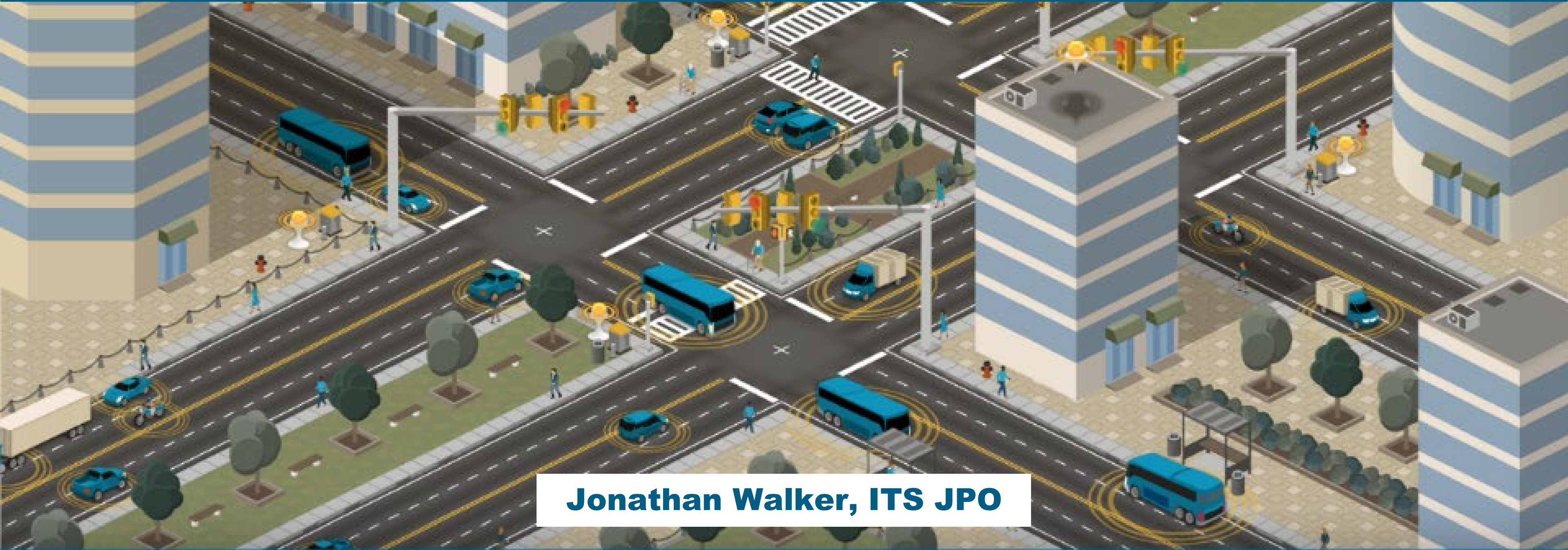
CONNECTED VEHICLE PILOT
Deployment Program

Measuring Success

Program Manager: Kate Hartman



Jonathan Walker, ITS JPO

What to Expect in this Session

- Connected Vehicle Pilot Deployment Program Overview
  - Summarize progress-to-date in the Connected Vehicle Pilot Deployment Program
  - Describe the deployment status of each of the three pilot sites
- Measuring Success
  - How each site plans to measure the effectiveness of the connected vehicle technology
  - How they will baseline their current traffic situations
  - How each of the applications performed in real-world settings

NYCDOT

Tampa (THEA)

WYDOT

USDOT

Session Agenda

- 6:00 – 6:15 PM Introduction and CV Pilots Overview

  Jonathan Walker, Program Manager, Research and Demonstration, ITS JPO, USDOT

- 6:15 – 6:35 PM Wyoming DOT Pilot Deployment

  Deepak Gopalakrishna, Principal, ICF

- 6:35 – 6:55 PM Tampa (THEA) Pilot Deployment

  Bob Frey, Planning Director, Tampa Hillsborough Expressway Authority (THEA)

- 6:55 – 7:15 PM NYCDOT Pilot Deployment

  Keir Opie, Principal, Cambridge Systematics

- 7:15 – 7:30 PM Q&A

CV PILOT DEPLOYMENT PROGRAM GOALS

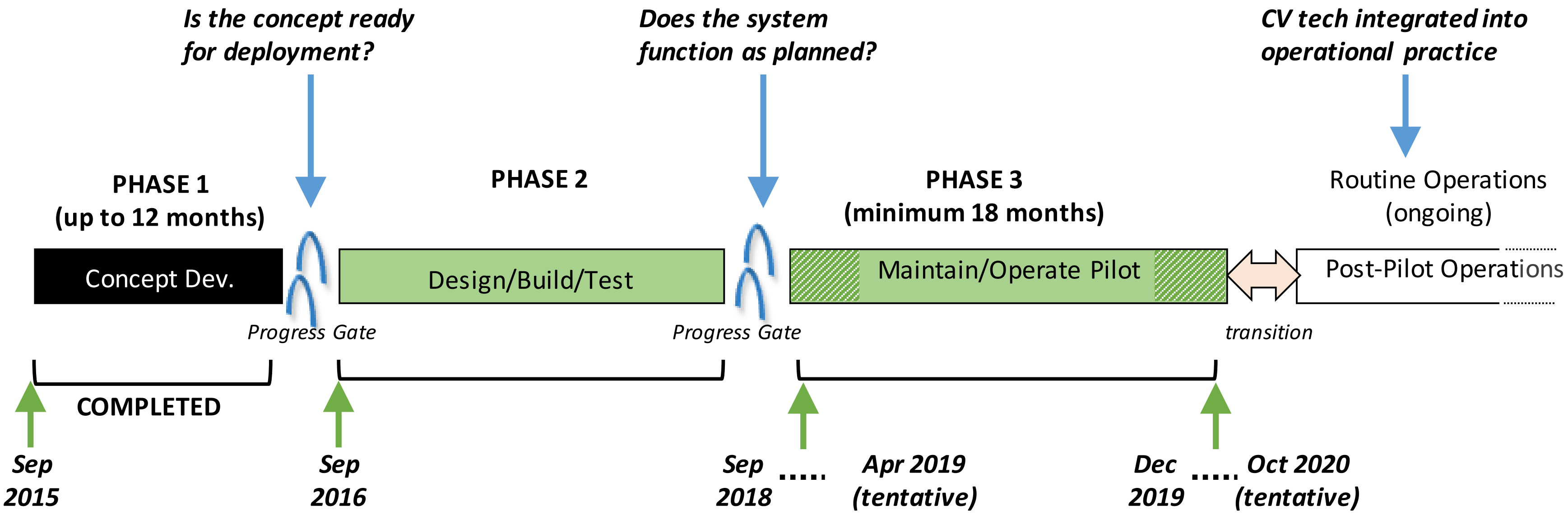
The Three Pilot Sites

- 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 Deployment Schedule



Last updated: August 2, 2018

Wyoming DOT Pilot Deployment

Deepak Gopalakrishna

Interstate 80 Corridor

- I-80 in Wyoming is one of the busiest freight corridors in the region
  - More than 32 million tons of freight per year.
  - Truck volume is 30-55% of the total traffic on an annual basis—can be as much as 70% on a seasonal basis.
- Difficult environment and terrain
  - Elevations above 6,000 feet across the entire corridor.

Connected Vehicle Pilot

75 ROADSIDE UNITS

Receive and broadcast messages using DSRC technology along sections of I-80. The units will be installed at locations along the corridor based on identified hotspots.

400 INSTRUMENTED FLEET VEHICLES

Equipped with DSRC-connected onboard units that broadcast basic safety messages, share alerts and advisories, and collect environmental data through mobile weather sensors.

WYDOT TRAVELER INFORMATION

The data collected by fleets and roadside units gives drivers in Wyoming improved travel information through services like the Wyoming 511 app and the commercial vehicle operator portal (CVOP).

WYDOT CV Pilot: Where are we today?

RSUs	• 60 RSUs of 77 total on the road. • RSUs are enrolled in the production SCMS. • RSUs and TMC servers and data warehouse are monitored for M&O in production.
OBUs	• 25 vehicles equipped of 400. • OBUs are enrolled in the production SCMS. • 23 Pilot Drivers trained.
Applications	• Forward Collision Warning, Distress Notification, Event Logging, and Traveler Information Messages are complete. • Applications for Over the Air (OTA) updates are being finalized.
TMC Systems in Production	• Operational Data Environment (i.e. CV Data Manager). • Pikalert (Road Weather Expert System). • Truck Parking. • Distress Notification Alerts. • Data transfers to the SDC and Public Data Hub.

Key Issues in Measuring Success

Limited number of vehicles	• 400 equipped vehicles to cover 402 miles and over 14k AADT.
Limited information	• Privacy concerns limit the type of data that can be collected.
Limited OBU capacity	• Storage capacity and transfer speed limit the amount of data collected and shared.
No home base for most of our vehicles	• Most of the vehicles are from private sector partners, limiting our access to them.

What are we doing about this?

Efficient logging of event data

Constant monitoring of equipment

Optimized data flow and analysis

Use of Analysis, Modeling and Simulation Tools

Core Principles

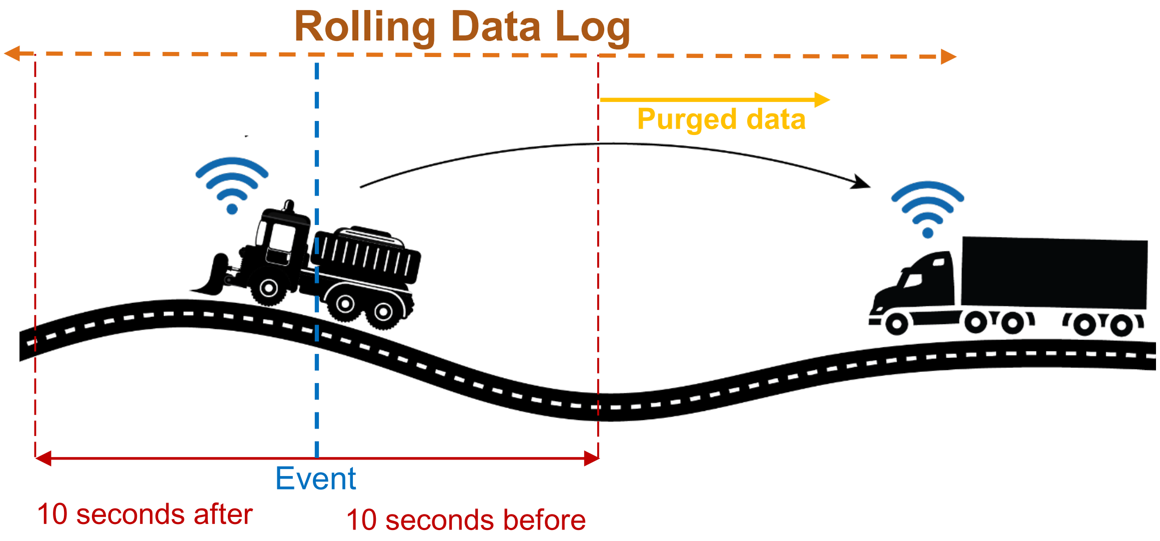
- Learn early and often
- Make immediate adjustments
- Minimize disruption to our drivers and fleet partners
- Be open with our data

Event Log

- Event Logs on the OBU are build for the following:
  - BSM during event
  - BSM every 30 seconds
  - TIM reception (SAT and RSU)
  - Distress Notification
  - Updates
  - Driver Alerts (TIMs, FCW, DN)

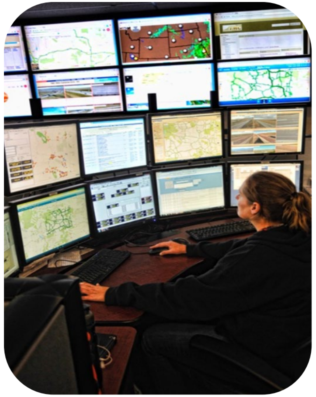
- Rotate at 100k in size, then zipped and sent to TMC when RSU is available

- Built with binary log file using ASN.1 where possible.



