phase is intended to provide one or more of the following benefits:

1. Graceful termination of the dialog, which can be initiated by either participating Unified Implementation of the Reference Architecture object.
2. Assurance that the dialog cannot later be denied by either of the participating Unified Implementation of the Reference Architecture objects.
3. Confirmation of receipt of sensitive information using signed/encrypted communications.

4. Confirmation of dialog results, such as bundles sent/received, for accounting purposes.

The “terminating” Unified Implementation of the Reference Architecture object shall initiate the nonrepudiation phase of the communications dialog when logic dictates that this is the correct choice. To affect this phase change, the “terminating” Unified Implementation of the Reference Architecture object will format, construct, and transmit a secure “Confirmation Acceptance” message in which it declare its intent to terminate the “peer-to-peer” data exchange. This “Confirmation Acceptance” message will include sufficient information so as to allow the corresponding Unified Implementation of the Reference Architecture to ensure nonrepudiation.

Upon receipt of the “Confirmation Acceptance” message, the corresponding Unified Implementation of the Reference Architecture object will format, construct, and transmit a secure “Confirmation Receipt” message in which it will confirm its agreement to terminate the “peer-to-peer” data exchange. This “Service Response” message will include sufficient information so as to allow the corresponding Unified Implementation of the Reference Architecture object to ensure nonrepudiation.

At this point, both Unified Implementation of the Reference Architecture objects have respectively confirmed the completion of the “peer-to-peer” data exchange, thus ensuring nonrepudiation.

Data Constructs

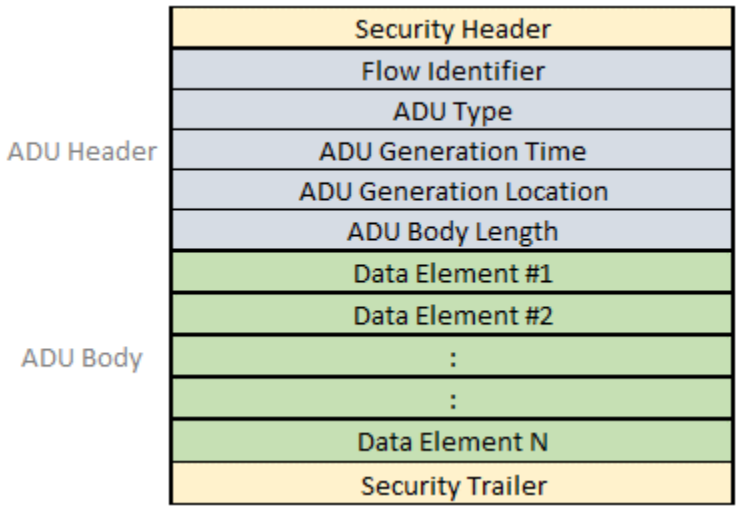
As research and development activities under the Connected Vehicle and Automated Vehicle Programs progress, exceptional amounts of useful data are being generated. This data is highly sought by the wider ITS research community and this, in turn, necessitates the development of effective and efficient means for capturing and securely exchanging the data, both for the meet immediate needs and to assess the efficacy of supporting increasingly high volumes of data exchanges as the ITS Program moves toward pilot deployments and then full-scale deployments.

Given the projected volumes of data and scale and diversity of data producers and consumers, new, innovative methods to collect, aggregate, process, exchange, analyze, and ultimately use this data will be needed. As described earlier in this document, the Unified Implementation of the Reference Architecture has implemented an enhanced Data Distribution Service that supports the brokered exchange between data producers and consumers. As part of this service, two categories of data construct types have been defined:

1. ***Application Data Unit (ADU)*** – An ADU is encoded information exchanged between Application Objects, generally installed and operational on different Physical Objects (devices). An ADU is an instantiation of an ADU Type, which is a formally defined data structure consisting of an ADU Header and an ADU Body, each consisting of one or more Data Elements. Each Data Element is an instantiation of a formally defined Data Element Type and is typically specified in a data dictionary.
2. ***ADU Bundle*** – An ADU Bundle is also encoded information exchanged between Application Objects, generally installed and operational on different Physical Objects (devices). An ADU Bundle is an instantiation of an ADU Bundle Type, which is a formally defined data structure containing of a Bundle Header consisting of one or more Data Elements and a Bundle Body, each consisting of one or more ADU Body data structures (see above).

Application Data Units

The following diagram illustrates an example ADU.



Source: USDOT

Figure 5. Example Application Data Unit Structure

Data Element Principles

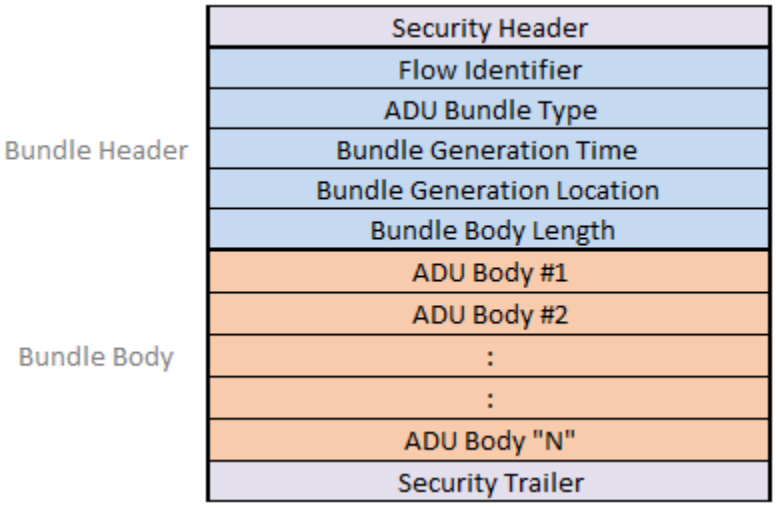
1. Data Element types of fixed composition will be supported.
2. Data Element types of variable composition will ***NOT*** be supported.

ADU Principles

1. Each unique combination of data element types is defined as an ADU Type.
2. ADU Types of fixed composition will be supported.
3. ADU Types of variable composition will ***NOT*** be supported.
4. ADU Types with fixed or variable sizes will be supported.
5. The structure and composition of ADU Types will be explicitly defined in other Unified Implementation of the Reference Architecture specifications.
6. One or more ADUs, of the same or different ADU Types can be sent as part of a “peer-to-peer” dialog (described above).

ADU Bundles

For efficiency of bandwidth and expediency, individual ADUS can be aggregated into a composite data construct referred to as an ADU Bundle.” An ADU Data Bundle will typically have the following structure, with the respective Bundle Header fields and constituent ADU Body Types varying for each ADU Bundle Type.



Source: USDOT

Figure 6. Example ADU Bundle Structure

ADU Bundle Principles

1. Each unique combination of ADU Body Types is defined as an ADU Bundle Type.
2. ADU Bundle Types containing ADU Bodies of a single ADU Type are supported.
3. ADU Bundle Types containing ADU Bodies of multiple ADU Types are supported.
4. ADU Bundle Types of fixed composition will be supported.
5. ADU Bundle Types of variable composition will ***NOT*** be supported.
6. The structure and composition of ADU Bundle Types will be explicitly defined in other Unified Implementation of the Reference Architecture specifications.
7. The number of discrete ADU Bodies within each ADU Bundle will be dynamically determined based on the aggregate size and the underlying communications media characteristics.
8. One or more ADU Bundles, of the same or different ADU Bundles Types, can be sent as part of a "peer-to-peer" dialog (described above).
9. Additional Bundle Header fields (not shown) can be inserted to facilitate the tracking (e.g., expected number of bundles) the transfer of multiple bundles as part of a "peer-to-peer" dialog (described above).

System Needs

The System Needs listed below are designed to answer two basic questions:

1. What does the system need to do?
2. What do users need from the system?

They are categorized for ease of use.

System User Authorization

The System needs to manage the authorization mechanisms to define roles, responsibilities, and permissions for System Users. This allows the Unified Implementation of the Reference Architecture's system administrators to establish operational environments where different connected vehicle system users may have different capabilities.

Table 2. System User Authorization Needs

Need ID	Need Description
CA-01	The System needs to manage authorization mechanisms to define roles, responsibilities, and permissions for System Elements. This enables the System to establish operational environments where different System Elements may have different capabilities in terms of interacting with one another.
CA-02	The System needs to manage authorization mechanisms to define roles, responsibilities, and permissions for System Users. This enables the System to establish operational environments where different System Users may have different capabilities in terms of accessing System Elements and interacting with one another. For instance, some mobile entities may be authorized to request signal priority, or some Centers may be permitted to use the geographic broadcast service, while those without those permissions would not.

Authorization Management

Security and credentials management (SCM) is a set of support applications that are used to ensure the trusted communications between mobile devices and other mobile devices or roadside devices and protect data they handle from unauthorized access. The applications grant trust credentials to qualified mobile devices so that those devices may be considered trusted by other devices that receive trust credentials from the SCM applications. The applications allow credentials to be requested and revoked, as well as to secure the exchange of trust credentials between parties, so that no other party can intercept and use those credentials illegitimately. The applications provide security to the transmissions between connected devices, ensuring authenticity and integrity of the transmissions. Additional security features include privacy protection, authorization and privilege class definition, and nonrepudiation of origin.

Table 3. Authorization Management Needs

Need ID	Need Description
AM-01	The System needs to grant trust credentials to System Elements so that they may be considered trusted by other System Elements that likewise receive trust credentials from the System.
AM-02	The System needs to be able to revoke the credentials it distributes, so that a misbehaving or malfunctioning System Element can be recognized as such.
AM-03	The System needs to secure the exchange of trust credentials between itself and its intended System Elements, so that no other party can intercept and use those credentials illegitimately.

Need ID	Need Description
AM-04	The System needs be constructed so that two or more System Elements are required to link the identity of a System User with a set of trust credentials, to protect user privacy.
AM-05	The System needs to be constructed so that two or more System Elements are required to associate multiple credentials that were distributed to a user, to protect user privacy.
AM-06	The System needs to accept misbehavior reports from users, so that malfunctioning and misbehaving System Users may be identified and their privileges revoked if necessary.
AM-07	The System needs to provide a mechanism for a System User without credentials to request credentials, so that the user may participate in Unified Implementation of the Reference Architecture activities.

Infrastructure Management

Infrastructure management is a support application that maintains and monitors the performance and configuration of the infrastructure portion of connected vehicles. This includes tracking and management of the infrastructure configuration as well as detection, isolation, and correction of infrastructure service problems. The application also includes performance monitoring of the infrastructure equipment, which includes the RSE as well as the communication link to back-office functions.

Table 4. Infrastructure Management Needs

Need ID	Need Description
IM-01	The System needs to track and manage of the configuration of infrastructure-based System Elements, which includes the RSE as well as the communication link to back-office functions.
IM-02	The System needs to detect, isolate, and correct infrastructure service problems of infrastructure-based System Elements.
IM-03	The System needs to monitor the performance of infrastructure-based System Elements.
IM-04	The System needs to monitor the physical and cyber security of infrastructure-based System Elements.
IM-05	The System needs to be designed to allow for sufficient configurability to support operational needs.
IM-06	The System needs to have sufficient internal operations and diagnostic message generation and logging capabilities to allow for operational monitoring, troubleshooting, and control.

Trusted Communications

Trusted communications is an essential foundation for all connected vehicle operations. These communications needs complement the Authorization Management needs to provide effective and secure communications between connected devices.

Table 5. Trusted Communications Needs

Need ID	Need Description
TC-01	The System needs to provide a secure repository for the collection, storage, and dissemination of the network addresses and services of System Elements. This is essentially a list of “what” services are supported, “who” provides each service, and “where” to go to obtain these services.
TC-02	The System needs to provide a mechanism for System Elements to store their current cyber addresses and services into a secure repository.
TC-03	The System needs to provide the trusted network addresses of System Elements located in a secure repository to other authorized System Elements.
TC-04	The System needs to provide secure communications mechanisms necessary to protect data it transmits and/or receives from unauthorized access. This is required to support applications that exchange sensitive information, such as personally identifying or financial information, which if intercepted could compromise the privacy or financial records of the user.
TC-05	The System needs to facilitate and establish trust between authorized entities that communicate with the System and with each other. Such trust relationships are necessary so that applications can be assured that entities are who they say they are, and therefore trust the source and data it receives.
TC-06	The System needs to revoke the trust relationship it has with authorized entities when necessary. A trusted entity may operate in a fashion that indicates it should no longer be trusted, in which case, applications must have a way of revoking that trust.
TC-07	All participants in the Unified Implementation of the Reference Architecture need to operate on a common time base. Coordination of time between the entities that operate applications as well as those providing Unified Implementation of the Reference Architecture services prevents internal errors and enables time-sensitive interactions between Unified Implementation of the Reference Architecture objects.
TC-08	The System needs to connect to the Internet. This allows the System to provide services to any entity capable of connecting to the Internet.
TC-09	Every message sent by a System User or a System Element to any other System User or a System Element needs to be able to be authenticated by the receiver, so the receiver knows that the originator is a trusted source.
TC-10	Every broadcast (DSRC) message needs to specify the privilege class of the originator, for example, to distinguish emergency vehicles from general vehicles.
TC-11	Messages need to be constructed in such a way as to make it difficult to associate messages with one another, to help maintain user privacy.
TC-12	Every broadcast (DSRC) message needs to be constructed in such a way as to make replay attacks impractical, to minimize the number of such attacks.
TC-13	Every broadcast (DSRC) message from the System needs to be non-reputable in origin; that is, the originator cannot deny having sent the message. This is because when a received message invokes actions on the receiver, it may be necessary to show that the behavior was in response to a specific transmitted message. Similarly, messages may be received that indicate misbehavior of the transmitting vehicle or its equipment that will give rise to a misbehavior report. Nonrepudiation of origin ensures that the originator of information cannot successfully deny having sent the information.
TC-14	Every broadcast (DSRC) message transmitted V2V needs to use pseudonyms to help protect the user's privacy.

Data Distribution

Data distribution manages the distribution of data from data providers to data consumers and protects this data from unauthorized access. The system informs data providers of how to provide data, manages data subscriptions, and provides data forwarding capabilities. The System also maintains a directory of data consumers that want data and supports multiple distribution mechanisms including publish-subscribe, data query directed to the System, and direct distribution from data provider to data consumer. The System allows data consumers to specify (and change the specification of) data they wish to receive.

