Connected Vehicle Pilot Deployment Program Phase 1,

Concept of Operations (ConOps) -

New York City

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Final ConOps — July 27, 2017

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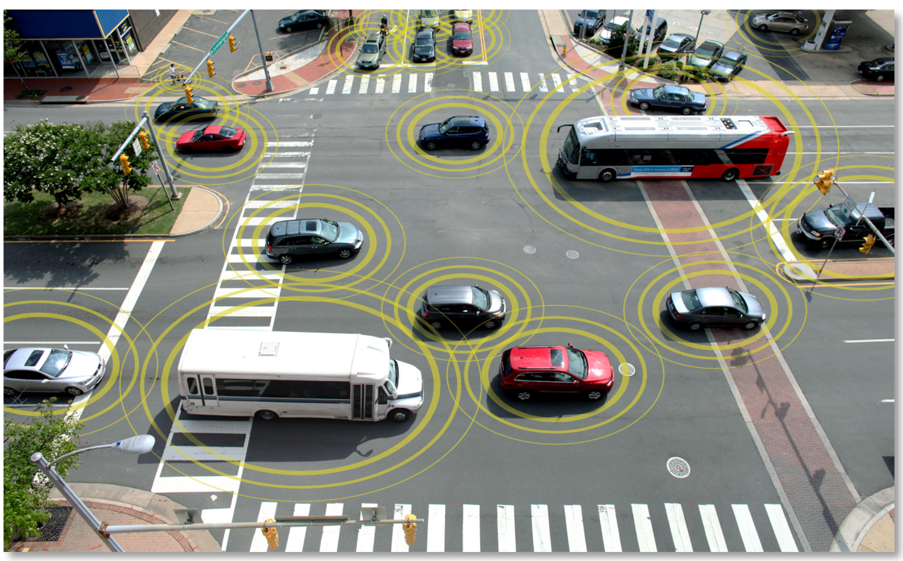

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16. Abstract

This document describes the Concept of Operations (ConOps) for the New York City Department of Transportation (NYC) Connected Vehicle Pilot Deployment (CVPD) Project. This ConOps describes the current state of operations, establishes the reasons for change, and defines the future system in terms of functions/features and supporting operations. It is the first of several planning documents for The Connected Vehicle Pilot Deployment Program, Phase 1 project funded by the United States Department of Transportation (USDOT). Other planning documents, developed under this project phase, that influence this ConOps include the Security Management Operational Concept, Performance Measurement and Evaluation Plan, Safety Management Plan, and Human Use Approval.

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0.0.7	1/22/2016	NYCDOT	Initial draft for USDOT review
0.2.8	03/14/2016	NYCDOT	Revised for USDOT and stakeholder comments
1.0	4/8/2016	NYCDOT	Revised for USDOT and stakeholder comments
1.1	5/16/2016	NYCDOT	Source references added to figures
FRevD1	7/27/2017	NYCDOT	Phase 2 revisions
Ph2Edit_F1	12/31/2020	NYCDOT	Final Phase 2 as-built update for 508 compliance
A2	4/15/2021	NYCDOT	Revised final Phase 2 as-built update for 508 compliance
A3	8/4/2021	NYCDOT	Updated font in Table of Contents

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The New York City Department of Transportation (NYCDOT) and its pilot deployment team thanks the many fleet owners dedicated to bringing connected vehicle technology to New York City. These stakeholder organizations demonstrate their commitment towards attaining Vision Zero's goals through their participation. The various NYCDOT vehicle fleets, NYC Department of Citywide Administrative Services (DCAS) vehicle fleets, MTA/NYCT, and Pedestrians for Accessible and Safe Streets (PASS) have expended considerable resources participating in the development of the overall Concept of Operations as well as this document.

Finally, the team wants to thank the USDOT for sponsoring this project and laying the foundation for future connected vehicle deployments.

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1. Scope

This document describes the Concept of Operations (ConOps) for the New York City Department of Transportation (NYCDOT) Connected Vehicle Pilot Deployment (CVPD) Project. This ConOps describes the current state of operations, establishes the reasons for change, and defines the future system in terms of functions/features and supporting operations that satisfy the needs of the stakeholders.

It is the first of several planning documents for The Connected Vehicle Pilot Deployment Program, Phase 1 project funded by the United States Department of Transportation (USDOT). Other planning documents, developed under this project phase, that influence this ConOps include the Security Management Operational Concept, Performance Measurement and Evaluation Plan, Safety Management Plan, and Human Use Approval.

Two other project phases are scheduled following the successful completion of Phase 1. Phase 2 consists of the design, deploy, and test project activities occurring over a 20-month period. A maintain and operate period comprises Phase 3 of the project over an 18-month period.

The document is organized to meet the requirements of the United States Department of Transportation (USDOT) System Engineering Process and Institute of Electrical and Electronics Engineers (IEEE) 1362-1998 as required by the USDOT Broad Agency Announcement (BAA) dated January 30, 2015 amended.

1.1 Identification

This document is identified as:

Agency:	New York City Department of Transportation
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1.2 Document Overview

The ConOps is a foundational document for communicating the user needs and associated potential operational capabilities of this program to project stakeholders and system developers. Systems engineers will then use this ConOps to develop detailed technical specifications that meet the user needs defined herein.

The document begins with a description of the project boundaries in terms of the geographic areas, the travel conditions, and safety experience. It discusses the project's overall objectives and the rational for building a system to attain them. While the project is an initial deployment of Connected Vehicle (CV) technology, certain research needs are addressed by the project in order to continue learning about the impacts of the technologies and provide lessons to future users who adopt and deploy the technology.

This background information provides a foundation for establishing the system's needs. The traffic management needs are listed along with the CV application deployed in the system to address those needs. Other needs of the project stakeholders such as vehicle fleet owners are then listed. Finally operational and performance measurement needs are discussed and the core service areas that address them in Section 4.2.

The concepts for the system's operation are presented in Section 5 from two perspectives. The first is a physical view that describes the devices, people, infrastructure facilities, and communication linkages that comprise the system. In the second view, the organizations that own, operate, and use the system are described along with the relationships between them. A summary of the envisioned connected vehicle applications follows the overview descriptions of the system.

A series of operational scenarios (similar to use cases) are documented in Section 6. These scenarios describe typical interactions of the system's entities under specific situations. These form a set of use cases that describe how the system operates in response to a given set of conditions. Note that the scenarios documented in this ConOps address the additional system management and performance evaluation concepts for the NYC CVPD project. The operational scenario's also document several CV applications tailored to address specific stakeholder needs under the NYC CVPD project. The un-modified CV applications are documented through the USDOT's Connected Vehicle Reference Implementation Architecture (CVRIA). This material is available at the CVRIA web site[6].

In the final two sections of the document the impacts of the system are discussed along with a discussion of the potential benefits and limitations of the proposed New York City (NYC) CV system. An overview of the system's performance assessment is also included.

A series of appendices are included to provide additional reference material. This material includes travel condition information such as traffic counts and crash history in the project corridors. The proposed locations of fixed communication devices are included.

The intended audience for this document includes the following:

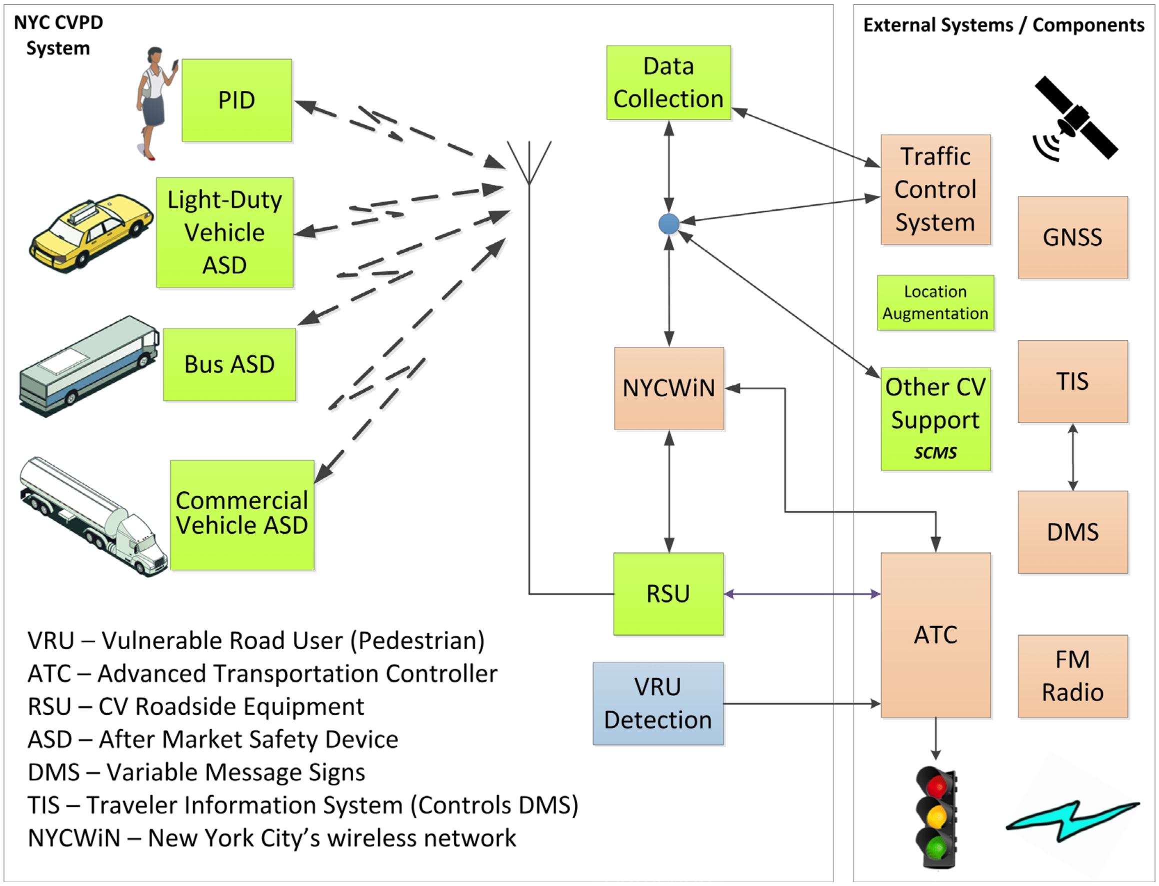
- New York City Department of Transportation (NYCDOT)
- New York City CV Architecture Team
- New York City CV Pilot Deployment Project Stakeholders
- Individuals interested in the NYC CV program
- ITS-JPO Program Leads and Support Staff
- ITS-JPO Program Engineering Teams
- Wave 1 CV Pilot Deployment Project Teams
- Future Connected Vehicle Deployment Project Teams

1.3 System Overview

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

It is important to understand the implications of the connected vehicle technology deployment in New York City. A total of 450 RSU locations in the New York City roadway network will have connected vehicle infrastructure installed. Vehicle-to-Infrastructure (V2I) applications such as Red Light Violation Warning, Speed Compliance, and Curve Speed Compliance will support connected vehicles operating in these areas. However, the geographic reach of the connected vehicle technology is much broader. Vehicles equipped with connected vehicle technology (i.e., aftermarket safety devices) will travel in this infrastructure equipped area *and throughout the City's transportation network*. Thus, the connected vehicle technology that supports Vehicle-to-Vehicle (V2V) applications will function anywhere two equipped vehicles are within range of one another. 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 Franklin D. Roosevelt (FDR) Drive and the Long Island Expressway. The large fleet size means that there will be many opportunities for the connected vehicle technology to perform over a large geographic area and diverse roadway environments.

The envisioned NYC CVPD system is depicted in Figure 1. The existing system elements, critical to the operation of the pilot system, are illustrated with beige backgrounds. These existing elements include the traffic management system, the traffic controller (ASTC), and supporting NYCWiN communications infrastructure. New system elements which exist and will be reused, modified, or integrated into the NYC CVPD system have green backgrounds. Aftermarket safety devices (ASD), roadside units (RSU), personal information devices (PID), and data collection/processing systems comprise the new system elements. The Vulnerable Road User (VRU) detection devices to be added to the system are shown with a blue background as these devices are relatively new and will be deployed on a very limited basis.

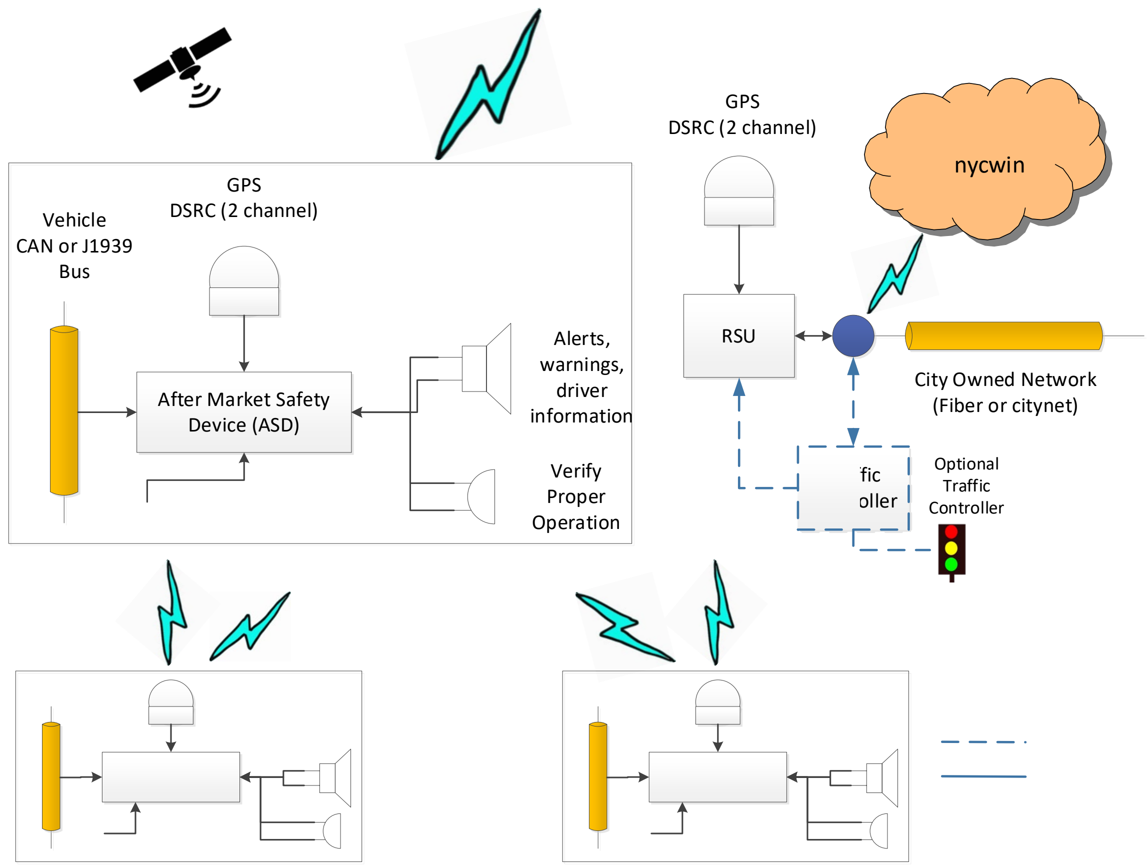


Source: NYCDOT

Figure 1. NYC CVPD System Concept

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 roadside units (RSU) to communicate with up to 3,000 vehicles equipped with aftermarket safety devices (ASD). 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 ASD is shown in Figure 2 below along with its interfaces to the driver, the Global Navigation Satellite System (GNSS), the vehicle data bus (CAN or J1939), and Dedicated Short Range Communications (DSRC) to other equipped vehicles and the infrastructure. This figure represents three ASD equipped vehicles in addition to DSRC enabled infrastructure.



Source: NYCDOT

Figure 2. Vehicle Equipment Concept

2. Referenced Documents

Table 1 lists the references used to develop the concepts in this document. As some of the base standards referred to in the list are currently evolving, their identifiers have been temporarily highlighted to indicate that the version may change.

Table 1. References

#	Document (Title, source, version, date, location)
1	*Initiatives - Vision Zero*, New York City Department of Transportation. http://www.nyc.gov/html/visionzero/pages/home/home.shtml
2	*Traffic Fatalities Fall in 2014, but Early Estimates Show 2015 Trending Higher*, National Highway Transportation Safety Administration (NHTSA). https://www.transportation.gov/briefing-room/traffic-fatalities-fall-2014-early-estimates-show-2015-trending-higher
3	*Borough Pedestrian Safety Action Plans*, New York City Department of Transportation. http://www.nyc.gov/html/dot/html/pedestrians/ped-safety-action-plan.shtml
4	*Vision Zero Action Plan*, New York City Department of Transportation. http://www.nyc.gov/html/visionzero/assets/downloads/pdf/nyc-vision-zero-action-plan.pdf
5	*Principles for a Connected Vehicle Environment*, U.S. Department of Transportation ITS Joint Program Office-HOIT, April 18, 2012 http://www.its.dot.gov/connected_vehicle/pdf/ConnectedVehiclePrinciples_final4-18-2012.pdf
6	*Connected Vehicle Reference Implementation Architecture Website*, US Department of Transportation, Office of the Assistant Secretary of Transportation for Research and Technology. http://www.iteris.com/cvria/
7	*Core System Concept of Operations*, US Department of Transportation, Research and Innovative Technology Administration, October24, 2011 http://www.its.dot.gov/docs/CoreSystemConOpsRevE2.pdf
8	*Core System Architecture Document*, US Department of Transportation, Research and Innovative Technology Administration, October14, 2011 http://www.its.dot.gov/docs/CoreSystemArchitectureDoc_revC.pdf
9	*Core System Requirements Specification*, US Department of Transportation, Research and Innovative Technology Administration, October14, 2011 http://www.its.dot.gov/docs/CoreSystem_SE_SyRS_RevF.pdf
10	*Core System Deployment Critical Risk Assessment Report*, US Department of Transportation, Research and Innovative Technology Administration, October28, 2011 http://www.its.dot.gov/docs/CoreSystem_RiskReport_RevB.pdf

#	Document (Title, source, version, date, location)
11	*Core System Standards Recommendations*, US Department of Transportation, Research and Innovative Technology Administration, October28, 2011 http://www.its.dot.gov/docs/CoreSystem_StdsRecommendations_RevA.pdf
12	*Connected Vehicle Technology - Test Bed Website*, US Department of Transportation, Office of the Assistant Secretary of Transportation for Research and Technology. http://www.its.dot.gov/testbed.htm
13	Safety Pilot Model Deployment – "5.9GHz DSRC Aftermarket Safety" Device Specification, US Department of Transportation, Research and Innovative Technology Administration, Version 3.0, December 26, 2011
14	Safety Pilot Model Deployment – *"5.9GHz DSRC Vehicle Awareness Device" Specification*, US Department of Transportation, Research and Innovative Technology Administration, Version 3.5, December 12, 2011 http://www.its.dot.gov/safety_pilot/pdf/Vehicle_Awareness_Device_Specification-r3-5--20111202.pdf
15	*1609.0-2013 - IEEE Guide for Wireless Access in Vehicular Environments (WAVE) – Architecture* http://standards.ieee.org/findstds/standard/1609.0-2013.html
16	*1609.2-2016 - IEEE Standard for Wireless Access in Vehicular Environments — Security Services for Applications and Management Messages* http://standards.ieee.org/findstds/standard/1609.2-2013.html
17	*1609.3-2010 - IEEE Standard for Wireless Access in Vehicular Environments (WAVE) - Networking Services* http://standards.ieee.org/findstds/standard/1609.3-2010-Cor_2-2014.html
18	*1609.4-2010 - IEEE Standard for Wireless Access in Vehicular Environments (WAVE)--Multi-channel Operation* http://standards.ieee.org/findstds/standard/1609.4-2010.html
19	*SAE J2735 - Dedicated Short Range Communications (DSRC) Message Set Dictionary™*, SAE International, March 30, 2016 http://standards.sae.org/j2735_201603/
20	*SAE J3067 - Candidate Improvements to Dedicated Short Range Communications (DSRC) Message Set Dictionary [SAE J2735] Using Systems Engineering Methods*, August 26, 2014 http://standards.sae.org/j3067_201408/
21	*SAE J2945/1_201603 - On-Board System Requirements for V2V Safety Communications*, SAE International, March 30, 2016 http://standards.sae.org/j2945/1_201603/
22	*USDOT Security Credential Management System*, US Department of Transportation, Research and Innovative Technology Administration, April 13, 2012. http://www.its.dot.gov/meetings/pdf/Security_Design20120413.pdf
23	*USDOT's Intelligent Transportation Systems (ITS) ITS Strategic Plan 2015-2019*, December, 2014 http://www.its.dot.gov/strategicplan.pdf
24	*ITU-R TF.460-4: Standard-frequency and time-signal emissions*, International Telecommunication Union. 1986. Annex I http://www.cl.cam.ac.uk/~mgk25/volatile/ITU-R-TF.460-4.pdf
25	*USDOT Broad Agency Announcement with New York City*, New York City Department of Transportation, September, 2015

#	Document (Title, source, version, date, location)
26	*DSRC Roadside Unit (RSU) Specifications Document*, USDOT, Version 4.1, October 31, 2016 http://www.its.dot.gov/testbed/PDF/USDOT_RSUSpecification4%200_Final.pdf
27	*Initiatives - Vision Zero*, New York City Department of Transportation. http://www.nyc.gov/html/visionzero/pages/home/home.shtml
28	*Traffic Fatalities Fall in 2014, but Early Estimates Show 2015 Trending Higher*, National Highway Transportation Safety Administration (NHTSA). https://www.transportation.gov/briefing-room/traffic-fatalities-fall-2014-early-estimates-show-2015-trending-higher
29	*Borough Pedestrian Safety Action Plans*, New York City Department of Transportation. http://www.nyc.gov/html/dot/html/pedestrians/ped-safety-action-plan.shtml
30	*Vision Zero Action Plan*, New York City Department of Transportation. http://www.nyc.gov/html/visionzero/assets/downloads/pdf/nyc-vision-zero-action-plan.pdf
31	*Traffic Data Viewer*, New York State Department of Transportation. http://gis3.dot.ny.gov/html5viewer/?viewer=tdv
32	*NYCDOT - Parkway Truck Restrictions*, New York City Department of Transportation. http://www.nyc.gov/html/dot/html/motorist/parkway-restrictions.shtml
33	*Google Maps*, Google. https://www.google.com/maps/@40.7733062,-73.9918439,13.25z?hl=en
34	*NYC Subways and Buses*, Metropolitan Transportation Authority. http://www.mta.info/nyct
35	*New York @ AA Roads - Interstate 278 Brooklyn-Queens Expressway (BQE) East*, AA Roads. http://www.aaroads.com/guide.php?page=i0278ecny
36	*NYCDOT - Trucks and Commercial Vehicles*, New York City Department of Transportation. http://www.nyc.gov/html/dot/html/motorist/trucks.shtml
37	U.S. DOT Issues Advance Notice of Proposed Rulemaking to Begin Implementation of Vehicle-to-Vehicle Communication Technology (NHTSA 34-14; dated Aug. 18, 2014)
38	*Accelerated Vehicle-to-Infrastructure (V2I) Safety Applications Concept of Operations Document*, Final Report—May 29, 2012 FHWA-JPO-13-058, www.its.dot.gov/index.htm
39	*Collision avoidance timing analysis of DSRC-based vehicles*, Accident Analysis and Prevention,2009, *www.elsevier.com*
40	*Connected Vehicle Pilot Deployment Program Phase 1, Security Management Operational Concept – New York City,* FHWA-JPO-16-300
41	*Connected Vehicle Pilot Deployment Program Phase 1, Performance Measurement and Evaluation Support Plan – New York City,* FHWA-JPO-16-302

3. Current System or Situation

This section describes the current traffic conditions and motivations for the NYC CVPD project. It begins with the motivation for the Vision Zero program and then provides information about the traffic environment and safety issues in the corridors where the initial connected vehicle facilities will be deployed.

3.1 Background, Objectives, and Scope

In 2014, NYC began its Vision Zero program to reduce the number of fatalities and injuries resulting from traffic crashes. The Mayor's Office developed the Vision Zero action plan which highlighted a set of initiatives for multiple city agencies to support the goal of improving street safety[27]. One of the major ongoing initiatives has been the citywide speed limit reduction from 30 miles per hour to 25 miles per hour (mph). According to the National Highway Transportation Safety Administration (NHTSA), speeding was a factor in more than one in four deaths[28]. Also, human factors were the critical cause in about 94% of all crashes while vehicle-related factors only apply to about 2% of all crashes.

The Borough Pedestrian Safety Action Plans is another Vision Zero initiative for tackling the different safety challenges of each borough. The safety action plans have identified a priority list of streets based on historical crash frequencies, pedestrian fatalities, and severe injuries. Based on these findings, engineering and design modifications have been recommended for implementation. Despite these efforts, dangerous driving behavior still remains as the primary cause of pedestrian fatalities in crashes. In Manhattan, 73% of all crash fatalities involve pedestrians while this figure is only 14% nationwide[29]. After pedestrian fatalities in NYC reached an all-time low in 2011 with 249, it surged to 297 in 2013. Senior citizens over age of 65 comprise of 12% of the population in NYC but about 33% of all pedestrian fatalities. Also, the primary reason for crash-related deaths of children under 14 was from being struck by a vehicle[30].

3.2 Operational Policies and Constraints

In New York City (NYC), the speed limit is 25 mph unless signed otherwise. This speed restriction has been recently implemented under the objectives of the Vision Zero program. In New York City, turns on red signals are treated differently than the remainder of the nation. Right-turn-on-red (RTOR) after stop is prohibited within New York City unless signed to indicate otherwise. This operational restriction has existed since the traffic laws were modified during the 1970s in response to fuel shortages. NYC has unique definitions for commercial vehicles and trucks that differ from New York State Department of Motor Vehicles classifications. It encourages drivers to check their vehicle's classification information before making trips and to review the City's truck route map to avoid problematic issues such as driving on the area's parkways.

3.3 Description of the Current System or Situation

The NYC CVPD project area encompasses three distinct areas in the boroughs of Manhattan and Brooklyn. Figure 3 shows the general location of these areas within NYC. The following describes these deployment areas in terms of their roadway characteristics and crash history.

The first area includes a 4-mile segment of Franklin D. Roosevelt (FDR) Drive from 50th Street to 90th Street in the Upper East Side and East Harlem neighborhoods of Manhattan. There are seven entrance/exit points within this area of the FDR Drive. The second area includes four one-way corridors of 1st Avenue, 2nd Avenue, and 5th Avenue from 14th Street to 67th Street and 6th Avenue from 14th Street to 59th Street in Midtown and Upper East Side neighborhoods of Manhattan. The segment lengths are 2.6 miles for 1st, 2nd, and 5th Avenues and 2.2 miles for 6th Avenue, respectively. The third area covers a 1.6-mile segment of Flatbush Avenue in Brooklyn from Tillary Street on the north and Grand Army Plaza near Prospect Park to the south. While FDR Drive is a freeway without signalized intersections, the four avenues and five cross-streets in Manhattan include 281 signalized intersections and Flatbush Avenue in Brooklyn includes 28 signalized intersections. These locations are shown in Figure 3 below.

Source: NYCDOT

Figure 3. Infrastructure Deployment Map

3.3.1 Roadway Conditions

This section describes the street configuration and existing traffic information of each CV pilot corridor. Corridor information including the direction of travel, speed limit, and the Annual Average Daily Traffic (AADT) information is provided in Tables 13 and 14 in Appendix B. The AADT data was provided by the Traffic Data Viewer tool from the New York State Department of Transportation (NYSDOT)[31]. Because of available AADT information, the AADT for FDR Drive and the four avenues in Manhattan are based on 2013 data, while the AADT for the five cross-streets in Manhattan are based on 2015 data.

FDR Drive from 50th Street to 90th Street is a two-way, north-south limited-access highway with six travel lanes, three in each direction, on the east side of Manhattan. Its challenges include short-radius curves, weight limit of 8,000 pounds, and minimum bridge clearance of 9'6". It also runs through two tunnels underneath the New York Presbyterian Hospital from 68th Street to 71st Street and Carl Schurz Park from 81st Street to 90th Street. Commercial vehicles, trucks, and tractor trailers are prohibited on all parts of the corridor and buses cannot access FDR Drive north of 23rd Street[32] . Northbound exits are at 96th Street and 125th Street, and southbound exits are at 125th, 116th, 106th, 96th, 79th, and 71st Streets. Pedestrian bridges are at 63rd, 71st, 78th, 81st, 102nd, 111th, and 120th Streets. One vehicular bridge on 91st Street provides access to a dockage and storage facility east of FDR Drive.

First Avenue is a one-way, northbound roadway with four total lanes from 14th Street to 49th Street and five total lanes from 49th Street to 67th Street. It includes one protected bike path south of 40th Street and north of 42nd Street, one bike lane from 40th Street to 42nd Street, and one parking lane on each side[33]. A bus lane effective on weekdays from 7-10AM and 2-7PM serves four routes: M15 local, M15 select bus service (SBS), M23, and M57[34]. There is a 4-lane underpass between 40th and 49th Streets near the United Nations headquarters.

Second Avenue is a one-way, southbound roadway with five total lanes from 67th Street to 14th Street. It includes one parking lane on the left side north of 24th Street, one bike lane from 57th Street to 34th Street, and one protected bike path south of 34th Street. A bus lane effective on weekdays from 7-10AM and 2-7PM serves five routes: M15 local, M15 SBS, M34A SBS, Q60, and Q101.

Fifth Avenue is a one-way, southbound roadway with four total lanes from 67th Street to 60th Street and five travel lanes from 60th Street to 14th Street. It includes one parking lane on the left side and one bike lane from 24th Street to 14th Street. A bus lane effective on weekdays from 7AM-7PM is north of 34th Street and serves both local and express routes: M1 through M5, M50, Q32, and several express routes to Brooklyn and Staten Island.

Sixth Avenue is a one-way, northbound roadway with six total lanes from 14th Street to 59th Street. It includes one parking lane on each side south of 30th Street and only on the left side north of 30th Street. Also, one bike lane exists south of 42nd Street on the left side. A bus lane effective on weekdays from 4-7PM serves a variety of local and express routes: M5, M7, M55, and several express routes to the Bronx and Queens.

Fourteenth Street is a two-way, east-west roadway with four total lanes with street parking on each side and serves the following local bus routes: M7, M11, M12, M14A and M14D. Street parking is prohibited on some stretches along this corridor. The current roadway configuration of Fourteenth Street may potentially be converted to a bus rapid transit (BRT) corridor upon MTA's L-train shutdown in 2019. This is listed as a confounding factor in Section 5.1.12 of the Connected Vehicle Pilot Deployment Program Phase 1, Performance Measurement and Evaluation Support Plan – New York City, FHWA-JPO-16-302.

Twenty-third Street is a two-way, east-west roadway with six total lanes with one dedicated bus lane on each side. Street parking is available on the eastbound approach throughout the corridor, but on the westbound approach street parking is prohibited west of Seventh Avenue and east of Fifth Avenue. Hence, in the sections west of Seventh Avenue and east of Fifth Avenue, only one general travel lane and one dedicated bus lane consist of the westbound approach. The westbound bus lane exists between First and Eighth avenues, and the eastbound bus lane exists between Tenth and Second avenues. The bus lane serves the following local and express bus routes: M9, M23 SBS, M101, M102, M103, and several express routes to the Bronx, Brooklyn, Queens, and Staten Island.

