Connected Vehicle Pilot Deployment Program Phase 3

Comprehensive Transition Plan (CTP) – Tampa (THEA)

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16. Abstract

This Comprehensive Transition Plan (CTP) describes how the Tampa Hillsborough Expressway Authority (THEA) will transition from the end of the Connected Vehicle Pilot Phase 3 to continued support of the deployment area.

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Acronyms

ACM	American Center for Mobility
ATCMTD	Advanced Transportation and Congestion Management Technologies Deployment
BOD	Board of Directors
BSM	Basic Safety Message
CAN	Controller Access Network
ConOps	Concept of Operations
CoT	City of Tampa
C-V2X	Cellular – Vehicle to Everything
CV	Connected Vehicle
CUTR	Center for Urban Transportation Research
CVRTS	Connected Vehicle Real-world Test Site
DMS	Dynamic Message Sign
D7	District 7
DSRC	Dedicated Short Range Communications
DTP	Deployment Transition Plan
EEBL	Electronic Emergency Brake Light
ERDW	End of Ramp Deceleration Warning
FCW	Forward Collision Warning
FDOT	Florida Department of Transportation
FRAME	Florida's Regional Advanced Mobility Elements
HART	Hillsborough Area Regional Transportation
HMI	Human Machine Interface
IMA	Intersection Movement Assist
IOO	Infrastructure Owner Operator
IP	Intellectual Property

ISS	Integrity Security Systems
NOFO	Notice of Funding Opportunity
OBU	Onboard Units
OEM	Original Equipment Manufacturer
ORP	Operational Readiness Plan
OTA	Over the Air
PCW	Pedestrian Collision Warning
PDETM	Probe Data Enabled Traffic Monitoring
Ped-Sig	Mobile Accessible Pedestrian Signal
PED-X	Pedestrian in Signalized Crosswalk Warning
PII	Personal Identifiable Information
PMP	Project Management Plan
PTMW	Pedestrian Transit Movement Warning
ROW	Right of Way
RLVW	Red Light Violation Warning
RSU	Roadside Units
SCMS	Security Credential Management System
SDC	Secure Data Commons
SRM	System Request Message
SSM	System Status Message
SyRS	System Requirement Specification
TSP	Transit Signal Priority
THEA	Tampa Hillsborough Expressway Authority
USDOT	United States Department of Transportation
USF	University of South Florida
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
VTRFTV	Vehicle Turning Right in Front of Transit Vehicle

WWE	Wrong Way Entry

1. Introduction

The Tampa Hillsborough Expressway Authority (THEA) is nearing the completion of its Connected Vehicle (CV) Pilot Project. Phase 3 of the CV Pilot completed in September 2020. For the last five years, THEA has successfully implemented all the Phases of the project. From September 2015 to August 2016, THEA completed Phase 1 Planning. Near the end of Phase 1, THEA was awarded the project for Phase 2 and Phase 3. Phase 2 Design and Deploy began in September 2016 and completed in February 2019. Phase 3 Operate and Maintain began in October 2018 overlapping with Phase 2 and completed in September 2020.

As THEA moves toward completion of Phase 3, THEA is implementing the transition of the CV Pilot from its current form to a CV Real-world Test Site (CVRTS). As such, the United States Department of Transportation (USDOT) executed an amendment to the existing CV Pilot. THEA has begun the initial Planning for the CVRTS. In Phase 4, THEA will deploy additional Roadside Units (RSUs). These RSUs will be dual mode; allowing them to broadcast messages on Dedicated Short Range Communications (DSRC) and Cellular Vehicle to Everything (C-V2C) individually. THEA plans to install a Spectrum Interference Testing Station (SPITS). THEA will be open for USDOT, device manufacturers, Original Equipment Manufacturers (OEMs) and others to come and test in the CV operational environment. Phase 4 will showcase the involvement of three OEMs, Hyundai, Honda, and Toyota. Each of these OEMs will actively participate in Phase 4 working with THEA to deploy their Onboard Units (OBUs) in their customer's vehicles. THEA will continue to utilize the existing participants as well. The goal is to have 600 vehicles participate; 400 existing participants and 200 OEM participants. These participants will be recruited from the existing participants where THEA is offering a $550 toll rebate as they did during the initial CV Pilot. Additional participants will be recruited from the list of drivers who use the Reversible Express Lane (REL) as in the initial CV Pilot. In the initial CV Pilot, THEA had over 5,000 people express interest in participating in the CV Pilot. However, due to multiple delays in the project, deployment of the OBUs was delayed multiple times causing people to lose interest and drop out. For Phase 4, THEA will build on these lessons learned to retain the existing participants by engaging them early to keep them in the CV Pilot with the incentive of the $550 toll rebate and an upgraded OBU.

The OEMs have agreed to develop six CV Pilot applications. They are:

- Forward Collision Warning (FCW)
- Electronic Emergency Brake Light (EEBL)
- Intersection Movement Assist (IMA)
- Wrong Way Entry (WWE)
- End of Ramp Deceleration Warning (ERDW)
- Pedestrian Collision Warning (PCW)

A seventh application, Red Light Violation Warning (RLVW) is being implemented by the OEMs.

The OEMs have selected Denso as their common OBU supplier. As such, THEA and its partners do not expect any interoperability issues between the OEMs. As for the OEM OBUs and the CV Pilot OBUs, Hyundai was included in the CV Pilot in Phase 3. During this time, Hyundai, working with Denso, developed FCW, EEBL, and IMA. These applications were tested for interoperability with CV Pilot OBUs at the American Center for Mobility (ACM). Brandmotion provided the CV Pilot OBUs with which the tests were performed. Results verified that all vehicles received BSMs correctly and issued the appropriate warning.

The remaining applications are Vehicle to Infrastructure (V2I) applications and do not require Vehicle to Vehicle (V2V) interaction.

Phase 4 of the CV Pilot will continue to operate as it did in Phase 3 using DSRC as the communication medium as directed by USDOT. Data will be received from the original participants vehicles, sent to the University of South Florida (USF) Center for Urban Transportation Research (CUTR). CUTR will sanitize the data, continuing to remove Personable Identifiable Information (PII) and send the sanitized data to the Secure Data Commons (SDC). When the OEM participants are deployed, the Basic Safety Messages (BSMs) will be "sniffed" by RSUs. These BSMs will be packaged and sent to CUTR. CUTR will analyze these BSMs to determine what information can be mined. These BSMs will be sent to the SDCs as well. New performance measures will be developed for OEM vehicle data that is received by RSUs. While this data will not be as robust as the current participant data, it creates new opportunities that were not possible during the prior three phases of the Pilot. For example, the OEM OBUs will be integrated in the vehicle's Controller Access Network (CAN) bus. Access to the CAN bus will provide data in the Basic Safety Message (BSM) Part II (e.g., Vehicle Status and Vehicle Safety Extensions data frames) for analysis of events and activations of vehicle-based systems such as antilock brakes and wiper status.

THEA is planning to expand the deployment area. In a separate project, THEA is partnering with the Florida Department of Transportation District 7 (FDOT D7) to connect the THEA deployment area to FDOT I-4 FRAME project which stretches from Tampa to Orlando along the I-4 corridor. This project is scheduled to kickoff in 2021 as FDOT has just recently began to plan the I-4 FRAME project.

In short, THEA continues to push the technology envelope to be a leader in deploying, operating, and maintaining CV technology. THEA strongly believes communicating with drivers using CV technology is critically important to improving their customers safety and mobility.

1.1. Purpose

The CV Pilot Post Deployment Transition Plan (DTP) describes how THEA will transition from Phase 3 of the CV Pilot project to usher in the next phase to create a live operational test bed environment which includes OEM participation.

1.2. Transition Timeline

THEA started preliminary planning for Phase 4 in June 2020 and expects to complete Part 1 Planning in October 2020 funded by THEA. THEA submitted the proposal to extend the existing Cooperative Agreement for Phase 4 on August 11, 2020 and was granted an extension to proceed with Phase 4. Phase 4 was initiated in September 2020. Phase 4 is a seamless transition from Phase 3 and will overlap for a short time. Phase 4 is scheduled to be completed in 24 months (September 2022).

The THEA/FDOT project, Regional Deployments Connection, is scheduled to start planning in 2021. FDOT initiated its I-4 FRAME project this summer (2020). The THEA/FDOT collaboration is not directly part of the CV Pilot Phase 4 efforts. None of the funds estimated for Phase 4 including any activities with I-4 FRAME. THEA and FDOT has set aside additional funds to collaborate on the THEA's deployment and FDOT's I-4 FRAME deployment. The I-4 Frame project is nearing 60% design. I-4 FRAME plans to initiate infrastructure deployment in mid-2022. Leading up to this deployment, THEA and FDOT will coordinate the connection the CV Pilot to I-4 FRAME, creating a connected corridor from downtown Tampa to Orlando. As FDOT has not finalized their design, there are still several opportunities such as collaborating on data collect that will be considered.

