CONNECTED VEHICLE PILOT
Deployment Program

Real-World Deployment of Connected Vehicles: Challenges and Lessons Learned

Program Manager: Kate Hartman

SESSION AGENDA

- 6:00 – 6:20 PM New York City DOT CV Pilot Overview

  Michael Replogle, New York City Department of Transportation

- 6:20 – 6:40 PM Measuring Success for Tampa (THEA) Pilot Deployment

  Sisinnio Concas, CUTR/University of South Florida

- 6:40 – 7:00 PM Wyoming CV Pilot Deployment Lessons Learned

  Deepak Gopalakrishna, ICF International Inc

- 7:00 – 7:15 PM 5.9 GHz for Vehicle Applications

  Michael Replogle, New York City Department of Transportation

- 7:15 – 7:30 PM Q&A

NYCDOT Tampa (THEA) WYDOT USDOT

NYCDOT CV Pilot Deployment Overview

Michael Replogle
Deputy Commissioner for Policy
New York City Department of Transportation

KEY OBJECTIVES FOR PILOT

- ✓Test 5.9 GHz DSRC (Direct Short Range Communications) Vehicle-to-Vehicle (V2V) & Vehicle-to-Infrastructure (V2I) Connected Vehicle (CV) technology in dense complex urban environment
- ✓Adjust and refine technology as required for safe effective deployment in street canyons
- ✓Ensure & demonstrate cybersecurity
- ✓Evaluate challenges of retrofitting infrastructure and diverse vehicle types for pilot

- Test key applications for traffic safety, operations & maintenance, and performance evaluation

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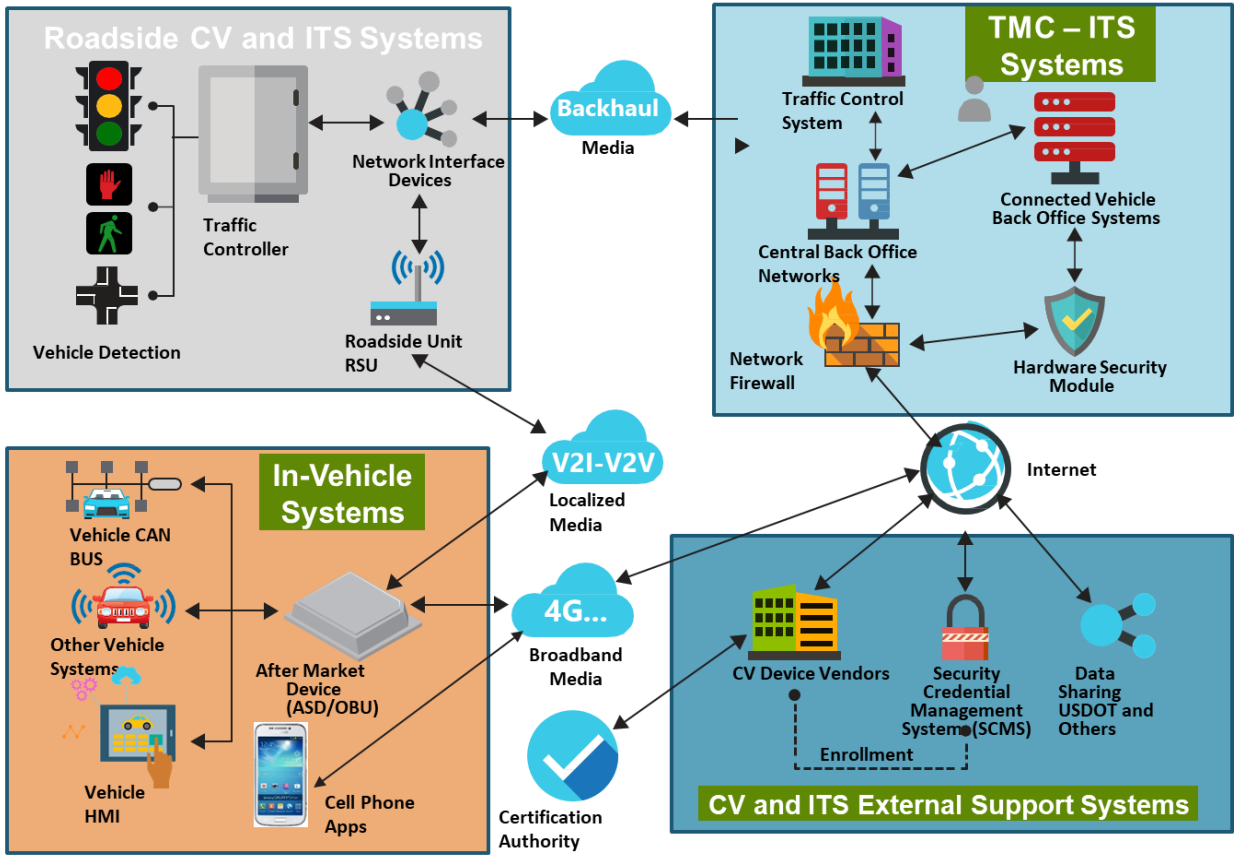
For Safer Transportation

U.S. Department of Transportation

Overview of the NY CV System



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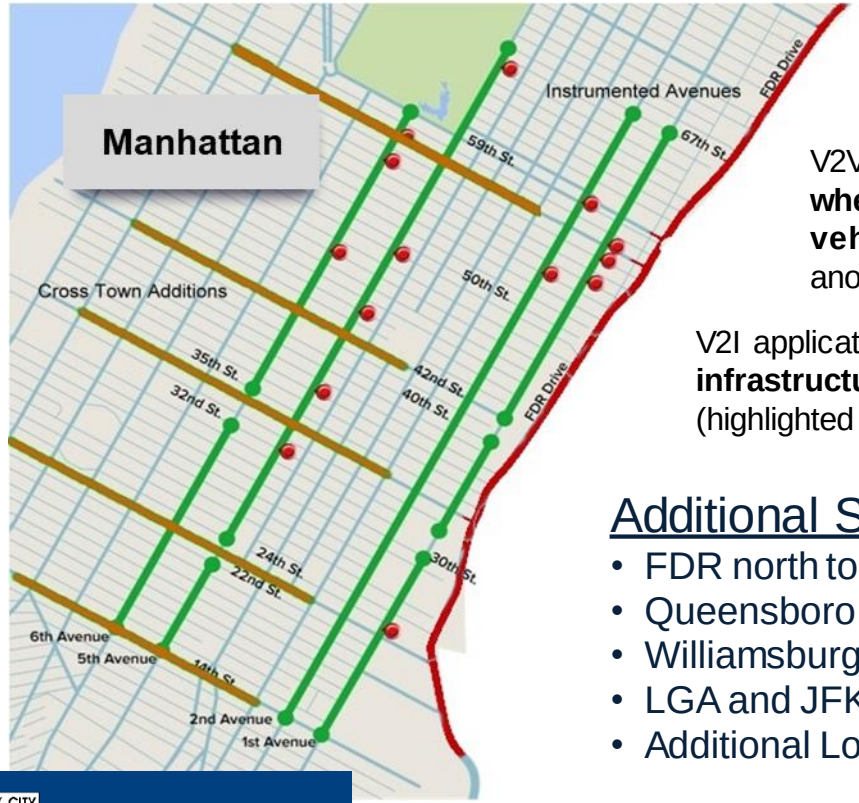
INFRASTRUCTURE DEPLOYMENT



