Connected Vehicles in the Real World

Egan Smith, Managing Director, ITS JPO, USDOT
SESSION AGENDA

- Overview of the Connected Vehicle Pilot Deployment Program
  - Egan Smith, Managing Director, ITS JPO, USDOT

- Connected Vehicle Pilot in New York City – Safety in a Dense Urban Grid Environment
  - Robert Rausch, TransCore ITS

- Connected Vehicle Pilot in Wyoming – Managing a Busy Freight Corridor under all Weather Conditions
  - Ali Ragan, Wyoming DOT

- Connected Vehicle Pilot in Tampa, Florida – Managing Safety and Mobility Impacts in Integrated Expressway/Surface Street Networks
  - Bob Frey, Tampa Hillsborough Expressway Authority

- Panel Discussion and Q&A
  - Egan Smith, Managing Director, ITS JPO, USDOT
CV PILOT DEPLOYMENT PROGRAM GOALS

- Spur Early CV Tech Deployment
  - Wirelessly Connected Vehicles
  - Mobile Devices
  - Infrastructure

- Measure Deployment Benefits
  - Safety
  - Mobility
  - Environment

- Resolve Deployment Issues
  - Technical
  - Institutional
  - Financial
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

Connected Vehicle Pilot Deployment (up to 50 months)

- 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)
Connected Vehicle Pilot in New York City – Safety in a Dense Urban Grid Environment

New York City DOT

Robert Rausch, P.E. - TransCore ITS
Connected Vehicle Technology

The Fundamentals --- Applied for NYC
VEHICLE-TO-VEHICLE (V2V) CONCEPT
Vehicles Broadcast:

**Basic Safety Message**

**Vehicles** receive the data –
- Determine immediate threats
- Alert driver
- Driver takes evasive actions

**Traffic Controllers** can monitor the data – measure traffic conditions, optimize signal timing

- **Security Mechanism establishes a “trusted environment”**
  
  *Messages can be signed, authenticated and encrypted as necessary*
INFRASTRUCTURE COMMUNICATIONS CONCEPT

VEHICLE INFRASTRUCTURE (V2I/I2V)
**INFRASTRUCTURE-TO-VEHICLE (I2V) **

**HOW IT WORKS**

**MAP Message**

**Intersection Geometric Information**
- Stop Bar
- Lanes
- Permitted Movements

**SPaT Message**

**Signal Timing Information**
- Time when it turns Yellow
- Time when it turns Red
- Time when it turns Green

- **Vehicles** receive the data –
- Determine immediate infrastructure issues
- Alert driver **Red Light Violation Warning (RLVW)**

**Other Messages:**
- Priority request/Status (SRM/SSM)
- Pedestrian (Personal) Safety message (PSM)

- Traveler Information Message - in-vehicle messages
- Location Correction (RTCM)
- Vehicle Event Message
DSRC
Dedicated Short Range Communications

Key Benefits:
• 802.11p technology similar to 802.11a
• Low latency communication (<< 50ms)
• High data transfer rates (3 – 27 Mbps)
• Typically 300M and 360°
• Up to 1000 M for emergency vehicles

Public Safety V2V Applications Channel (Dedicated)
Service Channel
- Download Application software and operational parameters

Control Channel
- Uploading Mobility, operations, & performance logs

Emergency Vehicles
Service Channel
- Uploading Mobility, operations, & performance logs

Frequency GHz

Service Channel
- Download Application software and operational parameters

Control Channel
- Uploading Mobility, operations, & performance logs

Emergency Vehicles
- Uploading Mobility, operations, & performance logs

U.S. Department of Transportation
New York City

Project Overview
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 will evaluate

- **Safety Benefits**
- **Challenges**

Of implementing **Connected Vehicle** technology with a significant number of vehicles in the **dense urban environment**.
OVERALL PROJECT CONCEPT