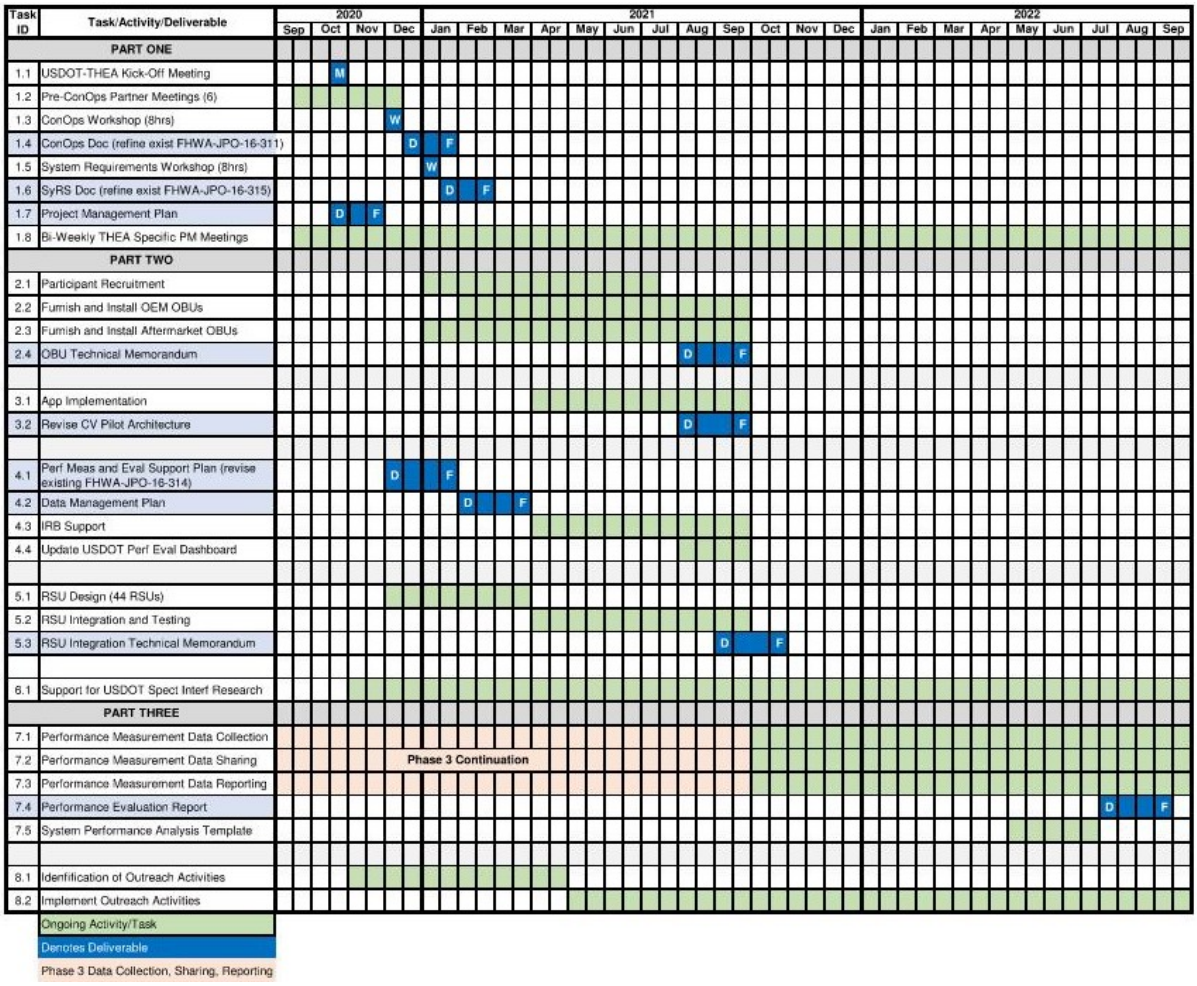
1.2.1. Schedule and Milestone Activities

As Phase 3 concludes and Phase 4 begins, there are several Milestones identified that will transition the CV Pilot from Phase 3 and Phase 4. Table 1 contains a list of the milestones.

TABLE 1 TRANSITION MILESTONE LIST

Phase	Milestone	Date
3	Original Equipment Manufacturers (OEMs); Honda, Hyundai, and Toyota Onboard	March 2020
3	THEA Submitted the Phase 4 Proposal	August 2020
3	Phase 3 Concept of Operations (ConOps) Update	December 2020
3	Phase 3 System Requirements Specification (SyRS) Update	December 2020
4	5 Dual Mode RSUs Procured	October 2020
4	400 OBUs procured	October 2020
4	USDOT-THEA Kick-Off Meeting	November 2020
4	Update Project Management Plan (PMP)	November 2020
4	Purchase Order Issued to DENSO	December 2020
4	Phase 4 ConOps Update	January 2021
4	Phase 4 SyRS Update	February 2021
4	OBU Technical Memorandum	September 2021
4	Revise CV Pilot Architecture	September 2021
4	Perform Measurement and Evaluation Support	January 2021
4	Data Management Plan	March 2021
4	RSU Technical Memorandum	October 2021
4	Support for USDOT Spectrum Interference Testing	TBD/Ongoing
4	Performance Evaluation Report	September 15, 2022
4	Implement Outreach Activities	TBD/Ongoing

Figure 1 shows the initial Phase 4 schedule.



M – Meeting
W- Workshop
D – Draft
F - Final

FIGURE 1 PHASE 4 SCHEDULE

1.3. Roles and Responsibilities

For Phase 4, THEA has largely retained its team with the exception of Global 5. THEA's communications team led by Sue Chrzan will perform the outreach activities. Brandmotion will interact with participants to schedule and support their non-OEM installs. The OEMs are considering using local dealerships as well as Brandmotion to interact with participants to schedule and support OEM installs.

Table 2 shows the team members and their responsibilities.

TABLE 2 - THEA TEAM ROLES AND RESPONSIBILITIES

Team Members	Phase 4 Leads	Project Role
USDOT	Jonathan Walker	COR
THEA	Bob Frey Sue Chrzan	Project Manager and communications and outreach
HNTB	Steve Cyra Elizabeth Putnam Steve Novosad	Program Management and System Engineering Technical Management
Siemens	Dave Miller	Infrastructure Integrator
Brandmotion	Rafal Ignatowicz	In-vehicle Integrator
Center for Urban Transportation Research (CUTR)	Dr. Sisinnio Concas	Data analysis and performance measurement evaluation
Sirius XM	Paul Marko	Non OEM OBU supplier and OBU support
Hyundai	Mahdi Ali	Hyundai project manager
Honda	Sue Bai	Honda project manager
Toyota	Hideki Hada	Toyota project manager

This team has been collaborating for several months in anticipation of Phase 4.

THEA continues to have strong relationships with its stakeholders. Table 3 identifies the stakeholders and their role.

TABLE 3 PHASE 4 STAKEHOLDERS

Stakeholders	Point of Contact	Title
THEA Board of Directors (BOD)	Vince Cassidy	BOD Chairman
THEA	Joe Waggoner	THEA Executive Director
USDOT	Jonathan Walker	COR
City of Tampa	Brandon Campbell	Smart Mobility Manager

Stakeholders	Point of Contact	Title
Hillsborough Area Regional Transportation (HART)	Dexter Corbin	Director of Technology and Innovation
FDOT District 7	Ron Chin	District Seven Traffic Operations Engineer
FDOT Central Office	Raj Ponnaluri	Connected Vehicles, Arterial Management, Managed Lanes Engineer

1.4. Assumptions

This DTP makes the following assumptions

- THEA's BOD approves THEA's portion of the Phase 4 budget.
- USDOT funds Phase 4.
- There will be adequate participants for both OEM and non-OEM OBUs.

1.5. References

TABLE 4: REFERENCE DOCUMENT NUMBER [RDN]

RD	Reference Document
1	Connected Vehicle Pilot Development Program Phase 1 Concept of Operations (ConOps) – Tampa (THEA), Final Report – February 2016, FHWA-JPO-16-311
2	Connected Vehicle Pilot Development Program Phase 1 Comprehensive Pilot Deployment Plan – Tampa (THEA), – August 2016, FHWA-JPO-16-321
3	Connected Vehicle Pilot Development Program Phase 2 Comprehensive Maintenance and Operations Plan – Tampa (THEA), Final Report – May 2018, FHWA-JPO-17-465
4	Connected Vehicle Pilot Deployment Program Phase 2 Operational Readiness Plan (ORP) – Tampa (THEA), Draft Report -May 2019, FHWA-JPO-17-464

2. Communications

As the THEA team and stakeholders are carrying over to Phase 4, all the regularly held internal meetings will remain the same. Currently, there are the following internal meetings:

- Biweekly call with the THEA, HNTB, Brandmotion, CUTR, Siemens, and OBU vendors (Sirius XM only for Phase 4). This call reviews any outstanding issues with the deployment i.e., RSU issues, OBU issues, data issues.
- Monthly project team call with THEA, City of Tampa (CoT), HART, Brandmotion, CUTR, and Siemens. This call provides updates to the stakeholders and discussion of any activities involving the stakeholder.

As the project ramps up, there will be additional internal technical meetings to discuss activities such as Concept of Operations (ConOps), System Requirement Specification (SyRS), design, deployment and others.

Communications with participants will be handled by THEA Communications Director Sue Chrzan and her team. They will continue maintaining the website, sending email updates, producing newsletters, and other participant information. Sue's team will restart the recruiting process as well.

When non-OEM participants arrive at the installation facility, Brandmotion staff will greet them, provide the necessary paperwork, perform training, answer questions, and take care of any other of the participants' needs.

For OEM participants, the OEMs are examining the use of local dealerships to perform installations. Their customer service department will be the interface to the participant. If no dealerships are participate, OEMs will utilize Brandmotion to perform the installation and be the participant interface.

2.1. Key Stakeholders

Table 3 identifies the key stakeholders for Phase 4. The THEA BOD approves and monitors the budget. The BOD meets monthly to review items and approve new task orders. Phase 4 of this project will consist of several task orders such a one for HNTB, CUTR, Siemens, and Brandmotion.

