Final Survey of Current Status

SwRI Project No. 10.24479

Using Third Parties to Deliver Infrastructure-to-Vehicle (I2V)

Version 1.2

June 5, 2020

Submitted to:

University of Virginia

On behalf of

Connected Vehicle Pooled Fund Study

Prepared by:

Southwest Research Institute®

http://swri.org

Prepared By: ______________________ Date: June 5, 2020

Darin Parish

Senior Computer Scientist

Southwest Research Institute

Approved By: ______________________ Date: June 5, 2020

Eric Thorn, Ph.D.

Manager R&D

Southwest Research Institute

SwRI Benefiting government, industry and the public through innovative science and technology

TABLE OF CONTENTS

1. SCOPE

The Final Survey of Current Status summarizes the stakeholders and provides information about the connected vehicle (CV) data sharing activities between infrastructure owners and operators (IOOs) and third-party providers or system integrators. Information is based on inquiries sent to stakeholders from the Stakeholder List established in a previous deliverable. Additionally, phone interviews with the stakeholders and the Connected Vehicle Pooled Fund Study (CV PFS) group members provide additional details.

1.1 Purpose

Existing data that is utilized by third parties and system integrators will be identified by this report. The third-party companies and system integrators have been identified, and a description of their company and offerings will be included in this document. Additionally, this document will identify the kinds / types of CV data and information that are currently being shared by IOOs and that may be of use to third-party data providers. The main target will be infrastructure data (e.g., Signal Phase and Timing (SPaT), Map, related geometric and signal timing information, etc.) but basic safety message (BSM) or BSM-derived data received by public agencies will also be included. A focus is placed on integration with standards developing organizations (SDOs) such as SAE International (originally known as Society of Automotive Engineering though it is no longer treated as an acronym and is now known as SAE International) and the Institute of Electrical and Electronics Engineers (IEEE).

1.2 Terms and Definitions

API	Application Programming Interface
ATMS	Advanced Traffic Management System
BSM	Basic Safety Message
CORS	Continuously Operating Reference Station
C-V2X	Cellular Vehicle to Everything
CV	Connected Vehicle
CVOP	Commercial Vehicle Operator Portal
DMS	Dynamic Message Signs
DOT	Department of Transportation
DSRC	Dedicated Short-Range Communications
EMS	Emergency Medical Services
ETA	Estimated Time of Arrival
FDOT	Florida Department of Transportation
FHWA	Federal Highway Administration
GDOT	Georgia Department of Transportation
GLOSA	Green Light Optimal Speed Advisory
GUI	Graphical User Interface

I2V	Infrastructure-to-Vehicle
IaaS	Information-as-a-Service
IBI	Intelligence, Buildings, and Infrastructure
IDE	Integrated Data Exchange
IOO	Infrastructure Owners and Operators
IoT	Internet of Things
ITS	Intelligent Transportation System
LTD	Live Traffic Data
LTE	Long-Term Evolution
MQTT	Message Query Telemetry Transport
NTCIP	National Transportation Communications for ITS Protocol
ODOT	Ohio Department of Transportation
OBU	On-Board Unit
ODE	Operational Data Environment
OEM	Original Equipment Manufacturer
OTA	Over-the-Air
PFS	Pooled Fund Study
PSM	Personal Safety Messages
RSU	Roadside Units
SPaT	Signal Phase and Timing
SPS	Signal Priority System
SwRI	Southwest Research Institute
THEA	Tampa Hillsborough Expressway Authority
TMC	Traffic Management Center
TPI	Third-Party Interface
TTS	Traffic Technology Services
UDOT	Utah Department of Transportation
UDP	User Datagram Protocol
USDOT	United States Department of Transportation
V2I	Vehicle-to-Infrastructure
V2P	Vehicle-to-Pedestrian
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-Everything
VCC	Virginia Connected Corridor
VTTI	Virginia Tech Transportation Institute
WYDOT	Wyoming Department of Transportation

1.3 Contacts

The following are contact persons for information regarding the project.

- Darin Parish, Senior Computer Scientist (SwRI)
  darin.parish@swri.org, 210-522-5669
- Cameron Mott, Senior Research Analyst (SwRI)
  cameron.mott@swri.org, 210-522-2583
- Dr. Eric Thorn, Manager – R&D (SwRI)
  ethorn@swri.org, 210-522-3915
- John Esposito, Engineer (SwRI)
  john.esposito@swri.org, 210-522-5609

1.4 Revision History

Version	Date	Comments
0.1	June 27, 2019	Draft
1.0	August 2, 2019	Final
1.1	April 27, 2020	Added stakeholder interview results
1.2	June 5, 2020	Added additional stakeholder input

2. STAKEHOLDER INFORMATION

2.1 Stakeholder List

The Stakeholder List for States/IOOs, Third Parties, System Integrators and OEMs appears in Table 1. This list is updated from the Final List of Stakeholders based on feedback from CV PFS group members. The outreach status for each stakeholder is indicated in the table, green highlight indicates that a stakeholder has provided a sufficient amount of information, blue highlight indicates that the research team is expecting further information from the stakeholder, orange highlight (unused) indicates that the research team has a point of contact but has yet to reach out with an inquiry and yellow highlight indicates that no primary point of contact is known for that stakeholder.

Table 1: List of Stakeholders by Category with Primary Point of Contact and Current Status of Outreach Efforts

Stakeholder Group	Stakeholder	Point of Contact	Current Status
States, IOOs	USDOT	Shehan, Robert	Information available online
	WYDOT		Information available online
	VTTI		Information available online
	Utah DOT	Leonard, Blaine	Blaine to provide additional contacts
	Ohio DOT	Hegemier, Nick	Interview completed
	GDOT	Davis, Alan	Interview completed
	NYC		Information available online
	THEA		Information available online
Third Parties	Traffic Technology Services, Inc.	Ova, Kiel	Interview completed
	Connected Signals	Etherington, David	Interview completed
	HERE	Corsaro, Frank	Initial email sent on 7/25/19
	TomTom		Contact unknown
	DeepMap		Contact unknown
	Uber		Contact unknown
	Google/Carahsoft	Lloyd, Porter	Email sent
	Live Traffic Data		Contact unknown
	TransCore	Wilson, Jim	Initial email sent on 7/25/19
	Inrix	Salerno, Angela	Initial email sent on 7/25/19
	DENSO	Smith, DJ	Waiting for response
	HNTB	Johnson, Steve	Sent both contacts a questionare about the types of applications they currently use.
	Miovision	Bergstrom, Jan	Some information received
	AI (Applied Information)	Mulligan, Bryan	Initial email sent on 7/25/19
	Qualcomm		Contact unknown
	SiriusXM	Wallace, Gary A.	Initial email sent on 7/25/19
	Voyage (ADS)		Contact unknown
	MH Corbin LLC	Corbin, Bill	Interview completed
	Waze		Contact unknown
	IBI	Corby, Mike	Some information received
	SPLUNK	Smigocki, Kimberly	Initial email sent on 7/25/19
System Integrators	eTrans Systems	Sprouffske, Steve	Initial email sent on 7/25/19
	Intelight (MaxView)	Gardner, Grant	Interview completed
	Econolite	Ringler, Jon	Initial email sent on 7/25/19
	Centracs		Contact unknown
	Siemens	Rogers, Mark	Initial email sent on 7/25/19
	Tactics		Contact unknown
	Panasonic	Pucher, Kellen	Initial email sent on 7/25/20
	Bosch	Poponea, Jon	Called 7/23, was asked to again email questions. Jon was headed out for travel.
OEMs	Ford	Ahmed-Zaid, Farid	Direct engagement not expected, have requested additional contacts from Farid
	BMW		Direct engagement not expected
	Audi		Direct engagement not expected
	Toyota		Direct engagement not expected
	GM		Direct engagement not expected
	Nissan		Direct engagement not expected

Of these stakeholders, it is noted that TTS and ConnectedSignals are high-priority stakeholders that need to be engaged to get the most out of this project. Responses have been received from these two stakeholders. Responses and interactions with the stakeholders will continue to be sought throughout this project.

2.2 Stakeholder Outreach

Stakeholders are being engaged in this project through connections from the CV PFS group. SwRI has requested that the CV PFS group members provide a point of contact and act as a referral to the potential stakeholder. Following this initial contact, SwRI provides information to the stakeholder over email and requests information relevant to the project from the stakeholders. Stakeholders are invited to provide additional details through phone interviews if additional information is desired. In order to improve the response rate from third-party companies, stakeholder engagement efforts will be continuing throughout the Task 3 efforts. This will allow real-time adjustments to the efforts for system engineering. Responses will be tracked and provided to the CV PFS team as the project progresses.

2.2.1 Questions

The stakeholder outreach requested the following information:

1. Company name
2. Name of contact
3. Position in the company
4. Email address
5. Phone (Optional)
6. Names of products / applications that are currently offered by your company that provide data to vehicles / devices.
7. Existing standards that are used by the application (other than network standards like HTTPS or TLS or formatting standards like HTML) to provide data from a back-end data source to a vehicle or device.
8. Are there existing System Engineering Documents (such as Concept of Operations, Systems Requirements or Interface Control Documents) related to your products/applications that can be shared?
9. Please provide a description of the data that is used by your product/application that comes from a State or IOO. Include relevant formats where appropriate.
10. Are there constraints to the data regarding accuracy or timeliness that will need to be considered?
11. If you were able to get other data from States/IOOs, what would be useful to you?