Security Management System

CV Support Systems

NYC Traffic Management Center

Traffic Control System

Internet

DSRC

NYCWiN

Traffic Signal Controller

ASD: Aftermarket Safety Device
CV DEPLOYMENT EQUIPMENT - VEHICLES

- Up to 8,000 fleet vehicles with Aftermarket Safety Devices (ASDs):
  - ~5,850 Taxis (Yellow Cabs)
  - ~1,250 MTA Buses
  - ~500 Sanitation & DOT vehicles
  - ~400 UPS vehicles

Pedestrian Trials
- Pedestrian PIDs
  - Visually Impaired
  - PED in Crosswalk

Interesting 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
CV Deployment Equipment – Infrastructure

- Roadside Units (RSU) at ~350 Locations
  - ~200 Manhattan Ave
  - ~80 Manhattan Cross
  - ~30 on Flatbush Ave
  - ~8 on FDR
  - ~36 Support locations (airports, river crossings, terminal facilities)
LOCATIONS (MANHATTAN, BROOKLYN)

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
AFTERMARKET SAFETY DEVICE FOR NYC

- Audio output only
  - Tones based on threat
  - Words based on situation

- ASD includes
  - Inertial Navigation
  - GNSS Navigation
  - Connection to Vehicle data Bus
  - Multi Channel DSRC support
  - Security Management Features

Source: NYCDOT
Vehicle-to-Vehicle (V2V) Safety Applications

- Vehicle Turning Right in Front of Bus Warning VTRW
- Forward Collision Warning FCW
- Emergency Electronic Brake Light EEBL
- Blind Spot Warning BSW
- Lane Change Warning/Assist LCA
- Intersection Movement Assist IMA

V2V applications based on existing demonstrations and prior developments and documentation
Vehicle-to-Infrastructure (V2I) Safety Applications

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

V2I applications based on existing demonstrations and/or modifications to prior developments and documentation
Other Applications

- Mobile [Visually Impaired] Ped Signal System PED-SIG
- Pedestrian in Signalized Intersection Warning PEDINXWALK
- CV Data for Intelligent Traffic Signal System I-SIGCVDAT

Operations, Maintenance, and Performance Analysis

- RF Monitoring RFMON
- OTA Firmware Update FRMWUPD
- Parameter Up/Down Loading PARMLD
- Traffic data collection TDC
- Event History Recording EVTRECORD
- Event History Up Load EVTCOLLECT

To Evaluate the benefits of

Roadway segment travel times
THE NYC APPROACH

- Focus on “proven” Safety Applications - Prior R&D has shown the benefits:
  - Pilot Deployment will evaluate the benefits on a much larger scale – dense urban situation

- Leverage “existing” safety applications (demonstrated)
  - Manage (Tune) the CV applications for NYC
  - Adjust operation for the congested traffic environment of NYC

- Modify several existing applications to encourage speed compliance
  - Note that the City reduced city-wide speed from 30 MPH to 25 MPH

- Leverage existing standards, infrastructure, and knowledge base

- Advance the state of the art:
  - Develop operations and maintenance applications
  - Develop data collection applications [for benefits analysis]
  - Develop benefit evaluation applications
CHALLENGES - EVERYWHERE

- **Stakeholder privacy** concerns – while still collecting meaningful statistics
- Stakeholder requirements to avoid *distracting* “cockpit” displays
- **Density** of Roadside DSRC Transponders
  - ~76 M for short blocks
  - ~200 M for the long blocks (between avenues)
- **Location Accuracy** – Urban Canyons (*both relative V2V and absolute V2I*)
  - Tests, trials, and consideration of alternative sources
- **Bandwidth limitations** of our wireless backhaul – *it is IPV4 only*
- Ongoing *maintenance and support* (in-vehicle and infrastructure) of the large scale deployment (8,000+ Vehicles and >350 RSUs)

- Security for all applications & DSRC Over-the-air (OTA) certificate distribution
- OTA [DSRC] data collection – bandwidth limited
- OTA [DSRC] software updates
- OTA [DSRC] parameter management
CHALLENGES WITH THE DENSE URBAN ENVIRONMENT
Safety Needs (ConOps)

Developed Questions for Evaluation

Performance Measurement Metrics ~47

Reduce Vehicle to Vehicle Crashes

V2V & V2I Safety Applications for Crash Avoidance

- Does number of crashes decrease?
- Does number and severity of red light violations decrease?
- Does number of bus / right turn vehicle crashes decrease?