Joe Waggoner is THEA's Executive Director and is responsible for the day to day operations of THEA. Mr. Waggoner approves the Phase 4 budget and associated task orders subject to BOD approval.

Brandon Campbell is COT's Smart Mobility Manager overseeing the traffic signals in the deployment area. THEA and COT will continue their partnership of utilizing COT's intersections in the deployment area. In order to continue to operator seamlessly, THEA will continue to operate and maintenance these RSUs during Phase 4.

Dexter Corbin is HART's Director of Technology and Innovation overseeing the allocation of buses and streetcars for the CV Pilot. While Phase 4 does not have any activities for the buses and streetcars, THEA will continue to provide data that is received to USDOT. As these are Savari OBUs, THEA will work with Brandmotion to engage Savari as needed.

Ron Chin is FDOT District Seven's Traffic Operations Engineer. FDOT was a key partner in the first 3 phases of the CV Pilot providing $500,000 in funding to install video detection along Florida Avenue to support Intelligent Signal System. Moving forward THEA and FDOT D7 will expand their partnership working to connect THEA's CV deployment with FDOT's I-4 FRAME project.

Raj Ponnaluri is FDOT's Central Office Connected Vehicles, Arterial Management, Managed Lanes Engineer. Mr. Ponnaluri will be an active participant in the connection of THEA's CV deployment and FDOT's I-4 FRAME project.

2.2. Public Outreach

THEA Communication Director, Sue Chrzan, will lead the public outreach to participants and media. Sue and her team will coordinate recruitment of existing participants to continue in the CV Pilot Phase 4. THEA will once again offer a $550 toll rebate. Existing participants' vehicles will be analyzed to determine what type of OBU they will be offered. If the participant owns a Honda, Hyundai, or Toyota vehicle and the vehicle meets the OEM criteria, the participant will have an OEM OBU installed most likely at a local dealership. If the participant has another OEM vehicle or does not meet the OEM criteria, the participant will receive an updated CV Pilot OBU. Throughout the course of Phase 4, the communication will provide regular updates to the participants through newsletters, website updates, and other communication mechanisms.

The communication team will handle all communications with the media and public inquiries. The communication team in cooperation with USDOT public outreach will execute press releases, coordinate demonstrations, and conferences.

For Phases 1 through 3, Global 5 Communications performed the Outreach activities under the direction of Mrs. Chrzan. When Global 5 Communications' contract was completed, Global 5 transitioned their materials, website, and other material to Mrs. Chrzan. In cooperation with Brandmotion and THEA's Outreach Consultant, Mrs. Chrzan is performing the outreach activities for Phase 4.

3. Transition Planning

THEA, working with USDOT, extended the CV Pilot to Phase 4. As such, this Transition Plan is focused on moving the CV Pilot into Phase 4 rather than transitioning the CV Pilot to operations and maintenance. There are several important components to Phase 4. First, the CV Pilot will continue to gather data and transmit to the USDOT. Additionally, there are new additions to Phase 4, such as

- OEM Participation
- Upgrade participant OBUs
- Spectrum Interference Test Site

The Phase 4 scope of work (See Attachment A) between THEA and USDOT describes the activities that will be performed.

The existing functions of the CV Pilot will continue seamlessly from Phase 3 to Phase 4. Data logs from existing participants will continue to be received by RSUs, transmitted to the Master Server from which the CUTR system retrieves the log for processing and analysis. Existing applications will continue to function in Phase 4 as they did in Phase 3. Participants will continue to receive warnings from both the V2V and V2I applications. The RSUs will continue to provide V2I messages to the OBUs to inform the participant. There is one exception to RSU communication with OBUs: THEA plans no further firmware updates to the OBUs. As such, the current Sirius XM firmware release (v 181) will be loaded onto the Sirius XM OBUs for use for the life of the CV Pilot. As outlined in this document, Siemens and Brandmotion will continue to support and troubleshoot issues that arise.

3.1. In Vehicle Hardware

As discussed previously, the existing participants will be recruited to remain in the CV Pilot. These participants will be offered the opportunity to replace their existing OBU with an upgraded CV Pilot OBU supplied by Sirius XM. These OBUs will be loaded with the last version of the firmware from Phase 3. These vehicles' OBUs will continue to transmit data logs to the RSUs and provide driver alerts thru the Human Machine Interface (HMI) in the mirror. The goal is to remove all Savari OBUs from service.

New participants will be recruited who meet the specific requirements provided by Honda, Hyundai, Toyota.

3.2. Infrastructure Hardware

All the infrastructure hardware will be retained and remain operational without an immediate need for transition planning at the end of Phase 3. The existing Phase 3 architecture anticipates expansion as the core of a wide area CV system extending across central Florida for future projects already planned:

- THEA: USDOT THEA CV Pilot Phase 4

- THEA: Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) submitted grant application on entire length of Selmon Expressway[1]
- FDOT: I-4 Frame from Tampa to Orlando
- FDOT: Selmon / I-4 Connector
- CoT: RSU expansion in Tampa

3.2.1. RSU Transition

RSUs are currently deployed on the Right of Way (ROW) of three Phase 3 stakeholder Infrastructure Owner Operators (IOO).

- THEA: RSUs located on the REL and Meridian Avenue
- FDOT: RSUs located on Florida state routes
- CoT: RSUs located on CoT signalized intersections and mid-block crosswalk

RSU transition shown in Table 5 from Phase 3 System Operations and Maintenance Plan monthly report, with columns added for Current Phase 3 operational state and Transition long term plans:

TABLE 5: RSU TRANSITION

				Current Phase 3			Transition		
Use Case	**RSU #**	**Location**	**IOO**	**LTE**	**CoT IP**	**V2I**	**LTE**	**CoT IP**	**V2I**
Morning Backup	1	REL, Pole A-1-P9 Curve	THEA	Y	N	DSRC	N	N	Dual
Wrong-way Entry	2	Twiggs & Meridian	THEA	N	N	DSRC	N	N	Dual
Pedestrian Safety	3	Twiggs & Courthouse	CoT	Y	N	DSRC	N	N	Dual
Transit Signal Priority	4	Marion & Tyler	CoT	Y	N	DSRC	N	N	Dual
	5	Marion & Cass	CoT	Y	N	DSRC	N	N	Dual
	6	Marion & Polk	CoT	Y	Y	DSRC	N	N	Dual
	7	Marion & Zack	CoT	Y	Y	DSRC	N	N	Dual
	8	Marion & Twiggs	CoT	Y	Y	DSRC	N	N	Dual
	9	Marion & Madison	CoT	Y	Y	DSRC	N	N	Dual
	10	Marion & Kennedy	FDOT	Y	Y	DSRC	N	N	Dual
	11	Marion & Jackson	FDOT	Y	Y	DSRC	N	N	Dual
	12	Morgan & Jackson	FDOT	Y	Y	DSRC	N	N	Dual
	13	Pierce & Jackson	FDOT	Y	Y	DSRC	N	N	Dual
	14	Jefferson & Jackson	FDOT	Y	Y	DSRC	N	N	Dual

[1] THEA's ATCMTD grant focuses on implementing traditional ITS technologies such as Dynamic Message Signs to warn drivers of impending mainline backups. RSUs are used to detect queues on exit ramps that could turn into mainline backs. When the RSUs determines the queue is long enough, it broadcasts a Traveler Information Message and send a message to the DMS to warn approaching drivers of the backup.

	15	Morgan & Kennedy	FDOT	Y	Y	DSRC	N	N	Dual
	16	Pierce & Kennedy	FDOT	Y	Y	DSRC	N	N	Dual
	17	Jefferson & Kennedy	FDOT	Y	Y	DSRC	N	N	Dual
Trolley Conflicts	18	Channelside & Morgan	CoT	N	N	DSRC	N	N	Dual
	19	Tampa & Whiting	CoT	Y	N	DSRC	N	N	Dual
	20	Tampa & Jackson	CoT	Y	Y	DSRC	N	N	Dual
	21	Florida & Whiting	CoT	Y	Y	DSRC	N	N	Dual
	22	Tampa & Kennedy	CoT	Y	N	DSRC	N	N	Dual
	23	Trolley Barn (E 6th Ave)	CoT	Y	N	DSRC	N	N	DSRC
	24	Channelside & Adamo	FDOT	N	N	DSRC	N	N	Dual
Traffic Progression	25	Kennedy & Meridian	FDOT	Y	Y	DSRC	N	N	Dual
	27	Whiting & Meridian	THEA	Y	N	DSRC	N	N	Dual
	28	Cumberland & Meridian	THEA	Y	Y	DSRC	N	N	Dual
	29	Channelside & Meridian	CoT	N	N	DSRC	N	N	Dual
	30	Nebraska & Cass	FDOT	Y	N	DSRC	N	N	Dual
	31	Nebraska & Twiggs	FDOT	Y	N	DSRC	N	N	Dual
	32	Nebraska & Kennedy	FDOT	Y	Y	DSRC	N	N	Dual
	33	Florida & Tyler	FDOT	Y	N	DSRC	N	N	Dual
	34	Florida & Cass	FDOT	Y	N	DSRC	N	N	Dual
	35	Florida & Polk	FDOT	Y	Y	DSRC	N	N	Dual
	36	Florida & Zack	FDOT	Y	Y	DSRC	N	N	Dual
	37	Florida & Twiggs	FDOT	Y	Y	DSRC	N	N	Dual
	38	Florida & Madison	FDOT	Y	Y	DSRC	N	N	Dual
	39	Florida & Kennedy	FDOT	Y	Y	DSRC	N	N	Dual
	40	Florida & Jackson	FDOT	Y	Y	DSRC	N	N	Dual
	41	Jackson & Meridian	THEA	Y	Y	DSRC	N	N	Dual
Over the Air Update	42	REL, 10S128, MM 6.4	THEA	Y	N	DSRC	N	N	Dual
	43	REL, F-1-P55, MM8.0	THEA	Y	N	DSRC	N	N	Dual
	44	REL, H-2-P80, MM 9.1	THEA	Y	N	DSRC	N	N	Dual
	45	REL, L-2-P110, MM 10.4	THEA	Y	N	DSRC	N	N	Dual
	46	REL, L-2-P132/CCTV-115, MM 11.9	THEA	Y	N	DSRC	N	N	Dual
	50	Florida & Harrison	FDOT		N	DSRC	N	N	DSRC
	51	Florida & Fortune	FDOT		N	DSRC	N	N	DSRC
	52	Bus Barn	THEA		N	DSRC	N	N	DSRC

