



CONNECTED VEHICLE PILOT Deployment Program



Wyoming DOT Pilot Update at the Operational Readiness Milestone



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ITS Joint Program Office



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

Wirelessly Connected Vehicles

Mobile Devices

Infrastructure

Measure Deployment Benefits

Safety

Mobility

Environment

Resolve Deployment Issues

Technical

Institutional

Financial

PILOT SITES



WYDOT

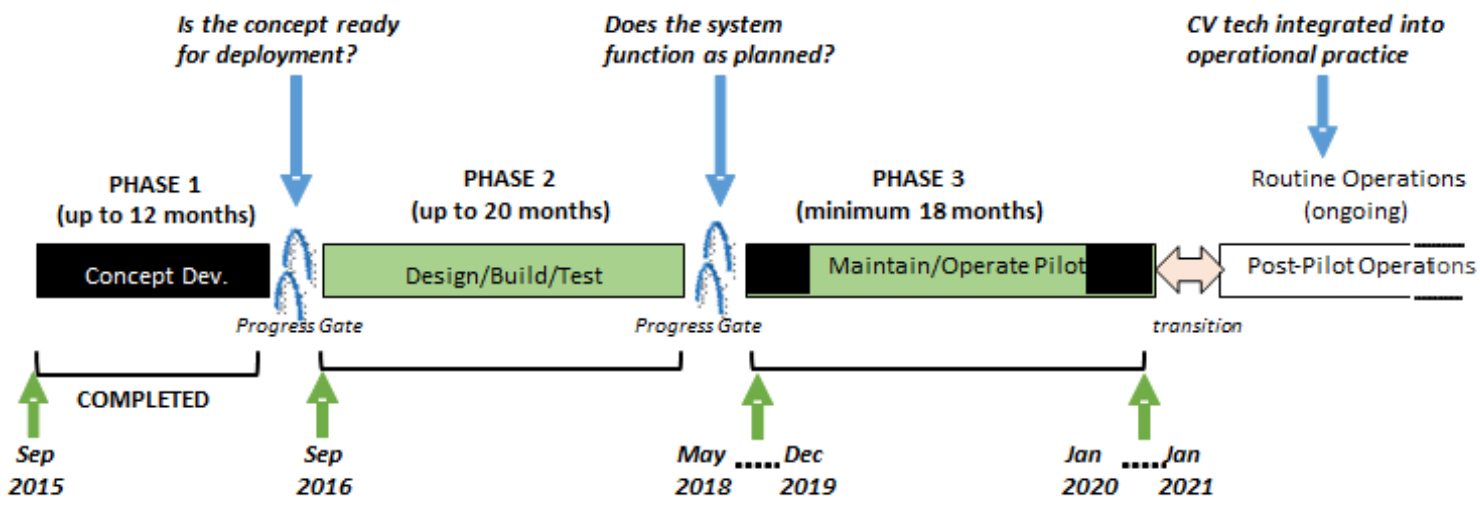


NYCDOT



Tampa (THEA)

PROGRAM SCHEDULE



U.S. Department of Transportation



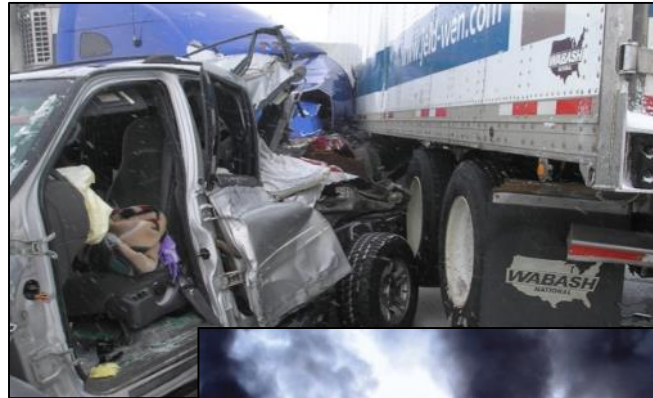
Wyoming DOT CV Pilot Deployment Overview

Vince Garcia

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)



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

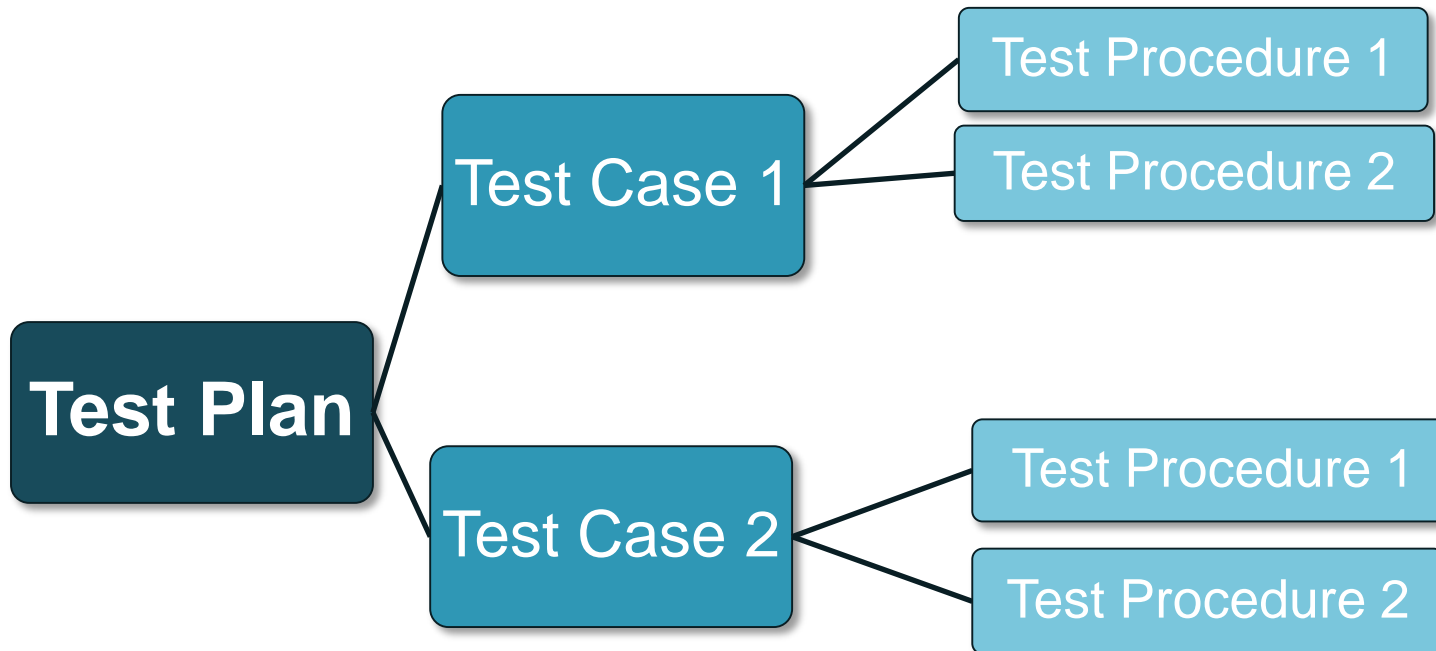
Approach to Operational Readiness



- 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 Plans, Cases, and Procedures