2.2.2 Stakeholder Responses

Stakeholders were contacted via email after an introduction from one of the CV PFS group members. The above questions were asked of stakeholders over email, and additional information was gathered via phone interviews for some stakeholders. The insight and details from these inquiries are captured in the subsections below for relevant stakeholders.

3. STATES/IOOS

Some states and IOOs are hosting data portals that provide I2V data from select deployments. These can be utilized for the project efforts, depending on the applicability. The relevant agencies with active data portal activities are captured below.

3.1 United States Department of Transportation (USDOT)

The USDOT has awarded three major CV Pilot Deployments collectively worth more than $45 million to applications from New York City, Wyoming, and THEA. The awards are to be used to further CV research and deployment efforts. [1] Along with these awards, the USDOT has released an Operational Data Environment (ODE). The USDOT ODE is a data portal that operates in real-time and provides infrastructure-to-vehicle (I2V) data to devices and other transportation management applications (see Figure 1). The ODE is a subscription-based service and incorporates data from vehicles, infrastructure, and traffic management centers. The ODE is open-source, with contributions from a community of collaborators. The data can be provided through a variety of standard interfaces, while still offering custom solutions where necessary. A RESTful interface is exposed that allows for developers to interact with the data portal. Examples in a variety of languages such as Perl, Java, C#, PHP and Obj-C are provided on the github site (https://usdot-jpo-ode.github.io/). The pilot programs are leveraging the USDOT ODE and expanding on it in a variety of ways.[2]

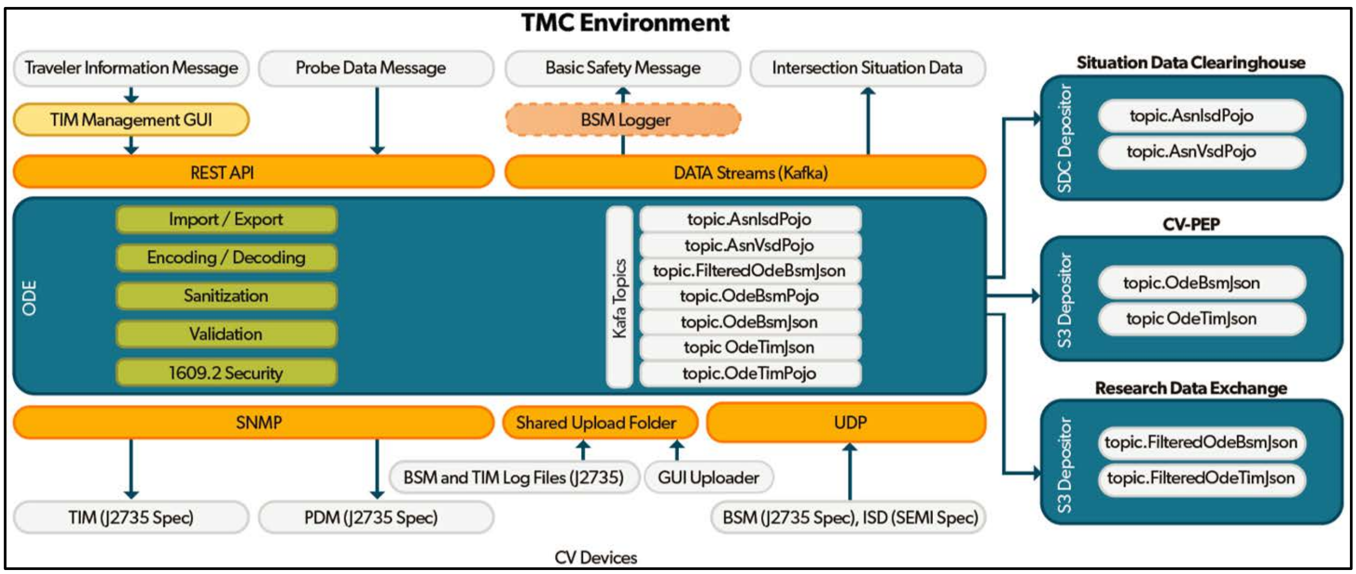

Figure 1: Dataflows within the ITS ODE framework.

3.2 Wyoming Department of Transportation (WYDOT)

WYDOT is operating a Commercial Vehicle Operator Portal (CVOP), which provides a third-party interface (TPI). This TPI includes System Requirements that are available online.[3] WYDOT originally utilized the USDOT ODE as the original base for their CVOP. WYDOT contributes back

[1] https://www.its.dot.gov/pilots/

[2] https://www.its.dot.gov/factsheets/pdf/ITSJPO_ODE.pdf

[3] https://rosap.ntl.bts.gov/view/dot/37391/dot_37391_DS1.pdf

to the USDOT ODE code base and has helped to define the format and process for incorporating OBU log files (with BSMs) into the ODE. Following the original efforts with the USDOT ODE, Trihydro has assumed management and continued development of the USDOT ODE.

3.3 Virginia Tech Transportation Institute (VTTI)

VTTI is actively seeking third-party application developers to work on a Virginia Connected Corridor (VCC) which is a cloud-oriented CV data environment. It is designed to be an open system with the ability to run applications directly in a cloud computing environment and is accessible through a public API by registered users.[4] A VCC mobile application provides information from the cloud environment out to vehicles. The SAE J2735 v2016 is one of the standards that is used by the VCC.[5] VCC provides a REST interface which allows external applications to interact with the system. Approved users submit HTTP requests to the VCC data portal, and information such as BSMs, SPaT, Map and TIM messages are returned. Examples of interacting with the cloud API are provided to registered users in languages such as Groovy and Python (see Figure 2). VCC provides their data to SmarterRoads via a websocket, and SmarterRoads provides additional options to their subscribers.

3.3.1 SmarterRoads, Affiliated with VCC

SmarterRoads[6] offers registered users access to a wide variety of datasets such as Map, SPaT, Speed Limits, Average Daily Traffic, Tolling Prices and Weather Events (see Figure 3). Users can subscribe to the datasets that they desire, and they are provided with a link that is specific to that user. Metadata about the dataset is provided via HTML (see Figure 4). Users (or applications) consume the data in JSON format with SAE J2735 Map messages encoded as UPER MessageFrames (see Figure 5).

---

[4] https://www.vtti.vt.edu/vcc/data-access.html

[5] https://www.vtti.vt.edu/vcc/development.html

[6] https://smarterroads.org/login

This partial Groovy example illustrates the Base64 encoding to produce a header of the appropriate format.

```
def http = new HTTPBuilder( 'https://vcc-api.vtti.vt.edu/' )
http.request(GET,JSON) { req ->
    uri.path = '/api/rse/2'
    headers.'Authorization' = 'Basic ' + 'MY_APP_TOKEN'.bytes.encodeBase64().toString
()
    ...
}
```

Figure 2: Example of Base64 encoding in Groovy from VCC External Communication System.

DATASET	DESCRIPTION	
Average Daily Traffic Update Rate: Yearly Format: Shapefile	Listing of each interstate and primary highway that estimates the average traffic on any given week day.	SUBSCRIBE
Crashes Update Rate: Yearly Format: Shapefile	Motor vehicle crash data that compiles all reportable accidents (crashes that involve a fatality, injury or property damage of at least $1,500).	SUBSCRIBE
Districts Update Rate: Yearly Format: Shapefile	Boundaries of the nine VDOT districts.	SUBSCRIBE
Dynamic Message Signs (Active) Update Rate: 1 Minute Format: XML	Information on the location and the current (active) messages of all active Dynamic Message Signs (DMS) signs across the state.	SUBSCRIBE
Dynamic Message Signs (All) Update Rate: 1 Minute Format: XML	Locations and current messages of all Dynamic Message Signs (DMS) signs across the state, regardless of being active or not.	SUBSCRIBE
Map Data (MAP) Update Rate: Daily Format: JSON	Intersection information, including the location of lanes and which signal group controls the movement of each lane. Provides opportunities for safety, mobility and environment applications.	UNSUBSCRIBE

Figure 3: Some of the data provided by SmarterRoads, in formats such as JSON, Shapefile, XML.

Map Data (MAP)

UNSUBSCRIBE

OBTAINING DATA

Most Recent Data: http://smarterroads.org/api/map?token=d1phZIL4hMg18sTuQo37rwUE280OzgSKipjtk4IF54NVCbDqIlaP8tslqG2WRp8Q

DESCRIPTION

MAP messages contain intersection information, including the location of lanes and which signal group controls the movement of each lane. This data set contains MAP messages for all supported intersections of the Virginia Connected Corridors project. The data for each intersection includes the id, revision, and the MapData message as an UPER-encoded MapData from the 2016 standard that is then base64 encoded and sent as a string. MAP messages are expected to change only infrequently and as needed when the intersection attributes change.

