Connected Vehicle Pilot Deployment Program Phase 2

Comprehensive Maintenance and Operations Plan – New York City

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16. Abstract

This Comprehensive Maintenance and Operations Plan (CMOP) describes the types and number of equipment to be operated and maintained for the proposed New York City (NYC) Connected Vehicle Pilot Deployment (CVPD) system. Its objective is to develop a plan for the operations and maintenance of in-vehicle, roadside, mobile device, center-related equipment, other equipment and supporting capabilities that comprise all of the NYC CVPD system. This document identifies the roles and responsibilities of organizations and stakeholders that will be involved in system operation and maintenance; proposes methods and procedures for operating and maintaining the NYC CVPD system in Phase 3; provides an overview of configuration and inventory management, inspection and maintenance schedule, and software licenses; and will go through an approval process to ensure safe, secure, and efficient operations and maintenance for the entire NYC CVPD system.

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Connected vehicles, DSRC, V2V, V2I, safety, system, architecture, maintenance, operations, configuration, inventory, inspection, licensing, New York City	

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1. Introduction

This document describes the Comprehensive Maintenance and Operations Plan (CMOP) for the New York City Department of Transportation (NYCDOT) Connected Vehicle Pilot Deployment (CVPD) Project. The CMOP describes the roles and responsibilities of organizations tasked with operating and maintaining the Connected Vehicle (CV) system and all the in-vehicle equipment, roadside unit, mobile device, center-related equipment, other equipment, and supporting capabilities for deploying the CV system in New York City (NYC). It also identifies the methods and procedures for operating and maintaining the NYC CVPD system as well as its aforementioned devices and equipment. In addition to the operations and maintenance approach, the CMOP presents a high-level overview of the inventory and configuration management, inspection and maintenance schedule, and applicable software licenses.

It is one of several documents for the CVPD Program, Phase 2 project funded by the United States Department of Transportation (USDOT). Upon completion of project design and test activities in Phase 2, the CV system deployment involving operations and maintenance will occur in Phase 3 of the project. At the time of this draft CMOP submission, details such as device procurement and software licensing are in progress. These items are indicated as such throughout this document and will be updated as they become finalized or available. The timing of document updates will depend on when the details such as device procurement and software licensing are finalized. The final deliverable will be completed when device testing and validation, and the operation and maintenance procedures have been verified by the vendors.

The document is organized to meet the requirements of the USDOT System Engineering Process and ISO/IEC/IEEE 42010-2011 standard as required by USDOT's Notice of Funding Opportunity (NOFO) for Phases 2 and 3 of the CVPD Program.

1.1. IDENTIFYING INFORMATION

This document is identified as the following:

- Agency: New York City Department of Transportation
- Organization: Bureau of Traffic Operations
- Project Name: New York City (NYC) Connected Vehicle Pilot Deployment (CVPD)
- Title: Connected Vehicle Pilot Deployment Program Phase 2
- Subtitle: Comprehensive Maintenance and Operations Plan (CMOP) - New York City
- Version: D3
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1.2. SUPPLEMENTARY INFORMATION

The key concept for the NYC CVPD project is to equip a large fleet of vehicles with CV technology to advance towards the Vision Zero goal of eliminating injuries and fatalities due to traffic crashes. To that end, the project approach is to acquire ASDs and RSUs that communicate over Dedicated Short-Range Communications (DSRC) and applications to provide drivers with alerts of identifiable safety situations. Other existing and new infrastructure will be used to support the accumulation of data for performance measurement and ongoing operations of the system.

The ASDs and RSUs will communicate over Dedicated Short-Range Communications (DSRC) using protocols covered by IEEE 802.11 and 1609 standards. They will utilize safety applications to provide drivers with alerts of identifiable safety situations. Also, they will connect with back-office applications to support information exchanges for data management and system operations.

The NYC CVPD project is one of three initial CV deployment projects that establish a base for growing a nation-wide connected vehicle system. As such, its focus is on utilizing standards to build basic infrastructure in a manner that provides a foundation for future deployments of connected vehicle technology.

2. Reference Documents

This section identifies the external documents referenced in this CMOP (e.g., standards, requirements, architecture, safety management plan, security management operation concept, ICDs, SDD, etc.). They are listed in Table 1 below. The NYC CVPD project deliverables (#1-10) are living documents and subject to future updates as the system evolves through the design and deployment phases.

Table 1. Reference Documents

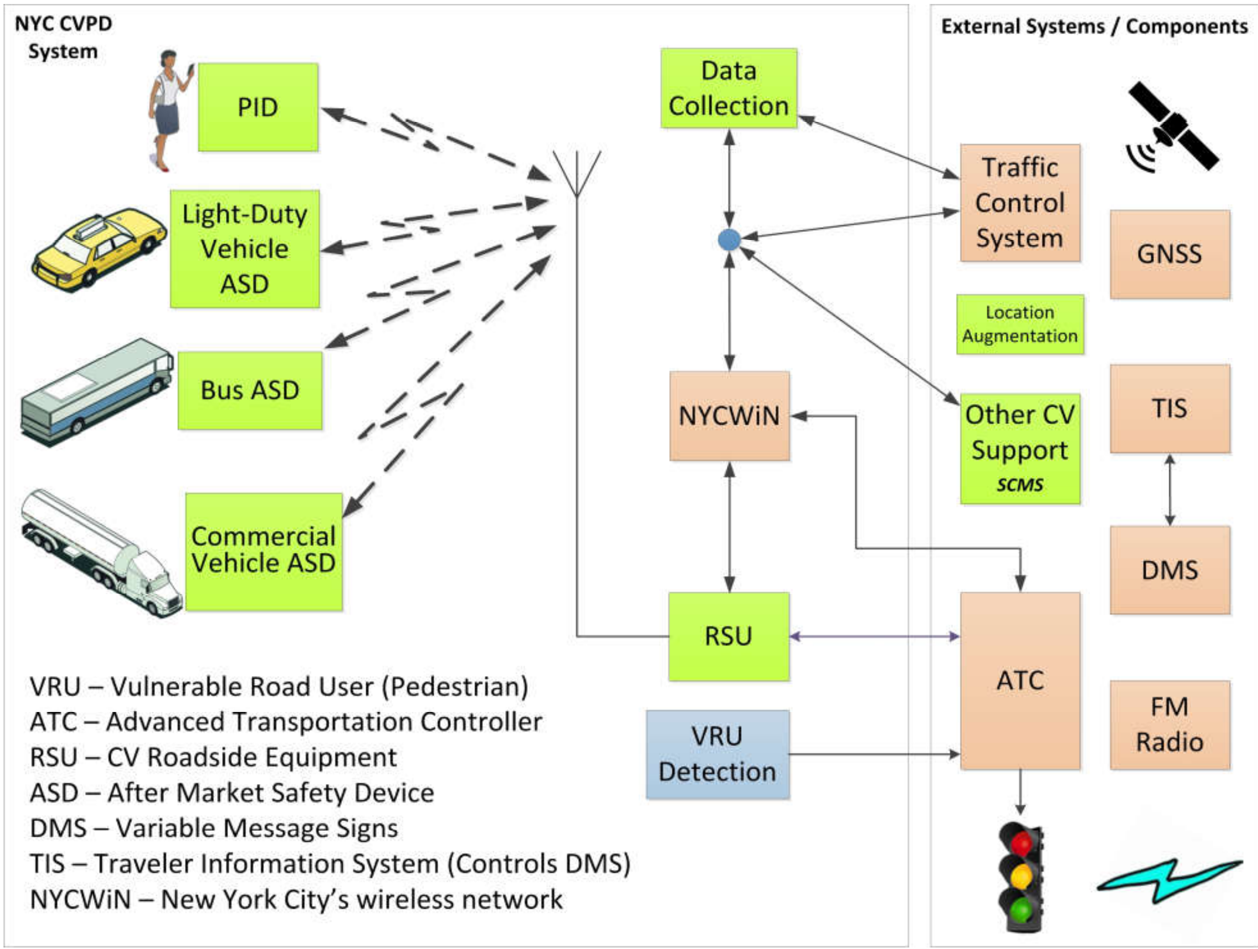
#	Document	Date	Version
1	System Requirements Specification (SyRS)	September 2017	FRevD3
2	System Architecture Document (SAD)	July, 2017	FRevD1
3	System Design Document (SDD)	September, 2017	D3
4	Comprehensive Acquisition Plan (CAP)	December, 2017	FRevD1
5	Comprehensive Installation Plan (CIP)	February, 2018	FRevD1
6	Operation Readiness Plan (ORP)	July, 2016	Draft
7	Security Management Operation Concept (SMOC)	June, 2016	Final
8	Safety Management Plan (SMP)	April, 2016	Final
9	Data Management Plan (DMP)	August, 2017	Draft Final
10	Participant and Staff Training Plan	Under Development	N/A
11	SAE J2735	March, 2016	201603
12	SAE J2945/1	March, 2016	201603
13	ASD Procurement Specification	November, 2017	2.3
14	RSU Procurement Specification	August, 2017	1.9
15	PID Procurement Specification	May, 2016	1.7A

3. System Overview

This project brings New York City (NYC) another step ahead towards reaching the Vision Zero goal of eliminating injuries and fatalities due to traffic crashes. The project's concept introduces CV technology and communications into the NYC travel environment by equipping several large vehicle fleets with the technology and equipping several areas with the corresponding connected vehicle infrastructure.

A portion of NYC's roadway network will have CV infrastructure installed via RSUs. Vehicle-to-Infrastructure (V2I) applications such as Red Light Violation Warning, Speed Compliance, and Curve Speed Compliance will support connected vehicles operating in the designated CV pilot corridors. However, the geographic reach of the CV technology is much broader. Vehicles equipped with CV technology through ASDs will travel through areas equipped with this CV infrastructure and throughout the City's transportation network. Thus, the CV technology that supports Vehicle-to-Vehicle (V2V) applications will function wherever two equipped vehicles are within range of one another and their ASDs can achieve lane level position accuracy of 1.5m, as specified by SAE J2945/1 standard. Equipped vehicle encounters may occur on the surface streets, in the tunnels and bridges crossing the rivers, at the airports, and on the City's higher speed facilities such as the FDR Drive and the Long Island Expressway. The large fleet size means that there will be many opportunities for the CV technology to perform over a large geographic area and diverse roadway environments.

Figure 1 depicts the envisioned NYC CVPD system and the boundary between the internal and external systems and components that interface with the NYC CVPD environment. The ASDs, RSUs, PIDs, data collection/processing system, NYCWiN, and VRU detection system are in the NYC CVPD system. The TCS, ATC, GNSS, TIS, DMS, FM Radio, and other CV support systems including the SCMS are the external systems and components.



Source: NYCDOT, 2016

Figure 1. NYC CVPD System Concept

The existing system elements critical to the operation of the pilot system are illustrated with beige backgrounds. These existing elements include the traffic control system (TCS), traffic controller (ATC), Global Navigation Satellite System (GNSS), Traveler Information System (TIS), Dynamic Message Signs (DMS), FM radio, and supporting New York City's wireless network (NYCWiN) communications infrastructure. The new system elements which exist and will be reused, modified, or integrated into the NYC CVPD system contain green backgrounds. They comprise of the ASDs in light-duty vehicles, buses, commercial vehicles, RSUs, PIDs, data collection/processing systems, and other CV support systems including the Security Credential Management System (SCMS). The Vulnerable Road User (VRU) detection devices are shown with a blue background. They are relatively new and will be deployed to the system on a very limited basis.

NYC's initial system deployment is anticipated to be the largest CV technology deployment to date. It is anticipated that approximately 281 intersections in Manhattan and 28 intersections along Flatbush Avenue in Brooklyn will be instrumented with RSUs to communicate with up to 8,000 vehicles equipped with ASDs. These devices will monitor communications with other connected vehicles and the infrastructure and provide alerts to vehicle drivers/operators. Other RSUs will be installed at locations to support system management functions such as providing security credentials, managing application and parameter configurations, and uploading logged information. These locations consist of fleet terminal facilities, airports, and river crossings (bridges and tunnels) where vehicles frequently travel.

