U.S. Department of Transportation
Office of the Assistant Secretary for Research and Technology

Planning for Connected Vehicles

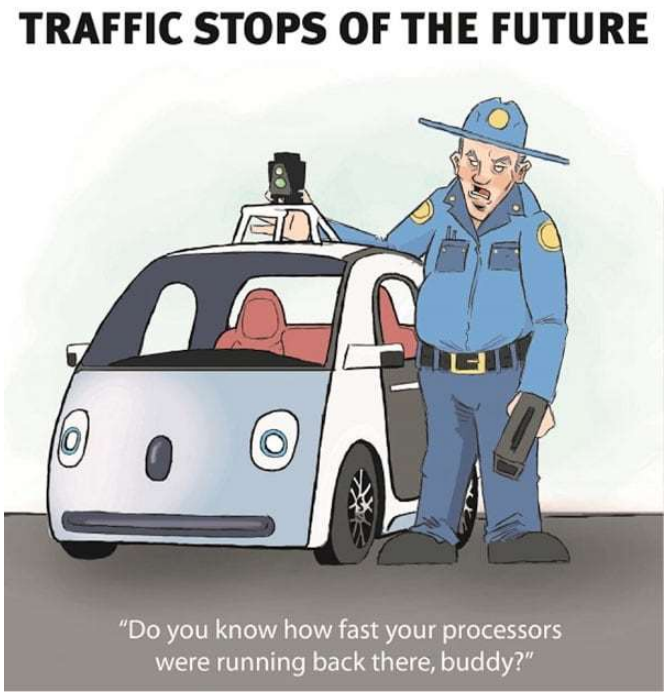
2017 AMPO Annual Conference

October 17, 2017

Elina Zlotchenko
Intelligent Transportation Systems Joint Program Office

OVERVIEW

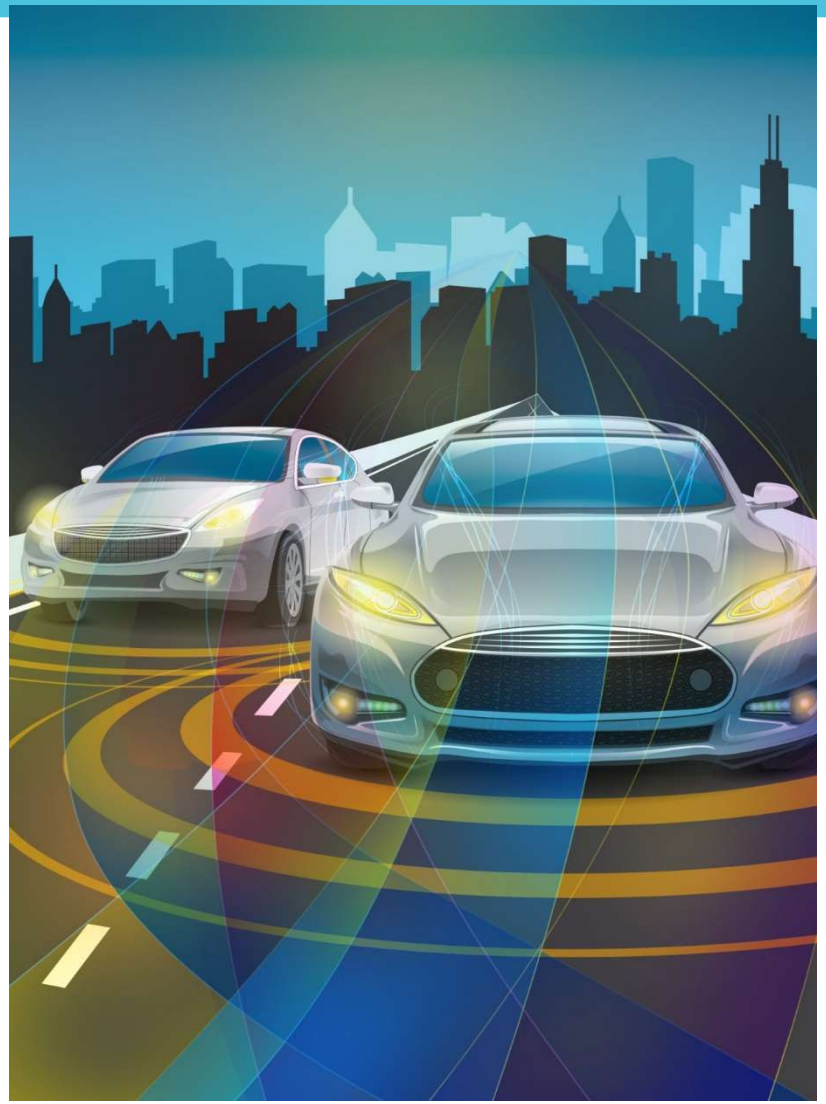
- Connected Vehicles
  - Basic Connected Vehicle Concepts
- Connected Vehicles Pilot Deployment Program Overview
  - Program Goals
  - Organizing Principles
  - Deployment Requirements
  - Deployment Schedule
- Overview of CV Pilot Program Award Sites
  - Wyoming DOT (WYDOT) CV Pilot Deployment
  - New York City (NYC) DOT CV Pilot Deployment
  - Tampa (THEA) CV Pilot Deployment
- Planning for Connected Vehicles
  - Planning considerations for connected vehicles



Connected Vehicles

How Connected Vehicles Work

- A wireless device in a car sends basic safety messages 10 times per second
- Other nearby cars and roadside equipment receive the messages
- Drivers get a warning of a potential crash



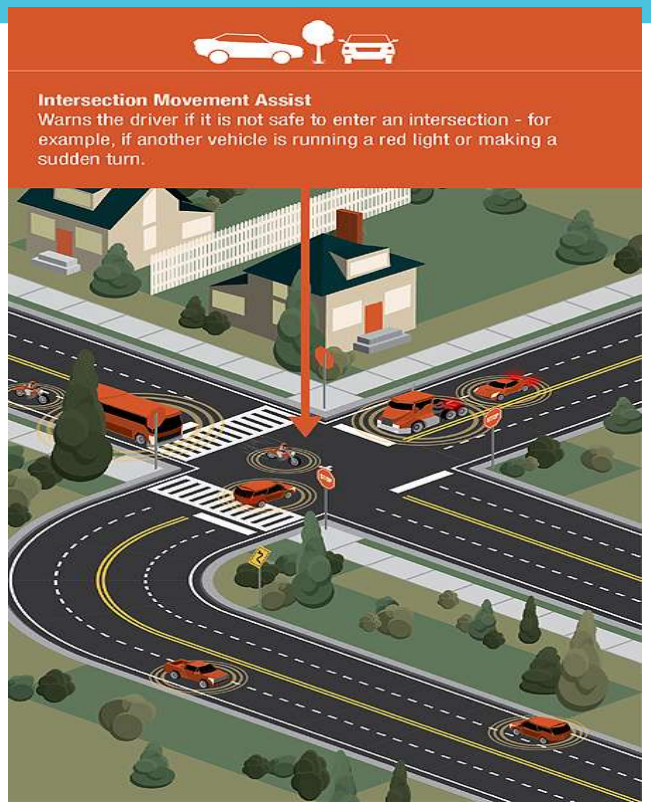
*Connected vehicles have the potential to reduce non-impaired crash scenarios by **80%****

*Source: NHTSA

Connected Vehicles

Intersection Movement Assist:

Warns the driver when it is not safe to enter an intersection—for example, when something is blocking the driver's view of opposing or crossing traffic



Queue Warning and Speed Harmonization:

Warns drivers of upcoming congestion and provides speed recommendations

Eco Approach and Departure at Signalized Intersections:

Presents information to drivers about traffic signal timing, allowing drivers to adapt their speed to pass the signal on green or decrease speed to a stop in the most eco-friendly way possible.