Table 6. Data Distribution Needs

Need ID	Need Description
DD-01	The System needs to protect data it handles from unauthorized access. This is required to support the exchange of sensitive information, such as personally identifying or financial information, which if intercepted could compromise the privacy or financial records of the user.
DD-02	The System needs to provide a mechanism for data providers to deposit “Store and Forward” data for subsequent retrieval by data consumers.
DD-03	The System needs to securely store all deposited data that is categorized as “Store and Forward.”
DD-04	The System needs to provide a mechanism for data consumers to retrieve “Store and Forward” data that has been previously deposited into the System by data providers. This is a single request for a certain set of data. Parameters include data type, time interval of data generation, and location of data generation. This enables the retrieval by interested data consumers of anonymously provided data, without requiring them to enter into a relationship with data providers.
DD-05	The System needs to dispose of all received data that is categorized as “Store and Forward” after the configurable “lifespan” interval has expired.
DD-06	The System needs to provide a mechanism for data providers to deposit “Immediately Forward” data for subsequent distribution to data consumers.
DD-07	The System needs to provide a mechanism for data consumers to request “Immediately Forward” data that will be deposited into the System by data providers. This is a single request for a subscription to a certain type of data. Parameters include data type, time interval of data generation, and location of data generation. This enables the “real-time” distribution of anonymously provided data to interested data consumers, without requiring them to enter into a relationship with data providers. Request formats need to provide data consumers with the ability to differentiate and receive only the types of data they requested. For example, this includes data type, geographic range, frequency, and sampling rate.
DD-08	The System needs to provide a mechanism for distribution of “Immediately Forward” data for subsequent distribution to data consumers.
DD-09	The System needs to dispose of all deposited data that is categorized as “Immediately Forward” upon completion of associated distribution.

Need ID	Need Description
DD-06	The System needs to supply information to data providers enabling them to transmit data to interested data consumers. At a minimum, data characteristics need to include type, frequency, and location where data was generated, so that users that have requested data (see need data request) can differentiate between available data. This need enables data providers to direct the data they create to data consumers, and serves as the provider-side corollary to the data request need. This supports a variety of applications, including those focused on the center provision of data to users. It also serves as the answer to the mobile entity's question of "I have data, how do I provide it and to whom?"
DD-07	Data Distribution needs to provide a mechanism to distribute data it receives. Data Distribution needs to provide this distribution mechanism, rather than relying on individual provider-consumer relationships, because multiple consumers may want access to the same data. By having Data Distribution distribute the data, data creators are relieved of the need to transmit the data multiple times. Also, some data may be critical to the proper functioning of mandatory applications, such as data supporting geo-location of users (position corrections), time base data, and roadway geometry data, all of which likely comes from a single source and needs to be distributed to large numbers of users. Additionally, mobile users may interact over resource-constrained communication links, so System-provided data redistribution reduces the potential load on those links.
DD-09	Data Distribution needs to provide the information necessary for applications that wish to communicate with a group of entities in a specific area to do so. This capability enables applications to target those in a specific area for information they wish to distribute without having to send individual messages to each recipient. Examples of applications that might use this include Amber Alerts, traffic information, and air quality alerts.

Signal Phase and Timing (SPaT)

SPaT is a support application that provides the current intersection signal light phases. The current state of all lanes at a single intersection are provided as well as any preemption or priority information. This application is used to support a variety of V2I applications.

Table 7. SPaT Needs

Need ID	Need Description
TSI-01	The System needs to provide an interface for transfer of traffic signal information from a traffic signal controller. This includes the value of the time remaining until the next change in the state of each lane movement at the intersection.
TSI-02	The System needs to accept and process traffic signal information from a traffic signal controller.
TSI-03	The System needs to translate native traffic signal information into SPaT messages as defined in SAE J2735. It is assumed that this translation will be accomplished by a SPaT "black box," which will be procured and therefore will not be developed as part of this project.
TSI-04	The System needs to regularly provide wireless transmission of the most recent SPaT message to connected vehicles and connected travelers approaching the signalized intersection.
TSI-05	The System needs to store generated SPaT messages in a bundled format for subsequent retrieval.

Need ID	Need Description
TSI-06	The System needs to provide an interface for the transfer of geometric intersection design (GID) of intersections. The GID needs to include all allowed movements regardless of the number of approaches or complexity of the intersection from the RSE in time for a mobile device to process and effectively use the information in corresponding applications.
TSI-07	The System needs to accept and process GID information.
TSI-08	The System needs to translate GID information into MAP messages as defined in SAE J2735.
TSI-09	The System needs to regularly provide wireless transmission of the most recent MAP message to connected vehicles and connected travelers approaching the signalized intersection.
TSI-10	The System needs to store generated MAP messages in a bundled format for subsequent retrieval.

User Support

The mechanisms for access to this System's resources need to be documented to the extent that users can access those resources in a straightforward manner.

Table 8. User Support Needs

Need ID	Need Description
US-01	System Implementers need the Unified Implementation of the Reference Architecture system and interface designs documented so that they can duplicate the Unified Implementation of the Reference Architecture interfaces and systems without access to the original System Implementers.
US-02	System Owners need the Unified Implementation of the Reference Architecture system and interface designs documented so that they can maintain the Unified Implementation of the Reference Architecture interfaces and systems without needing ongoing support from the System Implementers.
US-03	System Operators need the Unified Implementation of the Reference Architecture systems operational interfaces documented so that they may control all Unified Implementation of the Reference Architecture equipment and operations without needing ongoing support from the System Implementers.
US-04	System Users need the Unified Implementation of the Reference Architecture interfaces documented to the extent that they can use the Unified Implementation of the Reference Architecture without needing ongoing support from the System Implementers.

Chapter 3. Concepts for Proposed System

This section will describe the key concepts for the Unified Implementation of the Reference Architecture. Although it will cover the Unified Implementation of the Reference Architecture as a whole, it will primarily focus on the new concepts and features.

Operational Policies and Constraints

The following operational policies/constraints have been identified so far:

1. Privacy with respect to both the identity of users and of data exchanged will be "by design."
2. Electronic communications that need to be made secure (digitally signed and/or encrypted) will do so using a common process based on IEEE 1609.2 defined security mechanisms.
3. Information flows between Unified Implementation of the Reference Architecture objects, especially those that are characterized as a full round trip, will be based on a common message sequence pattern.
4. Information flows between Unified Implementation of the Reference Architecture objects will be digitally signed.
5. Unicast Information flows between Unified Implementation of the Reference Architecture objects will be encrypted.
6. All information flows that are unicast will be based on IPv6.
7. All unicast information flows that are characterized as "best effort" will utilize User Datagram Protocol (UDP).
8. ASN.1 encoding will be used for all data sent from onboard equipment (OBE) or from an RSE.
9. A more vulnerable Unified Implementation of the Reference Architecture object, from a security perspective, will always initiate any data exchange with a less vulnerable Unified Implementation of the Reference Architecture object. For example, vehicles always initiate exchanges with either roadside or center-based objects, and roadside objects always initiate exchanges with center-based objects. If two Unified Implementation of the Reference Architecture objects are considered equally vulnerable, then either may initiate the data exchange.
10. The DSRC 5.9 GHz spectrum will be exercised on all seven radio channels as defined by IEEE 1609.
11. Anyone can drive in the Unified Implementation of the Reference Architecture geographic area, but they must abide by Federal Communications Commission regulation in regards to 5.9 GHz bandwidth use (e.g., no harmful interference).

12. To participate collaboratively with others, participants must sign a memorandum of agreement (MOA). Interested parties are referred to the ITS JPO Affiliated Test Bed site.

Description of the Proposed System

The architecture presented in this section is directly based on the USDOT CVRIA and subsequently tailored to meet the needs and vision of the Unified Implementation of the Reference Architecture. More information on the CVRIA is available on the CVRIA website.

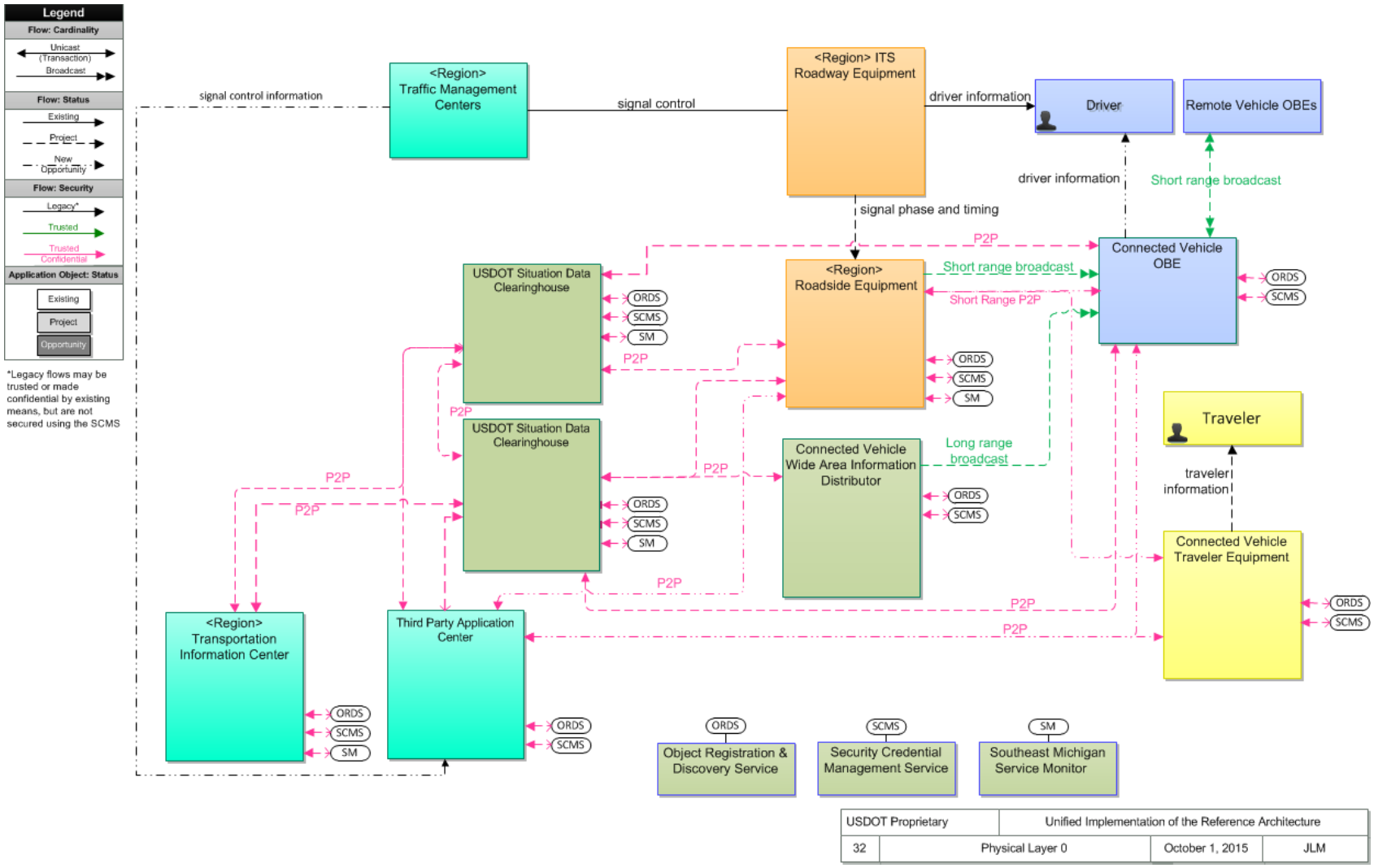
System Architecture

The architecture of the Unified Implementation of the Reference Architecture is illustrated and defined below. Both the physical and enterprise architectural views are presented, along with accompanying tables identifying and describing the architecture objects and the connections between them.

Physical View

The physical view of the Unified Implementation of the Reference Architecture starts with a top-level, called “Layer 0,” drawing depicting all of the physical objects in the project followed by the lower or middle, “Layer 1,” that adds application objects and their interconnects.

Physical – Layer 0
Figure 7 provides a high-level conceptual architecture for the Unified Implementation of the Reference Architecture. The following two tables provide definitions of the objects and physical interconnects.



Source: USDOT

Figure 7. Physical View – Layer 0

Physical – Layer 0 – Physical Objects

Table 9 includes the definitions of all of the physical objects shown in the Layer 0 and Layer 1 Physical View of the Unified Implementation of the Reference Architecture. Many of these objects are identical or related to CVRIA objects, so the relationship is shown.

Table 9. Physical View Layer 0 – Physical Objects

Physical Object	Physical Object Definition	CVRIA Relationship
<Region> ITS Roadway Equipment	"<Region> ITS Roadway Equipment" represents the ITS equipment that is distributed on and along the roadway of or a given Region and which monitors and controls traffic and monitors and manages the roadway itself. This physical object represents all of the other ITS field equipment that interfaces with and supports the <Region> Roadside Equipment. This physical object includes traffic detectors, environmental sensors, traffic signals, highway advisory radios, dynamic message signs, CCTV cameras and video image processing systems, grade crossing warning systems, and ramp metering systems. Lane management systems and barrier systems that control access to transportation infrastructure such as roadways, bridges, and tunnels are also included. This object also provides environmental monitoring including sensors that measure road conditions, surface weather, and vehicle emissions. Work zone systems including work zone surveillance, traffic control, driver warning, and work crew safety systems are also included.	Custom version of CVRIA “ITS Roadway Equipment”
<Region> Roadside Equipment	"<Region> Roadside Equipment" represents the connected vehicle roadside devices that are used to send messages to, and receive messages from, nearby vehicles using DSRC. Communications with adjacent <Region> ITS Roadway Equipment (see the separate object) and back-office centers that monitor and control the RSE are also supported. This device operates from a fixed position and may be permanently deployed or a portable device that is located temporarily in the vicinity of a traffic incident, road construction, or a special event. It includes a processor, data storage, and communications capabilities that support secure communications with passing vehicles, other RSE, and centers that provide back-office support.	Custom version of the CVRIA “Roadside Equipment”
<Region> Traffic Management Center	The "<Region> Traffic Management Center" monitors and controls traffic and the road network. It represents centers that manage a broad range of transportation facilities including freeway systems, rural and suburban highway systems, and urban and suburban traffic control systems. It communicates with ITS RSE to monitor and manage traffic flow and monitor the condition of the roadway, surrounding environmental conditions, and field equipment status. It manages traffic and transportation resources to support allied agencies in responding to, and recovering from, incidents ranging from minor traffic incidents through major disasters.	CVRIA Object
<Region> Transportation Information Center	The "<Region> Transportation Information Center" monitors and controls traffic and the road network. It represents centers that manage a broad range of transportation facilities including freeway systems, rural and suburban highway systems, and urban and suburban traffic control systems. It communicates with <Region> ITS Roadway Equipment and <Region> Roadside Equipment to monitor and manage traffic flow and monitor the condition of the roadway, surrounding environmental conditions, and field equipment status. It manages traffic and transportation resources to	CVRIA Object