Test Plan: Collection of Test Cases focused on requirements verification and/or acceptance of a component, subsystem, system, data flow or process

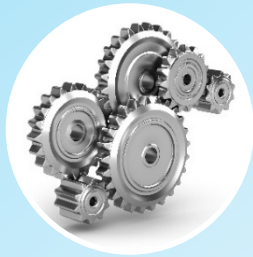
Test Case: Focused on a single test scenario or process

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 Case Types

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)



Test Case Number	TBD
Test Case Name	<u>OBU Basic Communications Functionality</u>
Test Objective	<ul style="list-style-type: none"> • 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.
Requirements Verified	<p>See <i>System Requirements Specification (SyRS), Version 2 – ICF/Wyoming</i> for details.</p> <p>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).</p> <p>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).</p> <p>VS-REQ-41 SLD Log Format – The event log format shall contain UTC time stamped text.</p> <p>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.</p> <p>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.</p> <p>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.</p> <p>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.</p>



Test Case Example (page 2 of 3)



Test Case Number	TBD				
Brief Description	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				
Test Location	Benchtop Laboratory Integration Test Environment with GPS satellite signal access				
Test Setup and Configuration	<ul style="list-style-type: none"> • 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 				
Step	Procedure	Expected Result	Measurement/ Verification Method	Pass / Fail	Remarks
1	Power on 2 OBUs	<ul style="list-style-type: none"> • GPS receiver indicator light flashes indicating power up of GPS then holds solid to indicate lock on Lat/Long 	Visual Demonstration, Inspection of Logs		<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • Bluetooth communications indicator display on each HMI 	Visual Demonstration, Inspection of Logs		<ul style="list-style-type: none"> • 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.	<ul style="list-style-type: none"> • Logging of BSM messages by each OBU from the other OBU. 	Inspection of Logs		<ul style="list-style-type: none"> • 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.



Test Case Example (page 3 of 3)



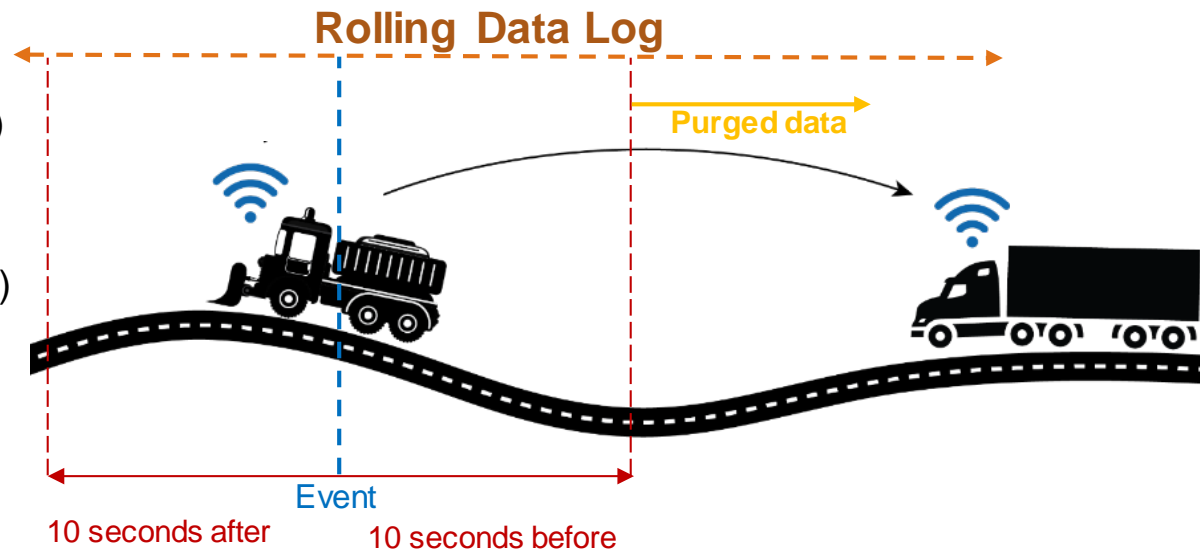
Test Case Number	TBD				
Step	Procedure	Expected Result	Measurement/ Verification Method	Pass/ Fail	Remarks
4	Initiate SAE J2735 2016 Packet Sniffer	<ul style="list-style-type: none"> Packet Sniffer successfully captures and parses BSMs from both OBUs. 	Inspection of Logs		<ul style="list-style-type: none"> Inspect Packet Sniffer log files to confirm compliance with SAE J2735 2016 specifications for BSMs.
5	Obtain OBU Certification Report	<ul style="list-style-type: none"> Compliance with Independent Certification Requirements 	Inspection of certificate		
6	Turn off power supply	<ul style="list-style-type: none"> Power indicator light is not illuminated. OBs now longer issues BSMs. 	Inspection of Logs		<ul style="list-style-type: none"> Inspect logs to confirm graceful shutdown of OBU when power is terminated.
Test Results and Remarks	<u>Verified OBU Basic Communications Functionality</u>				
Pass/Fail					



Event Log size management



- 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?