Data collection:
Everything that “occurred” immediately before and after the alert

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

- Turn-key ASD and RSU equipment procurement
- Multiple stage delivery
  - Prototypes install/test Hardware/software/DSRC
  - Award to 2 ASD Bidders (~1/2 each) and 1 RSU Bidder
  - Production delivery after proof of prototypes

- Concept: Verify the hardware & software platform early
  - Use OTA updates (firmware, parameters) to expand the applications

- The limiting factor – Installation time for 8000 vehicles!

- Expect Bid to be out in March 2017!
WHERE ARE WE NOW?

- Phase 2 – 20 Month Deployment
  - Started September 1, 2016
  - Official Kick Off September 23, 2016
  - Twenty (20) Months *(14 left!)*
    - Developing architecture, data management plan, detailed designs, procurement documents, etc.

- Phase 3 Evaluation
  - Starts April 2018

The Project Teams are sharing ideas, challenges, workshops, and the NY team is aggressively participating in the standards development program!
Connected Vehicle Pilot in Wyoming – Managing a Busy Freight Corridor under all Weather Conditions

Wyoming DOT

Ali Ragan, Wyoming Department of Transportation
Wyoming’s I-80 Corridor

Environmental Overview

- Project area: 402 miles from the border with Utah to the border with Nebraska
- Entire elevation higher than 6,000 feet; highest point 8,640 feet
  - Donner Pass, Calif.: 7,057 feet
  - Parley Summit, Utah: 7,120 feet
Wyoming’s I-80 Corridor

- Heavy winds, heavy snow and fog
- Severe blowing snow and low visibility
- Major E/W Freight corridor
- Freight over half of annual traffic
- Higher than normal incident rates
- Multi-vehicle crashes
- Fatalities

Source: WYDOT (Dec 17, 2015)
Wyoming’s I-80 Corridor

What’s Been Done?

Variable Speed Limits
Closures to Light, High Profile-Vehicles when wind gusts top 60 mph
More efficient road condition updating
Scope of the problem

700 incidents involving commercial vehicles occurred on I-80 10/15 to 09/16

1,600+ crashes
1,923 vehicles

$865.3M Societal Impact
I-80 Users Need Actionable Road Weather Information

The need for actionable information is growing

Estimated Firms Subscribed to WYDOT’s CVOP

September 2015

800

March 2017

65,869

Downloads of WYDOT 511 App*

Downloads since February 2016 when app was released

WYDOT’s Commercial Vehicle Operator Portal (CVOP)
Pilot Objectives

Road Weather Condition Input
1. Improve road weather condition reports received into the TMC

TMC Information Dissemination
1. Improve ability of the TMC to generate wide area alerts and advisories
2. Efficiently manage closures, restrictions and speed limits
3. Effectively disseminate and receive messages from TMC to en-route vehicles
4. Improve information to commercial vehicle fleet managers

Vehicle/Roadside Alerts & Advisories
1. Effectively transmit and receive V2V messages to reduce incidents and their severity
2. Enhance emergency notifications of a crash

Outcomes
1. Improve speed adherence and reduce speed variation
2. Reduce vehicle crashes
Pilot Elements

CV Environment
75 Roadside Units on I-80
400 Vehicles with DSRC Connectivity

V2V Applications
Forward Collision Warning
Distress Notification

V2I Applications
Situational Awareness
Spot Weather
Work Zone Warning

WYDOT’s CV Pilot System

Vehicle System

Wyoming CV System

Roadside Infrastructure

Back office system

External Interfaces

U.S. Department of Transportation
The pilot will develop five on-board applications that will provide road condition information to the drivers of equipped vehicles.