Physical Object	Physical Object Definition	CVRIA Relationship
	support allied agencies in responding to, and recovering from, incidents ranging from minor traffic incidents through major disasters.	
Connected Vehicle OBE	The “Connected Vehicle OBE” represents onboard devices that provide the vehicle-based processing, storage, and communications functions necessary to support connected vehicle operations. It is a custom version of the CVRIA “Vehicle OBE” object. The radio(s) supporting V2V and V2I communications are a key component of the Vehicle OBE. This communication platform for the vehicle is supported by processing and data storage capability in the OBE that provides the basic communications functions and higher level connected vehicle applications. The Connected Vehicle OBE interfaces with other onboard systems through a vehicle bus (e.g., CAN). Represented in CVRIA as the Vehicle Platform, this interface provides access to onboard sensors, monitoring and control systems, and information systems that support connected vehicle applications. In addition to the vehicle bus interface, the Connected Vehicle OBE also provides an interface to a location data source. Finally, a driver interface is included that supports visual, audio, and haptic interaction with the driver. In CVRIA, the Vehicle OBE includes the functions and interfaces that support connected vehicle applications for passenger cars and trucks. Many of these applications (e.g., V2V safety applications) apply to all vehicle types including personal automobiles, commercial vehicles, emergency vehicles, transit vehicles, and maintenance vehicles. In CVRIA, the Vehicle OBE is used to model the common interfaces and functions that apply to all of these vehicle types.	Custom version of CVRIA “Vehicle OBE”
Connected Vehicle Traveler Equipment	The "Connected Vehicle Traveler Equipment” is a customized version of the CVRIA “Personal Information Device" physical object. Among other things, it provides the capability for travelers and vehicles to receive formatted traveler information from the “USDOT Situation Data Warehouse” wherever they are. Capabilities include traveler information, trip planning, and route guidance. It provides travelers with the capability to receive route planning from the infrastructure at home, at work, or en route using personal devices that may be linked with connected vehicle onboard equipment.	Custom version of CVRIA “Personal Information Device”
Connected Vehicle Wide Area Information Distributor	“Connected Vehicle Wide Area Information Distributor" (WAID) represents the connected vehicle center-based systems and satellite equipment that is used to send messages to equipped vehicles using proprietary satellite or FM radio protocols.	None Identified
Driver	The "Driver" represents the person that operates a licensed vehicle on the roadway. Included are operators of private, transit, commercial, and emergency vehicles where the interactions are not particular to the type of vehicle (i.e., interactions supporting vehicle safety applications). Thus, the Driver originates driver requests and receives driver information that reflects the interactions that might be useful to all drivers, regardless of vehicle classification. This object also supports interactions for mobility applications that are primarily intended for drivers of private passenger vehicles. Information and interactions that are unique to drivers of a specific vehicle type (e.g., fleet interactions with transit, commercial, or emergency vehicle drivers) are covered by separate objects.	CVRIA Object

Physical Object	Physical Object Definition	CVRIA Relationship
Remote Vehicle OBEs	"Remote Vehicle OBEs" represent other connected vehicles that are communicating with the host vehicle. In CVRIA, this object provides a source and destination for information transfers between connected vehicles. The host vehicle OBE, represented by the Vehicle OBE physical object, sends information to and receives information from the Remote Vehicle OBEs to model all connected vehicle V2V communications in CVRIA.	CVRIA Object
Third Party Application Center	"Third Party Application Center" represents the private infrastructure used to develop, maintain, and/or host third-party applications.	This is a unique SE MI Object
Traveler	The "Traveler" represents any individual who uses transportation services provided by the Unified Implementation of the Reference Architecture. The interfaces to the traveler provide general pre-trip and en-route information supporting trip planning, personal guidance, and requests for assistance in an emergency that are relevant to all transportation system users. It also represents users of a public transportation system and addresses interfaces these users have within a transit vehicle or at transit facilities such as roadside stops and transit centers.	CVRIA Object
USDOT Object Registration and Discovery Service	"USDOT Object Registration and Discovery Service" represents one or more center-based applications that provide registration and discovery services necessary to allow Unified Implementation of the Reference Architecture objects to locate other Unified Implementation of the Reference Architecture objects operating within the Unified Implementation of the Reference Architecture. These services are not transportation applications or transportation services, but facilitative actions that enable other applications to provide transportation services.	This is a unique SE MI Object
USDOT Security Credential Management Service	"USDOT Security Credential Management Service" represents one or more center-based applications that provide security credentialing services necessary to other applications and/or devices operating within the Unified Implementation of the Reference Architecture. These services are not transportation applications or transportation services, but facilitative actions that enable other applications to provide transportation services.	This is a unique SE MI Object
USDOT Service Monitor	"USDOT Service Monitor" represents one or more center-based applications that provide monitoring, management and control services necessary to other applications and/or devices operating within the Unified Implementation of the Reference Architecture. These services are not transportation applications or transportation services, but facilitative actions that enable other applications to provide transportation services.	This is a unique SE MI Object
USDOT Situation Data Clearinghouse	The "USDOT Situation Data Clearinghouse" provides data collection and repacking functions, but only for data that is relevant in the immediate future. Data deposited at the USDOT Situation Data Warehouse is immediately delivered ("pushed") to all registered and available delivery locations.	Currently unique
USDOT Situation Data Warehouse	The "USDOT Situation Data Warehouse" is a Transportation Information Center that provides data collection, fusing, and repacking functions. Examples of data handled by this warehouse are speed limits, traffic signal locations, and road restrictions. Data deposited at the warehouse is retained for a variable amount of time (based on the time context of the data) and is available for ad-hoc ("pull") queries.	Currently unique

Physical – Layer 0 – Physical Interconnects

Table 11 includes the definitions of all of the physical and application interconnects shown in the Layer 0 and Layer 1 Unified Implementation of the Reference Architecture's Architecture (above). Each interconnect description will be accompanied by the source, destination, and its defining characteristics. At Layer 2, that will be defined later, the information flows have the same characteristics that are described in the table.

Table 10. Physical and Application Interconnect / Information Flow Characteristics

Interconnect / Flow Characteristic	Characteristic Values	Characteristic Value Description
Spatial Context	Adjacent	0-300 meters
	Local	300 meters - 3 kilometers
	Regional	CVRIA: 3 kilometers – 30 Kilometers Project: Southeast Michigan Project Geographical Area
	National	CVRIA: Continental U.S. Project: Southeast Michigan Project Geographical Area
Time Context	Now	Less than 1 Second
	Recent	1 second – 30 minutes
	Historical	30 minutes – 1 month
	Static	Greater than 1 month
Acknowledgement	False	Information flow receiver acknowledgement is required
	True	Information flow receiver acknowledgement is not required
Encryption	True	Information flow encryption is required
	False	Information flow encryption is not required
Authenticability	True	Information flow signature is required
	False	Information flow signature is not required
Cardinality	Broadcast	Information is sent to all potential recipients that are within range
	Multicast	Information is sent to multiple specific recipients
	Unicast	Information is sent to a single specific recipient

Table 11. Architecture Layer 0 – Physical Interconnects

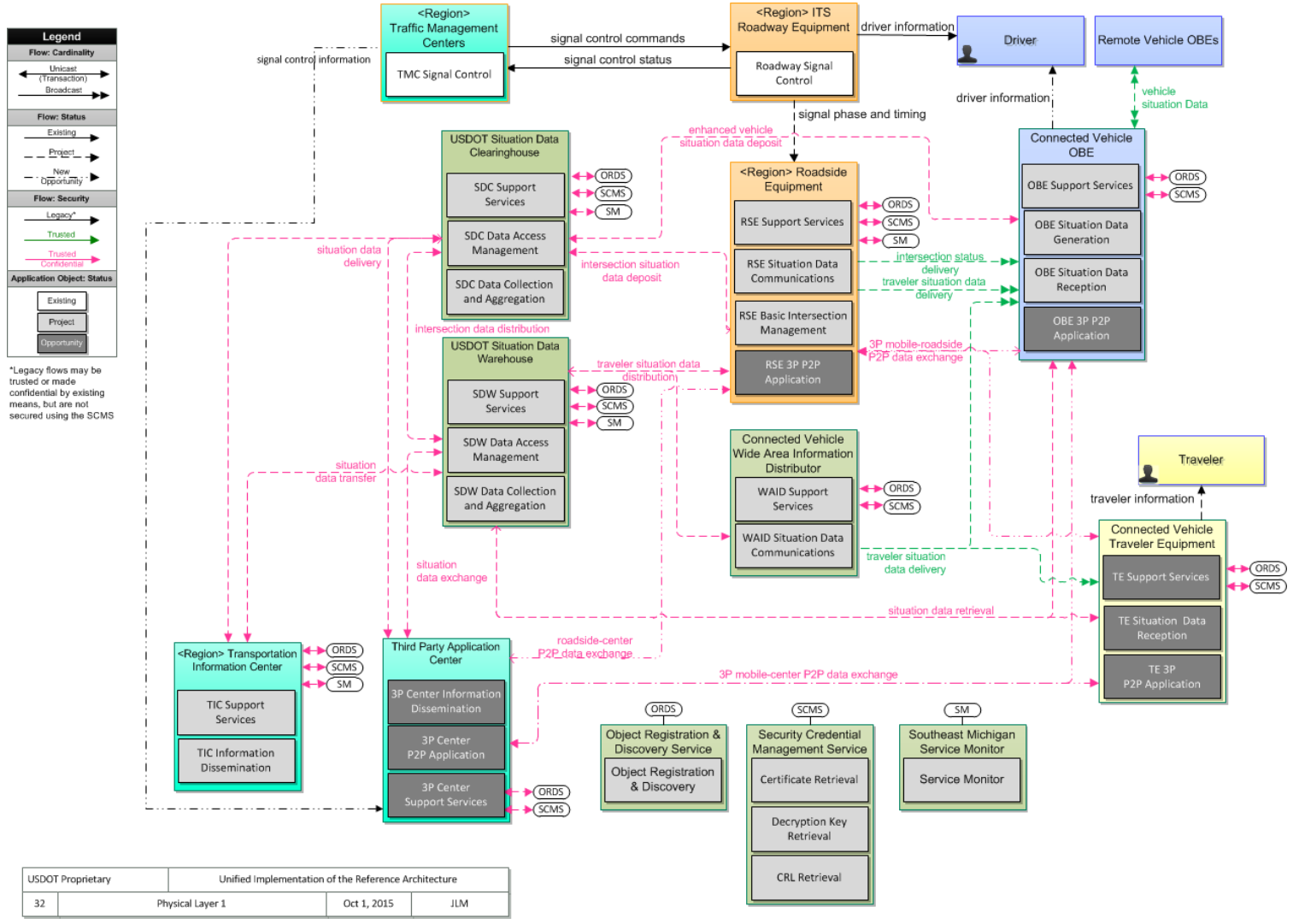
L0 Information Flow	Definition	Object 1	Object 2	Space Context	Time Context	Acknowledgement	Authenticability	Encryption
Driver Information	Legacy flow. Regulatory, warning, and guidance information provided to the driver while en-route to support safe and efficient vehicle operation.	ITS Roadway Equipment	Driver	R	H,S	No	No	No
		Connected Vehicle OBE	Driver	R	H,S	No	No	No
Long Range Broadcast	A flow where the initiator sends information on a predefined communications channel using a protocol that enables others who know how to listen to that channel to receive the information. One-to-many communication, with no dialog.	Wide Area Information Distributor	Connected Vehicle OBE	R,N	R,H,S	No	Yes	No
			Connected Vehicle Traveler Equipment	R,N	R,H,S	No	Yes	No
Peer to Peer (P2P)	A P2P flow, where a dialog between the entities involved includes some data exchange. A P2P flow requires the initiator to know how to communicate with the recipient.	Any Unified Implementation of the Reference Architecture physical object	Any other Unified Implementation of the Reference Architecture physical object	---	---	Yes	Yes	Yes
Short Range Broadcast	A flow where the initiator sends information on a predefined communications channel using a protocol that enables others who know how to listen to that channel to receive the information. One-to-many communication, with no dialog. Typically, this flow type is limited to short-range (1000m or less) communications media.	Connected Vehicle OBE	<Region> Roadside Equipment	A,L	N	No	Yes	No
		Connected Vehicle OBE	Remote Vehicle OBEs	A,L	N	No	Yes	No
		<Region> Roadside Equipment	Connected Vehicle Traveler Equipment	A,L	N	No	Yes	No

L0 Information Flow	Definition	Object 1	Object 2	Space Context	Time Context	Acknowledgement	Authenticability	Encryption
Short Range P2P	A P2P flow that is limited to short-range (1000m or less) communications media.	Connected Vehicle OBE	<Region> Roadside Equipment	A,L	N	Yes	Yes	Yes
		<Region> Roadside Equipment	Connected Vehicle OBE	A,L	N	Yes	Yes	Yes
		<Region> Roadside Equipment	Connected Vehicle Traveler Equipment	A	N	Yes	Yes	Yes
Support P2P	A P2P flow, where a dialog between the entities involved includes some data exchange. A P2P flow requires the initiator to know how to communicate with the recipient.	Any Unified Implementation of the Reference Architecture physical object	Any Unified Implementation of the Reference Architecture Support Service Object	---	---	Yes	Yes	Yes
Signal Control	Legacy flow. Operational and status data of traffic signal control equipment including operating condition and current indications. Control of traffic signal controllers or field masters including clock synchronization.	<Region> Traffic Management Centers	<Region> ITS Roadway Equipment	---	---	---	---	---
Signal Control Information	Adaptation of legacy flows containing the operational and status data of traffic signal control equipment including operating condition and current indications.	<Region> Traffic Management Centers	Third Party Application Center	A	R	No	Yes	No
Signal Phase and Timing (SPaT)	Data describing the SPaT information for all lanes at a signalized intersection. This flow identifies active lanes and lanes that are being stopped and specifies the length of time that the current state will persist for each lane. It also identifies signal priority and	<Region> ITS Roadway Equipment	<Region> Roadside Equipment	---	---	---	---	---

L0 Information Flow	Definition	Object 1	Object 2	Space Context	Time Context	Acknowledgement	Authenticability	Encryption
	preemption status and pedestrian crossing status information where applicable.							
Traveler Information	Regulatory, warning, and guidance information provided to the traveler while en-route to support safe and efficient travel operation.	Connected Vehicle Traveler Equipment	Traveler	N, R, L, A	S, H, R, N	No	No	No

Physical – Layer 1

Figure 8 provides a mid-level conceptual architecture for the Unified Implementation of the Reference Architecture. It is also based on the CVRIA described on the CVRIA website.



Source: USDOT

Figure 8. Physical View – Layer 1

Physical – Layer 1 – Application Objects

Table 12 provides definitions of all of the Layer 1 Application Objects shown in the Layer 1 Physical Architecture (above), which includes the Layer 0 Physical Objects defined in Table 9. Application objects represent collections of functionality within a physical object to deliver a set of requirements which could be implemented as software or hardware components. Many of these application objects are identical or related to CVRIA objects, so the relationship is shown.