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

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

Additional Sites not Shown:

- FDR north to Triboro Bridge
- Queensboro (59th St) Bridge Intersections (4) in Queens
- Williamsburg Bridge Intersections (2) in Brooklyn
- LGA and JFK airport
- Additional Locations to support OTA/SCMS access

V2V Safety Applications

- 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

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V2I Safety Applications

- Red Light Violation Warning
- Speed Compliance
- Curve Speed Compliance
- Speed Compliance/Work Zone
- Oversize Vehicle Compliance
- Emergency Comms & Evacuation Info
- Mobile Ped Signal System (visually impaired)
- Pedestrian in Signalized Intersection Warning
- CV Data for Intelligent Traffic Signal System

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O&M & Performance Management

- Radio frequency monitoring for encounters
- Over the air firmware updates and operational tuning
- Traffic data collection
  - Breadcrumbs for application tuning & validation
  - Vehicle travel times and adaptive signal controls
- Event warning and alert uploads with encription
- Uploading other logs for reliability and anomaly detection

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Operational Readiness Approach

- ✓Identify use cases to be demonstrated
- ✓Identify potential demonstration locations
- ✓Test demonstration locations with
  - ✓ Multiple drivers
  - ✓ Multiple vehicle types
  - ✓ Multiple vehicles of each type, if available
- ✓Develop and work punch list
- ✓Dry run demonstrations
- Actual demonstrations

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ACCOMPLISHMENTS

✓Purchased 4,000 production ASD units; 3,430 delivered; 1,200 installed

✓Purchased 550 Road Side Units (RSUs); 330 installed

Technical:

- ✓ CV Safety Applications are working; we continue to test and fine tune
- ✓ Created connectivity to the RSUs and can update firmware
- ✓ Collected the data developed for the NYC CV Pilot
- ✓ SCMS security top-off works and have deployed DSRC security
- ✓ Upgraded the NYC ITS security to DTLS and integrated into the production traffic control system
- ✓ Developed installation procedures for a wide variety of vehicle types
- ✓ Tested and evaluated Pedestrian Application for the Visually Impaired

Measuring Success for Tampa (THEA) Pilot Deployment

Sisinnio Concas

CUTR/University of South Florida

DEPLOYMENT LOCATION

- Located in the core of Tampa Central Business District
- Project managed by the Tampa-Hillsborough Expressway Authority (THEA)
  - Owns / operates Selmon Expressway
  - Owns Meridian Ave traffic signals
- West: Residential community of Brandon
- East: MacDill Air Force Base

Deployment Focus Areas

Pilot Goals

- **Enhance mobility**
  - Travel time
  - Travel time reliability
  - Delay
- **Increase safety**
  - Crashes
  - Conflicts
- **Help sustain environment**
  - Tailpipe emissions

VEHICLES


PHOTO: THEA

~1,000

Privately Owned Vehicles


PHOTO: THEA

8

TECO Line Streetcar Trolleys

PHOTO: THEA

10

Hillsborough Area Regional Transit (HART) buses

EQUIPMENT

PHOTO: Brandmotion

~1,000

On-Board Units (OBUs)

A rear view mirror for passenger vehicles and tablet display for transit vehicles


PHOTO: Siemens

47

Road Side Units (RSUs)

Mounted on existing structures throughout the deployment area

WARNINGS: HUMAN-MACHINE INTERFACE

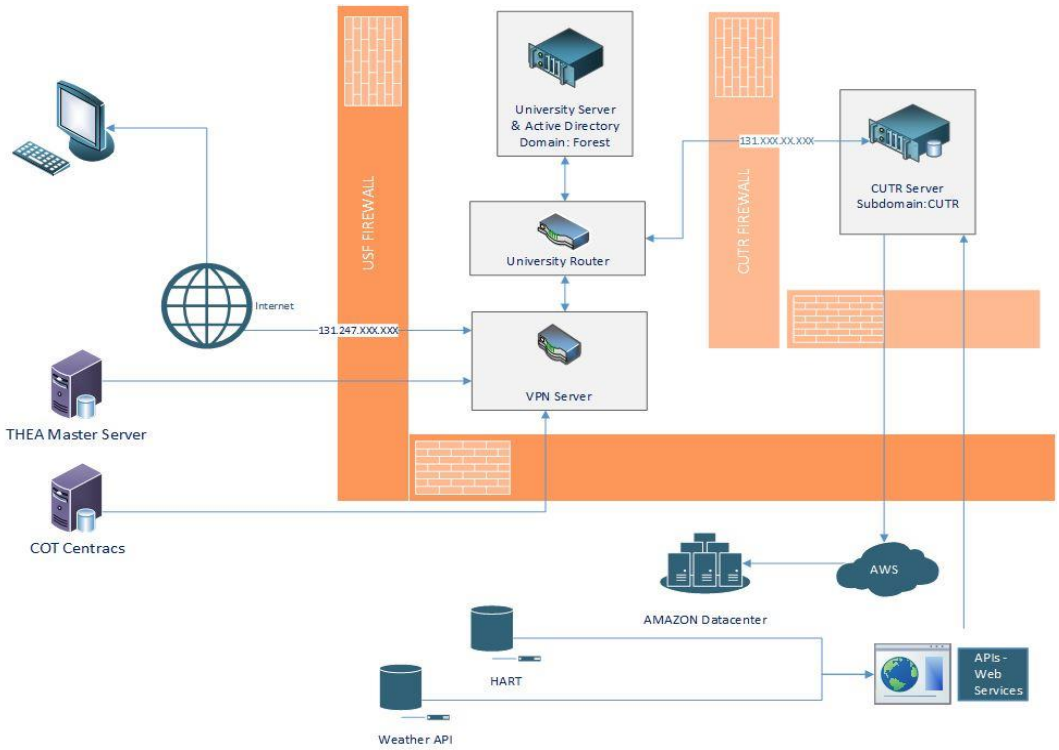
Participants exposed to HMI via experimental design:

- Treatment (HMI on)
- Control (HMI off, stealth mode data collection)
- Group Assignment
  - ~ 2 to 1 match stratified by sex, age, income, education
  - 1,006 active participants
  - Treatment = 615
  - Control = 391

