Wyoming DOT Pilot Update at the Operational Readiness Milestone

Vince Garcia, Tony English, Shane Zumpf, and Mohamed Ahmed
**TODAY’S AGENDA**

- **Purpose of this Webinar**
  - Provide an overview of WYDOT’s approach to test and demonstrate that the deployed system operates as designed in a safe and secure manner.
  - Share results, baseline performance measures and security-related lessons learned from the tests and demonstrations.

- **Webinar Content**
  - Connected Vehicle Pilot Deployment Program Overview
  - WYDOT Pilot Operational Readiness Approach, Results, and Lessons Learned
  - Stakeholder Q&A

- **Webinar Protocol**
  - Please mute your phone during the entire webinar.
  - You are welcome to ask questions via chatbox at the Q&A Section.
  - The webinar recording and the presentation material will be posted on the CV Pilots website.
CONNECTED VEHICLE PILOT DEPLOYMENT PROGRAM

PROGRAM GOALS

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

PILOT SITES

- WYDOT
- NYCDOT
- Tampa (THEA)

PROGRAM SCHEDULE

PHASE 1 (up to 12 months)
- Concept Dev.

PHASE 2 (up to 20 months)
- Design/Build/Test

PHASE 3 (minimum 18 months)
- Maintain/Operate Pilot
  - Routine Operations (ongoing)
  - Post-Pilot Operations (ongoing)

- Progress Gate
- Progress Gate
- transition

- Sep 2015
- Sep 2016
- May 2018 - Dec 2019
- Jan 2020 - Jan 2021

U.S. Department of Transportation
Wyoming DOT CV Pilot Deployment Overview

Vince Garcia
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.
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.

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

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)
Pilot Vision

- Improve Safety and Mobility
- CV Strategy
  - Timely and accurate in-vehicle information
  - Complete integration with existing/future WYDOT systems and infrastructure
  - Secure data management
  - Innate interoperability with all external equipment/vendors and neighboring deployments
  - Continuous maintenance of robust CV infrastructure
### WYDOT CV Pilot: Where are we today?

#### RSUs
- 76 RSUs of 77 total on the road
- RSUs are enrolled in the production SCMS
- RSUs and TMC servers and data warehouse are monitored for M&O in production

#### OBUs
- 25 vehicles equipped of 400
- OBUs are enrolled in the production SCMS
- 29 Pilot Drivers trained

#### Applications
- Forward Collision Warning, Distress Notification, Event Logging, and Traveler Information Messages are complete
- Applications for Over the Air (OTA) updates are being finalized

#### TMC Systems in Production
- Operational Data Environment (i.e., CV Data Manager)
- Integration with TMC TRAC system complete
- Pikalert® (Road Weather Expert System) being tested
- Truck Parking Availability
- Distress Notification Alerts
- Data transfers to the SDC and Public Data Hub
WYDOT CV Pilot Operational Readiness Approach

Tony English
Approach to Operational Readiness

- Bench test OBU, RSU, and TMC subsystem component functionality
- Initial road test for all features (V2V)
- Add SCMS/HSM at vehicle, roadside and TMC
- End to end test for all features (V2V; V2I; TMC)
- Acceptance testing to comply with detailed test cases
  - Support project scope (SyRS, SAD, SDD, ICD) functionality with traceability
  - Support project performance requirements defined in acceptance tests
  - Support robust system for operations
- Readiness includes
  - Test cases and procedures
  - Requirements validation
  - Pass acceptance test
  - Test results report
**Test Plan**: Collection of Test Cases focused on requirements verification and/or acceptance of a component, subsystem, system, data flow or process.