Day to Day Performance

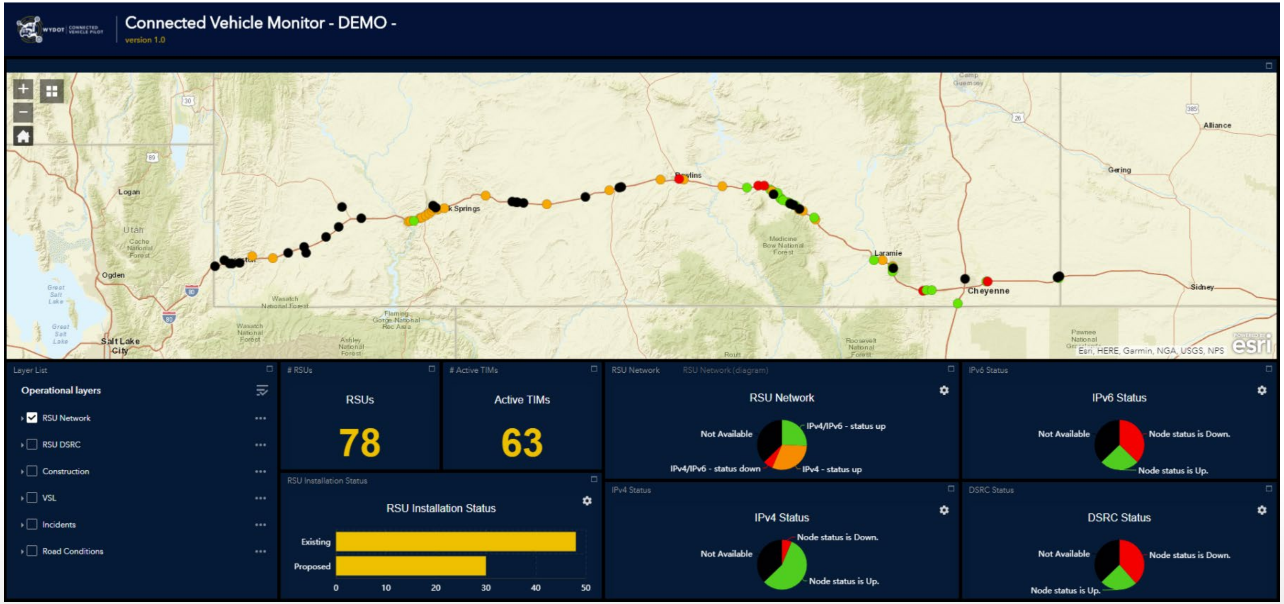
Day to Day Performance Monitoring



- Are the RSUs working?
- What are we currently posting on our RSUs?
- How many vehicles passed by the RSUs?
- How are our TMC systems working?

CV Monitor

- The CV monitor is used to monitor RSUs in real-time.
- Provides the status of communication, vehicle counts, posted TIMs and other information.
- A specialized version with an enhancement allows authorized people to apply firmware updates to RSUs.
- Publicly available https://wydotcvp.wyoroad.info/CVM/.



DEMO – CV MONITOR

Vehicle Count | Active TIM

Options | Filter by map extent | Zoom to | Clear selection | Refresh

Sitename	Site Status	Vehicle Count (past 24 hours)
I80 W 92.8	Existing	0
I80 W 94.2	Existing	0
Laramie WYDOT	Existing	0
Little America Parking Area	Existing	0
Lyman Parking Area	Existing	0
Lyman Parking Area 2	Existing	0
Lyman Rest Area	Existing	0
Lyman WYDOT	Existing	0

77 records

Measuring Impacts

Measuring Impacts

Define Objectives

- Eight (8) objectives

Define PMs for Objectives

- 21 PMs across all objectives

Define Baseline

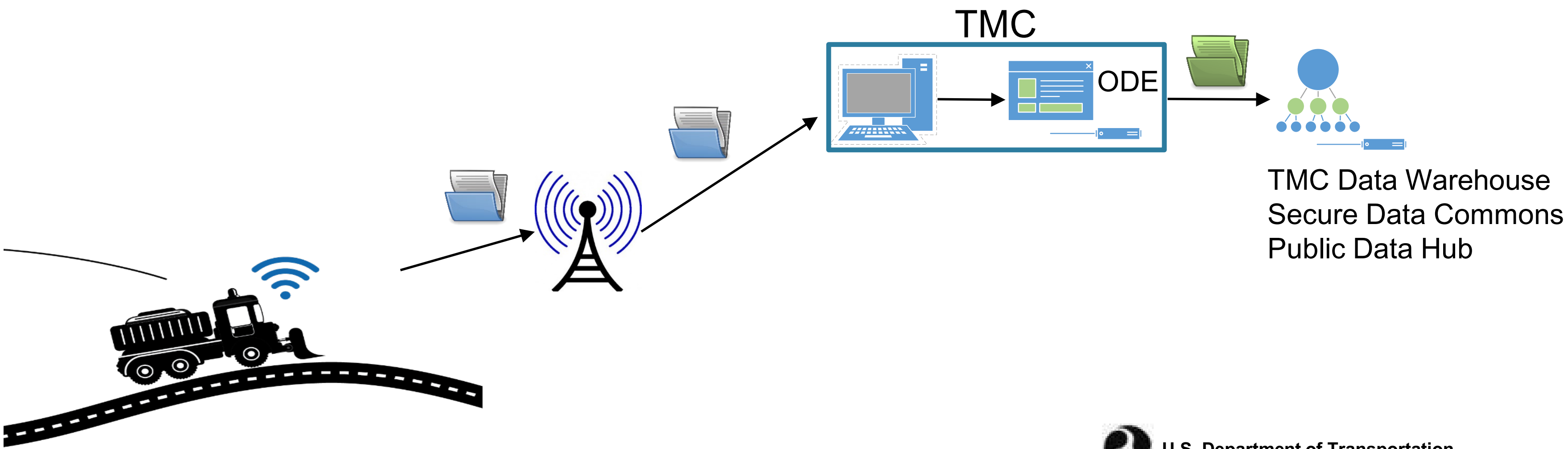
- Identify pre-deployment conditions

Define Data Collection & Analysis

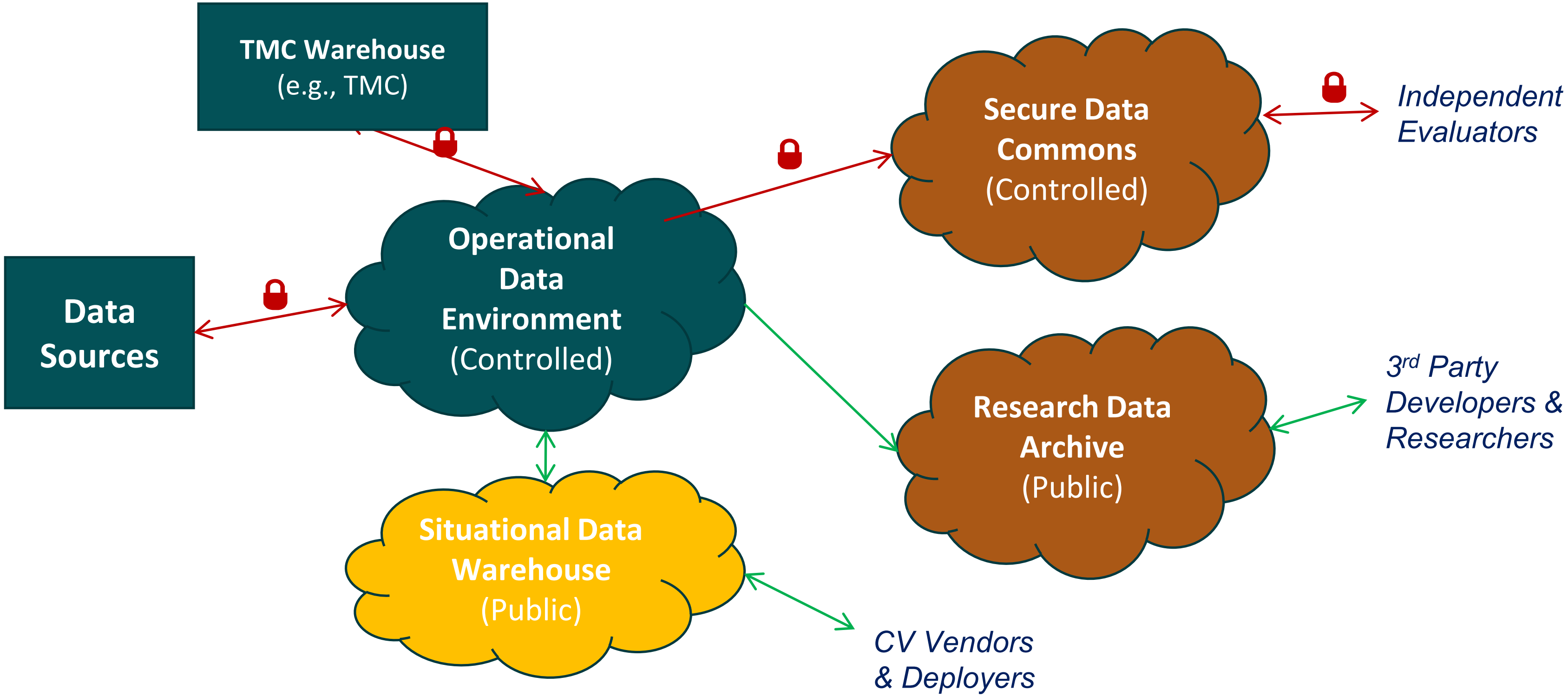
- Road Condition
- Speed
- Driver Survey
- Crash
- …