The columns of Table 5 indicate the operational status of each RSU at the end of Phase 3:

- Use Case: Phase 3 Use Case supported by RSU

- RSU #: RSU Identifier Number of the Master Server list view screen
- Location: Physical location of the RSU installation
- IOO: Owner Operator of the RSU
- LTE: RSU internal LTE modem is used for back haul instead of fiber
- CoT IP: RSU internal LTE modem is also used for back haul from signal controller to TMC
- V2I: 5.9GHz connection, either DSRC only or Dual Mode DSRC / C-V2X

The right-most six columns of Table 5 indicate the transition plan for each individual RSU as follows:

- Current Phase 3: Current operational state of each RSU at the end of Pilot Phase 3
- Transition: Long-term planned operational state of each RSU

RSU Operation After Transition for RSUs owned and operated by:

- THEA are planned to be updated to Dual Mode early in Pilot Phase 4
- CoT remain DSRC only but can be updated to Dual Mode in the future
- FDOT remain DSRC only but can be updated to Dual Mode in the future

3.2.2. RSU Maintenance Plan by each IOO:

As Phase 4 of the CV Pilot has been initiated, THEA will continue to maintain the RSUs. THEA will utilize Siemens to support the RSUs. The CoT and FDOT will not be involved in RSU maintenance except for providing access to signal controller cabinets, if necessary.

Beyond Phase 4, each IOO has an existing annual budget and resource to maintain signal controllers and other roadside equipment. For example, CoT regularly inspects and tests signal controllers, malfunction management units and general condition of equipment and cabling for each intersection. The RSU at each intersection will be added to the regular planned inspection and maintenance tasks conducted while the service technician is present at the intersection.

- THEA: RSUs are planned to be maintained by THEA
- CoT: RSUs are added to existing annual signal control maintenance budget and procedures
- FDOT: RSUs are added to existing annual signal control maintenance budget and procedures

Once Phase 4 is complete, it is anticipated the CoT and FDOT will integrate CV Pilot RSUs on their right of way into their existing systems to monitor the RSUs and perform troubleshooting as needed

3.2.3. RSU Communications Backhaul:

No communications transition plan is required at the end of Phase 3. To reduce or eliminate cellular data fees, RSUs and signal controllers are planned to be connected to existing fiber over time in the future.

- RSUs on the REL using RSU cellular modem will be reconnected to existing THEA fiber
- Signal controllers currently using RSU cellular modem for connection to TMC
    - Network switch in cabinet will be reconnected to CoT fiber
    - Signal controller will be reconnected to network switch
    - RSU will be reconnected to network switch
    - TMC management system communicates directly to signal controller
    - Concert management system communicates directly to RSU
- RSUs connected to Master Server currently using RSU cellular modem
    - RSU will be reconnected to CoT or FDOT fiber
    - Concert communicates directly to RSU via fiber switch instead of RSU cellular modem

3.2.4. Transition Plan by Use Case:

- UC 1: Morning Backup remains in place and operational
- UC 2: Wrong Way Entry remains in place and operational
- UC 3: Pedestrian Safety remains in place and operational
    - RSU 3 crosswalk is scheduled to undergo reconstruction as a signalized crosswalk
    - Sensors are planned to be moved from the courthouse to a crosswalk at Twiggs & Meridian
    - Twiggs & Meridian experienced large increase in pedestrians with new condos and Publix
- UC 4: Transit Signal Priority remains in place and operational from the infrastructure side
    - For Phase 4, THEA will continue to work to address Transit Signal Priority (TSP) issues. However, even when the issues are addressed, there is no guarantee, TSP can be implemented. At the time of this writing, HART continues to provide limited bus service with no plans to return to full service until further notice. There is no guarantee the buses currently installed with OBUs will return to the covered routes nor is there a guarantee the routes will not change due to the effect of COVID on ridership.
- UC5: Streetcar Conflicts remains in place and operational from the infrastructure side
- UC6: Traffic Progression
    - I-SIG operation is disabled at each RSU to avoid inadvertent operation
    - I-SIG research plan is disabled at the TMC to avoid inadvertent operation
    - For Phase 4, THEA will work with Siemens and Dr Larry Head to investigate using a later version of I-SIG currently deployed at Madison, Wisconsin.

3.2.5. Master Server Transition

No transition plan is required at the end of Phase 3. The Master Server is planned to remain in place and to be upgraded over time using future project funding as follows:

- Update to latest version of Concert software with graphical and performance improvements
- Expanded area map to include the entire length of the Selmon Expressway and I-4 Connector
- Expanded support for up to 100 RSUs
- NTCIP 1218 standard communications to RSUs
    - Replaces international outstation standard
    - Allows connection of 3rd party RSUs conformant to NTCIP 1218 standard on the area map
- Creation of standard Traveler Information Messages (TIM) from central to vehicles
- Dynamic Message Sign (DMS) support via NTCIP 1203 standard
- Travel time derived from RSU Bluetooth reader for all vehicles
- Incident detection from OBU-equipped vehicles
- Extended PII removal from OEM participants

3.3. Security Credential Management System

For the initial three phases of the CV Pilot, THEA utilized a private Security Credential Management System (SCMS) host by Integrity Security Systems (ISS). During the design, THEA made the decision to download 3 years of certificates; which would last through and beyond the CV Pilot Phase 3. As THEA has moved into Phase 4, THEA has contracted with ISS to provide an additional 30 months of certificates for Phase 4, which includes the 400 CV Pilot OBUs and 200 OEM OBUs.

Moving forward, THEA is in discussions with FDOT to utilize its statewide SCMS. THEA believes this is the proper path forward.

3.4. Spectrum Allocation

With the December 2020 ruling by the Federal Communications Commission (FCC), the use of DSRC and the entire 75 Mhz of the 5.9 Ghz spectrum is in question. The ruling reallocates the lower 45 Mhz to unlicensed wifi and the upper 30 Mhz to V2X. Additionally, the ruling phases out DSRC. To date, however, the final report and order has not been published starting the clock on spectrum reallocation. The CV Pilot, as directed, continues to utilize DSRC. When the report and order is finalized, THEA will develop a strategy on how to migrate for the current DSRC deployment to Cellular Vehicle to Everything (C-V2X).

3.5. Data

The existing CV Pilot data will continue to be gathered, sent to CUTR, and sent to USDOT. New data from the OEMs vehicles, specifically "sniffed" BSMs, will be captured by the RSUs and sent to CUTR for analysis and sent to USDOT.

Data collection will continue with respect to Use Case 3 (Pedestrian Safety), to collect data conducive to the performance evaluation this case. In addition, data collection will also continue for Use Case 4 (Transit Signal Priority) and Use Case 6 (Traffic Progression) as refinements to the TSP and I-SIG applications are deployed. See Section 3.2.4 UC6: Traffic Progression for information on potential update to I-SIG.

The THEA team will update the USDOT Performance Evaluation Dashboard to track the overall system functionality and performance.

Note: THEA is in discussions with the OEMs regarding access to OEM data logs. DENSO, the OEM OBU supplier provides the ability to offload data logs using cellular. These logs would have to be retrieved from a DENSO cloud. CUTR would then have to access the logs and convert them into the desired format. This was not known at the time of the NOFO response and is under consideration for implementation.

3.6. Application Intellectual Property

On the RSUs, there were five apps implemented excluding the Over The Air (OTA) firmware update and the Data Logger. Three of the apps were developed specifically for THEA: Wrong Way Entry, End of Ramp Deceleration Warning, and Pedestrian Collision Warning. Two other apps, Transit Signal Priority and Intelligent Signal System were based on open source code developed by the University of Arizona, under the guidance of Dr. Larry Head. Siemens designed and developed wrapper code to encapsulate the I-SIG code. This code was returned to the open source portal for access by others. Siemens retained the Intellectual Property (IP) of the remaining apps.

On the OBUs, there were eight applications implemented excluding the Over The Air (OTA) firmware update and the Data Logger. Three of the apps were developed specifically for THEA: Wrong Way Entry, End of Ramp Deceleration Warning, and Pedestrian Collision Warning. The remaining apps were existing apps either previously implemented or were under development at the time of the project. The OBUs vendors retained the IP to all of their apps.

Moving forward into Phase 4, new apps implemented, currently only Red Light Violation Warning, will remain the OBU supplier's IP.

4. Post Phase 3 Activities

As THEA and USDOT have agreed to continue the CV Pilot, Phase 4, much of the Phase 3 activities will continue seamlessly. The original concept of the CV Pilot, implementing 6 use cases, will continue. Private participants will continue to be part of the program. THEA will perform additional recruitment as needed to obtain the 400 participants for the aftermarket OBUs (referred to as CV Pilot OBUs). With the addition of

Honda, Hyundai and Toyota, THEA will be recruiting an additional 200 participants to received OEM OBUs. These OEM OBUs are specific to each OEM, but will run 7 common applications. Six CV Pilot applications

- FCW
- EEBL
- IMA
- PCW
- ERDW
- WWE

and one additional application specific to OEM OBUs, Red Light Violation Warning (RLVW).