Thirty-fourth Street is a two-way, east-west roadway with four lanes with one dedicated bus lane on each side. Parking lane exists on both westbound and eastbound approaches west of Tenth Avenue, westbound approach between FDR Drive and Third Avenue, and eastbound approach between Third Avenue and Second Avenue. A bus lane on each approach effective on weekdays from 7AM-7PM and serves the following local and express routes: M34 SBS, M34A SBS, and several express routes to the Bronx, Queens, and Staten Island.

Forty-second Street is a two-way, east-west roadway with six total lanes throughout the corridor. Street parking is allowed west of Tenth Avenue. It includes a bus only lane on each side from Dyer Avenue and Third Avenue which is effective on weekdays from 7-10AM and 4-7PM. It serves one local route M42 and several express routes to Queens and Staten Island.

Fifty-seventh Street is a two-way, east-west roadway with four total lanes between Twelfth Avenue six total lanes with dedicated parking lane on each side west of Eleventh Avenue and six total lanes between Eleventh Avenue and Sutton Place. Street parking is allowed on each side ,and from Eighth Avenue to Second Avenue it is shared with the bus lane on each side. The bus only lane from Eighth Avenue to Second Avenue is effective on weekdays from 7-10AM and 4-7PM and serves the following local and express routes: M10, M12, M31, M57, and several express routes to the Bronx, Brooklyn, Queens, and Staten Island. Also, several express bus routes terminate their inbound trips on Fifty-seventh Street and begin their outbound trips to the outer boroughs.

Flatbush Avenue is a bi-directional, north-south roadway with eight total lanes, four in each direction, with a median from Tillary Street to Fulton Street and six total lanes, three in each direction, from Fulton Street to Grand Army Plaza. There is one parking lane on each side and no bike lanes. Brooklyn Bridge does not allow commercial vehicles and vehicles over 11 feet high[35]. Therefore, these vehicles traveling from and to Manhattan are diverted to the Manhattan Bridge and either the Brooklyn-Queens Expressway (BQE) via Tillary Street or to Flatbush Avenue[36].

3.3.2 Safety Information

The NYC CVPD will focus on safety improvements for both motorists and non-motorists. In particular, the crash risks increase during nighttime hours when vehicle speeds tend to be higher and it becomes more difficult to see pedestrians crossing. Detailed summaries of crash records, injuries, and fatalities and severe injuries from 2010 to 2014 in each CV pilot corridor are provided in Table 15 - Table 17 in Appendix B. Note that the crash reporting information treats pedestrians and bicyclists independently.

The crash and fatality data were provided by New York City Department of Transportation (NYCDOT), and the injury data was provided by the New York State Department of Transportation (NYSDOT). Except for FDR Drive, the most common collision types in all CV pilot corridors were rear-end and sideswipe (same direction). The most common type of action performed by pedestrians and bicyclists during crashes was crossing with signal at signalized intersections. Also, crash frequency was higher during PM than AM hours in all corridors. Among all CV pilot corridors Second Avenue had the highest total number of crashes, while Sixth Avenue had the highest persons killed or severely injured (KSI) per mile.

3.4 Modes of Operation for the Current System or Situation

The NYC roadway network does not currently support CV applications or operations. Therefore, the current system does not have CV related modes of operation.

3.5 User Classes and Other Involved Personnel

A list of current users and one concept for classifying them is shown in Table 2. Note that vehicle owners and drivers/operators are listed separately because the relationship between owner and driver/operator varies among the different fleets. The user classification is provided as it groups users according to their perception of the system and the needs to be satisfied by the system.

Table 2. Users and Stakeholders

User	User Class
DCAS Drivers	Fleet Driver
DCAS Fleets	Fleet Owner, Installer
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

User	User Class
Texas Transportation Institute (TTI)	Performance Measurement User
Vendor for ASD, PID, RSU	Supplier

It should be noted that many of the vehicle fleet's drivers/operators are governed by collective bargaining agreements with the fleet owners. These agreements establish work rules and cover the operation of the vehicle fleets.

With the project plan to instrument 3,000 vehicles, the project will be dealing with a potentially much larger pool of driver/operators. This is due to the nature of the fleets and that multiple drivers may be used to operating the vehicles. Many of the fleet vehicles will be in service more than five days a week and for periods well beyond an eight (8) hour shift.

3.6 Support Environment

Support consists of the personnel that build, maintain, and operate the roadway system, the associated traffic control devices, as well as those responsible for the maintenance of the vehicle fleets. This section discusses the organizations and relationships that support the various roadway components.

NYCDOT is responsible for the roadway and traffic control devices in the project areas. It uses internal and external third-party resources to maintain the roadway infrastructure. There are well established relationships and procedures within the NYCDOT for these maintenance activities. These processes include reporting facilities (e.g., 511, web sites), work order generation and tracking, and management oversight.

Vehicle driver/operators are responsible for identifying issues with their vehicles and bringing those issues to the attention of the vehicle owners for repair. In the case of the vehicle fleets, some fleet owners have internal organizations for vehicle maintenance. Other fleet owners utilize third-party maintenance providers for vehicle maintenance on a contract basis.

NYCDOT and Department of Information Technology and Telecommunications (DoITT) share responsibility for communications infrastructure. Both organizations utilize a combination of internal staff as well as third-party contractors to maintain this equipment. The lines of demarcation between the organizations and their responsibilities are well known and managed through existing systems and processes.

4. Justification for and Nature of Changes

This chapter describes the shortcomings of the current system or situation that motivate development of a new system or modification of an existing system. These are typically expressed as a set of System or User *Needs* that will drive the scoping of the system development or modification.

4.1 Justification of Changes

This section describes the NYCDOT's objectives in deploying (i.e., creating) the system.

The fundamental message of the NYC Vision Zero initiative is that death and injury on city streets is not acceptable. These tragedies happen in every community within NYC, to families from every walk of life – from the Upper East Side to the Lower East Side; from Park Slope to Edenwald. They happen to people who drive and to those who bike; but overwhelmingly, the deadly toll is highest for pedestrians – especially children and seniors. The goal of Vision Zero is to eliminate traffic deaths by 2024. The NYC CV Pilot Deployment project will focus on safety improvements for both motorists and non-motorists. In particular, the crash risks increase during nighttime hours when vehicle speeds tend to be higher and it becomes more difficult for vehicle drivers to see pedestrians crossing the roadway.

As the safety statistics indicate, surface improvements on city streets alone will not mitigate the number of crashes, fatalities, and severe injuries long-term. While no Silver Bullet will end all crashes, multiple supplemental tools are needed that can work together to attain Vision Zero's goal. The CV technology is one of these tools and it presents a systematic approach in alerting vehicles of unsafe roadway conditions and prevents collisions with other vehicles, and pedestrians. It will provide numerous safety benefits that facilitate Vision Zero's goals and initiatives.

4.2 Description of Desired Changes

The NYCDOT is going to deploy connected vehicle technology to its roadway transportation network. This technology provides communications between the various transportation users using a technology termed Dedicated Short Range Communications (DSRC). This wireless communications technology enables applications that address the transportation user's need for safe travel, mobility as an individual within a diverse system, and reducing the impacts on the environment from traveling.

Connected vehicle technology will be deployed in vehicles, mobile PIDs, and at infrastructure locations such as intersections, roadway curves, and work zones. The vehicle mounted devices allow vehicles to communicate with one another and this communication is referred to as Vehicle-to-Vehicle (V2V) communications. These same in-vehicle devices will communicate with similar devices installed and connected to the transportation infrastructure. Vehicle-to-Infrastructure (V2I) communications describes this communications path. These communications and those with mobile personal information devices are collectively covered by the term Vehicle-to-X (V2X) communications.

4.3 System Needs Summary

This section describes the additional changes or enhancements necessary to realize the concepts of operation described in this document. It describes and organizes the needs of the various project users and stakeholders. These needs are presented using two perspectives – the NYCDOT traffic management needs and the stakeholders (i.e., fleet owners, driver/operators) needs for deploying, maintaining, and operating connected vehicle technology to be installed on their vehicles. Other needs for operating and maintaining the infrastructure (i.e., core services) are also identified.

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

- What does the System need to do?
- What do users need from the System?

They are organized according to the stakeholder class listed in Table 2 above. Each need is identified with a unique number for tracing the need through the system development life-cycle.

4.3.1 User Needs: Traffic Manager

As the traffic manager and the roadway infrastructure owner, NYCDOT has identified a set of traffic management needs to address the crashes described in the previous section. These needs encompass managing speed, reducing crashes and their severity, and managing mobility in the operational areas as listed in Table 3 below. These needs address the causes of fatalities described in the previous section as well as address common incidents that disrupt travel times and increase travel time variability. One or more CV applications will be deployed within the system concept to address each of these identified traffic management needs.

Table 3. Traffic Manager Needs

Need ID	Traffic Manager (NYCDOT) Needs	System Concept for Deployment (CV Application)	Support for Vision Zero
101.1	Need to manage speed on surface streets – 25 mph regulatory speed limit	Speed Compliance	Notify drivers when their speed exceeds the speed limit
101.2	Need to manage speeds on curves –regulatory speed limit	Curve Speed Compliance	Advise drivers to comply with the speed limit in curves, thus reducing the potential of a rollover and subsequent major traffic incident
101.3	Need to manage speed in work zones –speed limit	Speed Compliance / Work Zone	Facilitate widespread adherence to the NYC speed limit. Additional time-of-day and day-of-week restrictions, such as those associated with a school zones or moving construction (e.g., pothole repair) zones and bus lanes
102.1	Need to reduce crashes between vehicles	Forward Crash Warning (FCW)	Warn drivers in case of an impending rear-end crash with another vehicle ahead in the same lane and direction of travel
102.2	Need to reduce crashes between vehicles	Emergency Electronics Brake Light (EEBL)	Notify drivers when a vehicle ahead generates an emergency brake event
102.3	Need to reduce crashes between vehicles	Blind Spot Warning (BSW) + Lane Change Warning/Assist (LCA)	Warn the driver of the vehicle if the blind-spot zone is occupied by another vehicle traveling in the same direction during a lane change attempt and when it is not attempted
102.4	Need to reduce crashes between vehicles	Intersection Movement Assist (IMA)	Warn the driver of a vehicle when it is not safe to enter an intersection because of high crash probability with other vehicles at stop-controlled and uncontrolled intersections
102.5	Need to reduce crashes between vehicles	Vehicle Turning Right in Front of Bus Warning	Warn bus drivers of vehicles pulling up behind a stopped bus, making a lane changes to pass around the bus, and exhibiting a path to cross directly in front of the bus
102.6	Need to reduce crashes between vehicles	Red Light Violation Warning	Advise drivers if a vehicle is on an approach that is likely to result in the vehicle violating the red light
103	Need to reduce crashes between vehicles and infrastructure	Oversize Vehicle Warning	Provides warnings to vehicle drivers to avoid entering a height restricted facility and imminent low clearance location

Need ID	Traffic Manager (NYCDOT) Needs	System Concept for Deployment (CV Application)	Support for Vision Zero
104.1	Need to reduce crashes between vehicles and pedestrians	Pedestrian in Signalized Crosswalk Warning	Provide in-vehicle indication of pedestrians at intersections equipped with CV technologies
104.2	Need to reduce crashes between vehicles and visually / audibly-impaired pedestrians	Mobile Accessible Pedestrian Signal System (PED-SIG)	Allows for a visually impaired pedestrian to be notified of the traffic signal status via the PID and notify approaching drivers of the pedestrian's presence
105	Need to inform drivers of serious incidents	Evacuation Notification	Provides notification that an area is to be avoided and why (subset of Emergency Communications and Evacuation concepts)
106	Need to provide mobility information in heavily congested areas	Intelligent Traffic Signal System (I-SIGCVDATA)	Integration of CV movements with NYC's award winning Midtown In Motion (MIM) adaptive traffic signal system

NYCDOT proposes to deploy these CV applications on a significant number of vehicles composed of NYCDOT and City vehicles as well as MTA/NYCT buses as part of the system concept for addressing these needs. To assist the CV applications, NYCDOT will provide infrastructure at approximately 330 signalized intersections along 1st, 2nd, 5th, and 6th Avenues and 14th, 23rd, 34th, 42nd, and 57th crosstown streets in Manhattan and Flatbush Avenue in Brooklyn. The City will install additional infrastructure along the fleet barn entrance/exits and the mainline roadway of the FDR Drive in Manhattan as well as additional designated locations in Queens, Brooklyn, and the Bronx.

4.3.2 User Needs: Fleet Owners

NYCDOT sponsored a series of stakeholder meetings with its participating fleet owners. These stakeholders agree to have CV devices installed in their fleets to obtain the potential crash reduction benefits. The purpose of the meetings was to solicit the fleet owners' (i.e., stakeholders) needs with respect to the applications operation, vehicle installations of equipment, maintenance, and daily operations. This was accomplished by describing the CV applications and their operation. Following these discussions, NYCDOT described its procurement program for the equipment and its plans for installing, operating, and maintaining the infrastructure. The NYCDOT also explained the concepts for managing and measuring system performance.

A major stakeholder (i.e., fleet owners, vehicle operators/drivers) concern is the potential use of the data for enforcement or driver performance assessment. Although USDOT and NHTSA have policies stating that V2V DSRC data will not be used for these purposes, the potential that stored data could be the subject to subpoena or Freedom of Information Act (FOIA) requests exists. Due to the stored data's time and location content, it has the potential to be cross-referenced with external system data (e.g., crash reports, employment timecards, driving records) and isolated so that it loses its inherent anonymity and becomes Personally Identifiable Information (PII). This concern is treated as a privacy need later in this section.

Table 4. Fleet Owner Needs

Need ID	Fleet Owner Needs	System Concept for Deployment	Support
201	Need to have privacy	Data Normalization	Re-anchor time/location data to protect driver/operator while preserving vehicle trajectory details
202	Need to manage CV application for the traffic environment	CV Application Parameter Control	Manage parameters so that applications can be tuned for the traffic environment
203	Need to manage CV equipment maintenance	NYCDOT to provide equipment and maintain it	Establish a process for managing the installation of equipment and managing the inventory
204	Need to limit additional vehicle cab devices that have the potential to distract drivers	Provide audio warnings for the driver-vehicle interface	Provide either auditory sounds or short voice messages when warnings are triggered

4.3.3 User Needs: Roadway Users

This section describes needs generated by the roadway users. These users include the vehicle drivers/operators, unequipped pedestrians, and visually impaired pedestrians. It is important to be aware that the fleet owners and roadway users share the same concerns regarding the need for privacy and the management of the CV applications for the traffic environment. Therefore, these common needs are identified using a unique identifier while being listed for each stakeholder class.

Table 5. Roadway User Needs

Need ID	Roadway User Needs	System Concept for Deployment	Support
201	Need to have privacy	Data Normalization	Re-anchor time/location data to protect roadway users while preserving vehicle trajectory details
202	Need to manage CV application for the traffic environment	CV Application Parameter Control	Manage parameters so that applications can be tuned for the traffic environment
303	Need to notify vehicles of pedestrians	Pedestrian in Signalized Crosswalk	Visually impaired pedestrians want vehicle driver/operator notified due to limited deployment of the technology

4.3.4 User Needs: System Manager

The NYCDOT will be deploying CV infrastructure to support the operation and management services for the CV applications. These devices and facilities include roadside unit (RSU), wired and wireless communication networks, traffic signal controller (ASTC) upgrades, and back office facilities.

The back office facilities at NYCDOT Traffic Management Center (TMC) will integrate its processor system with a commercially available Hardware Security Module (HSM) provided by USDOT to allocate a secure storage of the cryptographic materials including the DSRC messages (BSM, SPaT, MAP, TIM) and their data. 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. 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 HSM for the SCMS is developed by USDOT, the NYCDOT TMC-HSM integration approach will be able to manage the SCMS functions and sign the certificates and messages transmitted by the devices.

The back office in the NYCDOT TMC will provide the following management functions:

- Managing RSU performance (failure identification, repair, maintenance)
- Managing RSU radio frequency (RF) footprints
- Managing CV application configuration
- Distributing obfuscated data externally to USDOT Independent Evaluator (IE)
- Collecting Data from the RSU/ASD
- Aggregating, normalizing, and obfuscating the CV data
- Assessing the NYC CVPD system performance and safety benefits

Table 6. System Manager Needs

Need ID	System Manager Needs	System Concept for Deployment	Support
401	Need to have trusted communications	Dedicated Short Range Communications and Security Credential Management System	Utilize existing standards and external systems to provide secure information exchanges
402	Need to manage equipment health	RF Monitoring	Equipped vehicles and infrastructure collect first / last contact with other equipped vehicles and infrastructure
403	Need to manage CV application life-cycle	Over-the-Air Firmware Updates	Provide an infrastructure to verify firmware versions and update when necessary

Need ID	System Manager Needs	System Concept for Deployment	Support
404	Need to manage CV application interrelationship	Configurable threat arbitration level for the CV applications	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 arbitration algorithm will be configurable such that additional applications can be added to the ASD.

4.3.5 User Needs: Independent Evaluator

The CV pilot deployment projects also have several goals built into the program in order to assess the benefits of the connected vehicle program. These goals require measuring the performance of the connected vehicle applications deployed in each project's respective environment. For the NYC environment, these measurements will aid in evaluating connected vehicle application performance in the dense urban environment where intersections are tightly clustered together (e.g., approximately 250 feet) and location accuracy has proven to be a technical challenge due to the canyon effect created by tall buildings and limited views of the Global Navigation Satellite System (GNSS) devices.

New York University (NYU) will be the NYCDOT Independent Review Board (IRB). It will perform the initial assessment of the vehicle and pedestrian data and the ensuing safety benefits. The PID equipment will be used to collect information about the performance of the pedestrian application in select number of intersections equipped with RSUs in Manhattan. Section 5.3.9 contains additional details on the pedestrian CV application that will be deployed in the NYC CVPD system.

The USDOT has engaged Texas Transportation Institute (TTI) as its independent evaluator (IE) to analyze the project's performance with respect to its goals as listed in Section 5.1. TTI will be responsible for analyzing the processed event data and the safety benefits of the NYC CVPD program. In addition to the safety benefits, the USDOT is interested in exploring what additional benefits such as mobility, environmental, and public agency efficiency are attained with the NYC CVPD. In order to measure the connected vehicle application's benefits, the project will incorporate a before/after evaluation using the connected vehicle equipment installed in fleet vehicles. The ASD equipment will be used to collect information regarding the performance of the CV applications in the project's geographic and traffic environment.

Table 7. Independent Evaluator Needs

Need ID	Performance Evaluator Needs	System Concept for Deployment	Support
501	Need to collect detailed information when a warning is issued	Event Recording	Vehicles record the previous X seconds of Basic Safety Message (BSM) data and the next Y seconds of BSM data for evaluation when a CV application issues a warning

Need ID	Performance Evaluator Needs	System Concept for Deployment	Support
502	Need to collect event recordings	Upload Event Recordings	Vehicles initiate uploads of their event recordings when the service is available
503	Need to assess speed compliance	Before/After Speed Compliance Comparison	Record speed compliance warning events and analyze them
504	Need to assess vehicle-vehicle crashes	Before/After Vehicle-Vehicle Crash Comparison	Record V2V application warning events and analyze them
505	Need to assess vehicle-pedestrian crashes	Before/After Vehicle-Pedestrian Crash Comparison	Record pedestrian crossing warning events and analyze them
506	Need to assess vehicle-infrastructure crashes	Before/After Vehicle-Infrastructure Crash Comparison	Record oversize vehicle warnings and analyze them
510	Need to assess all CV applications	System Performance and Benefits Evaluation	Assess and post-process the data records before sending them to USDOT IE

One new area of connected vehicle applications to be assessed within the project involves assisting/protecting pedestrians. This area is significant in the NYC environment due to the nature of vehicle-pedestrian crashes as described in Section 3.1.

Note that the data flows are added to handle the parameterization of the warnings, triggers, pre- and post- event recording times, etc. This is essential so that thresholds can be configured based on traffic conditions, time-of-day, day-of-week, etc. and the data collection can be managed to satisfy the measurement needs.

This approach protects project stakeholders while still providing aggregate data to measure performance. It means that the statistical evaluation of the CV application benefits must be pushed down with aggregation as quickly as possible. This data collection concept enables the before/after evaluation through the comparison of aggregate measures rather than at an individual driver or fleet performance comparison.

4.4 Priorities Among Changes

The number one user need to be satisfied by the system is the preservation of privacy voiced by the fleet owners and roadway users. For many of these stakeholders, satisfying this need is a requirement for their participation.

The need to manage the CV applications for the traffic environment is also a high priority. This need allows the fleet owners and roadway users to be comfortable that the expected warnings can be managed so as to not distract drivers and to manage the warnings provided by the technology.

Another need is addressing the the urban canyon effect on location accuracy of the ASDs. This need to maintain the accuracy of vehicle trajectories per SAE J2945/1 is critical in preventing false and missed alerts from being triggered. The NYC CVPD system will incorporate location correction mechanisms through Wide Area Augmentation System (WAAS) and additional device(s) as needed for GNSS augmentation and location accuracy.

4.5 Changes Considered but Not Included

The NYCDOT's intent for considering the Freight-Specific Dynamic Travel Planning application was to address issues on over-dimension vehicles entering prohibited roadways. For this need, the Oversize Vehicle Warning application provides a better fit than the Freight-Specific Dynamic Travel Planning application as it does not incorporate the extensive routing and regulator framework encompassed in the Freight-Specific Dynamic Travel Planning application. Also, the Freight-Specific Dynamic Travel Planning application as defined by the CVRIA contains elements that do not apply to the NYC CVPD. As a result, this application was deleted from the final list of CV applications for pilot deployment.

To that end, the ASD on board the vehicle must have route restriction information and the vehicle dimensions such that it can produce warnings to the driver if the driver appears to be entering a route which conflicts with the onboard information. The route specifics can be loaded from a roadside unit (RSU) at the warehouse (vehicle barn) or near the entry/exit ramp such that the information is present within the ASD before the vehicle reaches the restricted route or location.

The V2V application Stationary Vehicle Ahead has been dropped from inclusion in the project. While preparing use case, operational scenarios, and needs for this application, it became apparent that Stationary Vehicle Ahead conditions are a special case considered already under the Forward Crash Warning application as described in SAE J2945/1 and as described in *Collision avoidance timing analysis of DSRC-based vehicles*[1] by Tang and Yip. An analysis of these applications in the CVRIA indicates that the needs and requirements are identical except for the CVRIA indicating that the Forward Collision Warning[2] applications intent to advise the driver as to the specific action to be taken.

The initial proposal referenced several other applications for managing traffic speeds and these have been refined to meet the user needs. The original proposal listed Modified Eco-Speed Harmonization, Curve Speed Warning, and Reduced Speed / Work Zone applications. These have been revised to Speed Compliance, Curve Speed Compliance, and Speed Compliance /Work Zone to conform to the user’s traffic management needs. These replacement applications are intended to use the CV technology to manage speed in conformance with the regulatory limits.

[1] See reference 39
[2] The CVRIA Forward Collision Warning is similar to the SAE J2945/1 Forward Crash Warning.

5. Concepts for the Proposed System

This section will describe the key concepts for the NYC CVPD project. Although it will cover the NYC CVPD as a whole, it primarily focuses on the new concepts and functionality.

The key concept for the NYC CVPD project is to equip a large fleet of vehicles with CV technology in order to advance towards the Vision Zero goal of eliminating injuries and fatalities from traffic crashes. This section provides further detail as to the system concepts to be employed for satisfying the needs established in Section 4. Some of these system concepts (i.e., CV applications) already exist and are documented externally. The other concepts are new functionality to be developed and deployed for the first time within the NYC CVPD. System management and performance measurement are the primary needs area for this functionality. This section describes these areas of the system from a high-level perspective.

It is important to understand the implications of the connected vehicle technology deployment in New York City. A small portion of New York City roadway network will have connected vehicle infrastructure installed (i.e., RSU). Vehicle-to-Infrastructure (V2I) applications such as Red Light Violation Warning and Curve Speed Compliance will support connected vehicles operating in these areas. However, the geographic reach of the connected vehicle technology is much broader. Vehicles equipped with connected vehicle technology (i.e., aftermarket safety devices) will travel in this infrastructure equipped area *and throughout the City's transportation network*. Thus the connected vehicle technology that supports Vehicle-to-Vehicle (V2V) applications will function anywhere two equipped vehicles are within range of one another. 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 connected vehicle technology to perform over a large geographic area and diverse roadway environments.

5.1 Background, Objectives, and Scope

NYC is implementing the CV technology as another tool in its quest for Vision Zero. It is anticipated that the CV technology will reduce the number of and severity of crashes in the deployment area. In addition to deploying the technology, New York City will assess its impacts and potential for attaining the Vision Zero goal of zero crashes/fatalities/injuries. Figure 1. NYC CVPD System Concept provides a conceptual view of the system to be deployed. It also provides insight to whether a component is existing or to be newly deployed within the project.

The NYC CVPD project is one of three initial CV deployment projects that establish a base for growing a nationwide 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.

The NYC CVPD is designed to provide a real demonstration and evaluation of the benefits of the CV technology in a dense urban environment. NYC has deployed a robust infrastructure with advance traffic controllers (ATCs), 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 ASDs, our team 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 that are regularly driving in the area.

This project will also provide FHWA the opportunity to showcase the benefits of CV technology without replacing the vehicle fleet – which is likely to be the situation for many years to come. At the same time, the NYC CVPD will be used to demonstrate the benefits to vulnerable road users who suffer the most from roadway fatalities in NYC. The expected deployment of the applications inside of the vehicles is shown in Table 8.

Table 8. Vehicle Fleet Distribution

CV Application	NYCDOT Fleet	DCAS Fleet	MTA / NYCT Buses	Pedestrian Information Device (PID)
	1230	**1759**	**11**	**10**
	41.0%	**58.6%**	**0.4%**	**N/A**
Speed Comply	Yes	Yes	Yes	No
Curve Spd Comply	Yes	Yes	Yes	No
SpdComply/WrkZn	Yes	Yes	Yes	No
Frwd Crash Wrn	Yes	Yes	Yes	No
Emer Elec Brake	Yes	Yes	Yes	No
Blnd Spot Wrn	Yes	Yes	Yes	No
Ln Change Wrn	Yes	Yes	Yes	No
Int Mvmt Assist	Yes	Yes	Yes	No
VTRFBW	No	No	Yes	No
Red Lt Vio Wrn	Yes	Yes	Yes	No
PED in Sig Xwalk	Yes	Yes	Yes	Yes
PED-SIG	No	No	No	Yes
Oversize Veh Comply	No	Conditional	Conditional	No
EVAC Info	Yes	Yes	Yes	No
I-SIGCVDATA	No	No	No	No

The USDOT has also established three goals for this deployment program and these are summarized as follows:

- Spur Early CV Technology Deployment
  - Wirelessly Connected Vehicles
  - Mobile Devices
  - Infrastructure
- Measure Deployment Benefits
  - Safety
  - Mobility
  - Environment
- Resolve Deployment Issues
  - Technical
  - Institutional
  - Financial

These goals drive the program structure and the contents of the agreement between USDOT and each deployment site's team.

5.2 Operational Policies and Constraints

This section will provide a list of policies that may govern the system operation or constraints that will be factored into the development, operation, or maintenance of the system. The following operational policies/constraints have been identified so far.

The operational policies and constraints for the current system in Section 3.2 will carry forward to the proposed system and its operations. Additional policies and constraints are listed below.

From the beginning of the CV program, ensuring individual privacy has been a key to adoption of the CV technology. In order to produce these safety benefits consistent with the goals of the USDOT's connected vehicle program, the project will adopt the USDOT objective to "not collect or store any data on individuals or individual vehicles, or will it enable the government to do so[37]." Throughout all meetings with the project stakeholders, the stakeholders expressed that this objective must be met to continue their participation.

The stakeholder's concern is that time and location information constitutes potentially Personally Identifiable Information (PII) because it could be merged with other records (e.g., police crash reports) and used in legal proceedings, disciplinary proceedings, or insurance negotiations. Keeping data with this time/location information is a potential infringement of an individual's privacy. Concerns have also been expressed by the labor unions and legal departments that if such records were known to exist, they would be subpoenaed for criminal and/or civil suits and would be subject to FOIA requests – which are very frequent in NYC.

The goal of privacy poses a formidable challenge for the deployment of the NYC CVPD project. While privacy is a fundamental concept embedded in the CV system design, the need to measure deployment benefits necessitates knowing details regarding the vehicle and its whereabouts. To balance these competing objectives, the NYC CVPD will provide detailed vehicle operational information after it has been aggregated and normalized (i.e., scrubbed) of time and location details. This approach satisfies the detailed information needs for evaluation while protecting the privacy of the vehicle drivers/operators.

Another constraint is a result of the project's focus on safety. The NYC legal staff is concerned about the deployment of safety focused applications that may not provide warnings to the drivers/operators. On one hand, the concern is about a warning not being given to the driver/operator that could have mitigated a crash/injury/fatality situation. The other concern is that for the purposes of data collection for a before/after evaluation, the system will operate in silent mode for a time period in order to gather data. 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.

5.3 Description of the Proposed System

In this ConOps for the NYC CVPD, the proposed system is described using system architecture views based on USDOT's CVRIA and subsequently tailored to meet the needs and vision of the pilot deployment project. More information is described in the CVRIA website[6]. This section is divided into subsections that describe the overall physical view of the architecture as well as the enterprise view of the architecture. Later subsections provide information about the CV applications to be tailored for this deployment.

The physical view describes the physical objects (systems and devices) and their application objects, as well as the high-level interfaces between those physical objects. Functional and communications views can be included as subsets of the physical view components.

The enterprise view describes the relationships between organizations and the roles those organizations play within the connected vehicle environment. The organizations shown are those listed in Table 2 in Section 3.5.

The legend for the following figures is provided in Figure 23 in Appendix C due to the extensive information it contains. To summarize the legend, color is used to denote various types of devices, centers, people, and organizations. Communication paths and connections are shown however the detail regarding the information content, protocols, security, and timing involved with each path are not disclosed on these high-level views of the system's connections.

5.3.1 Physical View

The physical view of the NYC CVPD system is illustrated and defined below. Two layers are used to represent the system. The first or highest level, Layer 0, is a comprehensive view in which the physical objects or system elements are shown with high-level connectivity. This comprehensive view is followed by two Layer 1 drawings that show the applications or collections of functionality and their interactions. One Layer 1 shows a high-level view of the safety applications for the vehicles and roadway users and the second diagram shows the core services for operating and managing the system.

5.3.1.1 Physical - Layer 0

This section presents the top level, Layer 0, drawing for the physical view of the NYC CVPD. The following diagram provides a high-level conceptual view of the centers, infrastructure device, mobile devices, and external services/centers to be connected by the system. These entities are ordered left to right and the wireless communications that physically interconnect them are indicated.