**Test Case**: Focused on a single test scenario or process.

**Test Procedures**:  
- Integrated components of each Test Case  
- Step-by-step descriptions (pass/fail) of how the test is performed.
Acceptance Test Cases

Functional Test Cases
Verify component/subsystem/system performs all required functions as designed

Performance Test Cases
Verify performance (e.g. speed and bandwidth) necessary to support full operations

Robustness Test Cases
Verify consistent, reliable, and repeatable performance

Test Cases will be focused on requirements verification and augmented with functional, performance, and robustness test cases, as needed
### Test Case Example (page 1 of 3)

<table>
<thead>
<tr>
<th>Test Case Number</th>
<th>TBD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Case Name</td>
<td>OBU Basic Communications Functionality</td>
</tr>
</tbody>
</table>
| Test Objective   | - Verify OBU ability to receive GPS satellite data and determine latitude, longitude, and altitude  
                  - Verify OBU ability to transmit and receive J2735 compliant messages  
                  - Verify OBU ability to communicate with HMI via Bluetooth  
                  - Verify OBU ability to log DSRC messages  
                  - Verify OBU shuts down gracefully when power is terminated.  

                         | VS-REQ-1 Receive BSM – The Vehicle System shall receive Basic Safety Message Parts I and II (as defined in J2945/1) over DSRC from other connected vehicles consistent with Section 6.3.8 (BSM Scheduling and Congestion Control).  
                         | VS-REQ-33 BCVI Messages – The Vehicle System shall wirelessly broadcast over DSRC a basic safety message (BSM) to other connected devices. BSM includes the types of messages identified in Table 4 4. Part I data shall be included in every broadcast BSM. Part II trailer data items, defined in J2735 section 6.128, are required for vehicles with a FHWA classification 8-13 (FHWA, 2014).  
                         | VS-REQ-41 SLD Log Format – The event log format shall contain UTC time stamped text.  
                         | VS-REQ-42 SLD Log Data – The Vehicle System shall create event logs for all interactions with the Wyoming CV System or Vehicle System that is retained until it is sent to the Wyoming CV System or is older than TBD days. An interaction is defined as a received message from the Wyoming CV System or the Vehicle System. Each log should contain the information in Table 4 8.  
                         | VS-REQ-52 Architectural – All Vehicle Sub-Systems shall follow all core architectural requirements defined in Appendix A.2 OBU Core Architecture Requirements of this SyRS document.  
                         | ARQ-REQ-2 Basic Safety Message (BSM) – An OBU shall wirelessly broadcast BSM to other connected devices (i.e., another OBU or an RSU). The required broadcasting of the BSM Part II are defined in Section 4.2.5, Part I is always required.  
                         | CSC-REQ-2 OBU Certification - All OBUs used in the Wyoming Pilot shall be certified from a USDOT authorized testing facility based on J2945/1. At a minimum, the following applications interfaces and requirements from J2945/1 will be included in the certification testing. |
### Test Case Example (page 2 of 3)

<table>
<thead>
<tr>
<th>Test Case Number</th>
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<tbody>
<tr>
<td>Brief Description</td>
<td>Two DSRC OBUs intended for installation in Basic Equipped Vehicles are used in this test to verify basic OBU functions, including transmitting and receiving J2735 compliant messages and communicating with the HMI via Bluetooth</td>
</tr>
<tr>
<td>Test Location</td>
<td>Benchtop Laboratory Integration Test Environment with GPS satellite signal access</td>
</tr>
</tbody>
</table>
| Test Setup and Configuration | 2 simulated automotive power supplies  
2 “Basic Equipped Vehicle” OBUs with DSRC and GPS antennas mounted with power supplies for benchtop testing  
OBU BSM Generator and Receiver Test Application  
OBU Logging Application  
SAE J2735 2016 Packet Sniffer |