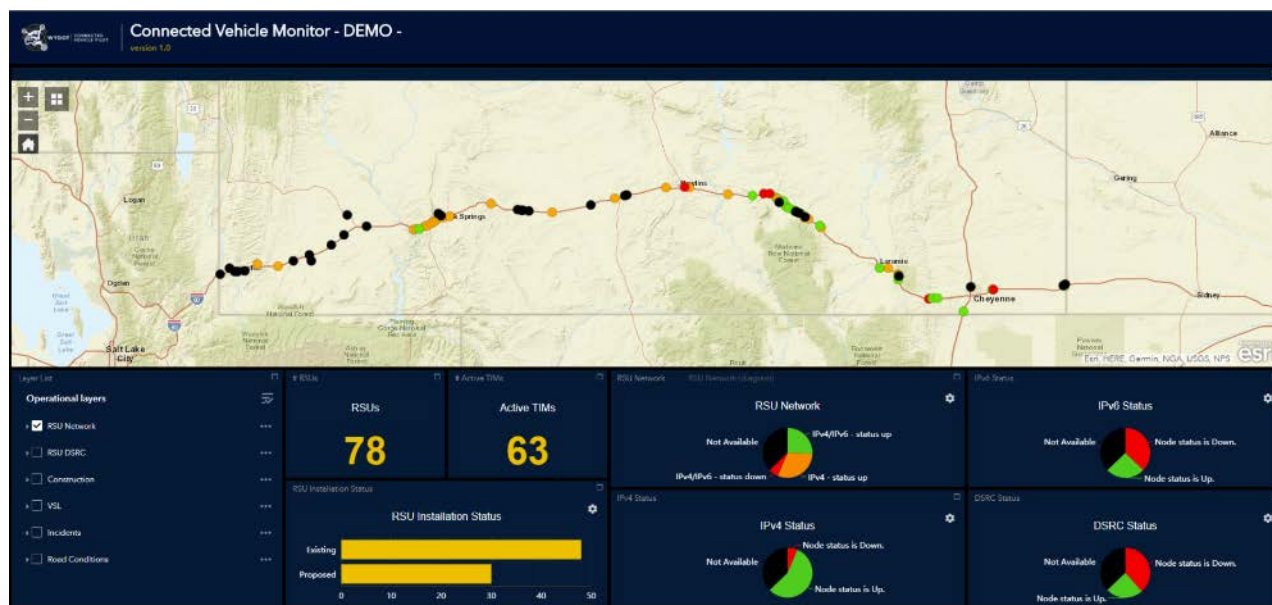
How are our TMC systems working?



CV Monitor



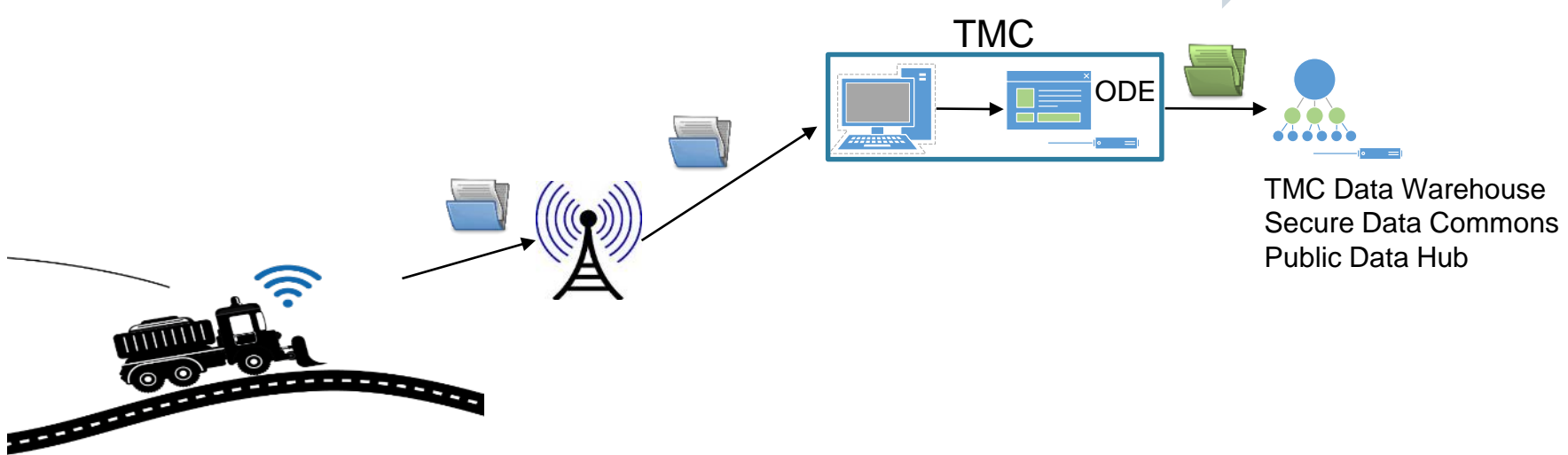
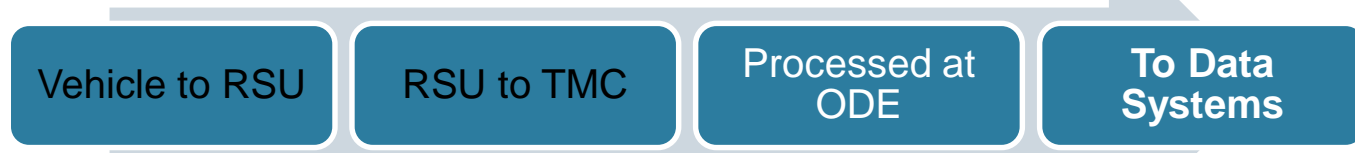
- The CV monitor is used to monitor RSUs in real-time.
- Provides the status of communication, vehicle counts, posted TIMs and other information.
- A specialized version with an enhancement allows authorized people to apply firmware updates to RSUs.
- Publicly available <https://wydotcwp.wyoroad.info/CVM/>.



