EFFECTIVE MEASURES OF SUCCESS: THE UNITED STATES CONNECTED VEHICLE PILOTS

Intelligent Transportation Systems Joint Program Office
September 19, 2018
Session Introduction

Kenneth Leonard, Director, ITS Joint Program Office (JPO), USDOT
SESSION AGENDA

- 1:30 – 1:35 PM - Session Introduction
  - Kenneth Leonard, Director, ITS Joint Program Office (JPO), USDOT

- 1:35 – 1:50 PM - Wyoming DOT Pilot Project
  - Kevin Gay, Chief, Policy, Architecture, & Knowledge Transfer, ITS JPO, USDOT

- 1:50 – 2:05 PM - Tampa (THEA) Pilot Project
  - Bob Frey, Planning Director, Tampa Hillsborough Expressway (THEA)

- 2:05 – 2:30 PM - New York City DOT Pilot Project
  - Mohamad Talas, Director of System Engineering, NYCDOT
  - Bob Rausch, Vice President, Transcore

- 2:30 – 2:45 PM - Interoperability Test Summary
  - Kevin Gay, Chief of Policy, Architecture, & Knowledge Transfer, ITS JPO, USDOT

- 2:45 – 3:00 PM: Questions and Answers
CV PILOT DEPLOYMENT PROGRAM GOALS

- Spur Early CV Tech Development
- Measure Deployment Benefits
- Resolve Deployments Issues

- Wireless Connected Vehicles
- Mobile Devices
- Infrastructure
- Safety
- Mobility
- Efficiency
- Technical
- Institutional
- Financial

Source: USDOT
CV PILOT DEPLOYMENT SCHEDULE

- **Phase 1: Concept Development (COMPLETE)**
  - Creates the foundational plan to enable further design and deployment.

- **Phase 2: Design/Deploy/Test**
  - Detailed design and deployment followed by testing to ensure deployment functions as intended (both technically and institutionally).

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

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**Is the concept ready for deployment?**

- PHASE 1 (up to 12 months): Concept Dev.
  - Sep 2015 (COMPLETED)

- PHASE 2: Design/Build/Test
  - Sep 2016

- PHASE 3 (minimum 18 months): Maintain/Operate Pilot
  - Sep 2018 (tentative)
  - Apr 2019 (tentative)
  - Dec 2019 (tentative)

**Does the system function as planned?**

- Transition
  - Oct 2020 (tentative)

**CV tech integrated into operational practice**

- Routine Operations (ongoing)
  - Post-Pilot Operations

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Last updated: August 2, 2018
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.

- 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.

- 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.
WYOMING DOT PILOT PROJECT

Kevin Gay, Chief
Policy, Architecture, & Knowledge Transfer, ITS J PO, USDOT
THE PROBLEM

Heavy Freight Traffic
- Major E/W freight corridor
- Freight = over half of annual traffic

Severe Weather Conditions
- Roadway elevation
- Heavy winds, heavy snow and fog
- Severe blowing snow and low visibility

Adverse Impacts on Trucks
- Higher than normal incident rates
- Multi-vehicle crashes
- Fatalities
### Impact to Freight

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<th>% of Total</th>
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<tr>
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<td>555</td>
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<tr>
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<td>714</td>
<td>34.3%</td>
</tr>
<tr>
<td>2017</td>
<td>408 (partial)</td>
<td>63.1%</td>
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One of the most heavily instrumented rural corridors in the United States

- 136 Variable Speed Limit Signs supported by 94 traffic sensors
- 54 Electronic Message Signs
- 44 Weather Stations
- 52 Webcams
**Achievements-to-Date**

**Connected Vehicle Pilot Deployment**

<table>
<thead>
<tr>
<th>Concept Development</th>
<th>Design/Deploy/Test</th>
<th>Maintain/Operate Pilot</th>
<th>Post-Pilot Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase I (12 months)</td>
<td>Phase 2 (up to 23 months)</td>
<td>Phase 3 (min. 12 months)</td>
<td>Routine Ops (ongoing)</td>
</tr>
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</table>

**Major Achievements**

- End to end BSM data
- ODE development/integration
- Installation of IPv6 backhaul
- RSU installation
- Equipped 2 vehicles (3-7Km range)
**Systems Overview**