SOURCE

Virginia Connected Corridors

INSTRUCTION

The message returned in the list is an UPERencoded message from the SAE International J2735 (2016-03) standard that is base64 encoded into a string.
In order to decode the output string into human-readable data elements, the following step-by-step instruction has to be followed:
First, converting the Base64 string to hexadecimals using the open-source "tomeko" online tool: http://tomeko.net/online_tools/base64.php?lang=en.
Second, in the SAE J2735 standard, all messages are sent as a MessageFrame. The MessageFrame contains information about which particular type of message is included within the MessageFrame. The proper way to decode the hexadecimals from step #1, is to select MessageFrame under the ASN.1 message in the open-source Marben online decoder tool: http://www.marben-products.com/asn.1/services/decoder-asn1-automotive.html.
The result of the V2X conversion statement should indicate "successful decoding".

Figure 4: Metadata about the Map Dataset, with a customized link, description and source.

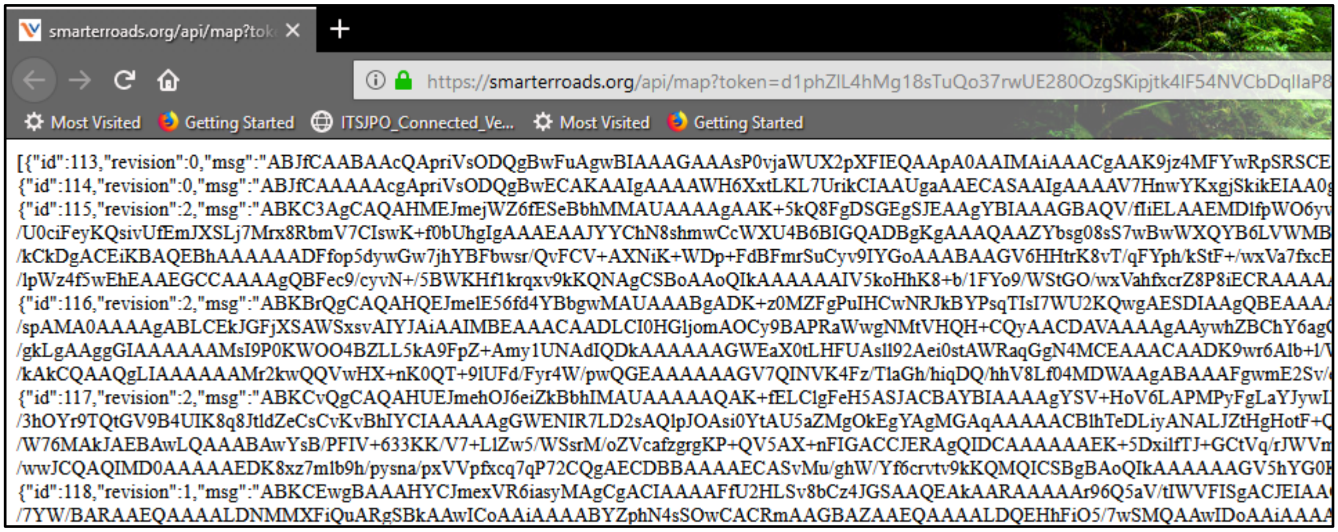

Figure 5: JSON datastream with Base64 encoded SAE J2735 Map messages.

SAE J2735 messages, in Unaligned Packed Encoding Rules (UPER) format, are encoded in Base64 (see Figure 5) and stored in a JSON format with all other SAE J2735 messages. Using multiple decoding steps, it's possible to get the Base64 string into a more human readable text, such as XML Encoding Rules (XER), as seen in Appendix A: XER Map. The process for converting this information into a human readable form is indicated in Figure 6.

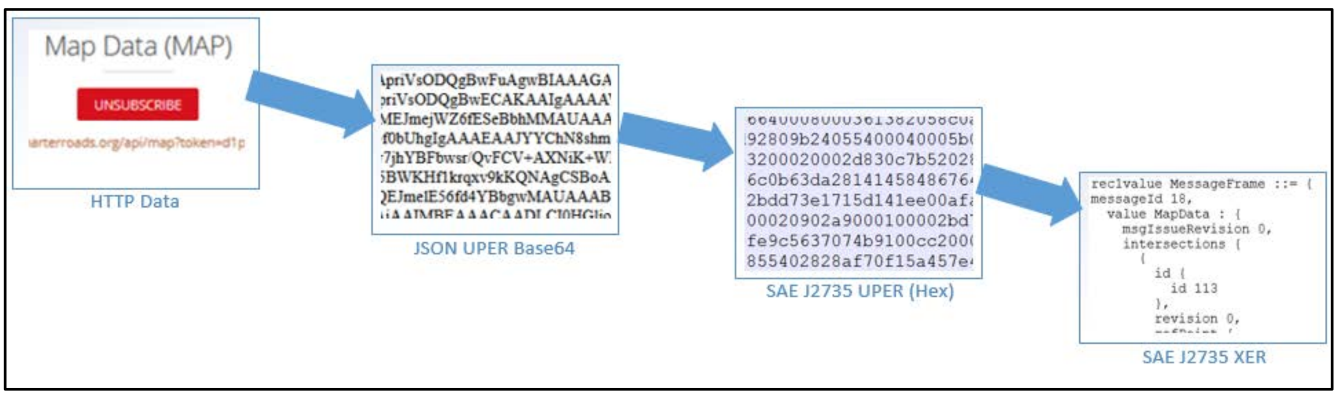

Figure 6: Process to convert Map data into XER using the SmarterRoads API.

The SmarterRoads data portal will provide registered users access to relevant VDOT transportation operations data. For most users, a subset of the data will be available on a read-only basis via a self-initiated system registration, while other types of data will be included in bi-directional exchange with the appropriate security and credentials. Forms are provided on the SmarterRoads website that allow users to sign up to access the data on the web portal. No changes are made to the data that flows through the SmarterRoads portal other than the conversion to the web-format. In order to address bandwidth limitations, only the messages that have changed are provided to a user between refreshes.

3.4 Utah Department of Transportation (UDOT)

Utah has received one of the Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) grants from the USDOT Federal Highway Administration (FHWA) for the Utah Connected Project. Through this $3 million grant, the Utah Department of Transportation (UDOT) will fund data-sharing portals that serve CV data to public and private participants.

UDOT works closely with Panasonic and their CIRRUS platform to enable CV applications through data aggregation and dissemination. Using the CIRRUS cloud-based platform, incident data is inferred from BSM data collections via RSUs along UDOT highways. Intelight traffic signal controllers running Maxview-CV are generating J2735 formatted messages that are collected and utilized. UDOT publishes an open-source Automated Traffic Signal Performance Measures (ATSPM) which create a visual representation of the high-resolution data that is available from the signal controllers.[7] Latency timing metadata is available from many of the devices, and varies dramatically per location, typically between 0.5 seconds and 3 seconds. Real-time data is not being gathered for high-frequency messages such as SPaT. These messages are instead gathered by a data logger and aggregated to an SQL server. A website front-end gathers the archived data from the SQL server and charts trends such as lane-by-lane counts of vehicles.

Efforts through UDOT are closely aligned with the CVDF, especially regarding the integration efforts from Panasonic and their CIRRUS platform.

3.5 Ohio Department of Transportation (ODOT) and DriveOhio

In January of 2018, Ohio Governor Kasich and ODOT Director Jerry Wray announced the DriveOhio Initiative to facilitate smart mobility innovations across Ohio. With this initiative, DriveOhio is now a one-stop shop for Ohio DOT and State of Ohio regarding CVs, Automated Vehicles (AV) and Unmanned Aerial Systems (UAS). Companies that are interested in operations within these technology areas are invited to collaborate with DriveOhio, which acts as the CV/AV technical specifications division for all of Ohio.

DriveOhio is working on a statewide Integrated Data Exchange (IDE) that will be an open-source information portal with real-time transportation related information[8]. This project has produced a ConOps (which will be referenced by the Using Third Party to Deliver I2V project) and System Requirements and ICDs are in development. The information portal is inspired by the data exchange from the City of Columbus. Columbus enables users of the data exchange to make

---

[7] https://github.com/udotdevelopment/atspm

[8] https://ops.fhwa.dot.gov/fastact/atcmtd/2017/applications/ohiodot/project.htm

queries and gather information from multiple sources. Through Columbus's development efforts, an open source operating system (called "Smart Columbus Operating System") has been created and deployed.[9] This OS supports anonymous logins, DriveOhio is building upon this model to support monetization of data using registered users instead of anonymous logins. This will allow registered users to submit and curate additional data sources within the DriveOhio data portal. Additionally, data is provided to the data portal from sensor databases that are gathering information from existing equipment throughout Ohio. Currently, DriveOhio data architects are creating a process for formatting and storing data. The data portal will be normalizing the data (manually at first, automatically later) and metadata would be affiliated with all data structures. Metadata will include qualities such as absolute timestamp, source, confidence, cleanliness and timeliness of the data.