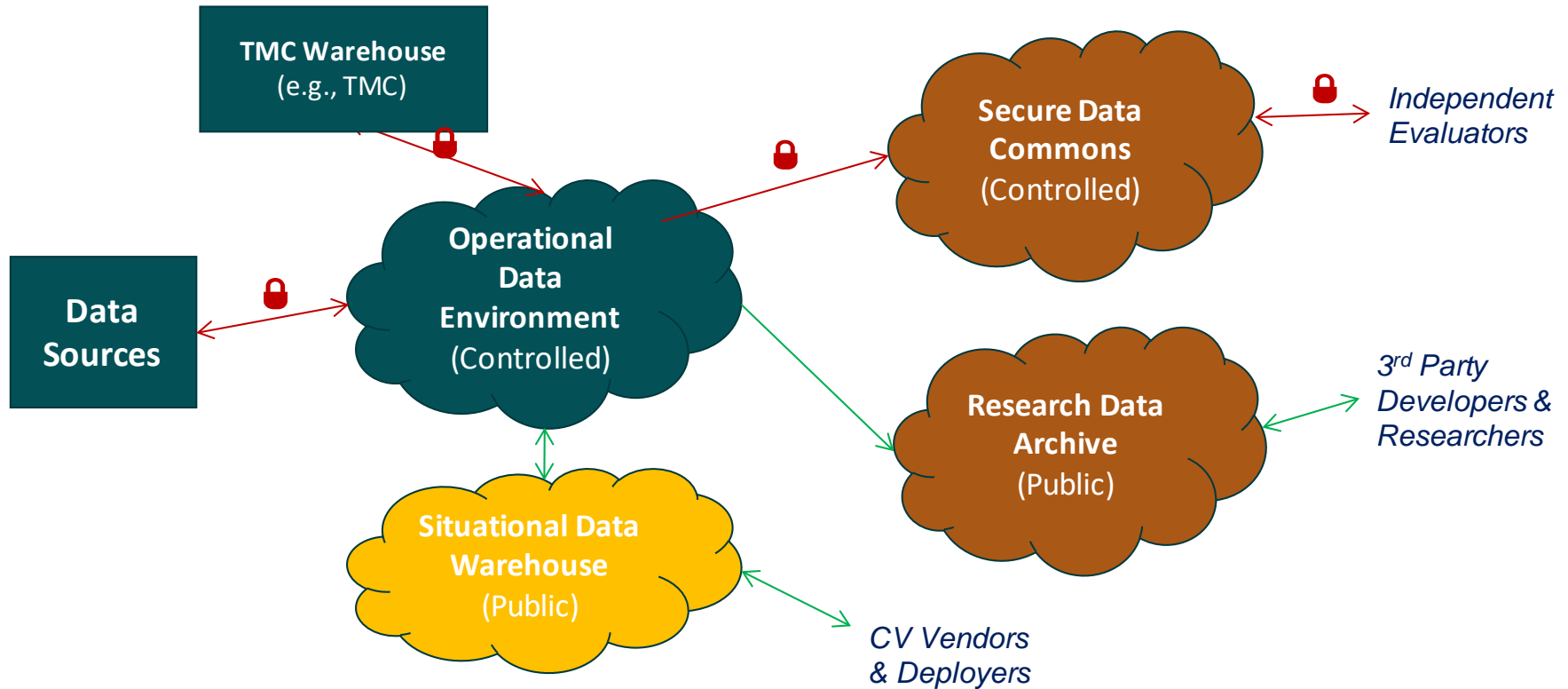
Real-Time Data Flow



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



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

BSM Query Tool

Date Time Options
Start Date: [06/01/19] Start Time: [Hour:Minute] [AM/PM]
End Date: [06/01/19] End Time: [Hour:Minute] [AM/PM]

Geospatial Options
Longitude: []
Latitude: [] OR Input CSV: [Choose File]
Radius (meters): []

Other Options
D: [] BSM Service: [ALL] []
Limit Records: [100] BSM Log Type: [ALL] []

Submit

KML Constructor

CSV Selection
[C:\Users\jwells\Downloads] [X]
[C:\Users\jwells\Downloads] [X]
Choose File

Select one or more CSV files, of multiple types and the results will be put into a single kml file

Submit

Driver Alert Query Tool

Date Time Options
Start Date: [] Start Time: [] [AM/PM]
End Date: [] End Time: [] [AM/PM]

Geospatial Options
Longitude: []
Latitude: [] OR Input KML: [Choose File]
Radius (meters): []

Other Options
Limit Records: [] Alert Type: [ALL] []

Submit

Export / Import Data

Export
Upload File Tag: [] [Zip Directory/For Upload] []
Choose File: [Choose File] OR Choose Directory: [Choose Directory]

Submit

Import
Download File Tag: [] Download Bucket Name: []
Download File Name: [] Download Profile Name: []

Submit



WYDOT CV Pilot Operational Readiness Test/Demonstration Results

Shane Zumpf



Test Results of Operational Readiness Demonstration

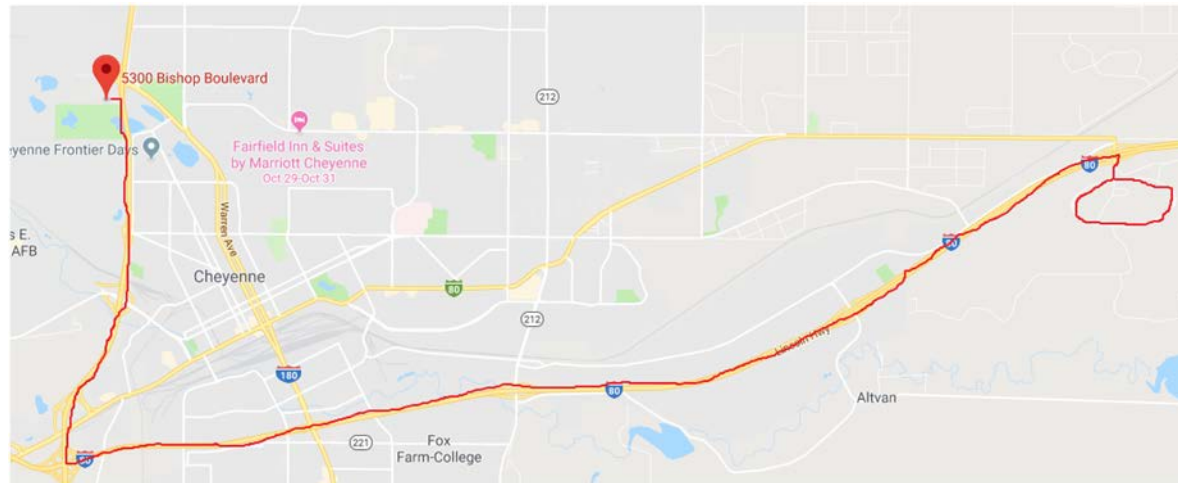
- Many tests were run prior to the Operational Readiness Demonstration (ORD)
- 1st ORD was run on 11/15/2017 - 11/16/2017
 - ORD was run on Lear devices with no Certificates
 - Tests were successful for FCW, DN, and I2V SA
 - Backoffice test was successful showing TIM creation and pushout for all TMC 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