The NYC CVPD project provides a real demonstration and evaluation of the benefits of the CV technology in a dense urban environment. NYC has deployed a robust infrastructure with advanced traffic controllers (ATC), an advanced adaptive traffic signal control system which currently uses travel times as part of its operational algorithms, an aggressive maintenance program, and a ubiquitous high-speed wireless network (NYCWiN). By deploying Aftermarket Safety Devices (ASD) and Roadside Units (RSU), the proposed system can bring the benefits of the CV paradigm to NYC's Vision Zero initiative and provide the opportunity to evaluate the benefits with a significant number of vehicles regularly driving in the area. Additional information on the overview of the NYC CVPD system can be found in Section 1.5 of the NYC System Requirements Specification (SyRS), FHWA-JPO-16-303.

At this time, location augmentation (i.e. RTCM) is not included in the NYC CVPD system and therefore not considered in this CMOP. The network servers for the support software will be held in NYCDOT TMC. The external systems (e.g. SCMS) will be operated and maintained by their respective owners and operators under contract to USDOT. NYC CVPD central systems will detect failures of the external interfaced systems, and the appropriate operators will be notified as directed by USDOT.

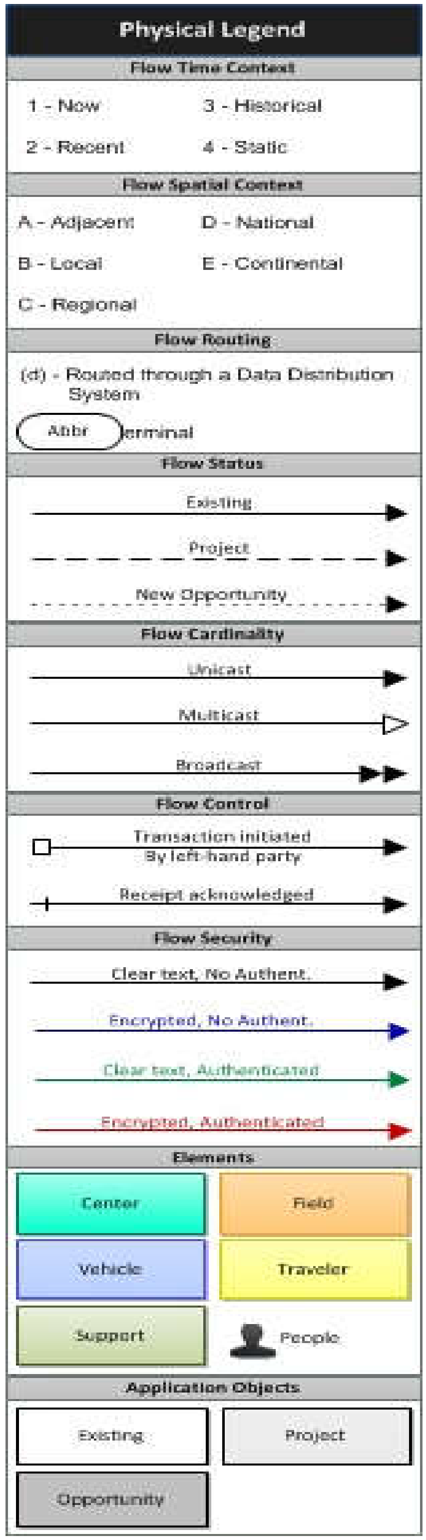
3.1. FUNCTIONAL SYSTEM OVERVIEW

The functional architecture view describes the abstract functional elements and their logical interactions that satisfy the system requirements. It contains a set of processes or functions that control and manage system behaviors and perform actions to achieve application objectives or support actions of other processes. It also describes data processing functions, data stores and the logical flows of information among these elements. The CVRIA recommends that the reader use the Physical View diagrams for graphical representations of the system behavior.

Performance data and event data lifecycle will serve as critical functions in the NYC CVPD system. As the data is collected from the ASDs in the vehicles, it will be logged, stored, processed, and sanitized of PII and location and time information. These are vital steps in evaluating the safety benefits before and after system deployment. This section provides the context of the NYC CVPD system and describes the performance and event data components and their lifecycle. Section 3.4 of the NYC System Architecture Document (SAD), FHWA-JPO-17-451 includes additional description and diagrams of the NYC CVPD functional architecture.

3.2. PHYSICAL SYSTEM OVERVIEW

According to the CVRIA, the physical views of the system describe the devices, facilities, and external interfaces that comprise the system. The devices may be mobile (for example ASD) or statically located (for example RSU), and the facilities could be concentrated or distributed over a geographic region. This section presents the NYC CVPD system's physical architecture in terms of the safety and support applications. Also, a high-level diagram is used to describe how all physical objects or system elements are connected by information flow triplets, which contains the specific data flow, the source element, and the destination element. The legend for interpreting the physical view diagrams in this document is shown in Figure 2 below:



Source: SET-IT, 2016

Figure 2. NYC CVPD System Physical View Diagram Legend

The NYC CVPD system will operate V2V and V2I safety applications that will be installed in the ASDs. The ASD in the host vehicles will broadcast BSMs to and from other remote vehicle on-board units (OBU) via DSRC channel 172. This is shown by the Vehicle Basic Safety application object in each ASD type. The vehicle control event information flow refers to the event data generated based on hard braking, and the vehicle location and motion information flow which indicates the vehicle's location in three dimensions (X, Y, Z coordinates), positional accuracy, speed, acceleration, heading, size, and type. While not illustrated in the V2V application diagram, the MAP message data stored in the ASDs will be updated as they pass by RSUs assigned to schedule the MAP message by day of the week (DOW) (that is, Monday-Friday, Saturday, Sunday) and/or time of day (TOD), depending on changes to the geometry and/or lane access restrictions. Such scheduling and configuration will originate from the NYCDOT TMC and be transmitted to designated RSUs which are capable of storing multiple MAP messages. More details on the physical architecture of these safety applications are found in Section 3.2.1 of the NYC SAD, FHWA-JPO-17-451.

In addition to the safety applications, the NYC CVPD physical architecture also consists of system support applications for managing the core services. The support applications will monitor, manage, and control services for applications and equipment that are operating in the CV system environment. The NYC CVPD will enable CV applications to provide services including device management, time synchronization, and trust management. Additional details on the physical architecture of the support applications are included in Section 3.2.2 of the NYC SAD, FHWA-JPO-17-451.

3.3. ENTERPRISE SYSTEM OVERVIEW

The enterprise view includes the active stakeholders, that is, those directly related to the deployment of the CVPD and responsible for some aspect of its operation. It does not consist of stakeholders who would be involved in the future as the system expands both geographically and operationally. The NYC CVPD project goal is driven by Vision Zero and NYCDOT is the primary stakeholder that will own and manage the NYC CVPD system. As the traffic manager, NYCDOT is bringing CV technology to its urban area in anticipation of the safety benefits for Vision Zero.

3.3.1. Stakeholders Involved

All project stakeholders are represented by the enterprise view architecture detailed in the NYC SAD, FHWA-JPO-17-451. They are listed in Table 2 below:

Table 2. Users and Stakeholders

User	User Class
DSNY Operators	Fleet Driver
MTA	Fleet Owner, Installer
MTA Bus Operators	Fleet Driver
New York University (NYU)	Performance Measurement User
NYC DoITT	Maintainer
NYCDOT	System Owner/ Traffic Manager, Integrator, Acquirer
NYCDOT Drivers	Fleet Driver
NYCDOT Fleets	Fleet Owner, Installer
NYCDOT Maintenance Personnel	Maintainer
NYCDOT Traffic Management Center (TMC) Operator	Operator
Pedestrian	Pedestrian
Pedestrians for Accessible and Safe Streets (PASS)	Pedestrian
Taxi & Limousine Commission (TLC)	Fleet Owner Regulator
Taxi Companies	Fleet Owner, Installer
Taxi Drivers	Fleet Driver
Texas Transportation Institute (TTI)	Performance Measurement User
UPS	Fleet Owner, Installer
UPS Drivers	Fleet Driver
Vendor for ASD, PID, RSU	Supplier

Note that NYC DoITT will maintain the backhaul network via NYCWiN, and NYCDOT maintenance personnel will be responsible for troubleshooting and repairing faults in the CV equipment software and hardware. The individual fleet owners will be in charge of maintaining their fleet vehicles and reporting issues with the CV technology and coordinating maintenance activities for ASD repairs with the NYCDOT maintenance personnel. Hence, the ASD in the taxis will be maintained by each taxi fleet while its repair will be conducted by the NYCDOT maintenance personnel.

3.3.2. Relationship Diagrams

The high-level (layer 0) Enterprise View of the NYC CVPD system is described through three architecture diagrams. The first diagram defines which enterprises own, operate, maintain, and regulate their target objects. The second diagram describes the specific relationships between each stakeholder organization pair through expectations and agreements forming those relationships. The third diagram focuses on NYCDOT as the system owner and its interactions with various stakeholders and participating organizations. The color schemes in the diagrams are based on the CVRIA and the SET-IT tool, the software tool used to generate the Physical and Communication View diagrams.

The NYC CVPD enterprise view architecture is illustrated through the following diagrams in Section 3.1.2 of the NYC SAD, FHWA-JPO-17-451: roles (owner/operator), relationships among the stakeholder organizations, and NYCDOT context. For instance, NYC DoITT will maintain the backhaul network via NYCWiN and NYCDOT maintenance personnel will be responsible for troubleshooting and repairing faults in the CV equipment software and hardware. The individual fleet owners will be in charge of maintaining their fleet vehicles and coordinating maintenance activities for ASD repairs with the NYCDOT maintenance personnel. Hence, the ASD in the taxis will be maintained by each taxi fleet while its repair will be conducted by the NYCDOT maintenance personnel.

3.4. COMMUNICATIONS OVERVIEW

The Communication View describes the communications protocols between the application objects. The protocols are needed to establish interoperability between the physical objects in the physical view described in Section 3, Physical System Overview, of this document. In the SET-IT tool, the information triple from the Physical View is mapped to one or more data dictionary standards, also known by CVRIA as information layer standards. These are used to build communication profiles that identify the communications protocols necessary for determining the data being transmitted based on its corresponding information flow.

Each Communications View Diagram contains layers that refer to abstract parts of the communication protocol diagrams or profiles. These layers are needed to achieve interoperability based on the CVRIA Communications Model. The eight (8) layer types are defined in Table 3 below:

Table 3. CVRIA Communication View Layers

Acronym / Abbreviation	Definition
ITS Application Information Layer	Structure, meaning, and control exchange of information between two end points.
Application Layer	Rules and procedures for exchanging encoded data.
Presentation Layer	Rules for representing the bits and bytes of information content to be transferred.
Session Layer	Mechanism for opening, closing and managing a dialogue between application processes.
Transport Layer	Rules and procedures for exchanging application data between endpoints on a network.
Network Layer	Routing, message disassembly/re-assembly and network management functions.
Data Link Layer	Rules and procedures for exchanging data between two adjacent devices over some communications media.
Physical Layer	Signaling standards that are typically developed for specific communications media and industry needs and address the needs of WAVE/DSRC (with the exception of IEEE802.11p (air interface to the 5.9GHz spectrum)).

Each Communications View Diagram in Section 3.3.2 of the NYC SAD, FHWA-JPO-17-451 includes the specific communication profile and information triple at the top. Below the information triple, the source, destination, and their potential communications protocols are shown in a layered stack. The diagram also consists of the security plane which is located in the middle between the source and destination columns. The security plane identifies the standards that specify policies and system-to-system authentication, as well as the encryption of data across one or more layers of the communications stack.

3.5. ADDITIONAL VIEWS (OPTIONAL)

At this time, the NYC CVPD system architecture does not include any additional views. Critical support functions such as the Security Credential Management System (SCMS) and location and time service (LTS) are part of the high-level physical architecture. They are illustrated in Section 3.2.2 of the NYC SAD, FHWA-JPO-17-451.