- **Forward Collision Warning (FCW)**
- **Infrastructure-to-Vehicle (I2V) Situational Awareness (SA)**
- **Work Zone Warning (WZW)**
- **Spot Weather Impact Warning (SWIW)**
- **Distress Notification (DN)**
Vehicle System

All vehicles that are part of the vehicle system will have:

- Ability to share information via DSRC with connected devices (vehicles and RSUs)
- Ability to broadcast Basic Safety Message Part I
- Ability to receive Traveler Information Messages (TIM)
- Human-Machine Interface (HMI) to communicate alerts and advisories to driver

Vehicle Sub-Systems
1. WYDOT Fleets
2. Integrated Trucks
3. Retrofit Vehicles
4. Basic Vehicles

On-board Vehicle Technologies
- OBU with DSRC only
- OBU with DSRC and Satellite Receiver
- Human Machine Interface
- CAN Bus Integration (selected vehicles)
- Environmental Sensors (selected vehicles)
CV Pilot Partnership

Internal Partnerships

- CVOP Subscribers
- Third Party Services
- Trucking Fleets
- Freight Distribution Centers

Freight Partners

- Independent Evaluator
- IRB
- Trucking Association
- Other CV Pilot Sites

Other Stakeholders

- Technical and Program Support
- System Developers and Integrators
- Human Use and Training

Subcontractors

- CV equipment
- Installation and support
- Other hardware and software

Vendors

WYDOT
### Next Steps and Activities

<table>
<thead>
<tr>
<th>Activity</th>
<th>Timeframe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Third-party data feed</td>
<td>Spring 2017</td>
</tr>
<tr>
<td>Install roadside equipment and in-vehicle systems on WYDOT fleets</td>
<td>Spring/Summer 2017</td>
</tr>
<tr>
<td>System operation and testing</td>
<td>Winter 2017/2018</td>
</tr>
<tr>
<td>Install equipment on private vehicles</td>
<td>Springs/Summer 2018</td>
</tr>
<tr>
<td>System operation</td>
<td>Winter 2018/2019</td>
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Connected Vehicle Pilot in Tampa, Florida – Managing Safety and Mobility Impacts in Integrated Expressway/Surface Street Networks

Bob Frey, Tampa Hillsborough Expressway Authority
### CV APPLICATIONS TO BE DEPLOYED

<table>
<thead>
<tr>
<th>Application</th>
<th>Description</th>
<th>Use Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curve Speed Warning</td>
<td>Alerts driver approaching curve with speed safety warning</td>
<td>1</td>
</tr>
<tr>
<td>Emergency Electronic Brake Light (EEBL)</td>
<td>Enables broadcast to surrounding vehicles of severe braking</td>
<td>1</td>
</tr>
<tr>
<td>Forward Collision Warning (FCW)</td>
<td>Warnings driver of impending collision ahead in same lane</td>
<td>1,3</td>
</tr>
<tr>
<td>Intersection Movement Assist (IMA)</td>
<td>Indicates unsafe (i.e., wrong way) entry into an intersection</td>
<td>2</td>
</tr>
<tr>
<td>Pedestrian in a Signalized Crosswalk (PED-X)</td>
<td>Alerts vehicle to the presence of pedestrian in a crosswalk</td>
<td>2,4,6</td>
</tr>
<tr>
<td>Pedestrian Mobility (PED-SIG)</td>
<td>Gives pedestrians priority with signal phase and timing (PED-SIG)</td>
<td>2,4,6</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>
<td>1,2,6</td>
</tr>
<tr>
<td>Vehicle Data for Traffic Operations (VDTO)</td>
<td>Uses vehicles as probes to detect potential incidents, (also called Probe-enabled Data Monitoring or PeDM)</td>
<td>6</td>
</tr>
<tr>
<td>Transit Signal Priority (TSP)</td>
<td>Allows transit vehicle to request and receive priority at a traffic signal</td>
<td>4</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</td>
<td>5</td>
</tr>
<tr>
<td>Red Light Violation Warning (RLVW)</td>
<td>Warns driver of potential of red light violation</td>
<td>2</td>
</tr>
</tbody>
</table>
**EQUIPMENT: BY THE NUMBERS**