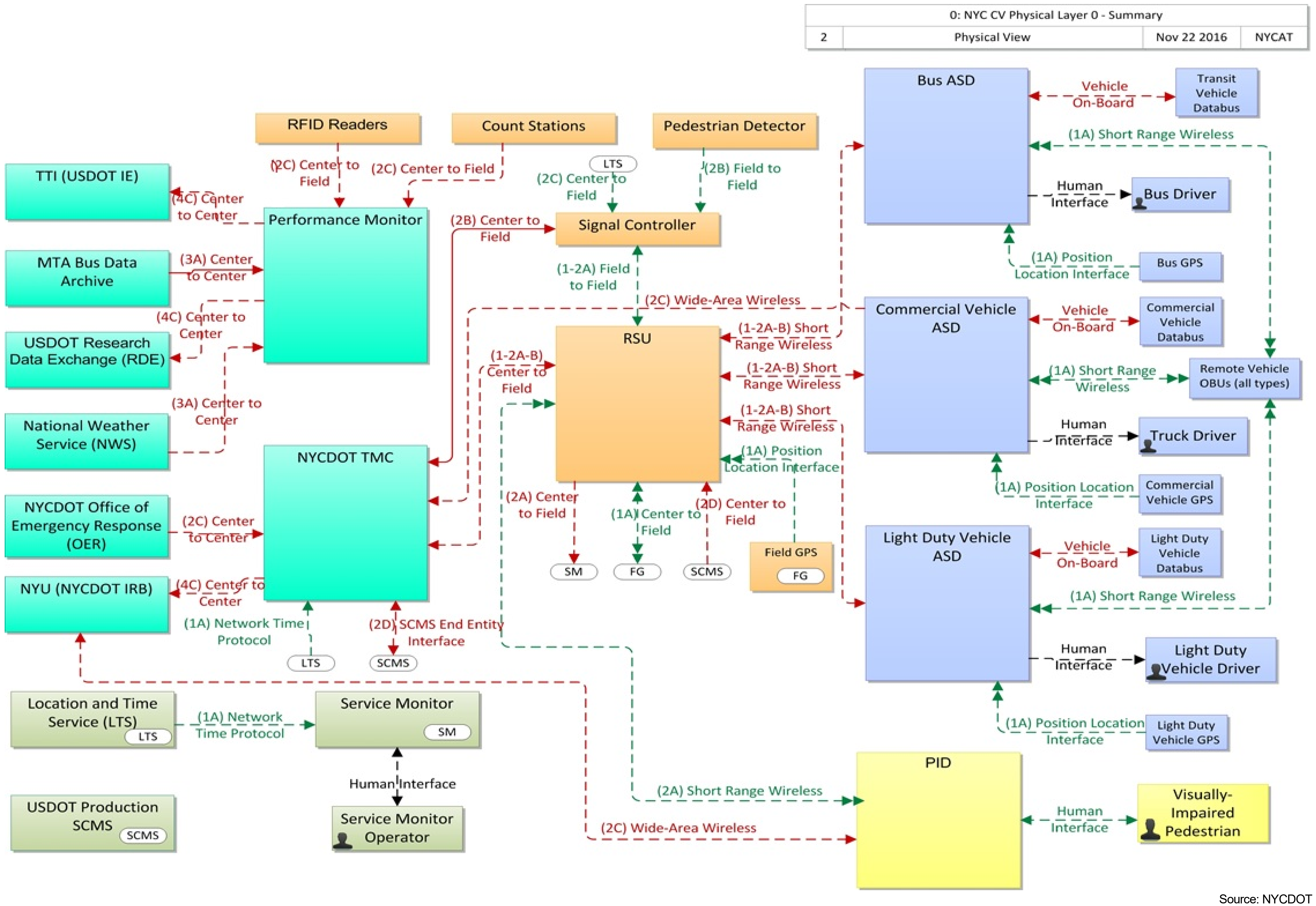


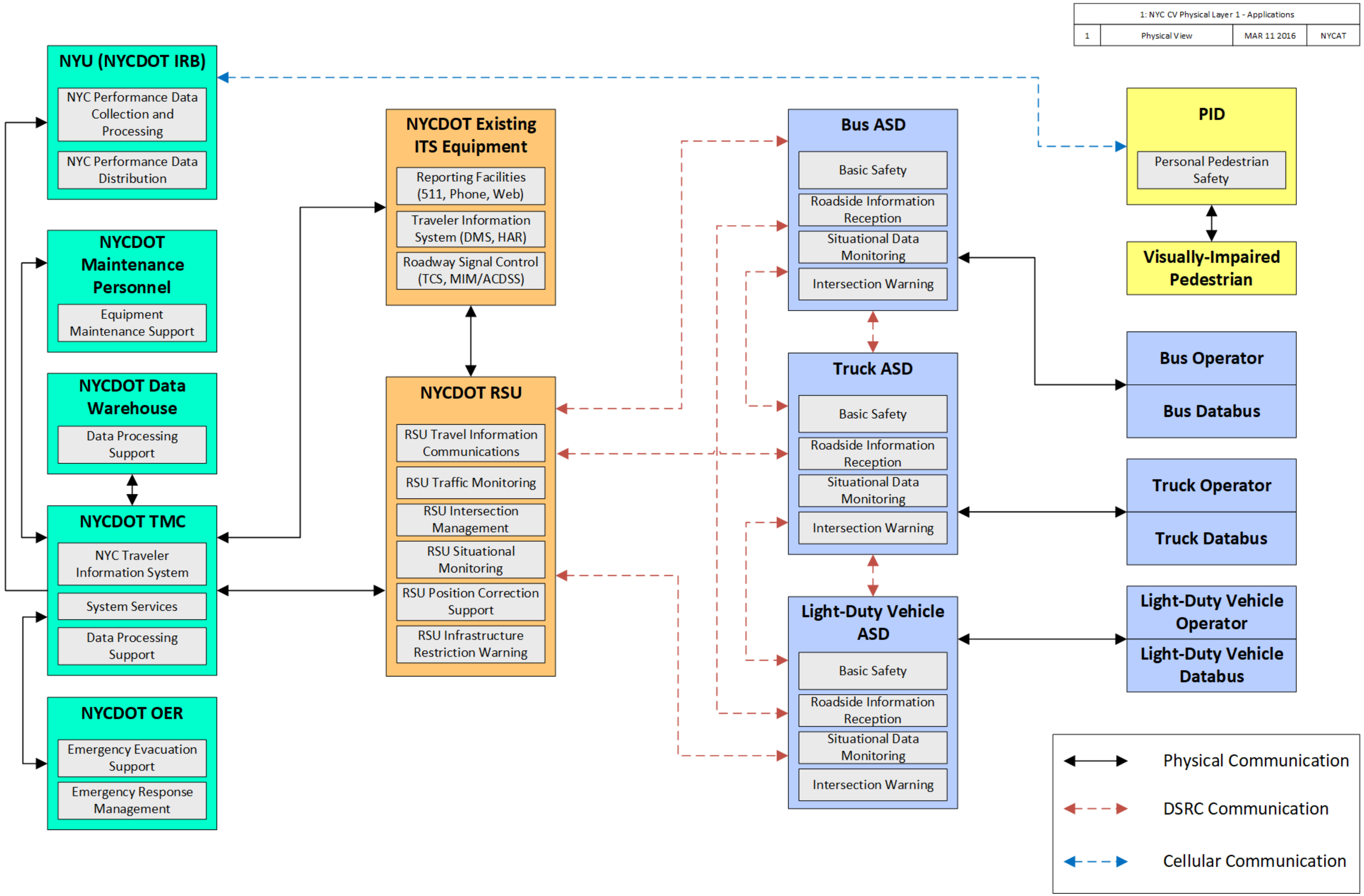
Figure 4. NYC CVPD System Physical Description (Layer 0)

5.3.1.2 Physical - Layer 1

The next two diagram(s) provide a mid-level conceptual architecture for the NYC CVPD. They are based on the CVRIA described at the CVRIA website[6]. These drawings contain the same elements shown in Layer 0 but add the application objects within each of the physical elements. These diagrams show how functionality is logically distributed throughout the entities within the Layer 0 description of the system.

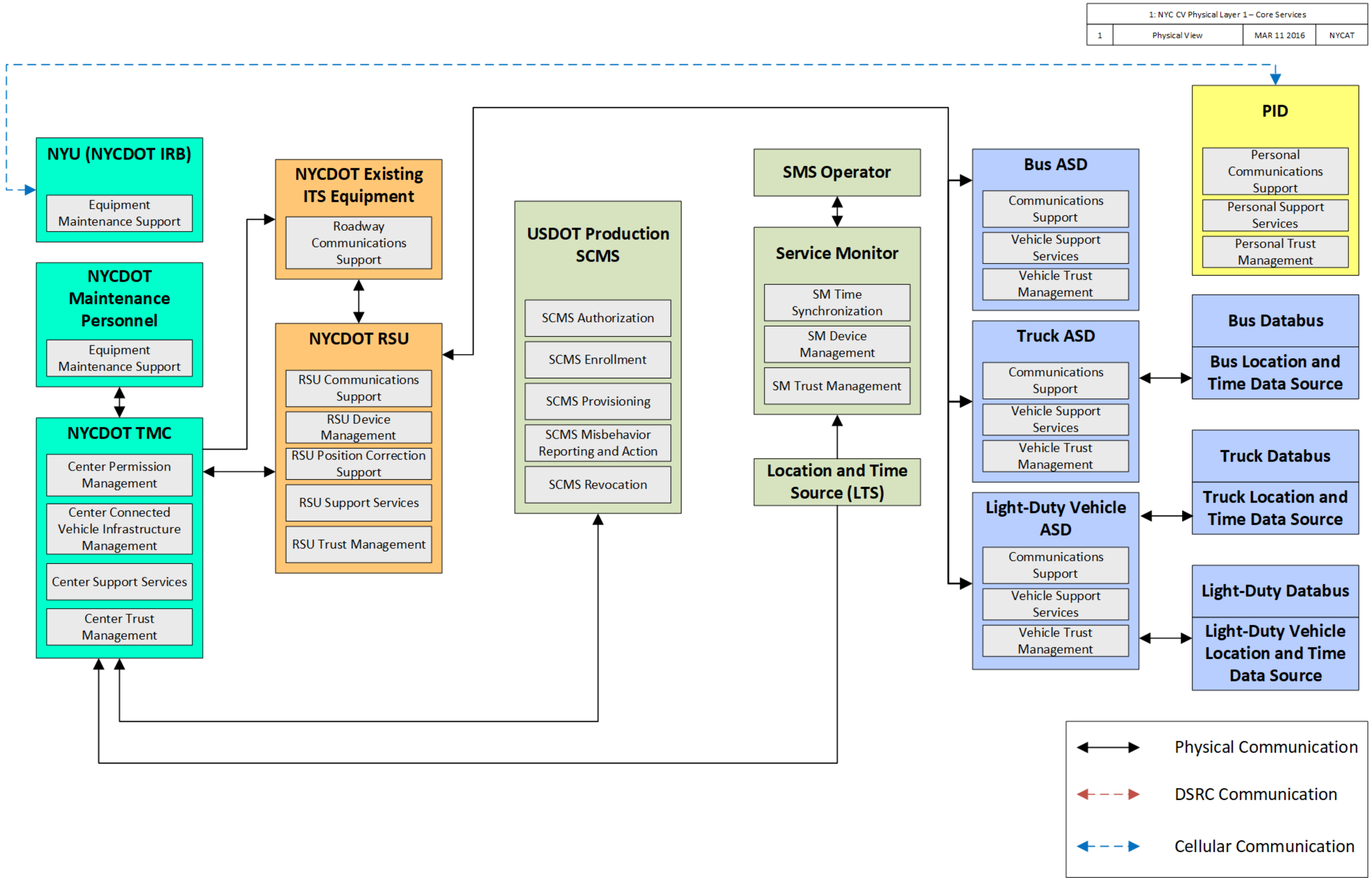
These application objects are the subsets of functionality of a physical element in the system. Only the elements whose functionality is central to the transportation service being deployed will contain an application object.

The lines between the elements on the Layer 1 drawing are called Application Interconnects. Application Interconnects are used to show the connections between the application objects. Like the Physical Interconnects on Layer 0 these correspond to one or more Information Flows that support the application. The application interconnects also have the same characteristics as the physical interconnects.



Source: NYCDOT

Figure 5. NYC CVPD System Physical Description (Layer 1 CV Applications)



Source: NYCDOT

Figure 6. NYC CVPD System Physical Description (Layer 1 Core Services)

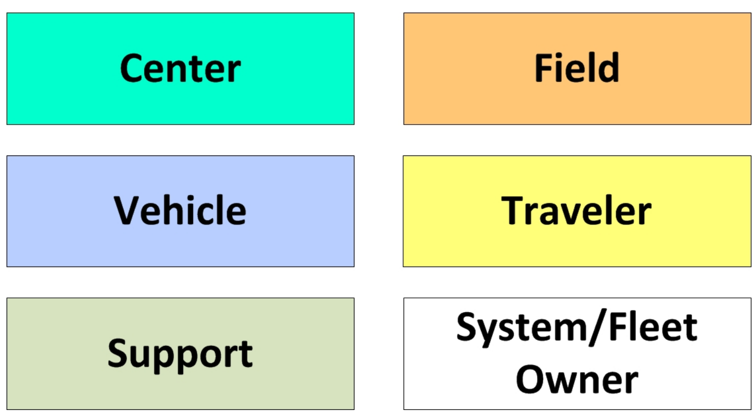
5.3.1.3 Physical - Layer 2

In addition to Layer 0 and Layer 1, the physical view also consists of a Layer 2 which provides a detailed view of each V2V and V2I safety applications as well as the support applications for the NYC CVPD system. They are illustrated alongside the operational scenarios in Chapter 6.

5.3.2 Enterprise View

The enterprise view describes the enterprises (i.e., stakeholders) and the relationships between them. The enterprise view is based on the roles those organizations play within the connected vehicle environment. 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. All project stakeholders are represented by the enterprise view architecture. They are described in detail in Section 3.5 and listed in Table 2.

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 legend for distinguishing the types of stakeholders and external organizations is shown in Figure 3 below.



Source: CVRIA, 2016

Figure 7. NYC CVPD System Enterprise View Diagram Legend

5.3.2.1 Owner/Operator

The first Enterprise View diagram defines the roles that various stakeholders have with the physical devices, back-office facilities, and external systems comprising of the NYC CVPD system infrastructure. NYCDOT owns multiple existing organizations as well as proposed devices in the NYC CVPD system. Those participants and the devices will also be operated by their assigned operators and drivers. Table 9 below lists and defines the roles the stakeholders perform in the enterprise view.

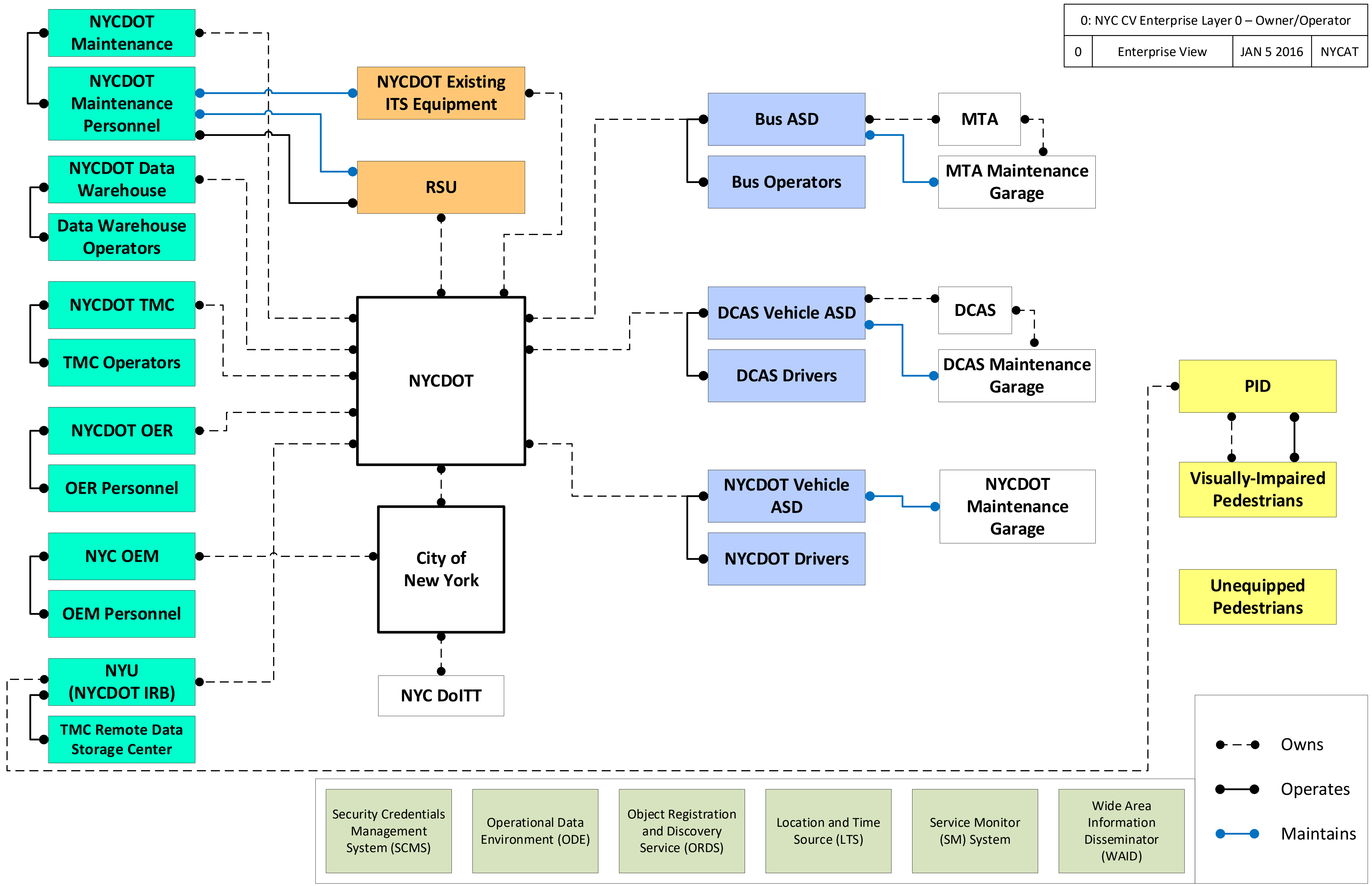
Table 9. Enterprise View Stakeholder Roles

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

Figure 8 illustrates the roles of the participating enterprises in the NYC CVPD system. During the installation and deployment of the pilot, the devices will be owned by NYCDOT. However, upon completion of the pilot the ownership will be turned over from NYCDOT to each fleet owner group.

As the NYCDOT IRB, NYU will own the PIDs during deployment while the visually-impaired pedestrians will take over the ownership role after the deployment phase. The unequipped pedestrians refer to pedestrians that will be sensed by the proposed pedestrian detectors at designated locations (i.e. 23rd Street) in the NYC CVPD pilot area. They will not carry any CV devices or interact with the enterprises in the NYC CVPD system.

The support interfaces are shown at the bottom of Figure 8. The Security Credential Management System (SCMS), Operational Data Environment (ODE), and Object Registration Discovery Service (ORDS) are expected to be developed and provided by the USDOT. The ODE has replaced the Data Distribution System (DDS) as the platform for routing the data from multiple data sources to a common, integrated format for subscribers to software applications such as CV applications. The Location and Time Source (LTS), Service Monitor (SM) System, and Wide Area Information Disseminator (WAID) will be provided by NYCDOT as the owner of the NYC CVPD system.



Source: NYCDOT

Figure 8. NYC CVPD Enterprise View (Layer 0 Roles)

5.3.2.2 Relationships

The second Enterprise View diagram describes the relationships among the stakeholder organizations and their operators or personnel. Multiple relationship types are expected in the NYC CVPD system, and Table 10 -Table 14 below list the pairs of enterprises that assume each relationship type. The overall representation of the various relationships is displayed in Figure 9.

Table 10 below identifies the stakeholder pairs with employment and operations agreements. The City of New York oversees NYCDOT and NYC DoITT, while NYCDOT consists of many key organizations that play distinct roles in the overall Enterprise architecture.

Table 10. Enterprises with Employment and Operations Agreements

Enterprise 1	Enterprise 2
City of New York	NYCDOT
City of New York	NYC DoITT
NYCDOT	NYC OEM
NYCDOT	NYCDOT Data Warehouse
NYCDOT	NYCDOT Maintenance
NYCDOT	NYCDOT OER
NYCDOT	NYCDOT TMC

Table 11 below presents the stakeholders that are expected to exchange enrollment certifications. The USDOT Certification Operating Council (COC) is expected to support the SCMS and develop certification services for the NYC CVPD equipment. The ASD, RSU, and PID vendors selected during procurement will be required to certify the devices in compliance with the USDOT COC and the SCMS.

Table 11. Enterprises with Enrollment Certifications

Enterprise 1	Enterprise 2
ASD, RSU, PID Vendors	Certification Operating Council (COC)
Certification Operating Council (COC)	USDOT SCMS

Table 12 below lists the stakeholder pairs with expectations of data or information exchange. This relationship type will occur whenever data is flown from one source to its destination in the NYC CVPD system. NYCDOT will be expected to interact with NYC DoITT which will monitor the communications data. Also, each fleet owner will be expected to exchange information with their respective drivers or operators.

Table 12. Enterprises with Expectations of Data or Information Exchange

Enterprise 1	Enterprise 2
DCAS	DCAS Drivers
MTA	Bus Operators
NYC DoITT	MTA
NYCDOT	NYC DoITT
NYCDOT	NYCDOT Fleet
NYCDOT	USDOT SCMS
NYCDOT Data Warehouse	TTI (USDOT IE)
NYCDOT Fleet	NYCDOT Drivers
NYCDOT TMC	NYCDOT Data Warehouse
NYU (NYCDOT IRB)	Visually-Impaired Pedestrians
TMC Remote Data Storage Center	NYCDOT Data Warehouse
TTI (USDOT IE)	USDOT SCMS

Table 13 shows the enterprise pairs with MOU and ASD usage agreements. This relationship type will be between NYCDOT and each fleet owner. Because NYCDOT is also a fleet owner, Figure 9 does not include this flow between NYCDOT and NYCDOT Fleet.

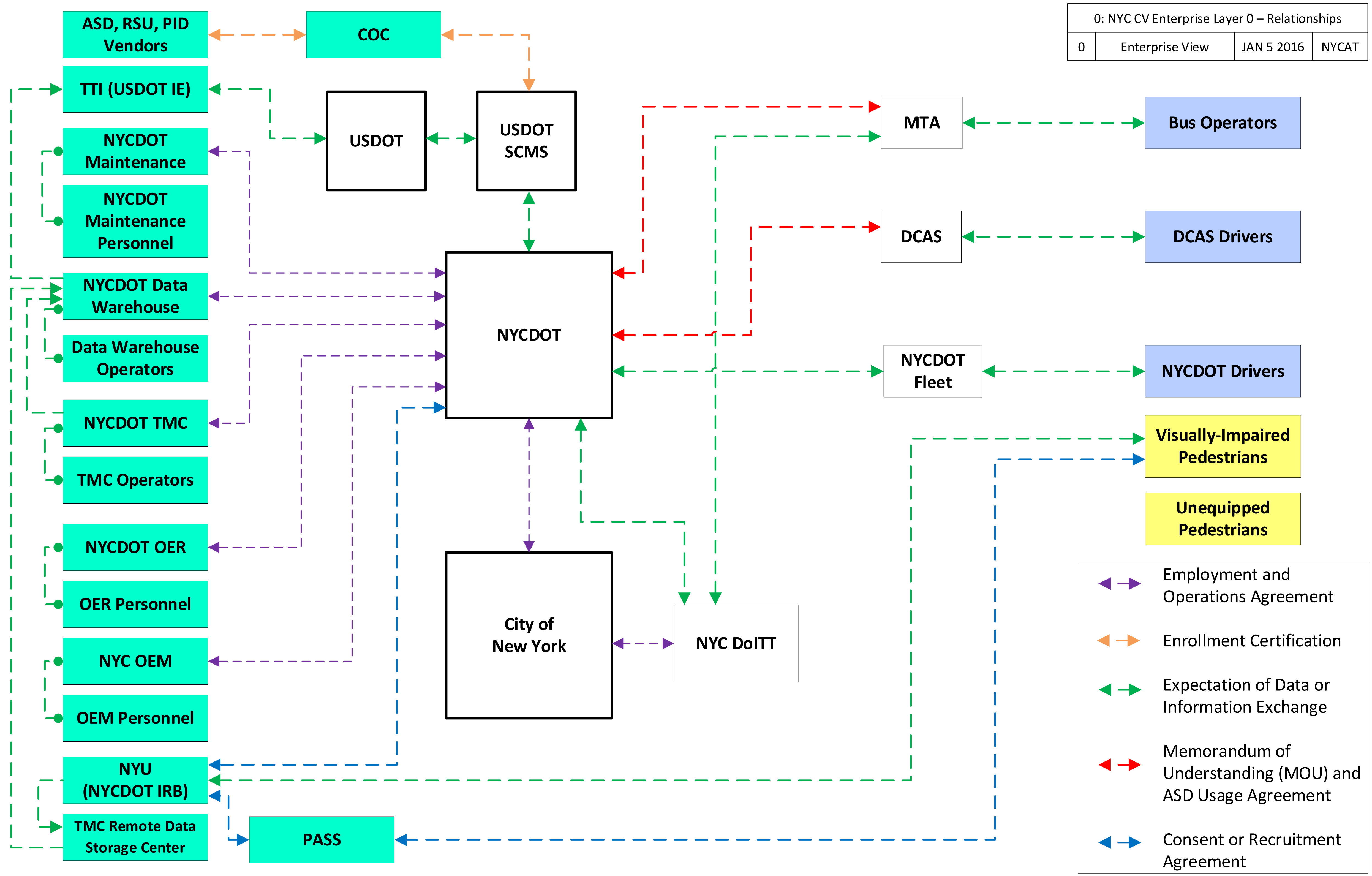
Table 13. Enterprises with MOU and ASD Usage Agreements

Enterprise 1	Enterprise 2
NYCDOT	DCAS
NYCDOT	MTA

Table 14 reveals the enterprise pairs with consent or recruitment agreements. NYU as the NYCDOT IRB 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 it to TTI in order for USDOT to conduct its own evaluation of the NYC CVPD safety benefits.

Table 14. Enterprises with Consent or Recruitment Agreements

Enterprise 1	Enterprise 2
NYU (NYCDOT IRB)	NYCDOT
NYU (NYCDOT IRB)	PASS
PASS	Visually-Impaired Pedestrians

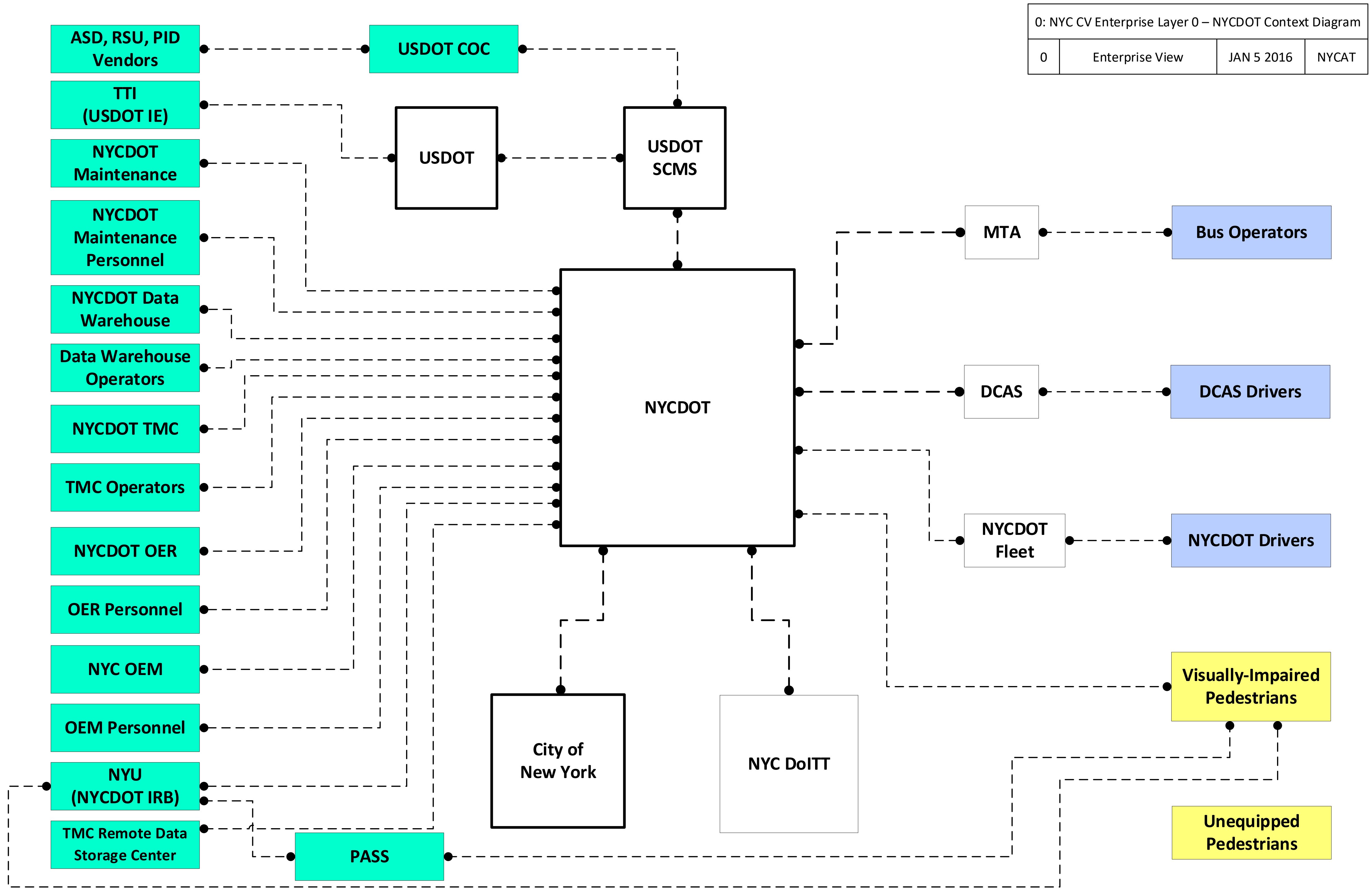


Source: NYCDOT

Figure 9. NYC CVPD System (Layer 0 Relationships)

5.3.2.3 Enterprise Context Diagrams

A context diagram provides the context for a system stakeholder by showing all of the interfaces for that stakeholder. This section includes a context diagram for NYCDOT, the primary stakeholder and the system owner as stated in Section 3.5. The NYCDOT enterprise diagram in Figure 10 focuses on the NYCDOT and its interactions with the other system stakeholders. It also indicates the context of the NYCDOT and its interfaces to the various operators and personnel of the participating fleet organizations.



Source: NYCDOT

Figure 10. NYC CVPD Enterprise View (Layer 0 NYCDOT Context Diagram)

5.3.3 Proposed Roadside Unit Locations

In order to capture vehicle data, the NYCDOT will deploy approximately 353 RSUs at signalized intersections on the avenues and cross-streets in Manhattan and Brooklyn. In addition, RSUs will be installed at other locations including vehicle fleet terminals, river crossings, airports, and others for communicating with ASDs. These additional locations are to support the transfer of performance measurement data, managing security credentials, and other administrative needs. The RSU quantities are summarized in below, and the proposed RSU locations are listed in Tables 23 - 34 in Appendix B.

Table 15. Proposed RSU Quantities

Location	RSU Quantity (Est.)
Manhattan arterials	202
Manhattan cross streets	92
Flatbush Ave	28
FDR	8
Support locations	120
Total	**450**

5.3.4 Existing CV Application References

Six of the CV applications are intended to be utilized unchanged from their initial concept of operations. These applications are listed in the SAE J2794/1 standard for V2V communications and the USDOT's publication FHWA-JPO-13-058. These applications do not need to be re-engineered as components of this project as this work has already been completed. The applications and references for them are listed in Table 16 below.