Autonomous Vehicles

Autonomous & Driverless Vehicles:

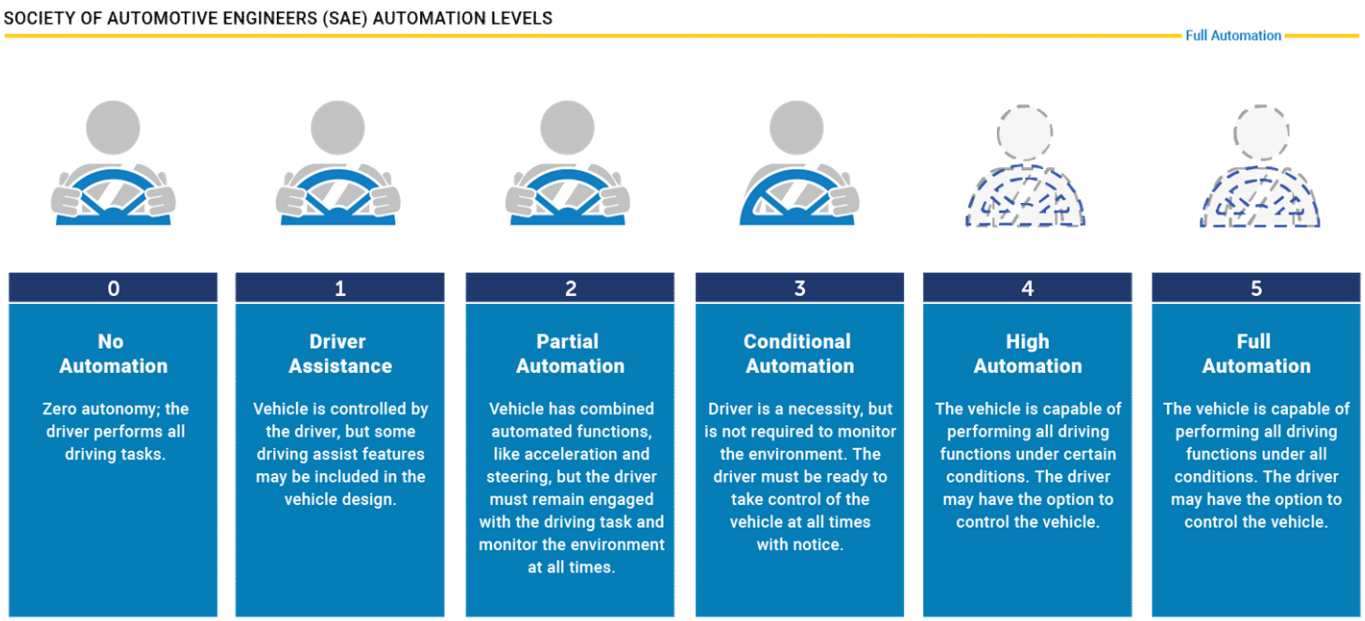
- Array of sensors to detect other vehicles and obstacles
- Requires Detailed map
- Use machine learning to make software smarter
- Doesn't rely on communication with other vehicles

Google's automated vehicle

Autonomous Vehicles

Automation builds off current driver assistance technologies such as adaptive cruise control, lane departure warning and left turn assist

- NHTSA adopt SAE 6 levels of automation
- Level 0,1, and 2 vehicles are on the road today



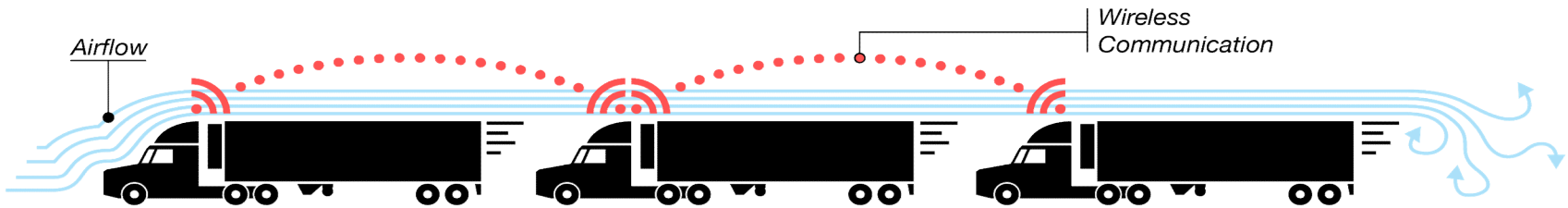
Connected Automated Vehicles

Greatest benefits come from both together. In addition to safety benefits, there are estimated mobility and economic impacts:

- Crash reduction
- Capacity increases in current roadway systems
- Cost savings running through many industries, possibly starting with freight
- The potential for disruption is enormous

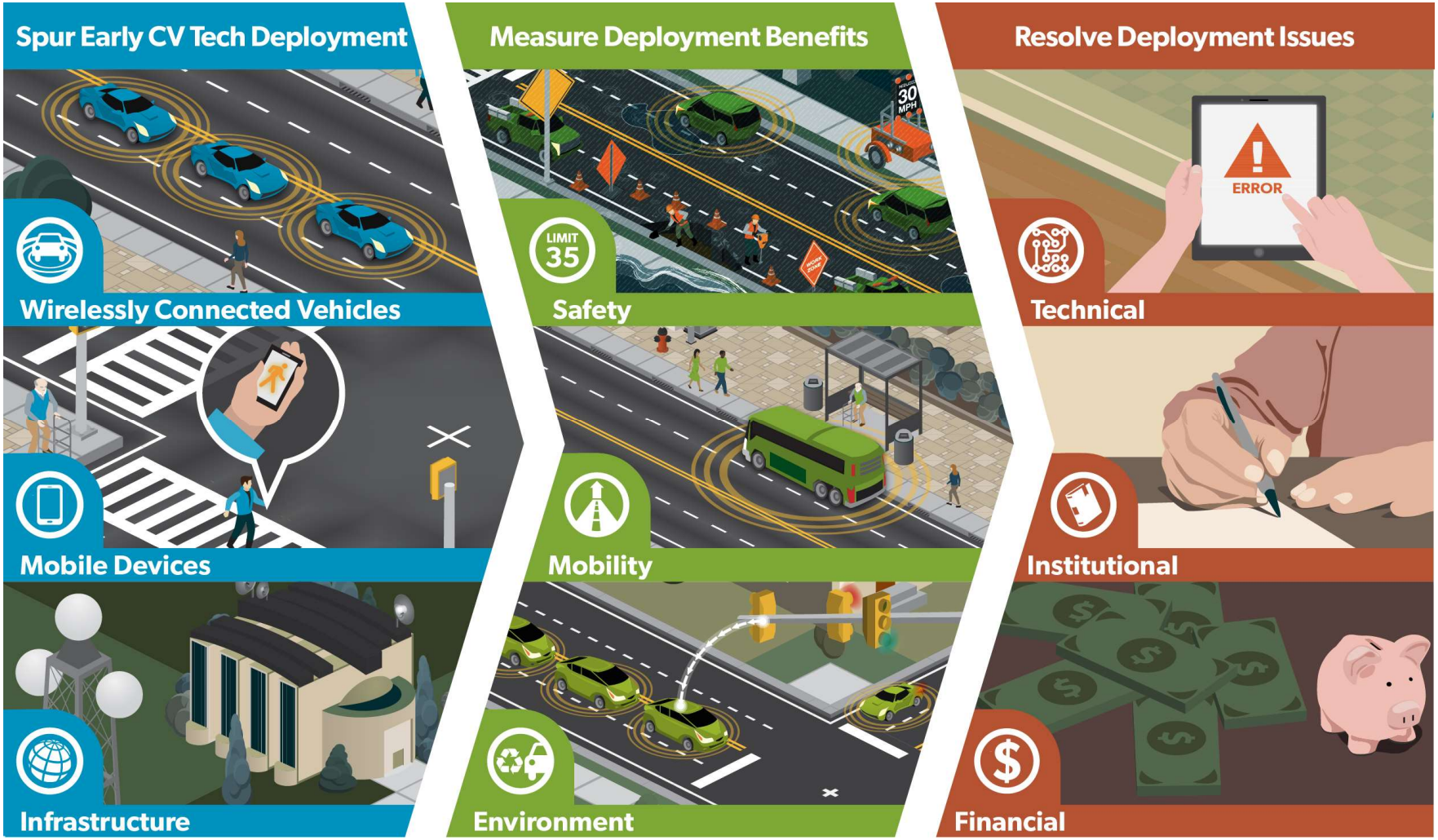
With Platooning

Automatic control means shorter gaps are possible without compromising safety.