Data from the CV Pilot OBUs will continue to be recorded and transferred to the CUTR system as it was throughout Phase 3. The OEM OBUs will create log files specific to each OEM. The OEMs have agreed in principal to share this data with THEA. CUTR will work with Denso, the OEM OBU provider, to develop the interface between the OEM OBU log files and the CUTR system. This data transfer will most likely be performed outside the CV Pilot infrastructure (i.e., RSUs).

THEA, FDOT District 7,CoT, and HART will continue their relationships established during Phase 1. THEA as the lead agency will maintain governance over the project. THEA will provide the funding to support and maintain the

- infrastructure,
- OBUs,
- upgrade installations, and
- new installations.

This funding will come from THEA approved funds and the USDOT Phase 4 funding. Beyond this funding, THEA has programmed $1 million dollars a year into its work program to support CV technology activities. This funding is targeted for future projects outside the CV Pilot, but could be used to expand the CV Pilot beyond what is planned for Phase 4.

The Phase 1 and Phase 2 ConOps and SyRS will be updated to reflect final outcome of the project at the end of Phase 3. These two documents will then be updated reflect the planned Phase 4 activities.

The RSUs will be supported and maintained by Siemens through Phase 4. This support will provide continuity to the infrastructure. Over the first half of Phase 4, the current RSUs will be replaced with new RSUs solving known issues in the THEA deployment as well as providing dual mode capability (i.e., DSRC or C-V2X). The OBUs will be supported and maintained by Brandmotion through Phase 4. Brandmotion will support the existing installed OBUs, upgrade the OBUs to the CV Pilot OBUs (Sirius XM), install OEM OBUs as the request of the OEM, support OEM dealerships in the installed of OEM OBUs, and support participants and OEM dealerships throughout Phase 4.

5. Concepts and Application Analysis

THEA originally planned the deployment of thirteen applications. These applications are listed in Table 6.

TABLE 6 ORIGINAL THEA CV PILOT APPLICATIONS

Number	Application
1	End of Ramp Deceleration Warning (ERDW)
2	Emergency Electronic Brake Light (EEBL)

Number	Application
3	Forward Collision Warning (FCW)
4	Wrong Way Entry (WWE)
5	Intersection Movement Assist (IMA)
6	Transit Signal Priority (TSP).
7	Vehicle Turning Right in Front of Transit Vehicle Warning (VTRFTV)
8	Intelligent Signal System (I-SIG)
9	Probe Data Enabled Traffic Monitoring (PDETM)
10	Pedestrian Collision Warning (PCW)
11	Pedestrian in Signalized Crosswalk Warning (PED-X)
12	Mobile Accessible Pedestrian Signal (Ped-Sig)
13	Pedestrian Transit Movement Warning (PTMW)

Ultimately ten of these applications were deployed. The applications can be divided into 3 areas:

- Working
- Partially Working
- Removed

5.1. Working Applications

Working applications are defined as applications that function correctly on the RSU and/or the OBU and provide the data to CUTR for analysis. These applications are

- ERDW
- EEBL
- FCW
- WWE
- IMA
- VTRFTV
- PCW

It is important to note, that this definition of working applications may not reflect the Performance Measurement findings. This difference is due to the fact the Performance Measurement team was analyzing the accuracy (i.e. false positive/false negatives) and effectiveness of the applications.

5.2. Partially Working Applications

Partially working applications are defined as applications that have proven to function correctly, but may not function reliably and/or have inconsistencies in data reporting.

- TSP
- I-SIG

The TSP application is an RSU/OBU application. The Bus OBU broadcasts System Request Messages (SRMs). When a RSU running TSP receives the SRMs, the RSU determines if the transit vehicle is behind schedule, takes necessary action with the signal controller if needed, and broadcasts a System Status Message (SSM). The Bus OBU receives and logs the SSMs. The history of these interactions including the SRMs and SSMs are transmitted to the RSU in data log file which in turn forwards the data log file to the Master Server farm including the CUTR servers. During the implementation of TSP several issues were encountered including:

- RSUs not receiving SRMs
- OBUs not receiving SSMs
- OBUs not logging the interaction of SRMs and SSMs.
- OBU not transmitting data log files

Even with these issues, there have been instances of the TSP application functioning properly and data received by the CUTR system. In Phase 4, THEA will continue to work toward solving these issues.

The I-SIG application is a combination of the Multimodal Intelligent Transportation Signal System (MMITSS) and custom code developed by Siemens to communicate parameter information to I-SIG and receive suggested signal timings from I-SIG. These timings would be used to flush an intersection and move a platoon of vehicles through a corridor seamlessly. During the implementation of I-SIG, several issues were encountered including:

- Discovering the saturation rate of CVs would have to exceed 90% for the algorithm to work effectively.
- Discovering issues inside the I-SIG itself (e.g., signal controller would get stuck between phases and would have to restarted). This code was used as is from University of Arizona.
- Effectively measuring the length of the queue at an intersection.

Even with these issues, there were instances where I-SIG would operate correctly and generate data. However, because of the concerns of signal controllers running in free mode and getting stuck phases, the application has been turned out. In Phase 4, THEA is looking at ways to implement I-SIG in a different manner. The THEA team is in discussion with Dr. Larry Head at the University of Arizona about using a new version of the code. One possibility is to implement the system deployment in Madison, Wisconsin.

5.3. Removed Applications

Removed applications are defined as applications that could not be implemented and made to function correctly. These applications were ones that would reside on a smart phone, specifically an Android. These applications were:

- PED-X

- Ped-Sig
- PTMW
- PDETM

PED-X was planned to warn pedestrians of a vehicle conflict while PCW was planned to warn vehicles of a pedestrian conflict. The PED-X application was removed while the PCW was implemented. PED-X would receive vehicle BSMs from the RSU, calculate if there was a potential collision with the vehicle and if so would warn the pedestrian. When testing PED-X, it was discovered that not all android phones have the ability to detect its heading built-in. Without the heading, the phone cannot determine which direction the person is headed. This information is critical to calculating collisions. In addition, PED-X was to generate PSMs, send them to the RSUs, so that the RSU could broadcast them to approaching equipped vehicles. Another issue with the phone was the GSP accuracy. Between the both these issues, an approaching equipped vehicle could receive incorrect data; causing the potential for the PCW to provide inaccurate information.

The Ped-SIG application was designed to allow pedestrians to request a crosswalk call without having to push the pedestrian crosswalk button. The heading issue discussed previous was a major factor in this application not functioning correctly. The smart phone communicated with the RSU via wifi. It was discovered during testing, the wifi connection between the smart phone and RSU would either not get established or would be intermittent causing the application to lock up. After analyzing this issue, it was determined the cause was due to the large number of wifi networks nearby.

The PTMW application was not implemented. When the issues with PED-X and Ped-Sig were discovered, the decision was made to not implement PTMW and focus resources on other applications.

The PDETM application was not implemented. Because of unforeseen circumstances MacDill Air Force Base staff did not participate in the CV Pilot. Therefore no data could be gathered for PEDTM to calculate travel times.

Attachment A

Tampa Hillsborough Expressway Authority (THEA) Connected Vehicle (CV) Pilot –
Amendment 7 to Cooperative Agreement DTFH6116H00025

Volume 1 – Technical Application

PART I –
TECHNICAL APPROACH

INTRODUCTION

To date, the Tampa Hillsborough Expressway Authority (THEA), in collaboration with the United States Department of Transportation (USDOT), have piloted Connected Vehicle (CV) technology in Tampa, Florida. Three (3) phases of the Pilot have been performed. Phase 1 largely focused on concept development, system requirements and initial deployment planning. In phase 2, detailed design was performed, and the initial system was implemented and tested. Phase 3 is ongoing and involves operation, maintenance and reporting on data-driven performance impacts of the deployment. This project (Amendment 7 of Cooperative Agreement DTFH6116H00025) is the fourth phase that will extend the Pilot to create a CV Real-World Test Site, hereafter referred to as the "THEA CVRTS".