REAL-TIME DATA FLOW

Vehicle to RSU → RSU to TMC → Processed at ODE → **To Data Systems**

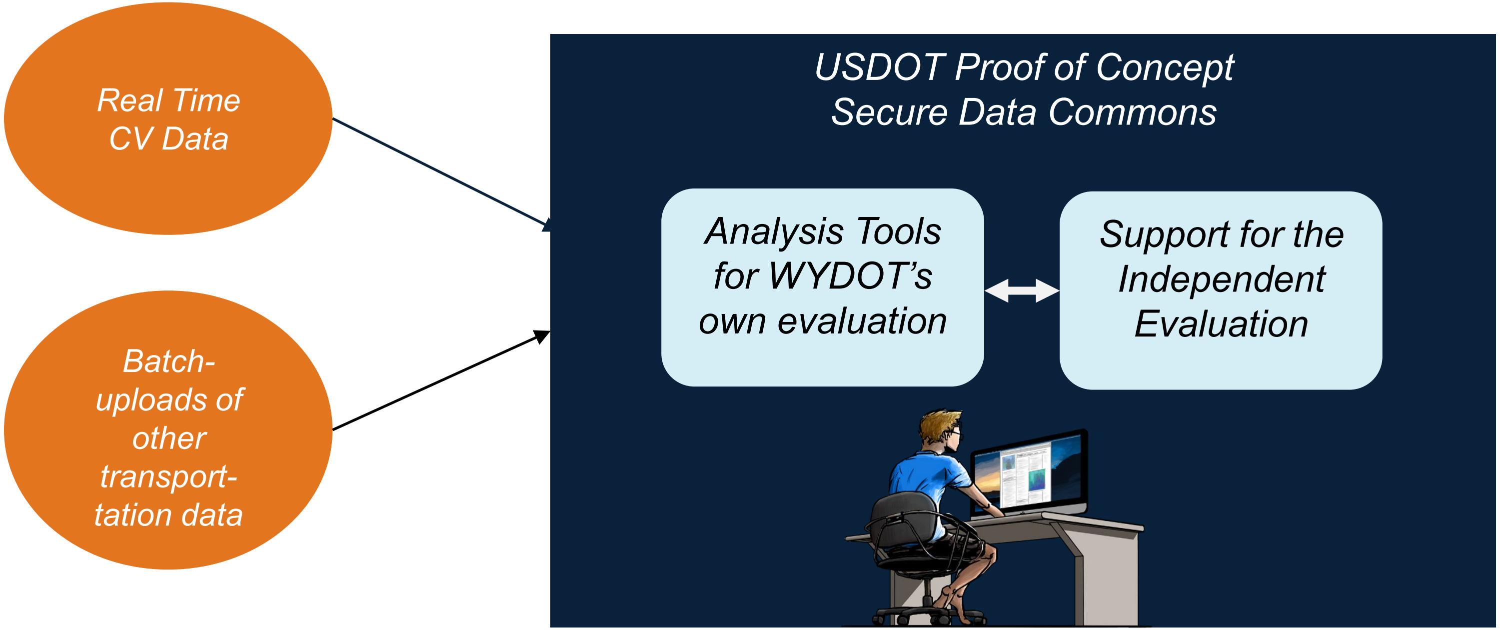


DATA MANAGEMENT



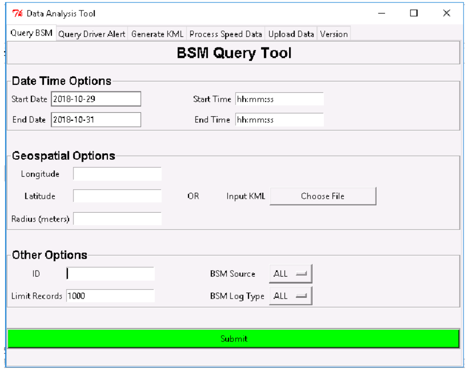
Programmatic privacy protection and data fluidity enable rapid innovation, now and in the future

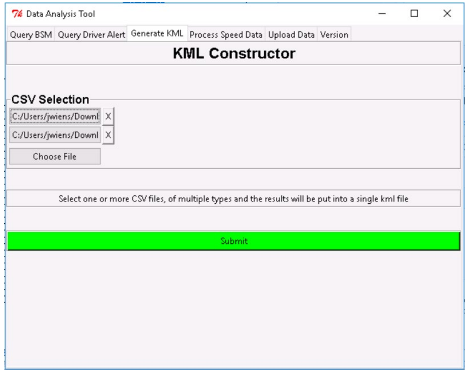
Utilizing the Secure Data Commons

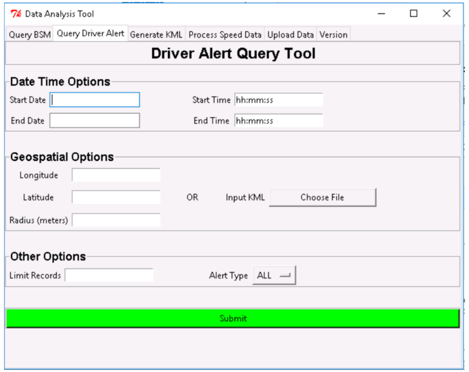


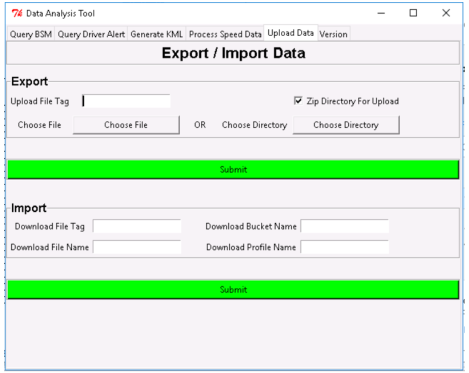
SDC CV Data Analysis Tools

- Grants easy access to customized data queries for BSM and Driver Alert data.
- Allows for auto report generation for speed, V2V and V2I datasets.
- Facilitates data export from Secure workstation for sharing and publishing results.
- Multiple Types of data can be superimposed on to one another to reconstruct road events for analysis.
    - BSM Data
    - Driver Alert Data
    - Forward Collision Warnings





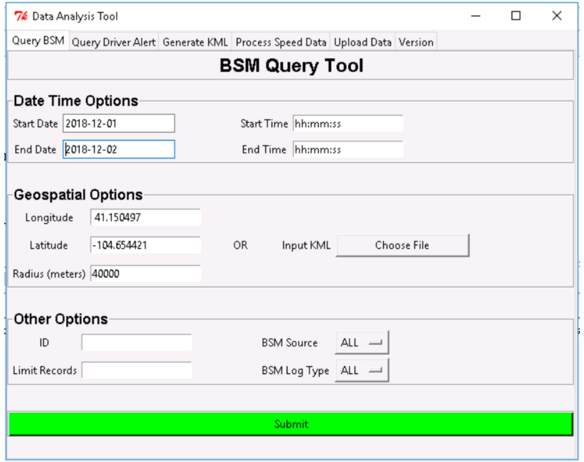


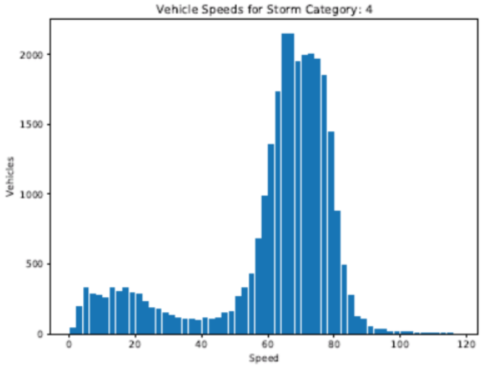


SDC REAL-TIME DATA ANALYSIS

Data is analyzed in a variety of formats including:

- KML Files
- CSV Files
- Auto Generated Reports
- Data Histograms





Speed (MPH)	Vehicle Count
0	39
2	191
4	327
6	286
8	274
10	254
12	329
14	300
16	332
18	295
20	280
22	230
24	189
26	177
28	147
30	127
32	113
34	104
36	105
38	99
40	110
42	100
44	116
46	147
48	160
50	266
52	332
54	428
56	680

SDC Graphical CV Data Analysis

KML files allow for graphical analysis of vehicle paths and interactions.

- Vehicles are denoted by colored arrows (one color per vehicle)
- Driver alerts, forward collision warnings, and imminent collision warnings are shown as colored triangles.

Impacts of CV Pilot on Vehicle Speeds

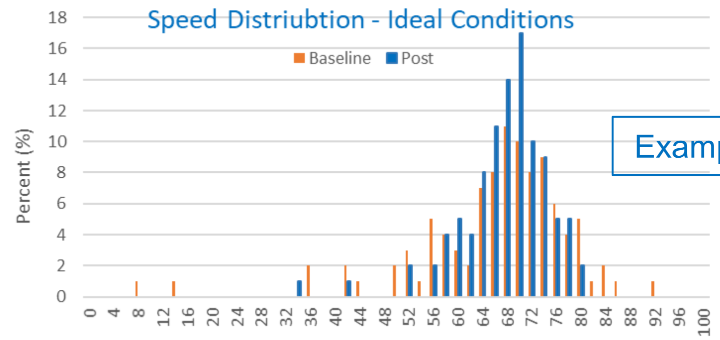
Hypothesis: CV Pilot will lead to increased speed compliance and harmonization

Pre- vs. Post-Deployment

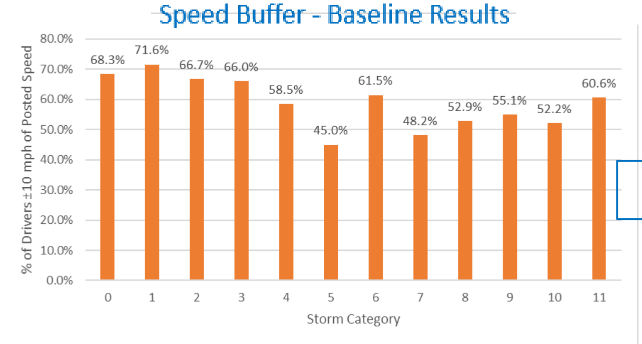
- Compare speed compliance, speed buffer/variance, and speed distributions
- Speed observations binned by weather category types

Equipped vs Non-Equipped Vehicles

- Compare speed compliance, speed buffer/variance and speed distributions
- Same location, time, vehicle classification and weather/road conditions