Location and Time Service (LTS) will be critical as the ASD-equipped vehicles travel through the dense environments in Manhattan and Brooklyn. It initially consisted of location augmentation involving map matching or dead reckoning for location accuracy. However, as stated in the beginning of Section 3, location augmentation (i.e. RTCM) is not included in the NYC CVPD system and therefore not considered in this CMOP. Instead, location accuracy will be established through the ASD utilizing RSU-centric triangulation to comply with the 1.5m location accuracy requirement per SAE J2945/1 standard.

As shown in the LTS physical architecture in Section 3.2.2 of the NYC SAD, the GPS in the ASD and field GPS for the RSU will be the baseline mechanisms for establishing the location referencing. However, to address the urban canyon effect on location accuracy, the RSUs will include location settings that can be configured by NYCDOT TMC and used by the ASDs to improve the accuracy and stability of the location determination algorithms. For time synchronization and accuracy, ASTC controllers maintain their time with the NYCDOT TMC based on the electric grid's line frequency clock (LFC). This time source is different than the GNSS time source used by the CV equipment, but the ASTCs will be modified to use the GNSS time source for coordination with the CV infrastructure.

3.6. SYSTEM UPDATES

As the system manager, NYCDOT will be deploying CV infrastructure to support the operation and maintenance services for its CV system. These devices include the ASD, RSU, PID, NYCWiN, traffic signal controller (ASTC) upgrades, and TMC back-office facilities. As the NYC CVPD system is deployed, the scheduling of updates will be determined by vendors' software release schedules and subsequent testing schedules. The system updates will be identified on a non-regular, as-needed basis, based on need, impacts, severity, and other factors as determined by the Change Control Board (CCB), Section 8 of this document. The maintenance procedures on such system updates are covered in Chapter 7 of this document.

3.7. SERVICE LEVEL AGREEMENTS (SLAS) (IF APPLICABLE)

No service level agreements (SLAS), system restrictions, or waivers of operational standards are expected for the NYC CVPD system.

3.8. SECURITY AND PRIVACY

3.8.1. Security Management Operating Concept

The NYC Security Management Operating Concept (SMOC), FHWA-JPO-16-300, outlines the security mechanisms that will be used to protect the information flows within the NYC CVPD system, additional practices to protect the privacy and security of data, and management processes and procedures to ensure that security operations are executed in a reliable and trustworthy way.

3.8.2. Hardware Security Module

The back-office facilities at NYCDOT Traffic Management Center (TMC) will integrate its processor system with a commercially available TMC Authority Hardware Security Module (HSM) by Green Hills ISS. Initially, the SCMS developed by USDOT was to be used for the NYC CVPD project. However, the commercially available HSM will reside in the NYCDOT TMC and sign the MAP and TIM messages instead of all DSRC messages. Also, through this approach, the TMC software applications (referred to as privileged applications) will utilize the SCMS application keys to sign, verify, encrypt, and decrypt the enrollment and pseudonym certificates and the safety messages at their source. Prior to obtaining the

SCMS key material, it must be provisioned with an SCMS identity via the SCMS bootstrap and enrollment process and use its enrollment keys to request the application keys.

Once the ISS CMS (that is, SCMS) is developed, the TMC Authority will be able to access it for managing the SCMS functions and certificates and signing and authenticating the MAP and TIM messages transmitted by the devices. The HSM and its supporting hardware are leased from Green Hills ISS for the NYC CVPD project.

The HSM in the ASD will be used to sign the BSMs, while the HSM in the RSU will be used to sign the SPaT messages. For O&M, if the ASD or the RSU is suspected of misbehavior or has been potentially compromised because its missing, then it will assume that its being attacked and notify Green Hills ISS to be placed on the Certificate Revocation List (CRL).

3.8.3. Certificate Management

Security of the data and field devices is an important part of the connected vehicle program. Communications between the roadside units (RSU) and aftermarket safety devices (ASD) is secured using SAE 1609.2 certificates generated by the SCMS and stored in hardware security modules (HSM) in the RSU and ASD. Access to the SCMS is not available to the advanced solid-state traffic controller (ASTC) in use by New York.

Communication security between the ASTC, RSU and the NY Traffic Management Center (TMC) will be provided through communications secured using the datagram transport layer security (DTLS) 1.2 standard with mutual authentication using X.509 certificates. The DTLS cipher suite will be TLS_ECDHE_RSA_WITH_AES_256_CBC_SHA.

3.9. SAFETY

The NYC CVPD project will consider disruptions that could come from any source, including the following:

- Inadequate design, including software flaws and inadequate power supplies
- Natural causes, such as storms and power outages
- Improper use, from installation, to operation, to maintenance

The NYC Safety Management Plan (SMP), FHWA-JPO-16-301, was developed in Phase 1 of the NYC CVPD project and will continue to be a living document throughout the deployment. Appendix C in the SMP consists of a preliminary hazard analysis and risk assessment that describes several potential scenarios and risks involving the operation and maintenance (O&M) of the NYC CVPD system. The SMP will serve as a living document and incorporate new input and findings from other stakeholders and team members.

Although safety goals were developed for a comprehensive list of threats, not all of the goals will be managed under the SMP. Some of the needs identified in this process will be transferred to other activities. For example, unjustified pedestrian signal requests and sophisticated attacks on the communications channels will be exported to security. The safety assessments will occur on an ongoing basis to address safety concerns throughout the life of the NYC CVPD system. As the safety manager of the NYC CVPD system, Rami Khashashina, with NYCDOT, will be responsible for ongoing reviews to address safety concerns.

4. Operations Roles and Responsibilities

This section provides a list of organizations that will be involved with operating the NYC CVPD system and/or the CV equipment. They are described in Table 4 below.

Table 4. Operation Roles and Responsibilities

Role (examples)	Primary	Back-Up	Organization
ASD Operations Manager	Hisham Khanzada	Tom Kelly	NYCDOT
RSU Operations Manager	Hisham Khanzada	Tom Kelly	NYCDOT
PID Operations Manager	Kaan Ozbay	Elena Pressas	NYU
TMC Operations Manager	Evgeniy Kudinov	Rachid Roumila	NYCDOT
Overall Operations Manager	Bob Rausch	N/A	TransCore

There will be a primary and back-up operations manager for each role. The NYCDOT assignments to these roles reflect their operational responsibilities. As the NYC CVPD site deployment lead, Mr. Bob Rausch, will serve as the overall operations manager for Phase 3. Each fleet owner identified in Section 3 Enterprise System Overview, of this document, will be communicating with the ASD Operations Manager to identify and report any issues and faults that may occur. The procedures for conducting such tasks and interactions between the fleet owner and the ASD Operations Manager are included in Section 5 Vehicles of this document.

4.1. ASD OPERATIONS MANAGER

NYCDOT will be responsible for operating the ASDs in the vehicles, and Hisham Khanzada will be the ASD operations manager. In particular, the NYCDOT ASD monitoring personnel is responsible for checking the health status and radio frequency (RF) footprint of the communication to and from ASDs in the NYC CVPD. The ASD will collect log information on its operational status by continually updating its system status log (SSL) which will be transferred to the TMC whenever ASD encounters an RSU advertising the upload service.

4.2. RSU OPERATIONS MANAGER

NYCDOT will be responsible for operating the RSUs at the intersections and support locations, and Hisham Khanzada will also be the RSU operations manager. In particular, the NYCDOT RSU monitoring personnel is responsible for checking the health status and RF footprint of the communication to and from RSUs in the NYC CVPD. The RSU monitoring will occur continuously, while the RF monitoring will occur weekly or as the experience dictates. When equipment failures are detected, they will notify and dispatch the maintenance personnel to the RSU. The proposed RSU locations consist of signalized intersection, vehicle fleet terminal, bridge/tunnel crossings, and other designated locations that may be outside the NYC CVPD pilot area.

4.3. PID OPERATIONS MANAGER

The NYCDOT IRB, NYU will own and operate the PIDs during deployment, while the visually-impaired pedestrians will take over the ownership role after the deployment phase. Kaan Ozbay will be the PID operations manager and responsible for monitoring, operation, and maintenance of the PIDs on a daily basis. NYU will obtain consent from NYCDOT to conduct its own data collection from the PIDs. It will work with PASS to obtain consent, recruit, and collect data from participating visually-impaired pedestrians. Upon collecting the necessary data, it will send the data to the TMC Remote Data Storage Center where any PII detected will be scrubbed and sanitized. The post-processed data will then be sent to the NYCDOT Data Warehouse for a final check before being submitted to USDOT Secure Data Commons (SDC) where additional evaluation of the NYC CVPD safety benefits will be conducted by the Independent Evaluators (TTI, Volpe) for USDOT.

Unlike the ASDs and the RSUs, the PIDs will not collect and record their RF signal level information. However, whether each device is operational or not will be logged by NYU (NYCDOT IRB). While only NYU will record the operating PIDs and their locations, any PII will be scrubbed prior to being uploaded to TMC's Performance Monitoring server for final post-processing and obfuscation (see Figure 37 in the System Architecture Document (SAD), FHWA-JPO-17-451). The PID data will be scrubbed at NYU by NYU. Scrubbed event data and operational statistics will be sent to the TMC for analysis and export. NYU will contact the PID users for device maintenance purposes.

The PIDs will receive MAP and SPaT messages via cellular connection through the Amazon Web Service (AWS) cloud. NYU will be responsible for monitoring, operation and maintenance of the PIDs on a daily basis or when in use. After the PID operating statistics are sent to the TMC by NYU, the TMC will notify NYU of apparent absence of PID participation. Also, the TMC will instruct NYU to contact the participants.

4.4. TMC OPERATIONS MANAGER

NYCDOT will be responsible for operating the CV equipment and components such as the performance data processing server and the HSM within its TMC. TMC monitoring will be performed by the current staff who manages the system on a 24-hour, 7-day-a-week basis. It will also be tasked with verifying that CV integrates with the existing network infrastructure. Evgeniy Kudinov will be the TMC operations manager.

5. Operations Procedures

5.1. OPERATIONS METHODS

During NYC CVPD system's normal operation, the CV device will be able to communicate via DSRC to and/or from the device. During performance evaluation, it will operate in either silent or active state as shown in Table 5.

Table 5. NYC CVPD System Operational States

State	Description
Silent	The device transmits and/or receives DSRC messages, but no event records are collected.
Active	The device transmits and/or receives DSRC messages while event records are collected.

During data collection before or after evaluation, the system will operate in silent mode for a time period to gather data. During this silent period, drivers will not be engaging with the NYC CVPD system and not receive alerts from the ASD. While the previous concern exists during this silent period, there is another regarding toggling the system between silent and active mode. This mode difference has the potential to impact drivers' decisions should they become secure in knowing the system will generate warnings, when in fact it is in silent mode. To address these concerns, the NYC project team proposes using a single transition from silent to active mode for the fleets.

The NYC CVPD system will operate on a daily schedule, with specific application alerts being triggered in only designated locations at certain hours of the day (for example, PEDINXWALK). The ASDs will start up after the vehicles begin their normal operations from their garages and verify that they are initiated for operation. They will shut down after the vehicles return to their garages at the end of their normal operating hours.

5.2. OPERATIONAL MODES

The NYC CVPD system will operate in either online or offline mode as shown in Table 6 below. The system offline mode does not mean that when a single device is powered off, the entire subsystem will be in offline mode. Instead, it occurs when at least a significant number of the devices that comprise its respective subsystem (that is, ASD, RSU, PID) has failed. System offline mode is classified into device fail modes, which are listed in Table 12, Section 7 of this document.

Table 6. NYC CVPD System Operational Modes

Mode	Description
Online	All subsystems and interfaces in the NYC CVPD system are operational. All external systems and components are operational.
Offline	One or more subsystems and interfaces in the NYC CVPD system have failed. A critical external system (for example, GNSS) has failed or a significant number of external units (e.g. ASTC) have failed. (Note that the significant number value will be established during the detailed design.)

A critical external system such as GNSS being offline will result in the NYC CVPD system being offline. When it pertains to individual devices, a threshold will be set for those individual device failures. At this time, quantitative goals for the NYC CVPD system performance have been identified for each device class including the devices themselves and their corresponding communication networks. Their criteria, percentage goal for being online, and the specific measurements used to determine the percentage goal are listed in Table 7 below.