Table 16. CV Application ConOp References

CV Application	Concept of Operations Reference
Forward Crash Warning	NHTSA DOT HS 811 492A
Emergency Electronic Brake Lights	NHTSA DOT HS 811 492A
Blind Spot Warning	NHTSA DOT HS 811 492A
Lane Change Warning	NHTSA DOT HS 811 492A
Intersection Movement Assist	NHTSA DOT HS 811 492A

CV Application	Concept of Operations Reference
Red Light Violation Warning	Accelerated Vehicle-to-Infrastructure (V2I) Safety Applications Concept of Operations Document Final Report —May 29, 2012 FHWA-JPO-13-058

5.3.5 Speed Compliance

This application provides warnings to drivers when they exceed the posted speed limit and encourages them to reduce their travel speed. Its focus is on encouraging drivers to comply with the regulatory speed limit, as opposed to harmonizing the traffic flow speed. When providing speed harmonization, speed recommendations can be provided to drivers via DSRC communications to connected vehicles and/or roadside signage for non-connected vehicles. Neither of these concepts is included in the scope of the NYC CVPD project.

This application will use a regulatory speed limit provided by the connected vehicle infrastructure in combination with the vehicle's speed and location to provide warnings to the driver. These warnings will occur via the MAP message when the vehicle speed exceeds the speed limit by a configurable amount or for a configurable time period based on whichever occurs first. The warnings (alert) will be provided via an audio tone(s) and/or spoken warning which will be determined during the detailed design.

5.3.6 Curve Speed Compliance

The Curve Speed Compliance will operate similarly as the Speed Compliance application. The difference will be the data source used to obtain the regulatory speed limit to be broadcast to vehicles. This data will be transmitted using the Traveler Information Message (TIM) described in SAE J2735 or revised per the CAMP Curve Speed Warning development currently underway.

5.3.7 Speed Compliance / Work Zone

This application will provide over speed warnings for work or school zones that are either statically or dynamically located. If there is a static work zone or restricted lanes such as bus-only lanes by DOW and TOD, then it is essentially a speed zone and operates as described above in Section 5.3.5. However, certain types of construction activities also may be moving work zones such as pothole repairs, striping, or even snow plowing under certain situations. This application is similar to the Speed Compliance application described above; however, regulatory speed limit information for the designated work zone or restricted lanes will be distributed by the infrastructure's RSU using the TIM message.

The NYCDOT TMC will be able to configure and schedule the MAP messages at RSU locations as needed. Hence, each RSU will be able to store several MAP messages to allow the TMC to schedule them by DOW and TOD. This will be critical at intersections and pilot corridor segments with lanes with limited access by TOD (i.e. bus-only lanes) and temporary work zones.

5.3.8 Pedestrian in Signalized Crosswalk Application

This application will use the pedestrian detection information to indicate the presence of pedestrians in a crosswalk at a signalized intersection. As a pedestrian passes through a crosswalk at a signalized intersection with additional pedestrian detection equipment installed, the pedestrian's presence will be detected by the traffic control system. The traffic control system will notify the vehicle of a pedestrian's presence in the crosswalk. The ASD will receive SPaT and MAP messages that indicate the intersection signal status and alert the driver in advance of the crosswalk location based on the intersection geometry configured and scheduled by the NYCDOT TMC.

At select number of intersections listed in Table 35 in Appendix B, normal pedestrians who are not participating in the NYC CVPD will be able to place pedestrian actuations or calls, which will be transmitted to the intersection signal controller then to the RSU. This pedestrian presence information will be sent to and processed by the RSU, which will then broadcast it to the ASDs in the vehicles. Hence, drivers will be notified of pedestrians crossing the street at intersections equipped with the pedestrian detection technology.

5.3.9 PED-SIG Application

At first, the intent of the project was to use the localized Signal Phase and Timing (SPaT) and Map Data (MAP) messages broadcast over Dedicated Short Range Communication (DSRC) to provide assistance for visually impaired pedestrians while navigating the crosswalks at connected vehicle (CV) instrumented intersections. It was recognized that this was experimental and would be a pilot trial of the use of the technology for this application. When DSRC enabled smartphones were no longer available, per the vendor's suggestion the project scope was modified to use cellular communications (4G, LTE) to the smartphone instead of the DSRC media from the local Roadside Unit (RSU). Since the SPaT information includes "time points", the latencies involved in providing the SPaT information via cellular service for this type of application were expected to have minimal effect on the performance of the application.

The advanced solid-state traffic controllers (ASTC) were modified to transmit SPaT information to the Traffic Management Center (TMC) for processing in preparation for use by the PID applications. This data is transmitted to the TMC from the ASTC "on change", such as when the values in the SPaT message changed. At the TMC, the information is time corrected to use Coordinated Universal Time (UTC) rather than Line Frequency Time and sent to the Amazon Web Services (AWS) cloud along with the MAP message content which is stored at the TMC. Thus, the AWS cloud is provided with the same data as the RSU so that the application can process this information and provide it to the PID to support intersection navigation assistance for a visually-impaired pedestrian.

The MAP message contents were developed using the USDOT "tool", updated with the sidewalk descriptions and augmented with the use of the Cyclomedia high resolution database to improve the accuracy of the location information for the crosswalks and landing zones. It should also be noted that the MAP message used by the PIDs is not size constrained in the same manner as the MAP message transmitted by the RSU such that the TMC sends more detailed information to the AWS cloud than is transmitted by the RSU. The TMC exports the MAP and SPaT information to the AWS cloud where it is used by the PED application as described in their design specification.

In addition, the vendor developed a "Location Augmentation Device" for use by the visually-impaired pedestrian to improve the overall accuracy of the location information when coupled with the smartphone to support the SC application. The location accuracy of a smartphone in the urban environment is inadequate for such applications. The Location Augmentation Device (LAD) is coupled to the smartphone using Bluetooth and the SC application uses both the smartphone location and compass coupled with the location information from the augmentation device to provide the assistance to the visually impaired pedestrian.

When the SC application is active, evaluation data is supposed to be collected and sent to New York University (NYU) servers where it will be used for the performance evaluation for the PID program. If the operation of the prototypes is acceptable, the plan is for NYU to acquire the smartphones, solicit participants, obtain consent from the users, and then distribute the smartphones to those users. The data collected along with survey information is to be evaluated to determine the overall utility, value, and issues associated with the PID and SC application for the user community. The project team worked with the NYU Independent Review Board (IRB) to ensure safety, and privacy of the participants.

5.3.10 Oversize Vehicle Compliance

This application provides warnings to the driver as the vehicle encounters restricted facilities and height restricted infrastructure. For NYC, there is no infrastructure data equipment for detecting and measuring the approaching vehicle's height and width as in the CVRIA concept for this application. Therefore, vehicle size information will be configured into the ASD for each vehicle. Using the pre-configured vehicle height information, the ASD determines whether the vehicle is able to pass through the bridge or tunnel. While the CVRIA refers to vehicles' weight measurement and supporting unequipped vehicles, these concepts are beyond the scope of the NYC CVPD project.

5.3.11 Emergency Communications and Evacuation Information

This application was added to support NYC's emergency communications and dissemination of evacuation traveler information. Centers including NYCDOT Traffic Management Center (TMC) and Office of Emergency Response (OER) will partake in the emergency operations and management functions. However, rail operations center, transit management center, special needs registry, population and housing data sets, public health system, and shelter provider center as defined in the CVRIA are not included in the NYC CVPD.

Note that the distribution of this information will be limited to the RSU locations and will be kept within the vehicles with a time-out and location (area/street) of relevance and only provided to the operator when the vehicle is within the designated area during the time of relevance.

5.3.12 Intelligent Signal System CV Data

This functionality utilizes CV data as an input to the existing Adaptive Control Decision Support System (ACDSS) augmenting or replacing the existing data from the toll tag reader system that provides travel time and speed information. It is the intent of the project to determine if the CV technology provides input which is equivalent to the existing data collection mechanism such that expansion of the ACDSS adaptive control system can rely on only the CV data collected.

5.3.13 Event Recording

The ASDs will log relevant information surrounding a triggered event. The trigger will be configurable and will include the CV application warnings, acceleration criteria, brake system status, etc. The time periods for collecting data before and after the trigger event will be configurable for each event trigger. These periods will consist of a few seconds (e.g., 10-20) prior to and a few seconds (e.g., 30-40) following the trigger's activation. The relevant information (data) will be limited to what the ASD provides, and it may include vehicle data when the ASD is connected to the vehicle's data bus (i.e., CAN, J1939). For instance, each event log entry will include location (i.e., latitude, longitude, elevation, 3-axis acceleration), indicated warnings, and the action (i.e., lights, wipers, turn signals, steering angles, brakes) of the vehicle. More importantly, this event log will be stored on the vehicle for later retrieval when the vehicle returns to its fleet terminal where the data will be offloaded.

Note that the definition of an event will be configurable so it can be used to collect short-term driver behavioral data (hard break, steering turns, accelerations, etc.) for aggregation and performance measures. However, such data will be cleansed of any traceable personal data (exact location and time) to prevent from being correlated to other records such as police reports.

5.4 Modes of Operation

The CV system is expected to always be in operation. Management provisions are made to monitor the operation of the system's devices in order to identify failures and resolve them. These fall into two areas – one for the infrastructure devices and their communications links with the other being the vehicle resident ASDs.

Driver/operators need to be informed when vehicles start that their vehicle resident ASD is operating properly. Failed ASD will not prevent the safe operation of the vehicle by the driver/operator – the driver will not receive alerts/alarms from the device in when it is failed. Support personnel will have to be notified by the driver/operator in order to begin the repair process.

When RSUs fail, vehicle drivers/operators will not be notified and will operate their vehicles normally without alerts/alarms from the ASDs for V2I applications. In this state, the V2V applications will continue to function and provide alerts/alarms when in the presence of other connected vehicles (assuming that their ASDs are also functioning properly).

5.5 User Classes and Other Involved Personnel

The users and support personnel for the CV system will be the same as those listed in Table 2. Users and Stakeholders under the discussion of the existing system.

5.6 Support Environment

This section describes the connected vehicle core services utilized by the NYC CVPD project. It also describes the additional equipment maintenance services necessary to keep the infrastructure and vehicle resident equipment functioning.

5.6.1 Core Services

The support environment for the CV system includes the following elements:

- USDOT Production Security Credentials Management System (SCMS)
- Operational Data Environment (ODE)
- Location and Time Source (LTS)
- Object Registration and Discovery Service (ORDS)
- Service Monitor System (SMS)
- Wide Area Information Disseminator (WAID)

5.6.1.1 USDOT Production Security Credentials Management System (SCMS)

The USDOT Production SCMS is also referred to as Cooperative Credentials Management System (CCMS) by the CVRIA. It represents the interconnected NYC CV system that enable trusted communications between ASDs, PIDs, RSUs, and centers (i.e., TMC) to protect the system and its data from unauthorized access. It will support the secure distribution, use, and revocation of trust credentials in the NYC CVPD.

Use of the SCMS is an important aspect of the NYC CVPD system since it will require certificates to authenticate the messages including Basic Safety Message (BSM), Signal Phase and Timing (SPaT), Map Data Message (MAP), and Traveler Information Message (TIM) from the RSU and a special permission to use the PED call feature. Thus, there will be security and subscription issues with the use of the application including enrollment certificates and pseudonym certificates for each application and the licensed user, as well as the normal privacy concerns to protect the PII which might be collected. This will also be an opportunity to work with the disabled community and the traffic signal operation in NYC to support safety improvements for each user and stakeholder.

Currently, the production SCMS is currently being developed by USDOT to protect the CV system and its data from unauthorized access. It will mandate security policy and support the secure distribution, use, and revocation of trust credentials while receiving device enrollment information from the NYC CVPD system. In addition to security and trust management, the NYCDOT TMC will need security credentials for scheduling and configuring the specific MAP messages in the RSUs by day of the week (DOW) and time of day (TOD). Each MAP message stored in the RSU transmitted by the NYCDOT TMC will be validated or authenticated. The vendors selected during procurement will be setting their own device enrollment certificates for communicating with the SCMS and receiving the necessary security credentials.

5.6.1.2 Operational Data Environment (ODE)

The USDOT ODE will be responsible for collecting, processing, and distributing near real-time CV data such as BSM, MAP, SPaT, and TIM messages. It will link the data produced by the roadway users with the USDOT situation data clearinghouse and warehouse facilities. In the NYC CVPD system, the NYCDOT TMC will post-process and obfuscate the time, date, and location data in the BSMs received by the vehicles and SPaT, MAP, and TIM messages broadcasted by the RSUs. It will utilize its own algorithm to aggregate, sanitize, and strip the data of any PII. At this time, the USDOT ODE is not expected to play a role and interact directly with the NYC CVPD.

5.6.1.3 Location and Time Source (LTS)

Location and Time Service (LTS) will be critical as the ASD-equipped vehicles travel through the dense environments in Manhattan and Brooklyn. As shown in the LTS physical architecture in Figure 15, 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.

5.6.1.4 Object Registration and Discovery Service (ORDS)

ORDS provides registration and look-up services for allowing objects to locate other objects in the CV environment for communication purposes. It will be used to provide registration and discovery services for enabling the secure data transfer applications in the NYC CVPD.

5.6.1.5 Service Monitor System (SMS)

SMS monitors, manages, and controls services for applications and equipment that are operating in the CV system environment. In the NYC CVPD, it will enable CV applications to provide services including device management, time synchronization, and trust management.

5.6.1.6 Wide Area Information Disseminator (WAID)

WAID represents the communications equipment in the CV system environment used to send messages to CV-equipped vehicles. The messages will be transmitted using DSRC at 5.9 GHz frequency and may be broadcasted to and from ASDs and RSUs.

5.6.2 CV Equipment Maintenance

5.6.2.1 Installation

NYCDOT will be responsible for procurement and installation of the CV equipment. The RSUs will be installed by City personnel at the designated locations shown in Table 16 - Table 21 in the Appendix. Installation manuals will be available for guidance. The ASDs will be provided to each fleet owner group who will install them in each participating vehicle. Installation details and requirements will be unique to each fleet type, and instructions for installation will also be supplied to each fleet owner group.

5.6.2.2 Maintenance

NYCDOT will be responsible for maintenance of the CV equipment software and hardware. The RSUs' operation will be monitored for issues that require site visits and field repairs. Once the issues are diagnosed, technicians will be dispatched to the RSU locations, address the issues, and report back to NYCDOT staff at the TMC.

If the ASD experiences a fault, the vehicle operator will be responsible for reporting to the fleet owner who will then notify NYCDOT. Scenarios describing user actions during normal ASD start-up and when ASD the fails are in Sections 6.2.1 and 6.2.2. Necessary repair work will be coordinated through the fleet owner's maintenance facilities where units will be available to swap out devices and minimize down time.

For software and firmware updates, the NYCDOT will work with the TMC to install them via the RSU at each fleet barn. Once the vehicle returns to its garage, the RSU will communicate with the ASD to check its firmware version. When an upgrade is needed, the ASD will initiate the over-the-air firmware update as described in Section 6.3.2.

Agreements between NYCDOT and each participating fleet owner will be needed in the NYC CVPD. Specific terms and conditions will need to be specified for the technicians and the fleet owners to protect each party and ensure safe maintenance and repair efforts.

6. Operational Scenarios

This section provides an overview of the major operational uses for the NYC CVPD project. These scenarios are arranged based on the users involved with the project.

Each scenario begins with a brief description followed by one or more diagrams that define different sequences of actions that occur in the scenario. Following each diagram, each sequence is described in terms of the overall flow of the application – what happens first, what information is shared, what activities are required in order for the application to succeed, and what other factors need to be considered.

Note that these scenarios do not document all of the individual CV applications for the reasons described in Section 4.5. Other material is available using the references listed in the section as well as at the CVRIA web site[6]. The operational scenarios documented in this ConOps address the project tailored connected vehicle applications and the additional system management and performance evaluation concepts for the NYC CVPD project.

Traffic Manager Scenarios

- Speed Compliance
- Speed Compliance / Work Zone
- Curve Speed Compliance
- Oversize Vehicle Compliance
- Emergency Communications and Evacuation Notification

Roadway User Scenarios

- Vehicle Trip Initiation
- Driver Reporting Suspected ASD Failure
- Pedestrian in Signalized Intersection Warning
- Mobile Accessible Pedestrian Signal System

System Manager Scenarios

- ASD CV Application Configuration Download
- ASD Firmware Update
- RSU RF Monitoring
- ASD RF Monitoring

Independent Evaluator Scenarios

- ASD Event Data Recording
- ASD Event Data Upload
- ASD Performance Measurement Data Processing

There are a number of applications that operate in a similar manner to each other related to speed compliance for New York City. The City felt that rather than attempt to provide a variety of different speeds based on vehicle types, roadway segment, traffic conditions, and weather (roadway surface and visibility), that all similar applications would provide warnings to the driver when their vehicle speed exceeded the regulatory speed limit for the roadway segment.

- Speed Compliance (General)
- Curve Speed Compliance (Specific Locations)
- Speed Compliance / Work Zone (or School Zone)

Therefore, these applications will provide warnings/alerts to the driver when the vehicle speed exceeds the regulatory speed limit. It is also expected that the operation of the application can be modified based on time-of-day, day-of-week, roadway segment, and other rules to minimize the false warnings or to become an annoyance to the driver such that they may seek to damage the equipment.

Each of these applications will be addressed separately in what follows, although the first application, NYC-CVDP Speed Compliance describes most of the applications. The differences between the applications are related to the different sources of the regulatory speed information provided by the infrastructure systems.

6.1 Traffic Manager Scenarios

6.1.1 Speed Compliance

The NYC Vision Zero is focused on the reduction of crashes and pedestrian injuries within the city limits. One method recently adopted by NYCDOT was a reduction in the citywide speed limit from 30 mph to 25 mph based on the assumption that slower speeds would provide drivers with more time to react to traffic conditions and to avoid pedestrians. Signals were retimed for the slower speed, and the City proposed to use CV technology to alert drivers when they are exceeding the speed limit. This becomes particularly important during late night when there is minimal traffic and speeds tend to far exceed the speed limit.

This application will use a *regulatory speed limit* in combination with the measured speed and location of the vehicle to provide warnings to the driver when they are exceeding the speed limit by a configurable amount or time. The warnings (alert) will be provided via an audio tone(s) and/or spoken warning which will be determined during the detailed design. It should be noted that the stakeholders did not want a visual warning; hence, the ASD will provide audio warnings.

After some discussion with the stakeholders, it was suggested that the application should be modified such that it adapts to the habits of the driver and can be tuned to minimize the annoyance effect while still producing the desired result, speed limit compliance through notification of over speed conditions.

Finally, the CVPD program requires the performance of the applications be measured. To accomplish this requirement, the application will be required to provide a ***trigger*** to the data collection application to capture the dynamic vehicle information immediately preceding and following the issuance of an alert for analysis. The data collection system is described in more detail later in the ConOps in Section 8.4.3.

Since multiple safety applications will be running on the ASD at the same time, 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 arbitration algorithm will be configurable such that additional applications can be added to the ASD.

This application is intended to work with generally static roadway conditions or zones that are triggered due to the time-of-day and day-of-week. The source of the regulatory speed limit will be messages from the local RSU associated with the roadway map, curve location, or zones (work as well as school). These speeds will be delivered to the vehicle through DSRC MAP, messages.

6.1.1.1 Application Needs

The following section describes the needs that were developed for the *speed compliance* application.

a) The need (Vision zero and NYCDOT) is to improve general speed compliance for all vehicles within the City limits with the intent to reduce crashes and pedestrian injuries.
b) The MAP message can provide this level of detail when the vehicle is in the vicinity of an RSU. The regulatory speed limit for each roadway segment may also change by time-of-day and day-of-week should the segment include a school zones.
c) The in-vehicle application needs to monitor the vehicle’s speed and alert the driver when the vehicle speed exceeds the regulatory speed limit for the roadway segment by a configurable amount or time.
d) The alert level (amount above the speed limit or time above the speed limit) needs to be configurable by time-of-day and day-of-week to manage the alert frequency. The alert will be provided to the driver as an audible message (tones and/or words).
e) The privacy of the data for the actions recorded for evaluation needs to be protected.

6.1.1.2 Scenario

a) The application is installed on the ASD and commissioned (i.e., it has an enrollment certificate and requests operating certificates from NYCDOT TMC such that it can receive and validate the data received and encrypt the data that is recorded on the ASD).
b) When the ASD passes an RSU that advertises the regulatory speed limit and/or any available updates for the speed map, the ASD receives the speed limit information and verifies whether it has the necessary changes and update its database accordingly.
c) The ASD monitors the vehicle location and issues a warning to the driver whenever the vehicle speed exceeds the speed limit for the roadway based on the time-of-day and day-of-week by a configured over speed parameter.

d) All warnings trigger an event to be recorded in the ASD performance monitoring application which in turn creates an event log for this alert which is encrypted such that it can only be decrypted by the event log processing center. (Refer to the project's Security Management Operating Concept (SMOC) and Performance Measurement and Evaluation Support Plan listed in the references.)
e) Whenever the ASD passes an RSU which advertises that it can upload the event logs, the stored encrypted event logs are uploaded and purged from the device when the upload is confirmed.
f) The ASD includes an application that can modify the parameters used for the speed compliance application.
g) *Optional* (TBD – future implementation): verbal directions could include lane or roadway restrictions based on the time-of-day and day-of-week that could be used in conjunction with speed restrictions or without speed restrictions.

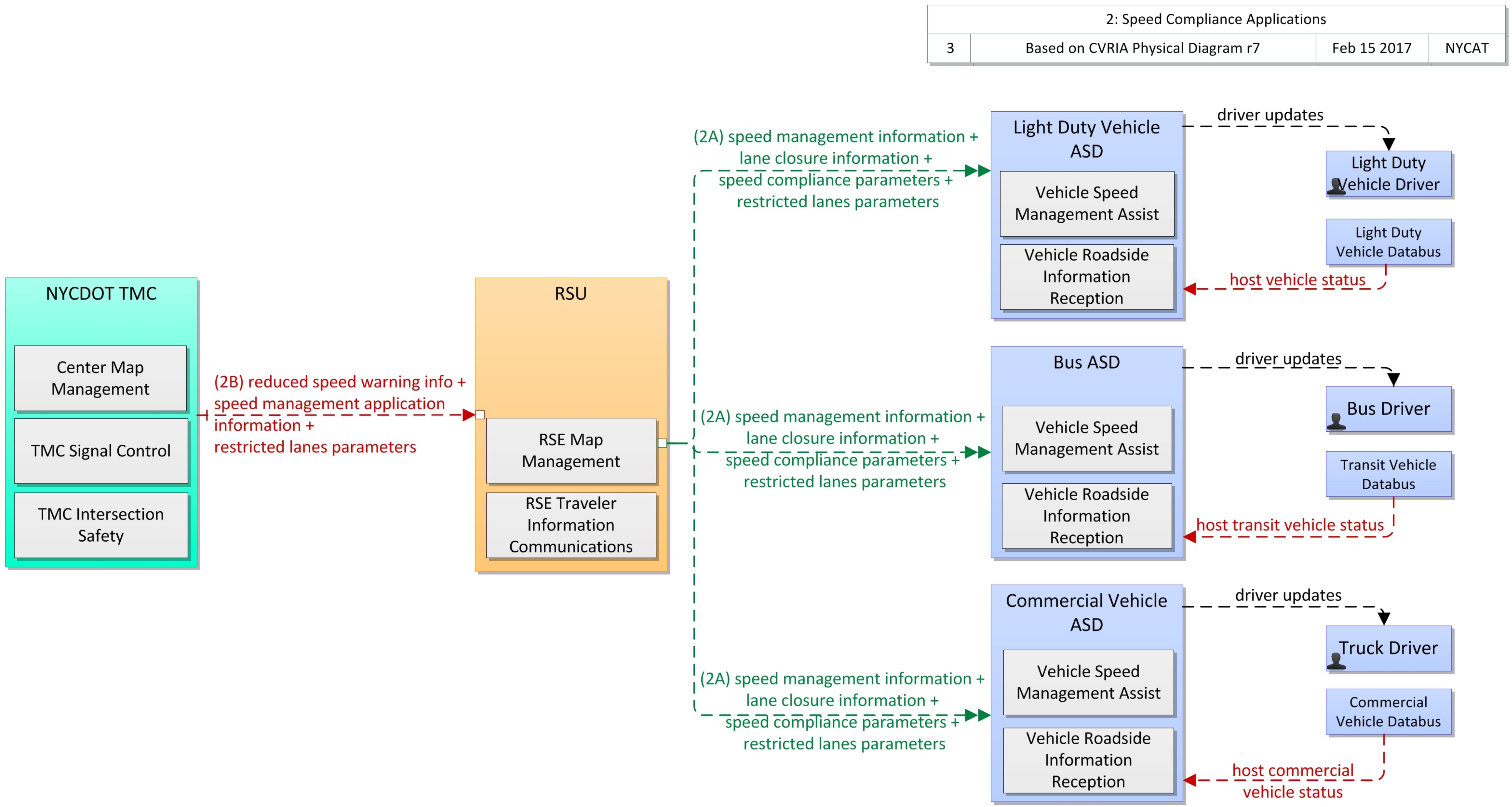
6.1.1.3 Notes

Note that whenever the regulatory speed limit is provided by a local RSU (see other applications) using the MAP message or the TIM,

- All messages to and from the ASD and the RSU for these applications will be authenticated. The data collected (log data) is automatically encrypted when added to the log and is, therefore, not readable by any authority except the performance analysis subsystem.
- The physical architecture for this application is shown in Figure 11. Note that only some of the data flows and processes are relevant for the speed compliance application. The RSU and ASD will include additional safety and data collection applications for which additional processing and data flows will be required.

Note that the intelligent transportation system (ITS) devices control the signage for the cases described in the following sections while the speed limit map database is used for the basic speed compliance application. This same application could be expanded to include additional verbal information such as lane restrictions that vary by time-of-day and day-of-week.

It is not clear which school or speed zones will be included in the initial CVDP since there is a cost associated with this aspect of the project. The initial intent is to include all of Manhattan in the subject area because there are also RSU choke points where the database can be uploaded.



Source: NYCDOT

Figure 11. Speed Compliance Applications

6.1.2 Speed Compliance / Work Zones

This application will provide over speed warnings for work or school zones that are either statically or dynamically located. If there is a static work zone, then it is essentially a speed zone and operates as described above. However, certain types of construction activities also may be moving work zones such as pothole repairs, striping, or even snow plowing under certain situations. This application is similar to the Speed Compliance application described above; however, regulatory speed limit information will be distributed by the infrastructure's RSU using the TIM DSRC message. The TIM messages for this application are from an WAVE Service Advertisement (WSA).

In the case of a moving work zone, an RSU would be installed on the barrier truck (or other vehicle which marks one end of the work zone) and it would provide the speed zone warning and identify the geographic limit of the work zone. Depending on the size of the work zone, a second RSU may need to be installed on another vehicle (e.g., lead vehicle) to mark the other end of the work zone. This would require that the RSU have a license for DSRC that is approved to travel within the geographic area of the City.

Some of the [static] speed zones vary by time-of-day and day-of-week (e.g., school zones); hence, this information must include a schedule and the geographic boundaries of the speed zone. Note that the regulatory speed is not universal for all roadways; expressways within the City have higher speed limits and hence, the speed limit will depend on the vehicle location.

This is a simplified version of the CVRIA work zone application because it only provides information to the approaching vehicles and does not attempt to track the approaching vehicles or warn the construction workers of errant vehicles which might pose a threat to the workers.

6.1.2.1 Additional Application Needs

The needs for this application can be either added to the speed compliance application or duplicated in case only this application is deployed. Since the NYC CVPD intends to implement all of the speed compliance applications listed, the needs of the preceding speed compliance application will be added to the following needs:

a) The in-vehicle application needs to listen for RSU messages that identify the presence of a speed zone such that it can identify the speed limit and geographic limit of the speed zone.
b) An RSU needs to be located at the entry points to the speed zone (depending on the area covered) such that it can notify approaching vehicles when the speed zone is active and the geographic limit of the speed zone.
c) The over-riding effect of the speed limit for the speed zone needs to include time-out or end times such that the vehicles do not use this replacement speed limit when it is not active.
d) The zone's speed limit change needs to be handled in a robust manner such that the failure of an RSU or the backhaul or core systems do not lead to prolonged incorrect invocation of the speed limitation and warnings to drivers.
e) For moving work zones, the RSU needs to monitor its position with respect to the proposed work zone (end-to-end) and provide updated (real time) geometric areas encompassed by the active work zone.
f) *Optional* (TBD – future implementation): verbal directions could include lane or roadway restrictions (detour) based on the time-of-day and day-of-week that could be used in conjunction with speed restrictions or without speed restrictions.

6.1.2.2 Notes

Figure 11 is identical for this aspect of the speed zone operation. However, the infrastructure operator is required to specify the geometric area and the reduced speed as well as the time-out time. Local RSUs are expected to communicate the changed speed limit to the ASD.

As noted in the speed compliance zone, this could also be augmented with verbal directions associated with the RSU broadcast changes such as lane restrictions, turn restrictions, no stopping restrictions, etc. for special events etc.

6.1.3 Curve Speed Compliance

The Curve Speed Compliance will operate similarly as the Speed Compliance application. The difference will be the data source used to obtain the regulatory speed limit to be broadcast to vehicles. This data will be transmitted using the TIM message described in SAE J2735 or revised per the CAMP Curve Speed Warning development currently underway. The message format selection will be the subject of an ongoing evaluation based on the progress of the CAMP work and the project schedule. The TIM messages for this application from an WAVE Service Advertisement (WSA).

6.1.4 Oversize Vehicle Compliance

This application will be used for trucks and other commercial vehicles traveling on FDR Drive in Manhattan. Currently, warning signs exist to let the drivers know about the 9'6" height restriction. However, over-height truck crashes still occur from drivers entering the roadway without being aware of the truck height. Nonlocal drivers unfamiliar with NYC streets are at greater risk of a crash. The focus of this application is on preventing such over-height crashes and supporting the safety goals of Vision Zero.

Oversize Vehicle Compliance (OVC) application in the ASD will use the individual commercial vehicle's height information to compare with FDR Drive's height restriction from the RSUs. Based on discussions with the stakeholders, commercial vehicle width will not be considered, and the warnings (alert) will be provided via an audio tone(s) and/or spoken warning. The details will be determined during the design phase.