The DriveOhio data portal has five key components:

1. **User Access (users create an online login)**
    a. Users (such as OEMs or Third-Party App Developers) register to be a data owner (with privileges to submit their data, manage data access permissions)
        i. Personally Identifiable Information (PII) is not intended to be stored here, if there is PII, access to it will be limited
2. **Data Access**
    a. Permission-based data access framework based on data owner's choices
        i. Could be fee-based or free ("old data" may cost less)
        ii. There will be a Yes/No, likely a Key/certification process
        iii. Business agreements may be pulled into the system, for now they are external
3. **Data Interface Portal**
    a. Data owners create an interface and store it
    b. Data doesn't have to be stored there (AWS to Azure interface wrapper)
        i. Registered owners see: Data owners and metadata about the data
4. **Data Storage**
    a. Based on procurement
    b. Length
        i. Short-term
        ii. Medium-term
        iii. Long-term (with interfaces to cloud service providers)
5. **Data Analytics**
    a. Data analytic component brings in multiple data sets, and algorithms analyze them
        i. Example: Bring in weather, friction alerts, speed data from vehicles, pavement condition sensors, accident data as input
        ii. Correlate causality of accidents and thresholds as output
    b. Generate alerts based on output from analytics algorithms with actionable events

---

9 www.SmartColumbusOS.com

   i. Example: Deploy police to a location, execute a variable speed limit
 c. Data owners could monetize the output and provide it as a new data set
   i. If procuring from third party, the original data owner is tagged to be able to recognize the future use of their data

Through this structure, the companies such as the stakeholders above could utilize the data that is available through DriveOhio's data portal. There have been discussions with OEMs, system integrators and third parties.

DriveOhio utilizes an event streaming platform (ESP) that requires a RESTful WebSocket to provide information to data subscribers. Their new solution will be based on Apache Kafka architecture for publishing, subscribing, and storing data. Subscribers will be required to provide the format in which they want the data to be provided to them and wait for notifications from the data publishers. The DriveOhio platform also performs analysis on published data and provides these insights to subscribers. Filters limit subscribers to only the data that they are authorized to access. These filters are based on the agreements set in place by the subscribers and data providers. The DriveOhio solution can be deployed on any DOT network or multiple DOT's CV data sharing environment can be combined on a single platform. DriveOhio is exploring various data encapsulation options including RESTful API, GraphQL, and even MQTT.

Some issues DriveOhio has encountered when implementing their data exchange include the following:

- Some of the data they received is unreliable
- They need to be able to pull camera feeds to verify the content of data inputted to the system
- Not all signal controllers currently support the sharing of SPaT data
- Having different nodes provide timestamps and synchronization information with different timesources

DriveOhio will be engaged in the CVDF efforts and will watch for integration opportunities.

3.6 Georgia Department of Transportation (GDOT)

GDOT is working with a system integrator, Intelight, to test a data portal that is intended to provide public access to SPaT and Map information for hundreds of intersections in Georgia. Intelight is creating a data portal (currently in the testing phase) that will provide an external web interface that provides SPaT and Map data. The target latency between an Intelight traffic signal controller and an external web interface will be < 1 second at scales of hundreds to thousands of intersections. Data will be provided in a JSON format and will utilize SAE J2735 encoding. See the Intelight section for more detailed information.

3.7 New York City DOT (NYCDOT)

NYCDOT was awarded a CV Pilot Deployment grant from ITS JPO. The New York City CV Pilot aims to improve the safety of travelers and pedestrians in the city through the deployment of CV technologies. This objective directly aligns with the city's Vision Zero initiative, which began in 2014 to reduce the number of fatalities and injuries resulting from traffic crashes.

System engineering documents relating to the program are available here:
https://www.its.dot.gov/pilots/technical_assistance_events.htm

NYCDOT has released a ConOps for their Phase 1, available here:
https://rosap.ntl.bts.gov/view/dot/30881

Open data sharing is not included as a part of the phase 1 efforts for NYCDOT. More information about NYCDOT's CV Pilot Deployment Program is found here:
https://www.its.dot.gov/factsheets/pdf/NYCCVPliot_Factsheet.pdf

3.8 Tampa-Hillsborough Expressway Authority (THEA)

THEA owns and operates the Selmon Reversible Express Lanes (REL), a unique roadway designed to address urban congestion in downtown Tampa. THEA was awarded a CV Pilot Deployment grant as one of the initial three recipients from ITS JPO. THEA is addressing many of the transportation challenges in Tampa through the use of CV technology. Some of the challenges include reversible lanes (with wrong-way driving events), red light violations, pedestrian safety concerns and rear-end crashes with corresponding secondary crashes.

System engineering documents relating to the program are available here:
https://www.its.dot.gov/pilots/technical_assistance_events.htm

ConOps document focusing on Phase 1 of their program is available at this link:
https://rosap.ntl.bts.gov/view/dot/3588

Open data sharing is not included as a part of the phase 1 efforts for THEA. More information about THEA's CV Pilot Deployment Program is found here:
https://www.its.dot.gov/factsheets/pdf/TampaCVPIlot_Factsheet.pdf

4. THIRD PARTIES

Third parties are companies (typically commercial) that are working with states and IOOs to utilize CV data and provide information to vehicles or fleet managers. A company is not considered a third party if the majority of their operational costs are covered by a state or IOO, these would be considered contractors and would already be following the state or IOO data format. The commercial products that are indicated below work strictly within the third party's product framework and no interoperability should be assumed unless otherwise noted.

4.1 Traffic Technology Services (TTS)

TTS is a cloud-based vehicle-to-infrastructure (V2I) company that provides services to insurance companies, automotive original equipment manufacturers (OEMs) and IOOs. Their products include a cloud service that queries IOOs databases for SPaT and Map content. TTS then sends the Map and SPaT to the OEM backend service that then forwards the information to their vehicles based on their geo-referenced location. In 2017, Kapsch TrafficCom invested a stake of ownership in TTS in a move to deploy a worldwide V2I service called Personal Signal Assistant.

https://www.traffictechservices.com/

4.1.1 Stakeholder Response - Traffic Technology Services, Inc.

Company Name: Traffic Technology Services, Inc.

Name of Contact: Kiel ("Kyle") Ova

Position in the Company: CMO

Email Address: kiel.ova@traffictechservices.com

Phone: (503) 785-9268

Names of products/applications: Personal Signal Assistant® - an Information-as-a-Service (IaaS)

Existing standards: All CV applications supported by our product utilize existing Wireless Internet Service Providers (WISPs). Through a project with the city of Mesa, Arizona, an Open Data Portal was created that provides I2V data in a Message Query Telemetry Transport (MQTT) format.

Existing System Engineering docs: Some exist but are not publicly available. Kiel will provide additional points of contact. A simplified application programming interface (API) will be provided by Kiel.

Description of data from States/IOOs: SPaT, Map (where available), static timing plans and min/max time for phases. These are available to TTS through an API integrated into most vendor's traffic signal controllers. Kiel will provide additional details before Final Survey is delivered.

Data Constraints: Status information is critical, within no more than 3-4 seconds from the source. Data must be time-stamped. Second-by-second information is valuable, sub-second is too frequent and is not needed.

Other useful data: Queue lengths, real-time flow rates, information about the equipment that is providing information such as a hardware model, firmware version, relevant configuration information. An indication of the freshness of time synchronization is desirable, synchronization every hour would be valuable. Event-triggers for preemption.

4.2 Connected Signals

Connected Signals provides cloud-based software that collects real-time traffic data collected from IOOs and utilizes it to provide enhanced in-vehicle functionality to subscribing OEMs or third parties. They do this by providing a DOT with a mini-computer (called a V2If) that plugs into the network switch connected to one or more traffic signal controllers and the Advanced Traffic Management System (ATMS). The V2If can be configured to listen for National Transportation Communications for ITS (Intelligent Transportation Systems) Protocol (NTCIP) packets going between the ATMS and the signal controller which it then encrypts and forwards through another Ethernet connection to the Connected Signals cloud server. These packets normally contain signal controller status information that is being reported back to the ATMS. All of this is being done using User Datagram Protocol (UDP) packets being sent between the traffic controller and ATMS and from the V2If to the Connected Signals server. The third parties then can use the information from Connected Signals to provide their users with better services and enhanced features. There are some valuable opportunities for additional data from IOOs, currently the Connected Signals solution is making a best-case estimate of light states. If information such as device state (connected/not connected), future light states, signal timing plans, pedestrian/vehicle calls, preemption, and TSP requests were available, this would be beneficial to Connected Signals, though not required. Connected Signals believes the amount of data traffic created by V2X applications is onerous. For example, SPaT information is produced at a rate of 10Hz but Connected Signals utilizes only 1Hz to support their applications and available bandwidth at scale. Connected Signals' solution is dealing with data volumes in the order of 20 Terabytes per month across their system. Data compression and data volume reduction is performed by the V2If as well as the cloud server. Connected Signals expects to follow the progress of the Connected Vehicle Data Framework.

https://connectedsignals.com/

4.2.1 Stakeholder Response - Connected Signals, Inc

Company Name: Connected Signals, Inc.