1,620
**On-Board Units (OBUs)**
A rear view mirror for passenger vehicles and tablet display for transit vehicles

500+
**Pedestrian smartphones (Android devices only)**

40
**Road Side Units (RSUs)**
Mounted on existing structures throughout the deployment area

PHOTO: THEA
PHOTO: NPR
PHOTO: SIEMENS
Morning Backup

Forward Collision Warning (FCW)
Emergency Electronic Brake Light (EEBL)
End of Ramp Deceleration Warning (ERDW)

Photo: Tampa Hillsborough Expressway Authority (THEA)
Wrong-Way Drivers

Wrong-way Entry
Intelligent Signal System (I-SIG)
Intersection Movement Assist (IMA)
PEDESTRIAN SAFETY

Mobile Accessible Pedestrian Signal System (PED-SIG)

Pedestrian in a Crosswalk Vehicle Warning (PED-X)

FCW

IMA
TRANSIT SIGNAL PRIORITY

I-SIG
Transit Signal Priority (TSP)
IMA

PHOTO: TAMPA HILLSBOROUGH EXPRESSWAY AUTHORITY (THEA)
STREETCAR CONFLICTS

Vehicle Turning Right in Front of Transit Vehicle (VTRFTV)

I-SIG

PED-SIG

PED-X

PHOTO: TAMPA HILLSBOROUGH EXPRESSWAY AUTHORITY (THEA)
INFORMATION FLOW

City of Tampa Traffic Management Center provides info

Safety message sent

Traffic info

Vehicle/ pedestrian info sent to RSU

Safety message displayed to commuter

Volpe Institute
THEA
THEA
THEA
RSU PHOTOS

Source: Siemens
Mirror display uses sticker to depict location and concept of warning. Actual image is still in development

Source: Brand Motion
**How Much Data?**

70 billion connected devices (2050)

2.8 trillion sensors (2019)

Autonomous Vehicles (L2)
- 80+ processors
- 200+ sensors
- 100M+ lines of code (GM)

2,500,000,000,000,000,000,000

2.5 Quintillion bytes EVERY DAY
WHAT IS IMPORTANT TO ROAD OPERATORS?
DAY TO DAY OPERATIONS
QUANTIFIABLE BENEFITS

- SAFETY: Connected vehicle technology could affect more than 80% of vehicular crash scenarios involving unimpaired drivers
- Improved mobility
- Reduce environmental impact
- Assist with toll interoperability
- Economic Impacts
  - Reduction in insurance rates
  - Realize fuel & maintenance savings – Inflation Fighter
  - Recoup productivity currently lost to long or erratic commutes
Selmon East Capacity Improvements (Sample Project)
- Additional lane in each direction for 16 miles - $200 million
- Selmon East Lane Harmonization
  - Bridge Improvements (3 Bridges) - $75 million
  - Speed Harmonization - $50 million

Potential Savings - $75 million or 6-7 years delay of capacity improvements

If nothing else, it is worth investigating…
For More Information...

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Panel Discussion and Q&A

Egan Smith, Managing Director, ITS JPO, USDOT
Visit USDOT Exhibition Booth for More Information
- USDOT Booth No: 409 (Near NASA)
  - March 12-14, 10:00 am to 6:00 pm
  - March 15, 10:00 am to 2:00 pm

Join us for the **Getting Ready for Deployment** Series
**Website:** http://www.its.dot.gov/pilots
- Discover more about the CV Pilot Sites
- Learn the Essential Steps to CV Deployment
- Engage in Technical Discussion

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