<table>
<thead>
<tr>
<th>Step</th>
<th>Procedure</th>
<th>Expected Result</th>
<th>Measurement/Verification Method</th>
<th>Pass/Fail</th>
<th>Remarks</th>
</tr>
</thead>
</table>
| 1    | Power on 2 OBUs | GPS receiver indicator light flashes indicating power up of GPS then holds solid to indicate lock on Lat/Long | Visual Demonstration, Inspection of Logs | Pass | • Inspect OBU log files to confirm successful receipt of GPS signals.  
• Inspect OBU log files to confirm latitude, longitude, and elevation and verify against independent source. |
| 2    | Power on 2 HMIs | Bluetooth communications indicator display on each HMI | Visual Demonstration, Inspection of Logs | Pass | • Inspect OBU log files to confirm successful HMI Bluetooth pairing and time.  
• Confirm each OBU is communicating with correct HMI. |
| 3    | Initiate OBU BSM Generator and Receiver Test Application on 2 OBUs. | Logging of BSM messages by each OBU from the other OBU. | Inspection of Logs | Pass | • Inspect OBU Test Application log files to confirm receipt of all BSMs sent in a 15 second period from one OBU to the other.  
• Inspect OBU Test Application log files to determine real-time data transfer rate. |
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<tr>
<td><strong>Step</strong></td>
<td><strong>Procedure</strong></td>
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<tr>
<td>4</td>
<td>Initiate SAE J2735 2016 Packet Sniffer</td>
</tr>
<tr>
<td>5</td>
<td>Obtain OBU Certification Report</td>
</tr>
<tr>
<td>6</td>
<td>Turn off power supply</td>
</tr>
<tr>
<td><strong>Test Results and Remarks</strong></td>
<td>Verified OBU Basic Communications Functionality</td>
</tr>
<tr>
<td><strong>Pass/Fail</strong></td>
<td></td>
</tr>
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</table>
Event Logs on the OBU are build for the following:
- BSM during event
- BSM every 30 seconds
- TIM reception (SAT and RSU)
- Distress Notification
- Updates
- Driver Alerts (TIMs, FCW, DN)

- Rotate at 100k in size, then zipped and sent to TMC when RSU is available
- Very limited bandwidth
- Built with binary log file using ASN.1 where possible.
Day to Day Readiness Monitoring

- Are the RSUs working?
- What are we currently posting on our RSUs?
- How many vehicles passed by the RSUs?
- How are our TMC systems working?
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/](https://wydotcvp.wyoroad.info/CVM/).
Real-Time Data Flow

Daily checks and reports of end to end data flows with Canary checks

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

TMC  ODE

TMC Data Warehouse
Secure Data Commons
Public Data Hub
Operational Data Management

Programmatic privacy protection and data fluidity enable rapid innovation, now and in the future.
SDC CV Data Analysis Tools

- Operational data queries for Performance Measures and System monitoring
- Grants easy access to customized data queries for BSM and Driver Alert data.
- Allows for auto report generation for speed, V2V and V2I datasets.
- Facilitates data export from Secure workstation for sharing and publishing results.
- Multiple Types of data can be superimposed on to one another to reconstruct road events for analysis.
  - BSM Data
  - Driver Alert Data
  - Forward Collision Warnings
WYDOT CV Pilot Operational Readiness Test/Demonstration Results

Shane Zumpf
Many tests were run prior to the Operational Readiness Demonstration (ORD)

1st ORD was run on 11/15/2017 - 11/16/2017
- ORD was run on Lear devices with no Certificates
- Tests were successful for FCW, DN, and I2V SA
- Backoffice test was successful showing TIM creation and pushout for all TMC applications

1st ORD test documentation didn't have full result set.

2nd ORD (less formal witness testing) performed on 9/27/2018 and had issues related to FCW

3rd testing over OCS - less formal witness testing performed on 10/30/2018

Decision was made to retest all applications on an Agile basis

Shakedown tests performed on OBUs until firmware was in a solid state and no high priority issues found

Latest version of firmware verified to work on shakedown tests for FCW, DN, I2V, and OTA
OCS Test Results

- Most tests during the Operational Capability Showcase Succeeded
  - WYDOT Team noticed some sporadic behavior with OBU results
- Issues were related to FCW and WSA applications
- Decision made to focus efforts on critical issues and OTA
Test schedule now includes Agile testing over the next 14 weeks (starting 7/15/2019)