Name of Contact: David Etherington

Position in the Company: President

Email Address: ether@connectedsignals.com

Phone: (541) 654-5802

Names of products/applications:

- **EnLighten®:** EnLighten is a free smartphone app that delivers real-time predictive traffic signal information to drivers, including red-light countdowns and enhanced Green Light Optimal Speed Advisory (GLOSA). Works with selected cities that chose to share their information with the public. The information shared between Connected Signals server and EnLighten application is in some proprietary format.
- **EnLighten/BMW:** EnLighten also works on a connected smartphone to provide signal information directly in the infotainment display of appropriately equipped BMWs.
- **SPS:** Connected Signals' Signal Priority System (SPS) provides transit signal priority with existing infrastructure without requiring special-purpose hardware on either the bus or

at the intersection. Our SPS suite also includes a "pedestrian signaling" app that automatically makes pedestrian calls from pedestrians' smartphones as they approach crosswalks. Applications for cyclists and emergency medical services (EMS) preemption are in the works.

- **Real-time predictive signal data**: Connected Signals licenses its real-time, predictive, signal information to connected and autonomous vehicle manufacturers (and other users) in a variety of formats.
- **Live phasemap display tool**: This tool lets traffic management agencies view the live (and predicted) state of their signals through a web-based interface.
- **V2If:** Raspberry PI computer that connects into the network switch at a signal controller. It listens for certain types of packets (NTCIP, SAEJ2735) going across the network, encrypts them and forwards them through a one-way open port in the network firewall to Connect Signals servers for rebroadcasting to their users and clients.

Existing standards: NTCIP, SAEJ2735, ECOM (Siemens proprietary format, requires a license). Connected signals will adjust their products to work in whatever format is being provided to collect the data they require for their models.

Existing System Engineering docs: They do have some internal documentation detailing how their applications and products work but cannot share them.

Description of data from States/IOOs: MAP, SPaT and Phase Diagrams. Especially need MAPs of the intersections along with SPaT data in order to correlate lanes with signals.

Data Constraints: Prefer to have data within 1s of when it was generated to include in their real-time models. Connected Signals have methods to handle bad or late data that can be incorporated into their models. Connected Signals will collect older data to be used in historical modeling.

Other useful data:

- The information being sent from their servers to their applications is in a proprietary format.
- Connected Signals is currently working on providing transit signal priority to vehicles in the city of Arcadia.
- All of their applications work using LTE. Their goal is to keep IOOs from having to deploy roadside equipment.
- V2If if provided free of charge, the IOOs need to only open a single port on their firewall that only allows one-way traffic. Each traffic controller requires a single V2If device. If the traffic controller supports Siemens proprietary data formats, then a licensing fee will need to be paid by the IOO.

4.3 HERE

HERE collects data from vehicle sensors to determine road hazard conditions and relay that information back to its cloud servers through the CV infotainment system. HERE then relays any detected warnings back to vehicles that might be impacted by the hazardous conditions. HERE also collects location data from all its CVs. HERE then uses the data to analyze traffic to give its customers information about congestion conditions along with map data.

https://www.here.com/

4.4 TomTom

OEMs use TomTom's CV services to provide its drivers with maps over a cellular connection to in-dash infotainment systems or smartphone application. TomTom generates these maps by collecting sensor information from devices running its software or through data shared by their partners. TomTom also use satellite imagery and community support to continuously update its maps.

https://www.tomtom.com/en_us/

4.5 DeepMap

Using LiDAR sensors (a technology that uses laser light to measure the relative position of physical objects within the senor's field of view) mounted on vehicles that collect point cloud data, DeepMap generates full 3D Maps for automated vehicles. These maps contain landmarks that vehicles can match with their own sensor data that is gathered in real time. The vehicle can then determine where it's located within the map based on the distance information between itself and the landmarks.

https://www.deepmap.ai/

4.6 Uber

Uber is a ridesharing company that develops and supports an application that connects private drivers with customers. Customers can request a ride from their current location to their desired location by using the Uber app on their smartphone. The app then routes the customer's request through an LTE or Wi-Fi connection to the Uber services that then selects a driver currently operating within the customer geographical area and sends the customers location along with a route to get to them. When the driver picks up the customer, they are then given a route to the customer's desired location. Uber is currently parting with OEMs in developing ridesharing technology that operates with automated vehicles.

https://www.uber.com/newsroom/toyota-denso-and-softbank-vision/

4.7 Google

Google collects vehicle localization data and users driving habits through other third-party vendors or cell phones running its Android OS. Google then provide the information to insurance companies that apply it in their risk models in deciding insurance premiums for individuals.

Through Google's Internet of Things (IoT) platform, vendors can track their packages while they are on the trucks out for delivery.

https://cloud.google.com/solutions/designing-connected-vehicle-platform

4.8 Live Traffic Data

Live Traffic Data (LTD) provides a data portal for live traffic through partnerships with traffic agencies and Traffic Management Centers (TMCs). LTD provides hardware that connects intersections wirelessly and provides performance measurement software to monitor and adjust traffic signal timing.

https://www.livetrafficdata.com/

4.9 TransCore

TransCore offers a software product called TransSuite, an ATMS which integrates with traffic signal controllers, freeway management sensors, ramp meter sensor, CCTV, incident management and response, and center-to-center interfaces. TransSuite is modular, customizable and based on published standards. It offers a Graphical User Interface (GUI) with high-resolution graphics in an easy-to-use environment.

https://www.transcore.com/its/transsuite

4.10 Inrix

Inrix develops analytic software for several industries including retail, insurance, advertising, media and automotive. By analyzing traffic data on congestion and roadwork, Inrix delivers estimated time of arrivals (ETA)s to its customers. Inrix roadway analytics tool is a cloud-based software that analyzes traffic data from public agencies to provide graphical representations of performance to be used to plan adjustments to roads.

http://inrix.com/

4.11 Denso

Denso uses CV telemetry data and a simulation environment to recognize and predict hazardous conditions, ETAs, and congested roadways. Denso then can relay that information back to their users who may use it in deciding their travel plans.

https://www.denso.com/global/en/innovation/technology/maas/

4.12 HNTB Corporation

HNTB provides infrastructure solutions to public and private organizations. HNTB have partnered with multiple companies and organizations in bringing intelligent transportation systems to cities. Recently, HNTB has worked with THEA in deploying dedicated short-range communication (DSRC) devices in downtown Tampa. Tampa currently has ten buses, eight streetcars, and 1000+ vehicles equipped with on-board units (OBUs) along with 46 roadside units (RSUs). HNTB has also been awarded a contract from the Florida department of transportation (FDOT) to support automated vehicle development within Florida.

http://www.hntb.com/Newsroom/Media-Kits/Intelligent-Transportation-Systems

https://www.tampacvpilot.com/

4.12.1 Stakeholder Response – HNTB Corporation

Company Name: HNTB Corporation

Name of Contact: Steve Johnson

Position in the Company: Associate Vice President

Email Address: stejohnson@HNTB.com

Phone: (813) 498-51111

Names of products/applications: HNTB does not offer any products. HNTB offers program and project management services in connected and automated vehicles. Current applications being developed, deployed and tested in the USDOT CV Pilot in Tampa, FL include FCW, PCW, EEBL, ERDW, VTRFTV, TSP, I-Sig, MMITSS, IMA.

Existing standards: The applications being deployed in Tampa support the following standards:

- SAE - J2735, J2945 and J3061
- IEEE 1609.2 and 802.11p
- NIST - 800-53 and 800-60
- FIPS 199, 200 and 140-2

Existing System Engineering docs: No response

Description of data from States/IOOs: No response

Data Constraints: No response

4.13 Miovision

Through Miovision TrafficLink hardware and software, IOOs can manage their traffic signals to reduce congestion and identify potential issues. Miovision also sell cameras that record traffic data and store it in their cloud servers where it can be accessed by their customers. Miovision's DataLink portals generate reports and visuals traffic engineers can use in their project plans.

https://miovision.com/

4.13.1 Stakeholder Response - Miovision Technologies

Company Name: Miovision Technologies Inc.

Name of Contact: Jan Bergstrom

Position in the Company: Director of Product Management

Email Address: jbergstrom@miovision.com

Phone: Not provided

Names of products/applications: Miovision Labs

Existing standards: We have done some early work in this area (under our Miovision Labs brand), but not enough that it is formalized in our products.