- **Wyoming CV System**
  - Roadside Units (RSUs)
  - Operational Data Environment (ODE)
  - Pikalert System
  - Data Broker (DB)
  - Data Warehouse

- **Vehicle System**
  - WYDOT Maintenance Vehicles
  - WYDOT Highway Patrol Vehicles
  - Integrated Commercial Vehicles
  - Retrofit Commercial Vehicles
  - Basic Equipped Vehicles

- **78 RSUs equipped with DSRC connectivity**
- **~400 vehicles equipped with OBU with DSRC connectivity**

- **66 snow plows**
- **33 patrol vehicles**
- **188 trucks**
- **121 small trucks & vehicles**
CONNECTED VEHICLE PILOT: INTEGRATION
CONNECTED VEHICLE PILOT: NEXT STEPS

Phase 1
- Planning
- (09/2015 – 09/2016)

Phase 2
- Deployment
- (10/2016 – September 2018)

Phase 3
- Demonstration
- (Fall 2018 – 10/2019)

Concept Development
System Planning
Deployment Plan

System Design
System Build
System Testing and Acceptance

Real-World Demonstration
Evaluation
Maintenance

U.S. Department of Transportation
Federal Highway Administration
TAMPA (THEA) PILOT PROJECT

Bob Frey, Planning Director
Tampa Hillsborough Expressway (THEA)
Focused Deployment Area

- Traffic Flow Optimization/Bus Priority
- Pedestrian Safety
- Rush Hour Collision Avoidance
- Wrong-Way Entry Prevention
- Traffic Management
- Traffic Flow Optimization
- Streetcar Safety
PARTICIPANTS

1,600 Privately Owned Vehicles

500+ Pedestrian Smartphones (Android devices only)

10 TECO Line Streetcar Trolleys

10 Hillsborough Area Regional Transit (HART) buses
STATUS

Level 6: Needs & Feasibility

Level 5: Concept of Operations, System Validation

Level 4: Requirements, System Verification

Level 3: High Level Design, Subsystems

Level 2: Detailed Design, Units / Devices

Level 1: Existing Software & Hardware (Available From)

Phase 2 Project Workflow:
- Subsystem LTP
- Subsystem HW Security & Test
- V2I Apps OSADP (Available From Siemens RSU)
- V2I Apps (Available From V2I Apps)
- Android Phone
- V2X Apps OSADP
- Vehicle HW Security & Test
- V2V & V2I Apps

Phase 3: September 1, 2018
- P3 Deliverable
- Measure the Effect
- Install & Test
- 40 Locations
- In 1500 Cars
- Integrate & Test
- 6 Use Cases
- Apps into RSU
- Apps into Phones
- Apps into OBU

SOURCE: HNTB
PHASE 3 - MEASURING PERFORMANCE

CUTR will 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
PHASE 3 – REPORTING PERFORMANCE

- **CUTR- Performance Evaluation Dashboard (PMED)**
- Clear, reliable, and responsive to change
- Customizable reporting frequency (daily, weekday, monthly basis).
- Downloadable custom queries.
- Performance measures algorithms, analysis tools available to select stakeholders.
IF WE COULD DO IT OVER AGAIN: WE WOULD

- Solidified 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
- Like More Transparency in the Device Certification Process From Vendors
- Complete Integration Testing Before Private Vehicle Installs Begin
- Have Shifted the Focus Much Sooner to a Commercial Security Credential Management System
- Identify the Need to Use Traditional ITS Devices as Part of Solution Earlier
LESSONS LEARNED

- **Standards:**
  - If a USA standard does not exist, design using international standards (Yeah, that went well...).
  - If no standard exists, refer to USDOT V2I Hub publication.