Table 12. Architecture Layer 1 – Application Objects

Application Object	Definition	CVRIA Relationship
Certificate Retrieval	"Certificate Retrieval" manages the distribution (both initial provisioning and refresh) of digital credentials used by connected vehicle objects to authenticate and preserve the integrity of information they exchange.	Under development in CVRIA
CRL Retrieval	"CRL Retrieval" manages the creation and distribution of credential revocation lists for previously distributed digital credentials used by connected vehicle objects to authenticate and preserve the integrity of information they exchange.	Under development in CVRIA
Decryption Key Retrieval	"Decryption Key Retrieval" manages the distribution of decryption keys for previously retrieved batches of digital credentials used by connected vehicle objects to authenticate and preserve the integrity of information they exchange.	Under development in CVRIA
OBE Situation Data Generation	"OBE Situation Data Generation" creates vehicle situation data messages and shares those messages with other entities in the vehicle's proximity, and also with the relevant situation data clearinghouse. This functionality is included in the CVRIA object "Vehicle Basic V2V Safety." The CVRIA object also includes safety application functionality (including driver-notification). However, depending on the types of data included in the enhanced situation data message, this might also include some of the functionality of the "Vehicle Enhanced Data Collection" CVRIA Object.	Subset of the CVRIA object: "Vehicle Basic V2V Safety"
OBE Situation Data Reception	"OBE Situation Data Reception" receives advisories, vehicle signage data, and other driver information and presents this information to the driver using in-vehicle equipment. Information presented may include fixed sign information, traffic control device status (e.g., signal phase and timing data), advisory and detour information, warnings of adverse road and weather conditions, travel times, and other driver information.	CVRIA Object
OBE Support Services	"OBE Support Services" provide for the exchange of information with two (ORDS, SCMS) of the three Unified Implementation of the Reference Architecture Support services.	Currently unique
OBE Third Party P2P Application	"OBE Third Party P2P Application" is a high-level generic application that provides some service relevant to the vehicle or its occupants. It is typically bidirectional communications between two entities. It is representative of many other CVRIA Application Objects and has a hierarchical relationship to many CVRIA Vehicle-based Application Objects.	Currently unique

Application Object	Definition	CVRIA Relationship
Object Registration and Discovery	The “Object Registration and Discovery” is the first point of contact for new devices that wish to operate within the Unified Implementation of the Reference Architecture. This service provides mechanisms for devices to register their existence, contact information (which could be an IP address, for example), types of information services and data they provide, mechanisms they use to provide data and information services, and over what time and spatial context those services and data are relevant. Subsequent to registration, devices may query this service to discover data provision and service information about other participants, enabling devices to learn about one another and interoperate in a relatively automated fashion.	Currently unique
Roadway Signal Control	"Roadway Signal Control" includes the field elements that monitor and control signalized intersections. It includes the traffic signal controllers, signal heads, detectors, and other ancillary equipment that supports traffic signal control. It also includes field masters and equipment that supports communications with a central monitoring and/or control system, as applicable. The communications link supports upload and download of signal timings and other parameters and reporting of current intersection status. It represents the field equipment used in all levels of traffic signal control from basic actuated systems that operate on fixed timing plans through adaptive systems. It also supports all signalized intersection configurations, including those that accommodate pedestrians.	CVRIA Object
RSE Basic Intersection Management	"RSE Basic Intersection Management" uses short-range communications and interfaces to local field ITS devices to support connected vehicle applications at signalized intersections. It communicates with approaching vehicles and ITS infrastructure (e.g., the traffic signal controller) to provide intersection status (signal phase and timing) information both to vehicles and interested centers.	Streamlined version of the CVRIA Object “RSE Intersection Management”
RSE Situation Data Communications	"RSE Situation Data Communications" includes field elements that distribute information to vehicles for in-vehicle display. The information may be provided by a center (e.g., variable information on traffic and road conditions in the vicinity of the field equipment) or it may be determined and output locally (e.g., static sign information, ramp metering signals). This includes the interface to the center or field equipment that controls the information distribution and the short-range communications equipment that provides information to passing vehicles.	CVRIA Object
RSE Support Services	“RSE Support Services” provides for the exchange of information with the three Unified Implementation of the Reference Architecture Support services.	Currently unique
RSE Third Party P2P Application	"RSE Third Party P2P Application" is a high-level generic application that provides some roadside service relevant to nearby vehicles or their occupants. It is typically a bidirectional communications between two entities. It is representative of many other CVRIA Application Objects and has a hierarchical relationship to many CVRIA Vehicle-based Application Objects.	Currently unique

Application Object	Definition	CVRIA Relationship
SDC Data Access Management	"SDC Data Access Management" provides management and control of data collection and distribution and provision of data to other transportation entities. It allows for the creation of data distribution profiles, such as subscriptions and pipes, and the assignment of permissions and rights to provide and access this data.	Currently unique
SDC Data Collection and Aggregation	"SDC Data Collection and Aggregation" provides for the collection of transportation-related information and the short-term storage and/organization of this data, including categorization, aggregation and sampling.	Currently unique
SDC Support Services	“SDC Support Services” provide for the exchange of information with the three Unified Implementation of the Reference Architecture Support services.	Currently unique
TIC Information Dissemination	"TIC Information Dissemination" disseminates traffic and road conditions, closure and detour information, incident information, driver advisories, and other traffic-related data to other centers, the media, and driver information systems. It monitors and controls driver information system field equipment including dynamic message signs and highway advisory radio, managing dissemination of driver information through these systems. It may also register for and accept deliveries of enhanced vehicle situation data from the USDOT Situation Data Warehouse.	CVRIA Object
TIC Support Services	“TIC Support Services” provide for the exchange of information with the three Unified Implementation of the Reference Architecture Support services.	Currently unique
SDW Data Access Management	"SDW Data Access Management" provides management and control of data collection and distribution and the provision of data to other transportation entities. It allows for the creation of data distribution profiles, such as subscriptions and pipes, and the assignment of permissions and rights to provide and access this data.	Currently unique
SDW Data Collection and Aggregation	"SDW Data Collection and Aggregation" provides for the collection of transportation-related information and the short-term storage and/organization of this data, including categorization, aggregation and sampling.	Currently unique
SDW Support Services	“SDW Support Services’ provide for the exchange of information with the three Unified Implementation of the Reference Architecture Support services.	Currently unique
Service Monitor	“Service Monitor” provides for the monitoring, management, and control of many of the other Unified Implementation of the Reference Architecture objects, both individually and collectively.	Currently unique
TE Situation Data Reception	"TE Situation Data Reception" receives advisories, vehicle signage data, and other driver information and presents this information to the driver using in-vehicle equipment. Information presented may include fixed sign information, traffic control device status (e.g., SPaT data), advisory and detour information, warnings of adverse road and weather conditions, travel times, and other driver information.	CVRIA Object

Application Object	Definition	CVRIA Relationship
TE Support Services	“TE Support Services” provide for the exchange of information with two (ORDS, SCMS) of the three Unified Implementation of the Reference Architecture Support services.	Currently unique
TE Third Party P2P Application	"TE Third Party P2P Application" is a high-level generic application that provides some service relevant to the vehicle or its occupants. It is typically bidirectional communications between two entities. It is representative of many other CVRIA Application Objects and has a hierarchical relationship to many CVRIA Vehicle-based Application Objects.	Currently unique
Third Party Center P2P Application	"Third Party Center P2P Application" is a high-level generic application that provides some center-based service relevant to vehicles or their occupants. It is typically bidirectional communications between two entities. It is representative of many other CVRIA Application Objects and has a hierarchical relationship to many CVRIA Vehicle-based Application Objects.	Currently unique
Third Party Center Support Services	“Third Party Center Support Services” provide for the exchange of information with the three Unified Implementation of the Reference Architecture Support services.	Currently unique
Third Party Information Dissemination	"Third Party Information Dissemination" disseminates traffic and road conditions, closure and detour information, incident information, driver advisories, and other traffic-related data to other centers, the media, and driver information systems. It monitors and controls driver information system field equipment including dynamic message signs and highway advisory radio, managing dissemination of driver information through these systems. It may also register for and accept deliveries of enhanced vehicle situation data from the USDOT Situation Data Warehouse.	Currently unique
Traffic Management Center (TMC) Signal Control	"TMC Signal Control" provides the capability for traffic managers to monitor and manage the traffic flow at signalized intersections. This capability includes analyzing and reducing the collected data from traffic surveillance equipment and developing and implementing control plans for signalized intersections. Control plans may be developed and implemented that coordinate signals at many intersections under the domain of a single traffic management subsystem and are responsive to traffic conditions and adapt to support incidents, preemption and priority requests, pedestrian crossing calls, etc.	CVRIA Object
WAID Situation Data Communications	"WAID Situation Data Communications" includes field elements that distribute information to vehicles for in-vehicle display. Dynamic information (e.g., variable information on traffic and road conditions in the vicinity of the mobile equipment) and static information (e.g., static sign information) will be supplied by a center. This includes the interface to the center or field equipment that controls the information distribution and the satellite communications equipment that provides information to passing vehicles.	Currently unique
WAID Support Services	“WAID Support Services” provides for the exchange of information with two (ORDS, SCMS) of the three Unified Implementation of the Reference Architecture Support services.	Currently unique

Physical – Layer 1 – Application Interconnects

Table 13 identifies and describes the application interconnects presented as arrows connecting the objects in the Layer 1 Physical Architecture illustrated in Figure 8 above. Each description will be accompanied by the source, destination, and defining characteristics. The definitions of the five characteristics (right most columns) of the Application Interconnects are defined in Table 10, above.

Table 13. Architecture Layer 1 – Application Interconnects

L1 Application Interconnect	Object 1	Object 2	Definition	Space Context	Time Context	Acknowledgement	Authenticability	Encryption
Driver Information	Driver	ITS Roadway Equipment	Legacy flow. Regulatory, warning, and guidance information provided to the driver while en route to support safe and efficient vehicle operation.	A,L,R	N,C,H	No	No	No
Driver Information	Driver	OBE	Legacy flow. Regulatory, warning, and guidance information provided to the driver while en route to support safe and efficient vehicle operation.	A,L,R	N,R,H	No	No	No
Signal Phase and Timing	ITS Roadway Equipment	Roadside Equipment	Current signal phase and timing information for all lanes at a signalized intersection. This flow identifies active lanes and lanes that are being stopped and specifies the length of time that the current state will persist for each lane.	---	---	---	---	---
Signal Control Status	ITS Roadway Equipment	Traffic Management Centers	Legacy flow. Operational and status data of traffic signal control equipment including operating condition and current indications.	---	---	---	---	---
Signal Control Commands	ITS Roadway Equipment	Traffic Management Centers	Legacy flow. Control of traffic signal controllers or field masters including clock synchronization.	---	---	---	---	---
Vehicle Situation Data	OBE	Remote Vehicle OBEs	Data describing the operational state at a specified location and specified time of the vehicle reporting the data. This may include vehicle position, speed, heading, acceleration and vehicle path history.	A	N	No	Yes	No

L1 Application Interconnect	Object 1	Object 2	Definition	Space Context	Time Context	Acknowledgement	Authenticability	Encryption
Traveler Situation Data Delivery	OBE	Roadside Equipment	Static and dynamic advisory information that is relevant to travelers in a small, well-defined area, including signage, information regarding incidents, unusual traffic conditions, transit issues, etc.	L	R	No	Yes	No
Third Party (3P) Mobile-Roadside Peer-to-Peer (P2P) Data Exchange	OBE	Roadside Equipment	Peer-to-peer information flow carrying data relevant to an [undefined] third party application operating on a mobile device and an [undefined] third party application operating on the roadside	---	---	---	Yes	Yes
Intersection Status Delivery	OBE	Roadside Equipment	Immediately relevant data describing the signal phase and timing information for all lanes at a signalized intersection near the source of the flow. This flow identifies active lanes and lanes that are being stopped and specifies the length of time that the current state will persist for each lane. This data also includes the latest version of the Intersection map containing detailed roadway geometry.	A	N	No	Yes	No
Enhanced Vehicle Situation Data Deposit	OBE	USDOT Situation Data Clearinghouse	This is Vehicle Situation Data plus additional elements including environmental and emissions-related situation data, relevant over a recent (approximately 10 to 30 minutes) period and the area over which the vehicle traveled in that time.	L	R	No	Yes	Yes
Traveler Situation Data Retrieval	OBE	USDOT Situation Data Warehouse	Static advisory information that is relevant to travelers over the area they have requested. This typically includes, but may not be limited to, electronic versions of metal signs.	R,N	H	No	Yes	Yes

L1 Application Interconnect	Object 1	Object 2	Definition	Space Context	Time Context	Acknowledgement	Authenticability	Encryption
Third Party (3P) Mobile-Center Peer-to-Peer (P2P) Data Exchange	OBE	Third Party Application Center	Peer-to-peer information flow carrying data relevant to an [undefined] third party application operating on a mobile device and an [undefined] third party application operating within the infrastructure.	---	---	---	Yes	Yes
RC Traveler Situation Data Delivery	OBE	Wide Area Information Distributor	Static and dynamic advisory information that is relevant to travelers within roughly 30 minutes over a specific region. This includes signage, information regarding incidents, unusual traffic conditions, transit issues, etc.	R,N	R	No	Yes	Yes
Intersection Situation Data Deposit	Roadside Equipment	USDOT Situation Data Clearinghouse	Bundles of data describing the recent signal phase and timing information for all lanes at a signalized intersection near the source of the flow. This flow identifies active lanes and lanes that are being stopped and specifies the length of time that the current state would persist for each lane. This data also includes the latest version of the Intersection map containing detailed roadway geometry.	A	R	Yes	Yes	Yes
Traveler Situation Data Distribution	Roadside Equipment	USDOT Situation Data Warehouse	Static and dynamic advisory information that is relevant to travelers in a small, well-defined area, including signage, information regarding incidents, unusual traffic conditions, transit issues, etc. This data is retrieved by the RSE from the USDOT Situation Data Warehouse	L	R	Yes	Yes	Yes
Third Party (3P) Roadside-Center Peer-to-Peer (P2P) Data Exchange	Roadside Equipment	Third Party Application Center	Peer-to-peer information flow carrying data relevant to “paired” applications operating respectively at the roadside and within the infrastructure.	---	---	---	Yes	Yes

L1 Application Interconnect	Object 1	Object 2	Definition	Space Context	Time Context	Acknowledgement	Authenticability	Encryption
Third Party (3P) Mobile-Roadside Peer-to-Peer (P2P) Data Exchange	<Region> Roadside Equipment	Traveler Equipment	Peer-to-peer information flow carrying data relevant to "paired" applications operating respectively at the roadside and on the mobile device.	---	---	---	Yes	Yes
Situation Data Delivery	USDOT Situation Data Clearinghouse	<Region> Transportation Information Center	The delivery of situation data that can include • Bundles of Enhanced Vehicle Situation Data and/or Intersection Situation Data that match the Transportation Information Center (TIC) subscription criteria and are then delivered by the Clearinghouse. These bundles contain information from the BSM plus additional elements including environmental and emissions-related situation data. • Bundles of Intersection Situation Data that describes the recent SPaT information for all lanes at a signalized intersection. The bundled data identifies active lanes and lanes that are being stopped and specifies the length of time that the current state will persist for each lane. It also identifies signal priority and preemption status and pedestrian crossing status information where applicable. This data also includes the latest version of the Intersection map containing detailed roadway geometry	L,R	R,H,S	No	Yes	Yes
Intersection Situation Data Distribution	USDOT Situation Data Clearinghouse	USDOT Situation Data Warehouse	The delivery of all intersection situation data bundles received by the USDOT Situation Data Clearinghouse. The bundled data identifies active lanes and lanes that are being stopped and specifies the length of time that the current state will persist for each lane. It also identifies signal priority and preemption status and pedestrian crossing status information where applicable. This data also includes the latest version of the Intersection map containing detailed roadway geometry.	L	R	No	Yes	Yes