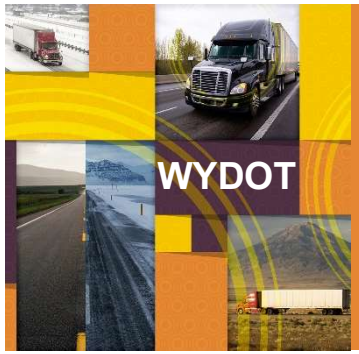


However, empirical data are needed to more accurately assess the safety, fuel consumption, capacity, and emissions impacts of this CV application.

CV Pilot Deployment Program Goals



THE THREE PILOT SITES



- Reduce the number and severity of adverse weather-related incidents in the I-80 Corridor in order to improve safety and reduce incident-related delays.
- Focused on the needs of commercial vehicle operators in the State of Wyoming.

- Improve safety and mobility of travelers in New York City through connected vehicle technologies.
- Vehicle to vehicle (V2V) technology installed in up to 8,000 vehicles in Midtown Manhattan, and vehicle to infrastructure (V2I) technology installed along high-accident rate arterials in Manhattan and Central Brooklyn.

- Alleviate congestion and improve safety during morning commuting hours.
- Deploy a variety of connected vehicle technologies on and in the vicinity of reversible express lanes and three major arterials in downtown Tampa to solve the transportation challenges.

CV Pilot Organizing Principles

- CV Pilots are *pilot deployments*, that is, real-world environment deployments
  - The successful, deployed technologies are expected to remain as permanent operational elements

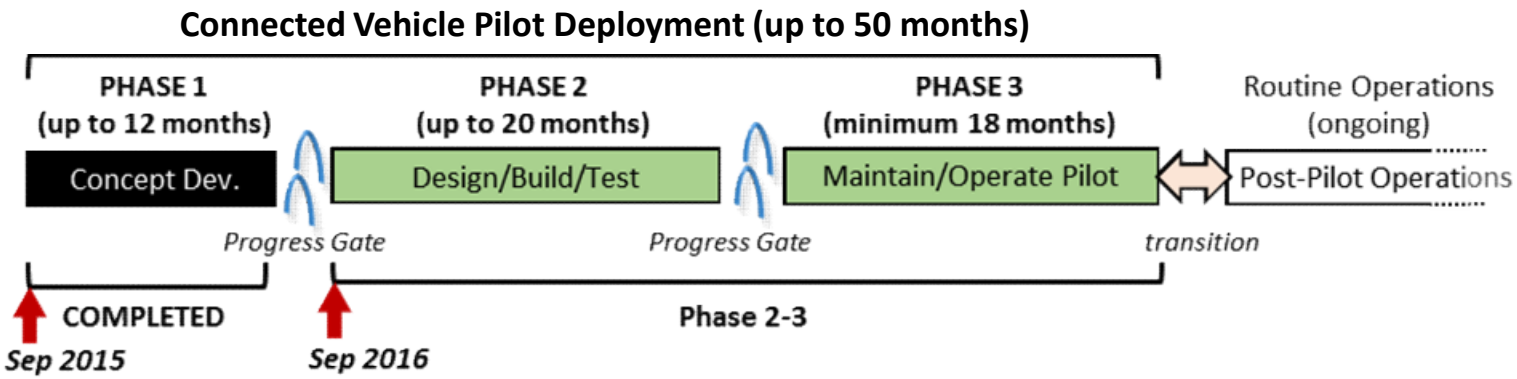
- Deployment concepts are needs-driven
  - Each site has different needs, focus and applications
    - That is, each pilot deployment will address critical problem(s)
    - The needs of each site will drive the deployment process

- Pilot deployments are expected to be both *large-scale with multiple applications*
  - *Large-scale* implies pilot deployments will have measureable impact, not a specific minimum geographic or vehicle fleet size
  - Sites will deploy *multiple applications* drawing on the products of USDOT and other connected vehicle research

CV Pilot Deployment Requirements

- Multiple connected vehicle applications will be deployed together
- Pilot deployments should leverage USDOT-sponsored research
- Pilot deployments include the capture of data from multiple sources
  - Integrated or carry-in devices for connected vehicles capable of generating an SAE J2735 Basic Safety Message (BSM)
  - Look to pilot deployment data while protecting privacy and intellectual property
- Dedicated Short Range Communications (DSRC) 5.9 GHz will be utilized as the communications technology
- Security and credentialing management system
- Well-defined, focused, quantitative performance measures
  - Support an independent evaluation effort

CV Pilot Deployment Schedule



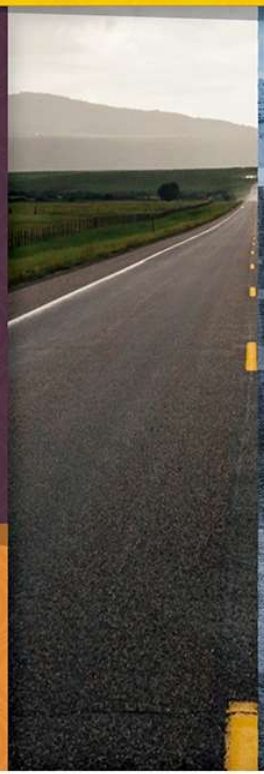
- **Phase 1: Concept Development (COMPLETE)**
  - Creates the foundational plan to enable further design and deployment
  - **Progress Gate: Is the concept ready for deployment?**

- **Phase 2: Design/Deploy/Test (CURRENT PHASE- began September 1, 2016)**
  - Detailed design and deployment followed by testing to ensure deployment functions as intended (both technically and institutionally)
  - Progress Gate: Does the system function as planned?

- **Phase 3: Maintain/Operate**
  - Focus is on assessing the performance of the deployed system
- Post Pilot Operations (CV tech integrated into operational practice)

Pilots Video

Wyoming DOT



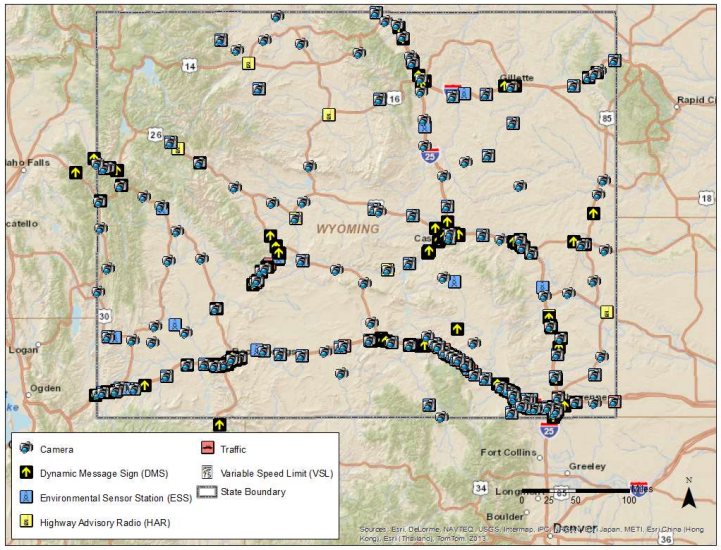
WYDOT Pilot Deployment Overview

Objective:

- Reduce the number and severity of adverse weather-related incidents (including secondary incidents) in the I-80 Corridor in order to improve safety and reduce incident-related delays.
  - Focused on the needs of the commercial vehicle operator in the State of Wyoming

Approach:

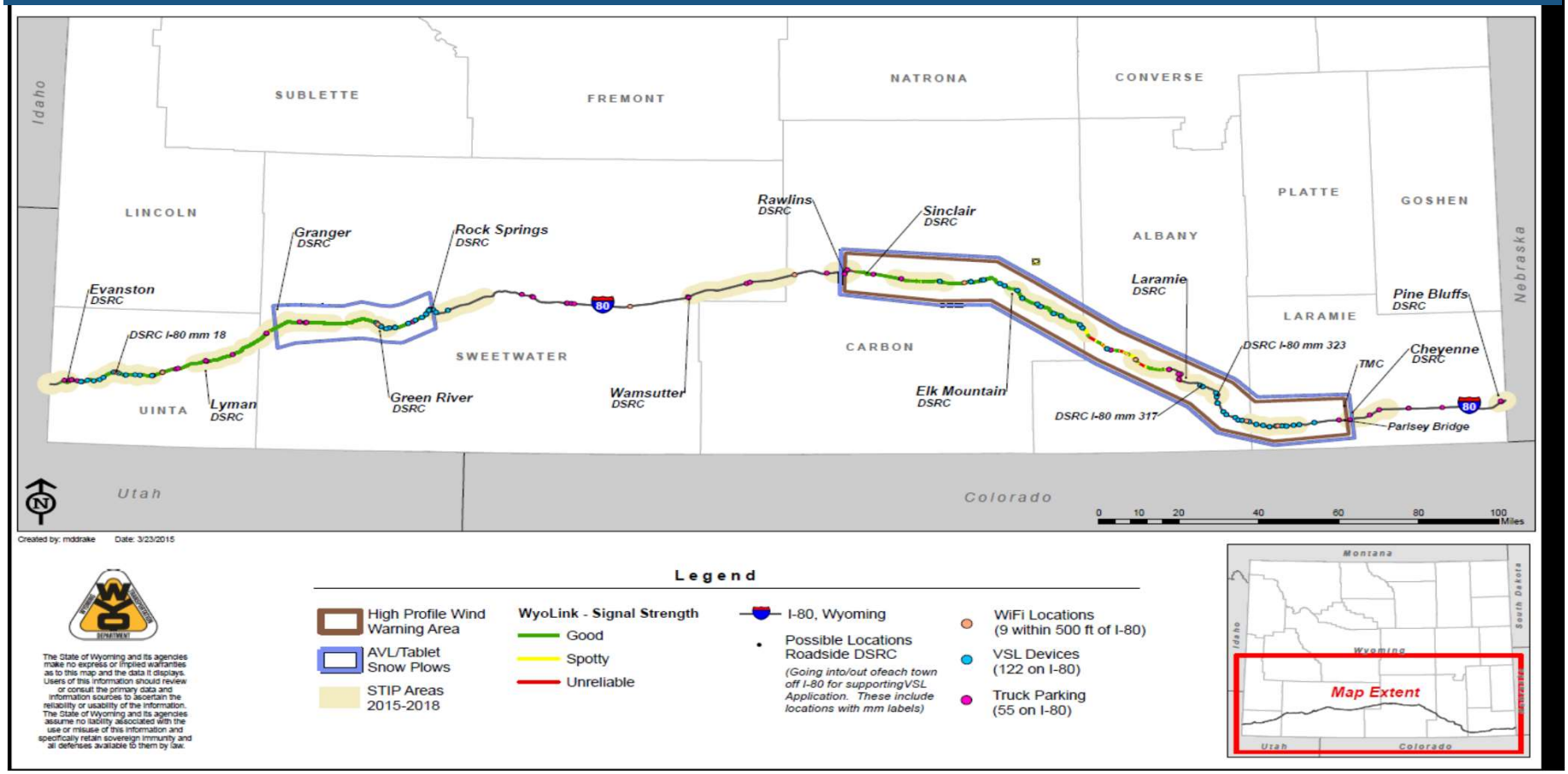
- Equip fleet vehicles (combination of snow plows, maintenance fleet vehicles, emergency vehicles, and private trucks) that frequently travel the I-80 corridor to transmit basic safety messages (BSMs), collect vehicle and road condition data and provide it remotely to the WYDOT TMCs
- Deploy DSRC roadside equipment (RSE) to supplement existing assets and initiatives
- Road weather data shared with freight carriers who will transmit to their trucks using exiting in-vehicle systems



Source: Wyoming DOT

WYDOT Pilot Deployment Site: High Priority Corridor

Wyoming I-80 Corridor – Connected Vehicle Map



Source: Wyoming CV Pilot Deployment Team

WYDOT Pilot Deployment Proposed CV Application-Fleet Distribution

CV Application	WYDOT Fleet	Integrated Commercial Trucks	Retrofit Vehicles	Basic Vehicles
	100	150-200	20-30	100-150
1. Forward Collision Warning	✓	✓	✓	✓
2. Spot Weather Impact Warning	✓	✓	✓	✓
3. Work Zone Warnings	✓	✓	✓	✓
4. Situational Awareness	✓	✓	✓	✓
5. Distress Notification	✓	✓		✓

Other related traffic management and traveler information services:

- Setting and removing variable speed limits along the I-80 corridor
- Supporting 511 and other traveler information
- Supporting road weather advisories and freight-specific travel guidance through CVOP

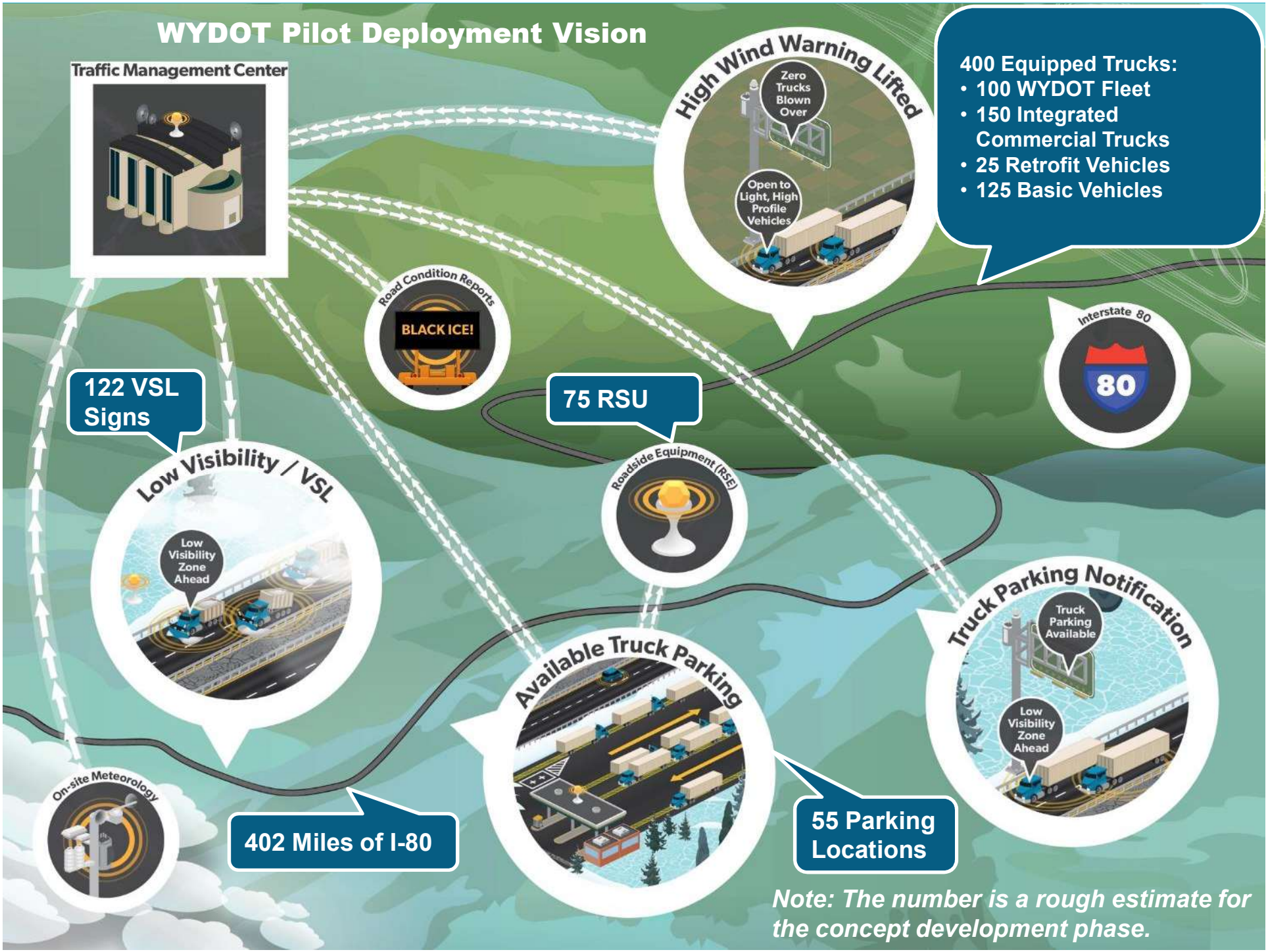
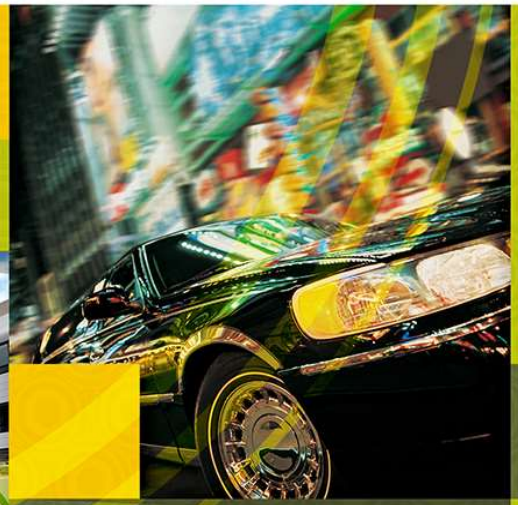