- **Interoperability:**
  - Identify common requirements that affect interoperability before the design started.
LESSONS LEARNED

- OBUs - 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.
LESSONS LEARNED

- Innovative ways to incentivize the public to participate helped
- Contracting – Fixed Fee and “Experimental Sole Source” way to go
- Cross functional coordination is absolutely critical
- Importance of face to face progress meetings
- Deployment in an area undergoing significant redevelopment complicated Pilot to deal with confounding factors
- Establish Communication usage on your channels early, CV is not only allowed user
- Certification process - Certification process was outside of Pilot control, mitigated by Conformance statement to self-certify
STAY CONNECTED

- **Contact for Tamp CV Pilot Project:**
  - Bob Frey, Project Manager
  - bobf@tampa-xway.com
- **USDOT Contacts:**
  - ITS JPO Agreement Officer:
    - Govindarajan Vadakpat, G.Vadakpat@dot.gov
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- **Consultant Technical Lead:**
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- **Performance Measurement Lead:**
  - Dr. Sisinnio Concas, concas@cutr.usf.edu
NEW YORK CITY PILOT PROJECT

Mohamad Talas, Director of System Engineering, NYC DOT

Bob Rausch, Vice President, Transcore
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
LOCATIONS (MANHATTAN, BROOKLYN)

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

The CV project leverages the City’s transportation investments.

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

Traffic Control System

NYCWiN

Advanced Traffic Controller (ATC)

NYC Connected Vehicle Project
For Safer Transportation
Vehicles

- Up to 8,000 fleet vehicles with Aftermarket Safety Devices (ASDs):
  - ~5,800 Taxis (Yellow Cabs)
  - ~ 700 MTA Buses
  - ~ 1,050 Sanitation & DOT vehicles
  - ~ 400 UPS vehicles

Pedestrians

- Pedestrian PIDs
  - Visually Impaired
    - 100 Subjects - PID
  - PED in Crosswalk
    - 10 Fully Instrumented Int.

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
SAFETY APPLICATIONS

**Vehicle-to-Vehicle (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

**Vehicle-to-Infrastructure (V2I) Safety Applications**
- Red Light Violation Warning
- Speed **Compliance**
- Curve Speed **Compliance**
- Speed **Compliance**/Work Zone
- Oversize Vehicle **Compliance**
  - Prohibited Facilities (Parkways)
  - Over Height
- Emergency Communications and Evacuation Information (Traveler
ADDITIONAL APPLICATIONS

Pedestrian
- Mobile [Visually Impaired] Ped Signal System - navigation assistance
- Pedestrian in Signalized Intersection Warning - to vehicles

Traffic Management
- CV Data for Intelligent Traffic Signal System

Operations, Maintenance, and Performance Analysis
- RF Monitoring
- OTA Firmware Update
- Parameter Up/Down Loading
- Traffic data collection
- Event History Recording
- Event History Up Load

To Evaluate the benefits
Roadway segment travel times
OVERALL PROJECT CONCEPT

PED APP

Smartphone/Personal DSRC App.

ASD Safety Device

DSRC 5.9 ch TBD

Bus/Transit ASD

DSRC 5.9 ch 172

ASD Commercial Vehicle Warning Device

Remote CV Support Services e.g. SCMS IE and RDE

TMC CV Support Services

NYCDOT Traffic Management Center

Traffic Control System

CV Data Collection & Analysis

TMC Local Area Networks

City Owned Fiber

NYCWIN NOC Operated By DoITT

NYCWIN

Wireless Router

NYCWIN Wireless Network

CV Roadside Unit (RSU)

PED Detection

Limited Deployment

Traffic Signal Controller

Source: NYCDOT
WHERE ARE WE NOW?

- **Phase 1 - Deliverables**
  - Concept of Operations
  - Security Management Operating Concept
  - Safety Management Plan
  - Performance Measurement Plan, System Requirements
  - Application Deployment Plan
  - Human Use Approval Summary, Training and Education Plan
  - Partnership Status Summary, Outreach Plan
  - Comprehensive Deployment Plan, Deployment Readiness Summary

- **Phase 2 - Design & Deployment**
  - Deployment of 100 Prototype ASD and RSU
  - Developing TMC software to support CV
  - Working with a PED application developer – **non DSRC**
  - **Interoperability testing**
  - Preparing for “production” deployment
INSTALLATION PLANNING AND TESTING

- Developing MAP message Content (USDOT)
- Planning RSU installation sites
  - Establishing Installation “partners”
- Developing vehicle installation kit designs
  - Working with vendors
  - Working with Fleet owners
  - Running samples - awaiting prototypes

~350 Roadside Units
36 Units at key locations
• 35 Prototype Fleet vehicle installed
• Testing through the glass and drilled mountings
• Working with various different vehicle types
NYC DOT INSTALLATIONS