Schedule includes retesting all applications/scenarios
- FCW
- DN
- I2V
- OTA

Agile testing process:
- Day 1: Live tests run
- Day 2: Results compiled and sent in for validation by 3rd party
- Repeat process above
Test Plans

- Include testing/light documentation over the next 14 weeks
- Formal testing for OTA, FCW, DN, and I2V
Critical to ensure fleet OBUs can be updated without touching vehicle/OBU multiple times for updates

Shakedown testing was done on multiple vehicles/OBUs over 3 months

Latest firmware version received in early June triggered go ahead for testing/deployment to friendly fleet.

Philosophy of why we can't touch vehicles and that this needs to be a solid solution - nonoptional

- Firmware
- Config
- HMI
Modeling and Simulation

Mohamed Ahmed
Using Truck Simulator Studies

Learning early about HMI effectiveness and driver responses

Impact of warnings on driver behavior

Make rapid adjustments to algorithms, HMI displays
High Fidelity Truck Cab Simulator – WYOSAFESIM
University of Wyoming
Scenario #1: *Work zone with Forward Collision Warning in fog*

CV Applications tested: *WZW & FCW*
Scenario #2: Slippery Road Surface due to snowy weather

CV Applications tested: SWIW & DN
Road Closure and Re-routing

Scenario #3: Road Closure due to accident in severe weather

CV Applications tested: SWIW & SA
Immediate impacts to pilot

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

Cumulative Effect of Weather Warnings

CV Scenario

Gradual Reduction in Speed

Baseline Scenario

Abrupt Reduction in Speed

Mean Driver Speed (MPH)

In clear conditions
Following fog warning
Following advisory speed warning
When encountered with fog

In clear conditions
Following fog warning
Following advisory speed warning
When encountered with fog

Time Interval

Less abrupt braking observed

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

Better speed adherence by CV-equipped drivers

Immediate impacts to pilot

Noticed some mixed results with work zone warnings
- Recommendations on HMI design changes

Noticed limited effectiveness with just weather warning
- Recommendation to pair with appropriate speed reduction which had a much more pronounced impact
HMI Improvement and Training

- Improving the HMI
- Provide Hands-on and Online Training on the WYDOT CV Applications to All Participants
WHP Training and Testing

Video URL: https://youtu.be/JLaS-s1OvCI
Traffic Safety Modeling

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

Microsimulation Modeling

- Using microsimulation modeling to derive Surrogate Measures of Safety;
- VISSIM simulation model for a 23-mile segment of the I-80 Cheyenne-Laramie VSL corridor;
- Surrogate Safety Assessment Model (SSAM) to analyze the number of traffic conflicts generated by VISSIM simulation model.
WYDOT CV Pilot Lessons Learned from Operational Readiness Test/Demonstration

Tony English
**Issues and Challenges**

**Issues:**
- Trucks are not cars, many standards and solutions do not fully apply—e.g., antenna location.
- Data volume increasing.
- OBU failing at scale, constant hardware and firmware updates.
- Technical challenges in ensuring a secure network—e.g., SCMS integration and firewall compatibility.
- General code stability (crashing, GPS not coming on line, HMI disconnecting, offloading random).
- DSRC performance for OTA and offloading.
Wyoming DOT CV Pilot
Next Steps

Vince Garcia
Next Steps

- Certify devices (RSUs certified)
- Continue to deploy on WYDOT and partner vehicles
- Finalize last few applications
- Start reporting on performance on a monthly basis from mid-2019
Please keep your phone muted

Please use chatbox to ask questions

Questions will be answered in the order in which they were received

- Discover more about the CV Pilot Sites
- Learn the Essential Steps to CV Deployment
- Engage in Technical Discussion

Visit the Pilot Site Websites for more Information:

- NYCDOT Pilot: https://www.cvp.nyc/
- Tampa (THEA): https://www.tampacvpilot.com/
- Wyoming DOT: https://wydotcvp.wyoroad.info/

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