Agile Testing



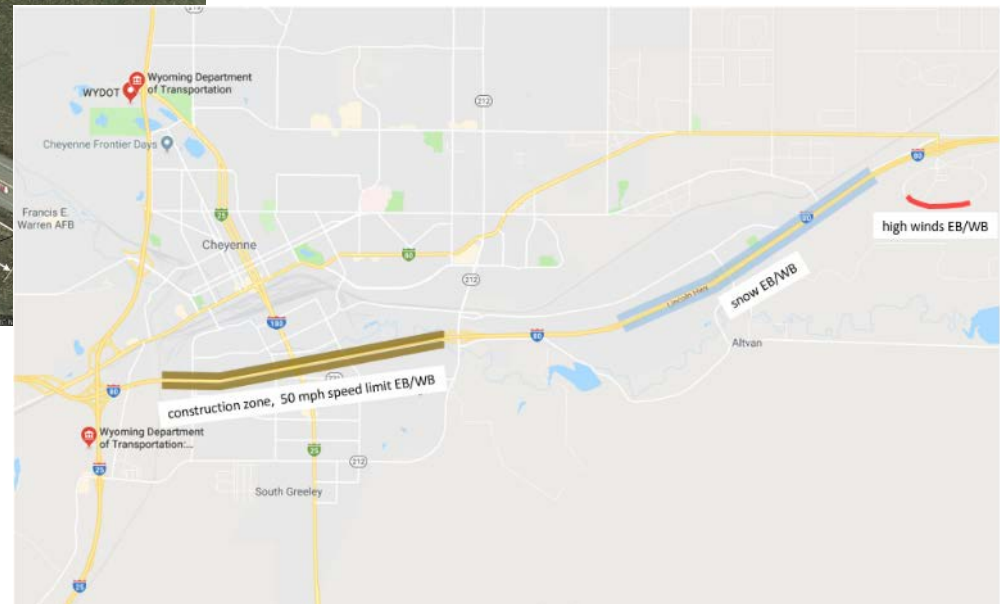
- Test schedule now includes Agile testing over the next 14 weeks (starting 7/15/2019)
- Schedule includes retesting all applications/scenarios
 - FCW
 - DN
 - I2V
 - OTA
- Agile testing process:
 - Day 1: Live tests run
 - Day 2: Results compiled and sent in for validation by 3rd party
 - Repeat process 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



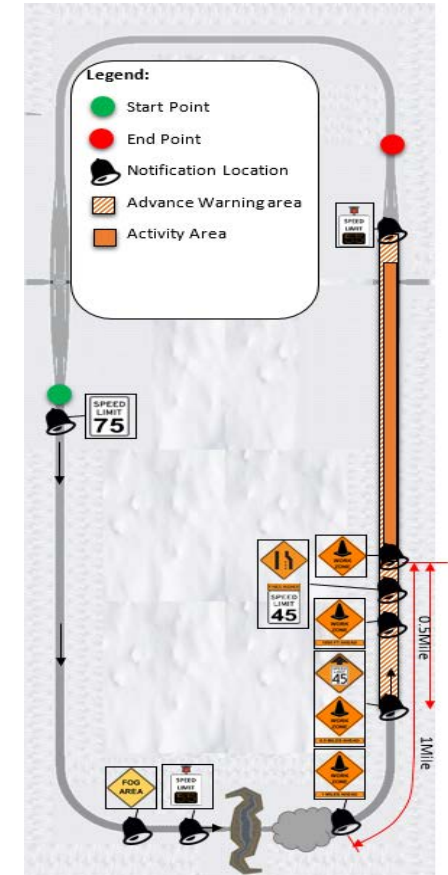
Make rapid adjustments to algorithms, HMI displays