Example



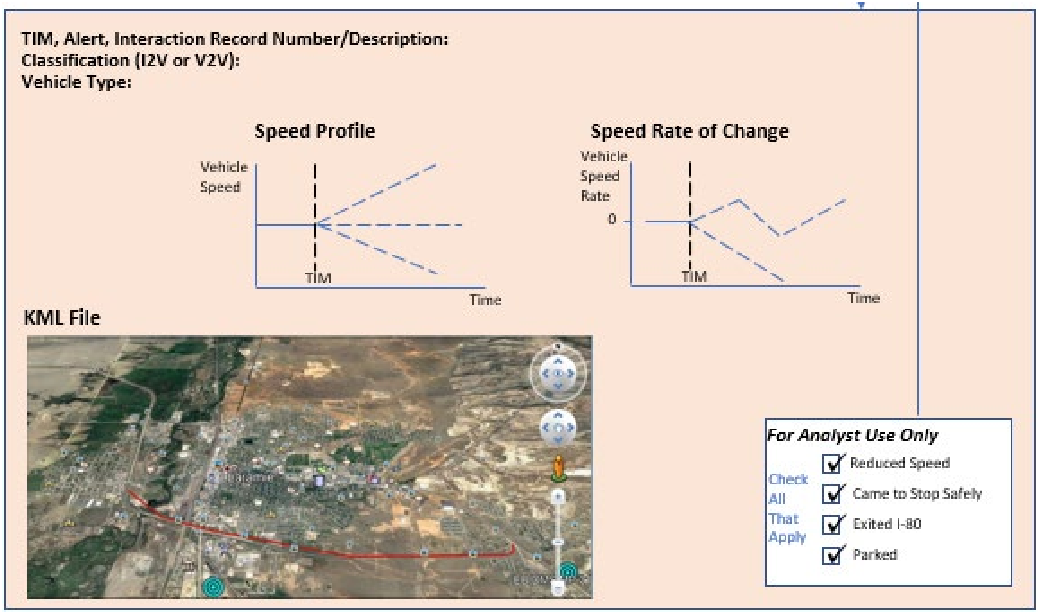
Baseline

Impacts of CV Pilot on Vehicle Speeds

Driver Reaction to Alert

Reaction Type:
Speed Change
Stop
Exit Corridor
Park

Analyzed by:
Alert Type, Vehicle Type, V2V vs. V2I



Modeling and Simulation

Using Truck Simulator Studies

Learning early about HMI effectiveness and driver responses

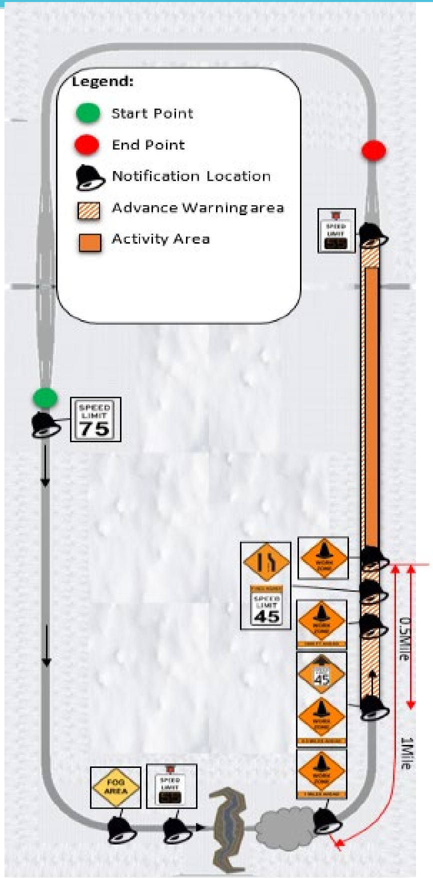
Impact of warnings on driver behavior

Make rapid adjustments to algorithms, HMI displays

Simulator Experiments

Source: NA

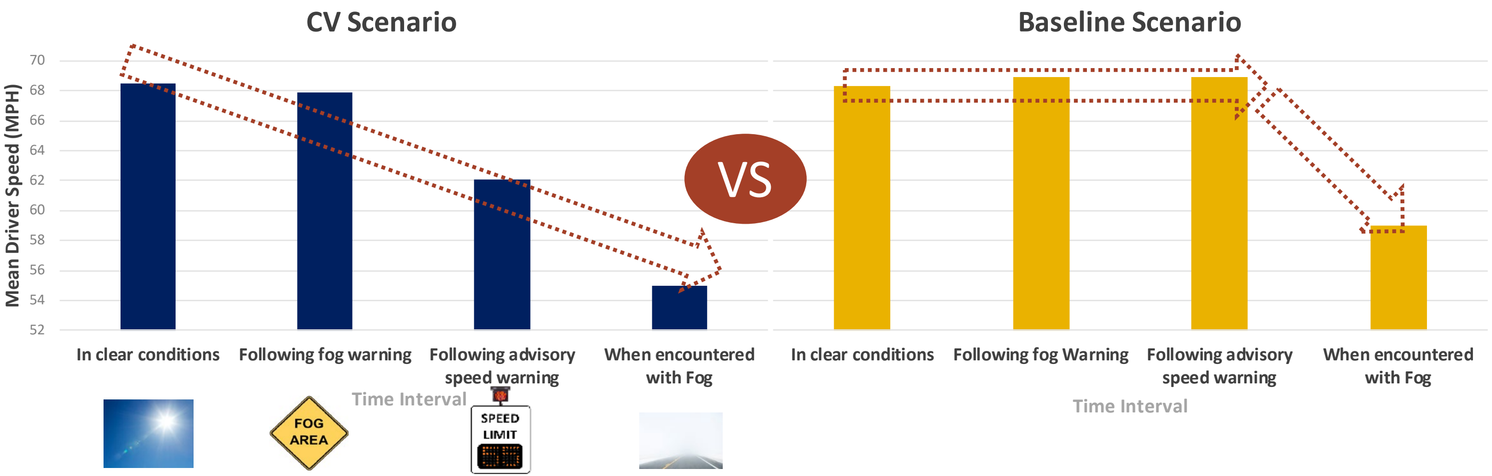
High Fidelity Truck Cab Simulator – WYOSAFESIM
University of Wyoming



IMMEDIATE IMPACTS TO PILOT

Starting to see some promising results (See TRB Papers presented by University of Wyoming)

Cumulative Effect of Weather Warnings



Gradual Reduction in Speed

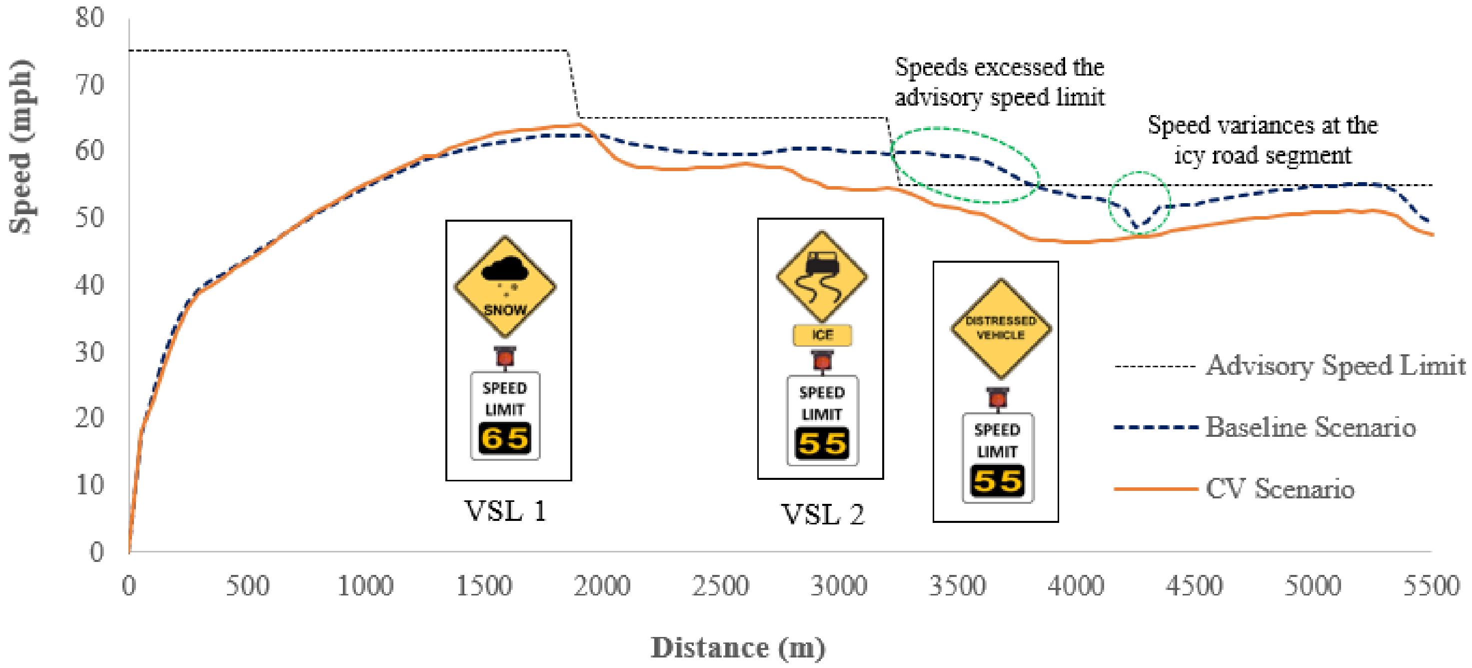
Abrupt Reduction in Speed

Less abrupt braking observed

Source: Univ. of Wyoming, TRB Paper, Evaluation of Connected Vehicle Real-Time Weather and Work Zone Warnings on the Behavior of Truck Drivers: A Driving Simulator Study

Immediate Impacts to Pilot

Better speed adherence by CV-equipped drivers



Source: Univ of Wyoming, TRB Paper, Impact of Variable Speed Limit in a Connected Vehicle Environment on Truck Driver Behavior under Adverse Weather Conditions: A Driving Simulator Study

IMMEDIATE IMPACTS TO PILOT

Noticed some mixed results with work zone warnings

- Recommendations on HMI design changes

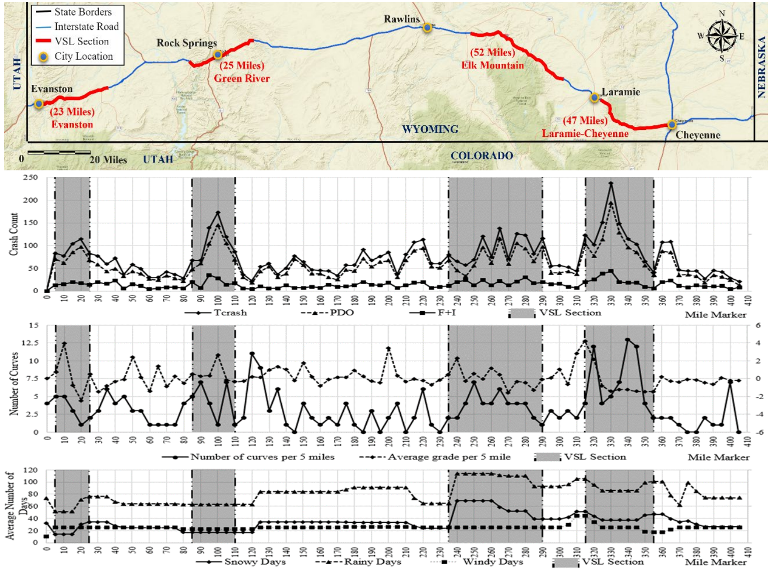
Noticed limited effectiveness with just weather warning

- Recommendation to pair with appropriate speed reduction which had a much more pronounced impact

SAFETY PERFORMANCE MODELING APPROACHES

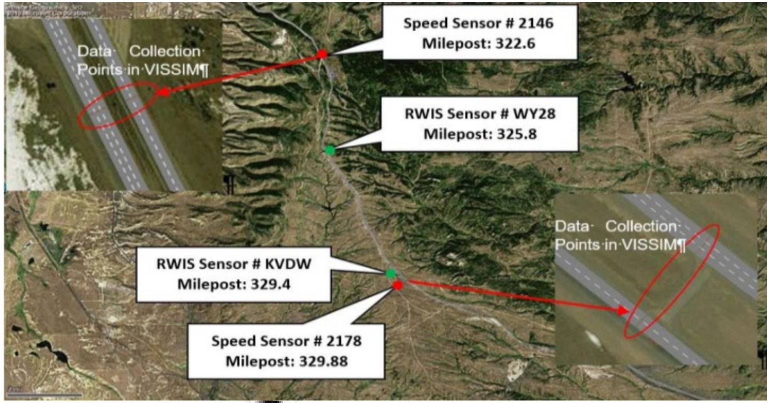
Traffic Safety Modeling

- ✓ Calibrate Safety Performance Functions (SPF) to predict number of crashes over a time period while accounting for various confounding factors;



Microsimulation Modeling

- ✓ Using microsimulation modeling to derive Surrogate Measures of Safety;
- ✓ VISSIM simulation model for a 23-mile segment of the I-80 Cheyenne-Laramie VSL corridor;
- ✓ Surrogate Safety Assessment Model (SSAM) to analyze the number of traffic conflicts generated by VISSIM simulation model.