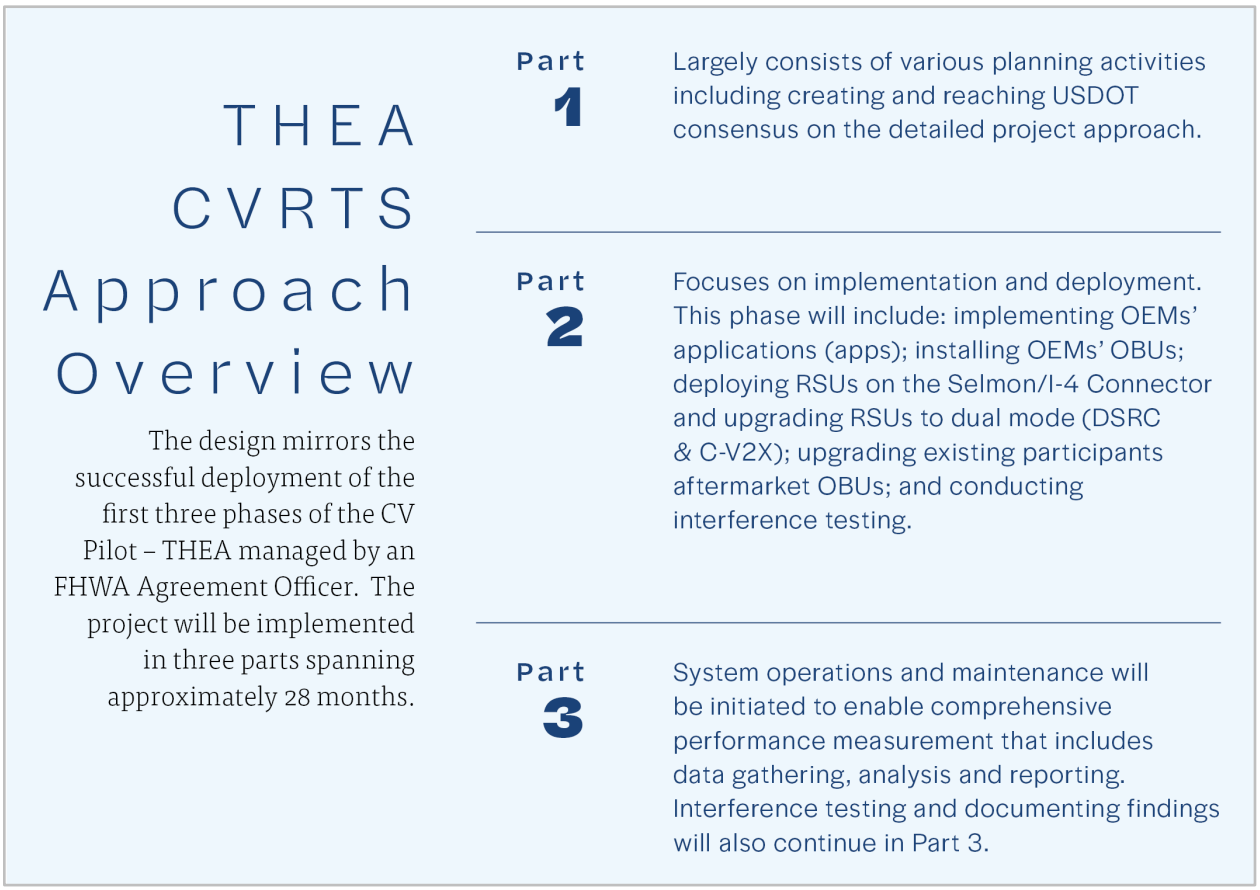
The approach to the THEA CVRTS will build on the Pilot's existing deployment of Dedicated Short Range Communications (DSRC), but by deploying additional Roadside Units (RSUs) with both DSRC and Cellular Vehicle to Everything (C-V2X) capabilities, the site will have the capability to measure the impacts of a joint technology environment that is anticipated with the Federal Communications Commission's (FCCs) proposed changes to the spectrum allocation. The THEA CVRTS effort recognizes that the next USDOT Intelligent Transportation Systems (ITS) Joint Program Office (JPO) research area will involve spectrum interference testing and thus is uniquely positioned to perform interference and channel capacity testing involving DSRC, C-V2X, and Wi-Fi.

Another important approach element involves direct participation of automobile Original Equipment Manufacturers (OEMs). The THEA CVRTS will collaborate with three (3) automobile OEMs (Hyundai, Honda and Toyota) to deploy their respective OEM CV Onboard Units (OBUs)

in their customer's privately-owned vehicles. New performance measures will be developed for OEM vehicle data that is received by RSUs. While this data will not be as robust as the current participant data, it creates new opportunities that were not possible during the prior three phases of the Pilot. For example, the OEM OBUs will be integrated in the vehicle's Controller Access Network (CAN) bus. Access to the CAN bus will provide data in the Basic Safety Message (BSM) Part II (e.g., Vehicle Status and Vehicle Safety Extensions data frames) for analysis of events and activations of vehicle-based systems such as antilock brakes (ABS) and wiper status.

As summarized in **Figure 1**, the approach to the THEA CVRTS, consists of three parts spanning approximately 28 months. Following Figure 1 are additional approach details at the task level.

FIGURE 1: THEA CVRTS APPROACH OVERVIEW



PART 1 - PLANNING

TASK 1. DETAILED PROJECT APPROACH PLANNING AND COORDINATION

1.1. Kick Off Meeting

To initiate the CVRTS effort, THEA and its team will organize and conduct one (1) kick-off meeting with the USDOT of up to three (3) hours in duration. The purpose of the meeting will be to discuss and validate the project management plan (subtask 1.7) including, roles, budget and schedule.

1.2. Pre-Concept of Operations (ConOps) Meetings

THEA and its team will conduct up to six (6), ninety (90) minute meetings with OEM/Aftermarket OBU partners of Hyundai, Honda, Toyota and Sirius XM. The purpose of these meetings is to confirm specifics about their involvement in the THEA CVRTS and expectations for developing/updating the ConOps in the next task.

1.3. ConOps Workshop

In this subtask, THEA and its team will coordinate with the USDOT to conduct and facilitate one (1) ConOps workshop of up to eight (8) hours in duration. This workshop and the subsequent ConOps and System Requirements Specifications (SyRS) documents (subtasks 1.4 and 1.6 respectively) will largely constitute the planning activities for the remainder of the CVRTS project, including development or refinement of a detailed approach. Expected participants will be the USDOT, THEA, HNTB, University of South Florida Center for Urban Transportation Research (CUTR), Sirius XM, Siemens, Brandmotion, the aforementioned OEM partners and other select stakeholders. Expected workshop discussion topics include:

- Validation of the overall project goal of expanding the THEA CV Pilot to a real-world urban test site;
- Defining and finalizing new and augmented operational scenarios and use cases including:
  - Spectrum interference testing (new)
  - Sniffed OEM Basic Safety Messages (BSMs) (new)
  - Red light running (new)

  - Morning backups (augmented from CV Pilot)
  - Wrong way entry (augmented from CV Pilot)
  - Pedestrian safety (augmented from CV Pilot)
  - I-4 intercity corridor (potential/new);

- Deployment (including installation) of additional Connected Vehicle Dedicated Short Range Communications (DSRC) and Cellular Vehicle-to-Everything or (C-V2X) infrastructure and devices;

- Application (app) identification and development needs;

- Performance measurement.

1.4. ConOps Document

Phase 1 of the THEA CV Pilot included preparation of a comprehensive ConOps (FHWA-JPO-16-311, February 2016) for system deployment. In this subtask, the THEA team will refine and update the existing ConOps document to include new and augmented CVRTS use cases, operational scenarios, current system changes and other results from the previous subtask's ConOps workshop. The refined ConOps will serve as a predecessor to developing system deployment requirements (subtask 1.5) and will also serve to guide CVRTS implementation in Part 2.

One (1) draft refinement of the existing ConOps (FHWA-JPO-16-311) will be prepared for USDOT review and comment. Upon receipt of USDOT comments, the THEA team will finalize the refined/updated ConOps.

1.5. System Requirements Workshop

Similar to the ConOps workshop in subtask 1.3 and in continuation of CVRTS part 1 planning activities, THEA and its team will coordinate with the USDOT to conduct and facilitate one (1) System Requirements workshop of up to eight (8) hours in duration. Expected system requirements workshop participants will be the USDOT, THEA, HNTB, CUTR, Sirius XM, Siemens, Brandmotion, the aforementioned OEM partners and other select stakeholders. Expected workshop discussion topics include:

- Defining and finalizing new and augmented requirements based on the ConOps operational scenarios and use cases including:
  - Integrating OEM vehicles into the THEA CV Pilot Deployment
  - Adding additional OEMs apps such as Red Light Violation Warning
  - Creating an urban interference test bed for USDOT usage
  - Creating an urban interference test bed for vendors to utilize
  - Analyzing how OEM OBUs interact with existing THEA participant OBUs

- Deployment (including installation) of additional Connected Vehicle Dedicated Short Range Communications (DSRC) and Cellular Vehicle-to-Everything or (C-V2X) infrastructure and devices;

- Defining app requirements;

- Defining new and augmented performance measurements.

1.6. System Requirements Specification

Phase 1 of the THEA CV Pilot included preparation of a comprehensive System Requirements Specification (SyRS) (FHWA-JPO-16-315, August 2016) for system deployment. In this subtask, the THEA team will refine and update the existing SyRS to integrate results from the previous subtask's System Requirements workshop and the proposed changes to the current system.

One (1) draft refinement of the existing SyRS document (FHWA-JPO-16-315) will be prepared for USDOT review and comment. Upon receipt of USDOT comments, the THEA team will finalize the refined/updated SyRS.

1.7. Project Management Plan (PMP)

Prior to conducting the Kick-Off meeting (subtask 1.1), the THEA team will prepare a draft CVRTS Project Management Plan (PMP) that reflects the Work Breakdown Structure that will be performed as part of the project. Additional PMP elements will include a detailed project schedule, risks, key milestones and an organizational chart highlighting key individuals responsible for project delivery. Upon completion of the Kick-Off meeting, the THEA team will incorporate meeting results and other USDOT PMP comments to prepare and deliver the final PMP (also refer to Part II Staffing and Management Approach).

1.8. Project Management

To facilitate communication on CVRTS progress, THEA and its team will participate in coordination meetings with the USDOT throughout the duration of the Three-Part, 28-month project. It is assumed that the meeting structure and frequency established for the THEA CV Pilot will be continued for this phase of the project and will consist of bi-weekly THEA-specific meetings as well as monthly CV "all-site" meetings and CV Pilot roundtable discussions as required.