- NYC DOT Installation
  - Various Makes/Models/Year NYC DOT vehicles are being equipped with prototype ASDs in order to fine tune and optimize installation methods and approaches
  - NYC DOT Vehicles 770
    - Toyota
      - Prius, RAV4
    - Ford
      - Fusion
      - F-150 – F-550
    - Chevrolet
      - Silverado
      - HD3500
      - Economy
MTA INSTALLATION

- The buses were installed to test RF DSRC communication with light vehicles, and to develop an installation template
- Key element for MTA - Through the glass Antenna
Taxi Installation

- Taxi Installations are estimated at 5000 vehicles between the participating fleet owners
- 2 authorized technology installers
- Taxi fleet is expected to include:
  - Toyota
  - Prius
  - Sienna
  - RAV4
  - Nissan NV 200
CYBERSECURITY IS FUNDAMENTAL TO CV DEPLOYMENT

CV depends on a “trusted” environment - vehicles & infrastructure

- Message authentication (BSM, SPaT, MAP, TIM, etc.)
- Data encryption of (To preserve privacy)
- Requires Equipment Certification
- Organizational IT security
  - Physical security of the TMC systems
  - Agency login and security practices
- Protection for all connections and data exchanges
- CV Hardware Impact
  - Hardware Security Module (HSM) for the TMC system
  - HSM inside the ASD/OBU and RSU
CHALLENGE – SCALABLE OTA DATA EXCHANGES

- Push (10 MB+) software updates to 8,000 vehicles efficiently over **DSRC**
  - No WiFi and No LTE/4G

- Developed Scheme to support broadcast updates
  - ASD’s read WSA from Control Channel
  - Directed to Service Channel if RSU supports Updates
  - RSU **broadcasts** available updates
    - Some updates broadcast (continuous) some available by unicast
    - Vehicles initiate update using unicast or monitor broadcast streams
    - Using licensed software to manage the efficient breakdown and assembly
    - Efficient Channel Use
    - Privacy is maintained
Location Accuracy -
- Urban Canyons pose issues (both relative V2V and absolute V2I)
  - Dropout at underpasses
  - Loss of GPS lock
- ASD vendor demonstrated RSU triangulation
- Established Compound ASD requirements:
  - Dead reckoning,
  - Triangulation with static DSRC locations,
  - Map matching,
  - Tethered to the vehicle - vehicle interface

Testing has been promising!
How V2X-Locate Works

Positioning software achieves sub-meter location positioning and is over 275% more accurate than comparable GNSS solutions.
RSU TRIANGULATION

V2X Locate uses
  • standard RSUs and OBUs
  • standard V2X over the air messages to determine position of vehicle by ranging

RSU location known thanks to standard advertisements

Fuses vehicle sensors and GNSS when available.

*Based on recommended deployment set-up
PRELIMINARY ACCURACY RESULTS

• No additional HW vs conventional V2X City / Car OEM install

• Doesn’t require GNSS availability

• Demonstrated in very tough New York 6th Ave

• Results are

• Performance exceeds SAE J 2945 requirements
  • (68% < 1.5m)

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OTHER TECHNICAL CHALLENGES

- Adjusting the applications for 25 MPH and Freeway speeds

- CAN/J (vehicle) Bus Interface -
  - Vendor resistance to providing necessary information
  - Purchasing a gateway device

- Many different vehicle types and model years
  - Varied installation kits
  - The Good part – they are fleets – we drill holes!
Thank You

For New York City DOT:
Mohamad Talas, P.E., PhD,
mtalas@dot.nyc.gov
New York City - Connected Vehicle Pilot
Some Lessons Learned and Challenges

Bob Rausch
Vice President
Transcore
A Few Comments Based On The NYC Project

- Standards
- Product Maturity
- Vehicle Integration
- Data Collection
- Security
PILOT VS. DEPLOYMENT

- Ambiguities within the standards
  - Need for “how to use” in many cases!
  - Protocols & Data elements must be the same for interoperability
  - Three pilots worked together
    - Review of all standards
      - Insure same “objects” for the same purpose and meaning
    - Requirements for messages all the same
      - Optional vs. Mandatory

- Product certification (US DOT Requirement) – OmniAir and their program
  - Trusted devices - - protect the integrity of the trusted environment
  - Fundamentals – messages, channel usage, security usage, timing, etc.
  - Need more extensive “certification” that applications meet some minimum?
NEED STANDARDS FOR THE APPLICATIONS