Connected Vehicle Applications

APPLICATION	DESCRIPTION
End of Ramp Deceleration Warning (ERDW)	Alerts driver approaching curve with speed safety warning
Emergency Electronic Brake Light (EEBL)	Enables broadcast to surrounding vehicles of severe braking
Forward Collision Warning (FCW)	Warns driver of impending collision ahead in same lane
Intersection Movement Assist (IMA)	Indicates unsafe (i.e., wrong way) entry into an intersection
Intelligent Traffic Signal System (I-SIG)	Adjusts signal timing for optimal flow along with PED-SIG and TSP
Pedestrian Collision Warning (PCW)	Warns driver of impending conflict with pedestrian
Transit Signal Priority (TSP)	Allows transit vehicle to request and receive priority at a traffic signal
Vehicle Turning Right in Front of a Transit Vehicle (VTRFTV)	Alerts transit vehicle driver that a car is attempting to turn right in front of the transit vehicle as well as the driver of the car.
Wrong Way Entry (WWE)	Warns driver of potential and actual wrong way travel direction

PERFORMANCE EVALUATION - INFRASTRUCTURE SETUP



CUTR Dedicated Servers

- SQL Databases (CV and non-CV Data)
- PII Removal
- USDOT SDC & ITS Public Data Hub data nightly upload
- Data parsing and analysis
- Participant misbehavior detection protocol
- Modeling and inference
- OBU vendor support to validate OBU Data Logs

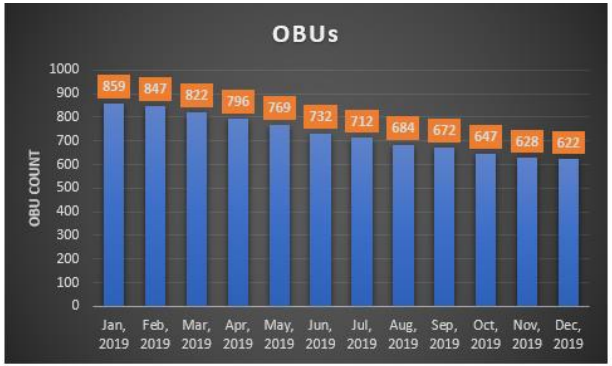
CONNECTED VEHICLE DATA GENERATION

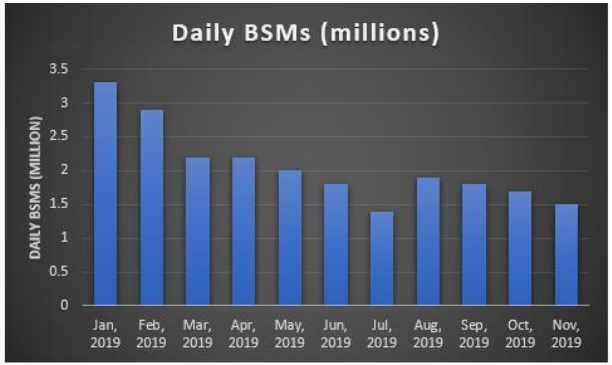
CV Data

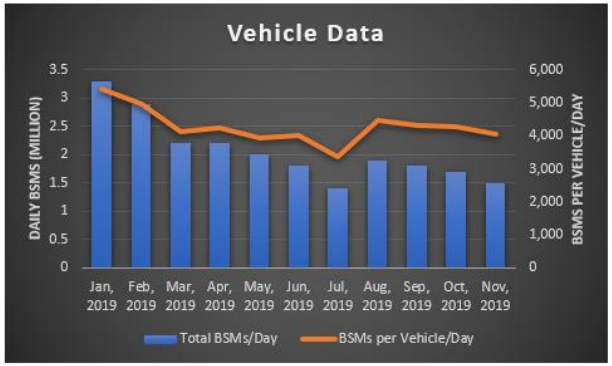
- About 475,000 files
- 17TB database
- Basic Safety Message (BSM)
- Traveler Information Message (TIM)
- Personal Safety Message (PSM)
- Signal Phasing and Timing (SPaT)
- Signal Request Message (SRM)
- Signal Status Message (SSM)
- MAP

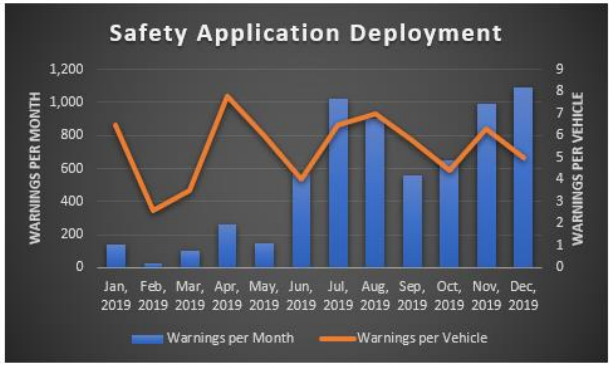
Non-CV Data

- Local weather (5-mins interval)
- Transit live GTFS data feeds
- Bluetooth readers
- Historical crash data
- Road closures, special events