Task 1 Deliverables:

a) Kick-off meeting agenda, presentation materials (as required), brief meeting summary with action items
b) OEM pre-ConOps meeting agendas and brief meeting summaries with action items
c) ConOps workshop invitations, agenda, draft/final presentation materials (workshop results will be summarized in the subtask 1.4 ConOps document)
d) Draft and final refinement of the existing THEA CV Pilot ConOps (FHWA-JPO-16-311)
e) System Requirements workshop invitations, agenda, draft/final presentation materials (workshop results will be summarized in the subtask 1.6 System Requirements Specification document)
f) Draft and final refinement of the existing THEA CV Pilot SyRS document (FHWA-JPO-16-315)
g) Draft and final THEA CVRTS PMP
h) Participation in coordination meetings

PART 2 – IMPLEMENTATION AND SPECTRUM TESTING

TASK 2. OBU INSTALLATION

2.1. Participant Recruitment

THEA will contact existing CV Pilot participants to gauge their interest in upgrading their installed OBU and continuing to participate in the project. If their vehicle qualifies for one of the OEM OBUs, they will be directed to the appropriate OEM dealership for installation. Otherwise, they will receive an upgraded Sirius XM CV Pilot OBU. The goal for the CVRTS is to have up to 600 vehicles equipped with either OEM or Sirius XM OBUs. The THEA team will leverage processes and lessons learned from prior CV Pilot OBU installations to minimize participant attrition rates and retain participation over the course of the CVRTS project. If additional participants are needed, they will be recruited from THEA's existing Selmon Expressway and Reversible Express Lanes (REL) customer pool. THEA will repeat the CV Pilot's approach to recruiting by offering a $550 toll discount and providing professional OBU installation as incentives to participate in this project. Qualified participants will be assigned to one of four classes: Hyundai, Honda, Toyota, or Aftermarket (Sirius XM) depending on the make of vehicle they own.

2.2. Furnish and Install OEM OBUs

As a means of advancing CV technology from a pilot environment to one that is more universal or widespread, the THEA team will coordinate with its OEM partners of Hyundai, Honda and Toyota to engage their respective local dealership(s) service departments in furnishing and professionally installing up to 200 OEM OBUs in the corresponding make of vehicles of the recruited project participants identified in the previous subtask. Dealer installed OEM OBUs will include integration of the device into the vehicle's Controller Access Network (CAN) bus which will enable data to be transmitted in BSM Part II (e.g., Vehicle Status and Vehicle Safety Extensions data frames) for analysis of events and activations of vehicle-based systems such as antilock brakes (ABS) and wiper status. THEA's team will interface with participants and the local OEM dealerships for scheduling installation appointments, responding to inquiries, addressing complaints and potentially assisting dealership technicians with the OBU installations. If the 200 OEM OBUs is not achieved, the THEA commits to fill the remainder of the OBUs with Sirius XM OBUs (see subtask 2.3) to ensure there are a minimum of 600 OBUs deployed.

THEA expects consideration of both DSRC and C-V2X OBUs for installation in participant vehicles. A determination will be made if C-V2X devices are available and can be procured as part of the planning/ConOps activities. Depending on C-V2X availability and cost, the total number of OEM OBUs installed is subject to change.

2.3. Furnish and Install Aftermarket OBUs

The previous subtask described furnishing and installing up to 200 OEM OBUs. Consistent with the previously stated CVRTS goal of up to a total 600 OBU equipped participant vehicles, this subtask involves the THEA team furnishing and installing up to an additional 400 new (and/or retrofitted) aftermarket OBUs in participant vehicles, including those that are currently participating in the CV Pilot. Also as described in subtask 2.2, the number of aftermarket OBUs furnished and installed may vary as required to meet the goal of a total 600 OBUs deployed. As with the OEM OBU installations, THEA's team will interface with participants for scheduling installation appointments, responding to inquiries, and addressing complaints.

2.4. OBU Installation Technical Memorandum

In this subtask, the THEA team will prepare a brief draft and final technical memorandum documenting the OEM and aftermarket OBU installation process. Topics included in the memorandum will include OEM dealership coordination, scheduling, installation methods, challenges and lessons learned. Upon receipt of USDOT comments on the draft, the THEA team will finalize.

Task 2 Deliverables:

a) Incentive-based participant recruitment with a goal of up to 600 vehicles equipped with OEM or upgraded Sirius XM OBUs
b) Furnishing and professionally installing of up to 200 OEM OBUs including coordinating with OEM dealerships and participants for scheduling, inquiries, troubleshooting, and other post-installation support
c) Furnishing and professionally installing of up to 400 aftermarket OBUs including coordinating with participants for scheduling, inquiries, troubleshooting, and other post-installation support
d) Draft and final THEA CVRTS OBU Installation Technical Memorandum

TASK 3. OEM APPLICATION (APP) IMPLEMENTATION

3.1. App Implementation

The THEA team expects that data originating from the new automotive OEM and aftermarket OBUs (including the aforementioned BSM Part II data) will enable enhancements to existing CV Pilot apps (e.g. Emergency Electronic Brake Light, End of Ramp Deceleration Warning, Wrong Way Entry and Pedestrian Collision Warning) as well as new apps currently being explored and/or developed by the OEMs (e.g., Red Light Violation Warning). While this subtask has been identified to document the apps to be used and their implementation, new OEM and/or updated existing apps will be initially determined and detailed during the planning/ConOps activities (subtasks 1.3 and 1.4).

3.2. Revise CV Pilot Architecture

In this subtask the THEA team will revise the existing THEA CV Pilot architecture to illustrate how the new or updated apps will be integrated into the system and their corresponding data paths.

Task 3 Deliverables:

a) Documentation of apps to implemented TBD depending on outcome of ConOps (subtasks 1.3 and 1.4)
b) Revised CV Pilot architecture illustrating new/updated apps and data paths

TASK 4. PERFORMANCE MEASUREMENT AND DATA ANALYSIS

4.1. Performance Measurement and Evaluation Support (PMESP)

The THEA team will update the THEA CV Pilot Performance Measurement and Evaluation Support Plan (FHWA-JPO-16-314) to document the experimental design, data collection, management, performance measurement and reporting to USDOT. In particular, the updated PMESP will detail newly developed performance measures that are consistent with USDOT's spectrum research efforts detailed in task 6.

The THEA team will also develop a Performance Measurement Evaluation Support Schedule (PMESS) to track the progress of the PMESP, along with all dependencies with respect to the ConOps and a risk assessment by task.

One (1) draft PMESP will be prepared for USDOT review and comment. Upon receipt of USDOT comments, the THEA team will finalize the PMESP.

4.2. Data Management Plan (DMP)

THEA and its team will develop a Data Management Plan (DMP). The plan will provide an overview of the data that will be collected through the project. The DMP will detail all the data elements, access policies, data sharing, storage, and archiving.

One (1) draft DMP will be prepared for USDOT review and comment. Upon receipt of USDOT comments, the THEA team will finalize the DMP.

4.3. Institutional Review Board (IRB) Support

The THEA team will update all required IRB documentation in conformity to IRB requirements pertaining to the retention of existing participants and the recruitment of new participants as detailed in subtask 2.1.

4.4. Update to USDOT Performance Evaluation Dashboard

The THEA team will update the USDOT Performance Evaluation Dashboard to track the overall system functionality and performance. The Dashboard will be updated to report newly developed performance measures based on the updated PMESP, with a focus of on performance measures relevant to USDOT's research on spectrum interference.

Task 4 Deliverables:

a) Draft and final PMESP
b) Draft and final PMESS
c) Draft and final DMP

d) Draft and final IRB documentation
e) Updated USDOT Performance Evaluation Dashboard

TASK 5. ROADSIDE UNIT (RSU) DEPLOYMENT

5.1. Design

THEA and its team will perform design activities necessary to deploy up to forty-four (44) Dual Mode (DSRC and C-V2X) RSUs, predominantly on the Selmon/I-4 Connector and along Meridian Avenue as well as other locations identified in the ConOps (subtasks 1.3 and 1.4). This subtask task includes developing RSU requirements to satisfy the intended CV functionality identified by the use cases and ConOps. The THEA team will perform field investigations for the optimal placement of RSUs and develop typical drawings for their installation and connection to existing THEA/FDOT communications systems. The THEA team will also perform the FCC licensing required for these RSUs.

5.2. RSU Integration and Testing

Based on the use cases identified in the ConOps, THEA's team will integrate the dual-mode RSUs with THEA's Traffic Management Center (TMC) CONCERT platform and test for intended functionality and data transfer. Any new apps that were identified in the ConOps will be developed, tested, and integrated into the existing CV Pilot deployment.

5.3. RSU Integration Technical Memorandum

In this subtask, the THEA team will prepare a brief draft and final technical memorandum documenting RSU integration activities, including challenges and lessons learned. Upon receipt of USDOT comments on the draft, the THEA team will finalize.

Task 5 Deliverables:

a) Dual-Mode RSU deployment requirements, locations and typical installation drawings
b) Draft/final RSU integration technical memorandum

TASK 6. PARTICIPATION IN USDOT'S SPECTRUM RESEARCH

6.1. Support for USDOT Spectrum Interference Research

In this task, the THEA team shall assist the USDOT in understanding cooperative-ITS Vehicle to Everything (V2X) radio propagation, interference, and the effects of uncontrolled environmental variables on V2X communications (both Dedicated Short Range Communications or DSRC and Long-Term Evolution Cellular Vehicle-to-Everything or LTE-CV2X). The task will also evaluate the effects of unlicensed Wi-Fi (UNII) transmissions on V2X communications while operating in the 5.9 GHz Spectrum (i.e., "Safety Band"). The data and results will add to the ongoing USDOT analysis being performed to provide recommendations to the FCC. The USDOT may use this information to make decisions about how to avoid interference with and ensure reliable operation of devices in the 5.9 GHz spectrum, as well as ensure highly available access of the spectrum to existing USDOT deployments.

