**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 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
OVERVIEW OF THE NY CV SYSTEM

Roadside CV and ITS Systems
- Traffic Controller
- Vehicle Detection
- Roadside Unit (RSU)
- Backhaul

Traffic Control System
- Network Interface Devices
- Central Back Office Networks
- Network Firewall
- Hardware Security Module

TMC – ITS Systems

In-Vehicle Systems
- Vehicle CAN BUS
- Other Vehicle Systems
- Vehicle HMI
- After Market Device (ASD/OBU)
- Cell Phone Apps

V2I-V2V
- Localized Media
- Broadband Media
- 4G...

4G
- Certification Authority
- CV Device Vendors
- Security Credential Management System (SCMS)
- Data Sharing US DOT and Others

CV and ITS External Support Systems

NYC Connected Vehicle Project
For Safer Transportation

U.S. Department of Transportation
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
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
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 encryption
- Uploading other logs for reliability and anomaly detection
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
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
Pilot Goals

- Enhance mobility
  - Travel time
  - Travel time reliability
  - Delay

- Increase safety
  - Crashes
  - Conflicts

- Help sustain environment
  - Tailpipe emissions
VEHICLES

~1,000
Privately Owned Vehicles

8
TECO Line
Streetcar Trolleys

10
Hillsborough Area Regional Transit (HART) buses
~1,000 On-Board Units (OBUs)
A rear view mirror for passenger vehicles and tablet display for transit vehicles

47 Road Side Units (RSUs)
Mounted on existing structures throughout the deployment area
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

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

- Historical individual vehicle profiles
- Algorithms to net out false positives:
  - OBU parameter conforming evaluation
  - Comparative behavioral response analysis of treatment (HMI active) versus control (HMI inactive)
- Dynamic event replay on Performance Evaluation Dashboard
- Quick response to OBU vendor for firmware/configuration resolution
- Precursory analysis

- 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
Spring-Summer 2020:
- System Impact Evaluation
- Statistical modeling for causal inference
- Summary of Impacts

Sisinnio Concas – concas@cutr.usf.edu
Autonomous & Connected Mobility Evaluation

https://www.its.dot.gov/data/index.html
Wyoming DOT Pilot Deployment Lessons Learned

Deepak Gopalakrishna
ICF International Inc
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 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

TIM Builder Website or Existing TMC Management Software

TIM Builder API/Service

Operational Data Exchange (ODE)

Road Side Units

Situation Data Warehouse

Hardware Security Module (SCMS Certificate Root)
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://wydotcvm.wyoroad.info/CVM/](https://wydotcvm.wyoroad.info/CVM/)
REAL-TIME DATA FLOW

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

TMC Data Warehouse
Secure Data Commons
Public Data Hub
Real Time CV Data

Batch-uploads of other transportation data

USDOT Secure Data Commons

Analysis tools for WYDOT's own evaluation

Support for the Independent Evaluation
Data is analyzed in a variety of formats including:

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

Connected Vehicle Pilot Deployment

- Concept Development
- Design/Deploy/Test
- GAP
- Operate Pilot at Scale
LESSONS LEARNED

SCMS Integration

Radio Integration

Log File Size

OBU Failing at Scale

Vendors

Network Security

DSRC Shadow

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
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
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 mHz for either C-V2X or DSRC (14% of remaining)
- 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.
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
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
Contact for CV Pilots Program/Site AORs:

- Kate Hartman, Program Manager, Wyoming DOT Site AOR; Kate.Hartman@dot.gov
- Jonathan Walker, NYCDOT Site AOR; Jonathan.b.Walker@dot.gov
- Govind Vadakpat, Tampa (THEA) Site AOR; G.Vadakpat@dot.gov

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/