L1 Application Interconnect	Object 1	Object 2	Definition	Space Context	Time Context	Acknowledgement	Authenticability	Encryption
Situation Data Delivery	USDOT Situation Data Clearinghouse	Third Party Application Center	The delivery of situation data that match the TPAC's subscription criteria and are then delivered by the USDOT Situation Data Clearinghouse: • Bundles of Enhanced Vehicle Situation Data and/or Intersection Situation Data. These bundles contain information from the BSM plus additional elements including environmental and emissions-related situation data. • Bundles of Intersection Situation Data that describes the recent SPaT information for all lanes at a signalized intersection. The bundled data identifies active lanes and lanes that are being stopped and specifies the length of time that the current state will persist for each lane. It also identifies signal priority and preemption status and pedestrian crossing status information where applicable. This data also includes the latest version of the Intersection map containing detailed roadway geometry.	L,R	R,H, S	No	Yes	Yes
Situation Data Exchange	<Region> Transportation Information Center (TIC)	USDOT Situation Data Warehouse	The delivery of situation data that match the <Region> TIC's subscription criteria and are then delivered by the Clearinghouse: • Bundles of Enhanced Vehicle Situation Data and/or Intersection Situation Data. These bundles contain information from the BSM plus additional elements including environmental and emissions-related situation data. • Bundles of Intersection Situation Data that describe the recent SPaT information for all lanes at a signalized intersection. The bundled data identifies active lanes and lanes that are being stopped and specifies the length of time that the current state will persist for each lane. It also identifies signal priority and preemption status and pedestrian crossing status information where applicable.	L,R	R,H,S	Yes	Yes	Yes

L1 Application Interconnect	Object 1	Object 2	Definition	Space Context	Time Context	Acknowledgement	Authenticability	Encryption
			This data also includes the latest version of the Intersection map containing detailed roadway geometry. • The <Region> TIC depositing Intersection Situation Data bundles that have been generated or derived from intersections that do not have RSE. The bundled data describes the SPaT information for all lanes at a signalized intersection. The bundled data identifies active lanes and lanes that are being stopped and specifies the length of time that the current state will persist for each lane. It also identifies signal priority and preemption status and pedestrian crossing status information where applicable. • The <Region> TIC depositing static and/or dynamic advisory information that is relevant to travelers in a small, well-defined area, including signage, information regarding incidents, unusual traffic conditions, transit issues, etc. This would be accompanied by dispatch instructions.					

L1 Application Interconnect	Object 1	Object 2	Definition	Space Context	Time Context	Acknowledgement	Authenticability	Encryption
Situation Data Exchange	USDOT Situation Data Warehouse	Third Party Application Center (TPAC)	The exchange of situation data that can include: • The TPAC retrieving specified bundles of Enhanced Vehicle Situation Data and/or Intersection Situation Data from the Warehouse. • The TPAC depositing Intersection Situation Data bundles that have been generated or derived from intersections that do not have RSE. The bundled data identifies active lanes and lanes that are being stopped and specifies the length of time that the current state will persist for each lane. It also identifies signal priority and preemption status and pedestrian crossing status information where applicable. • The TPAC depositing static and/or dynamic advisory information that is relevant to travelers in a small, well-defined area, including signage, information regarding incidents, unusual traffic conditions, transit issues, etc. This would be accompanied by dispatch instructions.	L,R,N	R,H,S	Yes	Yes	Yes
Situation Data Retrieval	USDOT Situation Data Warehouse	Traveler Equipment	The retrieval of Situation Data from the Warehouse: • Static advisory information that is relevant to travelers over the area they have requested. This typically includes, but may not be limited to, electronic versions of metal signs. • Bundled data describing the SPaT information for all lanes at a signalized intersection. This flow identifies active lanes and lanes that are being stopped and specifies the length of time that the current state will persist for each lane. It also identifies signal priority and preemption status and pedestrian crossing status information where applicable.	L,R	R,H,S	No	Yes	Yes

L1 Application Interconnect	Object 1	Object 2	Definition	Space Context	Time Context	Acknowledgement	Authenticability	Encryption
Traveler Situation Data Distribution	USDOT Situation Data Warehouse	Wide Area Information Distributor	The retrieval of Traveler Situation Data from the USDOT Situation Data Warehouse for subsequent redistribution. This is static advisory information that is relevant to travelers over the area they have requested. This typically includes, but may not be limited to, electronic versions of metal signs.	R,N	R,H,S	No	Yes	Yes
P2P Support Data	Support Services: • ORDS • SCMS • SM	All Unified Implementation of the Reference Architecture Objects	A P2P flow, where a dialog between the entities involved includes some data exchange that is relevant to a support application.	---	---	Yes	Yes	Yes
Signal Control Information	Third Party Application Center (TPAC)	Traffic Management Centers	Adaptation of legacy flows containing the operational and status data of traffic signal control equipment including operating condition and current indications. This signal control information may be utilized by the TPAC to generate or derive Intersection Situation Data.	A	R	No	Yes	No
Third Party (3P) Mobile-Center Peer-to-Peer (P2P) Data Exchange	Third Party Application Center	Traveler Equipment	P2P information flow carrying data relevant to an [undefined] third-party application operating on a mobile device and an [undefined] third-party application operating within the infrastructure.	---	---	---	Yes	Yes
Traveler Information	Traveler	Traveler Equipment	Legacy flow representing the distribution of traveler information to end users. Flow control is not explicitly shown; however, this flow supports general broadcast, interactive request/response, and publish/subscribe delivery of traveler information.	A,L,R	N,R,H,S	No	No	No

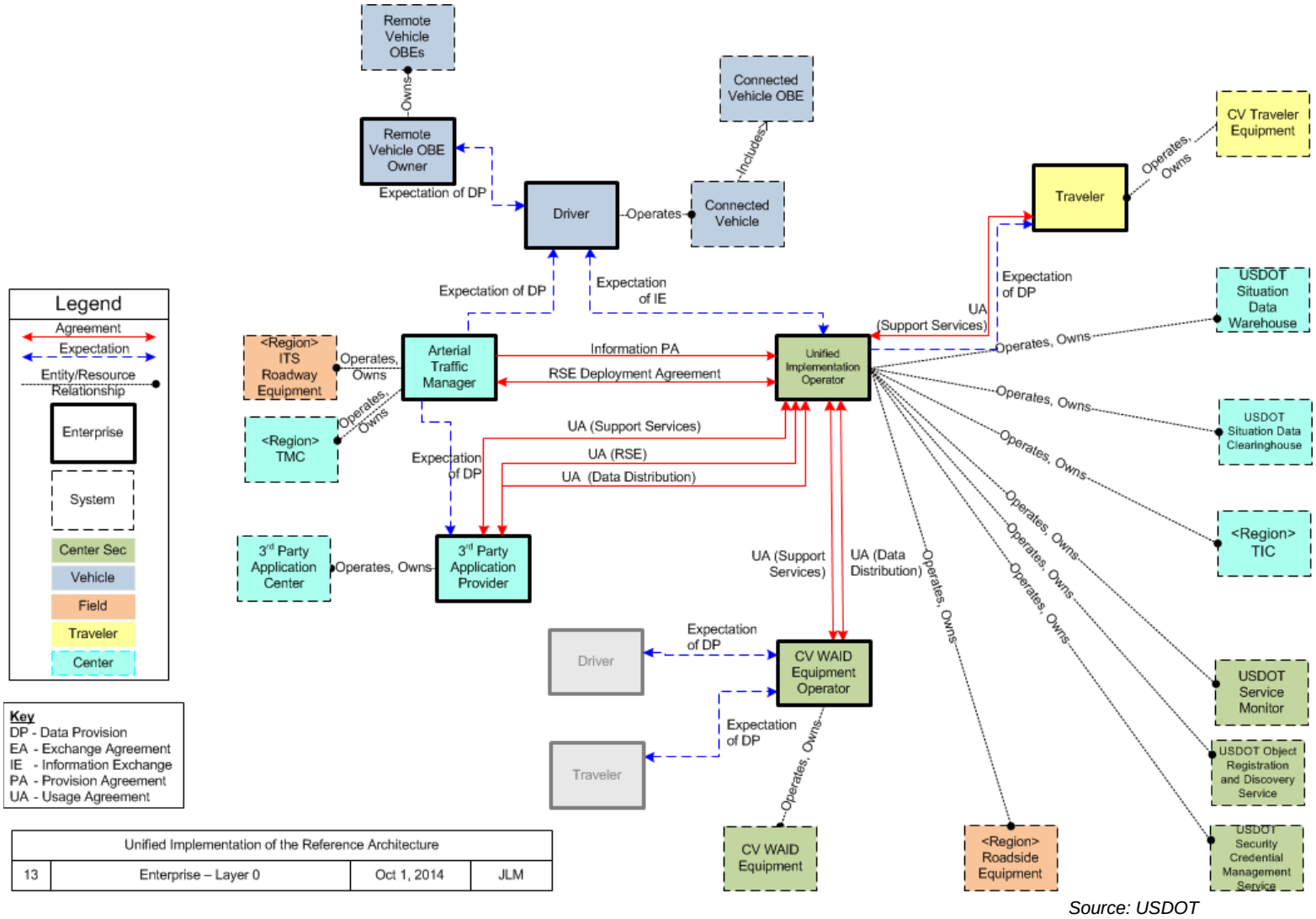
L1 Application Interconnect	Object 1	Object 2	Definition	Space Context	Time Context	Acknowledgement	Authenticability	Encryption
Traveler Situation Data Delivery	Traveler Equipment	Wide Area Information Distributor	The distribution of traveler situation data to the Traveler Equipment. This is static advisory information that is relevant to travelers over the area they have requested. This typically includes, but may not be limited to, electronic versions of metal signs.	R	R	No	Yes	Yes

Enterprise View

The Enterprise view describes the relationships between enterprises or stakeholders (organizations, agencies, users, etc.) and the roles those enterprises play within the Unified Implementation of the Reference Architecture as well as their relationships with one another.

Enterprise – Layer 0

The following top-level drawing reflects the Layer 0 Enterprise view for the Unified Implementation of the Reference Architecture, showing the stakeholders that own or operate the physical objects shown in the last section and their relationships with one other. The tables that follow the diagram describe the objects, roles, and relationships.



Source: USDOT

Figure 9. Enterprise View – Layer 0

Enterprise – Layer 0 – Objects

Table 14 describes each of the Enterprise Objects illustrated in the diagram above. The entries in the table are based on the descriptions listed in the CVRIA Enterprise Objects repository.

Table 14. Enterprise Objects – Layer 0

Object	Description
Arterial Traffic Manager	An entity responsible for the management of arterial traffic in the Unified Implementation of the Reference Architecture geographic region.
Connected Vehicle Wide Area Information Distribution Operator	The Wide Area Information Distribution Operator provides operational and technical support for Wide Area Information Distribution Operator systems and components. It owns and operates the Wide Area Information Distributor. The Operator facilitates and maintains multiple agreements with other Unified Implementation of the Reference Architecture Entities.
Remote Vehicle OBE Owner	Remote Vehicle Drivers (or Remote Mobile Device Operators) include the operators of any **other** vehicle or mobile device equipped with the enabling technologies and possessing valid security credentials that allow connected vehicle operations within the Unified Implementation of the Reference Architecture. This is an essentially artificial distinction created to better illustrate the relationship between connected vehicle-equipped vehicles.
Driver	Drivers include the operators of any vehicle or mobile device equipped with the enabling technologies and possessing valid security credentials that allow connected vehicle operations within the Unified Implementation of the Reference Architecture. Non-motorized mobile device operators (pedestrians and cyclists) have different operating characteristics and needs than motorized mobile device operators. Drivers operate connected vehicles and have an expectation of information exchange with the Unified Implementation Operator.
Reference Implementation Operator	The Reference Implementation Operator provides operational and technical support for the Unified Implementation of the Reference Architecture systems and components. This includes operational, technical, and management of deployed RSE units, Connected Vehicle OBEs, USDOT Data Distribution and Support Services and other infrastructure services and platforms, the supporting communications, security and management services and infrastructure. • Owns and operates the USDOT Object Registration and Discovery Service. Facilitates and maintains an expectation of information exchange with other Unified Implementation of the Reference Architecture Entities. • Owns and operates the USDOT Security Credential Management Service. Facilitates and maintains an associated Security Information Exchange Agreement with other Unified Implementation of the Reference Architecture Entities. • Owns and operates the USDOT Situation Data Clearinghouse. Facilitates and maintains an Information Provision Agreement with other Unified Implementation of the Reference Architecture Entities. • Owns and operates the USDOT Situation Data Warehouse. Facilitates and maintains an Information Provision Agreement with other Unified Implementation of the Reference Architecture Entities.

Object	Description
Third Party Application Provider	Third Party Application Providers are specified more by role than by function. They are responsible for the development of the third-party applications on either mobile, field, or center-based System Elements. This includes initial creation, enhancements, operational support, and maintenance. For those System Elements that they host, they are also responsible for the establishment, maintenance, and secure operations of the supporting computing infrastructure and facilities.
Third Party Driver	Third Party Drivers include the operators of any vehicle or mobile device equipped with the enabling technologies and possessing valid security credentials that allow connected vehicle operations within the Unified Implementation of the Reference Architecture. Non-motorized mobile device operators (pedestrians and cyclists) have different operating characteristics and needs than motorized mobile device operators.
Traveler	The "Traveler" represents any individual (other than a “Unified Implementation of the Reference Architecture Driver” or “Third Party Driver”) who uses transportation services. The interfaces to the traveler provide general pre-trip and en route information supporting trip planning, personal guidance, and requests for assistance in an emergency that are relevant to all transportation system users. It also represents users of a public transportation system and addresses interfaces these users have within a transit vehicle or at transit facilities such as roadside stops and transit centers. Travelers include the operators of any mobile device equipped with the enabling technologies and possessing valid security credentials that allow connected vehicle operations within the Unified Implementation of the Reference Architecture.

Enterprise – Layer 0 – Roles

Table 15 lists and defines the roles between the Enterprise Objects defined in Figure 9 and Table 14. They are based on the CVRIA Enterprise Roles defined in the CVRIA website.

Table 15. Enterprise Object – Layer 0 – Roles

Role Name	Description
Operates	An Enterprise controls the functionality and state of the target object.
Owns	An Enterprise has financial ownership and control over the target object.

Enterprise – Layer 0 – Relationships

Table 16 lists and defines the individual relationships between the Enterprise Objects defined in in Figure 9 and Table 14. They are based on the CVRIA Enterprise Relationships defined in the CVRIA website.