Table 7. Quantitative Goals for System Performance Criteria

Device Class	Criteria	Goal	Measurements
ASD	Hardware Availability	99%	Equipment failure
RSU	Hardware Availability	99%	Equipment failure
RSU-Back Office Communication	Link Accessibility	99%	Communication faults
RSU-ASTC Communication	Link Accessibility	99%	Communication faults
PID	Hardware Availability	99%	Equipment failure
TMC-AWS Communication	Link Accessibility	99%	Communication faults
AWS-PID Communication (e.g. Verizon)	Link Accessibility	99%	Communication faults
PID-NYU Communication	Link Accessibility	99%	Communication faults
NYU-TMC Communication	Link Accessibility	99%	Communication faults
ASTC	Hardware Availability	99%	Equipment failure
ASTC-Back Office Communication	Link Accessibility	99%	Communication faults
TMC HSM	Hardware Availability	99%	Equipment failure
TMC-HSM-SCMS Communication	Link Accessibility	99%	Communication faults
CV application server	Hardware Availability	99%	Equipment failure
TMC network	Link Accessibility	99%	System-wide communication faults
NYCWiN	Link Accessibility	99%	System-wide communication faults

In achieving the quantitative goals included in the above table, the following constraints will be considered for impacting the system performance:

1. The entire CV system from operation to data collection is dependent on the overall availability of communication to each of the remote locations. The reliability of communications to the CV infrastructure is determined by the service providers and the contract by NYC DoITT.

2. Monitoring the external event impacts from power interruptions, equipment knockdowns, lightning, and construction activities, etc., will be needed.

3. CV infrastructure maintenance will be limited to City maintenance personnel and schedules.

The NYC CVPD system devices will operate in the DSRC modes shown in Table 8, 9, and 10.

Table 8. RSU Operational Modes

Mode	Description
Online	The RSU communicates with other CV devices and subsystems.
Offline	The RSU no longer communicates with other CV devices and subsystems.

Table 9. ASD Operational Modes

Mode	Description
Online	The ASD communicates with other CV devices and subsystems.
Offline	The ASD no longer communicates with other CV devices and subsystems.

Table 10. PID Operational Modes

Mode	Description
Online	The PID communicates with other CV devices and subsystems.
Offline	The PID no longer communicates with other CV devices and subsystems.

5.3. OPERATIONAL PROCEDURES

This section describes the operating procedures for the NYC CVPD system and the equipment listed in Section 3 and Figure 1. It provides detailed steps to execute the system runs, software updates and startup/shutdown of the system devices, check the hardware/software version, verify results of specific processes, and perform manual operations in the field. The procedures in this section are based on the operational scenarios located in the NYC Concept of Operations (ConOps), FHWA-JPO-16-299. Note that this document does not address the testing and tuning of the incremental deployment of the infrastructure, vehicles, and applications. This document deals with the ongoing O&M post installation.

When the ASD issues the warnings/alerts, the vehicle operator will be expected to respond with action (for example. reducing speed, changing turning angle) or no action. NYCDOT has issued a memorandum of understanding (MOU) with each fleet owner to ensure that the logs collected from the ASDs in the vehicles are not used to evaluate the vehicle operators' driving performances. In other words, the participating vehicle operators are to be held harmless from the CV data collected.

5.3.1. Vehicles

This section applies to the vehicle operator beginning normal duties by starting the ignition of the ASD-equipped vehicle at the fleet garage. During this vehicle trip initiation, the ASD may either be in normal operating mode or fail mode. Also, at the end of each vehicle shift the vehicle operator will be expected to perform the following tasks to ensure that the ASD is turned off and that it is not drawing power from the vehicle after shutdown.

Note that the ASD is connected to both ignition power and battery power, such that it has sufficient power to continue normal operations for a short time after the ignition power is switched off. In normal operation, the ASD will transition from a quiescent state drawing less than 25 microamps to an operational state upon detection of the ignition circuit power. Thereafter, the ASD will continue operation for a brief time after the ignition switch is turned off during which it completes transmission, saves logs, and shuts down gracefully. If the battery is disconnected [for maintenance], the ASD will shut down immediately and some log entries may be lost but will be detected on power up. However, no other data or applications will be corrupted, and the loss of log data will be noted in the system log.

The NYC CVPD team will set up a website for the vehicle operators to provide anonymous feedback. It will periodically review the analysis of the operator actions and feedback with the device vendors to consider modifying or tuning the warnings or alerts by application.

5.3.1.1. Vehicle Trip End

1. Driver returns the vehicle to its fleet barn at the end of normal operation.

2. Driver turns off the vehicle ignition to end normal duties.

3. The ASD logs the shutdown event.

4. Driver observes that the ASD is turned off.

The data in the SSL and activity log will be collected as the vehicle approaches the barn. The system will be able to determine the specific vehicle (ASD serial number) has returned to the barn and its SSL will indicate what happened with respect to system operation. The event log will show alerts, etc., and the RF log will include the sightings and RF characteristics for the RSUs it was near. The logs may need to be uploaded throughout the day from any RSU to keep the size down and the TMC may need to merge them together for each vehicle before processing.

5.3.2. In-Vehicle Equipment (Aftermarket Safety Device)

5.3.2.1. Vehicle Trip Initiation

This scenario assumes that RSUs have been placed at a designated entry and exit point for the vehicle barn or garage such that it will recognize the presence of the vehicle and upload its SSL with the latest events or the event log. On entry to the garage, there are likely to be lots of entries in the event log, but on exit there may be only a single event (startup); there could be other events since multiple vehicles will be powered and in close proximity to each other.

The ASD speaker's audio voice prompt at startup will indicate whether the device initiates or fails to initiate. The required operating procedure for the driver is to notify the garage. The fleet owner will then schedule the necessary maintenance for the vehicle.

5.3.2.1.1. ASD in Normal Operation

1. Driver turns on the vehicle ignition to begin normal duties.

2. ASD reads the vehicle's VIN number and compares it to the VIN used during installation to determine whether the ASD has been moved to a different vehicle and enters this into the System Status Log (SSL).

3. ASD will not broadcast BSMs if the two VINs are not identical.

4. ASD listens to the microphone and creates a start-up log entry to verify that it is turned on and the CV applications are ready for operation.

5. As the vehicle exits the garage facility, the ASD uploads its System Status Log (SSL) with all events during the last 24-hour period, the ASD's serial number, and confirmation that it has not been moved to another vehicle.

6. Resume normal vehicle operation.

5.3.2.1.2. ASD Fails to Initiate

1. Driver turns on the vehicle ignition to begin normal duties.

2. The ASD detects the fault(s) and notifies the driver that it has failed to initiate and is not ready for operation.

3. The ASD logs the start-up event and the fault(s).

4. Driver notifies the fleet owner through the defect notification card in the vehicle by recording the fault(s) and dropping the card in a box as he or she leaves the garage.

5. Fleet owner notifies NYCDOT of the ASD failure.

6. NYCDOT ASD Operations Manager coordinates and arranges diagnostics and repair activities with the NYCDOT maintenance personnel and the fleet owner.

7. NYCDOT maintenance personnel visits the fleet garage and performs the repairs as needed.

8. Driver resumes normal duties with the vehicle.

5.3.2.2. RF Data Collection

The ASD will contain a support application to detect the presence or absence of other ASDs and RSUs during operation in the NYC CVPD environment. The data will be used to trace the radio frequency (RF) radiation issues to a specific vehicle or RSU. This will include the ASD serial number, not only for RF maintenance, but also for distinguishing the control group from the treatment group for performance measurement and evaluation. The ASD serial number by itself is not considered PII but is required to identify potentially defective devices. The information collected then may be provided to the fleet owner for arranging repairs or adjustments to be made to the vehicle. It will be encrypted but scrubbed following the performance analysis process at the TMC.

5.3.2.2.1. ASD Collects RF of another ASD

1. During normal operation, the ASD in the host vehicle hears another vehicle's ASD for the first time via BSM.

2. The ASD logs the host vehicle’s available vehicle ID, power level information, and its BSM which includes the vehicle’s location, heading, speed, date, and time.

3. The ASD also records the remote vehicle’s BSM, which consists of its location, heading, speed, date, and time.

4. Based on the ASD’s pre-determined acceptance criteria, the RF record is logged as the first and last message heard from the same ASD.

5. The ASD continues to receive BSMs and checks if they are from the same ASD. If this is the case, then the ASD replaces the last message log entry and continues to monitor incoming BSMs.

6. The ASD repeats the aforementioned step until the configurable duration for receiving additional BSMs times out and ends; no further log entries are recorded for that particular ASD sighting.

7. When the ASD in the host vehicle hears a different ASD, steps 1-6 are repeated for the new ASD. The ASD may hear multiple ASDs depending on spacing between ASDs, RF conditions, etc. It is critical that the ASD constructs the first and last entries for each ASD it hears, and all entries are collected simultaneously.

5.3.2.2.2. ASD Collects RF of another RSU

1. During normal operation, the ASD in the host vehicle hears an RSU for the first time via the SPaT message from that specific RSU.

2. The ASD logs the host vehicle’s available vehicle ID, power level information, and its BSM which includes the vehicle’s location, heading, speed, date, and time.

3. The ASD logs the available RSU ID and the RSU’s power level information.

4. Based on the ASD’s pre-determined acceptance criteria, the RF record is logged as the first and last message heard from the same RSU.

5. The ASD continues to receive SPaT messages from RSUs and checks if they are from the same RSU. If this is the case, then the ASD replaces the last message log entry and continues to monitor incoming SPaT messages.

6. The ASD repeats the aforementioned step until the duration for receiving additional SPaT messages times out and ends; no further entries are recorded for that particular RSU sighting.

7. When the ASD in the host vehicle hears a different RSU, steps 1-6 are repeated for the new RSU. The ASD may hear multiple RSUs depending on the spacing between adjacent RSUs, RF conditions, etc. It is critical that the ASD constructs the first and last entries for each RSU it hears, and all entries are collected simultaneously.

5.3.2.2.3. ASD Uploads RF Log to RSU

1. The ASD-equipped vehicle passes by the RSU which has been configured for uploading the RF log entry data.

2. The RSU broadcasts the WSA to the ASD to verify that it is ready to receive the RF log entries from the ASD.

3. The ASD hears the RSU's WSA and uploads the log entries that have timed out through the appropriate DSRC channel.

4. The RSU acknowledges successful receipt of the RF log entries.

5. The ASD purges the RF log entries after they are transmitted to the RSU.

6. This log upload process is repeated for a time period specified by the RSU.

Note that the above application will be supported by the BSMs from ASDs and SPaTs from RSUs. The RF monitoring data will support the NYC CV system's infrastructure management. It will not be encrypted since no PII data and transient data will be collected. Transmission to the RSU will be secure, and data collection will occur only when activated by the RSU and the TMC's back office CV data processing center for a specified duration.

5.3.2.3. Event Data Record

The ASD will contain a support application to log the information before and after a particular event. The number of seconds before and after each event is to be determined, and it may depend on the type of warning generated by the ASD. What data is recorded will be subject to whether OBD-II/CAN bus is accessible and what data is produced by the ASD. The log data is expected to include the location and time information from the BSM, the warning triggered and issued by the safety application in the ASD, any MAP, SPaT, and TIM messages from any RSU it can hear, and the vehicle maneuver as a result of that warning. As the vehicle returns to its fleet garage, the recorded data will be uploaded to the RSU located there. Other support RSU locations may be utilized for the ASDs to upload the event data.

1. During normal operation, an alert is triggered by the safety application in the ASD.

2. The information on vehicle location and time and driver's action are recorded at a resolution needed for the alert type (e.g. 1/10 second or 1 second interval) for periods before and after each alert with the duration of each period defined by the needs of the alert.

3. The ASD stores the event records from all alerts generated while the vehicle is in normal operation.

4. The driver returns the vehicle to its fleet terminal after normal operation.

5. The ASD transmits the event log data to the RSU at garage (or other location designated for advertising the service).

Note that in the NYC CVPD, the definition of an event will be configurable. It will be used to collect driver behavior data, which will be aggregated and analyzed for performance measures and safety benefits. Also, it will be processed to clean any personal traceable data to prevent any correlation with other records.