WYDOT Pilot Deployment Vision
Traffic Management Center
High Wind Warning Lifted
Zero Trucks Blown Over
Open to Light, High Profile Vehicles
400 Equipped Trucks:
• 100 WYDOT Fleet
• 150 Integrated Commercial Trucks
• 25 Retrofit Vehicles
• 125 Basic Vehicles
Road Condition Reports
BLACK ICE!
Interstate 80
80
122 VSL Signs
75 RSU
Roadside Equipment (RSE)
Low Visibility / VSL
Low Visibility Zone Ahead
Truck Parking Notification
Truck Parking Available
Low Visibility Zone Ahead
Available Truck Parking
On-site Meteorology
402 Miles of I-80
55 Parking Locations
Note: The number is a rough estimate for the concept development phase.

Photo Courtesy: MTA New York City Transit



New York City DOT

NYCDOT Pilot Deployment Overview

Objective:

- Improve safety and mobility of travelers in New York City through connected vehicle technologies
  - Aligned with the NYC's Vision Zero initiative, which seeks to reduce crashes and pedestrian fatalities, and increase safety of travelers in all modes of transportation

Approach:

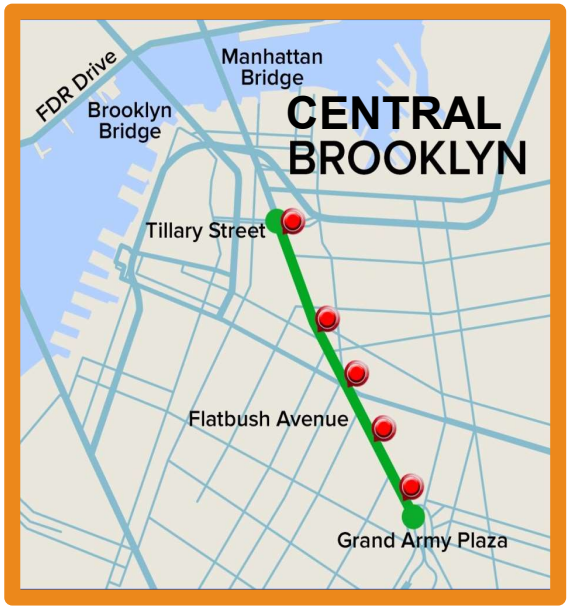
- Equip up to 8,000 vehicles (taxis, buses, commercial fleet delivery trucks, and City-owned vehicles) that frequently travel in Midtown Manhattan and Central Brooklyn to transmit and receive connected vehicle data
- Install V2I technology at high-accident rate arterials:
  - Upgrade 310 traffic signals along 1st, 2nd, 5th, and 6th Avenues in Manhattan and Flatbush Avenue in Central Brooklyn (emergency evacuation route)
  - Deploy Roadside equipment (RSE) along FDR Drive

Source: NYC DOT

NYCDOT Pilot Deployment Site

Manhattan Grid

- Closely spaced intersections (600' x 250')
- Day vs. Night conditions
- Residential/commercial mix
- High accident rate (red dot) (2012-2014)
  - 20 fatalities
  - 5,007 injuries
- 204 intersections



Central Brooklyn – Flatbush Ave

- Over-Height restrictions
  - Tillary St.; Brooklyn Bridge
- High accident rate (red dots) (2012-14)
  - 1,128 injuries
  - 8 fatalities
- Average AM speed 15 mph
- 35 intersections

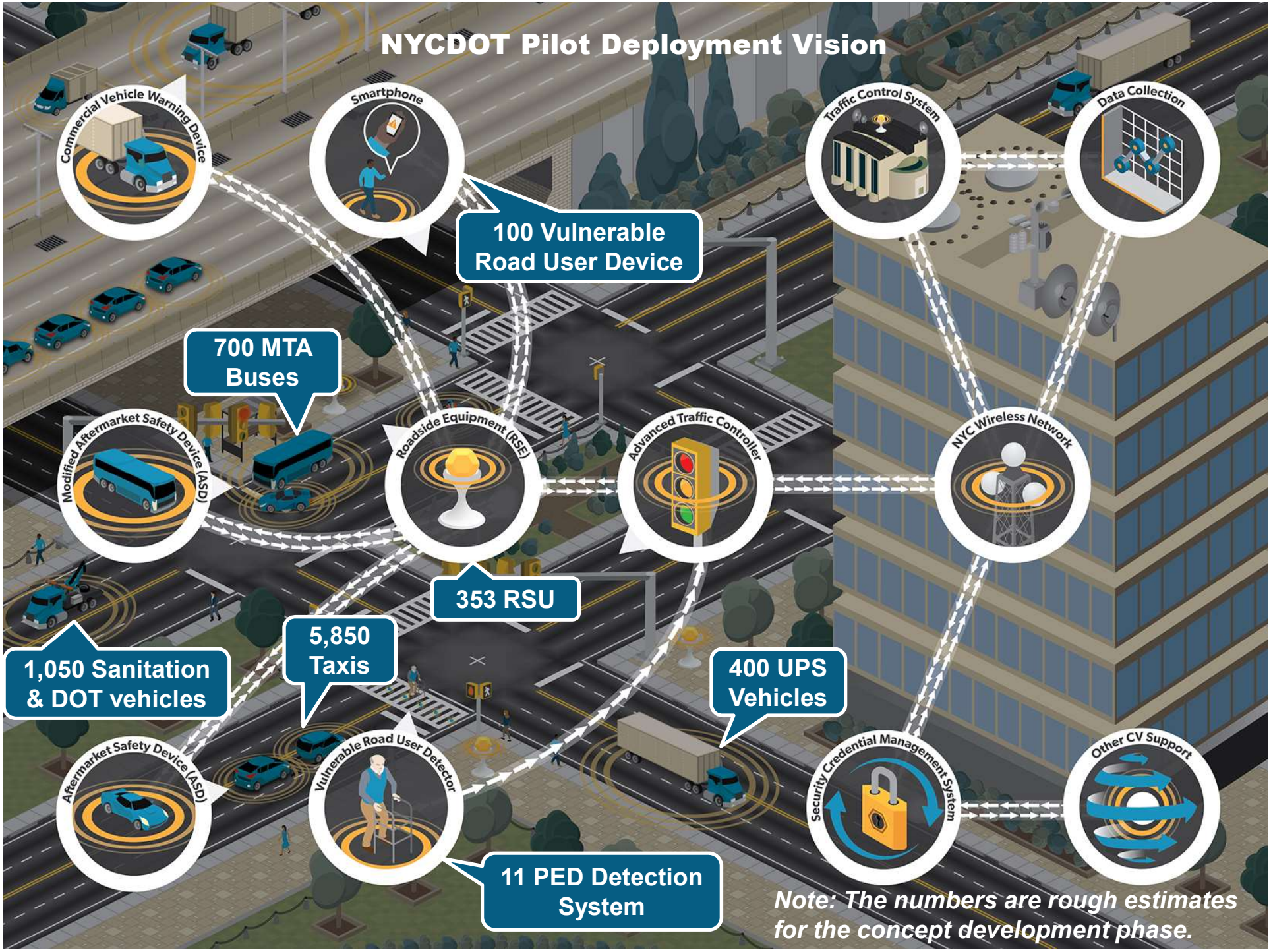
Manhattan – FDR Drive

- Limited access highway
- Excludes trucks/buses
- Short radius of curvature
- Over-Height restrictions
- $1,958,497 in Over-Height incident delay costs (2014)
  - 24% of City-wide total