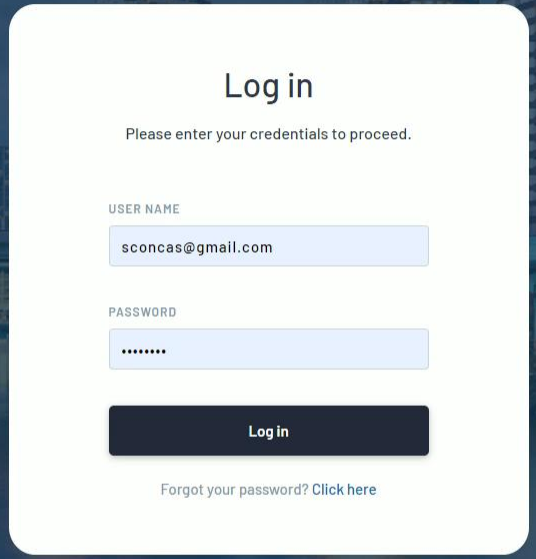






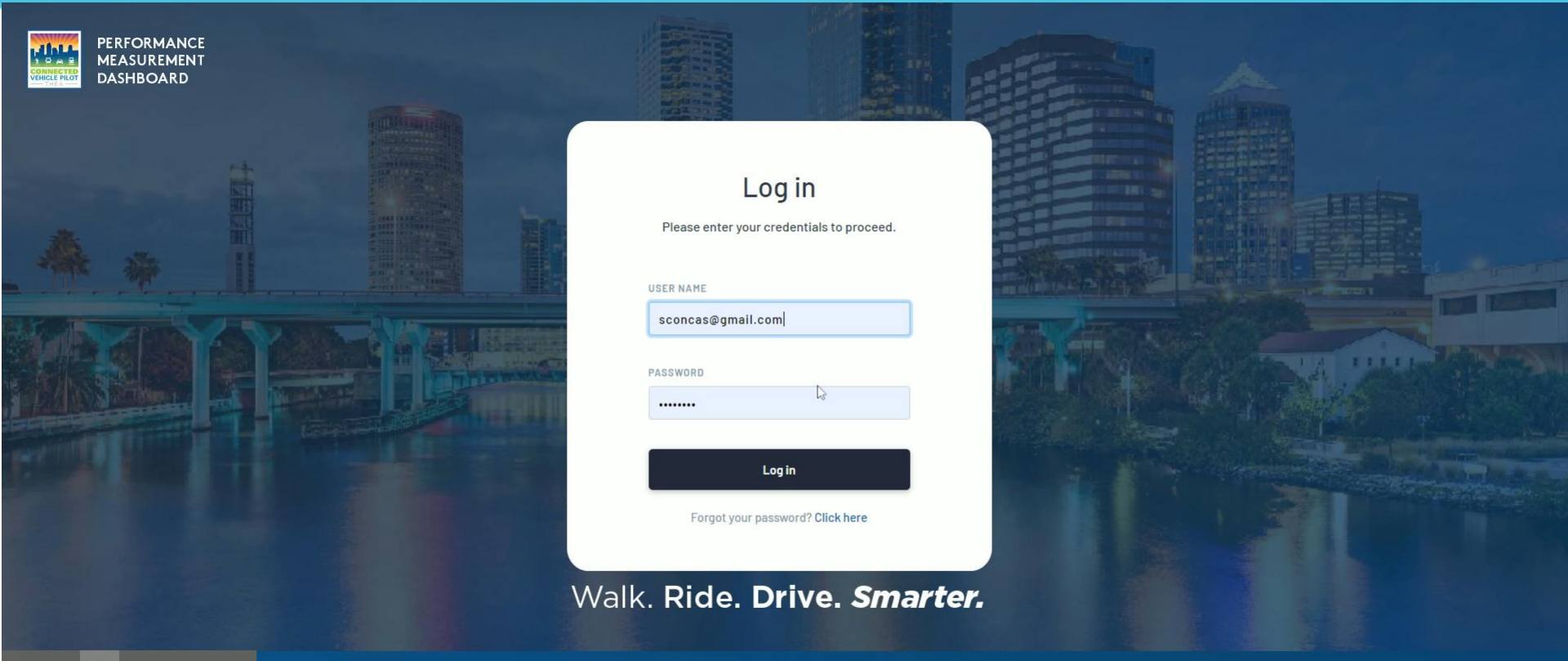
NEAR REAL TIME ANALYSIS

PERFORMANCE
MEASUREMENT
DASHBOARD



Walk. **Ride. Drive. *Smarter.***

Reporting to USDOT Officials



Transportation.gov
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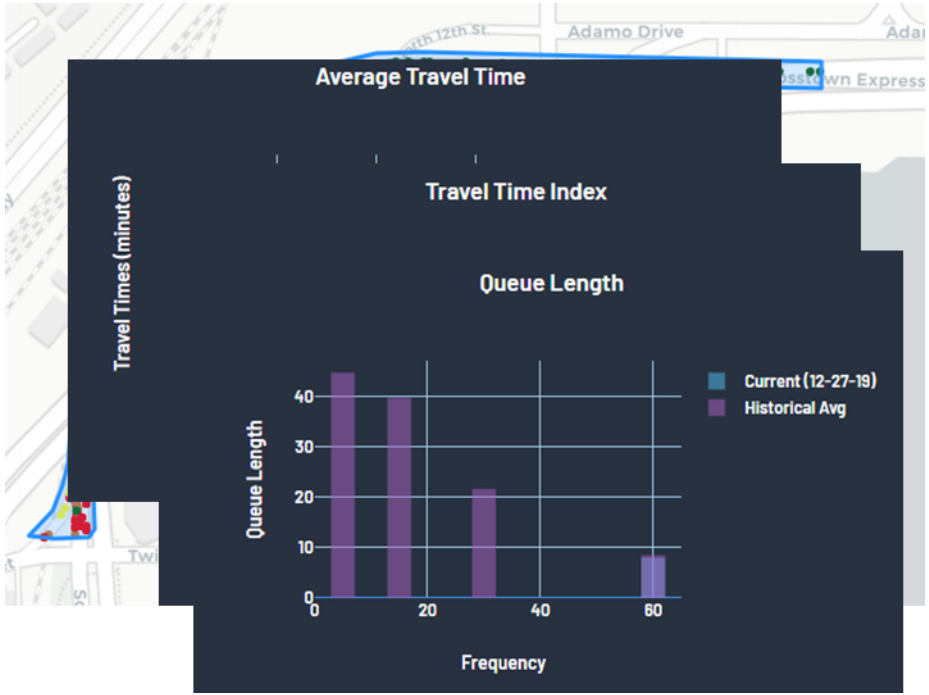
Mobility Applications Assessment



End of Ramp Deceleration Warning (ERDW)

- Speed advisory based on queue length in the a.m. peak hour

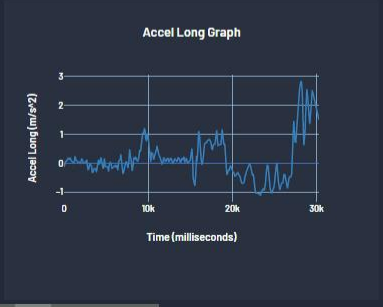
Transit Signal Priority

- Bus priority requests

Evaluation:

- Compare individual responses to speed advisories (treatment vs. control)
- Changes before vs. after app deployment
- Before vs. after transit travel time and reliability comparison

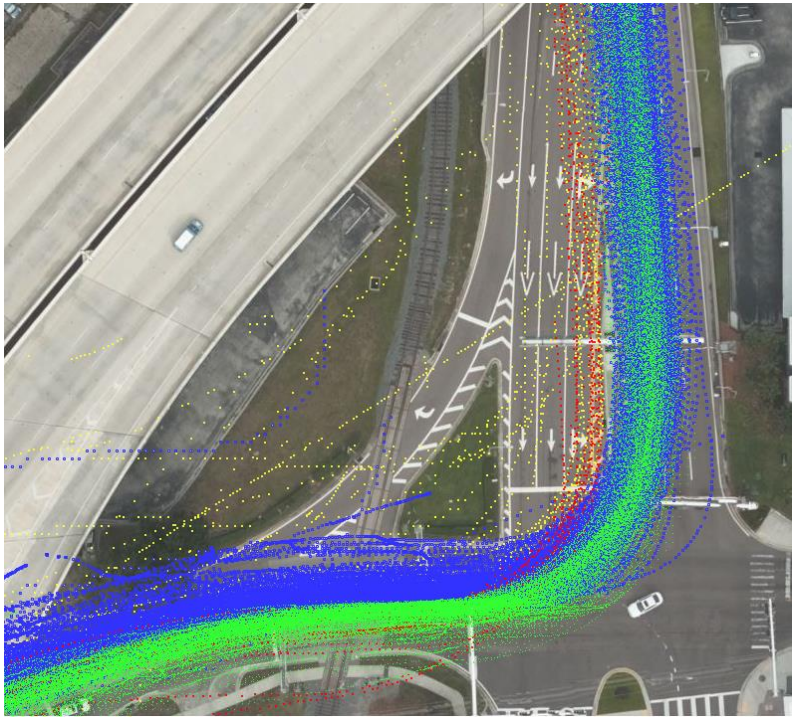
Safety Applications Assessment



- **Transit IMAs, Mar 31 – Dec 31, 2019:**
  - **17 warnings issued to participants**
  - **2 false positives**