5.3.3. Roadside Unit

5.3.3.1. RF Data Collection

In the NYC CVPD system operation, special cases including temporary occlusion by a commercial vehicle, vehicle ID change, and stopping or turning off the ASDs may occur. In the event of such temporary occlusion, a statistical approach will be used to build a projected profile or a single sighting. Also, during the data collection the first and last criteria may be determined by a percentage of messages received and the number of RSUs detected. The repetition rate may vary depending on whether single or multiple messages are received or when final time-out occurs. After the RSU collects the RF log entries, it will transmit them to the NYCDOT TMC’s back-office for post-processing and performance analysis of the collected data.

5.3.3.1.1. RSU Collects RF from ASDs

1. The RSU receives each BSM, including the vehicle ID, location, time stamp, heading, and speed, and the available RF signal levels, and builds the RF log entry.
2. The RSU compares the log for a particular vehicle ID with previously collected entries for the same vehicle ID to determine if this meets the criteria for first message received.
3. If the aforementioned criteria are met and no first message exists, the new message becomes the first entry for the same vehicle.
4. The RSU continues to receive BSMs and compares the log with previously collected entries for the same vehicle ID to determine if this meets the criteria for last message received.
5. The RSU logs the last entry for the same vehicle.
6. This process is repeated for each BSM received. The first and last entries for each unique vehicle ID are designated until the collection period times out, provided that the criteria for first and last messages are satisfied.

Note that the above application will be supported by the BSMs from ASDs and SPaTs from RSUs. The RF monitoring data will support the NYC CV system's infrastructure management. It will be encrypted but scrubbed following the performance analysis process at the TMC.

5.3.3.1.2. RSU Uploads RF Log to TMC

1. The RSU uploads the RF logs to the NYCDOT TMC’s back-office CV data processing center.
2. The RSU purges the RF log entries after they are transmitted to the TMC.
3. This log upload process is repeated for a time period specified by the TMC.

5.3.3.2. Event Data Upload

This support application will be used to transmit the event history log generated from the BSMs in the ASDs and MAPs in the ASDs from the RSUs. As the driver returns the vehicle to its respective fleet barn, the event data log will be transmitted from the ASD to the RSU at the barn. Then, the RSU will receive the data, acknowledge the transaction, and send it to NYCDOT TMC's back office data processing center.

1. The driver returns the vehicle to its fleet terminal after normal operation.
2. The RSU at the fleet barn (or another support location) receives the event log data from the ASD.
3. The RSU verifies receipt of the event log data transmission from the ASD.
4. The RSU sends the event data to the TMC back-office CV data processing center for post-processing and performance evaluation of the event data.
5. The RSU purges the event log entries after they are transmitted to the TMC.

Note that the above application will be supported by the BSMs from the ASDs and the SPaT and MAP from the RSUs collected by the ASDs. All messages to and from the ASD for this application will be authenticated. The event history will be automatically encrypted as the log data is generated and not readable by anyone except the NYCDOT TMC back office data center for analysis and processing.

5.3.4. Mobile Device (Personal Information Device)

The Mobile Accessible Pedestrian Signal System (PED-SIG) application is intended to use the MAP and SPaT messages to provide the intersection geometrics and the current status of the intersection signal displays (PED signals and vehicle signals) to assist the blind pedestrian in safely crossing the street. The general operation will involve using the MAP and SPaT messages received by the PID to orient the pedestrian, assist the pedestrian in confirming their location (street and cross street), and provide verbal information regarding the signal state and thus improve their ability to safely cross the street. The MAP message will include the location of the cross walks, and the application will use the pedestrian's location to determine the pedestrian orientation. The SPaT message will instruct the condition of the intended route based on the intersection signal. Both the SPaT and MAP messages for the PID are not expected to be signed at the TMC. The ASTC controller will generate the SPaT data and transmit it to the TMC, where the SPaT message will be created and shipped to the Amazon Web Service (AWS) cloud. Latency details have been addressed by design, and the accuracy is fundamental to the capability of the device (ASTC). The adequacy of the application will be evaluated during prototype testing.

5.3.4.1. PID Data Collection

1. The visually-impaired pedestrian arrives at a specific CV-equipped intersection.
2. The visually-impaired pedestrian awaits to cross the street.
3. The PED-SIG application communicates with the Amazon Web Service (AWS) cloud and receives the SPaT message from it based on the SPaT message sent to AWS by the TMC, based on the SPaT information from the ASTC traffic controller.
4. The PED-SIG application communicates with the AWS cloud to receive the MAP message from it based on the MAP message sent to AWS by the TMC.
5. The PED-SIG application broadcasts the orientation of the crosswalk to guide the visually-impaired pedestrian in crossing the street safely.

6. When the pedestrian walk interval begins, the PID communicates the audible walk (WLK) indicator to the visually-impaired pedestrian.

7. The visually-impaired pedestrian is guided to the crosswalk and crosses the street.

8. When the pedestrian clearance interval begins, the PID communicates the audible flashing don't walk (FDW) indicator to the visually-impaired pedestrian.

9. The visually-impaired pedestrian completes the crossing maneuver, and the PID acknowledges confirmation of the completed crossing action.

10. The PID collects and stores from the SPaT and MAP messages and the visually-impaired pedestrian's crossing maneuver.

5.3.4.2. PID Data Upload

1. The PID establishes communication with the Amazon Web Service (AWS) via 4G/LTE.

2. The PID uploads the collected data to AWS, a cloud data server where the PID data will be stored and obtained by NYU IRB for analysis and evaluation.

5.3.5. Traffic Management Center

5.3.5.1. MAP Data Change

Throughout the life-cycle of the NYC CVPD system, the intersections along the pilot corridors may undergo changes in their geometry and configuration. They may also be faced with lane or road closures from either short-term or long-term construction or changes to lane usage that vary by day of the week (DOW) or time of day (TOD), such as bus-only lanes. In such case, the MAP message data will have to be changed at the TMC and broadcasted to the corresponding RSUs for transmitting the updated MAP data to the ASDs. If the intersection geometry or the signalization (signal group ID reported by the MAP) changes, so as to render the MAP message incorrect, then no MAP message will be transmitted (i.e. sent to the intersection) until updated for consistency through a manual process.

5.3.5.1.1. Permanent or Temporary MAP Data Change

1. The NYCDOT engineer is notified of lane or road closures by either the NYCDOT's Office of Construction Mitigation and Coordination (OCMC), Transportation Planning and Management, or another outside entity.

2. The NYCDOT engineer verifies the changes to the intersection geometry and/or configuration from the lane or road closures.

3. The NYCDOT engineer updates the MAP message data based on the above intersection changes.

4. The NYCDOT engineer sends the updated MAP message data from Central to the corresponding RSUs via OTA.

5. The NYCDOT engineer verifies that the updated MAP message data has been transmitted to and received by the RSU via OTA.

6. As the NYCDOT engineer is notified of any additional changes to the intersection geometry and/or lane configuration, the engineer updates the MAP message data as needed and verifies that the updates are transmitted to and received by the RSU.

5.3.5.1.2. Periodic Map Data Change

1. The NYCDOT engineer configures the initial MAP message data for the intersections lane use changes by time-of-day (TOD) and/or day-of-the-week (DOW).

2. The NYCDOT engineer sends the updated MAP message data to the corresponding RSUs via OTA.

3. The NYCDOT engineer verifies that the MAP message data changes for the assigned lanes are transmitted to the RSUs at their assigned time changes.

4. As the NYCDOT engineer is notified of any additional changes to the intersection geometry and/or lane configuration, the engineer updates the MAP message data as needed and verifies that the updates are transmitted to and received by the RSU via OTA.

5.3.5.1.3. Signal Phasing and Timing Update by ASTC

After the NYCDOT Timing Group makes changes to the signal timing, either permanent or temporary, it communicates the modifications to NYCDOT TMC. The TMC operators are then responsible for receiving the changes to the signal timing information and verifying that they are updated on the Traffic Control System (TCS) and the ASTC controller in the field. As part of the NYC CVPD project, the ASTC controllers at intersections with RSUs will be updated to be able to generate SPaT messages and transmit it to the RSU which will then broadcast it to the ASDs.

1. NYCDOT Timing Group performs normal duties on modifying the signal, phasing, and timing information at an intersection on a NYC CV pilot corridor and downloading the .BLK file to the controller.

2. NYCDOT Timing Group notifies the NYCDOT engineer or TMC database administrator of the signal timing modifications to CV-equipped intersections.

3. The TMC operator performs normal duties by verifying that the updated timing is reflected in TCS and the ASTC controller.

4. The ASTC controller in the control cabinet at the intersection processes the signal phasing timing changes and generates updated SPaT message data.

5. The ASTC controller transmits the SPaT message to the RSU at the intersection via PoE network connection.

5.3.5.2. Performance Measurement Data Processing

This support application will process the event record data collected by the ASD and collected by the Event Data Upload application. After the RSU at the fleet terminal sends the event log data to a temporary server in the NYCDOT TMC's back office CV data center, the data will be processed for analyzing the benefits of the NYC CVPD. Then, the data will undergo extensive post-processing and normalization (i.e., cleansing) before being transmitted to the USDOT for additional evaluation.

The focus of the NYC CV pilot is to address stakeholder needs for safety. In addition to safety, the Intelligent Traffic Signal System (I-SIG) application for NYC will entail a vehicle's BSM being collected by RSUs at designated intersections to measure the travel time between those two points. The travel time results based on CV will be used for comparison with NYC's existing travel time calculation mechanism via its RFID toll tag readers.

The private data from ASD event logs will be collected and stored in the TMC back office CV data processing center. As it is aggregated, the types of event counts will be incremented by time-of-day, location, and event type into collection bins. Any traceable and private information will be discarded. Once all errors are addressed and checked, the raw data will be purged. The additional scenario below describes how the event data is recorded, processed, and transmitted from the NYCDOT TMC to USDOT.

1. The temporary server in the TMC back-office CV data processing center collects and stores the data transmitted from the RSU for performance measure analysis and the evaluation of safety benefits.

2. The analyzer/evaluator at the TMC back-office uses a periodic batch process to examine each raw event and aggregate it into bins based on the event type, time, and location of the event.

3. The analyzer/evaluator normalizes each event record by re-anchoring time and location data to create a cleansed event record. This process is repeated until all errors and issues are addressed.

4. The analyzer/evaluator checks and validates the aggregated and normalized data for any remains of PII.

5. The analyzer/evaluator completes the verification process and purges the raw event records.

6. The analyzer/evaluator conducts a before/after performance evaluation to measure the safety benefits and the effect of deploying CV technology in NYC.

7. The aggregated and normalized data is sent to the USDOT Secure Data Commons (SDC) where additional performance analysis and evaluation will be conducted by the Independent Evaluators (TTI, Volpe) for USDOT.

5.3.5.3. CV Data Processing Server

The operating procedures for the CV data processing server at the TMC will be determined during testing in Phase 2 of the NYC CVPD project.

5.3.5.4. Hardware Security Module

NYCDOT is currently in the process of procuring the HSM. The operating procedures for the HSM at the TMC will be determined during testing in Phase 2 of the NYC CVPD project.

5.3.5.5. RSU RF Operations

This process uses the first and last ASD sightings to generate a footprint of the RF signal reception for the RSU. Assessment of footprint changes will lead to RF maintenance activities, which are listed in Sections 7 Communication Failure of this document.

5.3.6. New York University (NYU) Independent Review Board (IRB)

New York University (NYU) will be the NYCDOT Independent Review Board (IRB). It will perform the initial assessment of the pedestrian data and the ensuing safety benefits. The PID equipment will be used to collect information about the performance of the pedestrian application in a select number of intersections equipped with RSUs in Manhattan.

5.3.6.1. PID Data Evaluation

1. The analyzer/evaluator at NYU retrieves the PID data from the AWS cloud server.
2. Upon successful download of the PID data, it is purged from the AWS cloud server.
3. The analyzer/evaluator conducts evaluation of the pedestrian data.

5.3.7. Other Supporting Equipment

5.3.7.1. ASN.1 Data Compiler

The operating procedures for the ASN.1 data compiler will be determined during testing in Phase 2 of the NYC CVPD project.