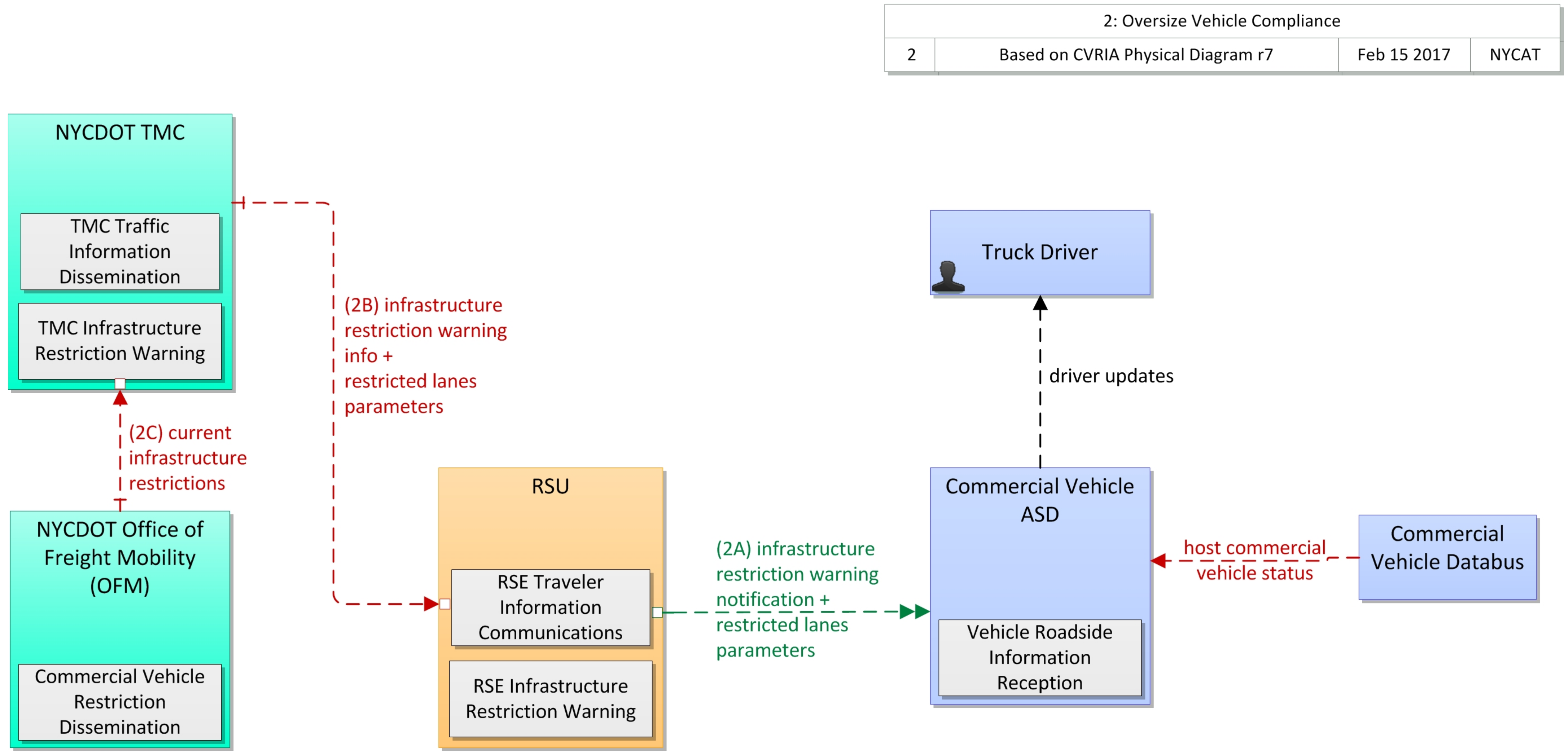
6.1.4.1 Scenario

a) The application is installed on the ASD and commissioned.
b) The driver operates a commercial vehicle on FDR Drive.
c) The ASD receives the height restriction information broadcasted from the nearby RSU at a bridge underpass or tunnel entrance.
d) The ASD compares the height restriction information with the commercial vehicle's pre-configured height.
e) If the ASD determines that the vehicle height exceeds the maximum, it alerts the driver of the impending low height obstacle at a pre-configured decision point before the bridge or tunnel on FDR Drive. If the ASD determines that the vehicle height is less than the maximum, then no alert is generated.
f) The driver makes a decision to find an alternate route, pull off the roadway, or ignore the alert. If the driver ignores the alert and continues along the route, the ASD will alert the driver of an impending collision at a pre-configured point upstream of the bridge or tunnel entrance.

g) All warnings trigger an event to be reported in the ASD performance monitoring application which in turn creates an event log for this alert which is encrypted such that it can only be decrypted by the event log processing center. (Reference the performance measurement data processing regarding security and performance log processing.)
h) Whenever the ASD passes an RSU which advertises that it can upload the event logs, the stored encrypted event logs are uploaded and purged from the device when the upload is confirmed.
i) The ASD includes an application that can modify the parameters used for the OVC application.

6.1.4.2 Notes

Note that the above application will be supported by the vehicle's pre-configured height stored in the ASD and FDR Drive's actual height restriction broadcasted from local RSUs. All messages to and from the ASD and RSU for this application will be authenticated. The physical architecture of the OVC application is shown in Figure 14 below.



Source: NYCDOT

Figure 12. Oversize Vehicle Compliance

6.1.5 Emergency Communications and Evacuation Information

This application will use the emergency and evacuation information from NYCDOT Office of Emergency Response (OER) and transmit them to the vehicles. The information may include location-specific directions for evacuation, location restrictions for entry, global emergency information, and route-specific information.

Currently, the OEM provides emergency-related information through an incident-based distribution program. The TMC receives the emergency-related and incident-based information feed from OER which coordinates emergency response management activities. It also distributes this information through its traveler information system and display them on NYC's dynamic message signs.

When incidents occur, emergency response information such as evacuation orders, routing information, and areas to avoid can be transmitted to the vehicles through the RSUs by evacuation zones. For the EVAC application, the OER will send the information on its response plans and actions to the TMC which will transmit the information feed to the RSUs located within and/or near the emergency zones via the TIM message. Then, the RSU will communicate the TIM message to the ASD-equipped vehicles traveling through, within, or near the emergency zones.

The messages will be reviewed at the TMC before being sent to the RSUs and broadcasted to the ASDs. In the event that the vehicle is within the area of influence, the messages may be alerted to the drivers in the form of spoken warning. The TIM messages for this application are from an WAVE Service Advertisement (WSA).

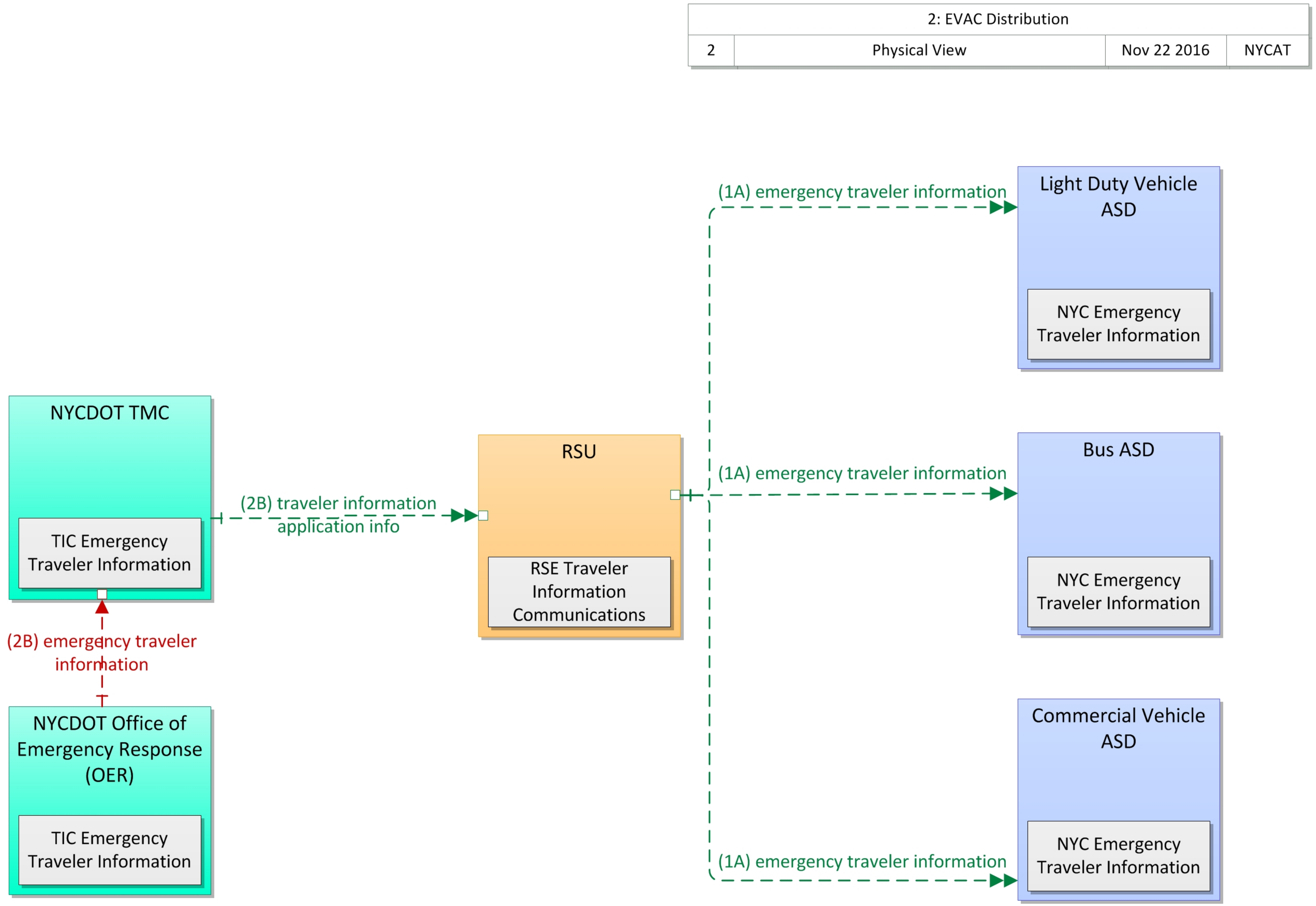
6.1.5.1 Scenario

a) The application is installed on the ASD and commissioned.
b) The driver operates a vehicle in New York City.
c) An incident occurs in New York City, and emergency response plan is activated by NYCDOT OER.
d) The OER coordinates emergency response management activities and distributes the information to its traveler information system. This is also communicated back to the TMC.
e) The TMC transmits the specific emergency-related information to the RSUs in the areas of interest.
f) The RSUs receive the emergency-related information and broadcast the TIM messages to the ASDs in the vehicles in the areas of interest.
g) The ASD alerts the driver on the emergency-related information via audio message.
h) The driver makes a decision to either avoid the affected geographical area and find an alternate route or ignore the alert and continue.
i) The ASD collects the BSMs before and after the alert and records the event.
j) Whenever the ASD passes an RSU which advertises that it can upload the event logs, the stored encrypted event logs are uploaded and purged from the device when the upload is confirmed.
k) The ASD includes an application that can modify the parameters used for the EVAC application.

6.1.5.2 Notes

Note that the above application will be supported by BSMs from the ASDs and TIM messages from the RSUs. All messages to and from the ASD and RSU for this application will be authenticated. The physical architecture of the EVAC application is shown in Figure 13 below.

The message will be received at the ASD when it approaches any RSU. The message will have a geographic area of interest and if the vehicle is in or enters that area, the alert will be played to the driver and that constitutes the event. If the vehicle is not in the area of interest – it will be held in the ASD until the message times-out unless the vehicle enters the area before that time in which case the alert will be presented to the driver. Note that the logging information may be adjusted for this application to track the driver response for a longer distance – but with a lower frequency of log entries. In that manner, the performance subsystem can determine what the driver did as a result of the notification.



Source: NYCDOT

Figure 13. Emergency Communications and Evacuation (EVAC) Distribution

6.2 Roadway User Scenarios

6.2.1 Vehicle Trip Initiation

In this scenario, the vehicle operator will begin normal duties by starting the ASD-equipped vehicle. The ASD will send a notification response to the driver, confirming that it is turned on and that CV applications are ready for operation. If the confirmation is received, then the vehicle operators will resume normal operation.

6.2.1.1 Scenario

The following are sequences for the ASD in normal operation and at fault during vehicle trip initiation.

6.2.1.1.1 ASD Good

a) Vehicle operator begins normal duties by turning on the ASD-equipped vehicle.
b) The ASD notifies the driver to confirm that it is turned on and that the connected vehicle applications are ready for operation.
c) ASD logs the start-up event.
d) Vehicle operator resumes his or her normal operation.

6.2.1.1.2 ASD Failure

a) Vehicle operator begins normal duties by turning on the ASD-equipped vehicle.
b) The ASD detects a fault and notifies the driver that it is not ready for operation.
c) ASD logs the start-up event and the fault.
d) The fleet owner notifies NYCDOT.
e) The operator resumes normal duties with the vehicle.
f) Vehicle operator notifies the fleet owner.

6.2.1.2 Notes

Note that the above scenario will be supported by the vehicle's log of the ASD start-up event. All messages generated from the ASD's start-up event will be authenticated. The same physical architecture as the Driver Reporting Suspected ASD Failure scenario will be used.

6.2.2 Driver Reporting Suspected ASD Failure

In this scenario, the vehicle operator will find that the ASD is no longer sending the audio alerts during normal operation. The operator will notify the fleet owner; then the fleet owner notifies NYCDOT maintenance personnel.

6.2.2.1 Scenario

a) Driver is operating the vehicle on normal duty.
b) Driver finds that the ASD is no longer sending the alerts.
c) Driver notifies the fleet owner.
d) Fleet owner notifies the NYCDOT CV equipment maintenance personnel.

6.2.2.2 Notes

Note that the above scenario will be supported by the driver of the vehicle finding the issue and notifying the fleet owner to arrange ASD repair efforts. Unlike other scenarios and applications, no messages will be generated.

6.2.3 Pedestrian in Signalized Intersection Warning

The NYC CVPD will deploy two pedestrian oriented applications: 1) a generalized warning to vehicles of pedestrians in the roadway and 2) support for visually impaired (blind) pedestrians. This section describes the application for warning the vehicles when pedestrians are crossing the road at signalized intersections.

This application will use the pedestrian detection information to indicate the presence of pedestrians in a crosswalk at a signalized intersection. At select number of intersections listed in Table 35 in Appendix B, normal pedestrians who are not participating in the NYC CVPD will be able to place pedestrian actuations or calls, which will be transmitted to the intersection signal controller then to the RSU. This pedestrian presence information will be sent to and processed by the RSU, which will then broadcast it to the ASDs in the vehicles. Hence, drivers will be notified of pedestrians crossing the street at intersections equipped with the pedestrian detection technology.

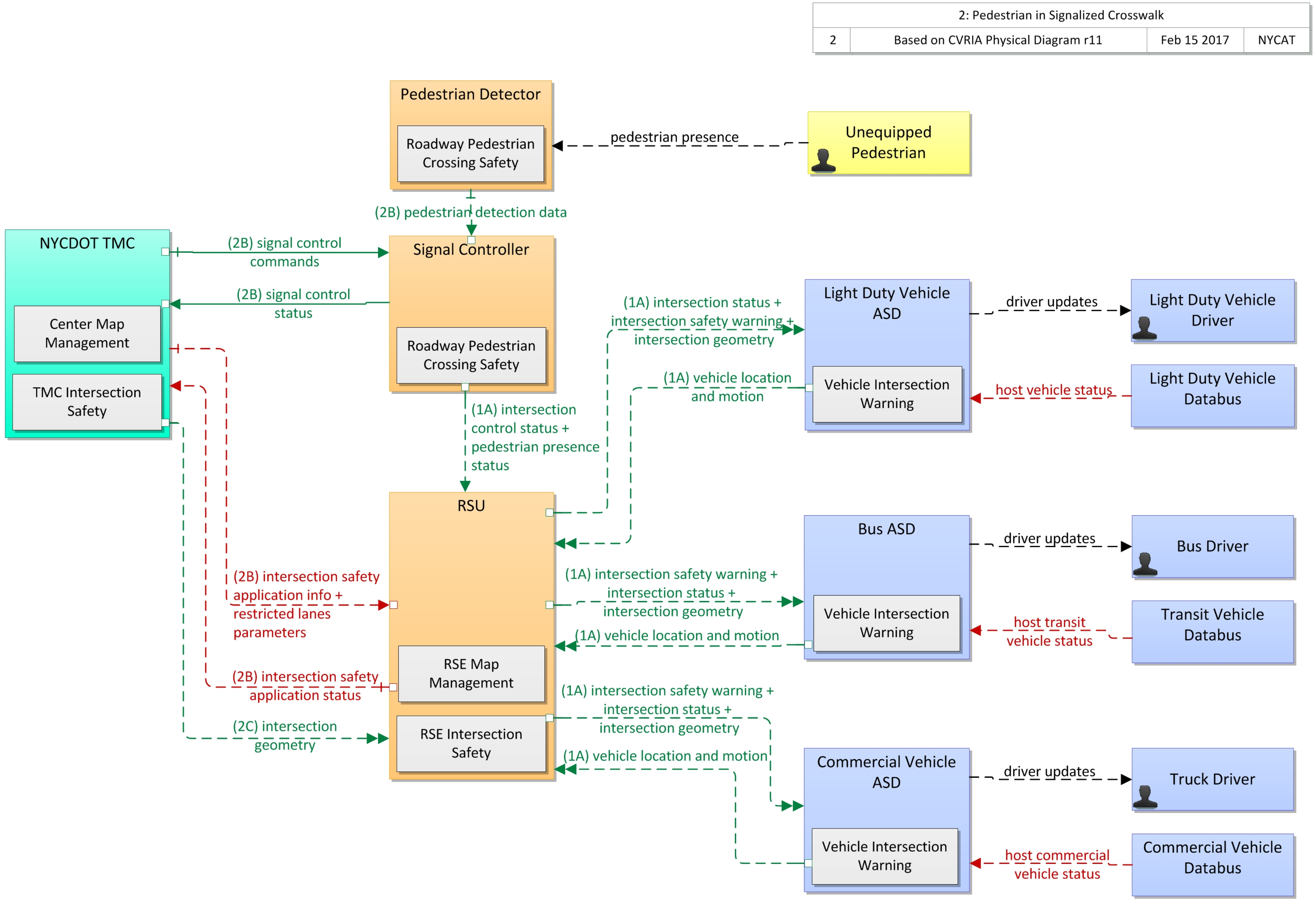
6.2.3.1 Scenario

a) The pedestrian approaches the crosswalk at a signalized intersection and is detected by the traffic control system.
b) The pedestrian's PID sends its BSM to the RSU and receives SPaT and MAP messages from the RSU.
c) The RSU receives the pedestrian detection information.
d) The pedestrian phase begins at the signal, and the pedestrian crosses the street.
e) The driver approaches a signalized intersection.
f) The ASD in the vehicle sends its BSM to the RSU and receives SPaT and MAP messages from the RSU.

g) The RSU receives the information from the ASD and alerts the driver that pedestrian is crossing.
h) The driver waits until the pedestrian phase is served and the signal for the vehicle's approach turns from red to green.

6.2.3.2 Notes

Note that the above application will be supported by the BSMs from the ASDs and SPaTs and MAPs from the RSUs. Communication will occur between the RSU and the PID and the RSU and the ASD but not between the PID and the ASD. The details will be determined during the design phase. Physical architecture of the PEDINXWALK application is shown in Figure 14.



Source: NYCDOT

Figure 14. Pedestrian in Signalized Crosswalk

6.2.4 Mobile Accessible Pedestrian Signal System

The NYC CVPD will deploy two pedestrian oriented applications: 1) a generalized warning to vehicles of pedestrians in the roadway and 2) support for visually impaired (blind) pedestrians. This section describes the street crossing safety application for visually-impaired pedestrian.

For the support for the blind, it is assumed that the application will be implemented using a PID (e.g., mobile device) which supports both normal cellular operation and communications in the DSRC spectrum such that the pedestrian can monitor the messages associated with the CV applications and provide input to the traffic controller to request service where PED operation is actuated. Communications to/from the traffic controller will use DSRC (5.9 GHz. 1609.x, J2735) message sets and will be available at any intersection which includes an RSU.

The PED 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.

Use of the SCMS is an important aspect of this application since it will require certificates to authenticate the SPaT and MAP messages from the RSU, and a special permission to use the PED call feature. Thus, there will be security and subscription issues with the use of the application including enrollment certificates for the application and the licensed user, as well as the normal privacy concerns to protect the PII which might be collected. It is expected that the operating certificates will be renewed on a weekly basis by the NYCDOT TMC to avoid the Certificate Revocation List (CRL) issues. This will also be an opportunity to work with the disabled community and the traffic signal operation to support safety improvements for this type of user.

6.2.4.1 Use Case Description

The following section describes the use case for the visually impaired pedestrian.

Actors

- Blind or Low Vision Pedestrian
- Traffic Controller
- Mobile Application
- Connected Vehicle

Pre-Conditions

- The user is located near an instrumented crosswalk in the NYC geographic area.

- Actor's mobile device uses geographic data from Google maps and 4G/LTE communications.
- Mobile device is able to orient the pedestrian with respect to the street crossing of interest.
- Communication baseline confirmed including security certificates for authentication and privileges to make crossing requests.
- SPAT message baseline set using 5.9 DSRC.

Summary
This use case describes the process of a blind pedestrian crossing the street or intersection using a mobile app and information from the traffic signal.

Assumptions

- The pedestrian is not deaf or hard of hearing.
- The pedestrian needs audible information regarding the signal display.
- The pedestrian needs help in orienting themselves to the crosswalk.
- The mobile application will notify the pedestrian when to start the crossing.

6.2.4.2 Scenario

a) The pedestrian arrives at a specific crosswalk within NYC.
b) The pedestrian looks for help crossing the street.
c) The pedestrian mobile app communicates with the RSU and receives the SPaT message, which is based on the signal and phasing information from the traffic controller.
d) The mobile app provides specific location criteria for the pedestrian to the traffic controller.
e) Traffic signal takes steps to address need based on security enrollment.
f) Pedestrian crossing phase activates based on special security permissions identified in IEEE 1609.2.
h) The PID communicates audible walk indicators to the pedestrian.
i) The actor proceeds to the crosswalk and crosses the street.
j) The PID acnkowledges confirmation of the completed crossing action.
k) The PID records statistics.

Post-Conditions on Success

- Confirmation of the completed action is acknowledged (automatically by user device based on location – or crossing time reaches the limit (max) and terminates the PED service).
- Information was received about pedestrian crossing in a non-visual manner.
- Pedestrian crosses successfully.
- Activity ends.
- Recovery period begins.
- Traffic controller records and sends statistics data.

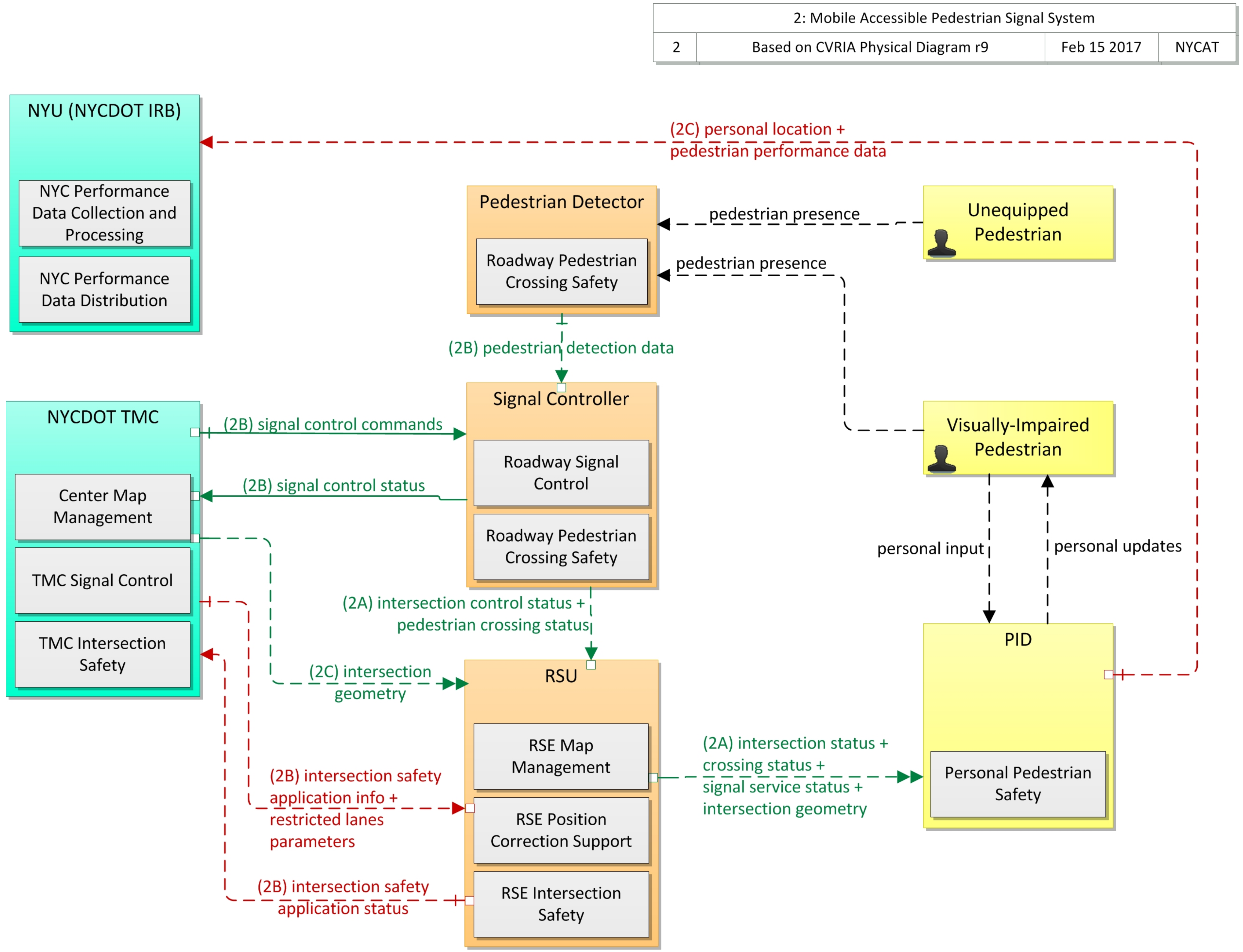
Alternative Path

1. Traffic signal receives request where the security certificate does not indicate permission to make the request.
2. Traffic signal transmits message to requestor –insufficient privileges and terminates any further support activities.
3. Mobile App indicates it is unable to provide service based on insufficient privileges.
4. Pedestrian looks for alternative method to cross at intersection.

Note: The PED actuation is not treated as a preemption request; the PED request will be serviced in the normal phase sequence; however, under some conditions the signal timing for the PED crossing may be extended thus requiring a recovery period to re-establish the signal progression. In such circumstances, the traffic engineering review may limit the number of consecutive requests that may be honored during a configured period of time in order to minimize the impact on traffic flow.

6.2.4.3 Notes

The PED support architecture is shown below. This is a modified version of the CVRIA PED application which supports the specific interactions described above. Note that the Signal Controller manages the traffic signal displays, and the RSU provides the standard messages (SPaT and MAP). Further design issues to be resolved include the location accuracy and whether the pedestrian requests and terminates the request or whether the device location accuracy is sufficient to automatically terminate the request when the pedestrian reaches the end of the crosswalk. This application is independent of the other PED warning application, PEDINXWALK application, described in Sections 5.3.8 and 6.2.3. The physical architecture of the PED-SIG application is shown in the in Figure 15 below.



Source: NYCDOT

Figure 15. Mobile Accessible Pedestrian Signal System

6.3 System Manager Scenarios

6.3.1 ASD CV Application Configuration Download

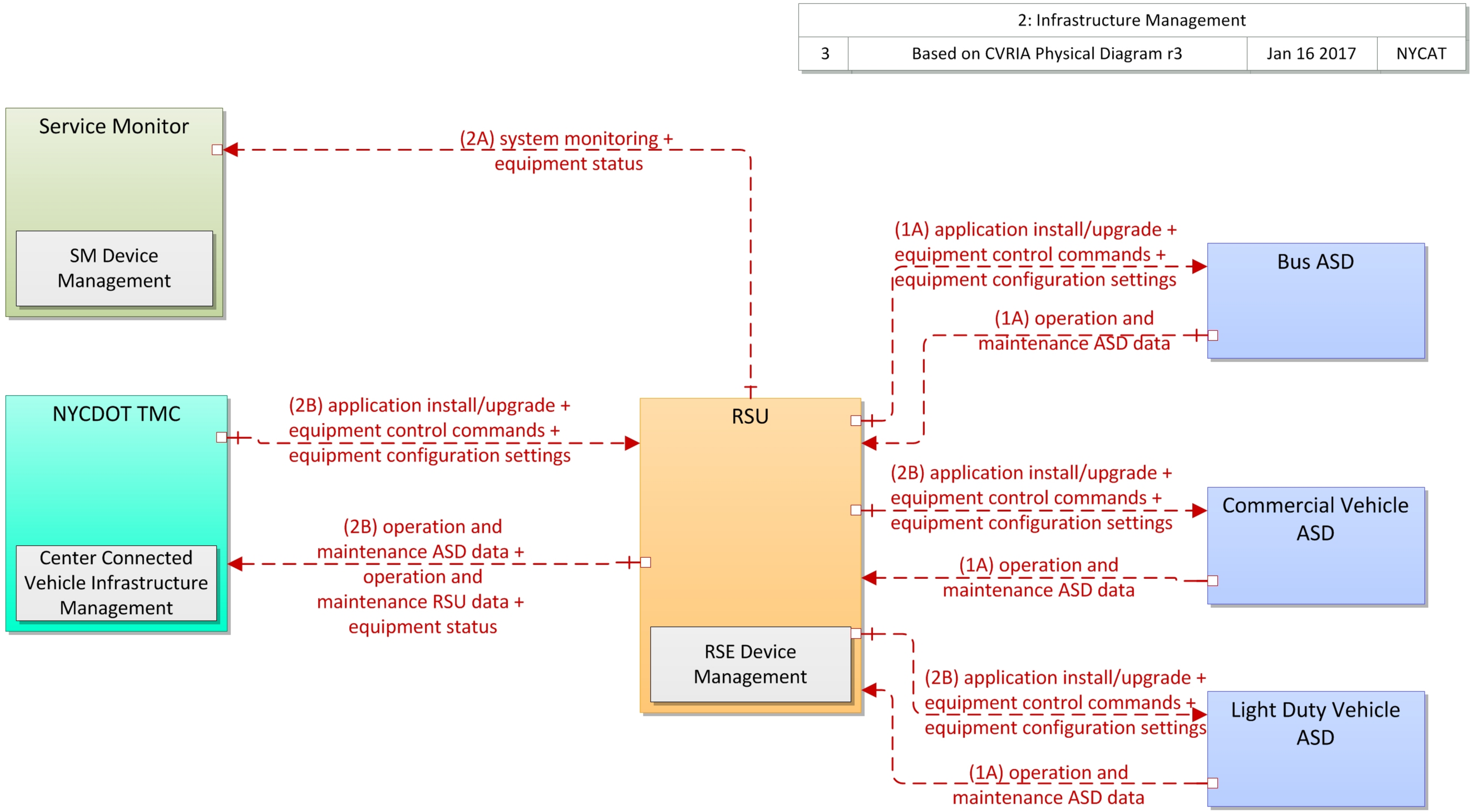
This support application will be used to upload or download the configuration parameters of V2I and V2V applications to the ASD. For example, the vehicle kinematics including but not limited to center of gravity, speed, and curve radius will be set as minimum thresholds before the ASD is deployed for 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.

6.3.1.1 Scenario

a) The driver returns the vehicle to its fleet barn after operating hours.
b) 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.
c) The CV application configuration parameters are checked and validated for operation.
d) The ASD is commissioned for operation.
e) This process is repeated whenever the parameters for a specific application need to be modified.
f) The ASD will access the SCMS through an RSU at the installation location to receive its initial operating certificates from the TMC.

6.3.1.2 Notes

Note that the above application will not be supported by the standard application messages. Instead, the ASD configuration parameters will 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. The physical architecture of the PARMLD application is shown in the Infrastructure Management diagram in Figure 16.



Source: NYCDOT

Figure 16. Infrastructure Management

6.3.2 ASD 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 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

Pre-conditions

- The RSU broadcasts WAVE Service Advertisement (WSA), indicating that it is prepared to transmit the firmware update parameters to the vehicle.

6.3.2.1 Scenario

a) The application is installed on the ASD and commissioned.
b) The driver operates a vehicle in New York City.
c) The vehicle returns to its assigned fleet barn.
d) The ASD listens for an OTA firmware update service advertisement.
e) The ASD determines whether its firmware needs to be updated to the advertised version.
f) When the ASD's firmware version needs updating, the ASD initiates an OTA firmware update transaction to the RSU obtain the new version.
g) The RSU forwards the firmware update transaction request to the TMC.
h) The TMC transmits the new firmware package to the RSU.
i) The RSU downloads the new firmware package to the ASD.
j) The ASD checks that the downloaded firmware package passes verification tests.
k) The ASD installs the firmware update and begins operating with it.