- “Demonstrations” by 6 vendors
  - Fundamental operation ~same
  - **BUT** – Differences
    - Configuration management
    - Operating parameter management
      - “Intensity” of application
  - “Need for ability to test applications
    - Controlled environment
    - Need “testable” requirements for applications – Precision!
FLEETS VS. OEMS

- There is a need for standard [secure] vehicle interface
  - Steering Wheel Angle, Yaw Rates, “hard breaking”
  - Speed, roadway friction, etc.
- Aftermarket devices NEED access to the vehicle data bus
  - Speed, directional, minimum – location enhancement
  - Transitional period to embedder safety systems
- Likely initial CV deployments
  - Agency or other fleets
  - UBI likely incentive
- Instead – OEMs reacting to “security” scares – making it harder!
- Future: CV can augment AV –
  - Regulations, Intersection operation, Map Dynamics (lane changes, construction, crash/incident/special event mitigation
- NYC – vehicle manufacturer cooperation (data interface and design sharing) – non existent!
- 2 Vendors – 2 different approaches – headache for everyone!
SCALEABLE AND RELIABLE DEPLOYMENT

- 100 vehicles - no problem
- 8,000 revenue generating vehicles
  - Cannot physically access - $$$ per minute/hour etc.
  - Project specifications stressed reliability and un-manned recovery
  - Work with the “experts” for installation
- Applications subject to changes
  - Schedule cannot wait until everything is “perfect”
    - 23 weeks to deploy
  - Needed reliable means to update and add applications
  - Needed reliable means to “tune” the applications
  - Likely future changes in communications media and standards
**SCALEABLE OTA EXCHANGES**

- NY System is DSRC 5.9 GHz only
  - 802.11P, 1609.x, J 2735/ISO 19091
- Data collection V2I
- Safety applications V2V and V2I
- Software updates I2V

- Worked to develop a network encoding approach – broadcast update to many vehicles -

*Using 6 of the 7 DSRC channels in the US 5.9 GHz Spectrum!*
DATA RECORDING ISSUES

This is not an R&D project!

What to collect

- What could I collect?
  - What is the raw data available
- What Do I need?
  - What is the intended use of the data?
- What should I collect?
  - To justify the costs!

What are the costs

- Backhaul communications
- Storage
- Processing
- FOIA requests
- Subpoena

Privacy Issues

- Prohibition of keeping PII
- Combination with other sources.
- Data Ownership
EXAMPLE – TRAVEL TIME

- Block Spacing ~70M Feet (230’)
- 20 MPH – 30 feet per second
- DSRC Range ~300M (1000’)
- BSMs Xmit @ 10 Hz
- Time between blocks ~8 seconds
- BSMs transmitted 80
- BSMs needed 2 - 3% a 97% reduction

Edge computing @ RSU
- RSU looks for vehicle entry to Intersection
- Transmits one BSM to TMC per vehicle
- TMC matches BSM – Vehicle ID
- TMC computes travel time
- Or TMC data times out - -
**Optimized Intersection Control**

- Edge computing @ traffic controller
  - Queue length - Stopped Vehicles
  - Vehicle speeds – Reported in local BSM
  - Priority and preemption – With local communications
  - Incident detection – deviation around obstacle
  - Pedestrian presence

- Send to TMC only what needs to be used
  - Platoon management (Freight priority)
  - Alternate route management/diversion
  - Incident detection
  - Travel Times (average link speed)
**PRACTICAL DATA COLLECTION - INCIDENTS**

- 1.2 M vehicles in NYC broadcast **83 TB/day**
- 13,000 NYC intersections broadcast **3 TB/Day SPaT & Map**
- 8,000 vehicles collect **2 TB BSM data/day**

**Data needed** for benefits analysis:
- How many crashes per day did we prevent
- How many crashes per day did we mitigate

**Edge computing – Onboard Unit (OBU)**
- OBU monitors vehicle operation (S, Yaw, etc.)
- OBU monitors surrounding vehicles’ operation
- OBU assesses threats
- OBU alerts driver to mitigate threat
- OBU records what the caused alert and driver actions
“Alert” triggers and event record