Existing System Engineering docs: Response pending

Description of data from States/IOOs: Response pending

Data Constraints: Response pending

Other useful data: Response pending

4.14 Applied Information

Applied Information created an app called TravelSafely that runs multiple vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I) and vehicle-to-pedestrian (V2P) safety applications that communicates over LTE. The app tracks the user location and relays surrounding signal information to the user. Based on the telemetry data from the user's phone, the app may display traffic signal information, school zone, and curve warnings. If other users of TravelSafely are around, then the app may display pedestrian or rear-end collision depending on the localization information from each phone.

https://appinfoinc.com/

4.15 Qualcomm

Qualcomm offers both C-V2X and DSRC chipsets for OEMs and third-party companies. Qualcomm partners with multiple OEMs including Nissan, Ford and Audi.

https://www.qualcomm.com/

4.16 SiriusXM

SiriusXM offers automotive dealers' connection to Sirius customers to driver's service reminders, recall notifications, and maintenance information directly to the customer smartphone. Sirius customers will also be able to track their vehicle location from their app and operate some of the smart home devices directly from their vehicle. SiriusXM are also partnering with credit card companies to create an electronic payment the driver can use from their vehicles to pay for tolls, locate and pay for parking, and prepay for gas.

http://investor.siriusxm.com/investor-overview/press-releases/press-release-details/2018/SiriusXM-Launches-New-Connected-Car-Solutions-for-Automotive-Dealers-and-Their-Customers/default.aspx

https://www.bloomberg.com/research/stocks/private/snapshot.asp?privcapid=244621875

4.17 Voyage

Voyage offers leases for autonomous vehicles to communities for ridesharing and taxi applications. Voyage retrofits hybrid mini-vans with LiDAR sensors and cameras to detect objects around them. The sensors run Voyages custom suite of automated vehicle software. Currently, Voyage vehicles are deployed in two retirement communities in the US.

https://news.voyage.auto/introducing-the-voyage-g2-autonomous-vehicle-5e15cca399b5

4.18 MH Corbin

MH Corbin provides ITS products which gather, analyze and communicate information from roadway equipment in real-time. Both hardware and software are provided by MH Corbin. Hardware products include wireless pavement sensors, weather sensors, electro-optical sensors, and RSUs (under the brand Connect:ITS and through a partnership with Kapsch). The IntelliZone ITS software integrates sensors, DMS, Highway Advisory Radio (HAR) and data analytics in order to provide warnings to motorists over various technologies.

http://mhcorbin.com/

4.18.1 Stakeholder Response - MH Corbin LLC

Company Name: MH Corbin LLC

Name of Contact: Bill Corbin

Position in the Company: President

Email Address: bcorbin@mhcorbin.com

Phone: (614) 873-5216

Names of products/applications:

- **Vulnerable road user detection**: Use camera analytic (and potentially LiDAR) data to broadcast safety messages such as Personal Safety Messages (PSM) and BSMs containing the location of pedestrians, bicycles, and other non-connected moving objects.
- **Signalized Intersections**: Kapsch partner application takes phase and timing data from the Traffic Controller, converts into SAE J2735 format to provide motorists with light timing (SPaT) and intersection geography (Map).
- **Hazards and Alerts**: Use of weather or other sensors to warn motorists of hazardous conditions (ice, reduced visibility, hydroplane, crosswinds) or temporary road situations (train approaching, work zone, disabled vehicle).
- **GPS Correction**: Gather correction data from Continuously Operating Reference Station (CORS) networks, convert into SAE J2735 for increased GPS accuracy.
- **Wrongway Vehicle**: Upon detection of a vehicle driving the wrong way, send out [a J2735 informational message] and activate various notification methods including email, flashing beacons, Dynamic Message Signs (DMS), remote relay, etc.
- **Queue Detection:** Upon detection of a vehicle queue, send out [J2735 informational messages] and activate various notification methods including email, flashing beacons, DMS, remote relay, etc.
- **Work-zone Intrusion:** If a vehicle enters the warning area, trigger an alarm for X seconds.

Existing standards: SAE J2735, IEEE 1609

Existing System Engineering docs: REST API for system integration.

Description of data from States/IOOs: MH Corbin device communicates directly with weather and traffic sensors using the manufacturer supplied protocols. The traffic data consists of object detection while weather data is environmental and surface observations. Most supply data over RS232/485 serial links while others use IP or 900 MHz wireless links.

Data Constraints: The device does not have any time constraint. MH Corbin stores short term data in a local database and can use push/pull methodologies for the analysis.

Other useful data: Not provided.

4.19 Waze

Waze (owned by Google) is a crowdsourced traffic, navigation, and rideshare app that runs on the user's phone. The app can be connected to a vehicle’s infotainment system to provide Waze with more information from the vehicle's sensors. Waze can use this data to sense hazardous road conditions and alert the driver or other Waze users. The app can tell the driver if they will need to find a gas station before reaching their destination and identify the closest refueling station to the user’s route. Waze can also connect users who have similar travel routes and schedules. Users can then coordinate carpooling together if they desire.

https://www.waze.com/

4.19.1 Waze Connected Citizens

Waze provides a two-way data exchange for IOOs to access Waze's database of information. This allows the IOOs to receive alerts that were generated on the Waze platform along with Waze's collection of traffic data that can be used in the future planning of roadway construction. IOOs have the option of either providing Waze with information using a web-based data feed or through their suite of tools that IOOs can use to manually update information stored in Waze databases.

In return, the IOOs also give Waze access to information regarding any road closure, reported construction, or crash report data which Waze can then share with their users. Waze offers a GeoRSS feed to its partners that gets updated every two minutes. This feed contains XML/JSON encoded content of data in a specific geographical region.

https://support.google.com/waze/partners/answer/9314915?hl=en&ref_topic=9313717

https://web-assets.waze.com/partners/ccp/WAZE-CCP-Factsheet.pdf

The information shared through Waze does not include SPaT information. All information related to maps is provided through crowd-sourced editing of map data by volunteers that are utilizing the online Waze Map Editor tool[10]. Waze users can indicate that a road is incorrectly mapped and share a GPS track in the region under question. Waze contributors can then view the existing map and the GPS track and attempt to address any discrepancies. See Figure 7 for a screenshot from the community map-editing tool.

10 https://www.waze.com/editor

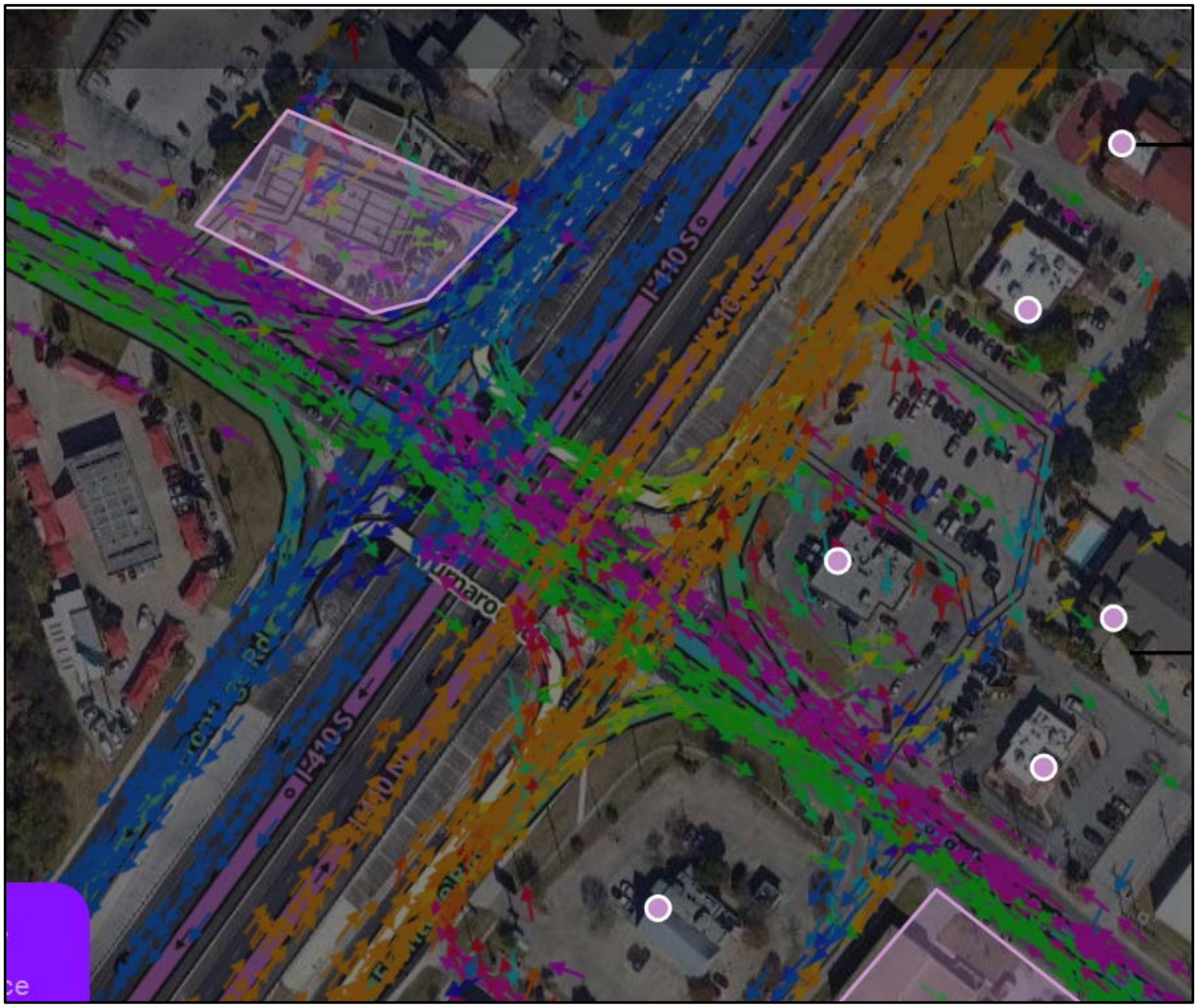

Figure 7: Waze map-editing tool that is available to registered users.