Table 16. Enterprise Objects – Layer 0 – Relationships

Object 1	Object 2	Relationship Type	Description
Arterial Traffic Manager	Driver	Expectation of Data Provision	An expectation by the Unified Implementation of the Reference Architecture Driver that the Arterial Traffic Manager will provide data on a regular and recurring basis, and that provisioned data will be useful to the Unified Implementation of the Reference Architecture Driver in the context of the Unified Implementation of the Reference Architecture Driver's vehicle applications. It includes some expectation of the content, timeliness, quality, precision and similar qualities of the data.
Arterial Traffic Manager	Unified Implementation Operator	Information Provision Agreement	An agreement where the Arterial Traffic Manager will provide the Unified Implementation of the Reference Architecture Operator with the agreed-upon information whenever such information is likely relevant to the recipient. Typically, this information will consist of SPaT information from traffic signal controllers and includes a clear expectation of the content, timeliness, quality, precision, and similar qualities of the information.
Arterial Traffic Manager	Unified Implementation Operator	RSE Deployment Agreement	Agreement to install, configure, and make operational RSE, between the Unified Implementation of the Reference Architecture Operator (which owns and operates the <Region> RSEs) and the Arterial Traffic Manager (which controls access to the roadside). It may define locations, expectation of power provision, backhaul responsibility, and installation restrictions.
Arterial Traffic Manager	Third Party Application Provider	Expectation of Data Provision	An expectation by the Third Party Application Provider that the Arterial Traffic Manager will provide data on a regular and recurring basis, and that provisioned data will be useful to the Third Party Application Provider in the context of the Third Party Application Provider's applications. It includes some expectation of the content, timeliness, quality, precision, and similar qualities of the data.
Arterial Traffic Manager	Third Party Driver	Expectation of Data Provision	An expectation by the Third Party Driver that the Arterial Traffic Manager will provide data on a regular and recurring basis, and that provisioned data will be useful to the Third Party Driver in the context of the Third Party Driver's vehicle applications. It includes some expectation of the content, timeliness, quality, precision, and similar qualities of the data.
Remote Vehicle OBE Owner	Driver	Expectation of Data Provision	An expectation by the Driver that the Remote Vehicle OBE Owner will provide data on a regular and recurring basis, and that provisioned data will be useful to the Driver in the context of the Driver's vehicle applications. It includes some expectation of the content, timeliness, quality, precision and similar qualities of the data.
Driver	Unified Implementation Operator	Expectation of Information Exchange	An expectation, held by both the Unified Implementation Operator and the Unified Implementation of the Driver, where each party believes and anticipates that the reciprocal party will provide information whenever such information is likely relevant to the recipient.

Object 1	Object 2	Relationship Type	Description
Driver	Wide Area Information Distribution Operator	Expectation of Data Provision	An expectation by the Driver that the Wide Area Information Distribution Operator will provide data on a regular and recurring basis, and that provisioned data will be useful to the Driver in the context of the Unified Implementation of the Driver's vehicle applications. It includes some expectation of the content, timeliness, quality, precision, and similar qualities of the data.
Unified Implementation Operator	Third Party Driver	Expectation of Information Exchange	An expectation, held by both the Unified Implementation of the Reference Architecture Operator and the Third Party Driver, where each party believes and anticipates that the reciprocal party will provide information whenever such information is likely relevant to the recipient.
Unified Implementation Operator	Third Party Driver	Usage Agreement (Support Services)	An agreement in which the Unified Implementation Operator that operates and controls the USDOT Object Registration and Discovery Service and the USDOT Security Credential Management Service objects gives the Third Party Driver the necessary tools and permission to interact with these Unified Implementation of the Reference Architecture objects.
Unified Implementation Operator	Third Party Application Provider	Usage Agreement (Support Services)	An agreement in which the Unified Implementation Operator that operates and controls the USDOT Object Registration and Discovery Service and the USDOT Security Credential Management Service objects gives the Third Party Application Provider the necessary tools and permission to interact with these Unified Implementation of the Reference Architecture objects.
Unified Implementation Operator	Third Party Application Provider	Usage Agreement (Data Distribution)	An agreement in which the Unified Implementation Operator that operates and controls the USDOT Situation Data Warehouse and USDOT Situation Data Clearinghouse objects gives the Third Party Application Provider the necessary tools and permission to interact with these Unified Implementation of the Reference Architecture objects.
Unified Implementation Operator	Third Party Application Provider	Usage Agreement (RSE)	An agreement in which the Unified Implementation Operator that operates and controls the <Region> RSE objects gives the Third Party Application Provider the necessary tools and permission to operate their application object(s) on one or more Unified Implementation of the <Region> RSEs.
Unified Implementation of the Reference Architecture Operator	Traveler	Expectation of Data Provision	An expectation by the Traveler that the Unified Implementation of the Reference Architecture Operator will provide data on a regular and recurring basis, and that provisioned data will be useful to the Traveler in the context of the Traveler's mobile applications. It includes some expectation of the content, timeliness, quality, precision, and similar qualities of the data.

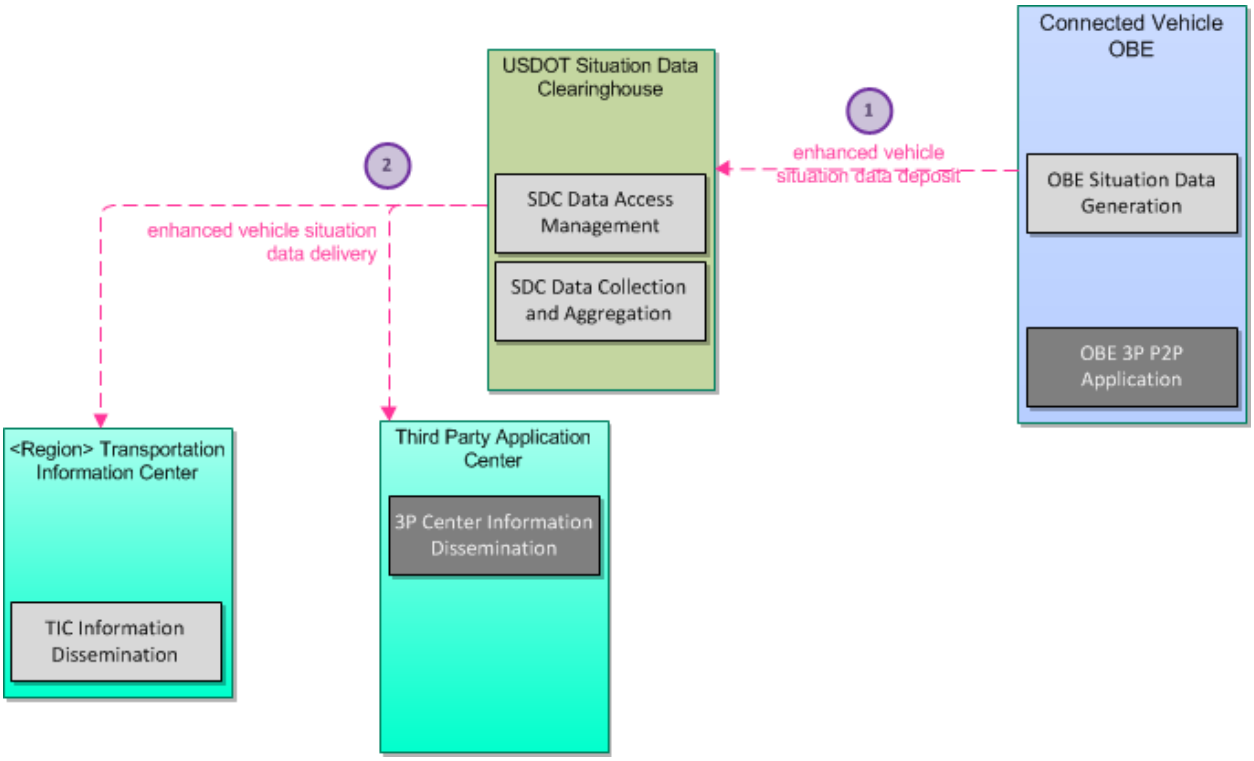
Object 1	Object 2	Relationship Type	Description
Unified Implementation Operator	Traveler	Usage Agreement (Support Services)	An agreement in which the Unified Implementation Operator that operates and controls the USDOT Object Registration and Discovery Service and the USDOT Security Credential Management Service objects gives the Traveler the necessary tools and permission to interact with these Unified Implementation of the Reference Architecture objects.
Unified Implementation Operator	Wide Area Information Distribution Operator	Usage Agreement (Support Services)	An agreement in which the Unified Implementation Operator that operates and controls the USDOT Object Registration and Discovery Service and the USDOT Security Credential Management Service objects gives the Wide Area Information Distribution Operator the necessary tools and permission to interact with these Unified Implementation of the Reference Architecture objects.
Unified Implementation Operator	Wide Area Information Distribution Operator	Usage Agreement (Data Distribution)	An agreement in which the Unified Implementation Operator that operates and controls the USDOT Situation Data Warehouse and USDOT Situation Data Clearinghouse objects gives the Wide Area Information Distribution Operator the necessary tools and permission to interact with these Unified Implementation of the Reference Architecture objects.
Traveler	Wide Area Information Distribution Operator	Expectation of Data Provision	An expectation by the Traveler that the Wide Area Information Distribution Operator will provide data on a regular and recurring basis, and that provisioned data will be useful to the Traveler in the context of the Traveler's mobile applications. It includes some expectation of the content, timeliness, quality, precision, and similar qualities of the data.

Chapter 4. Operational Scenarios

This section provides an overview of the major operational uses for the Unified Implementation of the Reference Architecture.

Enhanced Vehicle Situation Data Distribution

This scenario illustrates how enhanced vehicle situation data will be collected from the various Connected Vehicle OBEs and consolidated into a Data Distribution System (USDOT Situation Data Clearinghouse) for subsequent distribution to interested parties.



Source: USDOT

Figure 10. Enhanced Vehicle Situation Data Dissemination

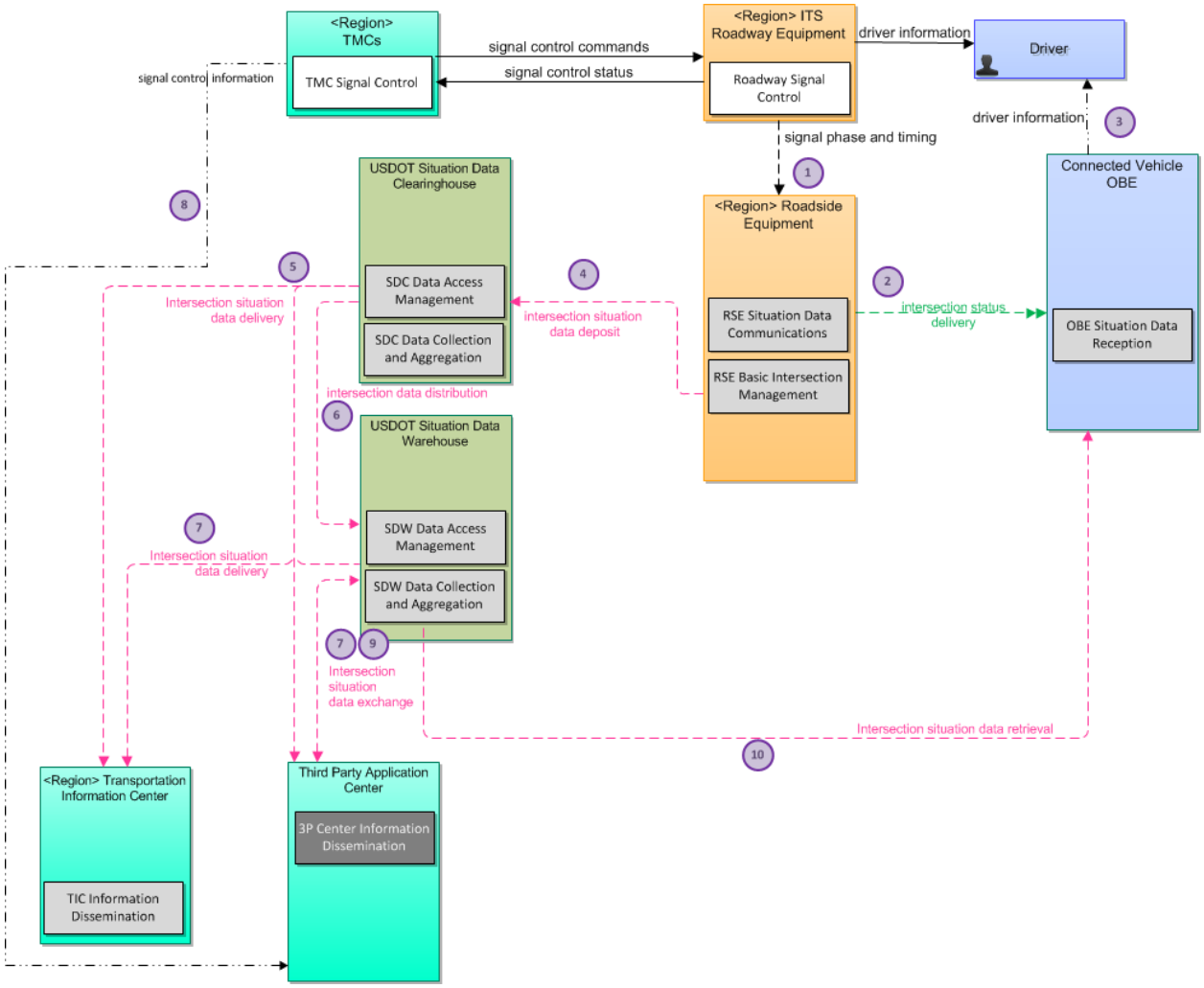
Operational Steps

1. Enhanced Situation Data Messages will be periodically generated by Connected Vehicle OBEs, and bundled for subsequent deposit into the USDOT Situation Data Clearinghouse.

2. The USDOT Situation Data Clearinghouse will “immediately forward” a copy of any deposited Enhance Vehicle Situation Data (EVSD) Bundle to any Unified Implementation Object that has subscribed to receive EVSD bundles with matching characteristics.

Intersection Situation Data Dissemination

This scenario illustrates how intersection situation data is generated and distributed throughout the Unified Implementation of the Reference Architecture.