Challenges to Performance Evaluation

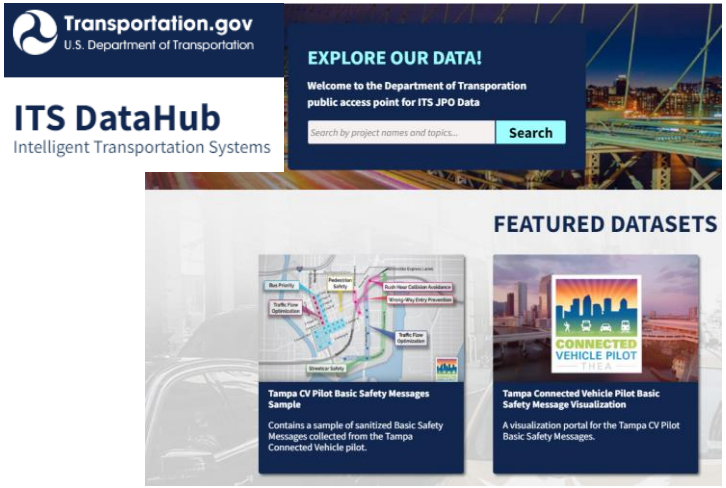
- After market OBU reliability
  - Hardware and firmware issues
  - Application safety parameters settings
- GPS signal accuracy in urban environments
- RSU integration with traffic signal applications (i.e., MMITSS)
- Over-the-air data transfer
- Participant attrition
- Confounding factors



WHAT'S NEXT

Spring-Summer 2020:

- System Impact Evaluation
- Statistical modeling for causal inference
- Summary of Impacts



https://www.its.dot.gov/data/index.html

Sisinnio Concas – concas@cutr.usf.edu

CUTR

Autonomous & Connected Mobility Evaluation

Wyoming DOT Pilot Deployment Lessons Learned

Deepak Gopalakrishna
ICF International Inc

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's Approach

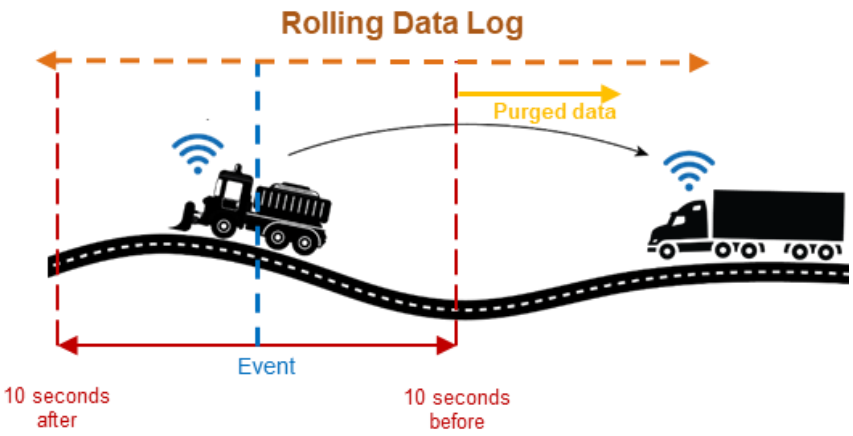
Roadway Design	• Good roadway design • Select best geometry using powerful modeling tools
Mitigation	• Slope modifications • Snowfence
Technology	• Intelligent transportation systems • Connected vehicle technology

System Interoperability

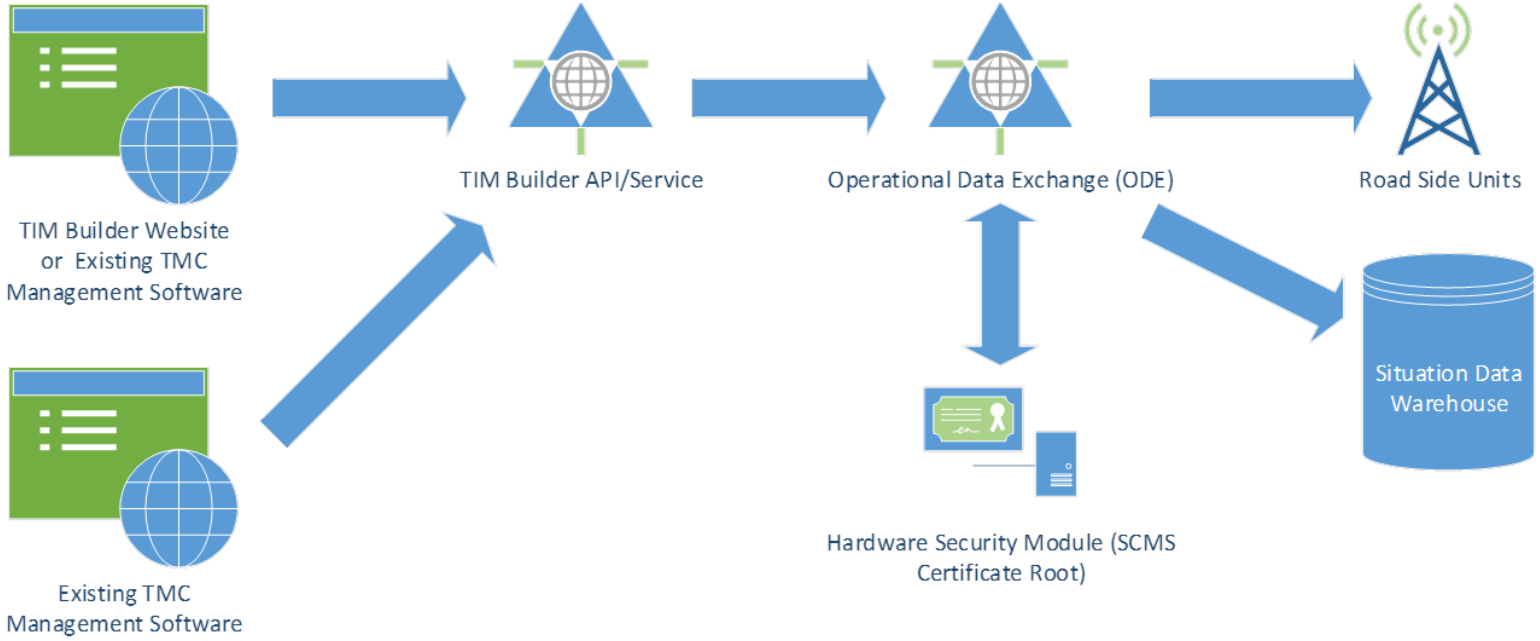
- Future CV Ecosystem
  - Many vehicles
  - Many vendors
  - Many jurisdictions
- Messages between vehicles and infrastructure must be seamlessly exchanged and understood by each other
- **Interoperability of CV Systems is vital to national deployment**