TALK TO US AT TRB

- Papers being presented on Performance Measurement
  - Mohamed Ahmed, Guangchuan Yang*, Sherif Gaweesh*, Fred Kitchener, Rhonda Young, **Performance Measurement and System Evaluation of Wyoming Connected Vehicle Pilot Deployment Program: Planning and Pre-Deployment Conditions**. Accepted for presentation at the **Transportation Research Board 98th Annual Meeting**, 2019.
  - Mohamed Ahmed, Guangchuan Yang*, Sherif Gaweesh*, **Assessment Of Connected Vehicle Human Machine Interface Using A High-Fidelity Driving Simulator: Preliminary Findings From The Wyoming Connected Vehicle Pilot Deployment Program**. Accepted for presentation at the **Transportation Research Board 98th Annual Meeting**, 2019.
  - Mohamed Ahmed, Sherif Gaweesh*, Guangchuan Yang*, **Development and Assessment of A Connected Vehicle Training Program For Truck Drivers**. Accepted for presentation and publication at the **Transportation Research Board 98th Annual Meeting**, 2019.
  - Mohamed Ahmed, Guangchuan Yang, Sherif Gaweesh*, **Impact Of Variable Speed Limit In A Connected Vehicle Environment On Truck Driver Behavior Under Adverse Weather Conditions: A Driving Simulator Study**. Accepted for presentation at the **Transportation Research Board 98th Annual Meeting**, 2019.
  - Sherif Gaweesh*, Mohamed Ahmed, **Exploring Factors Affecting Crash Severity for Large Trucks on Rural Mountainous Freeways using a Bayesian Logistic Regression: A Case Study on Wyoming Interstate 80**. Accepted for presentation at the **Transportation Research Board 98th Annual Meeting**, 2019.
  - Omar Raddaoui*, Mohamed Ahmed, Sherif Gaweesh*, **Evaluation of Connected Vehicle Real-Time Weather and Work Zone Warnings on the Behavior of Truck Drivers: A Driving Simulator Study**. Accepted for presentation at the **Transportation Research Board 98th Annual Meeting**, 2019.

NEXT STEPS

- Continue to deploy on WYDOT and partner vehicles
- Finalize last few applications
- Start reporting on performance on a monthly basis from mid-2019

Tampa (THEA) Pilot Deployment

Bob Frey

WHAT IS THEA?

INDEPENDENT

Agency of the State

- A local, user-financed public agency
  - Financed through revenue bonds
  - Supported by user tolls
  - No tax funding
  - Tolls stay local
- Seven Member Board
  - 4 Appointed by Governor
  - Mayor (or Council Chair)
  - Hillsborough County Commissioner
  - FDOT District 7 Secretary

THEA STRATEGIC OVERVIEW

CONNECTED VEHICLE PILOT
TAMPA

Mission

Our mission is to provide safe, reliable, and financially-sustainable transportation services to the Tampa Bay region while reinvesting customer-based revenues back into the community.

Vision

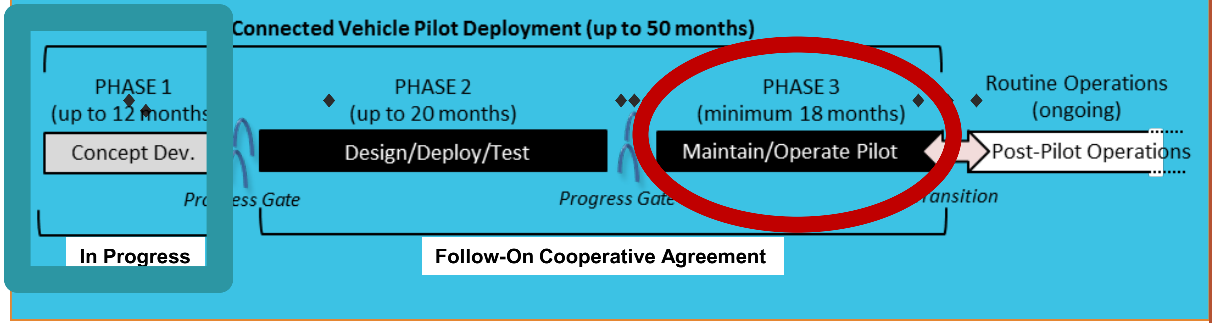
Our vision is to lead, partner, and implement safe, economically-sound, and innovative multi-modal transportation solutions for our Tampa Bay community.

Provide THEA customers with the safest, most efficient drive possible.

Advance Mobility Technology

Promote Tampa Bay

CONNECTED VEHICLE PILOT DEPLOYMENT PROGRAM



PILOT SITES

ICF/Wyoming DOT

NYCDOT

Tampa (THEA)

FOCUSED DEPLOYMENT AREA

CONNECTED VEHICLE PILOT TAMPA

PARTICIPANTS AND INFRASTRUCTURE

1,200

Privately Owned Installs

8

TECO Line Streetcar Trolleys

10

Hillsborough Area Regional Transit (HART) buses

PHOTO: SIEMENS

44

Roadside Units

IN VEHICLE USER INTERFACE

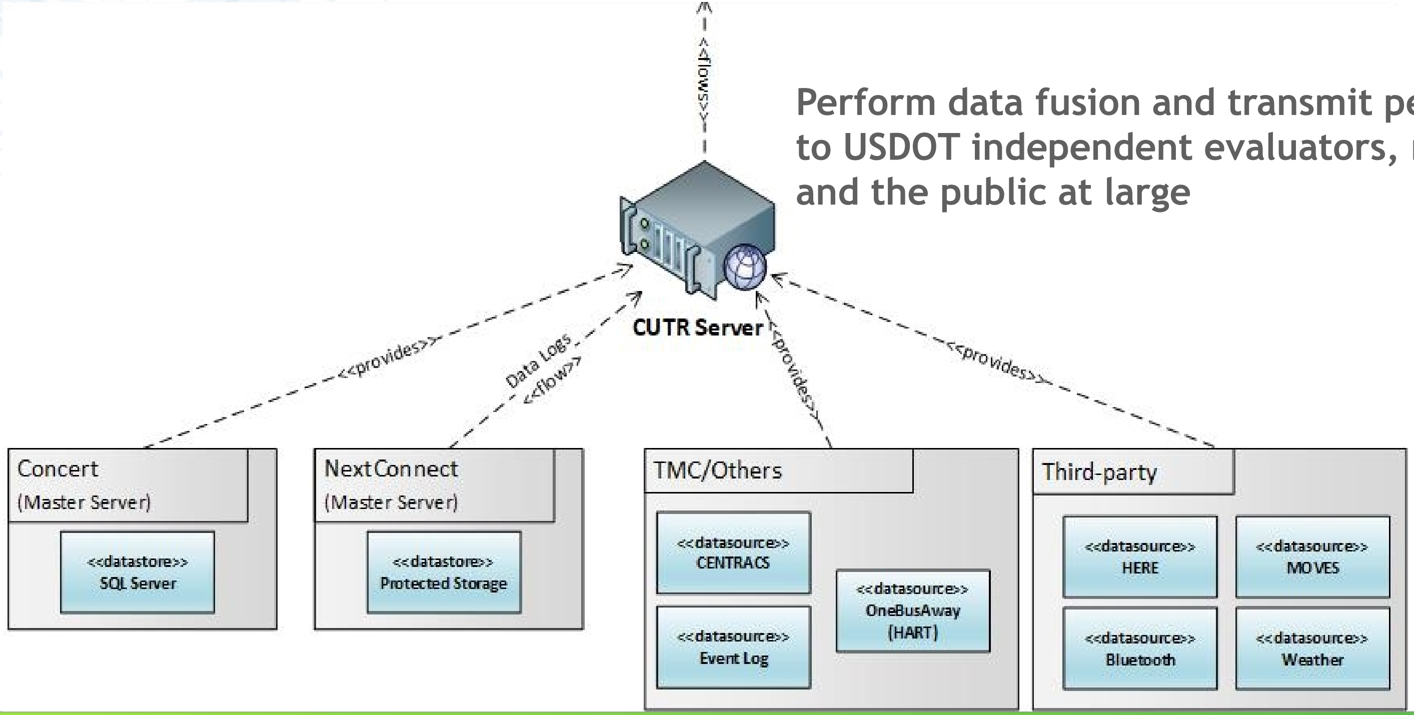
Safety warnings integrated into the rear-view mirror, visual (with auditory alert) examples shown below.

Electronic Brake Lamp Warning

Exit Ramp Deceleration Warning

Source: Brand Motion and Global 5

PHASE 3 - MEASURING PERFORMANCE



Perform data fusion and transmit performance measures to USDOT independent evaluators, research community, and the public at large

Mobility

- Travel time
- Travel time reliability
- Delay
- Throughput

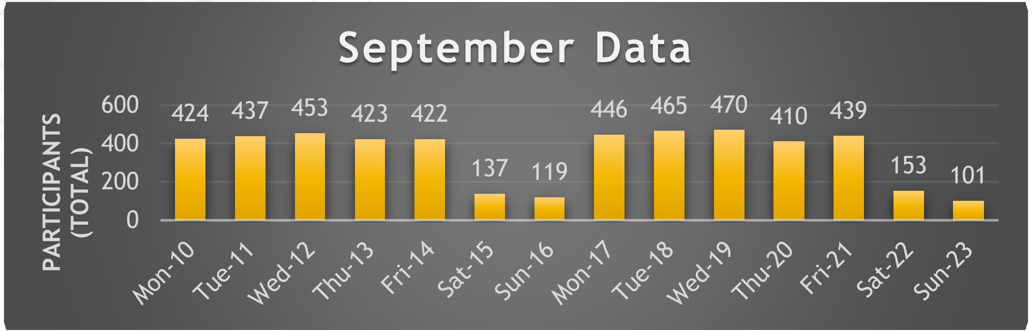
Safety

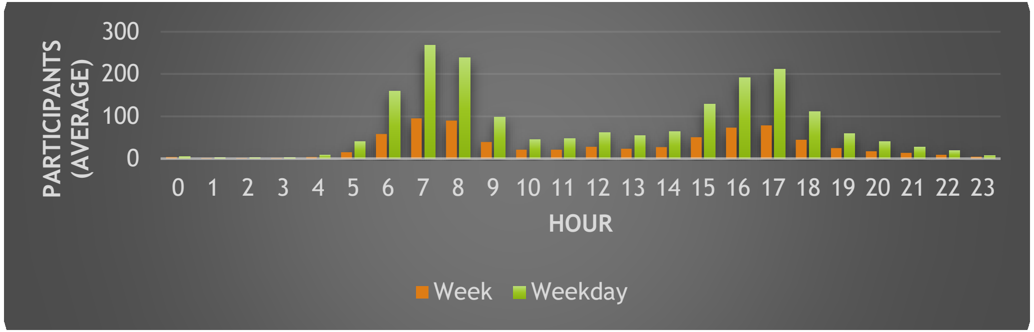
- Crash rates
- Type of conflicts
- Severity of conflicts

Environment

- Emission analysis

TRAVEL DATA

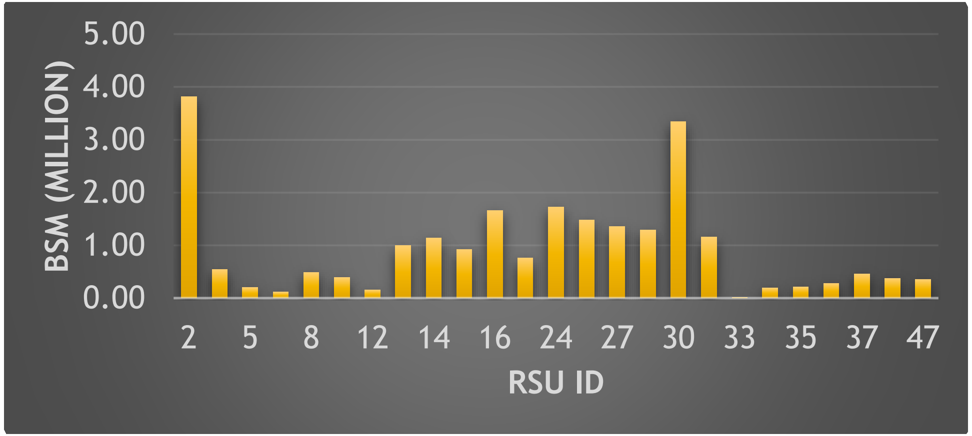




- Average of 1.7 million BSM/day
- About 0.9 million BSM/RSU
- Weekday travel patterns with a.m. and p.m. peak periods
- Up to 270 participants per hour on average at a.m. peak hour