4.20 IBI Group Inc.

IBI offers a suite of software that their customers can use to report traffic conditions to their users. IBI ATMS allows IOOs to monitor video feeds, interface with roadside hardware and monitor traffic conditions.

https://www.ibigroup.com/

4.20.1 Stakeholder Response - IBI Group

Company Name: IBI Group

Name of Contact: Mike Corby

Position in the Company: Director / Office Lead

Email Address: mcorby@IBIGroup.com

Phone: (905) 763-2322 extension 63401

Names of products/applications: not provided

Existing standards: not provided

4.21 Splunk

Splunk serves as an analytical software platform which provides the capability to consume, analyze and visualize machine-generated data from multiple sources. Data input includes websites, applications, sensors, etc. Real time processing is Splunk's biggest selling point. Formatting is not a constraint, as Splunk allows data formats to be defined. Splunk can provide alerts or events based on specific triggers. Prediction of resource needs is also an output. Bosch (another stakeholder) has utilized Splunk to perform data analysis, in the medical domain.

https://www.splunk.com/

5. SYSTEM INTEGRATORS

System integrators are companies (typically commercial) that are performing many of the same business operations as third parties and, in addition, are developing hardware that enables additional data gathering and data distribution to vehicles. Additional information from system integrators will continue to be requested by SwRI through the course of the Task 3 efforts and responses will be shared with the CV PFS team.

5.1 eTrans Systems

eTrans Systems (owned by Kapsch TrafficCom) sells a software suite that works on multiple vendors' OBUs and connects to drivers' smartphones through an app to provide users with alerts. eTrans also develop RSUs that utilize DSRC. eTrans' equipment operate as proxy units that forward any messages it receives from and to the cloud server so that the data processing is not handled by the RSU. eTrans cloud server can also be used to track fleets of vehicles or allow customers to request a ride.

http://www.etranssystems.com/#av_section_3

5.2 Intelight

Intelight is both a hardware manufacturer and software developer specializing in traffic signal technology. Intelight signal controllers follow multiple technical standards which allow them to be integrated with other systems. Intelight also sells traffic control modules that interface with RSUs allowing the transmission of Map and SPaT messages populated by the traffic controller. The RSU can also forward incoming BSMs to the traffic controller which can then pass the messages along to the ATMS where it can be decoded and analyzed.

https://www.intelight-its.com/

5.2.1 Stakeholder Response – Intelight

Company name: Intelight

Name of contact: Grant Gardner

Position in the company: Vice President Engineering

Email address: grant.gardner@intelight-its.com

Phone: none provided

Names of products / applications that are currently offered by your company that provide data to vehicles / devices. Maxview CV is the outward facing portal product

Existing standards that are used by the application (other than network standards like HTTPS or TLS or formatting standards like HTML) to provide data from a back-end data source to a vehicle or device? JSON (data format) with a RESTFUL interface (resource based) – GraphQL (way that the data messages are grouped and published and subscribed as data changes) as API

Are there existing System Engineering Documents (such as Concept of Operations, Systems Requirements or Interface Control Documents) related to your products/applications that can be shared? Yes, an API document will be provided

Please provide a description of the data that is used by your product/application that comes from a State or IOO. Include relevant formats where appropriate. Data is available from Intelight's equipment directly, States or IOOs interact with Maxview CV by entering intersection information and verifying data.

Are there constraints to the data regarding accuracy or timeliness that will need to be considered? Outgoing data is expected to have processing latency of less than 10 milliseconds, network latency on a fiber backhaul is expected to be less than 100 milliseconds.

What additional data what would be useful to you? Activation (state) of traffic detectors, this is in development.

A phone interview and interactive screen sharing session was conducted with Intelight, where Grant provided a walk-through of their outward facing data portal called Maxview CV. A product demo can be viewed here: https://maxview.intelight-dev.io/cv/ with credentials of admin/admin. Maxview CV provides real-time SPaT and Map as a visual layer using a real-time connection to the Intelight equipment that is deployed in the field. Maxview CV also provides an

API that third parties can consume. Intelight can provide an API document for the Maxview CV product. Maxview is an aggregator of device management, CV data collector, ATMS and Analytics Engine. Regarding Map messages, Maxview CV incorporates the capabilities of the USDOT ISD Message Creator web-based application.[11] Additional metadata about intersections can also be created in the Maxview CV interface, such as connections between intersections, location of detectors and phases within the intersection. Using this interface, Map messages for each intersection and the whole network of intersections can be generated and distributed to signal controller equipment as well as externally to users of the data portal.

Data is provided over a RESTFUL API using GraphQL and formatted in JSON (see Figure 8). Data is updated in real-time using a publish-subscribe mechanism between the server and Intelight field devices. Field devices are listening for websocket connections over an Ethernet interface. This allows the server to initiate connections from anywhere, and updates are provided based on changes to the requested data. The data that is provided is very similar to SAE J2735 messages such as SPaT and Map but with additional metadata and different structures. This data is then available from the server as JSON formatted data. Some metadata (such as a specific traffic signal controller's software version) is available on the server side but is not exposed outwardly over JSON.

5.2.1.1 Recommended Encoding Format

From Intelight's perspective, the order of preference from least preferred to most preferred encoding format would be:

- UPER encoding
- XER encoding
- ASN.1 formatting
- SAE J2735 data
- JSON

[11] https://webapp.connectedvcs.com/isd/

```
{
  "nodes": [
    {
      "id": 1,
      "number": 1,
      "name": "Bell Street and 4th Avenue",
      "host": "embedded.inteligt-dev.io",
      "productKeys": [
        "maxview",
        "cv",
        "analytics",
        "adaptive"
      ],
      "lon": -122.344138207074,
      "lat": 47.6152885081165,
      "legs": []
    },
    {
      "id": 2,
      "number": 2,
      "name": "Blanchard Street and 7th Avenue",
      "host": "embedded.inteligt-dev.io",
      "productKeys": [
```


Figure 8: JSON formatting of map information from Intelight

5.3 Econolite

Econolite builds traffic signal controllers and generate and provide CV information such as SPaT and Map messages, and distribute this information to back-end ATMS and to RSUs. Econolite also supplies various other roadside sensors for vehicle and pedestrian detection that tie into their traffic controllers. Econolite's suite of ATMS software allows IOOs to interface with traffic controllers and roadside sensors from a remote location.

Econolite is pushing for a standard among the signal controller community with a focus on deciding on a format for which data can be collected from signal controllers for V2X applications. This standard will be a mapping of NTCIP MIBs to SAE V2X standard messages, and builds upon the J2735 standard. This standard is being championed by Econolite's Chief Technology Officer, Eric Raamot. Data normalization is an important component of the work done to-date, as much of the NTCIP data is phase-centric (relative to the internal traffic signal phases and wiring in the traffic controller), but the CV applications and SAE J2735 data elements utilize intersection-centric data (relative to location-based and real-world information such as the GPS position of lanes or the color of the traffic signal). Data fusion will be a necessary component of this effort as well, as the information to fill in these missing data elements is expected to draw from a variety of sources. The major challenge for the data standardization would be the standardized testing and characterization of the data, which would need to be verifiable and repeatable. It is expected that the standardization effort will start as a J2945/X data normalization standard, and then get incorporated into SAE J2735. The effort to create an NTCIP MIB to SAE mapping is aligned with the Connected Vehicle Data Framework (though the CVDF would not require data normalization), and standardization through ITE, SAE, AASHTO and other SDOs is being considered.

https://www.econolite.com/

5.4 Centracs

Centracs is an ATMS that is offered by Econolite that interacts with field equipment and provides a GUI representation of the equipment, tools and status of traffic within the region. Centracs utilizes a client-server architecture with scalability through distribution of processes. Customized configurations of Centracs are supported through this architecture. The software integrates in real-time to traffic detection sensors, performs data analytics on the sensor data in order to send alerts and coordinate responses. Centracs partners with Savari in order to connect Econolite's Cobalt line of traffic signal controllers with Savari's Streetwave RSU and Mobiwave OBU.

https://www.econolite.com/products/software/centracs/

5.5 Siemens

Siemens builds three classes of OBUs and an RSU. The class 1 OBU is meant to be installed on factory new vehicles while class 2 is an aftermarket unit. The class 3 OBU is an adaptor for smartphones which allows them to transmit on the 5.9 GHz bandwidth. Each OBU/RSU runs applications that handle the transmission and reception of the SAE J2735 message set.

https://w3.usa.siemens.com/mobility/us/en/road-solutions/traffic-management/pages/connected-vehicle.aspx

5.6 TACTICS

TACTICS is an ATMS that is developed by Siemens. It provides web-based traffic management capabilities while advertising reliability, scalability and usability. The ATMS manages field devices, monitors system status, provides the ability to update firmware (and schedule future updates), perform data analytics and search and filter information. YAML formatting is used to simplify the formatting of configuration parameters. Remote communication to field equipment is supported by the TACTICS smartGuard product which supports remote access on internet connected devices including desktops, smart phones or properly equipped tablets. Viewing of the status of field devices is available by authenticating using a username and password. Two Factor Authentication (2FA) is used to authenticate any requests to change configurations.

https://w3.usa.siemens.com/mobility/us/en/road-solutions/traffic-management/pages/tactics.aspx

5.7 Panasonic

Panasonic has created CIRRUS, a vehicle-to-everything (V2X) ecosystem that allows IOOs and users to share information through RSUs and OBUs. Panasonic has been working with Colorado DOT since 2017 to deploy CV technology along the I-70 corridor between Denver and Vail. This deployment includes 100 RSUs along I-70, and almost 100 vehicles outfitted with V2X equipment. Additionally, they were awarded a system integration contract by UDOT for their CIRRUS platform. Panasonic is working with UDOT to deploy the CIRRUS platform in support of UDOT efforts, with 16 miles of roadway covered by 10 RSUs and almost 50 OBUs in various vehicles in Utah.