Source: USDOT

Figure 11. Intersection Situation Data Dissemination

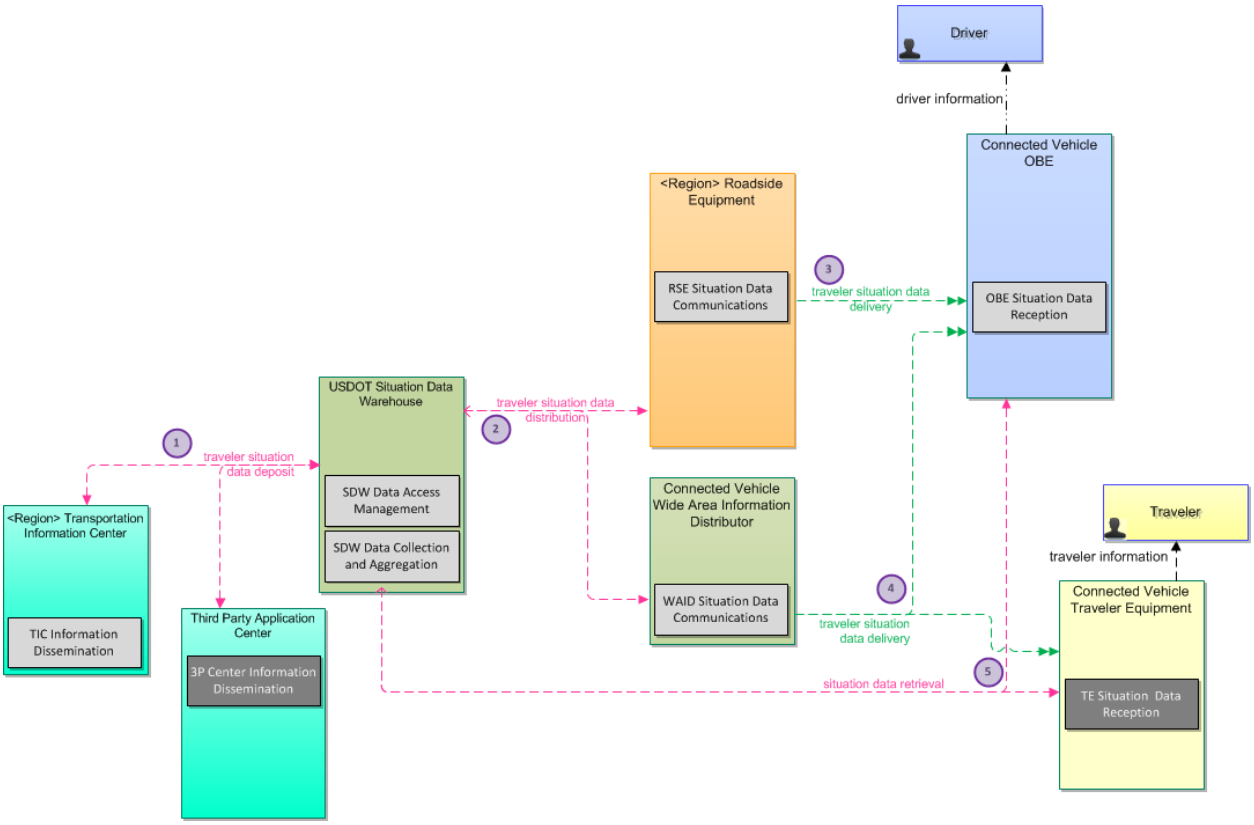
Operational Steps

1. <Region> ITS Roadway Equipment will send the SPaT information it generates to the RSE.

2. The <Region> RSE will generate periodic snapshots of this information into SPaT messages and will broadcast them to passing Connected Vehicles OBEs.
3. Each Connected Vehicle OBE that receives the SPaT message may present part or all of the SPaT information received in the SPaT message to its Driver.
4. Some or all of the SPaT messages will be bundled by the RSE, along with the current MAP into Intersection Situation Data (ISD) Bundles, and deposited at the USDOT Situation Data Clearinghouse.
5. The USDOT Situation Data Clearinghouse will “immediately forward” a copy of any deposited ISD Bundle to any Unified Implementation of the Reference Architecture Object that has subscribed to receive ISD bundles with matching characteristics.
6. The USDOT Situation Data Clearinghouse will “immediately forward” a copy of **all** deposited ISD Bundles to the USDOT Situation Data Warehouse for subsequent retrieval by other Unified Implementation of the Reference Architecture Objects.
7. The <Region> Transportation Information Center and any Third Party Application Center may query and retrieve stored ISD bundles from the USDOT Situation Data Warehouse, prior to the expiration of these bundles.
8. Selected Third Party Application Centers may directly receive SPaT information and GID information, via <Region> Traffic Management Centers, for intersections that are not collocated with <Region> RSEs.
9. The Third Party Application Centers will generate SPaT messages for these intersections and bundle them, along with corresponding MAP message into ISD bundles that will be deposited into the USDOT Situation Data Warehouse. Additionally, the Third Party Application Centers could generate SPaT messages for targeted non-signalized intersections, and bundle them, along with corresponding MAP message into ISD bundles that will also be deposited into the USDOT Situation Data Warehouse.
10. Connected Vehicle OBEs may periodically query the USDOT Situation Data Warehouse for retrieval of ISD bundles within a geographic boundary. The USDOT Situation Data Warehouse will deliver these bundles to the requesting Connected Vehicle OBE; which will use them for various onboard applications.

Traveler Situation Data Dissemination

This scenario illustrates how traveler situation data is generated and distributed throughout the Unified Implementation of the Reference Architecture.



Source: USDOT

Figure 12. Traveler Situation Data Dissemination

Operational Steps

1. The <Region> Transportation Information Center or an authorized Third Party Application Center, generate and send one (or more) traveler (advisory) situation data message and its associated dispatch instructions to the USDOT Situation Data Warehouse.
2. The USDOT Situation Data Warehouse validates, sorts, and bundles these messages into data stores based on the geographic area associated with the advisory message.
3. The Connected Vehicle WAID and <Region> RSEs periodically request all traveler situation data bundles within their respective geographic boundary and construct their respective “playlists” based on the dispatch instructions associated with the constituent messages within the retrieved bundles.
4. The Connected Vehicle WAID and <Region> RSEs periodically transmit (broadcast) their playlists to any Connected Vehicle OBEs and Connected Vehicle Traveler Equipment within broadcast range.
5. Connected Vehicle OBEs and Connected Vehicle Traveler Equipment can (as needed) request delivery of bundles of traveler (advisory) situation data messages based on their respective geographic boundary of interest. The USDOT Situation Data Warehouse will accordingly deliver these bundled messages to the requesting vehicle.

References

Table 17 lists the references used to develop the concepts in this document. Any hyperlinks provided are accurate as of the date of publication.

Table 17. References

#	Document (Location)
1	*Principles for a Connected Vehicle Environment*, U.S. Department of Transportation ITS Joint Program Office-HOIT, April 18, 2012 http://www.its.dot.gov/connected_vehicle/pdf/ConnectedVehiclePrinciples_final4-18-2012.pdf
2	*Connected Vehicle Reference Implementation Architecture Website*, U.S. Department of Transportation, Office of the Assistant Secretary of Transportation for Research and Technology. http://www.iteris.com/cvria/
3	*Core System Concept of Operations*, U.S. Department of Transportation, Research and Innovative Technology Administration, October 24, 2011 http://www.its.dot.gov/docs/CoreSystemConOpsRevE2.pdf
4	*Core System Architecture Document*, U.S. Department of Transportation, Research and Innovative Technology Administration, October 14, 2011 http://www.its.dot.gov/docs/CoreSystemArchitectureDoc_revC.pdf
5	*Core System Requirements Specification*, U.S. Department of Transportation, Research and Innovative Technology Administration, October 14, 2011 http://www.its.dot.gov/docs/CoreSystem_SE_SyRS_RevF.pdf
6	*Core System Deployment Critical Risk Assessment Report*, U.S. Department of Transportation, Research and Innovative Technology Administration, October 28, 2011 http://www.its.dot.gov/docs/CoreSystem_RiskReport_RevB.pdf
7	*Core System Standards Recommendations*, U.S. Department of Transportation, Research and Innovative Technology Administration, October 28, 2011 http://www.its.dot.gov/docs/CoreSystem_StdsRecommendations_RevA.pdf
8	*Connected Vehicle Technology - Test Bed Website*, U.S. Department of Transportation, Office of the Assistant Secretary of Transportation for Research and Technology. http://www.its.dot.gov/testbed.htm
9	Safety Pilot Model Deployment – "5.9GHz DSRC Aftermarket Safety" Device Specification, U.S. Department of Transportation, Research and Innovative Technology Administration, Version 3.0, December 26, 2011
10	Safety Pilot Model Deployment – *"5.9GHz DSRC Roadside Equipment" Device Specification*, U.S. Department of Transportation, Research and Innovative Technology Administration, Version 3.0, March 1, 2012 http://www.its.dot.gov/safety_pilot/pdf/T-10001-T2-05_RSE_Device_Design_Specification_v30.pdf
11	Safety Pilot Model Deployment – *"5.9GHz DSRC Vehicle Awareness Device" Specification*, U.S. Department of Transportation, Research and Innovative Technology Administration, Version 3.5, December 12, 2011 http://www.its.dot.gov/safety_pilot/pdf/Vehicle_Awareness_Device_Specification-r3-5--20111202.pdf
12	*1609.0-2013 - IEEE Guide for Wireless Access in Vehicular Environments (WAVE) – Architecture* http://standards.ieee.org/findstds/standard/1609.0-2013.html
13	*1609.2-2013 - IEEE Standard for Wireless Access in Vehicular Environments — Security Services for Applications and Management Messages* http://standards.ieee.org/findstds/standard/1609.2-2013.html

#	Document (Location)
14	*1609.3-2010 - IEEE Standard for Wireless Access in Vehicular Environments (WAVE) - Networking Services* http://standards.ieee.org/findstds/standard/1609.3-2010-Cor_2-2014.html
15	*1609.4-2010 - IEEE Standard for Wireless Access in Vehicular Environments (WAVE)--Multi-channel Operation* http://standards.ieee.org/findstds/standard/1609.4-2010.html
16	*SAE J2735 - Dedicated Short Range Communications (DSRC) Message Set Dictionary*™, September 2, 2015 http://standards.sae.org/j2735_201509/
17	*SAE J3067 - Candidate Improvements to Dedicated Short Range Communications (DSRC) Message Set Dictionary [SAE J2735] Using Systems Engineering Methods*, August 26, 2014 http://standards.sae.org/j3067_201408/
18	*SAE J2945 - Dedicated Short Range Communication (DSRC) Minimum Performance Requirements*™, Work in Progress http://standards.sae.org/wip/j2945/
19	*USDOT Security Credential Management System*, U.S. Department of Transportation, Research and Innovative Technology Administration, April 13, 2012. http://www.its.dot.gov/meetings/pdf/Security_Design20120413.pdf
20	*USDOT's Intelligent Transportation Systems (ITS) ITS Strategic Plan 2015-2019*, December 2014 http://www.its.dot.gov/strategicplan.pdf
21	*ITU-R TF.460-4: Standard-frequency and time-signal emissions*, International Telecommunication Union. 1986. Annex I http://www.cl.cam.ac.uk/~mgk25/volatile/ITU-R-TF.460-4.pdf

Acronyms and Definitions

Table 18 defines selected project specific terms used throughout this ConOps document.

Table 18. Acronyms

Term	Definition
3G	Third Generation
3P	Third Party
4G	Fourth Generation
A	Adjacent
ACL	Access Control List
APDU	Application Protocol Data Unit
API	Application Programming Interface
ASD	Aftermarket Safety Device
ASN.1	Abstract Syntax Notation.1
ATIS	Advanced Traveler Information System
BSM	Basic Safety Message
C	Continental
C2C	Center to Center
C2F	Center to Field
CA	Certificate Authority
CAMP	Crash Avoidance Metrics Partnership
ConOps	Concept of Operations
CRL	Certificate Revocation List
CV	Connected Vehicle
CVRIA	Connected Vehicle Reference Implementation Architecture
DD	Data Distribution
DNS	Domain Name System
DOT	Department of Transportation
DSRC	Dedicated Short-Range Communications
EVSD	Enhance Vehicle Situation Data
Gbps	Gigabits per second
GHz	Gigahertz
GID	Geographic Intersection Description
GPS	Global Positioning System
H	Historic
HMI	Human Machine Interface
HTTPS	Hypertext Transfer Protocol (Secured)
I2V	Infrastructure to Vehicle
IP	Internet Protocol
ISD	Intersection Situation Data
ITS	Intelligent Transportation System

Term	Definition
JPO	Joint Program Office
L	Local
MAP	Map Data Message
MOA	Memorandum of Agreement
N	Now
N	National
NHTSA	National Highway Traffic Safety Administration
O&M	Operations and Maintenance
OBE	Onboard Equipment
ODE	Operational Data Environment
ORDS	Object Registration and Recovery Service
OST-R	Office of the Assistant Secretary of Transportation for Research and Technology
P2P	Peer-to-Peer
PDU	Protocol Data Unit
PII	Personal Identifiable Information
PKI	Public Key Infrastructure
POC	Proof of Concept
R	Recent
R	Regional
RA	Registration Authority
RDE	Research Data Exchange
RF	Radio Frequency
RSE	Roadside Equipment
S	Static
SAE	Society of Automotive Engineers
SCM	Security and Credential Management
SCMS	Security Credential Management System/Service
SDC	Situation Data Clearinghouse
SDW	Situation Data Warehouse
SM	Service Monitor
SPaT	Signal Phase and Timing
SPMD	Safety Pilot Model Deployment
SSL	Secure Sockets Layer
TBD	To Be Determined
TCP	Transmission Control Protocol
TE	Traveler Equipment
TIC	<Region> Transportation Information Center
TMC	Traffic Management Center
TPAC	Third Party Application Center
TSD	Traveler Situation Data
UDP	User Datagram Protocol
USDOT	United States Department of Transportation
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
WAID	Wide Area Information Distributor
WAVE	Wireless Access in Vehicular Environments

Term	Definition
Wi-Fi	Wireless Fidelity (short to mid-range wireless network)
WiMAX	Worldwide Interoperability for Microwave Access
WSM	WAVE Short Messages
WSMP	WAVE Short Message Protocol
XML	eXtensible Markup Language

Table 19. Definitions

Term	Definition
Access Control	Refers to mechanisms and policies that restrict access to computer resources. An access control list (ACL), for example, specifies what operations different users can perform on specific files and directories.
Administrator	These are the operators that set control parameters, implement system policies, monitor system configuration, and make changes to the system as needed.
Aggregation	The process of combining data elements of similar format into a single data element that is a statistical representation of the original elements.
Analysis	The process of studying a system by partitioning the system into parts (functions, components, or objects) and determining how the parts relate to each other.
Anonymity	Lacking individuality, distinction, and “recognizability” within message exchanges.
Anonymous Certificate	A certificate that contains a pseudonym of the System User instead of the real identity in the subject of the certificate and thus prevents other System Users from identifying the certificate owner when the certificate is used to sign or encrypt a message in the connected vehicle program. The real identity of the anonymous certificates can be traced by Authorized System Operators by using the services of Registration Authority and Certification Authority.
APDU	Application Protocol Data Unit. This is a defined data structure that is transferred at a peer level between two applications.
Application	One or more pieces of software designed to perform some specific function; it is a configuration of interacting Engineering Objects. A computer software program with an interface, enabling people to use a computer as a tool to accomplish a specific task.
Application User	A user who interfaces with Application Layer software for a desired function or feature.
Assumption	A judgment about unknown factors and the future that is made in analyzing alternative courses of action.
Authenticate	The process of ensuring that an APDU originated from a source identified within the message.
Authentication	The process of determining the identity of a user that is attempting to access a network.
Authenticability	The ability of the receiver of information to authenticate the sender’s identity or trustworthiness to send data within the domain. If required, this can be accomplished by verifying the incoming message has been digitally ‘signed’ by the sender.
Authenticity	The quality of being genuine or authentic, which is to have the origin supported by unquestionable evidence, authenticated, verified. This includes whether the software or hardware came from an authorized source.
Authorization	The process of determining what types of activities or access are permitted on a network. Usually used in the context of authentication—once you have authenticated a user, they may be authorized to have access to a specific service.