Event Log Size Management

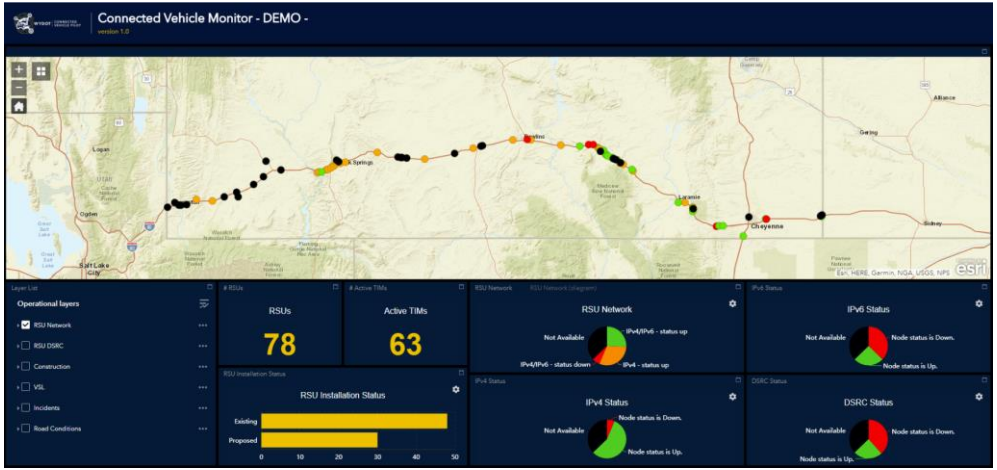
- Event Logs on the OBU are built for the following:
  - BSM during event
  - BSM every 30 seconds
  - TIM reception (SAT and RSU)
  - Distress Notification
  - Updates
  - Driver Alerts (TIMs, FCW, DN)
- Rotate at 100k in size, then zipped and sent to TMC when RSU is available
- Very limited bandwidth
- Built with binary log file using ASN.1 where possible.