Source: NYC DOT

NYCDOT Pilot Deployment Proposed CV Application-Fleet Distribution

CV Application	Taxi & Limousine	NYC DOT/ Sanitation	MTA/ NYCTA Buses	Commercial Vehicles	Pedestrian
	5,850	1,050	700	400	100
1. Speed Compliance	✓	✓	✓	✓	
2. Red Light Violation Warning	✓	✓	✓	✓	
3. Ped. in Signalized Crosswalk Warn.	✓	✓	✓	✓	✓
4. RT Vehicle in Front of Bus Warning			✓		
5. Mobile Accessible Ped Signal Sys.					✓
6. Curve Speed Compliance	✓	✓	✓	✓	
7. Oversize Vehicle Compliance		✓	✓	✓	
8. Work Zone Speed Compliance	✓	✓	✓	✓	
9. I-SIG	✓	✓	✓	✓	
10-14. V2V Applications (5)	✓	✓	✓	✓	
15. Evacuation Information	✓	✓	✓	✓	


NYCDOT Pilot Deployment Vision
Commercial Vehicle Warning Device
Smartphone
100 Vulnerable Road User Device
Traffic Control System
Data Collection
700 MTA Buses
Modified Aftermarket Safety Device (ASD)
Roadside Equipment (RSE)
Advanced Traffic Controller
NYC Wireless Network
353 RSU
1,050 Sanitation & DOT vehicles
5,850 Taxis
400 UPS Vehicles
Aftermarket Safety Device (ASD)
Vulnerable Road User Detector
Security Credential Management System
Other CV Support
11 PED Detection System
Note: The numbers are rough estimates for the concept development phase.

Tampa (THEA)

Tampa Hillsborough Expressway Authority

TAMPA (THEA) PILOT DEPLOYMENT OVERVIEW

Objective:

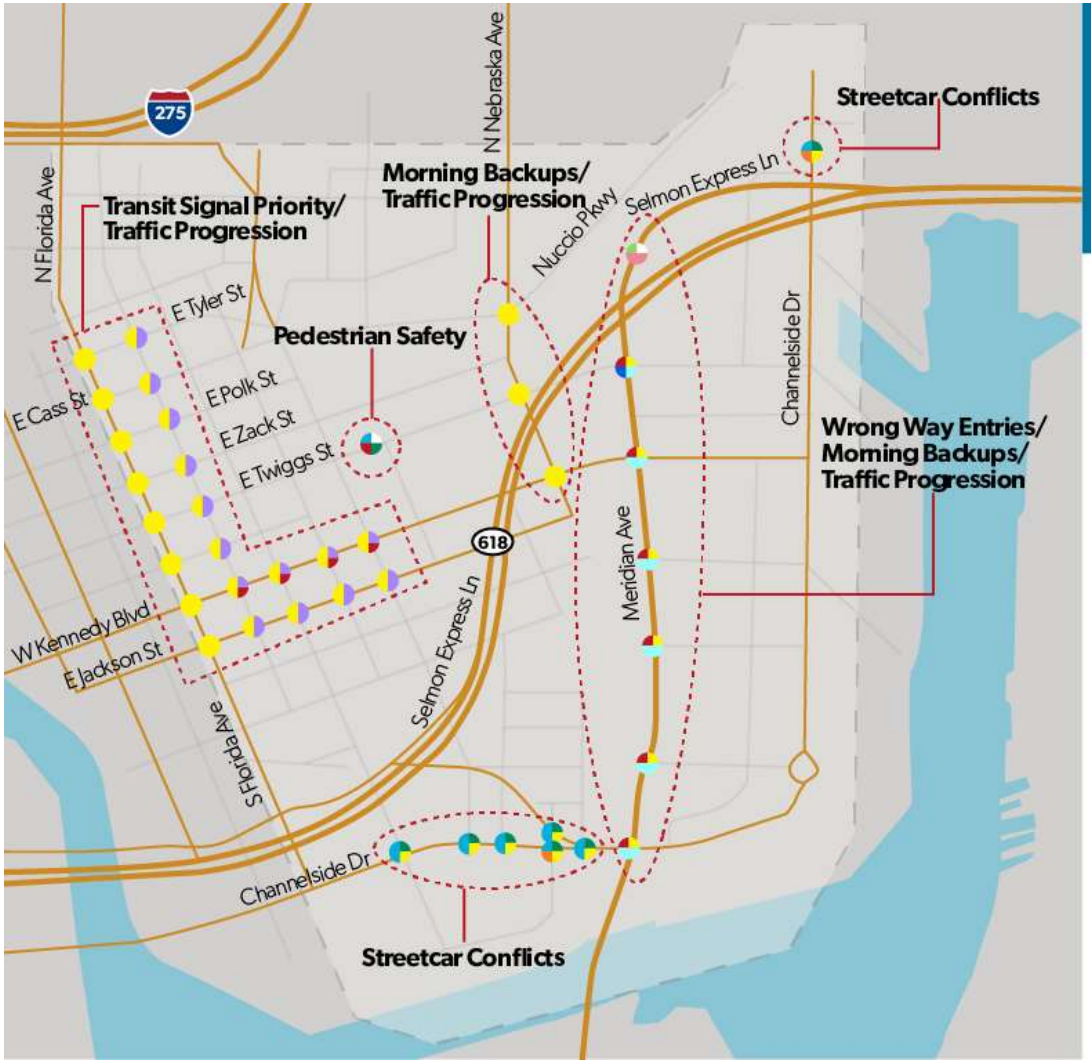
- The primary objective of this deployment is to alleviate congestion and improve safety during morning commuting hours.
  - Deploy a variety of vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) safety, mobility, and agency data applications to create reinforcing benefits for motorists, pedestrians, and transit operation.

Source: THEA

Approach:

- Deploy a variety of connected vehicle technologies on and in the vicinity of reversible express lanes and three major arterials in downtown Tampa to solve the following transportation challenges:
- Morning peak hour queues, wrong-way entries, pedestrian safety, bus rapid transit (BRT) signal priority optimization, trip time and safety, streetcar trolley conflicts, and enhanced signal coordination and traffic progression.

TAMPA (THEA) PILOT DEPLOYMENT SITE
AN OVERVIEW OF DOWNTOWN TAMPA



Tampa Hillsborough Expressway Authority – Connected Vehicle Map

LEGEND: Connected Vehicle Application

V2I Safety
- End of Ramp Deceleration Warning (ERDW)
- Wrong Way Entry (WWE)
- Pedestrian in Signalized Crosswalk (PED-X)
- Mobile Accessible Pedestrian Signal (PED-SIG)