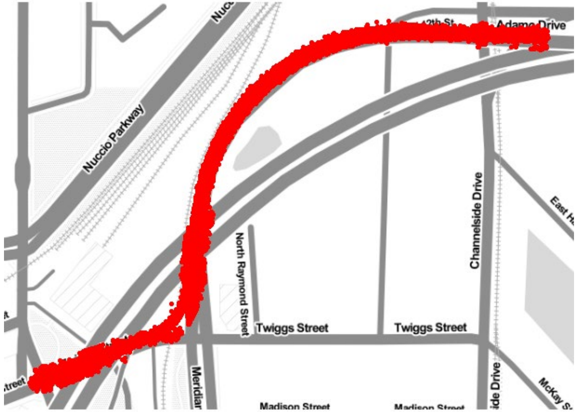
BSM AND RSU: STUDY AREA

- Some RSU receive more BSM than others
- Coverage of entire study area ensured

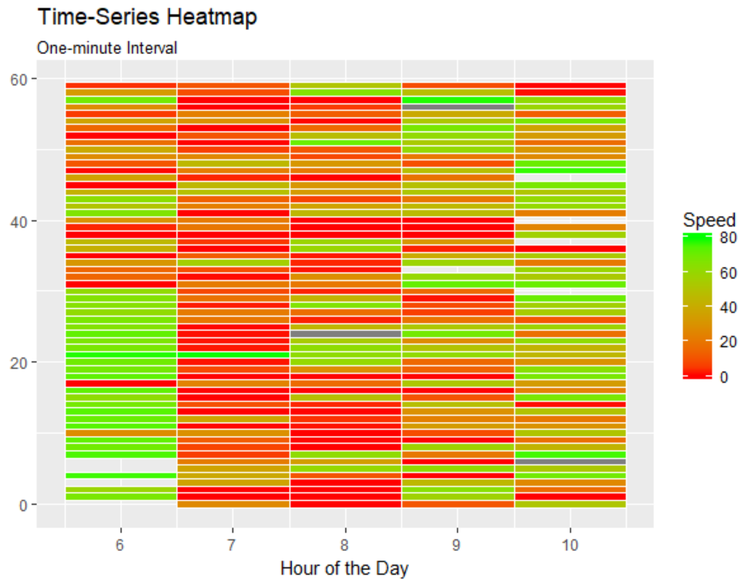


BSM AND MOBILITY

- RSU collected BSM allow generating mobility performance measures by Use Case
- Cluster analysis of events to spot areas prone to accidents



BSM Density



TAMPA CHANNEL ALLOCATION

- 172 - BSM, MAP, SPaT, RTCM
- 176 - PSM, SCMS, SRM, SSM, DataLog
- 178 - WSA, TIM, RSA
- 180 – DataLog
- 182 – Over the Air

IF WE COULD DO IT OVER AGAIN: WE WOULD

- Solidify Standards Earlier
- Obtain a Better Understanding of “Available” Applications’ Maturity
- Obtain a Better Understanding of “Available RSU and OBU Hardware
- Obtain a Better Understanding of Vendors’ Depth and Resources
- Complete Integration Testing Before Private Vehicle Installs Begin
- Identify the ability to Use Traditional ITS Devices as Part of Solution Earlier

LESSONS LEARNED – IN-VEHICLE

- OBUS - DON'T DO IT!!! Hire auto professionals to manage!
- Multiple Technical Scans using RFPs (with on the road testing)
- Early Sourcing of Suppliers to Create a Collaborative Environment
- Early real-life testing with infrastructure in place to verify end-to-end system/application performance
- Distributed Team Across the Country and in Europe, be careful can they support you from overseas?
- New development efforts - **OTA and security** - need to be piloted, i.e. tested early in the program
- Adequate incentives with community/media support engage the driver/consumer community
- Recognizing the need for a complete and experience project team - systems, infrastructure, vehicle systems, performance measurement, etc. You will need multiple disciplines, some not typical for civil projects.

STAY CONNECTED

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NYCDOT Pilot Deployment

Keir Opie

Performance Measurement Lead

Mohamad Talas

Project Manager

NYC PROJECT GOALS

New York City is aggressively pursuing "Vision Zero"

"Traffic Death and Injury on City streets is not acceptable"

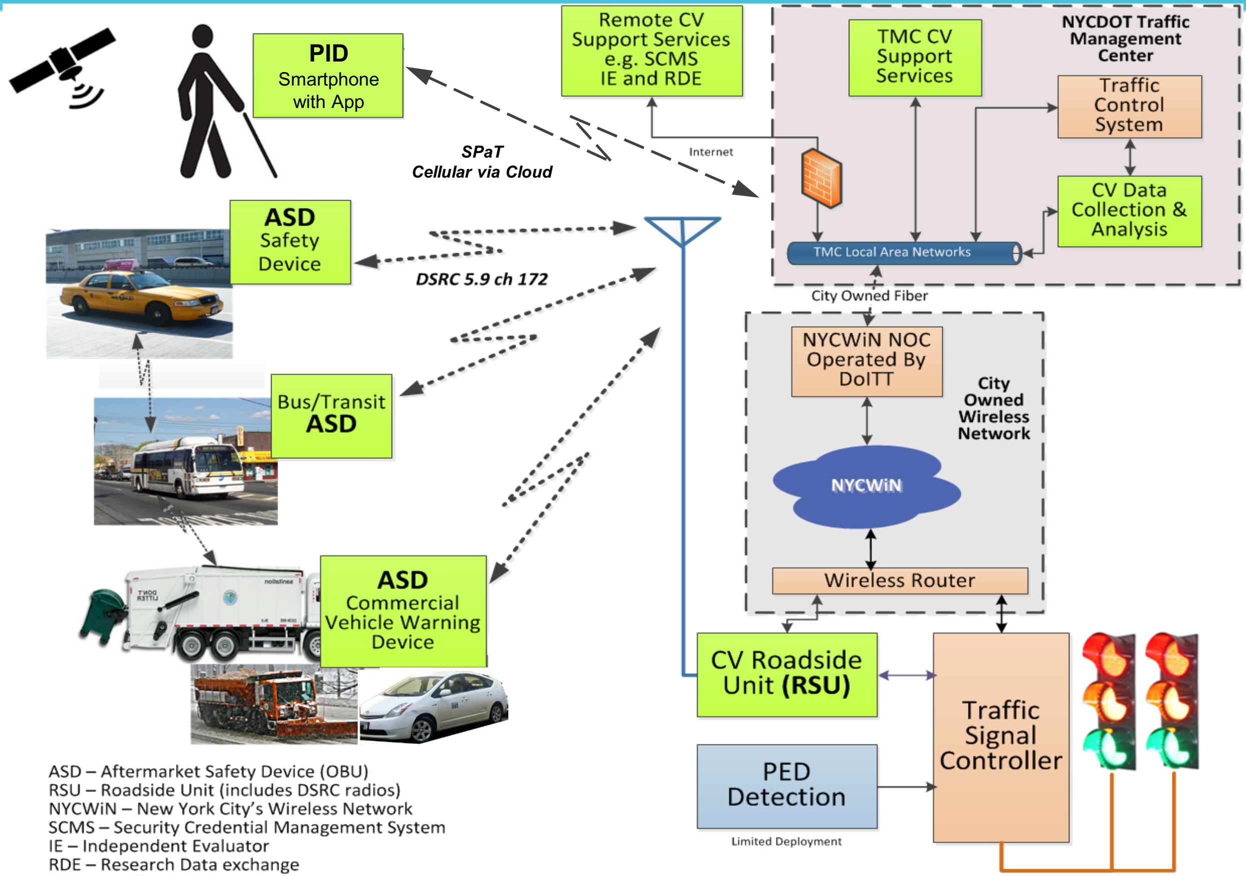
Vision Zero Goal : to eliminate traffic deaths by 2024

NYC CV Pilot will evaluate

- ***Safety** benefits of CV technology*
- *Address CV deployment challenges*
  - *With a large number of vehicles & types*
  - *Issues associated with the dense urban environment*

NEW YORK CITY DOT

Overall Deployment Concept



ASD – Aftermarket Safety Device (OBU)
RSU – Roadside Unit (includes DSRC radios)
NYCWiN – New York City's Wireless Network
SCMS – Security Credential Management System
IE – Independent Evaluator
RDE – Research Data exchange
TMC – Traffic Management Center

V2V applications work **wherever** equipped vehicles encounter one another.

V2I applications work where **infrastructure is installed** (highlighted streets).

The CV project leverages the City's transportation investments

Source: NYCDOT

Additional Sites not Shown:
- -FDR north to Triboro Bridge
- -Queensboro (59th St) Bridge Intersections (4) in Queens
- -Williamsburg Bridge Intersections (2) in Brooklyn

NYC DOT Pilot Overview

- Up to 8,000 **fleet** vehicles with Aftermarket Safety Devices (ASDs):
  - Taxis (Yellow Cabs)
  - MTA Buses
  - Sanitation & DOT vehicles
  - DCAS vehicles
- Pedestrian PIDs ~100 units
  - Visually Impaired Navigation
- Roadside Units (RSU) at

~353 Locations
  - ~202 Manhattan Avenues
  - ~ 79 Manhattan Cross Streets
  - ~ 28 on Flatbush Avenue
  - ~ 8 on FDR
  - ~ 36 Support locations (airports, river crossings, terminal facilities)

Operating Statistics:
*Vehicles are in motion or active ~**14 hours per day!***
Average taxi drives 197 miles per day
Fleet Total Vehicle Miles Traveled:
>1.3 Million Miles per day
~40 Million Miles per month

NYC CV Safety Applications

Vehicle-to-Vehicle

- Vehicle Turning Right in Front of Bus Warning
- Forward Collision Warning
- Emergency Electronic Brake Light
- Blind Spot Warning
- Lane Change Warning/Assist
- Intersection Movement Assist

Pedestrian Applications

- Pedestrian in Crosswalk (RSU)
- Visually Impaired Crossing (PID)

Customized Applications

Vehicle-to-Infrastructure

- Red Light Violation Warning
- Speed **Compliance**
- Curve Speed **Compliance**
- Speed **Compliance**/Work Zone
- Oversize Vehicle **Compliance**
  - Prohibited Facilities (Parkways)
  - Over Height warning
- Emergency Communications and Evacuation Information

NYC Developed CV Support Applications

Other Applications

- OTA Firmware Update
- OTA Uploading of Data Collected
- Application Parameter Modifications (Tuning)

Data Collection: Operations, Maintenance, and Performance Analysis

- CV Data for Intelligent Traffic Signal System
- RF Monitoring
- Traffic data collection
- *Event History Recording*
- *Event History Up Load*

To Meet USDOT Requirements for Benefit Analysis

NYC Data Collection Issues

What to collect?

- What could we collect?
  - What is the raw data available
- What do we need?
  - What is the intended use of the data?
- What should we collect?
  - Needs to justify the costs

What are the costs?