**StartUp**
- CVApp_x
- BSM_{HV}
- BSM_{TV}
- BSM_{RVN}
- SPaT
- MAP

**EvtRcdApp**

**EvtRcd**
- Parameter
- Control
- Parameter
- SpdThreshold

**EvtRecord**

- Begin Record
- Trigger
- End Record

**Time Before**

**Time After**

**All of the data collected during T_k is transferred to the event record, and after the trigger the data is collected and added to the record until T_k expires.**
DATA REDUCTION AND PRIVACY PROTECTION

- Instead of 2 TB - only 116 GB per day
  - 17 times less - and more useful detail (@4 events/hour)
  - Includes SPaT and MAP information
  - @1 event / hour /vehicle = 29 GB/day or 67x reduction!

- If BSM data were to be collected - -
  - 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

- Even though CV vehicle ID is randomly changed - the raw data can be tracked to an individual vehicle
Obfuscation of OBU Action Logs

- Obfuscation process to scrub precise time and location data
  - Relative details retained
  - Non-obfuscated data will be destroyed following the obfuscation process
OTHER EXAMPLES – OPERATIONS DATA

- RF Data – Proactive Analysis
  - Records first and Last BSM heard from each OBU
  - Time-out to find dropouts
  - At 1000 ft. vehicle “hears” RSU for 50 seconds
  - Actual BSMs from that vehicle – 500
  - Assuming 4 dropouts – actual BSMs needed – 8 or 2%
  - Edge computing RSU - monitor OBU keep first/last
  - Same for OBU – 98% bandwidth reduction!
  - Only 8 BSMs actually captured

- Guess who I saw today
  - Track other OBUs seen throughout the City
  - Approximately 2 bytes per encounter
LESSONS LEARNED ON DATA COLLECTION

- The CV technology could make “mountains of data” available
  - but there is a cost
    - DSRC Channel time
    - Cellular media monthly limitations
    - Processing and storage
    - Retrieval (FOIA) & Subpoena

- NYC pilot deployment project
  - Tailored data collection to meet needs
  - Concept is to distribute processing to the edge
  - Added RSU locations to collect data

NYC System - DSRC only V2I
Security Issues - Extend Everywhere

Connected Vehicle has security requirements - well defined and standards

- Issue
  - All of the ITS and IT systems need to adjust operations
  - Classic ITS - adopted security measures
  - Certificate management
  - Certificate Revocation Lists
  - Need for real time access to SCMS
  - Secure Boot of all field devices
    - OBU, RSU - Traffic Controller?
  - Physical security re-visited (cabinet keys)
  - Password policies
  - Firewall rules - etc.
  - Misbehavior detection coming soon!

SECURITY ISSUES – EXTEND EVERYWHERE

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  - Misbehavior detection coming soon!
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INTEROPERABILITY TEST SUMMARY

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OVERVIEW OF INTEROPERABILITY TEST

- Objectives:
  - Test interoperability among connected vehicle (CV) devices from the three sites as well as to identify potential interoperability issues that may require resolution prior to the sites advancing to an operational phase of the CV Pilot Deployment Program later in 2018.

- Interoperability Definition:
  - “A vehicle with an onboard unit (OBU) from one of the three CV Pilot sites is able to interact with OBUs and roadside units (RSUs) from each of the other sites in accordance with the key connected vehicle interfaces and standards.”
INTEROPERABILITY TEST INFORMATION

- Dates/Location: June 25 – 28, 2018 at FHWA Turner-Fairbank Highway Research Center (TFHRC)
- Participating Organizations (63 attendees in total):
  - USDOT, technical support contractor (Noblis), Saxton Laboratory (STOL) contractor (Leidos)
  - New York City Pilot: NYCDOT and Transcore
  - Tampa Pilot: THEA, HNTB, Siemens, CUTR and Brandmotion
  - Wyoming Pilot: ICF and Neaera Consulting Group
  - OBU/RSU Vendors: Commsignia, Danlaw, Lear, Savari, Siemens and Sirius XM
  - Others: Certification (OmniAir), CV Pilots Independent Evaluator (TTI), Photographers (BAH)
- **NYC OBUs:**
  - Danlaw
  - Savari
- **Tampa OBUs:**
  - Commsignia
  - Savari
  - Sirius XM
- **Wyoming OBU:**
  - Lear
- **TFHRC RSUs:**
  - Siemens RSUs loaded with NYC/Tampa software
OVERVIEW OF TEST PLAN