In each element of testing, USDOT seeks to build incrementally upon test results, introducing new elements after having created a baseline. Once a baseline is established, wherein the "environmental variables" are documented, testing is performed under highly controlled conditions and then uncontrolled conditions (for instance, typically deployment conditions) to understand the changes in radio performance in the presence of new and potentially random variables. With this understanding, USDOT and test partners can then analyze applications to understand how they can or cannot compensate when in the presence of interference and/or other uncontrolled variables (such as foliage, building reflection, or others). In this respect, the collected data will convey the impact of the radio environment on the overall communication system.

Using the THEA's Connected Vehicle Deployment, the USDOT's spectrum team will collaborate with the THEA team to perform Radio Frequency (RF) field measurements to achieve specific goals and objectives; the USDOT will need assistance from THEA's team to leverage their existing network(s) and technical staff in retrieving data. The USDOT's specific goals and objectives for this task are as follows:

Goals:

1. In an urban environment, there is a need to understand the impacts of unlicensed devices, DSRC devices and LTE-CV2X devices all operating in the DSRC band:
    a. There is a need to understand the impact of potential interference (co-channel and adjacent channel) when co-existing or sharing the Radio Frequency (RF) spectrum;
    b. There is a need to define requirements necessary for avoiding interference with and ensuring reliable operations of devices in the 5.9 GHz Safety Band, including the implications of operations within proposed band plans.
    c. There is a need to understand how the applications, in the presence of interference and degradation of the existing communication link robustness, can adjust/compensate appropriately to continue reliable operations.
2. There is a need to create data and test results in a manner similar to other USDOT test data and results gathered in a highly controlled environment in order to be able to compare and understand commonalities and differences.

Objectives:

In abbreviated form, the specific USDOT objectives are:

1. THEA shall support USDOT in the development of a plan to evaluate interference affecting 5.9 GHz V2X communications with the expectation of collecting data sets that include or allow for, at a minimum:
    a. Packet Error Rate (PER)/Packet Completion Rate (PCR)
    b. Latency
    c. Inter-Packet Gap (IPG)
    d. Signal Strength
    e. Development of power over distance curves
    f. Signal over noise performance for DSRC and LTE-CV2X and UNII.
2. THEA shall support USDOT in the creation of a thorough radio survey baseline of the test environment area including in and near the CV Pilot deployment; potentially by mapping location points with power levels to see where communications are effective and to identify where nulls and/or unexpected propagations occur.
3. THEA shall support USDOT to determine the minimum received power at which 5.9 GHz devices can sense each other in both the baseline and deployment environments.
4. THEA shall support USDOT in the measurement of interference on radio performance and vehicle-safety communications, including at different times of the day; with and without U-NII installations; co-channel and adjacent channel operations; and, considering both point-to-point (P2P) and point-to-multipoint (P2M) Unlicensed operations:
    a. Unlicensed to DSRC (from below and above the DSRC channels)
    b. Unlicensed to LTE-CV2X (from below and above the LTE-CV2X channel)
    c. LTE-CV2X to DSRC and DSRC to LTE-CV2X
    d. DSRC and LTE C-V2X to Unlicensed

e. Effects of Unlicensed or WISP operations (if still operational nearby the CV Pilot site) on the background noise.

5. THEA shall support USDOT in the measurement of interference that causes RF suppression on the Clear Channel Assessment (CCA) mechanism.
6. THEA shall support USDOT in the measurement of interference of unlicensed and LTE-CV2X device transmissions on DSRC devices previously installed in the CV Pilot deployment.
7. THEA shall support USDOT in the measurement other impacts (as identified) on 5.9 GHz channel quality caused by Unlicensed and LTE-CV2X device transmissions;
8. Where data is available, THEA shall support USDOT in the investigation of the GPS coverage, establish conditions under which GPS becomes unavailable to the applications (i.e., underpasses, tunnels, natural outages, etc.), and measure the effects on V2X communications.
9. Using the "mixed DSRC and LTE-CV2X" available fleet, THEA shall support USDOT in documenting any mutual interference at the OBU level, potentially employing the dual mode RSUs and recording data at time/location of different vehicles in close proximity to look for any cross-impacts.
10. THEA shall support USDOT in the investigation of how the change in the size of the bandwidth (i.e., 20 MHz, 40 MHz, 80 MHz, or 160 MHz) affects the power levels or the signal transmissions, which then may affect CV Pilot deployment.
11. THEA shall support USDOT to understand how V2X applications are affected and then might be adapted/modified in the presence of interference from unlicensed devices.
12. THEA shall support USDOT in the use of the collected data to investigate mitigation possibilities due to potential interference; if possibilities are identified, USDOT and THEA may conduct some additional tests on the application modifications or other identified mitigations.
13. Based on the plans, USDOT will bring the necessary spectrum measurement equipment to the THEA site to work in conjunction with the THEA V2X and unlicensed equipment.

The THEA team acknowledges that the following technical papers may be referenced to obtain a full understanding of USDOT Spectrum Research in the 5.9 GHz Safety Band:

- "USDOT Spectrum Sharing Analysis Plan: Effects of Unlicensed-National Information Infrastructure (U-NII) Devices on Dedicated Short-Range Communications (DSRC)" at https://www.its.dot.gov/research_archives/connected_vehicle/dsrc_testplan.htm and results at: https://www.transportation.gov/research-and-technology/us-dot-spectrum-sharing-test-report-effects-unlicensed-national-information.
- "Impairing Traffic Safety from Changes in the Safety Band: Introduction of Interference from Unlicensed Users" at https://www.transportation.gov/research-and-technology/impairing-traffic-safety-changes-safety-band-introduction-interference.

- "Analysis of FCC Phase I Sharing Report: Out of Band Emissions for UNII Adjacent and Next Adjacent Channel Power" at https://www.transportation.gov/research-and-technology/analysis-fcc-phase-i-sharing-report-out-band-emissions-unii-adjacent-and.
- "Preliminary Technical Assessment of Out-of-Channel Interference (Out-of-Band Emissions)" at https://www.transportation.gov/research-and-technology/preliminary-technical-assessment-out-channel-interference-out-band-emissions.
- And other resources at: https://www.transportation.gov/research-and-technology/safety-band-testing-plans-and-technical-info.

PART 3 – PERFORMANCE MEASUREMENT, REPORTING AND OUTREACH

TASK 7. PERFORMANCE MEASUREMENT

7.1. Data Collection

The THEA team will collect all data elements detailed in the updated PMESP developed during Part 2 under subtask 4.1. The data will be collected using established procedures detailed in the DMP developed during Part 2 under subtask 4.2.

7.2. Data Sharing

One of the main goals of the THEA CV Pilot and this deployment extension is to provide data in a manner that encourages both access and reuse to help advance research and inform policymaking. Consistent with the DMP, the THEA team will adopt procedures for quality checking, cleaning, and removal of sensitive Personal Identifiable Information (PII), yielding data that are appropriately structured and accurately documented. Given that this project will be located in a study area shared with the THEA CV Pilot, the team will continue implementing PII protocols previously established in coordination with the USDOT.

THEA's team will upload all the data in the USDOT system via uploads to a USDOT-identified data storage platform. To ensure long-term data archiving and to guarantee re-uploading if necessary, the data will also be securely archived in the CUTR server. Data in the CUTR server

will be archived for a minimum of five years after this project's (Amendment 7) period of performance expires.

7.3. Reporting

In this subtask, THEA's team will implement the new performance measures for OEM and aftermarket OBU vehicle data developed during Part 2 under subtask 4.1. THEA's team will report on the progress daily via the USDOT Performance Evaluation Dashboard. THEA will also inform USDOT on a weekly basis on the overall progress of the performance evaluation by updating its Performance Measurement Evaluation Schedule. On a quarterly basis, the THEA will submit a system performance report.

7.4. Performance Evaluation Report

THEA's team will prepare an overall system impact report that details the entire PMESP effort and summarizes the results of the spectrum research. One (1) draft Performance Evaluation Report will be prepared for USDOT review and comment. Upon receipt of USDOT comments, the THEA team will finalize the document.

7.5. System Performance Analysis Template

The THEA team will prepare a draft and final system performance analysis template. The template will ensure measuring and monitoring system performance and reliability and will produce measures that are consistent with the updated PMESP and USDOT's efforts on spectrum interference.

Task 7 Deliverables:

a) Data collection and sharing via nightly batch-uploads to USDOT
b) Weekly PMESS
c) Draft/Final system performance analysis template
d) Quarterly system performance analysis reports
e) Near real-time reporting on the USDOT Performance Evaluation Dashboard
f) Draft/Final Performance Evaluation Report

TASK 8. OUTREACH

8.1. Identification of Outreach Activities

The THEA team will collaborate with THEA's Director of Public Affairs & Communications and their Communications Consultant to identify the appropriate outreach activities for this phase of the THEA CV Pilot. It is expected that outreach to participants (identified in subtask 2.1) will include monthly newsletters, email updates, and other information as needed. It is also expected that general public outreach will include press releases, presentations and demonstrations. Identified outreach activities will be documented in list format.

8.2. Implement Outreach Activities

THEA and its Communications Consultant will perform outreach to participants and to the general public using the activities and methodologies identified in the previous subtask.

Task 8 Deliverables:

a) Monthly newsletter
b) Email updates
c) Other participant information
d) Press releases
e) Eight (8) presentations including the ITS World Congress
f) Four (4) demonstrations