- Backhaul communications
- Storage
- Processing
- Supporting FOIA requests
- Supporting Subpoenas

What are the Privacy Issues?

- Prohibition of keeping PII
- Combination with other sources
- Data Ownership

What Data We Are Collecting and Why?

- Data collection plan structured on information needed to answer deployment questions and goals:
  - Primary Goal: Improve safety through the reduction of vehicle and pedestrian crashes, injuries, and fatalities
  - Secondary Goal: Improve mobility and reliability through crash prevention and lowered crash severity

Safety Needs (ConOps) → CV Safety Apps → Developed Questions for Evaluation → Performance Measurement Metrics

- Numerous Needs, Questions, and Metrics Identified
- Details See: NYC CVPD Phase 1 Performance Measurement and Evaluation Support Plan (FHWA-JPO-16-302) https://www.its.dot.gov/pilots/pilots_nycdot.htm

Performance Measurement Data Collection Example

Reduce Vehicle to Vehicle Crashes

V2V & V2I Safety Applications for Crash Avoidance

Evaluation Questions

-Does the number of crashes decrease?

-Does the number and severity of red light violations decrease?

-Does number of bus / right turn vehicle crashes decrease?

-And others…

Data Needed:

- Fatality crash counts
- Injury crash counts
- Property damage only crash counts
- Red light violation counts
- Red light violation crash counts
- Bus & right turn related crash counts
- *Time to Collision*
- *Driver actions and/or impact of actions when they receive alerts*
- *Number of warnings generated*
- *Right-turning vehicle & bus related conflicts*

Data Collection Methods:

Non CV Data

- Traditional data collection methods

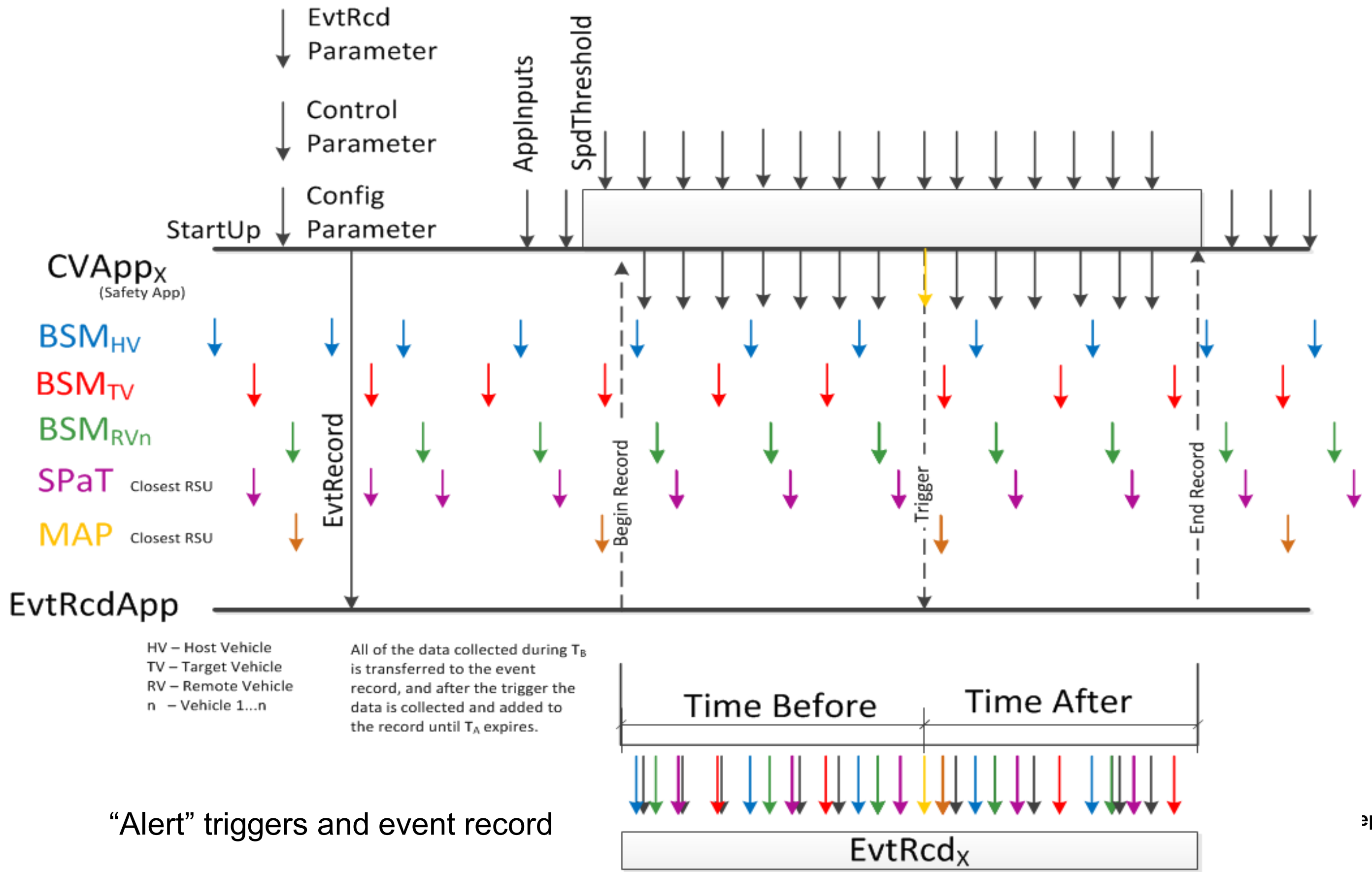
CV-Based collection:

- *Everything that "occurred" immediately before and/or after the CV Safety App alert*

CV Pilot Data Collection Summary

- CV Device Data
  - ASD Action Log Data
  - RSU Mobility Data
  - PID Log Data
  - System Operations Data
- Non-CV Device Data
  - Crash Data
  - Operations Conditions Data
  - Confounding Factors Data

ASD Event Data Collection



"Alert" triggers and event record

Retains data needed for evaluation with dramatic reduction in data transmissions

- *Estimated 77GB per day for all pilot vehicles*
- *Estimated 2TB per day for everything*

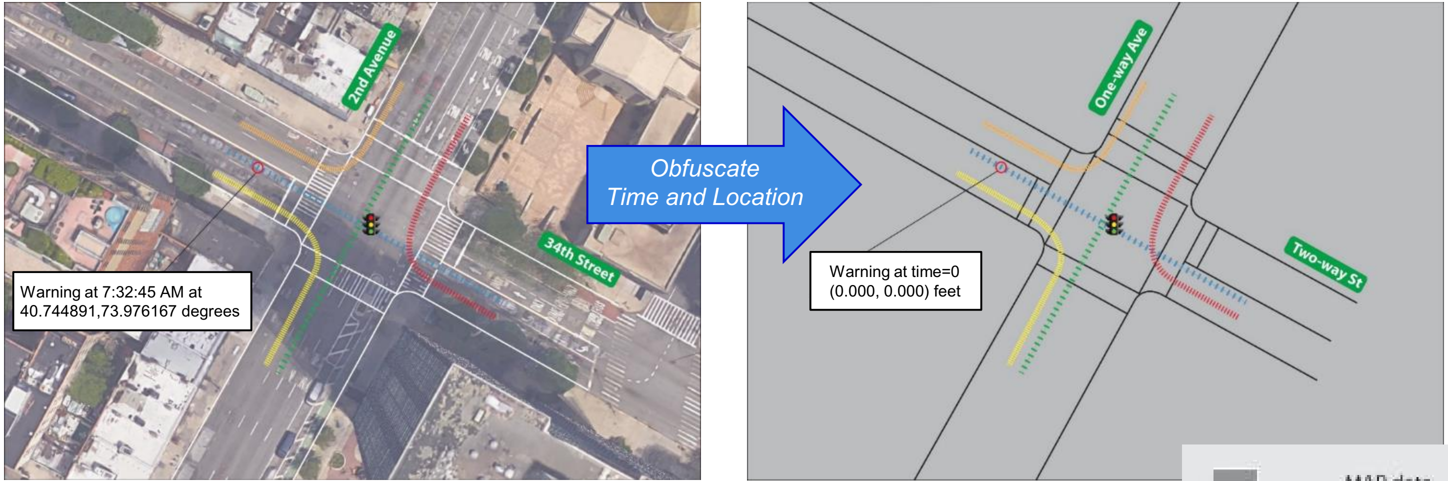
Real Privacy Concerns

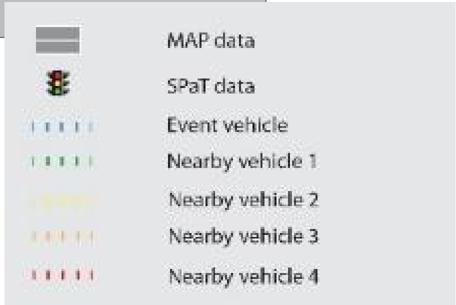
- If unobscured BSM data were to be collected in event records
  - Provides vehicle locations at 0.1 second intervals
  - Time-of-day Stamped to 0.1 second accuracy
  - Police Records indicate “final position” of vehicles and time of day
  - CV data could be used to recreate the accident scene and vehicle actions before crash
- Even though CV vehicle ID is randomly changed – the raw data can be tracked to an individual vehicle with secondary data sources with PII (e.g. crash records)