5.3.7.2. RF Testing Equipment

NYCDOT has procured the RF testing equipment to test the RF frequency and operation of the CV devices. The operating procedures for the RF testing equipment will be determined during testing in Phase 2 of the NYC CVPD project.

5.4. DIAGNOSTIC AND ERROR HANDLING PROCEDURES

This section describes the diagnostic or error-detection features of the system software, the purpose of the diagnostic features, and the setup and execution procedures for any software diagnostic procedures. It identifies potential problems that may occur and the error codes, messages, or other indications that accompany those potential problems. The procedures for these will be determined upon device testing and verification, and this document will be updated accordingly.

5.5. RESTART/RECOVERY PROCEDURES

This section provides the procedures for restart/recovery in the event of an equipment failure. It describes any other applicable procedures or measures to ensure continuity of operations in the event of emergencies (e.g., procedures for switching to a fail-safe mode if needed). The procedures for these will be determined upon device testing and verification, and this document will be updated accordingly.

5.6. MONITORING PROCEDURES

This section describes the tools and procedures for monitoring system usage, performance, and activity during operations. It identifies the hours of peak demand and available indicators, interpretation of those indicators, and special monitoring procedures to be followed. It also provides instructions for conducting and documenting troubleshooting activities. The procedures for the setup and monitoring of the operating system and capturing and logging the errors will be determined upon device testing and verification, and this document will be updated accordingly.

5.6.1. System Activity

The status of the ASD and RSU will be monitored by the operators at NYCDOT TMC. NYCDOT currently utilizes Traffic Control Software (TCS) as its central traffic management software. TCS will be upgraded to include status indicators for these devices. The PID status will be monitored by NYU, and the monitoring mechanism for this has not been determined at this time. Once this is established, this document will be updated accordingly.

5.6.2. System Monitoring

As part of system monitoring, the NYC CVPD team will conduct operational checks at the time of installation. Thereafter, it will monitor the RF performance data that will be uploaded to the TMC for maintenance of the radio communications as indicated in the RF Data Collection Section of this document. For instance, the antenna needs to be positioned correctly for the ASD to establish its location and DSRC communication. The antennas are permanently affixed, and their installation has undergone repeated passes through car washes and bus washes. These are no temporary antenna installations, and we do not anticipate movement such as when magnetic-mount antennas are temporarily installed.

During installation in Phase 2, operational checks will be performed by the NYC CVPD team. Once the system is deployed in Phase 3 through real-world operation and maintenance, the fleet owners and drivers will be responsible for notifying in the NYC CVPD maintenance personnel about any issues in their devices and equipment, as described in the procedures in Section 7 of this document, In-Vehicle Equipment (Aftermarket Safety Device).

6. Maintenance Roles and Responsibilities

This section provides a list of organizations that will be involved with maintaining the NYC CVPD system and the CV equipment. The roles and responsibilities are described in Table 11 below.

Table 11. Maintenance Roles and Responsibilities

Role (examples)	Primary	Backup	Organization
ASD Operations Manager	Hisham Khanzada	Tom Kelly	NYCDOT
RSU Operations Manager	Hisham Khanzada	Tom Kelly	NYCDOT
PID Operations Manager	Kaan Ozbay	Elena Pressas	NYU
TMC Operations Manager	Evgeniy Kudinov	Rachid Roumila	NYCDOT

There will be a primary and back-up maintenance manager for each role. The NYCDOT assignments to these roles reflect their maintenance responsibilities. Each fleet owner identified in Section 3 of this document, will be communicating with the ASD Maintenance Manager to address the issues and faults identified and ensure that proper maintenance and repair works are conducted.

6.1. ASD MAINTENANCE MANAGER

NYCDOT will be responsible for maintaining the ASDs in the vehicles at the intersections and support locations. Hisham Khanzada will be the ASD maintenance manager. When equipment faults are detected, the monitoring personnel will notify and dispatch the maintenance personnel to the vehicle fleet barn, where troubleshooting and repair works will be performed.

6.2. RSU MAINTENANCE MANAGER

NYCDOT will be responsible for maintaining the RSUs at the intersections and support locations, and Hisham Khanzada will also be the RSU maintenance manager. When equipment failures are detected, the RSU maintenance manager will notify and dispatch the maintenance personnel to the RSU. The proposed RSU locations consist of signalized intersections, vehicle fleet terminals, bridge/tunnel crossings, and other designated locations that may be outside the NYC CVPD pilot area.

6.3. PID MAINTENANCE MANAGER

NYU will own and maintain the PIDs during deployment while the visually-impaired pedestrians will take over the ownership role after the deployment phase. Kaan Ozbay will be the PID maintenance manager. NYU will obtain consent from NYCDOT to conduct its own data collection from the PIDs. It will work with PASS to obtain consent, recruit, and collect data from participating visually-impaired pedestrians. Upon collecting the necessary data, it will send the data to the TMC Remote Data Storage Center where any PII detected will be scrubbed and sanitized. The post-processed data will then be sent to the NYCDOT Data Warehouse for a final check before being submitted to the USDOT Secure Data Commons (SDC) where additional evaluation of the NYC CVPD safety benefits will be conducted by the Independent Evaluators (TTI, Volpe) for USDOT.

6.4. TMC OPERATIONS MANAGER

NYCDOT will be responsible for maintaining the CV equipment and components such as the performance data processing server and the HSM within its TMC. It will also be tasked with verifying that CV integrates with the existing network infrastructure. Evgeniy Kudinov will be the TMC maintenance manager.

7. Maintenance Procedures

7.1. MAINTENANCE MODES

This CMOP shall provide an overview of the proposed operational methods and processes, a high-level maintenance approach, as well as a high-level plan for inventory and configuration management.

The ASD and RSU shall revert to a fail-safe mode as specified in Table 12 when unable to perform its normal operations.

Table 12. Device Fail Modes (Preliminary)

Fail Mode	Description
Mechanical	Corrosion, shock
Electrical	Electrostatic discharge, short circuit
Location Accuracy Loss	Device’s location accuracy estimates exceed the minimum performance ranges established by standards.
Certificates Unavailable	The device has been refused additional operational certificates.

For establishing location accuracy, the GNSS in the ASD will stop tracking when its location accuracy falls below 1.5m per SAE J2945/1. In this case, the ASD will stop transmitting BSMs when the location accuracy falls below 1.5m but will not stop tracking for as long as it has a GNSS signal. This will be a challenge in the urban canyon effect of the NYC corridors, specifically in parts of Manhattan and Brooklyn.

7.2. MAINTENANCE PROCEDURES

This section describes the procedures for maintaining the NYC CVPD and its equipment. It provides detailed steps for maintaining the fleet vehicles, CV devices, and related equipment in the field. Both corrective maintenance and preventative maintenance are covered in this section. Note that the diagnosis and repair activities will not be automatic. The fleet operator or driver is to notify the fleet owner immediately for contacting the appropriate maintenance personnel to be dispatched and arranging the repair activities. The timeline for conducting the diagnosis and repairs will be determined during Task 2-F. Participant and Staff Training.

7.2.1. Vehicles

This section describes the procedures for maintaining all vehicles participating in the NYC CVPD system. Each fleet owner will be expected to maintain its vehicles in accordance with its own standard operating procedures (SOP), QA/QC processes, hardware/software system configuration processes, recall processes and spare parts/warranty contingency plans.

7.2.1.1. Vehicle Inspection and Maintenance Routine

The fleet owner will be responsible for inspecting and maintaining its own vehicle fleet on a regular basis. The fleet vehicle operator will be responsible for checking the vehicle at the beginning of each shift for its safety and maintenance features. Any issues found during inspection and maintenance of the vehicle should be logged in writing and reported to the respective fleet manager or owner immediately.

7.2.1.2. Equipment Maintenance

The fleet owner will be responsible for inspecting and maintaining the vehicle equipment and components, such as the vehicle bus (J1939 for commercial vehicles or trucks and J1962 or OBD-II port for light-duty vehicles). At the beginning of each shift for maintenance, the fleet vehicle operator will be responsible for checking that the vehicle equipment and components are operating correctly. Any issues found during inspection and maintenance of the vehicle equipment and components should be logged in writing and reported to the respective fleet manager or owner immediately.

7.2.1.3. Hardware/Software System Configuration

The vehicle's existing hardware/software system configuration is not to be altered by the ASD in any way. However, if it goes through updates, the fleet vehicle operator will be responsible for checking that the ASD is functioning without conflicts or changes as a result of the vehicle hardware/software system configuration upgrade. If the ASD is not able to operate, then the fleet vehicle operator is to notify the issue to the fleet owner, who will then arrange and coordinate maintenance activities with the NYC CVPD maintenance personnel to repair the integration between the vehicle and the ASD.

7.2.1.4. Vehicle Replacement

The fleet vehicle operator will be responsible for checking the vehicle at the beginning of each shift for its safety and maintenance features. Any issues found during inspection and maintenance of the vehicle equipment and components should be logged in writing and reported to the respective fleet manager or owner immediately. If the vehicle is inspected and found to need replacement, the fleet owner will be responsible for replacing it with a new vehicle based on the fleet's standard maintenance procedures.

7.2.2. In-Vehicle Equipment (Aftermarket Safety Device)

This section describes procedures for maintaining the ASD. It also lists the steps for updating and installing the firmware, parameters, and certificates. All equipment removed from service for suspected improper operation will be returned to the vendor for repair and validation or replacement of the enrollment certificates.

7.2.2.1. Audio Alert Failure

1. Driver begins and continues normal operation of the vehicle.
2. Driver finds that the ASD is no longer sending the audio alerts.
3. Driver notifies the fleet owner immediately.
4. Fleet owner notifies the appropriate CV equipment maintenance personnel.
5. CV equipment maintenance personnel conducts diagnosis and repair of the fault.

7.2.2.2. Antenna Failure

1. Driver begins and continues normal operation of the vehicle.
2. Driver finds that the ASD antenna is no longer functioning and GNSS position has stopped tracking.
3. Driver notifies the fleet owner immediately.
4. Fleet owner notifies the appropriate CV equipment maintenance personnel.
5. The CV equipment maintenance personnel conducts diagnosis and either repairs or replaces the antenna and/or its components.

7.2.2.3. Communication Failure

1. Begin and continue normal operation of the vehicle.
2. The ASD stops communicating and receiving the DSRC messages.
3. Notify the fleet owner immediately.
4. Fleet owner notifies the appropriate CV equipment maintenance personnel.
5. The CV equipment maintenance personnel conducts diagnosis and either repairs or replaces the antenna and/or its components.

7.2.2.4. Parameter Tuning/Update

In the event that multiple alerts are triggered at the same time, the vehicle operator will need to hear the most critical alert above the others. This is the reason a configurable arbitration technique will be employed to ensure that the warning with the highest immediate threat is the warning presented to the driver. The threat arbitration algorithm will be configurable such that additional applications can be added to the ASD.

7.2.2.5. Enrollment Certificate

1. The device vendor enrolls the initial operating certificate to the ASD.
2. The ASD is shipped to NYCDOT for testing and validation.
3. The engineer/technician verifies that the initial enrollment certificate will be installed by the device vendor.

7.2.2.6. CV Application Configuration Download

This support application will be used to upload or download the configuration parameters of V2I and V2V applications to the ASD. For example, the vehicle kinematics including but not limited to center of gravity, speed, and curve radius will be set as minimum thresholds before the ASD is deployed for installation and operation in the vehicle. Any upload, download, and modification of the parameters to the ASDs will be performed by the NYCDOT CV equipment personnel at the time of installation, and the activities are described in the scenarios below:

1. The driver returns the vehicle to its fleet barn after operating hours.
2. The vehicle configuration parameters are downloaded to the ASD. The configuration parameter will depend on the vehicle type (bus, light-duty, truck). (Note that the ASD will include a RJ45 jack and network connection to enable this downloading at installation and in the future for any reloading and reinstallation.
3. The CV application configuration parameters are checked and validated for operation.
4. The ASD is commissioned for operation.
5. This process is repeated whenever the parameters for a specific application need to be modified.
6. The ASD will access the SCMS through an RSU at the installation location to receive its initial operating certificates from the TMC.