6.3.2.2 Notes

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. The physical architecture of the FRMWUPD application is shown in the Infrastructure Management diagram in Figure 16 above.

6.3.3 RSU RF Monitoring

Special cases including temporary occlusion by a commercial vehicle, vehicle ID change, and stopping or turning off the ASDs may occur. The NYC CV system will utilize a statistical approach to build a projected profile or a single sighting in the event of such temporary occlusion. 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.

Pre-conditions

- It is enabled for the collection of such information and transmits it to the TMC back office for analysis.
- Both the RSU and ASD clocks are synchronized to within 10 ms and use the same time reference.

Post-conditions

- All log entries have been transmitted to the TMC and purged from the RSU database.
- Once the log collection period ends, the RSU stops its data collection.

6.3.3.1 Scenario

a) The application is installed on the ASD and commissioned.
b) The driver operates a vehicle in New York City.
c) The ASD transmits the BSMs to the RSU.
d) The RSU logs each BSM, including vehicle ID, location, time stamp, heading, and speed, and the available RF signal levels.
e) 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.
f) If the aforementioned criteria are met and no first message exists, the new message becomes the first entry for the same vehicle.
g) 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.
h) The RSU logs the last entry for the same vehicle.
i) 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.

6.3.3.2 Notes

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. The physical architecture of the application is shown in Figure 16 above.

6.3.4 ASD RF Monitoring

This support application will be used to detect the presence or absence of ASDs in the NYC CVPD. It will trace the radio frequency (RF) radiation issues to a specific vehicle, which may require using properties of the SCMS certificates for identifying the specific vehicle. The information collected then may be provided to the fleet owner for arranging repairs or adjustments to be made to the vehicle. The details will be determined during the design phase.

Pre-Conditions

- Both the RSU and ASD clocks are synchronized to within 10 ms and use the same time reference.

Post-Conditions

- The ASDs will be expected to eventually upload all of their RF log entries through passing by an activated RSU.
- Once the log collection period ends, the ASD stops its data collection.

6.3.4.1 Scenario

The following are sequences for ASD's RSU data collection, ASD data collection, and log upload.

6.3.4.1.1 RSU Data Collection by the ASD

a) The application is installed on the ASD and commissioned.
b) The driver operates a vehicle in New York City.
c) The ASD in the vehicle hears an RSU for the first time via SPaT message for a specific RSU.
d) The ASD logs the available RSU ID and power level information and the vehicle's location, heading, speed, date, and time via BSM.
e) If the message reliability meets the pre-determined acceptance criteria, it is logged as the first and last message heard from the same RSU.
f) The ASD continues to receive SPaT messages from RSUs and checks if they are from a same RSU. If so, it replaces the last message log entry and continues monitoring.
g) The aforementioned step is repeated until time-out for receiving additional SPaT messages occurs. No further entries are recorded for that particular RSU sighting.
h) When the ASD hears a different RSU, steps c to g are repeated for the new RSU. The ASD may hear multiple RSUs depending on spacing between 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.

6.3.4.1.2 ASD Data Collection by the ASD

a) The application is installed on the ASD and commissioned.
b) The driver operates a vehicle in New York City.
c) The ASD hears another vehicle's ASD for the first time via BSM.
d) The ASD logs the available vehicle ID and power level information and the vehicle’s location, heading, speed, date, and time. It also records the BSM from the other vehicle logging its location, heading, speed, date, and time.
e) If the message reliability meets the pre-determined acceptance criteria, it is logged as the first and last message heard from the same ASD.
f) The ASD continues to receive BSMs and checks if they are from a same ASD. If so, the ASD replaces the last message log entry and continues monitoring.
g) The aforementioned step is repeated until time-out for receiving additional BSMs occurs. No further entries are recorded for that particular ASD sighting.

h) When the ASD hears a different ASD, steps c to g 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.

6.3.4.1.3 Log Upload from ASD to RSU

a) The RSU broadcasts WSA it is receiving RF log entries.
b) The ASD hears the RSU's WSA and uploads the log entries that have timed out through the appropriate DSRC channel.
c) The RSU acknowledges successful receipt and processes the RF log entries.
d) The ASD purges the RF log entries transmitted to the RSU.
e) This log upload process is repeated for a time period specified by the RSU.

6.3.4.2 Notes

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. The physical architecture of the application is shown in Figure 16 above.

6.4 Independent Evaluator Scenarios

6.4.1 ASD Event Data Recording

This support application will be used 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 location information from the BSMs, the warning issued by the ASD, any SPaT and MAP messages from any RSU it can hear, and the vehicle maneuver as a result of that warning. As the vehicle returns to its fleet terminal, the recorded data will be uploaded to the RSU at the terminal. We may also establish other upload locations at selected facilities depending on the initial results and testing.

6.4.1.1 Scenario

a) The application is installed on the ASD and commissioned.
b) The driver operates a vehicle in New York City.
c) When an alert is triggered, the information on vehicle location and driver's action is recorded at a resolution necessary for the alert type (e.g1/10 second interval or 1 second interval) for periods before and after each alert with the duration of each period defined by the needs of the alert.
d) The ASD stores event records from all alerts generated while the vehicle is in normal operation.
e) The driver returns the vehicle to its fleet terminal (i.e., barn).
f) The event log data is transmitted to the RSU at the fleet barn (or other location advertising the service).

6.4.1.2 Notes

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 for cleaning any personal traceable data to prevent any correlation with other records.

6.4.2 ASD Event Data Upload

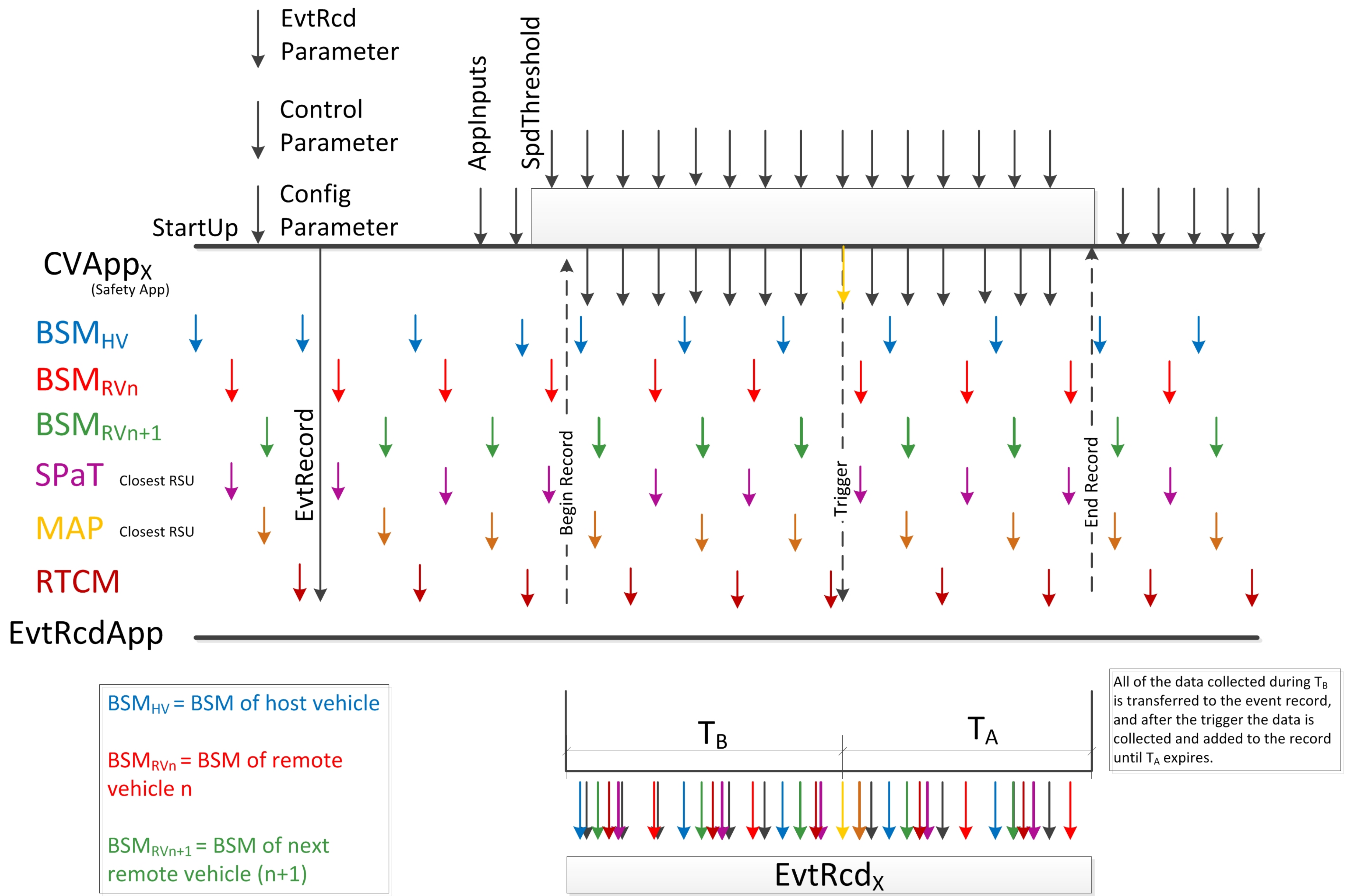
This support application will be used to transmit the event history log generated from the BSMs in the ASDs and MAPs in the ASDs from the RSUs. As the driver returns the vehicle to its respective fleet barn, the event data log will be transmitted from the ASD to the RSU at the barn. Then, the RSU will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

6.4.2.1 Scenario

a) The driver returns the vehicle to its fleet terminal at the end of daily operation.
b) The ASD transmits the event log data to the RSU at the fleet terminal.
c) The RSU at the fleet terminal sends the event data to a temporary server in the TMC back office CV data processing center for analysis and processing.

6.4.2.2 Notes

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.



Source: NYCDOT, 2016

Figure 17. ASD Event Recording Context

6.4.3 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 safety 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.

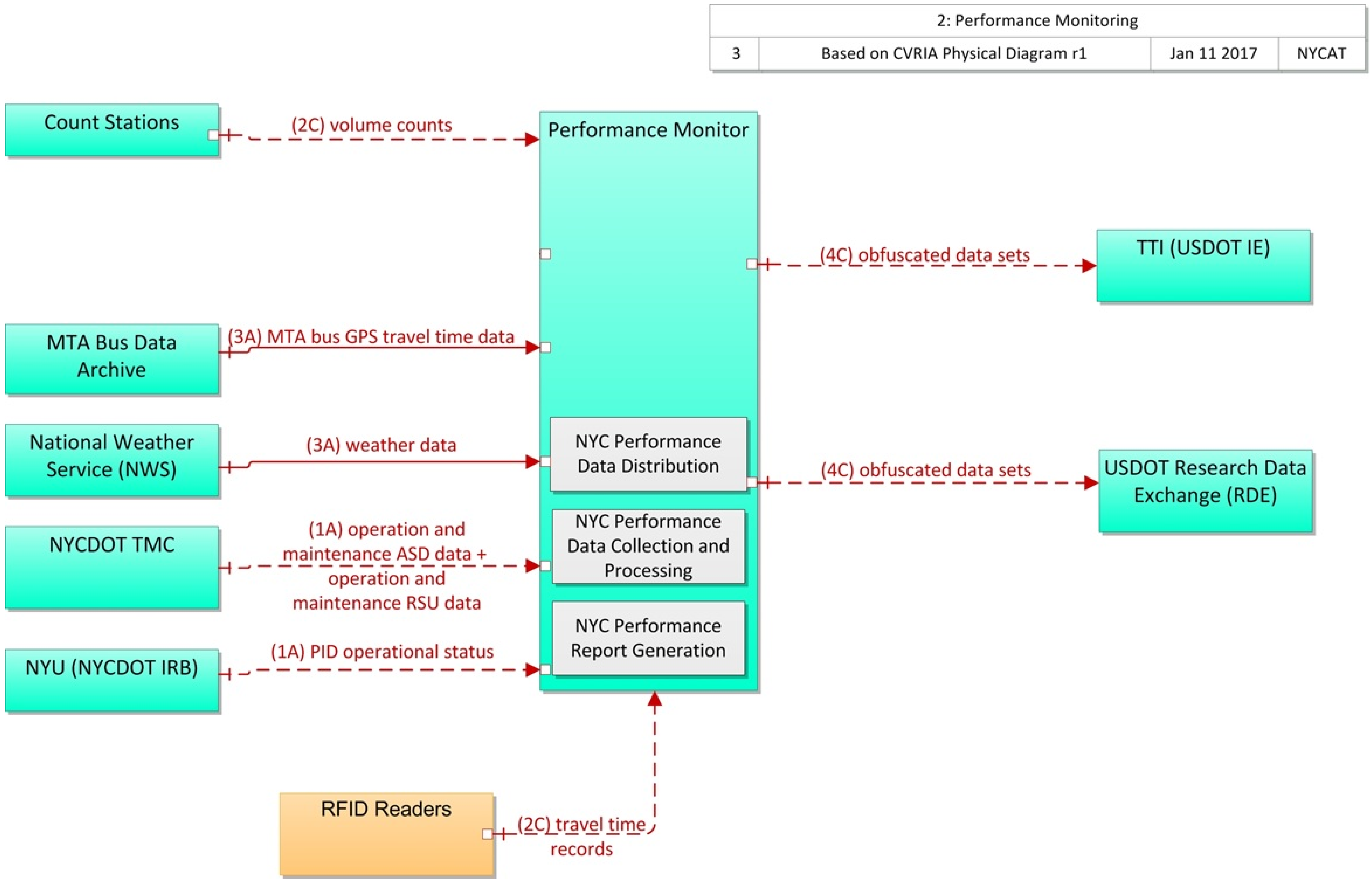
The private data from ASD event logs will be collected and stored in the TMC back office CV data processing center. As it is aggregated, the types of event counts will be incremented by time-of-day, location, and event type into collection bins. Any traceable and private information will be discarded. 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.

6.4.3.1 Scenario

a) 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.
b) Periodically using a batch process, each raw event recorded is examined and aggregated into bins based on the event type, time, and location of the event. The event record is normalized by re-anchoring time and location data to create a cleansed event record.
c) This process is repeated until all errors and issues are addressed.
d) The aggregated and normalized data is checked for any remains of PII and validated.
e) When the data processing is completed and all verification checks complete successfully, the raw event records are purged.
f) The aggregated and normalized data is sent to the USDOT Research Data Exchange, and the independent evaluator.

6.4.3.2 Notes

Note that the above application will be supported by the DSRC messages (i.e., BSM, MAP, SPaT, TIM, etc.) used to generate the event records. All messages from the RSU for this application will be authenticated, encrypted, and kept private from all parties except for the NYCDOT TMC back office data center for analysis and processing. The raw data will be re-anchored, and only the data without private information such as aggregated count data will be retained. Any traceable information including but not limited to time and location will not be retained.



Source: NYCDOT

Figure 18. Performance Monitoring

7. Summary of Impacts

The following section discusses the impacts of the NYC CVPD on the daily operations, participating stakeholder organizations, and future development of the CV technology in NYC.

7.1 Operational Impacts

The NYC CVPD is not expected to bring major impact on day-to-day traffic operations in the pilot areas of Manhattan and Brooklyn. Nonetheless, its goal is to address safety concerns regarding fatalities and severe injuries from traffic crashes in NYC. Before and after data will be collected and analyzed to determine the safety benefits achieved in this pilot deployment project.

The most noticeable impact will be the introduction of warnings to the vehicle driver/operators. It is unknown how frequent these warnings will be as this project will be the first to introduce over a dozen applications into a highly congested urban environment.

The management of the raw event records is another area that impacts daily operations. This data is sensitive and requires additional protections. The project team is accustomed to working with similarly sensitive data such as is found in the crash databases; therefore, it is not anticipated to be a significant issue.

7.2 Organizational Impacts

Fleet owning stakeholders are expected to opt in to the NYC CVPD and acknowledge the terms of their participation through memorandum of agreement (MOA) or memorandum of understanding (MOU). These documents will address each organization's privacy concerns and protection of each vehicle operator's identity and PII. This project is not expected to involve any major organizational changes in the operating agencies such as NYCDOT and NYC DoITT.

7.3 Impacts During Development

The NYC CVPD is expected to follow all new, stable standards and adhere to the backwards compatibility required starting in 2016. Interoperability among all devices will be critical in using standard message formats between all system nodes for communication. Also, equipment obsolescence and technology advancements will be discussed and evaluated during early stages of development. Equipment evolution will need to be accommodated by developing flexible system requirements for the NYC CVPD.

8. Analysis of the Proposed System

The following section discusses how the success of the CV system deployment will be assessed. It summarizes the improvements provided by the system, the advantages and limitations of the system, and alternatives considered for other operational changes. Finally it discusses the approach to measuring the system's impacts with respect to the primary user needs.

8.1 Summary of Improvements

The improvements provided by the NYC CVPD project are summarized in the following list:

- Vehicle fleets equipped with aftermarket safety devices for DSRC communications.
- Initial intersections equipped with RSU for DSRC communications.
- Initial curves, entrance/exit ramps, and work zones equipped with RSUs.
- Fleet terminal facility areas equipped with RSU for DSRC communications.
- Significant deployment of connected vehicle safety applications.
- New applications for managing DSRC devices from over-the-air updates to radio frequency link monitoring.

8.2 Disadvantages and Limitations

A few challenges are anticipated in completing the project. There are concerns about too many alerts/alarms being generated due to the vehicular/pedestrian traffic density causing vehicle driver/operators to ignore them. Because of the low travel speeds and high traffic volumes during peak period and business hours, the system may not provide the anticipated benefits during these periods while providing significant benefits during lower volume/higher speed periods overnight. A flexible parameter upload and download feature will be incorporated to manage the operation of the applications in response to these concerns.

The project's legal advisors have expressed concerns that once the CV system is activated, it cannot be turned off for selective evaluation periods. To address this concern the performance measurement plan is based on a before-after model to limit transitions from a silent to an active mode.

The NYC CVPD is a deployment project. It is intended to be a cornerstone for the deployment of CV systems across the country. As an initial rollout of the CV technology, it is expected to adhere to the CV system's architecture and continue to operate at the completion of the project's Phase 3 operational period. These deployment intentions drive many decisions to ensure that the system is interoperable with other CV deployment sites.

The project is intended to provide a limited research environment, albeit different from the safety pilot project research or other proof of concept projects have been operating. During these projects, drivers were recruited and were willing participants – even allowing in-vehicle video and other in-vehicle monitoring devices to be installed to collect data and study the effects of the CV technology. In contrast, the NYC CVPD project is a deployment project that has certain needs for evaluating the deployment and gain knowledge/experience to assist future deployments. On this basis, the NYC CVPD project has selected proven applications for deployment on a larger scale and focused on management tools for operating a large scale system. With the project's focus on improving safety through the reduction in crashes and pedestrian injuries/fatalities, its data collection is, therefore, focused on measuring these types of benefits for the system.

8.3 Alternatives and Trade-Offs Considered

At this time, no alternatives and trade-offs are considered for the NYC CVPD. However, any future alternatives and trade-offs will be documented as the project advances to procurement, design, and deployment.

8.4 Performance Measurement

This section discusses the performance questions to be assessed, the data sources to be used, the approach to collecting data, and issues impacting the assessment process. It also lists the performance measures to be used in assessing the system's benefits. Whereas this Concept of Operations document has been prepared midway in the project's planning phase, the project's Performance Measurement and Evaluation Support Plan (FHWA-JPO-16-302) should be referenced for additional details regarding the system's performance measurement.

8.4.1 Performance Analysis

The planned CV applications require the analysis of crash information and the event oriented data to determine the safety benefits achieved. In addition to the safety benefits, it is essential that we consider monitoring the performance of the equipment and the RF (DSRC) communications system. Aggregated and anonymous statistics will be recorded for the individual units to monitor the DSRC activity.

8.4.2 Performance Data Sources

There are two primary sources of information for analyzing the system's performance. The first is crash data stored in several databases operated by various government and private organizations. The second is a new temporary source consisting of the detailed event records to be recorded by the connected vehicle aftermarket safety devices. This section describes these data resources.

Traditional crash record geodatabases already collected will be available and included in the performance evaluation process. These databases are created from existing police crash records, which do contain PII data for those involved.

- Only reported crashes in the study area will be recorded. Many minor fender bender crashes go unreported. The criteria for a police report are a crash with either injuries/fatalities or more than $1000 amount of damage.
- The existing police crash reporting system will not be modified to identify if any of the involved vehicles are CV equipped vehicles or pedestrians.
- Due to privacy/liability concerns, police crash records will not be able to be tied to ASD/RSU data. Similar PII concerns exist for any crash related data from the vehicle that may be recorded (via OBD or accelerometers).
- Reporting schedule for the crashes may be problematic for the CV deployment reporting schedule (estimated 12 month turn around for full access to police crash records).

The duration for which of the crash records has yet to be determined, but will likely be analyzed several years prior to the CV deployment to increase the sample size of crashes to calculate crash rates from. Crashes will be stratified by intersection, but will also likely be analyzed by corridor as well to increase sample sizes further. The same analysis will be completed for the active CV deployment evaluation period.

Data feeds from existing weather data collection services (e.g., National Weather Service (NWS)) will be included in the performance evaluation plan. The nearest existing weather station will be used to tie weather related data to recorded CV app event data. To further remove the possibility of unusual weather events to particular dates, the precise nature of the weather events may be summarized as sunny, cloudy, light rain, heavy rain, light snow, heavy snow (or similar) instead of precise precipitation amounts or rates.

8.4.3 Data Collection

The project's legal advisors have expressed concerns that once the CV system is activated, it cannot be turned off for selective evaluation periods. This eliminates the option of doing more robust analysis of with and without driver populations at the same time. Instead, before and after periods will be defined as:

- Before period: System fully deployed and operational but ***without*** user notification of ASD perceived warnings and ***without*** modification to operations of signals or other infrastructure.
- After period: System fully deployed and operational but ***with*** user notification of ASD perceived warnings and ***with*** modification to operations of signals or other infrastructure.

Through an examination of the detailed trajectory data recorded during events under both the before (silent) and after (active) periods of the CV deployment, impacts of the CV apps on changing driver performance and behaviors can be assessed and quantified for each of CV app warnings.

ASDs will record the first SPaT, MAP, and BSM heard from any RSU or other vehicle (with time stamp, location, and signal strength, if known) and the last message heard for each of the above. RSUs will record the first BSM heard from each vehicle (with time stamp, location, and signal strength, if known) and the last location. This data can be used to monitor the RF signal issues and develop a general map of the RF coverage for each vehicle and RSU. The exact criteria for the first or last such message need to be determined as part of the NYC CVPD design, and should consider some reliability check such as when 3 of 5 are heard or when less than 3 of 5 are heard, etc. This approach is anticipated to work well for a 10 Hz operation but may change because of changing message rates due to channel congestion or changes to transmission rates if implementation suggests that 10 Hz is too frequent. In addition, each RSU will periodically log SPaT and MAP messages received from other RSUs. This will provide an indication of the range for each of the RSUs which may be used to allow tuning the power levels to reduce channel congestion where tight block spacing is involved.

It is important to note that not all of the BSM/SPaT/MAP messages received will be logged – only the select few such that the system can determine the RF characteristics of each RSU and ASD. While this data can be tracked to specific locations for RSUs, such data is not traceable to PII for any participant. The actual logged data (from ASDs) could be further aggregated if necessary such that only the RF information is used for further analysis.

ASDs will also be used to report major system activity such as down time, lost signals on ASDs, and other system performance measurements to be determined.

Other non-CV Pilot data collection methods will be continued and recorded as part of the CV Pilot evaluation. This includes:

- Volume monitoring from permanent count stations through the study area, toll collection counts, etc.
- Speed monitoring from Midtown in Motion, TRANSMIT readers, etc.
- Travel time monitoring via TRANSMIT readers

8.4.3.1 Aggregated Mobility Data

The USDOT has expressed a need to collect ongoing vehicle situation data and infrastructure situational data that can be used by other applications through the CV data distribution system and stored into the USDOT data warehouse for analysis of network performance.

For this type of data, it should be possible to log and upload a subset of the BSM data that does not provide possible incriminating data. The rate of collection could be lengthened to once per second or longer. Since there are a significant number of vehicles within the NYC CVPD project area, collection of this type of data without vehicle identifiers can then be used to monitor network performance because the logged BSMs act as breadcrumbs for the vehicle's history noting location and speed (and such speed could be averaged over several samples). For the NYC CVPD, this data will be obtained via the I-SIG CVDATA application to provide input to the Midtown in Motion (MIM) adaptive control system and the speed detection system. Both the MIM and speed detection systems are currently using RFID readers and monitoring the travel times of vehicles with toll tags. The MIM also uses the field measured volume and occupancy from midblock microwave detectors (RTMS) providing volume and occupancy. Traffic volume and occupancy data may not be able to be replaced by CV data at this time due to the penetration rate of the connected vehicle technology.

8.4.3.2 Simulation Modeling

It is understood by the NYC CVPD project team that the level of data that can be observed or field measured planned before and after CV deployment periods may be insufficient to estimate detailed conclusions about the efficacy and benefits of each CV app independently. The influences of confounding factors will be difficult to isolate from the impacts of the CV app deployment under such before and after measurement periods, and while a significant number of vehicles in the study areas will be equipped with ASDs, it will still be only a subset of the entire vehicle population and the full effect of the CV apps may be difficult to assess (especially for V2V apps). Finally, it is also expected that the observed numbers of crashes during each of the before and after periods may not be enough to prove the impacts of the CV apps in reducing the number of crashes, at least to a reasonable level of statistical significance.

Given these issues, part of the performance evaluation plan will include analysis using simulation modeling techniques instead of direct field observation. While further details will be established during the creation of the performance evaluation plan, two levels of simulation modeling are currently planned to be included:

- **System Performance Simulation Modeling:** In order to quantify benefits associated with changing driver behaviors on non-safety related issues (e.g., mobility), systemwide simulation modeling will be conducted. The existing Manhattan Traffic Model (MTM) (an Aimsun-based microscopic model covering Midtown Manhattan) will be utilized to simulate operational conditions in the study area network both with and without CV app deployments (or more precisely with and without changes in driver behaviors and signal operation changes observed before and after the CV app deployments). Expansions or updates to the MTM may be required to recalibrate to the before conditions and/or to expand or create an additional model to include the Brooklyn roadways included in the study area. By simulating network performance under a variety of recurring and non-recurring congestion scenarios, the mobility, reliability, and environmental impacts of the NYC CVPD impacts on system performance and reduction in crashes can be estimated. Monetization of all of these user and system benefits can allow for a robust assessment of the impacts and cost effectiveness of the NYC CVPD deployment.
- **Crash Prediction Modeling Using Surrogate Safety Measures:** Through an examination of the recorded detailed trajectory data recorded during events under both the before (silent) and after (active) periods of the CV deployment, impacts of the CV apps on changing driver performance and behaviors can be assessed and quantified for each CV app warnings. Using those observed changes in driver reaction times or otherwise modified driver behaviors, changes to the microscopic driver behavior parameters (car following parameters, driver awareness, driver reaction time, speed limit adherence, etc.) will be estimated, calibrated, and incorporated into simulation modeling exercises for a series of scenarios for both with and without CV apps. Using existing research on surrogate safety measures and simulation modeling, the simulation results will be used to predict impacts on crash rates of the CV deployment. These simulations can also isolate the benefits from individual CV apps and eliminate the impacts of confounding factors, both items that cannot be reasonable be achieved in the direct field observations planned. These tests can also be scaled up to predict the safety impacts if all vehicles (or a higher proportion) of vehicles were equipped with similar ASDs. It is preferred to use the MTM model for such purposes; however, we will also consider other simulation modeling options (e.g., smaller scale models) to reduce stochastic noise in a model the size of the MTM model and to better isolate just the impacts the before and after effects on driver behaviors and actions from the CV deployment.

8.4.4 Performance Measures and Targets

The project will assess the safety benefits by evaluating the traffic manager's user needs described earlier. These needs involve managing traffic speeds and reducing crashes of various types. The following table lists these needs and the specific data measures to be used in analyzing whether the need has been satisfied.

Note that the targets for these data measures are yet to be determined. They will be established following the collection of the Before Study data because the evaluators don't currently have any information as to the number of events that could be observed. The tuning of the CV applications and the Before Study data collection will provide experience and a basis for setting the target goals. Another factor that will impact the collection is the setting of the geographic limits for the event recording bins. The bins must balance the need to be small enough to collect a significant number of events against being large enough to ensure that re-anchored event data could not be traced back to any specific crash event. The project team won't be able to assess these geographic area sizes until data has been collected and analyzed.