Simulator Experiments



**High Fidelity Truck Cab Simulator –
WYOSAFESIM
University of Wyoming**

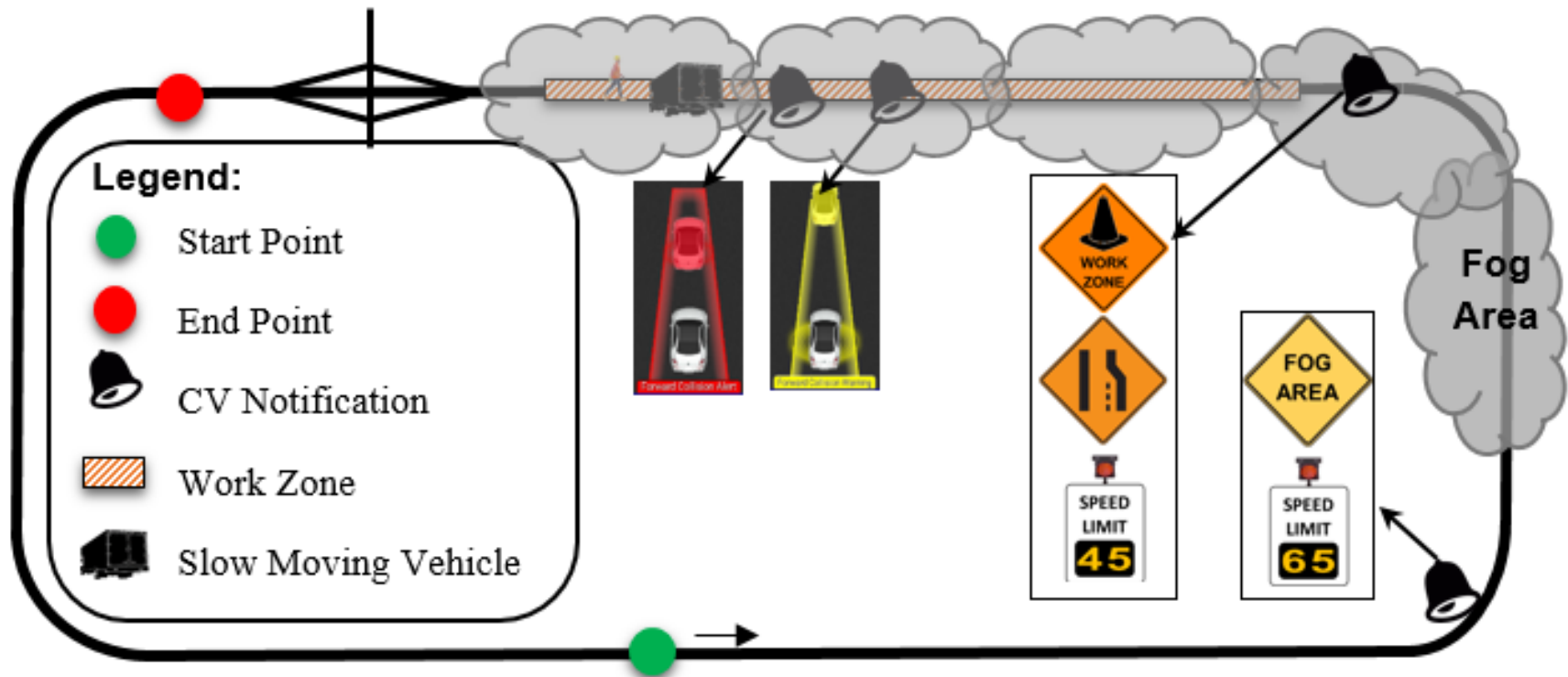




Work Zone & FCW

Scenario #1: *Work zone with Forward Collision Warning in fog*

CV Applications tested: *WZW & FCW*

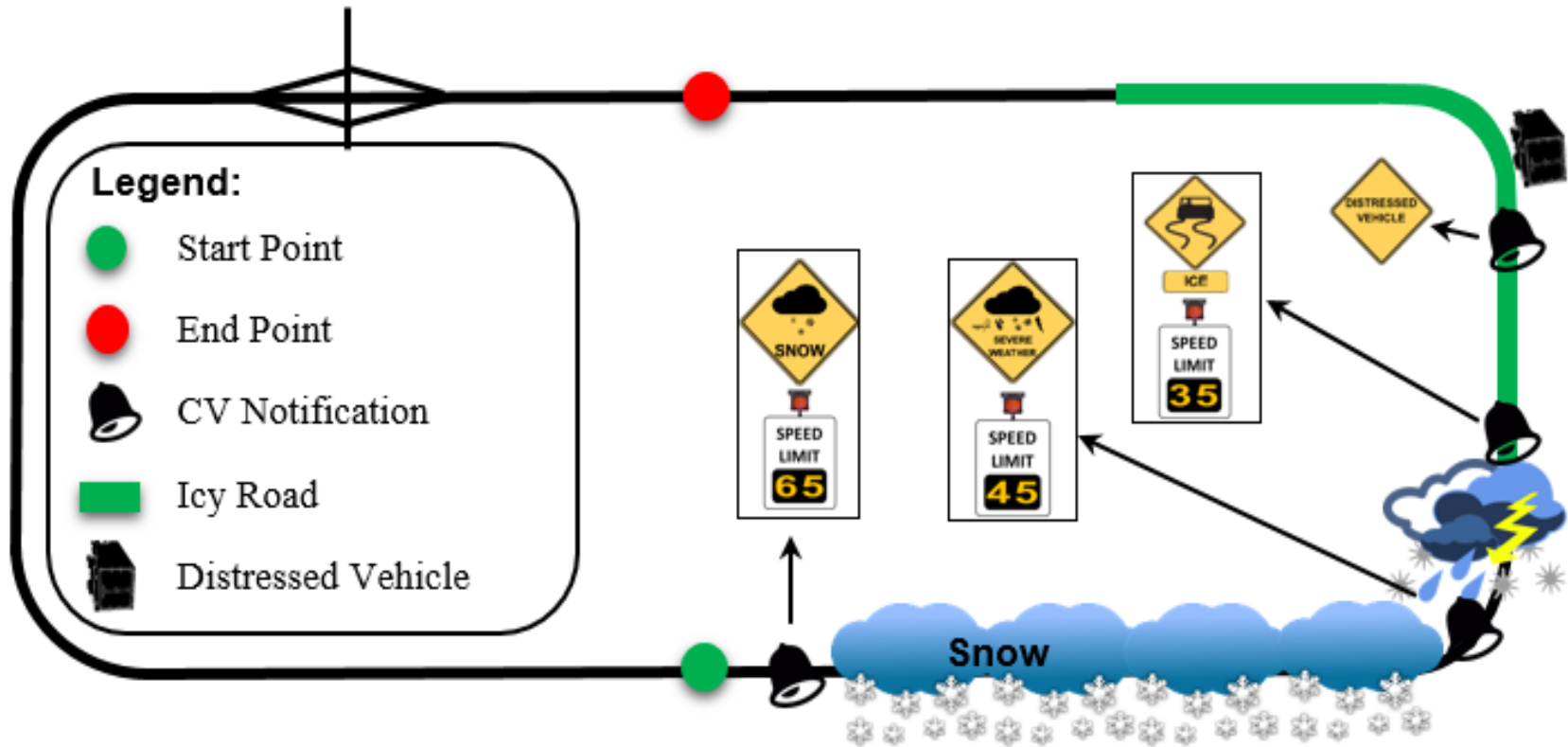


Adverse Weather



Scenario #2: *Slippery Road Surface due to snowy weather*

CV Applications tested: *SWIW & DN*

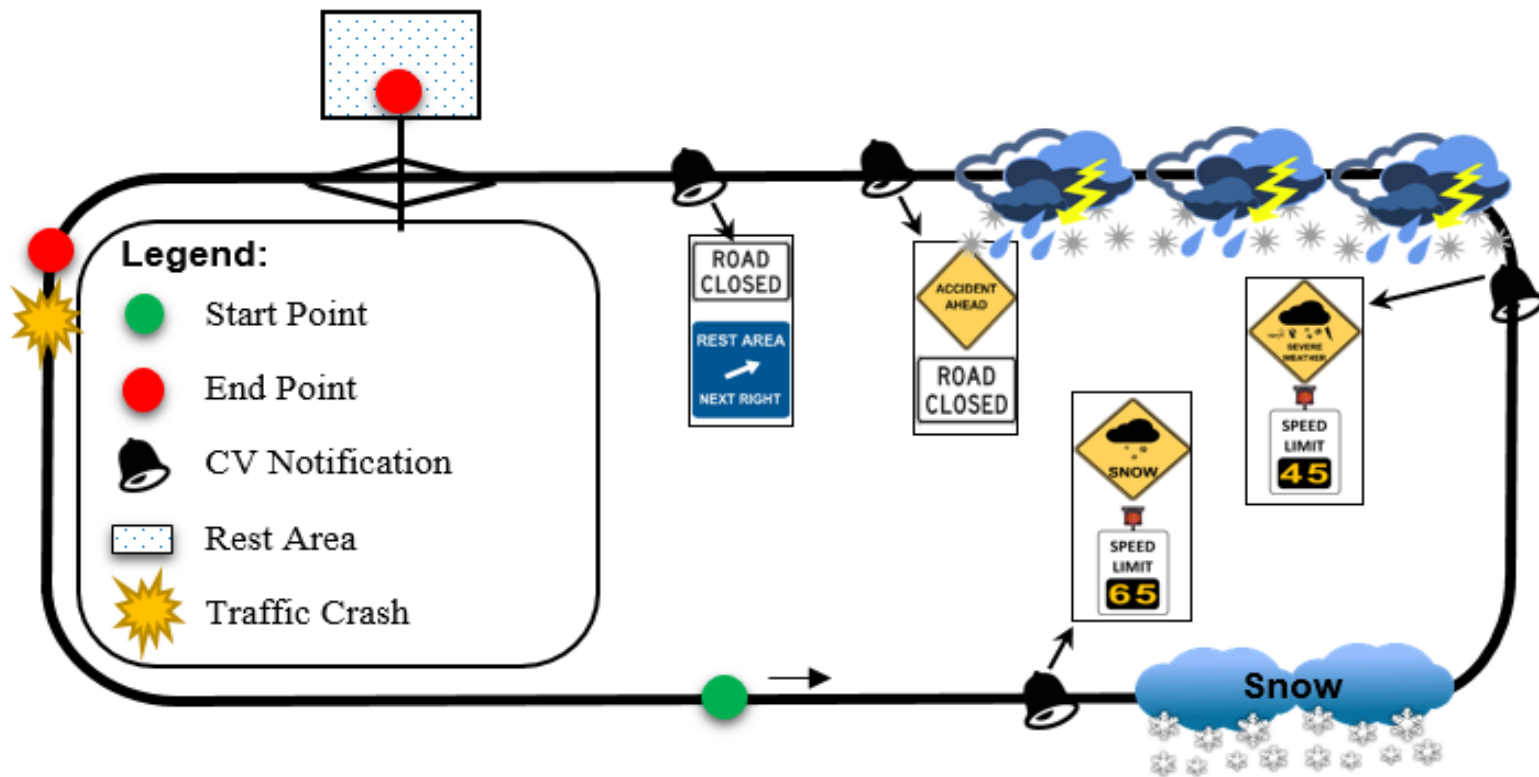


Road Closure and Re-routing



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

CV Applications tested: *SWIW & SA*

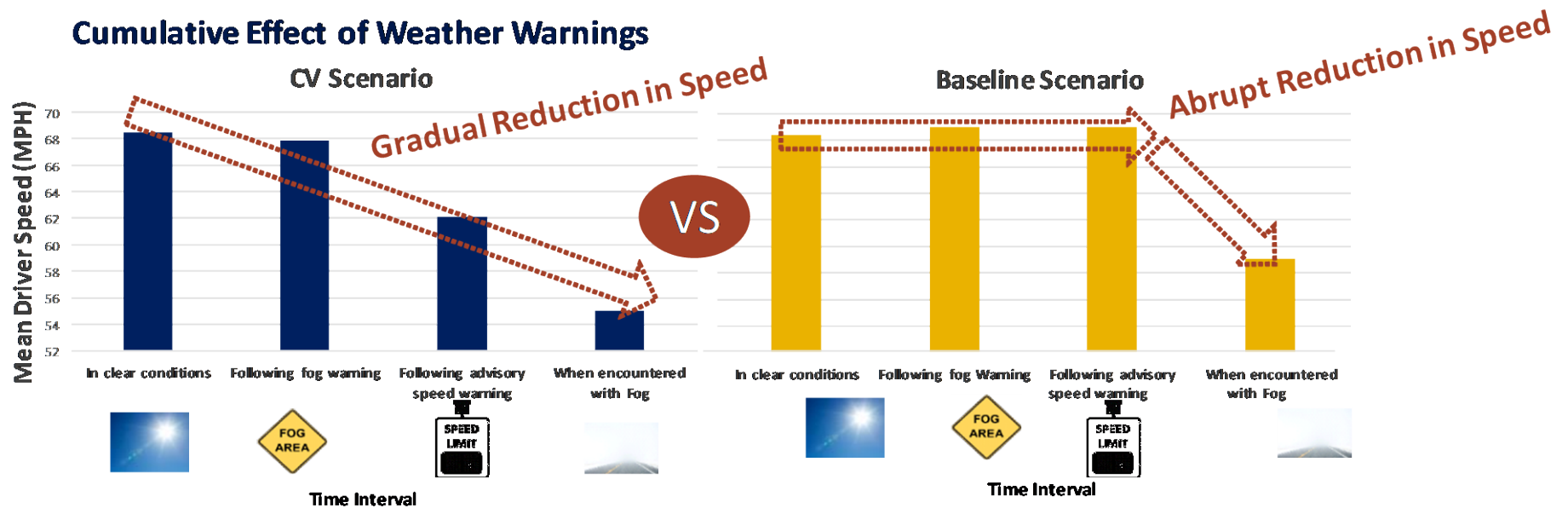




Immediate impacts to pilot

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