Term	Definition
Available	Ready or able to be used.
Backup	The ability of one System Element replacing another System Element's functionality upon the failure of that System Element.
Bad Actor	A role played by a user or another system that provides false or misleading data, operates in such a fashion as to impede other users, or operates outside of its authorized scope.
Boundaries	The area of management and control for a System or Object. It could be by latitude/longitude or by county or by regional jurisdictions.
Broadcast	A flow where the initiator sends information on a predefined communications channel using a protocol that enables others who know how to listen to that channel to receive the information. One-to-many communication, with no dialog.
Cardinality	The characterization of the relationship between the number of sender(s) and receiver(s) of a data exchange (e.g., broadcast (one-to-many) unicast (one to one)).
Center	An entity that provides application, management, administrative, and support functions from a fixed location not in proximity to the road network. The terms "back office" and "center" are used interchangeably. Center is traditionally a transportation-focused term, evoking management centers to support transportation needs, while back-office generally refers to commercial applications. From the perspective of this ConOps Specification, these are considered the same.
Concept of Operations (ConOps)	A user-oriented document that describes a system's operational characteristics from the end user's viewpoint.
Confidentiality	The property of being unable to read PDU contents by any listener that is not the intended receiver.
Configurable Parameter	Non-static data that can be adjustable and updated when needed.
Configuration	Data that is used to customize the operational environment for a System Element or System User, or the System as a whole.
Configure	The process of selecting from a set of option(s) or alternative values in order to create a specific operational environment.
Constraint	An externally imposed limitation on system requirements, design, or implementation or on the process used to develop or modify a system. A constraint is a factor that lies outside – but has a direct impact on – a system design effort. Constraints may relate to laws and regulations or technological, socio-political, financial, or operational factors.
Contract	In project management, a legally binding document agreed upon by the customer and the hardware or software developer or supplier; includes the technical, organizational, cost, and/or scheduling requirements of a project.
Control	To exercise influence over.
Coverage Area	A geographic jurisdiction within which the System provides services.
Cyber Address	The cyber or network address of a Unified Implementation of the Reference Architecture object.
Data Consumer	1) A user or system that is receiving or using data from another user or system. 2) Any Unified Implementation of the Reference Architecture object that registers with and subsequently requests and receives delivery of data from a data warehouse.
Data Provider	1) Any Unified Implementation of the Reference Architecture object that registers with and subsequently deposits data into a data warehouse. 2) A System User that is supplying or transmitting data to another user or system. A data provider is likely to be an aggregator of data.

Term	Definition
Data Warehouse	A data storage facility that supports the input (deposit) and retrieval (delivery) of clearly defined data objects. This can be designed and implemented in a variety of ways, including publish/subscribe and a traditional query-based database.
Decrypt	To decode or decipher data that has previously been encoded in such a way to secure its contents from unauthorized access. See Encryption.
Digital Certificate or Signature	A digital certificate is an electronic "identification card" that establishes your credentials when doing business or other transactions on the Web. It is issued by a certification authority. It contains your name, a serial number, expiration dates, a copy of the certificate holder's public key (used for encrypting messages and digital signatures), and the digital signature of the certificate-issuing authority so that a recipient can verify that the certificate is real. Note: From the SysAdmin, Audit, Network, Security Institute - www.sans.org website.
DNS (Domain Name System)	The internet protocol for mapping host names, domain names, and aliases to IP addresses.
Encryption	Scrambling data in such a way that it can only be unscrambled through the application of the correct cryptographic key.
End-User	The ultimate user of a product or service, especially of a computer system, application, or network.
Environment	The circumstances, objects, and conditions that surround a system to be built; includes technical, political, commercial, cultural, organizational, and physical influences as well as standards and policies that govern what a system must do or how it will do it.
Extensibility	The ability to add or modify functionality or features with little or no design changes.
Field	These are intelligent infrastructure distributed near or along the transportation network that perform surveillance (e.g., traffic detectors, cameras), traffic control (e.g., signal controllers), information provision (e.g., dynamic message signs) and local transaction (e.g., tolling, parking) functions. Typically, their operation is governed by transportation management functions running in back offices. Field also includes RSE and other non-DSRC wireless communications infrastructure that provides communications between Mobile elements and fixed infrastructure.
Forwarding	The process of forward sending data onto another entity (system user) without modifying or storing the data for any substantial length of time.
Functionality	The capabilities of the various computational, user interfaces, input, output, data management, and other features provided by a product.
Geo-Fence	An electronic set of geo reference points that form a bounded geographic region.
Geo-Referencing	The process of scaling, rotating, translating, and de-skewing the image to match a particular size and position. To define something in terms of its physical location in space.
Hardware	Hardware refers to the physical parts of a computer and related devices. Internal hardware devices include motherboards, hard drives, and memory. External hardware devices include monitors, keyboards, mice, printers, and scanners.
Now (N)	Transient Data that is hyper current (relevant at the time of reporting for applications that require sub-second response).
Adjacent (A)	Data that is hyper local (relevant to a geographic area within approximately 1-minute travel distance).
Recent (R)	Transient Data that is current (relevant at the time of reporting for applications that do not require sub-second response).
Local (L)	Data that is local (relevant to a geographic area within a 10-minute travel distance).

Term	Definition
Historic (H)	Transient Data that is historical (relevant at the time of reporting for an indefinite interval).
Regional (R)	Data that is regional in scope (relevant to a geographic area greater than a 10-minute travel distance).
National (N)	Data that is national in scope.
Continental (C)	Data that is continental in scope.
Static (S)	Data that is permanent (relevant at the time of reporting for an indefinite interval).
Identity Certificate	A certificate that uses a digital signature to bind a public key with an identity - information such as the name of a person or an organization, their address, and so forth. The certificate can be used to verify that a public key belongs to an individual.
Integrity	(1) To maintain a system that is secure, complete, and conforming to an acceptable conduct without being vulnerable and corruptible. (2) The property of being certain that a message's contents are the same at the receiver as at the sender.
Interconnect	The communications link between two architectural objects.
Internet	An interconnected system of networks that connects computers around the world via the TCP/IP protocol.
Issuance	For Anonymous Certificates: Blocks of certificates for a System User that are generated by the Certificate Authority (CA) with mappings between the System User's real identity and the pseudo-identity in the certificates are maintained by the Registration Authority (RA). For Identity Certificates: Blocks of certificates for a System User that are generated by the CA with information such as the name of a person or an organization, their address, etc., maintained by the RA. Both certificates are installed in the System User equipment by online (through a communication channel with encrypted communications) or offline (mechanisms such as USB download) mechanisms.
Jurisdictional Scope	The power, right, or authority to interpret and apply the law within the limits or territory that authority may be exercised.
Link	A Link is the locus of relations among Nodes. It provides interconnections between Nodes for communication and coordination. It may be implemented by a wired connection or with some radio frequency (RF) or optical communications media. Links implement the primary function of transporting data. Links connect to Nodes at a Port.
Logical Security	Safeguards that include user identification and password access, authentication, access rights, and authority levels.
Misbehaving user	A user who exhibits misbehavior.
Misbehavior	The act of providing false or misleading data, operating in such a fashion as to impede other users, or to operate outside of their authorized scope. This includes suspicions behavior as in wrong message types or frequencies, invalid logins and unauthorized access, or incorrect signed or encrypted messages. etc.—either purposeful or unintended
Misbehavior Information	Includes Misbehavior Reports from System Users, as well as other improper System User acts, such as sending wrong message types, invalid logins, unauthorized access, incorrectly signed messages, and other inappropriate System User behavior.
Misbehavior Report	Data from a System User identifying suspicious behavior from another System User that can be characterized as misbehavior.
Mobile	These are vehicle types (private/personal, trucks, transit, emergency, commercial, maintenance, and construction vehicles) as well as non-vehicle-

Term	Definition
	based platforms including portable personal devices (smartphones, PDAs, tablets, etc.) used by travelers (vehicle operators, passengers, cyclists, pedestrians, etc.) to provide and receive transportation information.
Nonrepudiation	The property whereby a PDU is constructed in such a way that the PDU sender cannot effectively deny having been the sender of that PDU; and the PDU receiver cannot effectively deny having received a particular PDU.
Onboard Equipment	Computer modules, display and a DSRC radio, that is installed and embedded into vehicles that provide an interface to vehicular sensors, as well as a wireless communication interface to the roadside and back-office environment.
Operational Data Environment (ODE)	The ODE consists of several different USDOT-developed smart data routers brokering processed data between various data sources, including the Unified Implementation of the Reference Architecture, and a variety of data users (e.g., RDE, TMCs). As a smart data router, the ODE routes data from disparate data sources to software applications (including connected vehicle applications) that have placed data subscription requests to the ODE. The ODE also performs necessary security / credential checks and, as needed, data valuation, aggregation, integration, and propagation functions.
Operators	These are the day-to-day users of the System that monitor the health of the system components, adjust parameters to improve performance, and collect and report statistics of the overall system.
Permission	Authorization granted to do something. From the System's perspective, permissions are granted to System Users and Operators determining what actions they are allowed to take when interacting with the System.
Persistent Connection	A connection between two networked devices that remains open after the initial request is completed, to handle multiple requests thereafter. This reduces resource overhead of re-establishing connections for each message sent and received. This is opposite of Session-oriented Connection.
Physical Security	Safeguards to deny access to unauthorized personnel (including attackers or even accidental intruders) from physically accessing a building, facility, resource, or stored information. This can range from simply a locked door to badge entry, with armed security guards.
Priority	A rank order of status, activities, or tasks. Priority is particularly important when resources are limited.
Privacy	The ability of an individual to seclude information about themselves, and thereby reveal information about themselves selectively.
Process	A series of actions, changes, or functions bringing about a result.
Protocol Data Unit	A defined data structure that is transferred at a peer level between corresponding software entities functioning at the same layer in the OSI standard model that are operating on different computing platforms that are interconnected via communications media .
Public Key	In cryptography, a public key is a value provided by some designated authority as an encryption key that, combined with a private key derived from the public key, can be used to effectively encrypt messages and digitally sign them. The use of combined public and private keys is known as asymmetric cryptography. A system for using public keys is called a public key infrastructure.
Regional (R)	Data that is regional (relevant to a geographic area within approximately 30-minute travel distance).
Registry	A repository for maintaining data requester's information including the type of data they are subscribing to, their address, etc.
Reliability	Providing consistent and dependable system output or results.
Repackage Data	Data that is broken down for aggregation, parsing, or sampling.
Research Data Exchange	A web-based data resource provided by the USDOT ITS JPO's Real-Time Data Capture and Management (DCM) program that collects, manages, and provides

Term	Definition
	archived and real-time multi-source and multi-modal data to support the development and testing of ITS applications.
Scalability	The capable of being easily grown, expanded, or upgraded upon demand without requiring a redesign.
Scenario	A step-by-step description of a series of events that may occur concurrently or sequentially.
Secure Storage	Encrypted or protected data that requires a user or a process to authenticate itself before accessing to the data. Secure storage persists when the power is turned off.
Secure Transmission	To protect the transfer of confidential or sensitive data usually by encryption, Secure Sockets Layer (SSL), Hypertext Transfer Protocol Secure (HTTPS) or similar secure communications.
Secure/Securely	Referring to storage, which consists of both logical and physical safeguards.
Session-oriented Connection	A connection between two networked devices that is established intermittently and to handle few requests thereafter. The connection is meant to be temporary lasting for minutes, hours, but likely not more than a day before it is closed. This is opposite of Persistent Connection.
Software	Software is a general term that describes computer programs. Terms such as software programs, applications, scripts, and instruction sets all fall under the category of computer software.
States	A distinct system setting in which the same user input will produce different results than it would in other settings. The System as a whole is always in one state. A state is typically commanded or placed in that state by an operator. States are Installation, Operational, Maintenance, Training, and Standby.
Status	Anomalies, actions, intermittent and other conditions used to inform the System Operator for reparation or maintenance.
Subsystem	An integrated set of components that accomplish a clearly distinguishable set of functions with similar or related uses.
Synchronization	The act or results of occurrence or operating at the same time or rate.
System	(A) A collection of interacting elements organized to accomplish a specified function or set of functions within a specified environment. Typically, the System Elements within the System are operationally self-contained but are interconnected and collaborate to meet the needs of the System and its Users. (B) A group of people, objects, and procedures constituted to achieve defined objectives of some operational role by performing specified functions. A complete system includes all of the associated equipment, facilities, material, computer programs, firmware, technical documentation, services, and personnel required for operations and support to the degree necessary for self-sufficient use in its intended environment.
System Element	(A) A collection of interacting components organized to accomplish a specified function or set of functions within a specified environment. (B) An object and procedures constituted to achieve defined objectives of some operational role by performing specified functions. A complete system element includes all of the associated equipment, facilities, material, computer programs, firmware, technical documentation, services, and personnel required for operations and support to the degree necessary for self-sufficient use in its intended environment. An integrated set of components that accomplish a clearly distinguishable set of functions with similar or related uses.
System Need	A capability that is identified and supported within the System to accomplish a specific goal or solve a problem.
System Personnel	This represents the staff that operates and maintains the System. In addition to network managers and operations personnel, System Personnel includes the

Term	Definition
	Administrators, Operators, Maintainers, Developers, Deployment teams, and Testers.
System User	System Users refers to Mobile, Field, and Center Systems.
Testers	These users verify the System's operation when any changes are made to its operating hardware or software.
Time	A measurable period during which an action, process, or condition occurs.
Time synchronization	Calibration adjustment of date, hour, minutes, and seconds for keeping the same time within a system.
Time-of-Day	Current hours, minutes, and seconds within a day.
Traceability	The identification and documentation of derivation paths (upward) and allocation or flow down paths (downward) of work products in the work product hierarchy. Important kinds of traceability include to or from external sources to or from system requirements; to or from system requirements to or from lowest level requirements; to or from requirements to or from design; to or from design to or from implementation; to or from implementation to test; and to or from requirements to test.
Transition	A passage from one state, stage, subject, or place to another.
Trust Credentials	A user's authentication information that determines permissions and/or allowed actions with a system and other users.
Unicast	The sending of a message to a single network destination identified by a unique address.
User	An individual who uses a computer, program, network, and related services of a hardware and/or software system, usually associated with granting that individual with an account and permissions.
User Need	A capability that is identified to accomplish a specific goal or solve a problem that is to be supported by the system.
Valid	When data values within a message are acceptable and logical (e.g., numbers fall within a range, numeric data are all digits).
Validate	To establish or confirm the correctness of the structure, format, and/or contents of a data object.

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