OBFUSCATION OF ASD ACTION LOGS

Raw ASD Action Log Data

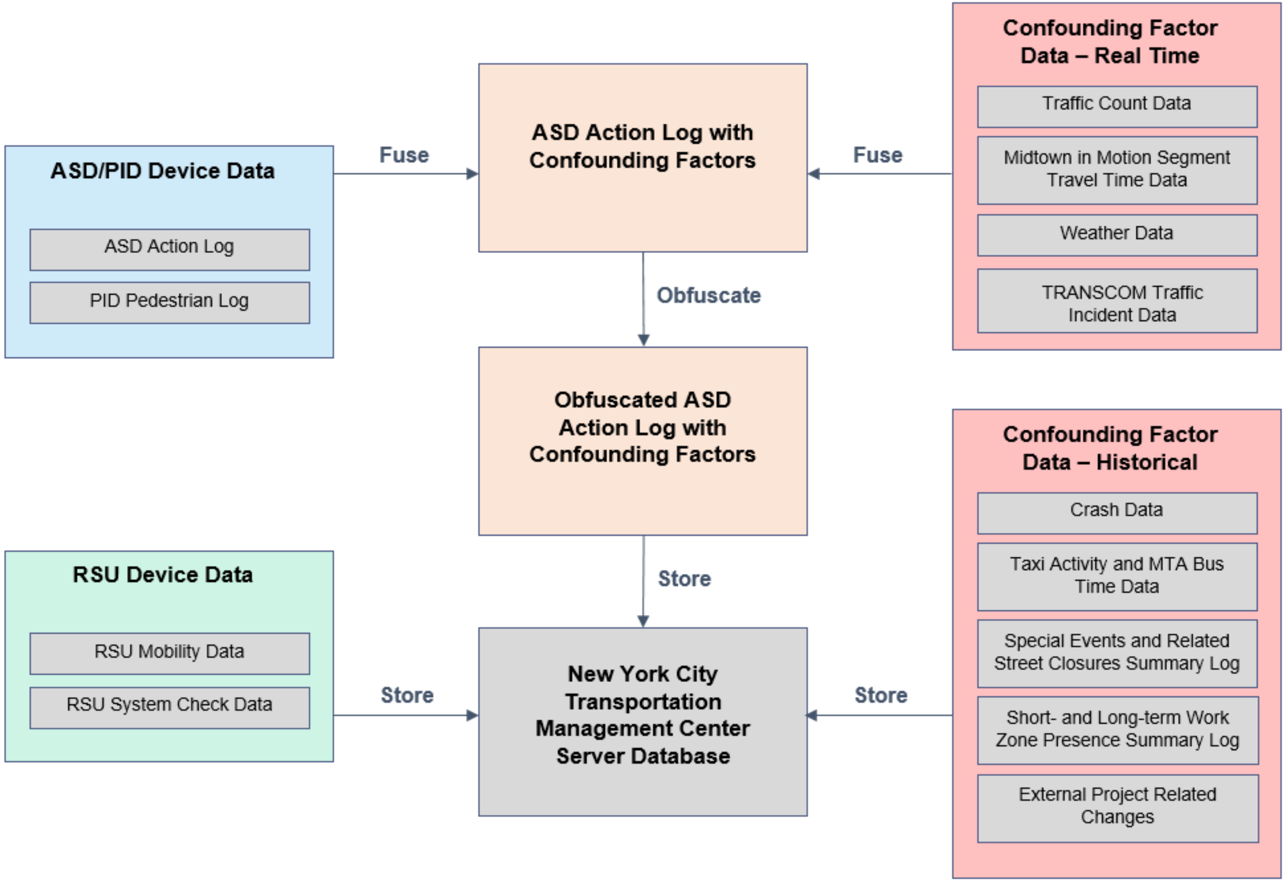
Obfuscated ASD Action Log Data





- Obfuscation process to scrub precise time and location data
  - Relative details of BSM, SPaT, and MAP retained
- Time-of-day / Day-of-week / General location bins will be populated as well to retain some time and location context
- Non-obfuscated data will be destroyed following the obfuscation process

Fusion of Confounding Data in the Obfuscation Process



Other Data – Operations Data

- RF Data – Proactive Analysis
  - Records first and Last BSM heard from each OBU
  - OBU records the first and last SPaT heard from each RSU
  - Time-out to determine limit of coverage
  - This data is captured at both the RSU and the OBU to track performance of RSUs and OBUs to address maintenance needs.
- 'Guess Who I saw'
  - Track other OBUs seen throughout the City
  - Record 2 bytes per encounter
  - This lets us know how many encounters there were
- BSM for each vehicle as it enters the RSU intersection
  - This is passed to the TMC and used to measure link travel times as a performance measure for adaptive control

This data is intended to provide the O&M support and overall reliability data for evaluating the issues with CV deployment

This data supports mobility impacts assessment of the NYC CV Pilot

With and Without CV Data Collection

Two Modes of Operation for ASDs

- **Silent Mode** (or Without CV): System fully deployed and operational but ***without*** user notification of ASD perceived warnings.
  - In silent mode, the ASDs will record normal driver behaviors and reactions during conditions that the ASDs would have issued a warning if active.
- **Active Mode** (or With CV): System fully deployed and operational but ***with*** user notification of ASD perceived warnings.
  - In active mode, the ASDs will record the normal driver behaviors before the issue of the ASD warning and the modified or revised behavior and actions following that warning.

Evaluation Design

Phase 2 | Phase 3

		3-6 months	15-12 months
Vehicle Group	Prototype Install Test Tune	Before Silent	After Audible
Taxi Control	T1 T2 T3 … Tn	T1 T2 T3 … Tn	T1 T2 T3 … Tn
Taxi Treatment	T1 T2 ~~T3~~ … Tn	T1 T2 T3 … Tn	T1 T2 T3 … Tn

Silent

Active

Calculate Before Performance Measures

Calculate After Performance Measures

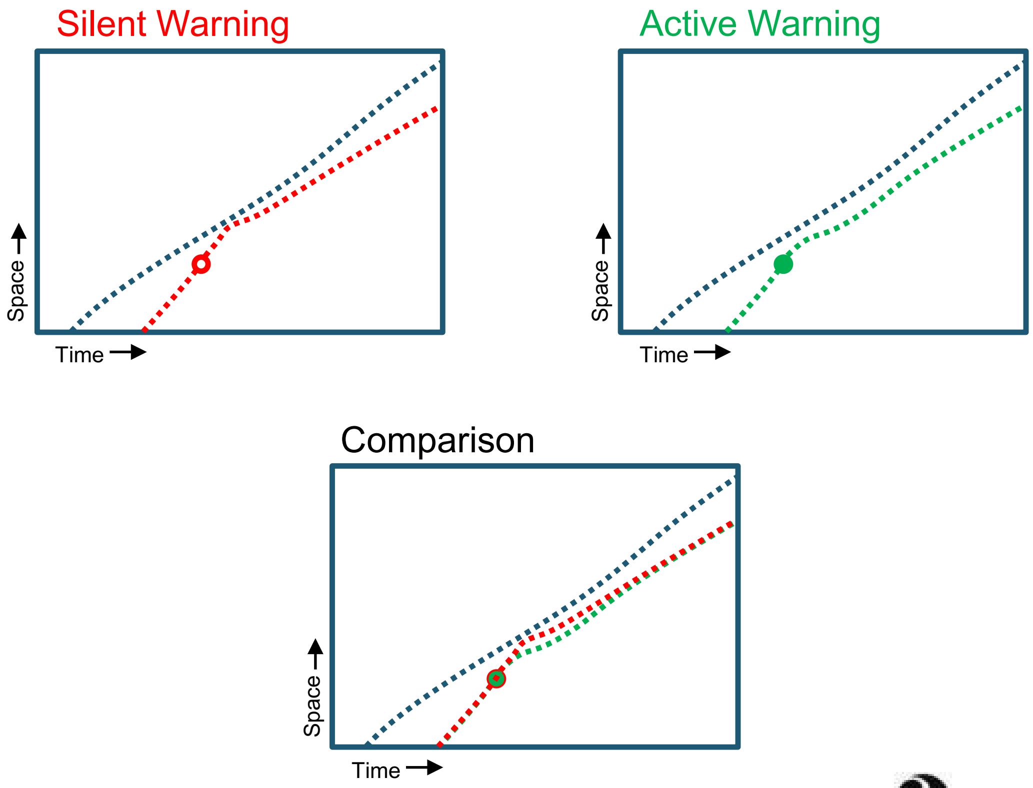
Design Considerations:

- Multiple drivers for each vehicle
- Drivers using different vehicles (control vs treatment)
- Manage with control group being specific fleet owners
- Don't know silent time period or control group size yet
- Depends on the data quantity

Evaluation Analysis Methods

	Safety Impacts	Non-Safety Impacts
Empirical	***Before & After Analysis of Crash Records*** • *Actual Records* • *Confounding Factors* • *Statistical Significance?*	***Mobility Speed/Travel Time Records from CV Devices*** • *Actual probe data samples* • *Confounding Factors* • *Sample Size?*
Simulated	***Safety Surrogate Measures (SSM) Simulations*** • *Calibration to ASD Action Log Data* • *Confounding Factors Isolated* • *Risk Based Analysis of Safety*	***Mobility & Reliability Simulations*** • *Systemwide Impact Assessments* • *Confounding Factor Isolated* • *Estimate Crash Costs on User Delay* • *Estimate Emissions Impacts*

Extracting Driver Behavior from Event Records – Trajectory Analysis



Safety Impacts: Safety Surrogate Measures (SSM) Simulations

- Assess changes in driver behavior from CV deployment and estimate changes in risk of crashes

- Small scale very-detailed microsimulations needed building on existing SSM simulation research
  - Customize driver behavior models based on observed changes in driver behavior and reactions from observed ASD datasets
  - Calibration of vehicle movements (trajectory level calibration)

- Multiple simulation scenarios under pre- and post-CV deployment for:
  - Different geometric conditions
  - Confounding factors (demands, weather, etc.)
  - Stochastic Randomness

Non-Safety Impacts: Systemwide Mobility & Reliability Simulations

- Assess impacts on mobility and reliability of reduced number and/or severity of crashes from the CV deployment

- Use the Manhattan Traffic Model (MTM)
  - An Aimsun microsimulation of Midtown Manhattan
    - 14th Street to 66th Street, Hudson River to East River
  - Incorporate changes on mobility from ASD datasets
    - Reduced speeding or speed variation on roadways

- Multiple scenarios under pre- and post-CV deployment for:
  - Multiple types, locations, and severity of crashes
  - Prevented crashes or reduced severity crashes (faster clearance)
  - Assessment of differences in system user impacts of each scenario
  - Estimate of mobile emissions using simulation outputs

DEPLOYMENT STATUS

- RSUs
  - 20 Prototypes have been installed
    - Testing V2X Locate accuracy for urban canyons
  - First 30 Production units are being installed
    - RSUs Basic RSU software is complete
    - OTA software update (broadcast) tested
    - Next testing to be data collection
- ASDs
    - 80 samples installed in City Vehicles
    - 50 Prototypes being installed to replace samples
    - Applications completed – pending only OTA data collection

DEPLOYMENT STATUS

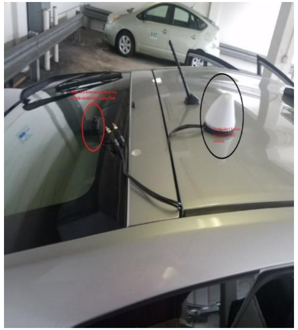
- Working through technical and install issues with prototype units
  - Location accuracy
  - Vehicle installation methods

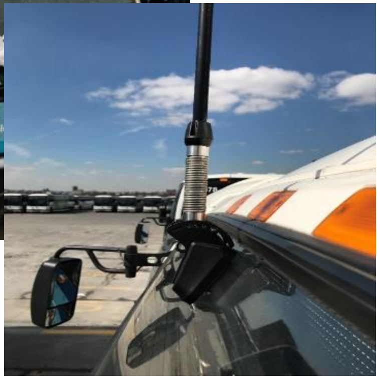
- Finalizing the software development and testing
  - ATC updates - completed
  - PID Smartphone App – preparing for stakeholder review of interface
  - Data Transfer Protocols – in final testing

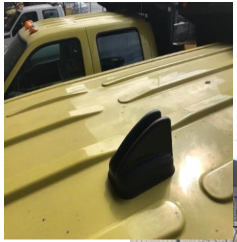
- Focus is now on back-office data collection and analysis

ASD/OBU Installation Procedure Development

- Testing of procedures and communications
- Establishing contracts with professional installation firms
- Prototype OBUs installed in a variety of vehicle types
- Resolving technical issues encountered







Performance Measurement Next Steps

- Draft Safety and Non-Safety AMS plans completed
- Update to Phase 1 Performance Measurement and Evaluation Support Plan ongoing
- Base Mobility Simulation models (pre-CV conditions) nearing completion for peak periods
- Awaiting first production unit deployments to start trial data collection, Safety Simulation model development, and finalization of performance measures tools
  - Detailed procedures and methods are under development for automated ASD Event record data error checking, non-CV data fusion, and obfuscation processing
  - PID application performance measures software is under development and we have achieved end-to-end live data from controller to PID and data collection

Q&A

NYCDOT

Tampa (THEA)

WYDOT

USDOT

Stay Connected

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Visit CV Pilot and Pilot Site Websites for more Information:

- CV Pilots Program: http://www.its.dot.gov/pilots
- NYCDOT Pilot: https://www.cvp.nyc/
- Tampa (THEA): https://www.tampacvpilot.com/
- Wyoming DOT: https://wydotcvp.wyoroad.info/

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