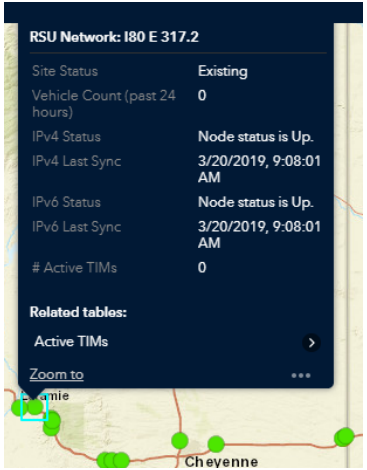


TMC Integration



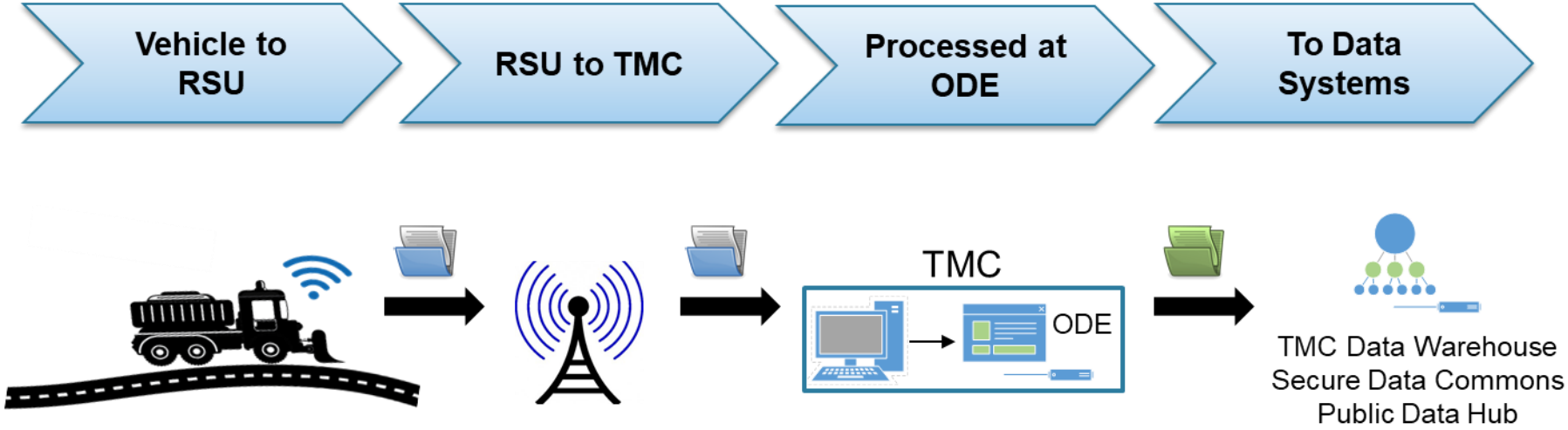
CV Monitor



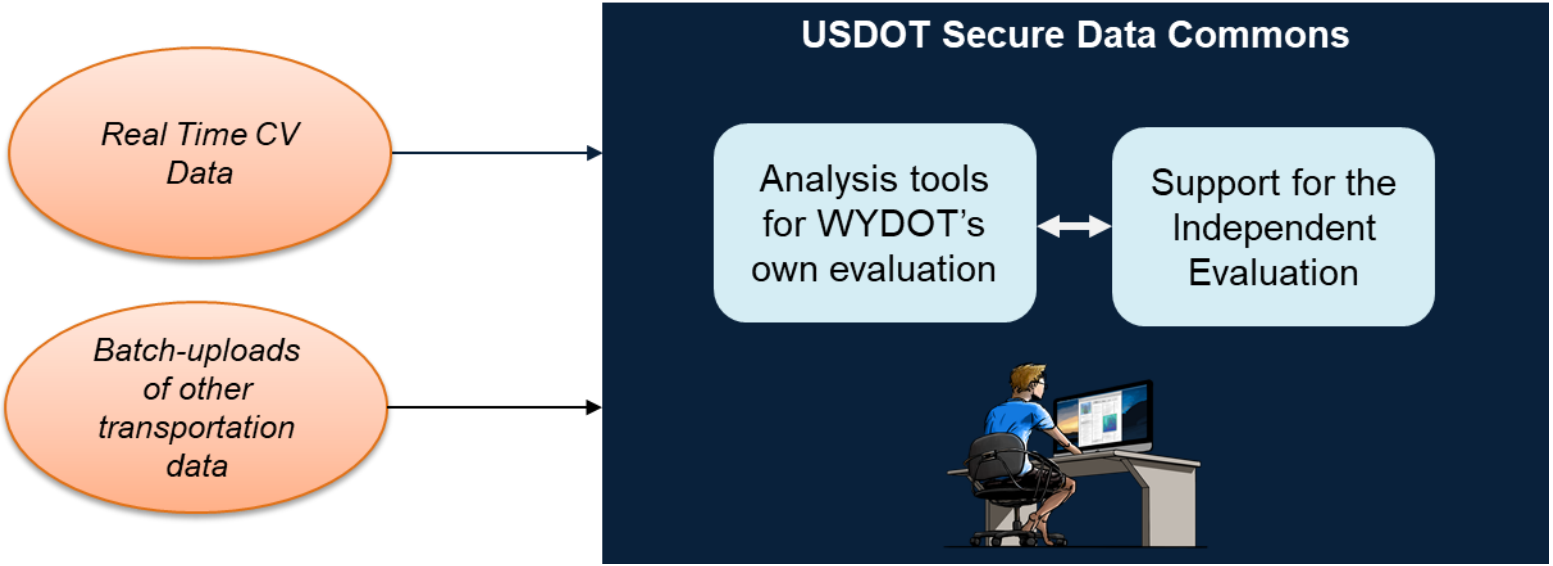


- The CV monitor is used to monitor RSUs in real-time
- Provides the status of communication, vehicle counts, posted TIMs and other information
- A specialized version with an enhancement allows authorized people to apply firmware updates to RSUs
- Publicly available https://wydotcvp.wyoroad.info/CVM/

REAL-TIME DATA FLOW



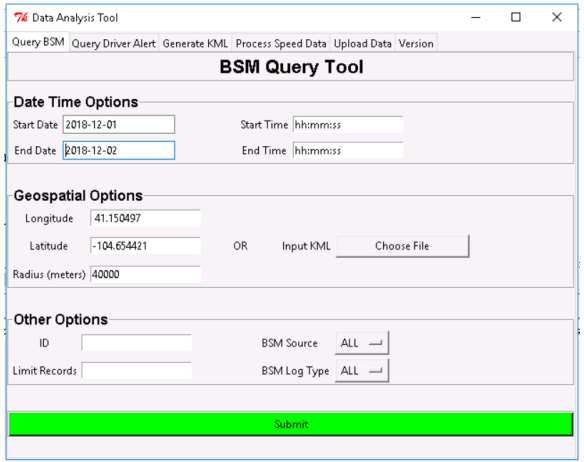
Utilizing the Secure Data Commons

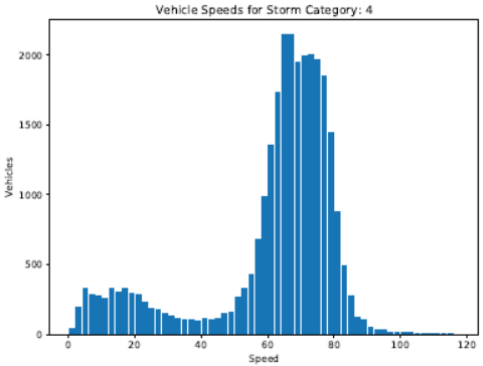


SDC Real-Time Data Analysis

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

Over the Air Updates for OBUs

- Critical to ensure fleet OBUs can be updated without touching vehicle/OBU multiple times for updates
- Philosophy of why we can't touch vehicles and that this needs to be a solid solution - nonoptional
  - Firmware
  - Config
  - HMI

Open Source Software for CV

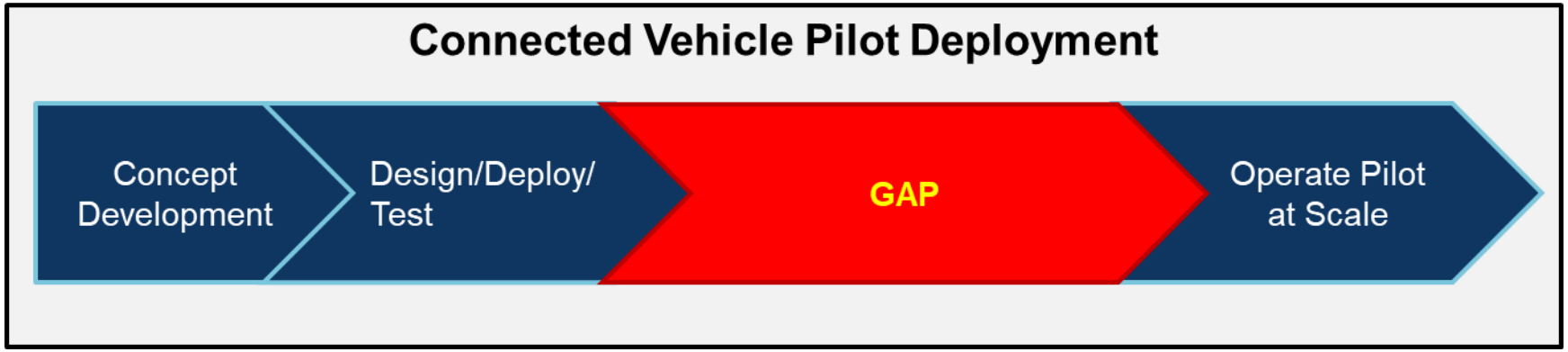
- Operational Data Environment
  - Privacy Protection Module
  - ASN.1 Encoder Decoder
- TIM builder
- V2X Hub
- Secure Data Commons
- Data Hub
- Pikalert

EMPHASIS ON TRAINING

- Truck driving simulator with CV HMI at University of Wyoming Driving Simulator Lab (WyoSafeSim)
- 18 snowplow truck drivers from WYDOT participated in the experiment.
- Highway Patrol officers are often required to drive at high speeds under enormous workload regardless of the road and weather conditions which increases the risk of crashes.
  - CV warnings are easy to understand (average likert score 6.2 out of 7).
  - Adverse weather, work zones and surface conditions noted as priority

https://www.youtube.com/watch?v=JLaS-s1OvCI&feature=youtu.be

Issues and Challenges



LESSONS LEARNED

- SCMS Integration
- Vendors
- Radio Integration
- Network Security
- Log File Size
- DSRC Shadow
- OBU Failing at Scale
- Data Volume

Issue – Radio Integration

Radio Integration

- Needed an updated firmware
- WYDOT had no direct relationship with OBU component vendors

Mitigation Strategy

OBU Vendors should have better service agreements with their component vendors

Issue – Log File Size

Log File Size

- DSRC off-leading and over-the-air update speed
  - At highway speeds, contact time with vehicles is short and off-loading of data is a challenge
  - We are collecting performance data for evaluation purposes