Note that the above application will not be supported by the standard application messages. Instead, the ASD configuration parameters will be uploaded, downloaded, or modified by the NYCDOT CV equipment maintenance personnel at the vehicle fleet barns. The details will be determined during the design phase.

7.2.2.7. Firmware Update

This support application will be used to determine the ASD's firmware version and perform over-the-air (OTA) firmware updates as needed. The upgrade will occur from the RSU at the fleet terminal or other locations where the service is advertised. When the vehicles return to their respective fleet terminals, their ASD will encounter the RSU advertisement of the firmware update service. The ASD will verify its firmware version against the advertised available version. When the ASD's version needs to be updated, the ASD will initiate the firmware update transaction. The ASD supplier or vendor will be the source for the initial firmware and firmware updates and provide the firmware to the NYCDOT TMC.

1. The vehicle returns to its assigned fleet barn.
2. The ASD listens for an OTA firmware update service advertisement.
3. The ASD determines whether its firmware needs to be updated to the advertised version.
4. When the ASD's firmware version needs updating, the ASD initiates an OTA firmware update transaction to the RSU obtain the new version.
5. The RSU forwards the firmware update transaction request to the TMC.
6. The TMC transmits the new firmware package to the RSU.
7. The RSU downloads the new firmware package to the ASD.
8. The ASD checks that the downloaded firmware package passes verification tests.
9. The ASD installs the firmware update and begins operating with it.

Note that the above application will not be supported by the standard application messages. Instead, the ASD configuration or control setting including the firmware version will be transmitted as a message to the RSU. This message will not be encrypted since no PII data will be collected, but it will be transmitted securely from the RSU to the ASD.

7.2.2.8. Device Replacement/Swapping

The vehicle identification number (VIN) storage and verification by ASD will be needed to prevent swapping of ASD from an origin vehicle to a destination vehicle without update of configuration parameters.

1. The ASD is found to be defective and in needs of replacement.
2. The vehicle returns to its assigned fleet barn.
3. The defective ASD is removed and decommissioned from the vehicle.
4. The new replacement ASD is installed into the vehicle.
5. The new replacement ASD undergoes initialization via its GUI.
6. The VIN number for the vehicle is configured into the new ASD.

7.2.3. Roadside Unit

This section describes procedures for maintaining the RSU. It also lists the steps for updating and installing the firmware, parameters, and certificates. The maintenance of RSUs will be tracked through NYCDOT's existing signal defect reporting system. All equipment removed from service for suspected improper operation will be returned to the vendor for repair and validation or replacement of the enrollment certificates.

While diagnostics and repair activities for the devices will not be automatic, the NYC CVPD system will export the RSU status to the Traffic Control System (TCS) for displaying on the traffic signal system map. The CV system will also export the RSU RF signal range information to the TMC for processing where it may be placed on system displays and other applications to manage the hardware.

7.2.3.1. Communication Failure

1. The RSU stops communicating with the TMC and/or the ASD.
2. Technician is dispatched to the RSU location for diagnosis and repair.
3. If the RSU fault(s) can be repaired, the technician either performs the repair either at the site or at a separate repair center. Otherwise, the technician removes and decommissions the RSU and installs a new, replacement RSU.
4. Technician reconfigures the RSU with TMC support.

7.2.3.2. Enrollment Certificate

1. The device vendor enrolls the initial operating certificate to the RSU.
2. The RSU is shipped to NYCDOT for testing and validation.
3. The engineer/technician verifies that the initial enrollment certificate will be installed by the device vendor.

7.2.3.3. *Re-enroll Certificate*

The RSU re-enrollment process depends on the RSU maintaining the original X.509 enrollment certificate available. If the RSU communication with Central is not re-established prior to the expiration of the operational certificate, the RSU will not be able to open a DTLS communication channel with Central until a new operational certificate is installed.

The physical location of the RSU on a pole requires a more automated process to install a new certificate. After the communication problem has been corrected, a technician will go to the RSU location and power cycle the RSU. When the RSU boots up, it can determine if the current operational certificate is expired. The RSU will then attempt to obtain a new certificate from Central.

7.2.3.4. *RSU Firmware Update*

WAVE service advertisements (WSA) will be used to announce the availability of each device for transmitting the data and messages. The WSAs will be broadcasted from the RSU but are originated from the TMC to announce to the RSU that the firmware update service is available.

1. The RSU listens for an OTA WAVE Service Advertisement (WSA) from the TMC.
2. The RSU determines whether its firmware needs to be updated to the advertised version.
3. If the RSU determines that its firmware version needs to be updated, then it initiates an OTA firmware update transaction to the TMC for obtaining the new version.
4. The RSU forwards the firmware update transaction request to the TMC.
5. The TMC transmits the new firmware package to the RSU.
6. The RSU checks that the downloaded firmware package passes verification tests.
7. The RSU installs the firmware update and begins operating with it.

7.2.3.5. *SNMPv3 Configuration*

Management of passwords and password changes will be critical for SNMPv3 configuration. The NYCDOT technicians will be required to follow a documented process for keeping the passwords secure.

1. The NYCDOT technician configures a public type of user/password that will allow the data to be polled.
2. The NYCDOT technician obtains another user with a password to allow the data to be changed.
3. The NYCDOT technician, from a security perspective, limits access to the password for the privileged user.

The NYCDOT technician changes this password on a regular basis while keeping it the same for all devices. (Options are being evaluated.)

7.2.3.6. RSU Device Exchange

The NYC CVPD team will consider operational action for RSU failures in the same way as for ASTC controller failures. RSU failures at the intersection will not have safety implications because the RSU will stop transmitting SPaT and MAP messages until the failure is rectified. To resolve such failure, the existing device will be replaced with a new device which will be reinstalled and bootstrapped for initialization.

7.2.4. Mobile Device (Personal Information Device)

This section describes procedures for maintaining the PID. It also lists the steps for updating and installing the firmware, parameters, and certificates. When the physical device is found to need maintenance, NYU will receive the PID from the visually-impaired user and send it to the maintenance personnel for troubleshooting, diagnosis, and repair. All equipment removed from service for suspected improper operation will be returned to the vendor for repair and validation or replacement of the enrollment certificates.

7.2.4.1. Audio Alert Failure

1. Visually-impaired pedestrian begins and continues normal operation of the PID.
2. Visually-impaired pedestrian finds that the PID is no longer sending the audio alerts.
3. Visually-impaired pedestrian notifies NYU immediately.
4. NYU notifies the appropriate CV equipment maintenance personnel.
5. The CV equipment maintenance personnel conducts diagnosis and repair of the fault.

7.2.4.2. Communication Failure

1. Visually-impaired pedestrian begins and continues normal operation of the PID.
2. Visually-impaired pedestrian finds that the PID stops communicating and receiving the SPaT and MAP messages.
3. Visually-impaired pedestrian notifies NYU immediately.
4. NYU notifies the appropriate CV equipment maintenance personnel.
5. The CV equipment maintenance personnel conducts diagnosis and either repairs or replaces the antenna and/or its components.

7.2.4.3. Enrollment Certificate

1. The device vendor enrolls the initial operating certificate to the PID.
2. The PID is shipped to NYCDOT for testing and validation.
3. The engineer/technician verifies that the initial enrollment certificate will be installed by the device vendor.

7.2.4.4. Firmware Update

1. The PID listens for any firmware update from the device vendor via 4G/LTE.
2. When the device vendor advertises the firmware update, the PID initiates the firmware update.
3. The PID checks that the downloaded firmware package passes verification tests.
4. The PID installs the firmware update and begins operating with it.

7.2.5. Traffic Management Center

This section describes procedures for maintaining the TMC and its equipment. It also lists the steps for updating and installing the components needed for keeping the TMC and its backhaul network secure in a proactive manner. While diagnostics and repair activities for the devices will not be automatic, the NYC CVPD system will export the RSU status to the Traffic Control System (TCS) for displaying on the traffic signal system map. The CV system will also export the RSU RF signal range information to the TMC for processing where it may be placed on system displays and other applications to manage the hardware.

7.2.5.1. Hardware Security Module

This approach involves the TMC integrating a commercially available HSM with a TMC processor system to provide secure storage of the cryptographic materials and provides for the TMC signing of TMC originated data. The HSM will be used to sign and authenticate the MAP and TIM messages prior to their transmission to the RSU.

7.2.5.2. Enrollment Certificate

1. A technician in the field will contact the TMC to start the initialization process for an ASTC or RSU.
2. The TMC operator will request an operational certificate for the field device from the CA.
3. Once the operational certificate has been created the technician will start the ASTC or RSU.
4. The TMC operator will manually start the initialization process to bring a new device online.
5. The initialization process will establish a DTLS connection with the device using the enrollment certificate.
6. After the DTLS connection is established, the initialization process will replace the enrollment certificate with the generated operational certificate for the specified device.
7. Once the initialization process has determined that the operational certificate has been successfully installed in the device, the DTLS connection will be broken and the initialization process will exit.

7.2.5.3. Operational Certificates

Operational certificates will be provided to ASTC and RSU devices on a periodic basis. The operational certificates will have a limited lifespan to avoid the complexities of managing a certificate revocation list (CRL).

The initial period of an operational certificate will be 8 days (192 hours). The TMC will update the certificates in each ASTC and RSU at 7 days (168 hours). The extra day will allow for identification and repair of a communication failure with an ASTC or RSU.

7.2.5.4. MAP and SPaT Data Inconsistency

The MAP message data updates will be transmitted via OTA from Central to the RSU. SPaT message data will be transmitted by the ASTC controller to the RSU via PoE. As indicated in Section 5, MAP Data Change, no MAP message will be transmitted if the intersection geometry or the signalization (signal group ID reported by the MAP) changes that makes the MAP message incorrect. MAP message transmission will resume only when it is updated for consistency through a manual process. In the event that data inconsistencies are discovered, maintenance personnel will be dispatched to diagnose and repair the issue(s) to ensure that message data inconsistencies are addressed.

7.2.6. Other Supporting Equipment

This section describes the procedures for maintaining other supporting equipment. It describes the procedures for installing and testing system updates, moving /installing the system updates to the operational environment, and replacing equipment and updating maintenance reports.

7.2.6.1. ASN.1 Data Compiler

The maintenance procedures for the ASN.1 data compiler will be determined during testing in Phase 2 of the NYC CVPD project.

7.2.6.2. RF Testing Equipment

NYCDOT has procured the RF testing equipment to test the RF frequency and operation of the CV devices. The maintenance procedures for the RF testing equipment will be determined during testing in Phase 2 of the NYC CVPD project.

8. Configuration and Inventory Management

This section describes the configuration management procedures that will be followed and the interactions that will occur for configuration control, change control, and configuration status account reporting (for example, installed, installed and tested, operational, under repair/not in operation), categorized by type, with their physical locations where appropriate for maintaining the configuration information for the hardware and software actually installed.

This section also describes the procedures for maintaining hardware and/or software at the operational sites. It includes the procedures for maintaining floor plans showing the location of all installed equipment, instructions to add/delete/modify the plans, a description of how many spares/parts will be maintain for inventory, and documents how spares would be used in place of a part for each equipment item specified in Section 7 of this document. More details can be found in the NYC CVPD Comprehensive Installation Plan (CIP), FHWA-JPO-17-455.

8.1. CONFIGURATION MANAGEMENT

The City will manage the configuration of the CV back office development source code developed during the design and prototype phase and throughout the entire System Development Life Cycle (SDLC). This methodology includes the evaluation, coordination, approval and implementation of any proposed changes to the baseline system. The baseline system will be developed during the prototype phase after vendors provide their respective source codes, and the City completes testing and tuning the devices for the NYC environment. The baseline for back-office CV software will be assigned Version 1.0 upon completion of testing and approval. Any changes to the baseline consisting of any modification to the hardware or software components that are currently approved and installed would generate a configuration change request and a new version number. The versions of different device components (for example, ASD, RSU, PID) will be assigned and managed by the Change Control Board (CCB) and Change Request Form (CR) processes as described in this section below.