Table 17. Performance Measure Targets

USER NEED	AREA	OBJECTIVE	CV APPLICATION	ID	MEASURE	TARGET VALUE IMPROVEMENT
Manage Speed	Safety and Mobility	Discourage Spot Speeding	Speed Compliance	1a	Average number of stops	No target
Manage Speed	Safety and Mobility	Discourage Spot Speeding	Speed Compliance	1b	Average speeds	No target
Manage Speed	Safety and Mobility	Discourage Spot Speeding	Speed Compliance	1c	Average emissions	No target
Manage Speed	Safety and Mobility	Discourage Spot Speeding	Speed Compliance	1d	Reduction in speed limit violations	To be determined
Manage Speed	Safety and Mobility	Discourage Spot Speeding	Speed Compliance	1e	Speed variation	To be determined
Manage Speed	Safety and Mobility	Discourage Spot Speeding	Speed Compliance	1f	Driver actions and/or impact on actions in response to warnings - vehicle trajectories	No target
Manage Speed	Safety	Improve Truck safety	Curve Speed Compliance	2a	Speed related crash counts and rates	To be determined
Manage Speed	Safety	Improve Truck safety	Curve Speed Compliance	2b	Time to collision measurement	No target
Manage Speed	Safety	Improve Truck safety	Curve Speed Compliance	2c	Vehicle speeds at curve entry	No target
Manage Speed	Safety	Improve Truck safety	Curve Speed Compliance	2d	Driver actions and/or impact on actions in response to warnings - vehicle trajectories	No target
Manage Speed	Safety	Improve Truck safety	Curve Speed Compliance	2e	Number of warnings generated	No target

USER NEED	AREA	OBJECTIVE	CV APPLICATION	ID	MEASURE	TARGET VALUE IMPROVEMENT
Manage Speed	Safety	Improve Work Zone Safety	Speed Compliance / Work Zone	3a	Average speed at work zone compared to posted speeds	No target
Manage Speed	Safety	Improve Work Zone Safety	Speed Compliance / Work Zone	3b	Vehicle speed limit violation in variable speed zone areas	To be determined
Manage Speed	Safety	Improve Work Zone Safety	Speed Compliance / Work Zone	3c	Work zone-related crash counts and rates in reduced speed zones	To be determined
Manage Speed	Safety	Improve Work Zone Safety	Speed Compliance / Work Zone	3d	Time to collision to measure instantaneous safety in reduced speed zone	No target
Manage Speed	Safety	Improve Work Zone Safety	Speed Compliance / Work Zone	3e	Driver actions and/or impact on actions in response to warnings - vehicle trajectories	No target
Reduce Vehicle to Vehicle Crashes	Safety	V2V Safety Applications	FCWEEBLBSWLC WIMA	4a	Fatality crash rate	To be determined
Reduce Vehicle to Vehicle Crashes	Safety	V2V Safety Applications	FCWEEBLBSWLC WIMA	4b	Injury crash rate	To be determined
Reduce Vehicle to Vehicle Crashes	Safety	V2V Safety Applications	FCWEEBLBSWLC WIMA	4c	Property damage only crash rate	To be determined
Reduce Vehicle to Vehicle Crashes	Safety	V2V Safety Applications	FCWEEBLBSWLC WIMA	4d	Time to collision as instantaneous safety measurement	No target
Reduce Vehicle to Vehicle Crashes	Safety	Reduce Accidents at High Incident Intersections	Red Light Violation Warning	5a	Red light violation counts and rates	To be determined
Reduce Vehicle to Vehicle Crashes	Safety	Reduce Accidents at High Incident Intersections	Red Light Violation Warning	5b	Red light violation related crash counts and rates	To be determined

USER NEED	AREA	OBJECTIVE	CV APPLICATION	ID	MEASURE	TARGET VALUE IMPROVEMENT
Reduce Vehicle to Vehicle Crashes	Safety	Reduce Accidents at High Incident Intersections	Red Light Violation Warning	5c	Time to collision at the intersection to measure instantaneous safety	No target
Reduce Vehicle to Vehicle Crashes	Safety	Reduce Accidents at High Incident Intersections	Red Light Violation Warning	5d	Driver actions and/or impact on actions in response to warnings - vehicle trajectories	No target
Reduce Vehicle to Vehicle Crashes	Safety	Reduce Incidents, Improve Safety	Vehicle Turning Right in Front of Bus Warning	6a	Bus and right turn related crash counts and rates	To be determined
Reduce Vehicle to Vehicle Crashes	Safety	Reduce Incidents, Improve Safety	Vehicle Turning Right in Front of Bus Warning	6b	Right-turning related conflicts	No target
Reduce Vehicle to Vehicle Crashes	Safety	Reduce Incidents, Improve Safety	Vehicle Turning Right in Front of Bus Warning	6c	Time to collision to measure instantaneous safety	No target
Reduce Vehicle to Vehicle Crashes	Safety	Reduce Incidents, Improve Safety	Vehicle Turning Right in Front of Bus Warning	6d	Number of warnings generated	No target
Reduce Vehicle to Vehicle Crashes	Safety	Reduce Incidents, Improve Safety	Vehicle Turning Right in Front of Bus Warning	6e	Driver actions and/or impact on actions in response to warnings - vehicle trajectories	No target

USER NEED	AREA	OBJECTIVE	CV APPLICATION	ID	MEASURE	TARGET VALUE IMPROVEMENT
Reduce Vehicle to Pedestrian Crashes	Safety	Improve Pedestrian Safety on Heavily Traveled Bus Routes	Pedestrian in Signalized Crosswalk Warning	7a	Pedestrian related crash counts and rates	To be determined
Reduce Vehicle to Pedestrian Crashes	Safety	Improve Pedestrian Safety on Heavily Traveled Bus Routes	Pedestrian in Signalized Crosswalk Warning	7b	Number of warnings generated	No target
Reduce Vehicle to Pedestrian Crashes	Safety	Improve Pedestrian Safety on Heavily Traveled Bus Routes	Pedestrian in Signalized Crosswalk Warning	7c	Pedestrian-related conflicts/hard braking events	To be determined
Reduce Vehicle to Pedestrian Crashes	Safety	Improve Pedestrian Safety on Heavily Traveled Bus Routes	Pedestrian in Signalized Crosswalk Warning	7d	Time to collision to measure instantaneous safety	No target
Reduce Vehicle to Pedestrian Crashes	Safety	Improve Pedestrian Safety on Heavily Traveled Bus Routes	Pedestrian in Signalized Crosswalk Warning	7e	Driver actions and/or impact on actions in response to warnings - vehicle trajectories	No target
Reduce Vehicle to Pedestrian Crashes	Safety	Improve Safety of Visually and Audibly-impaired pedestrians	Mobile Accessible Pedestrian Signal System (PED-SIG)	8a	Number of pedestrian crossing violation reductions	To be determined
Reduce Vehicle to Pedestrian Crashes	Safety	Improve Safety of Visually and Audibly-impaired pedestrians	Mobile Accessible Pedestrian Signal System (PED-SIG)	8b	Visually-impaired pedestrian-related crash counts and rates	To be determined
Reduce Vehicle to Pedestrian Crashes	Safety	Improve Safety of Visually and Audibly-impaired pedestrians	Mobile Accessible Pedestrian Signal System (PED-SIG)	8c	Conflicts with visually impaired pedestrians	No target

USER NEED	AREA	OBJECTIVE	CV APPLICATION	ID	MEASURE	TARGET VALUE IMPROVEMENT
Reduce Vehicle to Pedestrian Crashes	Safety	Improve Safety of Visually and Audibly-impaired pedestrians	Mobile Accessible Pedestrian Signal System (PED-SIG)	8d	Time to collision to measure instantaneous safety	No target
Reduce Vehicle to Pedestrian Crashes	Safety	Improve Safety of Visually and Audibly-impaired pedestrians	Mobile Accessible Pedestrian Signal System (PED-SIG)	8e	Waiting time at intersection for crossing	No target
Reduce Vehicle to Infrastructure Crashes	Mobility	Address Bridge Low Clearance Issues/Enforce Truck Route Restriction	Oversized Vehicle Compliance	9a	Number of warnings generated	No target
				9b	Reduction in truck route violations	To be determined
Inform Drivers of Serious Incidents	Mobility	Inform Drivers	Emergency Communications and Evacuation Information	10a	Number of vehicles receiving information when generated	No target
Provide Mobility Information	Mobility	Replace Legacy Measurements	Intelligent Traffic Signal System Connected Vehicle Data (I-SIGCVDATA)	11a	Average speed from CV compared to legacy detection systems	No target

USER NEED	AREA	OBJECTIVE	CV APPLICATION	ID	MEASURE	TARGET VALUE IMPROVEMENT
Provide Mobility Information	Mobility	Replace Legacy Measurements	Intelligent Traffic Signal System Connected Vehicle Data (I-SIGCVDATA)	11b	Average travel time from CV compared to legacy detection systems	No target
Manage System Operations	System Operations	Ensure Operations of the CV Deployment	NA	12a	System performance statistics (system activity, down time, radio frequency monitoring range on ASDs and RSUs, number of event warnings by app)	To be determined

The Emergency Communications and Evacuation Notification application and the Intelligent Traffic Signal System Connected Vehicle Data applications are proofs of concept for the dissemination of incident information using DSRC and the usage of connected vehicle data for the Adaptive Control Decision Support System input. They are included in the project to test their viability. As such they have limited performance measures defined that are based on their respective objectives.

8.4.5 Performance Assessment Issues

The primary issue for the performance assessment has been the fleet owner's and roadway user's need for privacy as discussed previously. Two key system features are being used to address this issue. The event recording data is being secured immediately upon each event's capture. This will protect the data throughout its life-cycle from the capture to final destruction and purging of the raw data. The other feature protecting privacy is the normalizing of the data by re-anchoring it to common points. By having a sufficient number of events using an identical anchor point, no single event will be distinguishable from the others thereby protecting privacy.

9. Notes

This section contains miscellaneous notes for the report. At the time of publication there are no additional notes to record.

Appendix A **Traffic Conditions**

Table 18. CV Pilot Corridor Information for Avenues

Corridor	Direction	Speed Limit (MPH)	AADT (2013)
FDR	Bi-Directional	40	136060
First Avenue	One-way, Southbound	25	36770
Second Avenue	One-way, Northbound	25	45590
Fifth Avenue	One-way, Southbound	25	23710
Sixth Avenue	One-way, Northbound	25	29610
Flatbush Avenue	Bi-Directional	25	43620

(Source: NYCDOT, NYSDOT)

Table 19. CV Pilot Corridor Information for Cross-streets

Corridor	Direction	Speed Limit (MPH)	AADT (2015)
Fourteenth Street	Bi-Directional	25	15840
Twenty-third Street	Bi-Directional	25	22560
Thirty-fourth Street	Bi-Directional	25	19710
Forty-second Street	Bi-Directional	25	19870
Fifty-seventh Street	Bi-Directional	25	23480

(Source: NYCDOT, NYSDOT)

Table 20. Crash Summary (2010-2014)

Corridor	Motor Vehicle	Pedestrian	Bicyclist	Total
FDR	1574	N/A	N/A	1574
First Avenue	798	396	143	1337
Second Avenue	1297	486	237	2020
Fifth Avenue	866	390	176	1432

Sixth Avenue	777	449	223	1449
Flatbush Avenue	857	172	59	1088

(Source: NYCDOT, NYSDOT)

Table 21. Injury Summary (2010-2014)

Corridor	Motor Vehicle	Pedestrian	Bicyclist	Total
FDR	1080	N/A	N/A	1080
First Avenue	624	412	144	1180
Second Avenue	933	493	237	1663
Fifth Avenue	660	416	175	1251
Sixth Avenue	635	481	229	1345
Flatbush Avenue	947	173	60	1180

(Source: NYCDOT, NYSDOT)

Table 22. Fatality and Severe Injury Summary

Corridor	Motor Vehicle	Pedestrian	Bicyclist	Total Fatalities	Severe Injuries	Persons Killed or Severely Injured (KSI)	KSI per mile
FDR	7	N/A	N/A	7	N/A	N/A	N/A
First Avenue	0	4	0	4	83	87	31.8
Second Avenue	0	3	1	4	109	113	40.6
Fifth Avenue	0	3	0	3	91	94	34.3
Sixth Avenue	0	2	0	2	109	111	48.4
Flatbush Avenue	1	5	0	6	67	73	43.2

(Source: NYCDOT, NYSDOT)

Appendix B Roadside Unit Locations

Tables 23 - 26 list the RSU locations along the avenues Manhattan.

Table 23. RSU Locations on First Avenue

Borough	Main Street	Cross Street
MAN	1 AVENUE	EAST 14 STREET
MAN	1 AVENUE	EAST 15 STREET
MAN	1 AVENUE	EAST 16 STREET
MAN	1 AVENUE	EAST 17 STREET
MAN	1 AVENUE	EAST 18 STREET
MAN	1 AVENUE	EAST 19 STREET
MAN	1 AVENUE	EAST 20 STREET
MAN	1 AVENUE	EAST 21 STREET
MAN	1 AVENUE	EAST 22 STREET
MAN	1 AVENUE	EAST 23 STREET
MAN	1 AVENUE	EAST 24 STREET
MAN	1 AVENUE	EAST 25 STREET
MAN	1 AVENUE	EAST 26 STREET
MAN	1 AVENUE	EAST 27 STREET
MAN	1 AVENUE	EAST 28 STREET
MAN	1 AVENUE	EAST 29 STREET
MAN	1 AVENUE	EAST 30 STREET
MAN	1 AVENUE	EAST 32 STREET/270' NORTH OF 30 ST
MAN	1 AVENUE	EAST 33 STREET
MAN	1 AVENUE	EAST 34 STREET
MAN	1 AVENUE	EAST 35 STREET
MAN	1 AVENUE	EAST 36 STREET
MAN	1 AVENUE	EAST 37 STREET
MAN	1 AVENUE	EAST 38 STREET
MAN	1 AVENUE	EAST 39 STREET
MAN	1 AVENUE	EAST 40 STREET
MAN	1 AVENUE	EAST 42 STREET

Borough	Main Street	Cross Street
MAN	1 AVENUE	EAST 43 STREET
MAN	1 AVENUE	EAST 44 STREET
MAN	1 AVENUE	EAST 45 STREET
MAN	1 AVENUE	EAST 46 STREET
MAN	1 AVENUE	EAST 47 STREET
MAN	1 AVENUE	EAST 48 STREET
MAN	1 AVENUE	EAST 49 STREET
MAN	1 AVENUE	EAST 50 STREET
MAN	1 AVENUE	EAST 51 STREET
MAN	1 AVENUE	EAST 52 STREET
MAN	1 AVENUE	EAST 53 STREET
MAN	1 AVENUE	EAST 54 STREET
MAN	1 AVENUE	EAST 55 STREET
MAN	1 AVENUE	EAST 56 STREET
MAN	1 AVENUE	EAST 57 STREET
MAN	1 AVENUE	EAST 58 STREET
MAN	1 AVENUE	EAST 59 STREET
MAN	1 AVENUE	EAST 60 STREET
MAN	1 AVENUE	EAST 61 STREET
MAN	1 AVENUE	EAST 62 STREET
MAN	1 AVENUE	EAST 63 STREET
MAN	1 AVENUE	EAST 64 STREET
MAN	1 AVENUE	EAST 65 STREET
MAN	1 AVENUE	EAST 66 STREET
MAN	1 AVENUE	EAST 67 STREET

(Source: NYCDOT)

Table 24. RSU Locations on Second Avenue

Borough	Main Street	Cross Street
MAN	2 AVENUE	EAST 14 STREET
MAN	2 AVENUE	EAST 15 STREET
MAN	2 AVENUE	EAST 16 STREET
MAN	2 AVENUE	EAST 17 STREET
MAN	2 AVENUE	EAST 18 STREET
MAN	2 AVENUE	EAST 19 STREET
MAN	2 AVENUE	EAST 20 STREET
MAN	2 AVENUE	EAST 21 STREET
MAN	2 AVENUE	EAST 22 STREET
MAN	2 AVENUE	EAST 23 STREET
MAN	2 AVENUE	EAST 24 STREET
MAN	2 AVENUE	EAST 25 STREET
MAN	2 AVENUE	EAST 26 STREET
MAN	2 AVENUE	EAST 27 STREET
MAN	2 AVENUE	EAST 28 STREET
MAN	2 AVENUE	EAST 29 STREET
MAN	2 AVENUE	EAST 30 STREET
MAN	2 AVENUE	EAST 31 STREET
MAN	2 AVENUE	EAST 32 STREET
MAN	2 AVENUE	EAST 33 STREET
MAN	2 AVENUE	EAST 34 STREET
MAN	2 AVENUE	EAST 35 STREET
MAN	2 AVENUE	EAST 36 STREET
MAN	2 AVENUE	EAST 37 STREET
MAN	2 AVENUE	EAST 38 STREET
MAN	2 AVENUE	EAST 39 STREET
MAN	2 AVENUE	EAST 40 STREET
MAN	2 AVENUE	EAST 41 STREET
MAN	2 AVENUE	EAST 42 STREET
MAN	2 AVENUE	EAST 43 STREET
MAN	2 AVENUE	EAST 44 STREET

Borough	Main Street	Cross Street
MAN	2 AVENUE	EAST 45 STREET
MAN	2 AVENUE	EAST 46 STREET
MAN	2 AVENUE	EAST 47 STREET
MAN	2 AVENUE	EAST 48 STREET
MAN	2 AVENUE	EAST 49 STREET
MAN	2 AVENUE	EAST 50 STREET
MAN	2 AVENUE	EAST 51 STREET
MAN	2 AVENUE	EAST 52 STREET
MAN	2 AVENUE	EAST 53 STREET
MAN	2 AVENUE	EAST 54 STREET
MAN	2 AVENUE	EAST 55 STREET
MAN	2 AVENUE	EAST 56 STREET
MAN	2 AVENUE	EAST 57 STREET
MAN	2 AVENUE	EAST 58 STREET
MAN	2 AVENUE	EAST 59 STREET
MAN	2 AVENUE	EAST 60 STREET
MAN	2 AVENUE	EAST 61 STREET
MAN	2 AVENUE	EAST 62 STREET
MAN	2 AVENUE	EAST 63 STREET
MAN	2 AVENUE	EAST 64 STREET
MAN	2 AVENUE	EAST 65 STREET
MAN	2 AVENUE	EAST 66 STREET
MAN	2 AVENUE	EAST 67 STREET

(Source: NYCDOT)

Table 25. RSU Locations on Fifth Avenue

Borough	Main Street	Cross Street
MAN	5 AVENUE	EAST 14 STREET
MAN	5 AVENUE	EAST 15 STREET
MAN	5 AVENUE	EAST 16 STREET
MAN	5 AVENUE	EAST 17 STREET
MAN	5 AVENUE	EAST 18 STREET
MAN	5 AVENUE	EAST 19 STREET
MAN	5 AVENUE	EAST 20 STREET
MAN	5 AVENUE	EAST 21 STREET
MAN	5 AVENUE	EAST 22 STREET
MAN	5 AVENUE	EAST 23 STREET
MAN	5 AVENUE	EAST 24 STREET
MAN	5 AVENUE	EAST 25 STREET
MAN	5 AVENUE	EAST 26 STREET
MAN	5 AVENUE	EAST 27 STREET
MAN	5 AVENUE	EAST 28 STREET
MAN	5 AVENUE	EAST 29 STREET
MAN	5 AVENUE	EAST 30 STREET
MAN	5 AVENUE	EAST 31 STREET
MAN	5 AVENUE	EAST 32 STREET
MAN	5 AVENUE	EAST 33 STREET
MAN	5 AVENUE	EAST 34 STREET
MAN	5 AVENUE	EAST 35 STREET
MAN	5 AVENUE	EAST 36 STREET
MAN	5 AVENUE	EAST 37 STREET
MAN	5 AVENUE	EAST 38 STREET
MAN	5 AVENUE	EAST 39 STREET
MAN	5 AVENUE	EAST 40 STREET
MAN	5 AVENUE	EAST 41 STREET
MAN	5 AVENUE	EAST 42 STREET
MAN	5 AVENUE	EAST 43 STREET
MAN	5 AVENUE	EAST 44 STREET

Borough	Main Street	Cross Street
MAN	5 AVENUE	EAST 45 STREET
MAN	5 AVENUE	EAST 46 STREET
MAN	5 AVENUE	EAST 47 STREET
MAN	5 AVENUE	EAST 48 STREET
MAN	5 AVENUE	EAST 49 STREET
MAN	5 AVENUE	EAST 50 STREET
MAN	5 AVENUE	EAST 51 STREET
MAN	5 AVENUE	EAST 52 STREET
MAN	5 AVENUE	EAST 53 STREET
MAN	5 AVENUE	EAST 54 STREET
MAN	5 AVENUE	EAST 55 STREET
MAN	5 AVENUE	EAST 56 STREET
MAN	5 AVENUE	EAST 57 STREET
MAN	5 AVENUE	EAST 58 STREET
MAN	5 AVENUE	EAST 59 STREET
MAN	5 AVENUE	EAST 60 STREET
MAN	5 AVENUE	EAST 61 STREET
MAN	5 AVENUE	EAST 62 STREET
MAN	5 AVENUE	EAST 63 STREET
MAN	5 AVENUE	EAST 64 STREET
MAN	5 AVENUE	EAST 65 STREET
MAN	5 AVENUE	EAST 66 STREET
MAN	5 AVENUE	EAST 67 STREET

(Source: NYCDOT)

Table 26. RSU Locations on Sixth Avenue

Borough	Main Street	Cross Street
MAN	6 AVENUE	WEST 14 STREET
MAN	6 AVENUE	WEST 15 STREET
MAN	6 AVENUE	WEST 16 STREET
MAN	6 AVENUE	WEST 17 STREET
MAN	6 AVENUE	WEST 18 STREET
MAN	6 AVENUE	WEST 19 STREET
MAN	6 AVENUE	WEST 20 STREET
MAN	6 AVENUE	WEST 21 STREET
MAN	6 AVENUE	WEST 22 STREET
MAN	6 AVENUE	WEST 23 STREET
MAN	6 AVENUE	WEST 24 STREET
MAN	6 AVENUE	WEST 25 STREET
MAN	6 AVENUE	WEST 26 STREET
MAN	6 AVENUE	WEST 27 STREET
MAN	6 AVENUE	WEST 28 STREET
MAN	6 AVENUE	WEST 29 STREET
MAN	6 AVENUE	WEST 30 STREET
MAN	6 AVENUE	WEST 31 STREET
MAN	6 AVENUE	WEST 32 STREET
MAN	6 AVENUE	WEST 35 STREET
MAN	6 AVENUE	WEST 36 STREET
MAN	6 AVENUE	WEST 37 STREET
MAN	6 AVENUE	WEST 38 STREET
MAN	6 AVENUE	WEST 39 STREET
MAN	6 AVENUE	WEST 40 STREET
MAN	6 AVENUE	WEST 41 STREET
MAN	6 AVENUE	WEST 42 STREET
MAN	6 AVENUE	WEST 43 STREET
MAN	6 AVENUE	WEST 44 STREET
MAN	6 AVENUE	WEST 45 STREET
MAN	6 AVENUE	WEST 46 STREET
MAN	6 AVENUE	WEST 47 STREET
MAN	6 AVENUE	WEST 48 STREET

Borough	Main Street	Cross Street
MAN	6 AVENUE	WEST 49 STREET
MAN	6 AVENUE	WEST 50 STREET
MAN	6 AVENUE	WEST 51 STREET
MAN	6 AVENUE	WEST 52 STREET
MAN	6 AVENUE	WEST 53 STREET
MAN	6 AVENUE	WEST 54 STREET
MAN	6 AVENUE	WEST 55 STREET
MAN	6 AVENUE	WEST 56 STREET
MAN	6 AVENUE	WEST 57 STREET
MAN	6 AVENUE	WEST 58 STREET
MAN	6 AVENUE	CENTRAL PARK SOUTH/59 STREET

(Source: NYCDOT)

Table 27 lists the proposed RSU location on FDR Drive in Manhattan, and Table 28 lists the proposed RSU location on Flatbush Avenue in Brooklyn.

Table 27. RSU Locations on FDR Drive

Borough	Main Street	Cross Street
MAN	EAST END AVENUE	E 90 STREET
MAN	FDR DRIVE/YORK AVENUE	E 96 STREET
MAN	FDR DRIVE	E 81 STREET
MAN	FDR DRIVE	E 79 STREET
MAN	FDR DRIVE	E 53 STREET
MAN	FDR DRIVE	E 48 STREET
MAN	FDR DRIVE	E 63 STREET
MAN	FDR DRIVE	E 73 STREET

(Source: NYCDOT)

Table 28. RSU Locations on Flatbush Avenue

Borough	Main Street	Cross Street
BKN	FLATBUSH AVENUE	CONCORD STREET
BKN	FLATBUSH AVENUE	TILLARY STREET

Borough	Main Street	Cross Street
BKN	FLATBUSH AVENUE	TECH PLACE/JOHNSON ST
BKN	FLATBUSH AVENUE	MYRTLE AVENUE
BKN	FLATBUSH AVENUE	WILLOUGHBY STREET
BKN	FLATBUSH AVENUE	FLEET ST
BKN	FLATBUSH AVENUE	DE KALB AVENUE
BKN	FLATBUSH AVENUE	FULTON STREET/NEVINS STREET
BKN	FLATBUSH AVENUE	LIVINGSTON STREET
BKN	FLATBUSH AVENUE	LAFAYETTE AVENUE
BKN	FLATBUSH AVENUE	4 AVE
BKN	FLATBUSH AVENUE	ATLANTIC AVENUE
BKN	FLATBUSH AVENUE	PACIFIC STREET
BKN	FLATBUSH AVENUE	5 AVENUE
BKN	FLATBUSH AVENUE	DEAN STREET
BKN	FLATBUSH AVENUE	BERGEN STREET
BKN	FLATBUSH AVENUE	6 AVENUE
BKN	FLATBUSH AVENUE	ST MARKS AVENUE
BKN	FLATBUSH AVENUE	PROSPECT PLACE
BKN	FLATBUSH AVENUE	7 AVENUE
BKN	FLATBUSH AVENUE	PARK PLACE
BKN	FLATBUSH AVENUE	STERLING PLACE
BKN	FLATBUSH AVENUE	8 AVENUE
BKN	FLATBUSH AVENUE	PLAZA STREET/ST. JOHNS PLACE
BKN	FLATBUSH AVENUE	PROSPECT PARK WEST/UNION/PLAZA ST W
BKN	FLATBUSH AVENUE	VANDERBILT AVE
BKN	FLATBUSH AVENUE	VANDERBILT AVE/PEDESTRIAN CROSSING
BKN	FLATBUSH AVENUE	BETWEEN FLATBUSH AVE AND UNION ST

(Source: NYCDOT)

Tables 29 - 33 list the proposed RSU location on the cross-streets (14th, 23th, 34th, 42th, 57th) in Manhattan. The intersections crossing 1st, 2nd, 5th, or 6th avenues are omitted from these tables because they are already included in Tables 17 - 20.

Table 29. RSU Locations on 14 Street

Borough	Main Street	Cross Street
MAN	11 AVENUE	WEST 14 STREET
MAN	10 AVENUE	WEST 14 STREET
MAN	WASHINGTON STREET	WEST 14 STREET
MAN	9 AVENUE	WEST 14 STREET
MAN	8 AVENUE	WEST 14 STREET
MAN	7 AVENUE	WEST 14 STREET
MAN	UNIVERSITY PLACE	EAST 14 STREET
MAN	BROADWAY	EAST 14 STREET
MAN	4 AVENUE	EAST 14 STREET
MAN	IRVING PLACE	EAST 14 STREET
MAN	3 AVENUE	EAST 14 STREET
MAN	AVENUE A	EAST 14 STREET
MAN	AVENUE B	EAST 14 STREET
MAN	AVENUE C	EAST 14 STREET

(Source: NYCDOT)

Table 30. RSU Locations on 23 Street

Borough	Main Street	Cross Street
MAN	12 AVENUE	WEST 23 STREET
MAN	11 AVENUE	WEST 23 STREET
MAN	10 AVENUE	WEST 23 STREET
MAN	9 AVENUE	WEST 23 STREET
MAN	8 AVENUE	WEST 23 STREET
MAN	7 AVENUE	WEST 23 STREET
MAN	PED CROSSING BETWEEN 6 AVENUE AND 7 AVENUE	WEST 23 STREET
MAN	MADISON AVENUE	EAST 23 STREET
MAN	PARK AVENUE	EAST 23 STREET
MAN	LEXINGTON AVENUE	EAST 23 STREET
MAN	3 AVENUE	EAST 23 STREET
MAN	ASSER LEVY PLACE	EAST 23 STREET
MAN	FDR DRIVE	EAST 23 STREET

(Source: NYCDOT)

Table 31. RSU Locations on 34 Street

Borough	Main Street	Cross Street
MAN	12 AVENUE	WEST 34 STREET
MAN	11 AVENUE	WEST 34 STREET
MAN	HUDSON BOULEVARD EAST	WEST 34 STREET
MAN	10 AVENUE	WEST 34 STREET
MAN	DYER AVENUE	WEST 34 STREET
MAN	9 AVENUE	WEST 34 STREET
MAN	PED CROSSING BETWEEN 8 AVENUE AND 9 AVENUE	WEST 34 STREET
MAN	8 AVENUE	WEST 34 STREET
MAN	7 AVENUE	WEST 34 STREET
MAN	PED CROSSING BETWEEN 6 AVENUE AND 7 AVENUE	WEST 34 STREET
MAN	PED CROSSING BETWEEN 5 AVENUE AND 6 AVENUE	EAST 34 STREET
MAN	MADISON AVENUE	EAST 34 STREET
MAN	PARK AVENUE	EAST 34 STREET
MAN	LEXINGTON AVENUE	EAST 34 STREET
MAN	3 AVENUE	EAST 34 STREET
MAN	QUEENS-MIDTOWN TUNNEL EXIT	EAST 34 STREET
MAN	QUEENS-MIDTOWN TUNNEL ENTRANCE	EAST 34 STREET
MAN	FDR DRIVE	EAST 34 STREET

(Source: NYCDOT)

Table 32. RSU Locations on 42 Street

Borough	Main Street	Cross Street
MAN	12 AVENUE	WEST 42 STREET
MAN	11 AVENUE	WEST 42 STREET
MAN	10 AVENUE	WEST 42 STREET
MAN	DYER AVENUE	WEST 42 STREET
MAN	9 AVENUE	WEST 42 STREET
MAN	PED CROSSING BETWEEN 8 AVENUE AND 9 AVENUE	WEST 42 STREET
MAN	8 AVENUE	WEST 42 STREET

Borough	Main Street	Cross Street
MAN	PED CROSSING BETWEEN 7 AVENUE AND 8 AVENUE	WEST 42 STREET
MAN	7 AVENUE	WEST 42 STREET
MAN	BROADWAY	WEST 42 STREET
MAN	PED CROSSING BETWEEN 5 AVENUE AND 6 AVENUE	WEST 42 STREET
MAN	MADISON AVENUE	EAST 42 STREET
MAN	VANDERBILT AVENUE	EAST 42 STREET
MAN	PARK AVENUE	EAST 42 STREET
MAN	LEXINGTON AVENUE	EAST 42 STREET
MAN	3 AVENUE	EAST 42 STREET

(Source: NYCDOT)

Table 33. RSU Locations on 57 Street

Borough	Main Street	Cross Street
MAN	12 AVENUE	WEST 57 STREET
MAN	11 AVENUE	WEST 57 STREET
MAN	10 AVENUE	WEST 57 STREET
MAN	DYER AVENUE	WEST 57 STREET
MAN	9 AVENUE	WEST 57 STREET
MAN	PED CROSSING BETWEEN 8 AVENUE AND 9 AVENUE	WEST 57 STREET
MAN	8 AVENUE	WEST 57 STREET
MAN	BROADWAY	WEST 57 STREET
MAN	7 AVENUE	WEST 57 STREET
MAN	PED CROSSING BETWEEN 6 AVENUE AND 7 AVENUE	WEST 57 STREET
MAN	PED CROSSING BETWEEN 5 AVENUE AND 6 AVENUE	WEST 57 STREET
MAN	MADISON AVENUE	EAST 57 STREET
MAN	PARK AVENUE	EAST 57 STREET
MAN	LEXINGTON AVENUE	EAST 57 STREET
MAN	3 AVENUE	EAST 57 STREET
MAN	QUEENSBORO BRIDGE ENTRANCE	EAST 57 STREET
MAN	SUTTON PLACE	EAST 57 STREET

Table 34 below lists the proposed support sites for OTA device monitoring and firmware updates.