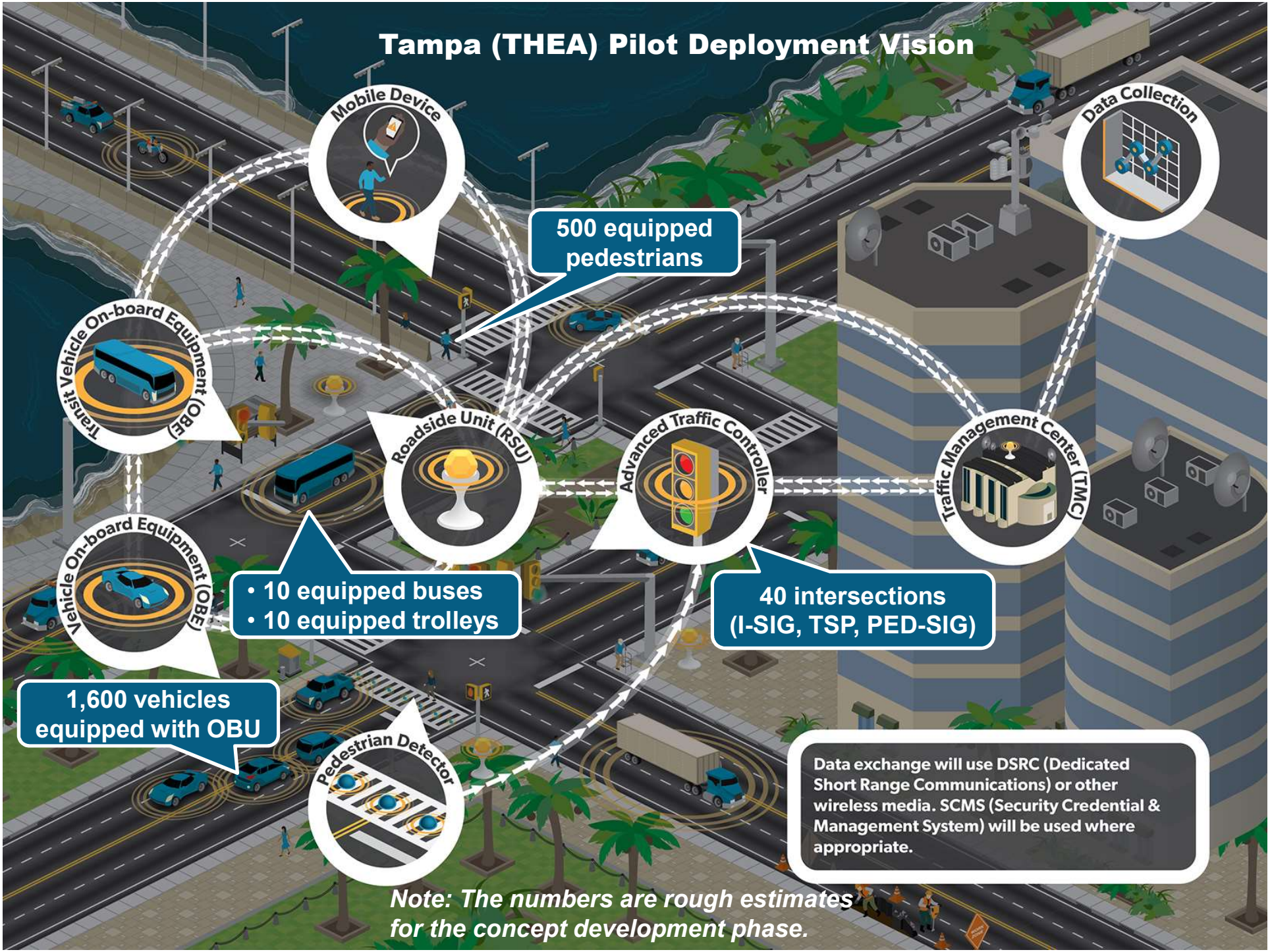
V2V Safety
- Emergency Electronic Brake Light (EEBL)
- Forward Collision Warning (FCW)
- Intersection Movement Assist (IMA)
- Vehicle Turn Right in Front of Transit Vehicle (VTRFTV)

V2I Mobility
- Intelligent Traffic Signal System (I-SIG)
- Transit Signal Priority (TSP)

V2I Agency Data
- Probe Data Enabled Traffic Monitoring (PDETM)

Tampa (THEA) Pilot Deployment Site Needs: Issues and Applications Relationship

Use Case No.	Description	Applications Involved
1	Morning Backup	End of Ramp Deceleration Warning Intelligent Signal Control Emergency Electronic Brake Light Forward Collision Warning
2	Wrong Way Entry	Wrong Way Entry Intelligent Signal Control Intersection Movement Assist
3	Pedestrian Safety	Pedestrian in a signalized crosswalk warning Mobile Accessible Pedestrian Signal Intelligent Signal Control
4	Transit Signal Priority	Intelligent Signal Control Transit Signal Priority Intersection Movement Assist
5	Trolley Conflicts	Intelligent Signal Control Mobile Accessible Pedestrian Signal Pedestrians in Signalized Crosswalk Vehicle Turning in Front of a Transit Vehicle
6	Traffic Progression	Intelligent Signal Control Probe Data Enabled Traffic Monitoring Intersection Movement Assist


Tampa (THEA) Pilot Deployment Vision
Mobile Device
500 equipped pedestrians
Data Collection
Transit Vehicle On-board Equipment (OBE)
Roadside Unit (RSU)
Advanced Traffic Controller
Traffic Management Center (TMC)
Vehicle On-board Equipment (OBE)
• 10 equipped buses
• 10 equipped trolleys
40 intersections (I-SIG, TSP, PED-SIG)
1,600 vehicles equipped with OBU
Pedestrian Detector
Data exchange will use DSRC (Dedicated Short Range Communications) or other wireless media. SCMS (Security Credential & Management System) will be used where appropriate.
Note: The numbers are rough estimates for the concept development phase.

Overview of Pilot Deployment Proposed CV Applications

Category	WYDOT – CV Application
V2V Safety	Forward Collision Warning (FCW)
V2I/I2V Safety	**I2V Situational Awareness***
	Work Zone Warnings (WZW)*
	Spot Weather Impact Warning (SWIW)*
V2I and V2V Safety	**Distress Notification (DN)**

Category	Tampa (THEA) – CV Application
V2I Safety	End of Ramp Deceleration Warning (ERDW)
	Pedestrian in Signalized Crosswalk Warning (PED-X)
	Wrong Way Entry (WWE)
V2V Safety	Emergency Electronic Brake Lights (EEBL)
	Forward Collision Warning (FCW)
	Intersection Movement Assist (IMA)
	Vehicle Turning Right in Front of a Transit Vehicle (VTRFTV)
Mobility	Mobile Accessible Pedestrian Signal System (PED-SIG)
	Intelligent Traffic Signal System (I-SIG)
	Transit Signal Priority (TSP)
Agency Data	Probe-enabled Data Monitoring (PeDM)

Category	NYCDOT – CV Application
V2I/I2V Safety	Speed Compliance
	Curve Speed Compliance
	Speed Compliance/Work Zone
	Red Light Violation Warning
	Oversize Vehicle Compliance
	Emergency Communications and Evacuation Information
V2V Safety	Forward Crash Warning (FCW)
	Emergency Electronics Brake Lights (EEBL)
	Blind Spot Warning (BSW)
	Lane Change Warning/Assist (LCA)
	Intersection Movement Assist (IMA)
	Vehicle Turning Right in Front of Bus Warning
V2I/I2V Pedestrian	Pedestrian in Signalized Crosswalk
	Mobile Accessible Pedestrian Signal System (PED-SIG)
Mobility	Intelligent Traffic Signal System (I-SIGCVDATA)

** The applications have mobility/ efficiency as a secondary benefit.*

Overview of Pilot Deployment Proposed CV Devices

WYDOT – Devices	Estimated Number
Roadside Unit (RSU)	75
WYDOT Fleet Subsystem On-Board Unit (OBU)	100
Integrated Commercial Truck Subsystem OBU	150
Retrofit Vehicle Subsystem OBU	25
Basic Vehicle Subsystem OBU	125
Total Equipped Vehicles	*400*

Tampa (THEA) – Devices	Estimated Number
Roadside Unit (RSU) at Intersection	40
Vehicle Equipped with On-Board Unit (OBU)	1,600
Pedestrian Equipped with App in Smartphone	500
HART Transit Bus Equipped with OBU	10
TECO Line Street Car Equipped with OBU	10
Total Equipped Vehicles	*1,620*

NYCDOT – Devices	Estimated Number
Roadside Unit (RSU) at Manhattan and Brooklyn Intersections and FDR Drive	353
Taxi Equipped with Aftermarket Safety Device (ASD)*	5,850
MTA Fleet Equipped with ASD*	700
UPS Truck Equipped with ASD*	400
NYCDOT Fleet Equipped with ASD*	800
DSNY Fleet Equipped with ASD*	250
Vulnerable Road User (Pedestrians/Bicyclists) Device	100
PED Detection System	10 + 1 spare
Total Equipped Vehicles	*8,000*

MTA: Metropolitan Transportation Authority; DSNY: City of New York Department of Sanitation

** In addition, 600 spare ASDs will be purchased.*

STAY CONNECTED

Join us for the *Getting Ready for Deployment* Series

- Discover more about the CV Pilot Sites
- Learn the Essential Steps to CV Deployment
- Engage in Technical Discussion

Website: http://www.its.dot.gov/pilots

Twitter: @ITSJPODirector

Facebook: https://www.facebook.com/USDOTResearch

Contact for CV Pilots Program:

Kate Hartman, Program Manager

Kate.hartman@dot.gov

Contact for Pilot Sites:

- Kate Hartman, WYDOT Site AOR
  Kate.Hartman@dot.gov
- Jonathan Walker, NYCDOT Site AOR
  Jonathan.b.Walker@dot.gov
- Govind Vadakpat, THEA Site AOR
  G.Vadakpat@dot.gov

Planning for Connected Vehicles

What should be considered?