In order to effectively support complete system configuration management, this plan identifies four distinctive CM processes to manage change for software and hardware Configuration Items. These carefully managed processes are described as follows:

8.1.1. Software Configuration Management

This process is used to manage and control changes in the evolution of a software system and the supporting documentation. The effective and efficient performance of this process is achieved by using automated tools to track all modifications to the software system. This will be done via a Change Request (CR) Form.

8.1.2. Hardware Configuration Management

This process is used for creating and maintaining a hardware baseline to ensure that components are capable of accepting and sustaining the operations of the NYC CVPD program. Once the baseline is established, any replacement component that is not currently approved as a standard baseline item is first evaluated for compliance before integration into the baseline system. This will be done via a Change Request (CR) Form.

8.1.3. Document Management

The process is used for creating and delivering documentation, and specifications required for the design, procurement, installation, commissioning, and acceptance of hardware and/or software. This will be done via a Change Request (CR) Form.

8.1.4. Subsystem Testing

The process is required to ensure each subsystem/component is tested, properly configured and made available to the team at the required time. This will be done via a Change Request (CR) Form as described in Change Request Form (CR) Section below.

8.1.5. Change Control Board (CCB)

The City will implement a formal configuration management process. A Change Control Board has been designated as shown in Table 13 to review, evaluate, and approve requested changes to the baseline. As the NYC CVPD system is deployed, the scheduling of updates will be determined by vendors’ software release schedules and subsequent testing schedules. The system updates will be identified based on need, impacts, severity, and other factors as determined by the Change Control Board (CCB) for the update on a non-regular, as-needed basis.

Table 13. NYC CVPD Change Control Board

Name	Signature	Date
Nader Barhoum – Systems Engineer	______________________________	__________________
Robert Rausch – Site Lead	______________________________	__________________
Keith Patton/ Evgeniy Kudinow – Network Administrator	______________________________	__________________
Mohamad Talas – Program Manager	______________________________	__________________

8.1.6. Change Request Form (CR)

The City currently implements a formal configuration management process. This existing process will take effect after the CV Back office software is baselined to version 1.0 upon completion of the system design, and completion of the prototype phase with the vendors. A Change Request Form is currently utilized to formalize the process. The NYC CVPD Change Request Form V1.0 is included in Appendix C of the NYC Comprehensive Installation Plan (CIP), FHWA-JPO-17-455.

The mechanism for the CR has been designed to collect and manage the version from the ASDs. However, merging this data with the Master Inventory Spreadsheet in real time is not recommended, unless there is an operational issue that warrants it.

8.2. INVENTORY MANAGEMENT

The NYC CVPD team will maintain a Master Inventory Spreadsheet to document how spares would be used in place of a part for each equipment specified in Chapter 7. This spreadsheet will be managed and updated regularly by City Staff. In addition to the Master Inventory Spreadsheet, the following software tools will be utilized:

1. Microsoft Word — used to produce deliverables, procedures, and other documentation.

2. Microsoft Excel — used to track checklists and schedules.

3. Microsoft Office Project — used to establish and monitor planned Acquisition and receipt tasks in the project work plan.

8.2.1. Inventory Control

The purpose of the NYC CVPD Inventory Tracking Tool is to document products received for the NYC CVPD program in a manner that conforms to NYCDOT inventory tracking and documentation requirements. It is also a central tool to read, write, and modify information regarding equipment receipt as it becomes available. The Master Inventory Spreadsheet will be divided into 5 respective categories. Inventory will be tracked, input, and managed based on the 5 main categories. The document will reference any Purchase Order (PO) detail, and Invoicing documents. The Vendors will be required to provide all equipment provided as noted in the Procurement Specification with Part# and Serial # visible on both Devices and Packaging. NYCDOT will receive and document all product receipts. Below displays the categories under which the inventory will be controlled.

The Master Inventory Spreadsheet will have specific fields updated that will help the City manage the CV inventory as it is received and installed. The following fields will need to be updated based on the availability of product, stakeholder readiness, and schedule requirements. Section 3.3.1 in the NYC CIP, FHWA-JPO-17-455 contains more details on the required fields to be updated in the Master Inventory Tool.

The Master Inventory Spreadsheet is designed to provide all the required fields to manage the SF-428 Tangible Personal Property Reporting. Figure 3 and Figure 4 below show how the City has aligned specific fields based on SF-428 federal reporting requirements and SF-428B/SF-428C supplementary reporting requirements.

	SF-428/ SF428A								
LN	Equipment Type/Description	Part/Model#	Serial#	Vendor	Cost	Federal Participation	Acquisition/Receipt Date	NYC DOT PO#	Contract Name

Source: NYCDOT, 2016

Figure 3. SF-428/SF-428A Reporting Requirements

SF428B/SF428C	
Disposition	Disposition Date

Source: NYCDOT, 2016

Figure 4. SF-428B/SF-428C Supplementary Report Requirements

The versions of the different software/firmware configurations (for example, ASD, RSU, PID) for the inventoried hardware will be managed by the Change Control Board (CCB) and Change Request Form (CR) processes as described in this section.

8.2.2. Inventory Storage and Logistics

Items procured for the NYC CVPD program will need to be installed and deployed in various geographic sections of New York City depending on the form and purpose of the equipment. For example, RSUs will be deployed at fixed field locations, while ASDs will need to be installed in various fleet vehicles belonging to the participating stakeholders. The warehousing of equipment, parts, assets, etc. will be managed, coordinated, and secured by NYC DOT personnel as well as the staging, storage, and inventory tracking of all necessary equipment for all phases of installation and maintenance as equipment arrives and is checked out of the warehouse facility.

Table 14 below explains where the items will be delivered prior to distribution by the City for field installation or stakeholder vehicle installations.

Table 14. Equipment Delivery Locations

Equipment Type	Type	Delivery Location	Deployment Location
ASD	HW	CV Container NYC DOT 45-02 37th Ave, Long Island City, NY 11101	Will be installed in DOT vehicles and distributed to stakeholders for in vehicle installation in 8,000 participating vehicles.
RSU	HW	CV Container NYC DOT 45-02 37th Ave, Long Island City, NY 11101	Will be installed by DOT personnel at 353 signalized and support sites in Midtown Manhattan, FDR, Flatbush, and designated RSU support sites
PID	HW	NYU Review Board	Pedestrians participating in the Pilot
TMC Equipment - CV Data Storage Collection	HW/SW	NYC DOT Traffic Management Center 28-11 Queens Plaza North, Long Island City, NY 11101	NYC DOT Traffic Management Center 28-11 Queens Plaza North, Long Island City, NY 11101
TMC Equipment - CV Network Integration Equipment	HW/SW	NYC DOT Traffic Management Center 28-11 Queens Plaza North, Long Island City, NY 11101	NYC DOT Traffic Management Center 28-11 Queens Plaza North, Long Island City, NY 11101
ASN.1 Java/Tool Compiler	SW	SW license delivery	TransCore ITS 192 Technology Parkway, Suite 500 Peachtree Corners, GA 30092
RF Testing Devices	HW	NYC DOT 34-02 Queens Blvd, Long Island City, NY 11101	NYC DOT 34-02 Queens Blvd, Long Island City, NY 11101

NYCDOT has designated a 40ft Cube Container at its warehouse location to store and distribute the spare RSUs and ASDs. The address of the location is as follows:

NYCDOT
45-02 37th Ave.
Long Island City, NY 11101

This location is kept secure by NYCDOT personnel who monitor the premises entry and exit and only allow NYCDOT personnel to gain access. It is a designated lot for NYC DOT vehicles, tools and equipment. The container will also be secured with a padlock and keys distributed to key CV team personnel as shown in Figure 8 3.

Source: NYCDOT, 2016

Figure 5. Secure Location for Storing and Distributing Spare CV Parts and Equipment

This location will serve as the storage location for RSUs and ASDs. We intend to stage the delivery from the vendor based on their production schedule, which will be finalized after completing the prototype phase. Upon completion of the prototype phase, the vendor will deliver the items ordered to this location, where the City will verify receipt, log it into the inventory, and distribute to installers and/or stakeholders.

In addition, parts and equipment for the back-office network will be kept directly at the TMC at the below address. This location is secured by electronic access control and armed guards. The address is as follows:

NYCDOT Traffic Management Center
28-11 Queens Plaza North,
Long Island City, NY 11101

9. Inspection / Maintenance Schedule

This section describes the procedures for inspecting the NYC CVPD system. It specifies the step by step procedures indicating what will be inspected and how often it will be inspected. The Inspection and Maintenance Schedule is shown in Table 15 below. At this time, the Inspection and Maintenance Schedule has not been determined. It will be provided based on vendor coordination and upon testing and verification of the devices.

Table 15. Inspection / Maintenance Schedule

Component	Inspected
ASD	Inspected after every TBD hours of operation
RSU	Inspected after every TBD hours of operation
PID	Inspected after every TBD hours of operation
TMC	Inspected after every TBD hours of operation

10. Software Licensing (If Applicable)

This section provides a listing of any software and other products/services that is applicable that will be used during the operation and maintenance of the system. At this time, the devices are being procured and their software licensing has not been determined. Once they are sent by the device vendors, the software licensing will be provided in this document.

Table 16. Software Licensing

Item	Details
Software	TBD
Version	TBD
Responsible Party	TBD
License	TBD

11. Approvals

This section provides a listing of the individuals who can sign off indicating the entire system is safe and efficient for operation and maintenance and can proceed to the next stage. This plan is effective as of the most recent date from the signatures provided below. All signatures indicate acceptance of the CMOP.

Name (Role)	Date

Name (Role)	Date

Name (Role)	Date

Name (Role)	Date

12. Glossary

The terms and acronyms used in this document are defined in Table 17 below:

Table 17. Acronym List

Acronym	Definition
AO	Agreement Officer
AOR	Agreement Officer Representative
ASD	Aftermarket Safety Devices
ASN.1	Abstract Syntax Notation One
ASTC	Advanced Solid-state Traffic Controller
ATC	Advanced Traffic Controller
AWS	Amazon Web Services
BSM	Basic Safety Message
CAN	Controller Area Network
C2F	Center-to-Field
CAMP	Crash Avoidance Metrics Partnership
CCB	Change Control Board
CMOP	Comprehensive Maintenance and Operations Plan
ConOps	Concept of Operations
CR	Change Request Form
CRL	Certificate Revocation List
CV	Connected Vehicle
CVPD	Connected Vehicle Pilot Deployment
DSRC	Dedicated Short Range Communications
DTLS	Datagram Transport Layer Security
F2F	Field-to-Field
FHWA	Federal Highway Administration
GUI	Graphical Interface Unit
HSM	Hardware Security Module
I2V	Infrastructure-to-Vehicle
IE	Independent Evaluator
IEC	International Electrotechnical Commission
IRB	Independent Review Board
ISO	International Organization for Standardization
ITS	Intelligent Transportation Systems
JPO	Joint Program Office
MAP	Map Data Message
NTCIP	National Transportation Communications for Intelligent Transportation System Protocol

Acronym	Definition
NYC	New York City
NYC DoITT	New York City Department of Information Technology and Telecommunications
NYCDOT	New York City Department of Transportation
NYCWiN	New York City Wireless Network
NYU	New York University
O&M	Operation and Maintenance
OBE	On-Board Equipment
OBU	On-Board Unit
OCMC	Office of Construction Mitigation and Coordination
OTA	Over-the-Air
PED	Pedestrian
PID	Personal Information Device
PMESP	Performance Measurement and Evaluation Support Plan
RF	Radio Frequency
RSE	Roadside Equipment
RSU	Roadside Unit
RTCM	Radio Technical Commission for Maritime Services
SAE	Society of Automotive Engineers
SCMS	Security Credential Management System
SDD	System Design Document
SMP	Safety Management Plan
SPaT	Signal Phase and Timing
SSL	System Status Log
SyRS	System Requirements Specification
TCS	Traffic Control System
THEA	Tampa Hillsborough Expressway Authority
TIM	Traveler Information Message
TLS	Transport Layer Security
TMC	Traffic Management Center
TTI	Texas Transportation Institute
USDOT	United States Department of Transportation
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
WAVE	Wireless Access in Vehicular Environments
WSA	WAVE Service Advertisement

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