Cumulative Effect of Weather Warnings



Less abrupt braking observed

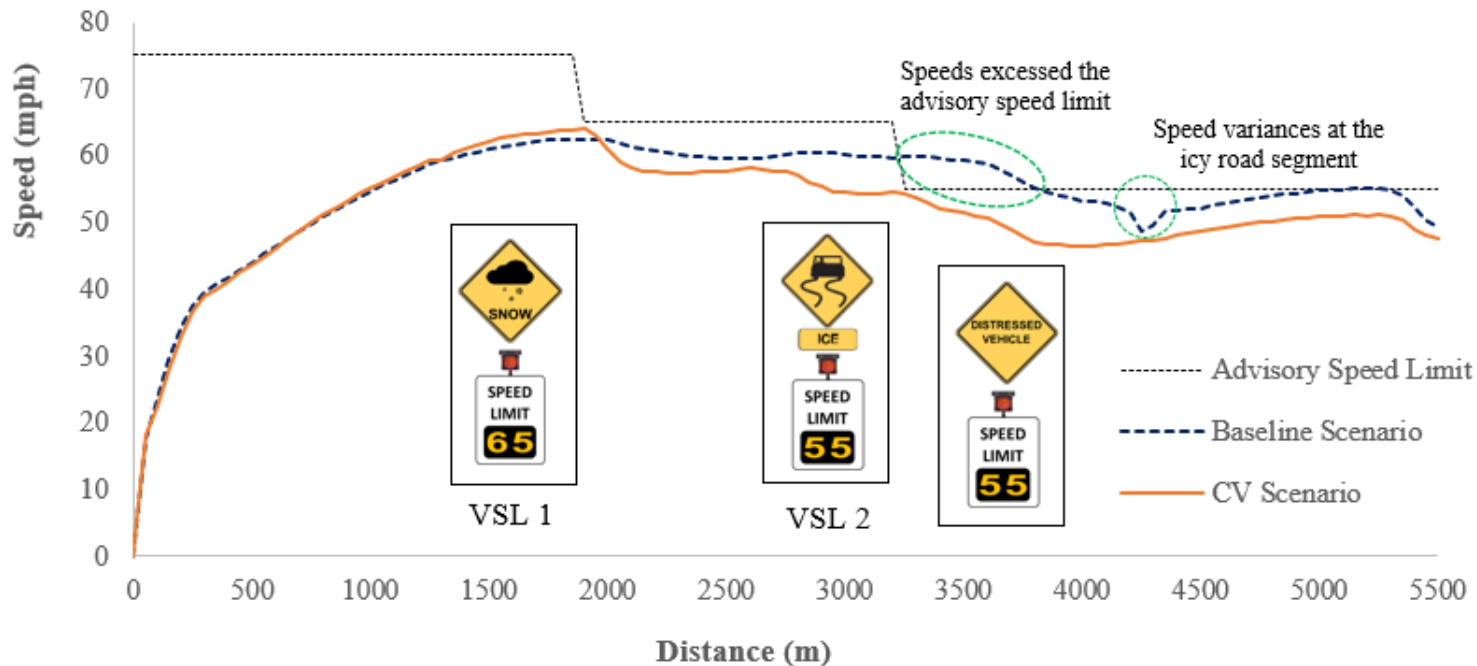
Source: Univ of Wyoming, TRB Paper, Evaluation of Connected Vehicle Real-Time Weather and Work Zone Warnings on the Behavior of Truck Drivers: A Driving Simulator Study



Immediate impacts to pilot



Better speed adherence by CV-equipped drivers



Source: Univ of Wyoming, TRB Paper, Impact of Variable Speed Limit in a Connected Vehicle Environment on Truck Driver Behavior under Adverse Weather Conditions: A Driving Simulator Study



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>

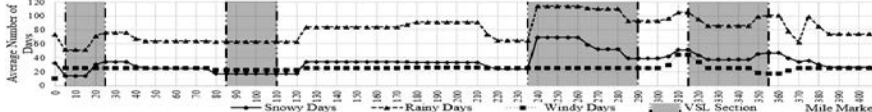
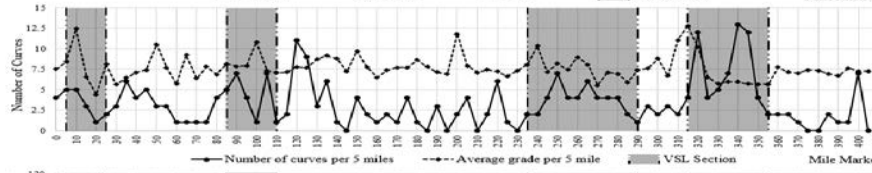