CIRRUS is hosted in the cloud as an Amazon Service using Amazon Web Service (AWS). They are leveraging both GraphQL and RESTful API interfaces. An Amazon module called a Polling Center acts as the central source for correlating all of the data that is collected from the various deployments. Applications such as Crash Detection and Spot Weather Warning are implemented. Additional applications such as Data Visualization, Queue Warning, Red Light Violation Warning, and Curve Speed Warning are in the project plan, and custom third-party applications can be developed using an SDK created by Panasonic.

With regards to data communication, currently the CIRRUS system collects BSMs from RSUs and integrates these with weather station data. Additionally, advanced BSM information can be gathered and stored in the CIRRUS platform based on data-gathering agreements with OEM partners. Data from vehicles is being gathered through both DSRC communication as well as LTE communication. The Probe Vehicle Data message is providing Panasonic with the data necessary to create a virtual representation of traffic conditions. SPaT and Map information is not currently integrated into CIRRUS. Data can be queried from the CIRRUS system using the AWS API. Plans are in place to incorporate V2X applications into CIRRUS including curve speed warning and spot weather warning, under an ATCMTD project with UDOT in June/July in 2020. Panasonic will provide an SDK that allows third parties to develop their own applications that can be incorporated with the CIRRUS platform. Data is consumed by the CIRRUS system as raw UPER encoded packets that are then decoded and transformed into JSON. The data is stored and provided in a JSON format through a GraphQL query.

They also have been working with additional stakeholders including third-party companies that are consuming the data and RSUs manufactures that may incorporate the CIRRUS system with their hardware. The goals of CIRRUS and the Connected Vehicle Data Framework are aligned well, and Panasonic expects to stay engaged as standardization progress continues.

https://na.panasonic.com/us/intelligent-transportation

5.8 Trihydro

Trihydro, a private engineering consultation company, has assumed management and expansion of the USDOT ODE. As an initial implementation, Trihydro established a Situation Data Exchange through the WYDOT CV Pilot that integrates with the USDOT Data Warehouse. In the future, Trihydro plans to distribute Map and road construction information through the Work Zone Data Exchange project being sponsored by the USDOT[12]. SPaT messages are generated using signal controllers under WYDOT control and then uploaded to the data exchange through the TMCs. Security and validation of SPaT message are handled by the TMCs. Information on low bridge heights, curve speed warnings, broken down vehicles, and truck parking are distributed through the Situation Data Exchange. Geofencing limits what information can be uploaded by data providers as well as the data that users can receive. Information collected by the data exchange is not altered or analyzed, no normalization is being performed on the data itself.

In addition to SPaT messages, TIMs are also generated and stored on the data exchange using 511 alerts uploaded on WYDOT website. A RESTful API service subscribes to the 511 alerts to generate the TIMS. Trihydro will convert the TIMs to Roadside Safety Alerts (RSAs) once the standard for RSAs is finalized. Data is also collected from snowplows and provided to WYDOT's Pikealert system, where TMC operators can generate TIMs used in road condition monitoring systems. The TMC operators generate the alerts using a web-based API. Some Lear and SiriusXM units are already configured to receive the alerts and distribute them to their users. The RESTful API[13] is aligned well with the CVDF efforts, and Trihydro has indicated their interest in following the progress of the standardization efforts.

5.9 Bosch

Bosch produces a hybrid OBU that supports DSRC, cellular vehicle-to-everything (C-V2X), Wi-Fi, and LTE communications. The OBU prioritizes each communication interface before implementing them to ensure communications remains stable when switching between them. Bosch also supports Over-the-air OTA updates to vehicles through their cloud service connecting to their OBUs. Bosch also provide weather information, emergency calls, and wrong-way driving alerts to vehicles using its OBU.

https://www.bosch-mobility-solutions.com/en/products-and-services/passenger-cars-and-light-commercial-vehicles/connectivity-solutions/v2x-connectivity-control-unit/

6. OEMS

6.1 Ford

Ford collaborates with Qualcomm in order to enable connectivity to their vehicles over C-V2X technology. We have reached out to our contacts at Ford to request additional insight into Ford's

---

[12] https://www.transportation.gov/sites/dot.gov/files/docs/policy-initiatives/automated-vehicles/325341/work-zone-data-exchange-overview.pdf

[13] https://sdx-service.trihydro.com/index.html

efforts with regards to data sharing from IOOs. Ford is developing their own V2X system in their vehicles using LTE and C-V2X communication. They do not plan to allow third parties to deploy their own applications in their vehicles. We anticipate being supported by Ford as we proceed in this project.

https://www.qualcomm.com/news/releases/2018/01/09/qualcomm-and-ford-collaborate-c-v2x-global-initiative-improve-vehicle

6.2 BMW

BMW uses information from Connected Signals to provide their drivers with predictions of traffic signals. BMW was the first OEM to leverage this information from Connected Signals' EnLighten app. BMW integrated the information into their infotainment screens in their iOS supported vehicles. See the Connected Signals section above for additional information.

https://www.bmw.com/en/index.html

6.3 Audi

Audi displays information from IOOs to their drivers through a data feed from TTS. This information includes the predicted state of the traffic signals ahead of the Audi. The Audi feature is called Traffic Light Information and was launched in 2016. Both time to green and green speed applications are targeted as valuable applications for drivers. The compatible cars receive real-time traffic signal data from enabled AMTS and utilize a 4G LTE data connection.

https://www.audiusa.com/newsroom/news/press-releases/2016/12/audi-launches-vehicle-to-infrastructure-tech-in-vegas

6.4 Toyota

As CV PFS team members, Toyota will be engaged with the efforts for this project. We will be integrating feedback and information from Toyota as we receive it for use in the Task 3 efforts.

6.5 GM

As CV PFS team members, GM will be engaged with the efforts for this project. We will be integrating feedback and information from GM as we receive it for use in the Task 3 efforts.

6.6 Nissan

As CV PFS team members, Nissan will be engaged with the efforts for this project. We will be integrating feedback and information from Nissan as we receive it for use in the Task 3 efforts.

Appendix A – XER Map Example

The text below is an example of a Map message in XER format that was extracted and converted from the SmarterRoads website.


```
rec1value MessageFrame ::= {
messageId 18,
  value MapData : {
    msgIssueRevision 0,
    intersections {
      {
        id {
          id 113
        },
        revision 0,
        refPoint {
          lat 498557400,
          long 85880335
        },
        laneWidth 366,
        laneSet {
          {
            laneID 1,
            laneAttributes {
              directionalUse '01'B,
              sharedWith '0000000000'B,
              laneType vehicle : '00000000'B
            },
            maneuvers '011000000000'B,
            nodeList nodes : {
              {
                delta node-XY6 : {
                  x 2025,
                  y -915
                }
              },
              {
                delta node-XY6 : {
                  x 5215,
                  y -5545
                }
              }
            },
            connectsTo {
              {
                connectingLane {
                  lane 2,
                  maneuver '001000000000'B
                },
                signalGroup 1
              },
              {
                connectingLane {
                  lane 3,
```

```
                maneuver '010000000000'B
              },
              signalGroup 2
            }
          }
        },
        {
          laneID 2,
          laneAttributes {
            directionalUse '01'B,
            sharedWith '0000000000'B,
            laneType vehicle : '00000000'B
          },
          maneuvers '101000000000'B,
          nodeList nodes : {
            {
              delta node-XY6 : {
                x -1250,
                y -1000
              }
            },
            {
              delta node-XY6 : {
                x -7420,
                y -5815
              }
            }
          },
          connectsTo {
            {
              connectingLane {
                lane 4,
                maneuver '001000000000'B
              },
              signalGroup 3
            },
            {
              connectingLane {
                lane 2,
                maneuver '100000000000'B
              },
              signalGroup 4
            }
          }
        },
        {
          laneID 3,
          laneAttributes {
            directionalUse '01'B,
            sharedWith '0000000000'B,
            laneType vehicle : '00000000'B
          },
          maneuvers '110000000000'B,
          nodeList nodes : {
```

```
              {
                delta node-XY6 : {
                  x 1330,
                  y 1540
                }
              },
              {
                delta node-XY6 : {
                  x 5275,
                  y 4295
                }
              }
            },
            connectsTo {
              {
                connectingLane {
                  lane 3,
                  maneuver '100000000000'B
                },
                signalGroup 5
              },
              {
                connectingLane {
                  lane 4,
                  maneuver '010000000000'B
                },
                signalGroup 6
              }
            }
          }
        }
      }
    }
  }
}
```