- CV Pilots Phase 2 Interoperability Test demonstrated interactions among different site’s OBUs and among selected OBUs and RSUs.
  - OBU Interactions:
    a. Receive Basic Safety Messages (BSMs) transmitted by the other site’s OBUs via DSRC; authenticate them as needed; parse them; and process them in accordance with SAE J 2945/1.
    a. CV applications: Forward Collision Warning (FCW), Electronic Emergency Brake Light (EEBL), and Intersection Movement Assist (IMA) - only NYC/Tampa
  - OBU and RSU interactions:
    a. Signal Phase and Timing (SPaT) and MAP (only NYC and Tampa)
To have an OBU from each CV Pilot deployment project demonstrate that they can produce a FCW to a driver when receiving BSMs from one of the other site devices.

Photo: a Wyoming (Lear) vehicle received a FCW alert from a stationary NYC (Danlaw) vehicle in the same lane.
To have an OBU from each CV Pilot deployment project demonstrate that they do not produce an FCW warning when approaching another vehicle producing BSMs in an adjacent lane.

Photo: a Tampa (Commsignia) vehicle drove in an adjacent lane without triggering a FCW alert from a stationary NYC (Savari) vehicle.
**Reception of SPaT/MAP Messages**

- To have an OBU from the NYC and THEA CV Pilot sites demonstrate that they can receive SPaT and MAP messages from the other CV Pilot deployments RSUs.
- Photo: a Tampa (Savari) vehicle approached an intersection with a TFHRC RSU (Siemens) configured for NYC.
To have an OBU from the NYC and THEA CV Pilot sites demonstrate that they can produce an IMA warning to a driver when receiving BSMs from one of the other site devices.

- Video: a Tampa (Commsignia) vehicle received an IMA warning being triggered by a NYC (Danlaw) vehicle.
- Add-on Test: To have an OBU from each CV Pilot deployment project demonstrate that they can produce a FCW alert to a driver when receiving BSMs from one of the other site devices with a parallel platoon in an adjacent lane.
- Video: a Wyoming (Lear) vehicle received a FCW alert being triggered by a NYC (Savari) vehicle with the other four vehicles driving by the adjacent lane.
**SUMMARY OF KEY RESULTS**

- **More than 100 test runs within three days.** In total, 102 interoperability test runs were conducted for four test cases – FCW, IMA, EEBL, and SPAT/MAP Messages and 90% plus were successful.

- **Successful message transfer via multiple communications.**
  - Results of the testing indicated successful transfer of messages between the six vehicles from five different vendors. Out of the five vendors, four used DSRC and one used DSRC and SiriusXM Radio.
  - Additionally, equipment from each vendor demonstrated the successful transfer of messages between the RSUs and each sites’ OBUs.

- **SCMS enrollment permitted sites to sign messages and change certificates without issue.**
  All devices used for the test were enrolled with a commercial security credential management system (SCMS) that the sites plan to use for their Phase 3 Operational Phase.

- **Nearly 5 GB of test data generated for analysis.**
  - Data was collected by each site and its vendors and will be uploaded to the USDOT’s Secure Data Commons (SDC).
  - The USDOT plans to continue to work with the CV Pilot sites to develop a Test Report documenting the results of the Phase 2 Interoperability Test.
TESTIMONIALS WITH RESPECT TO VALUE

- Test Team did outstanding job planning and organizing tests.
  - Test plan was generally thorough, clear, and concise.
  - Installation of equipment went relatively smoothly.
  - Sites well prepared for test.
  - Overview and Q/A discussion added before each test proved beneficial.

- Everyone had a good experience with the testing.
  - Good to interact with other teams.
  - Allowed developers to test applications using equipment they don’t generally have.
  - It was the most successful CV testing they had ever participated in.
  - A unicorn event - six vendors, three sites, multiple communications media - and it worked!

- A test of this nature had never been conducted before.
  - A watershed moment for connected vehicle technology, and an important milestone in the maturation of these technologies for operational deployment.
  - Just from the security standpoint alone, more than worth the effort to conduct.
Question and Answers

NYCDOT  Tampa (THEA)  WYDOT
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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/