Table 34. Other RSU Locations

Borough	Main Street	Cross Street
MAN	MADISON AVENUE	EAST 56 STREET
MAN	MADISON AVENUE	EAST 55 STREET
MAN	7 AVE (ADAM C POWELL JR. BLVD)	EAST 55 STREET
MAN	7 AVE (ADAM C POWELL JR. BLVD)	EAST 56 STREET
QNS	47TH AVENUE	34TH STREET
MAN	CANAL STREET	BOWERY STREET
MAN	CANAL STREET	CHRYSTIE STREET
MAN	BROOKLYN BR ENTR	CENTRE ST/PED-CROSSING
MAN	CHAMBERS STREET	CENTRE STREET
MAN	Robert F. Wagner PL	PEARL STREET
MAN	PARK ROW	SPRUCE STREET
MAN	CANAL STREET	FORSYTH STREET
MAN	34 ST E	QNS MIDTOWN TUNNEL
MAN	QUEENS MIDTOWN TUNNEL EXIT	EAST 34 STREET
MAN	QUEENSBORO BRDG EXIT	57 ST E
QNS	QUEENS PLZ N	29 ST
QNS	QUEENS PLZ N	CRESCENT STREET
QNS	QUEENS PLZ N	21 ST
QNS	QUEENSBORO BRDG N RDWY	THOMSON AVENUE
QNS	QUEENS BLVD	VAN DAM ST
BKLN	Cadman Plz W	TILLARY STREET
BKLN	OLD FULTON STREET	HICKS STREET
BKLN	PEARL STREET	SANDS STREET
BKLN	ADAMS STREET	TILLARY STREET
BKLN	Cadman Plz E	PROSPECT STREET
BKLN	BROADWAY STREET	DRIGGS STREET
BKLN	HAVEMEYER STREET	SOUTH 5TH STREET
QNS	QUEENS BLVD	39 STREET
QNS	NORTHERN BOULEVARD	39 AVENUE
MAN	55 STREET	BETWEEN 5TH AND 6TH AVE
QNS	QUEENS BLVD	35TH STREET
QNS	CRESCENT STREET	41 AVENUE
QNS	QUEENS PLZ N	28 STREET
QNS	47TH AVENUE	35TH STREET
MAN	7 AVE (ADAM C POWELL JR. BLVD)	WEST 147 STREET
MAN	LENOX AVENUE (MALCOLM X BLVD)	WEST 146 STREET
MAN	BROADWAY	WEST 132 STREET

QNS	METROPOLITAN AVENUE	RENTAR PLAZA WEST EN
QNS	GRAND CENTRAL PKWY W/B S/R	94 STREET
BKLN	HAMILTON AV	14 ST
QNS	ASTORIA BLVD S (BQE EXIT)	BOODY STREET
MAN	12 AVENUE	WEST 133 STREET
MAN	2 AVENUE	EAST 126 STREET
MAN	2 AVENUE	EAST 125 STREET
QNS	METROPOLITAN AVENUE	RENTAR PLAZA EAST ET
BKLN	BROADWAY STREET	ROEBLING STREET
MAN	12 AVENUE	WEST 57 STREET
MAN	DELANCEY STREET	CLINTON STREET
QNS	57TH ROAD	59 STREET
QNS	NORTHERN BOULEVARD	31 STREET
MAN	11 AVENUE	WEST 40 STREET
QNS	QUEENS BLVD	SKILLMAN AVENUE
QNS	QUEENS BLVD	JACKSON AVE
MAN	LEXINGTON AVENUE	E 100 ST
QNS	MARINA RD	HARPER STREET
BKLN	SOUTH 4 STREET	ROEBLING STREET
MAN	8 AVE (FREDERICK DOUGLASS BLVD)	WEST 40 STREET
MAN	8 AVE (FREDERICK DOUGLASS BLVD)	WEST 41 STREET
QNS	QUEENS PLZ S	21 STREET
QNS	21ST	QUEENSBORO BRDG EXIT
QNS	CHARLIE CHOP SHOP	N/A
QNS	RADIO REPAIR SHOP	N/A
QNS	QUEENSBORO BRDG S RDWY	THOMSON AVENUE
MAN	1 AVENUE	EAST 125 STREET
MAN	1 AVENUE	96 STREET
MAN	MADISON AVENUE	EAST 49 STREET
MAN	MADISON AVENUE	EAST 50 STREET
MAN	MADISON AVENUE	EAST 51 STREET
MAN	MADISON AVENUE	EAST 52 STREET
MAN	MADISON AVENUE	EAST 53 STREET
MAN	MADISON AVENUE	EAST 54 STREET
MAN	MADISON AVENUE	EAST 43 STREET
MAN	MADISON AVENUE	EAST 41 STREET
MAN	MADISON AVENUE	EAST 58 STREET
MAN	MADISON AVENUE	EAST 59 STREET
MAN	MADISON AVENUE	EAST 60 STREET
MAN	MADISON AVENUE	EAST 61 STREET
MAN	MADISON AVENUE	EAST 62 STREET
MAN	MADISON AVENUE	EAST 63 STREET

MAN	MADISON AVENUE	EAST 64 STREET
MAN	MADISON AVENUE	EAST 65 STREET
MAN	MADISON AVENUE	EAST 66 STREET
MAN	MADISON AVENUE	EAST 67 STREET
MAN	YORK AVENUE	EAST 92 STREET
MAN	PLEASANT AVE	116 STREET
QNS	HOYT AV N	29 STREET
QNS	HOYT AV S	29 STREET
MAN	Harlem River Driveway	W 155 STREET
MAN	YORK AVE	E 70 ST
MOBILE	DOT VEHICLE	N/A
BKLN	JOHNSON STREET	JAY STREET
MAN	11 AVENUE	WEST 59 STREET
MAN	11 AVENUE	WEST 44 STREET
MAN	12 AVENUE	WEST 43 STREET
MAN	SPRING STREET	GREENWICH STREET
QNS	CONDUIT AV N	VAN WYCK EXPY W S/R
QNS	VAN WYCK EXPY E S/R	133 AV
QNS	LONG IS EXPY N S/R	VAN DAM ST
QNS	HORACE HARDING E/B S/R	GRAND CENTRAL PKWY W S/R
BKLN	BORINQUEN PL	MARCY AVENUE
QNS	23 AVENUE	85 STREET
MAN	DYER AVENUE	WEST 36 STREET
MAN	QUEENS MIDTOWN TUNNEL APPROACH	E 36 ST
MAN	BOWERY ST	BAYARD STREET
MAN	11 AVENUE	WEST 35 STREET
MAN	CANAL STREET	WASHINGTON STREET
MAN	3 AVENUE	EAST 59 STREET
Staten Island	RICHMOND TERRACE	WALL STREET
Staten Island	BAY STREET	RICHMOND TERRACE
BKLN	EMMONS AVENUE	KNAPP STREET
QNS	50TH AVENUE	21 STREET
MAN	MANHATTAN BRIDGE EXIT	CANAL STREET
MAN	VANDERBILT AVENUE	E 46 ST
MAN	8 AVE (FREDERICK DOUGLASS BLVD)	WEST 44 STREET
MAN	3 AVENUE	EAST 41 STREET
QNS	47TH AVENUE	VAN DAM STREET
MAN	9 AVENUE	WEST 38 STREET
MAN	9 AVENUE	WEST 41 STREET
QNS	21ST	41 AV

(Source: NYCDOT)

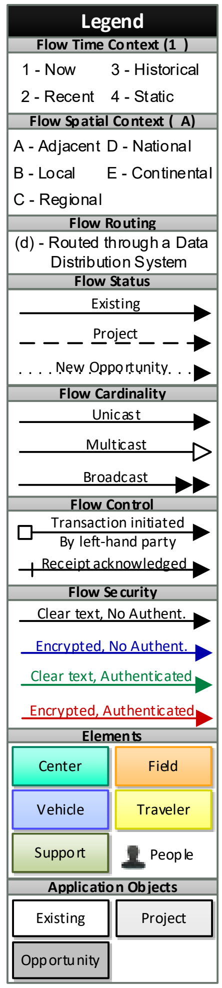
Table 35 below lists the ten (10) priority intersections proposed for testing the pedestrian application and installing new pedestrian detection.

Table 35. Proposed Priority Sites for Pedestrian Detection

Borough	Main Street	Cross Street
MAN	5 AVENUE	EAST 14 STREET
MAN	5 AVENUE /BROADWAY	WEST 23 STREET
MAN	6 AVENUE	WEST 14 STREET
MAN	6 AVENUE	WEST 23 STREET
MAN	6 AVENUE / BROADWAY	WEST 34 STREET
MAN	7 AVENUE	WEST 23 STREET
MAN	9 AVENUE	WEST 23 STREET
MAN	PARK AVENUE	EAST 57 STREET
BKN	FLATBUSH AVENUE	WILLOUGHBY STREET
BKN	FLATBUSH AVENUE	ATLANTIC AVENUE

Appendix C Physical View Legend

The legend in Figure 19 includes the definitions of the physical interconnects, the lines between the elements, shown in the Layer 0 diagrams in Section 5.3.1.



Source: NYCDOT

Figure 19. Physical View Legend

Each interconnect in Layer 0 or 1 includes a set of defining characteristics. These characteristics are described in the Table 36 below.

Table 36. Physical/Application Interconnect Characteristics

Interconnect Characteristics	Values	Characteristic Value Description	Graphic Appearance
Encryption	True	Information flows on this interconnect must be encrypted	Red, if Authenticability is also True; Blue if Authenticability is False
	False	Information flow encryption is not required	Black, if Authenticability is also False; Green if Authenticability is True
Authenticability	True	Information flows on this interconnect must include a digital signature (signed certificate credential)	Red, if Encryption is also True; Green if Encryption is False
	False	Information flow signature is not required	Black, if Encryption is also False; Blue if Encryption is True
Cardinality	Broadcast	Information flows on this interconnect are sent to all potential recipients that are within range	Double, filled arrowheads on the destination
	Multicast	Information is sent to multiple specific recipients	Single, open arrowhead on the destination
	Unicast	Information is sent to a single specific recipient	Single, filled arrowhead on the destination
Bidirectional	Yes	Information flows on this interconnect may flow in either direction	Arrowheads on both the source and destination end
	No	Information flows on this interconnect flow in one direction only	Arrowheads on the destination end
Status	Existing	Information flows on this interconnect are deployed today	Solid line
	Project	Information flows are going to be developed and deployed as part of this New York City (NYC) Connected Vehicle Pilot Deployment (CVPD)	Dashed line
	New Opportunity	Information flows on this interconnect are not planned currently but may be part of a future deployment	Dotted line

Glossary

The following table defines selected project-specific terms used throughout this Concept of Operations document.

Glossary of Terms

Term	Definition
Access Control	Refers to mechanisms and policies that restrict access to computer resources. An access control list (ACL), for example, specifies what operations different users can perform on specific files and directories.
Adjacent (A)	Data that is hyper local (relevant to a geographic area within approximately 1 minute travel distance).
Administrator	These are the operators that set control parameters, implement system policies, monitor system configuration, and make changes to the system as needed.
Aggregation	The process of combining data elements of similar format into a single data element that is a statistical representation of the original elements.
Analysis	The process of studying a system by partitioning the system into parts (functions, components, or objects) and determining how the parts relate to each other.
Anonymity	Lacking individuality, distinction, and recognizability within message exchanges.
Anonymous Certificate	A certificate which contains a pseudonym of the System User instead of his real identity in the subject of the certificate and thus prevents other System Users from identifying the certificate owner when the certificate is used to sign or encrypt a message in the connected vehicle program. The real identity of the anonymous certificates can be traced by Authorized System Operators by using the services of Registration Authority and Certification Authority.
APDU	Application Protocol Data Unit. This is a defined data structure that is transferred at a peer level between two applications.
Application	One or more pieces of software designed to perform some specific function; it is a configuration of interacting Engineering Objects. A computer software program with an interface, enabling people to use a computer as a tool to accomplish a specific task.
Application User	A user who interfaces with Application Layer software for a desired function or feature.

Term	Definition
Assumption	A judgment about unknown factors and the future which is made in analyzing alternative courses of action.
Authenticate	The process of ensuring that an APDU originated from a source identified within the message.
Authenticate-ability	The ability of the receiver of information to authenticate the sender's identity or trustworthiness to send data within the domain. If required, this can be accomplished by verifying the incoming message has been digitally signed by the sender.
Authentication	The process of determining the identity of a user that is attempting to access a network.
Authenticity	The quality of being genuine or authentic; which is to have the origin supported by unquestionable evidence; authenticated; verified. This includes whether the software or hardware came from an authorized source.
Authorization	The process of determining what types of activities or access are permitted on a network. Usually used in the context of authentication: once you have authenticated a user, they may be authorized to have access to a specific service.
Available	Ready or able to be used.
Backup	The ability of one System Element replacing another System Element's functionality upon the failure of that System Element.
Bad Actor	A role played by a user or another system that provides false or misleading data, operates in such a fashion as to impede other users, operates outside of its authorized scope.
Boundaries	The area of management and control for a System or Object. It could be by latitude/longitude or by county or by regional jurisdictions.
Broadcast	A flow where the initiator sends information on a predefined communications channel using a protocol that enables others who know how to listen to that channel to receive the information. One-to-many communication, with no dialog.
Cardinality	The characterization of the relationship between the number of sender(s) and receiver(s) of a data exchange. (e.g., broadcast (one-to-many) unicast (one to one)).
Center	An entity that provides application, management, administrative, and support functions from a fixed location not in proximity to the road network. The terms back office and center are used interchangeably. Center is traditionally a transportation-focused term, evoking management centers to support transportation needs, while back office generally refers to commercial applications. From the perspective of this ConOps Specification these are considered the same.
Concept of Operations (ConOps)	A user-oriented document that describes a system's operational characteristics from the end user's viewpoint.

Term	Definition
Confidentiality	The property of being unable to read PDU contents by any listener that is not the intended receiver.
Configurable Parameter	Non-static data that can be adjustable and updated when needed.
Configuration	Data that is used to customize the operational environment for a System Element or System User, or the System as a whole.
Configure	The process of selecting from a set of option(s) or alternative values in order to create a specific operational environment.
Constraint	An externally imposed limitation on system requirements, design, or implementation or on the process used to develop or modify a system. A constraint is a factor that lies outside – but has a direct impact on – a system design effort. Constraints may relate to laws and regulations or technological, socio-political, financial, or operational factors.
Continental (C)	Data that is continental in scope.
Contract	In project management, a legally binding document agreed upon by the customer and the hardware or software developer or supplier; includes the technical, organizational, cost, and/or scheduling requirements of a project.
Control	To exercise influence over.
Coverage Area	A geographic jurisdiction within which the System provides services.
Cyber Address	The cyber or network address of a Unified Implementation of the Reference Architecture object.
Data Consumer	A user or system that is receiving or using data from another user or system. Any Unified Implementation of the Reference Architecture object that registers with and subsequently requests and receives delivery of data from a data warehouse.
Data Provider	Any Unified Implementation of the Reference Architecture object that registers with and subsequently deposits data into a data warehouse. A System User that is supplying or transmitting data to another user or system. A data provider is likely to be an aggregator of data.
Data Warehouse	A data storage facility that supports the input (deposit) and retrieval (delivery) of clearly defined data objects. This can be designed and implemented in a variety of ways, including publish/subscribe and a traditional query based database.
Decrypt	To decode or decipher data that has previously been encoded in such a way to secure its contents from unauthorized access. See Encryption.
Deployment Benefits	This term refers to the measures of effectiveness used by the NYCDOT and the Independent Evaluator on a periodic basis to assess the benefits realized from the utilization of connected vehicle technology and applications within the project's deployment areas.

Term	Definition
Digital Certificate or Signature	A digital certificate is an electronic identification card that establishes your credentials when doing business or other transactions on the Web. It is issued by a certification authority. It contains your name, a serial number, expiration dates, a copy of the certificate holder's public key (used for encrypting messages and digital signatures), and the digital signature of the certificate-issuing authority so that a recipient can verify that the certificate is real. Note: From the SysAdmin, Audit, Network, Security Institute - www.sans.org website.
DNS (Domain Name System)	The internet protocol for mapping host names, domain names, and aliases to IP addresses.
Encryption	Scrambling data in such a way that it can only be unscrambled through the application of the correct cryptographic key.
End-User	The ultimate user of a product or service, especially of a computer system, application, or network.
Environment	The circumstances, objects, and conditions that surround a system to be built; includes technical, political, commercial, cultural, organizational, and physical influences as well as standards and policies that govern what a system must do or how it will do it.
Extensibility	The ability to add or modify functionality or features with little or no design changes.
Field	These are intelligent infrastructure distributed near or along the transportation network which perform surveillance (e.g., traffic detectors, cameras), traffic control (e.g., signal controllers), information provision (e.g., dynamic message signs (DMS)) and local transaction (e.g., tolling, parking) functions. Typically, their operation is governed by transportation management functions running in back offices. Field also includes RSU and other non-DSRC wireless communications infrastructure that provides communications between Mobile elements and fixed infrastructure.
Forwarding	The process of forward sending data onto another entity (system user) without modifying or storing the data for any substantial length of time.
Functionality	The capabilities of the various computational, user interfaces, input, output, data management, and other features provided by a product.
Geo-Fence	An electronic set of geo reference points that form a bounded geographic region.
Geo-Referencing	The process of scaling, rotating, translating and de-skewing the image to match a particular size and position. To define something in terms of its physical location in space.
Hardware	Hardware refers to the physical parts of a computer and related devices. Internal hardware devices include motherboards, hard drives, and memory. External hardware devices include monitors, keyboards, mice, printers, and scanners.

Term	Definition
Hardware	Hardware refers to the physical parts of a computer and related devices. Internal hardware devices include motherboards, hard drives, and memory. External hardware devices include monitors, keyboards, mice, printers, and scanners.
Historic (H)	Transient Data that is historical (relevant at the time of reporting for an indefinite interval).
Identity Certificate	A certificate that uses a digital signature to bind a public key with an identity - information such as the name of a person or an organization, their address, and so forth. The certificate can be used to verify that a public key belongs to an individual.
Integrity	To maintain a system that is secure, complete, and conforming to an acceptable conduct without being vulnerable and corruptible. The property of being certain that a message's contents are the same at the receiver as at the sender.
Interconnect	The communications link between two architectural objects.
Internet	An interconnected system of networks that connects computers around the world via the TCP/IP protocol.
Issuance	For Anonymous Certificates: Blocks of certificates for a System User which are generated by the Certificate Authority (CA) with mappings between the System User's real identity and the pseudo-identity in the certificates are maintained by the Registration Authority (RA). For Identity Certificates: Blocks of certificates for a System User which are generated by the Certificate Authority (CA) with information such as the name of a person or an organization, their address, etc., maintained by the Registration Authority (RA). Both certificates are installed in the System User equipment by online (through a communication channel with encrypted communications) or offline (mechanisms such as USB download) mechanisms.
Jurisdictional Scope	The power, right, or authority to interpret and apply the law within the limits or territory which authority may be exercised.
Link	A Link is the locus of relations among Nodes. It provides interconnections between Nodes for communication and coordination. It may be implemented by a wired connection or with some radio frequency (RF) or optical communications media. Links implement the primary function of transporting data. Links connect to Nodes at a Port.
Local (L)	Data that is local (relevant to a geographic area within 10 minute travel distance).
Logical Security	Safeguards that include user identification and password access, authentication, access rights and authority levels.
Misbehaving User	A user who exhibits misbehavior.

Term	Definition
Misbehavior	The act of providing false or misleading data, operating in such a fashion as to impede other users, or to operate outside of their authorized scope. This includes suspicions behavior as in wrong message types or frequencies, invalid logins and unauthorized access, or incorrect signed or encrypted messages. etc.; either purposeful or unintended.
Misbehavior Information	Includes Misbehavior Reports from System Users, as well as other improper System User acts, such as sending wrong message types, invalid logins, unauthorized access, incorrectly signed messages, and other inappropriate System User behavior.
Misbehavior Report	Data from a System User identifying suspicious behavior from another System User that can be characterized as misbehavior.
Mobile	These are vehicle types (private/personal, trucks, transit, emergency, commercial, maintenance, and construction vehicles) as well as non-vehicle-based platforms including portable personal devices (smartphones, PDAs, tablets, etc.) used by travelers (vehicle operators, passengers, cyclists, pedestrians, etc.) to provide and receive transportation information.
National (N)	Data that is national in scope.
Non-repudiation	The property whereby a PDU is constructed in such a way that the PDU sender cannot effectively deny having been the sender of that PDU; and the PDU receiver cannot effectively deny having received a particular PDU.
Now (N)	Transient Data that is hyper current (relevant at the time of reporting for applications that require sub-second response).
On-Board Equipment (OBE)	Computer modules, display and a DSRC radio, that is installed and embedded into vehicles which provide an interface to vehicular sensors, as well as a wireless communication interface to the roadside and back office environment.
Operational Data Environment	The ODE consist of several different USDOT developed smart data routers brokering processed data between various data sources, including the Unified Implementation of the Reference Architecture, and a variety of data users (e.g., Research Data Exchange (RDE), TMCs). As a smart data router, the ODE routes data from disparate data sources to software applications (including CV applications) that have placed data subscription requests to the ODE. The ODE also performs necessary security / credential checks and, as needed, data valuation, aggregation, integration and propagation functions.
Operators	These are the day-to-day users of the System that monitor the health of the system components, adjust parameters to improve performance, and collect and report statistics of the overall system.
Permission	Authorization granted to do something. From the System’s perspective, permissions are granted to System Users and Operators determining what actions they are allowed to take when interacting with the System.

Term	Definition
Persistent Connection	A connection between two networked devices that remains open after the initial request is completed, to handle multiple requests thereafter. This reduces resource overhead of re-establishing connections for each message sent and received. This is opposite of Session-oriented Connection.
Physical Security	Safeguards to deny access to unauthorized personnel (including attackers or even accidental intruders) from physically accessing a building, facility, resource, or stored information. This can range from simply a locked door to badge entry, with armed security guards.
Priority	A rank order of status, activities, or tasks. Priority is particularly important when resources are limited.
Privacy	The ability of an individual to seclude information about themselves, and thereby reveal information about themselves selectively.
Process	A series of actions, changes, or functions bringing about a result.
Protocol Data Unit (PDU)	A defined data structure that is transferred at a peer level between corresponding software entities functioning at the same layer in the OSI standard model which are operating on different computing platforms that are interconnected via communications media.
Public Key	In cryptography, a public key is a value provided by some designated authority as an encryption key that, combined with a private key derived from the public key, can be used to effectively encrypt messages and digitally sign them. The use of combined public and private keys is known as asymmetric cryptography. A system for using public keys is called a public key infrastructure (PKI).
Recent (R)	Transient Data that is current (relevant at the time of reporting for applications that do not require sub-second response).
Registry	A repository for maintaining data requester's information including the type of data they are subscribing to, their address, etc.
Reliability	Providing consistent and dependable system output or results.
Repackage Data	Data that is broken down for aggregation, parsing, or sampling.
Research Data Exchange	A web-based data resource provided by the USDOT ITS-JPO's Real-Time Data Capture and Management (DCM) program which collects, manages, and provides archived and real-time multi-source and multi-modal data to support the development and testing of ITS applications.
Scalability	The capability of being easily grown, expanded or upgraded upon demand without requiring a redesign.
Scenario	A step-by-step description of a series of events that may occur concurrently or sequentially.
Secure Storage	Encrypted or protected data that requires a user or a process to authenticate itself before accessing to the data. Secure storage persists when the power is turned off.

Term	Definition
Secure Transmission	To protect the transfer of confidential or sensitive data usually by encryption, Secure Sockets Layer (SSL), Hypertext Transfer Protocol Secure (HTTPS) or similar secure communications.
Secure/Securely	Referring to storage, which consists of both logical and physical safeguards.
Session-oriented Connection	A connection between two networked devices that is established intermittently and to handle few requests thereafter. The connection is meant to be temporary lasting for minutes, hours, but likely not more than a day before it is closed. This is opposite of Persistent Connection.
Software	Software is a general term that describes computer programs. Terms such as software programs, applications, scripts, and instruction sets all fall under the category of computer software.
States	A distinct system setting in which the same user input will produce different results than it would in other settings. The System as a whole is always in one state. A state is typically commanded or placed in that state by an operator. States are Installation, Operational, Maintenance, Training, and Standby.
Static (S)	Data that is permanent (relevant at the time of reporting for an indefinite interval).
Status	Anomalies, actions, intermittent and other conditions used to inform the System Operator for reparation or maintenance.
Subsystem	An integrated set of components that accomplish a clearly distinguishable set of functions with similar or related uses.
Synchronization	The act or results of occurrence or operating at the same time or rate.
System	(A) A collection of interacting elements organized to accomplish a specified function or set of functions within a specified environment. Typically the System Elements within the System are operationally self- contained but are interconnected and collaborate to meet the needs of the System and its Users. (B) A group of people, objects, and procedures constituted to achieve defined objectives of some operational role by performing specified functions. A complete system includes all of the associated equipment, facilities, material, computer programs, firmware, technical documentation, services, and personnel required for operations and support to the degree necessary for self-sufficient use in its intended environment.
System Element	(A) A collection of interacting components organized to accomplish a specified function or set of functions within a specified environment. (B) An object and procedures constituted to achieve defined objectives of some operational role by performing specified functions. A complete system element includes all of the associated equipment, facilities, material, computer programs, firmware, technical documentation, services, and personnel required for operations and support to the degree necessary for self-sufficient use in its intended environment. An integrated set of components that accomplish a clearly distinguishable set of functions with similar or related uses.

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

The following table defines selected project-specific acronyms used throughout this Concept of Operations document.

Acronym List

Acronym / Abbreviation	Definition
4G	Fourth Generation
AADT	Annual Average Daily Traffic
ACDSS	Adaptive Control Decision Support System
ACL	Access Control List
APDU	Application Protocol Data Unit
ASD	Aftermarket Safety Device
ASTC	Advanced Solid-state Traffic Controller (NYC standard traffic signal controller device)
ATC	Advance Traffic Controller (see ASTC)
BAA	Broad Agency Announcement
BSM	Basic Safety Message
CA	Certificate Authority
CAMP	Crash Avoidance Metrics Partnership
CAN	Controller Area Network
CCMS	Cooperative ITS Credentials Management System
ConOps	Concept of Operations
CRL	Certificate Revocation List
CV	Connected Vehicle
CVPD	Connected Vehicle Pilot Deployment
CVRIA	Connected Vehicle Reference Implementation Architecture
DDS	Data Distribution System
DNS	Domain Name System
DSNY	New York City Department of Sanitation
DOT	Department of Transportation
DoITT	Department of Information Technology and Telecommunications
DSRC	Dedicated Short Range Communications
FDR Drive	Franklin D. Roosevelt Drive
FOIA	Freedom of Information Act
GHz	Gigahertz
GNSS	Global Navigation Satellite System

Acronym / Abbreviation	Definition
GPS	Global Positioning System
HSM	Hardware Security Module
HTTPS	Hypertext Transfer Protocol (Secured)
I2V	Infrastructure to Vehicle
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
ITS	Intelligent Transportation System
JPO	Joint Program office
KSI	Killed or Severally Injured
LCA	Lane Change Warning/Assist
MAP	Map Data Message (a DSRC message)
MIM	Midtown in Motion
MOA	Memorandum of Agreement
MOU	Memorandum of Understanding
MPH	Miles Per Hour
MTA	Metropolitan Transportation Authority
MTM	Manhattan Traffic Model
NHTSA	National Highway Traffic Safety Administration
NTS	Network Time Source
NWS	National Weather Service
NYC	New York City
NYCDOT	New York City Department of Transportation
NYCWiN	New York City Wireless Network
NYSDOT	New York State Department of Transportation
OBD	On-Board Diagnostics
OBE	On-Board Equipment
OEM	Office of Emergency Management
OER	Office of Emergency Response
ORDS	Object Registration & Recovery Service
OTA	Over-the-Air
OVC	Oversize Vehicle Compliance
PDU	Protocol Data Unit

Acronym / Abbreviation	Definition
PID	Personal Information Device (e.g., mobile device)
PII	Personally Identifiable Information
PKI	Public Key Infrastructure
RA	Registration Authority
RDE	Research Data Exchange
RF	Radio Frequency
RSA	Roadside Alert
RSE	Roadside Equipment
RSU	Roadside Unit
RTOR	Right-Turn-On-Red
SAE	Society of Automotive Engineers International
SCMS	Security Credential Management System/Service
SMS	Service Monitor System
SPaT	Signal Phase and Timing (a DSRC message)
SSL	Secure Sockets Layer
TBD	To Be Determined
TCP	Transmission Control Protocol
TIM	Traveler Information Message
TLC	New York City Taxi & Limousine Commission
TMC	Traffic Management Center
TTI	Texas Transportation Institute
UPS	United Parcel Service
USDOT	United States Department of Transportation
V2I (I2V)	Vehicle-to-Infrastructure (Infrastructure-to-Vehicle)
V2V	Vehicle-to-Vehicle
VRU	Vulnerable Road User
WAID	Wide Area Information Distributor
WAVE	Wireless Access in Vehicular Environments
WSA	WAVE Service Advertisement

As-Built Addendum

This section highlights changes made to the overall ConOps due to the final deployment and the schedule of activity. Elements within this section supersede portions of the document not altered to reflect the details of the changes.

a. The architecture diagram (Figure 15) shows that the PID will receive the SPaT and MAP information over a DSRC or local short range communications media. While a number of vendors had indicated that they could supply smart phones with DSRC capability, when the project attempted to pursue the use of such devices, they were no longer available. An alternate approach was used where the traffic controller (ASTC) sends the SPaT information to the TMC on a change driven basis and the MAP database is maintained at the TMC. The MAP data and the SPaT data are then transmitted to an Amazon Cloud (AWS) where it is processed and distributed using cellular service to the smartphones for use with the PID application. This same data flow (2A) shown in Figure 4 is now provided from the AWS cloud using a cellular service rather than directly to the PID using DSRC.

b. The PID application to assist the visually impaired pedestrian at CV equipped intersections has changed significantly. The SPaT information is received from the ASTC, combined with the MAP information stored at the TMC and sent to the AWS cloud where the SmartCross application process the data and distributes it to the appropriate PID using a cellular service. The data is then collected and exported to the NYU data collection system where it is evaluated. Instead of distributing PIDs to the user community for testing/trials and evaluation, the 10 prototypes will be used with selected participants who will test/trial the PID application in a protected and assisted environment. Evaluation of the preliminary results indicated that the application was not robust enough to be distributed without supervision in a protected environment. The detailed design is provided in a separate document. Section 5.3.9 has been updated accordingly. In addition, the PID will not be enrolled with the SCMS as previously described.

c. Note that the communications between the TMC and the RSU uses 2 different protocols: SNMPv3 for management of the MIB objects supported by the RSU, and XFER a proprietary protocol developed by the RSU vendor for uploading and downloading files used for data collection, and RSU configuration. It should be noted that NTCIP 1218 had not been developed at the time of this project, and it was necessary to utilize the vendor's protocol to support these exchanges. The vendor has made this protocol readily and publicly available without restriction for use with their RSUs.

d. While there is some discussion of the use of UPS participation and the participation of the Taxi fleets/owners, both of these did not become active participants in the project, The fleet is primarily composed of various City fleets including DCAS, Parks, DOT, Department of Corrections (DOC), Department of Environmental Protection (DEP), Department of Health Services (DHS), and other service fleets operated by NYC. The City fleets are generally equipped with Geotab devices which monitors their general usage; this data has been available to the CVPD project to determine the general routes and locations frequented by the City fleets participating in the CVPD project. This data will be used to evaluate the accuracy of the data collected and to assist the project in monitoring the health of the CV equipped vehicles.

e. The HSM is a rack-mountable appliance installed at the TMC to expand TMC operations with direct-to-vehicle messaging over latest V2X network technology. Traveler Information, MAP, and other infrastructure messages are inspected and digitally signed to prevent hacking so TMC messages can be trusted. The HSM authenticates incoming messages and signs certificates for outgoing messages to and from the TMC. The HSM inspects and formats TMC messages for acceptance by V2X networked devices. Installed RSUs and ASDs do not require any additional components. In addition to the NYCDOT TMC back-office management functions, the HSM has been critical for maintaining the security of the data being transmitted. Also known as the TMC Authority, provides complete support for IEEE 1609.2 algorithms and protocols including SAE J2735, and J2945/x. It also provides FIPS 140-2 Level 3 protection for V2X signing keys. The TMC Authority checks and digitally signs traffic management center messages for instant verification and acceptance, compliant with IEEE 1609.2 standards and cryptography. Data is secured inside and out with FIPS 140-2 Level 3 protection of keys and TLS v1.2 tunnels to TMC servers. High availability network failover is standard, including redundant power supplies and storage; the TMC Authority maintains trusted reliable operation, even in untrusted environments.

f. Achieving location augmentation has been critical especially in the urban canyon parts of the NYC CV Pilot area. To improve location accuracy for the DSRC devices in the NYC CV project, using the DSRC Radio Technical Commission for Maritime (RTCM) was considered first. As defined in SAE J2735, the RTCM messages would be transmitted along with the other DSRC messages over channel 172. However, the V2XLocate technology was chosen instead after multiple tests and demonstrations in the Manhattan grid section of the NYC CV pilot area.

g. The previous total vehicle count of 8,000 has been updated to 3,000 in Sections 1.3 and 3.5.

h. The total number of RSUs has been updated from 353 to 450. Table 34. Other RSU Locations has also been updated.

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