Mitigation Strategy

Trim logged messages and have over the air updates be re-startable

Issue – OBU Failing at Scale

OBU Failing at Scale

- Maintaining an OBU fleet is hard
- Security obfuscation makes it harder
- General code stability (crashing, GPS not coming online, HMI disconnecting, offloading random)
- HSMs are essential

Mitigation Strategy

Periodically touch OBUs to review fleets

Issue – Tech Challenge to Network Security

Network Security

- We went for the big play with full IPv6 end-to-end
- Public sector networks typically do not think about or support IPv6
- This resulted in firewall updates
- Router configuration changes

Mitigation Strategy

Continuously upgrade, patch, lock, probe, and analyze

5.9 GHz for Vehicle Applications

Michael Replogle
Deputy Commissioner for Policy
New York City Department of Transportation

DSRC Based V2V and V2X: Ready to Save Lives

- Nearly 40,000 people/year die on US roads
- Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), & Vehicle-to-Everything (V2X) communications promise to save thousands of lives/year through –
  - Traffic warning systems
  - Automated braking and other collision avoidance systems
  - Speed warnings and management
  - Traffic advisories
  - Traffic/transit operations support
  - Transportation performance management

DSRC Based V2V and V2X: Ready to save lives

- 1999: FCC allocated 75 mHz in 5.9 GHz band for Intelligent Transportation: DSRC standard
- 2012: NHTSA proposed FMVSS 150 mandating DSRC V2V for new vehicles starting in 2020
- Much of industry accepted NPRM & made plans for deployment, with some still proceeding 2019
- 2017 projection: 70 million light-duty vehicles globally likely to have DSRC V2V by 2025
- DSRC standard supported/adopted by
  - Association of Global Automakers
  - GM, Toyota, Honda, Nissan, Kia, Delphi
  - 50 state DOTs
  - European Union

Proposed spectrum sharing in the 5.9 GHz band is the most serious risk and uncertainty" for connected vehicle system deployment. – TRB/NAS 2019 letter to FCC

DSRC Based V2V and V2X: Ready to Save Lives

- DSRC 5.9 GHz V2V:
  - Has undergone extensive testing
  - Proven safe & ready-to-deploy now
  - Available in some mass-market vehicles
- Competing Cellular V2X (C-V2X) would be based on still-under-development 5G cellular systems
- C-V2X supported by: Ford (since 1/2019), BMW, Qualcomm, Ericsson
- Dual DSRV/C-V2X chips promise standard complementarity for phased transition should C-V2X be proven effective, with immediate benefits

C-V2X Based V2V and V2X: Needs Years to Test

- Emerging C-V2X standards only now being initiated
- DSRC standards like IEEE 1609.x required multiple revisions; so will C-V2X
- Earliest C-V2X pilot testing in early/mid-2020s
- C-V2X and 5G will require extensive new microgrids: US labor shortage and industry capacity in question
- Complementarity of DSRC and C-V2X standards for phased transition will likely be dashed if FCC destroys DSRC spectrum

FCC & NHTSA Policies Delay V2V, V2I, V2X

- 1/30/2017: Executive Order indicated administration will not finalize NHTSA rule mandating V2V, slowing adoption
- 12/12/2019: After years of threats. FCC voted to reallocate the DSRC 5.9 GHz band from 100% dedicated, tested, proven and emerging transportation safety uses to instead provide:
  - 45 mHz for unlicensed operations
  - 20 mHz for Cellular V2X (C-V2X)
  - 10 mHx for either C-V2X or DSRC (14% of remaining)
- 12/19/2019: FCC issued NPRM to this effect with 30-day comment period (ET Docket No. 19-138, https://docs.fcc.gov/public/attachments/FCC-19-129A1.pdf)
- This action undermines DSRC and its deployment, delaying V2V, V2I, V2X until likely mid-2020s or later

FCC & NHTSA Delay Will Cost Many American Lives

- University of Michigan Transportation Research Institute (UMTRI): FMVSS 150 DSRC based V2V could avert 2 million crashes by 2030, saving thousands of lives
- 2019 UMTRI study (Sayer, Flannagan, Leslie) estimates lives lost to road crashes due to V2V implementation delay, comparing adoption of FMVSS 150 now using DSRC vs. delayed V2V implementation using C-V2X
- Expected delays of 3 to 7 years for V2V will result in 7.4 m to 19.1 m added crashes and 40,717 to 105,746 lives lost in coming years

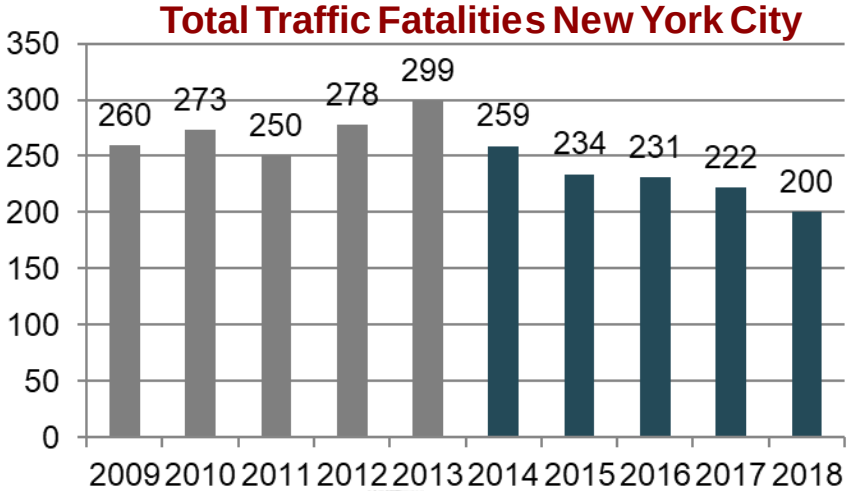
IMPACT OF FCC 5.9 GHZ RULE ON NYC CV PILOT

Loss of lower 4 channels in the 5.9 GHz DSRC band and re-assignment of upper 2 channels for C-V2X will require --

- Replacement of all installed CV devices at considerable time and cost
- Alternate methods for data collection and other functions now on lost channels
- Redesign of the security system and its interfaces to the Security Credential Management System
- Placing current safety messages & traveler information on safety channel or an alternate media, requiring review & simulation of channel loading in remaining single 10 MHz channel
- Unlicensed Wi-Fi in the lower 45 MHz of the 5.9 GHz band likely to interfere with the rest of the band, compromising core safety functionality

NHTSA & FCC Should Prioritize Traffic Safety Not WiFi

- NYC's Vision Zero initiative has cut road traffic deaths in City by nearly 1/3 since 2013, but progress stalled last year
- Cities and states lack authority to regulate motor vehicle safety standards
- To save tens of thousands of lives --
  - NHTSA needs to mandate V2V in FMVSS
  - FCC needs to protect 5.9 GHz for DSRC, and not give away this bandwidth for faster WiFi



Q&A

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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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