Fundamental Consideration

- Knowing is half the battle…
  - Planners need to become familiar Connected Vehicle technologies and applications
- Planners don't need to know "guts" of technology but need to track developments
  - Conceptual knowledge of systems and technological readiness
  - Timeframes for implementation (is implementation referring to technology or project?)
  - Funding – who pays and how?
  - Societal/organizational impacts
  - Understand data outputs to support planning needs

Fundamental Consideration

- **Data Collection, Processing and Analysis**
  - Allowing transportation agencies to use data
    - Privacy, ownership and security concerns to be addressed
    - Coordination with private parties
    - Compatibility with current and planned DOT systems
  - Need to aggregate and turn large amounts of data into useful information
  - Applications for real-time systems analysis and operational planning
  - Applications for asset management – possible replacement of labor-intensive methods
  - Making efficient use of the data across multiple functions

Fundamental Consideration

- Long-Term Infrastructure Investment
  - Larger questions about future capital investment strategies
    - Will capacity improvements from CV reduce need for physical expansion?
    - Will safety improvements from CV reduce need for safety infrastructure investments?
    - Will roadway configurations have to change during period of mixed fleet operation? Separation of automated and non-automated vehicles?
    - What are impacts on major transit investments? Will automated vehicles replace or supplement some transit services?
    - What functions will be handled solely by the vehicle and what functions will need agency support?

Typical Planning Products

Typical Planning Products		
Non-constrained	Strategic	MPO Long Range Plan
		State Long Range Plan
		MPO Congestion Management Plan
		MPO Transit Development Plan
		MPO Non-motorized Plan
		Statewide Freight Plan
	Project (or Activity) Focused	ITS Architecture & Operations/ITS Plan
Constrained	Project (or Activity) Focused	Statewide Transportation Improvement Program
		MPO Transportation Improvement Program
		State DOT Highway Safety Improvement Program
		Unified Planning Work Program

Non-constrained Strategic Plans

Consideration #1: Baseline Analysis

- MTPs will need to identify existing infrastructure to be upgraded/integrated to support CV
  - MPOs have the opportunity to schedule CV upgrades during planned replacements/maintenance of infrastructure
- Estimates of the regional CV market penetration will be needed to anticipate the extent of CV impacts on all modes/projects in the MTP over the next 20 years
  - MPOs should establish a regular process for reviewing CV technology and trends to help inform the MTP baseline analysis

Non-constrained Strategic Plans

Consideration #2: Revisit Vision Statement…consider adding words like "connected" or "integrated‘

MWCOG TPB Vision Statement

*In the 21st Century, the Washington metropolitan region remains a vibrant world capital, with a transportation system that provides efficient movement of people and goods. This system promotes the region's economy and environmental quality, and operates in an attractive and safe setting--it is a system that serves everyone. The system is fiscally sustainable, promotes areas of concentrated growth, manages both demand and capacity, employs the best technology, and joins rail, roadway, bus, air, water, pedestrian and bicycle facilities into a fully inter**connected** network.*

Non-constrained Strategic Plans

Consideration #3: Goals and objectives are typically based on federally prescribed planning factors and may be impacted by connected vehicles (e.g., changes in travel behavior and data collection; access to new technology).

- Scenario planning around CV can help MPOs understand the range of potential impacts.
  - Planners will need to evaluate a wider range of possible demographic, economic and transportation system scenarios.

- MPOs should proactively factor in these issues while envisioning CV infrastructure and policies

Non-constrained Strategic Plans

Consideration #4: Revisit Performance Measures...

- Connected vehicle deployments are anticipated to have a significant impact on performance measure targets.
  - For example, connected vehicle deployments are projected to reduce crash rates over time and, therefore, impact safety performance measures and targets.
- The types of performance measure that are able to be collected will likely expand with new data available from connected vehicle deployments.

Non-constrained Strategic Plans

Consideration #5: Revisit strategies…

- Strategies that include connected vehicle applications should be considered.

- New models may be necessary to evaluate alternate strategies that include connected vehicles.

Typical Planning Products

Typical Planning Products		
Non-constrained	Strategic	MPO Long Range Plan
		State Long Range Plan
		MPO Congestion Management Plan
		MPO Transit Development Plan
		MPO Non-motorized Plan
		Statewide Freight Plan
	Project (or Activity) Focused	ITS Architecture & Operations/ITS Plan
Constrained	Project (or Activity) Focused	Statewide Transportation Improvement Program
		MPO Transportation Improvement Program
		State DOT Highway Safety Improvement Program
		Unified Planning Work Program

Non-constrained Project (or Activity) Centric Plans

Regional and statewide ITS architecture are the primary example of a non-constrained project centric plan. IT architecture need to be updated to include connected vehicle applications.

- Generally, CV will significantly impact statewide ITS architectures by:
  - Enhancing current ITS services
  - Strengthening the linkage between operations and planning of ITS
  - Changing and introducing new priorities in ITS operations planning
- Reference the Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT) in order to assess how connected vehicle applications (or services) should be incorporated in regional ITS architecture.
- ARC-IT Link: https://local.iteris.com/arc-it/

Typical Planning Products

Typical Planning Products		
Non-constrained	Strategic	MPO Long Range Plan
		State Long Range Plan
		MPO Congestion Management Plan
		MPO Transit Development Plan
		MPO Non-motorized Plan
		Statewide Freight Plan
	Project (or Activity) Focused	ITS Architecture & Operations/ITS Plan
Constrained	Project (or Activity) Focused	Statewide Transportation Improvement Program
		MPO Transportation Improvement Program
		State DOT Highway Safety Improvement Program
		Unified Planning Work Program

Constrained Project (or Activity) Centric Program Plans

Consideration #1: Agencies responsible for developing State and regional transportation programs need to revisit project selection and prioritization process to ensure that connected vehicle projects are adequately considered.

- Agencies should evaluate whether their project selection criteria can accommodate CV projects, and work to make changes in the criteria if needed.
  - It may be difficult to quantitatively rank CV projects in the beginning because traditional evaluation metrics, such as cost-benefit ratios, are still preliminary for CV technology.

- CO-PILOT is available for high-level cost estimation
  https://co-pilot.noblis.org/CVP_CET/

- Public involvement in selecting early CV projects should accommodate the general public's likely limited awareness of CV with educational components.

Constrained Project (or Activity) Centric Program Plans

Consideration #2: Initial Connected Vehicle infrastructure investments will likely be CV supporting infrastructure or demonstration projects. These type of projects generally do not require public involvement.

Examples CV supporting infrastructure projects:

- Backhaul communications infrastructure for transmission of CV data to TOCs and other recipients
- Replacement of field equipment, such as signal controllers, should accommodate V2I technology; for example incorporating DSRC units
- Data management initiatives

Training Resources

- Connected Vehicle Impacts on Transportation Planning – Primer (Technology Summary)
  https://ntl.bts.gov/lib/60000/60200/60240/FHWA-JPO-16-4201.pdf
- Connected Vehicles 101
  https://www.pcb.its.dot.gov/documents/Connected_Vehicles_101.pdf
- Connected Vehicles 102 - Applications and Planning for Implementation
  https://www.pcb.its.dot.gov/documents/Connected_Vehicles_102.pdf
- ITS PCB archived webinars:
  - CV Basics
    https://www.pcb.its.dot.gov/t3/s140424_cv_basics.asp
  - National Connected Vehicle Field Infrastructure Footprint Analysis
    https://www.pcb.its.dot.gov/t3/s140522_cv_footprint_analysis.asp
- ITS ePrimer (Module 13: Connected Vehicles)
  - https://www.pcb.its.dot.gov/eprimer/module13.aspx

- ITS JPO Connected Vehicle Deployment Resources for Planners
  https://www.its.dot.gov/research_areas/cv_planners.htm