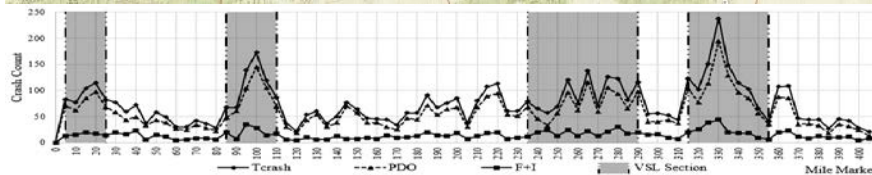
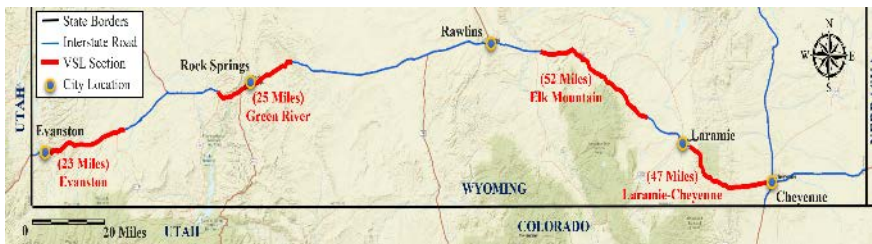


Safety Performance Modeling Approaches



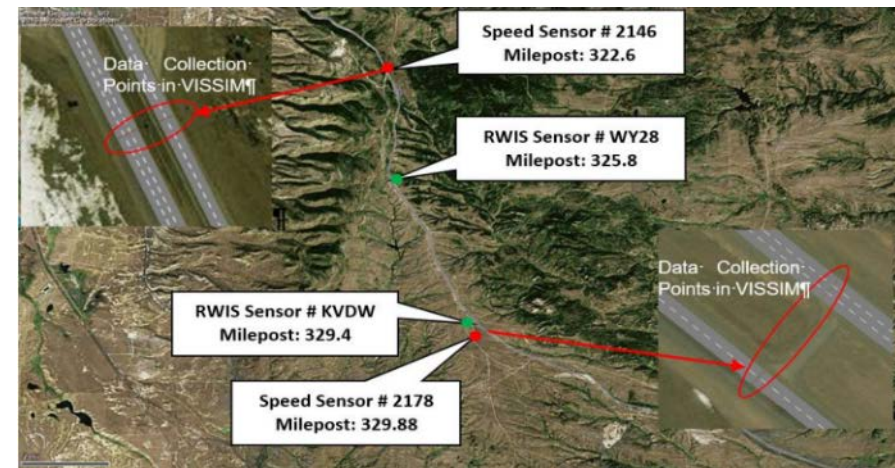
Traffic Safety Modeling

- ✓ 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



STAKEHOLDER Q&A



- Please keep your phone muted
- Please use chatbox to ask questions
- Questions will be answered in the order in which they were received

STAY CONNECTED



Join us for *Using Connected Vehicle Technologies to Solve Real-World Operational Problems Series at*

<https://www.its.dot.gov/pilots/>

- 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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