Wyoming DOT
Connected Vehicle Pilot

SYSTEM DESIGN WEBINAR
CV Pilot Deployment Overview

KATE HARTMAN, U.S. DOT
CV Pilot Deployment Overview

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

Wirelessly Connected Vehicles
- Safety

Mobile Devices
- Mobility

Infrastructure
- Environment

Financial
- Institutional
- Technical
Wyoming CV Pilot Presentation Overview

- Site Overview – Vince Garcia
- From Planning to Deployment – Deepak Gopalakrishna
- From Planning to System Architecture – Deepak Gopalakrishna
- From Architecture to System Design – Shane Zumpf
- From Traceability to Readiness – Denny Stephens
- Lessons Learned – Tony English
- Next Steps – Vince Garcia
Site Overview

VINCE GARCIA, WYDOT
WYDOT CV Pilot Overview

Measures of Success

- Improved safety and mobility along I-80 through real-time communication with fleet drivers and managers
- Improved awareness of hazards through CV pilot applications

Implementation Elements

- 75 Roadside Units (RSUs) broadcasting and receiving messages via DSRC
- 400 equipped vehicles with on-board units (OBUs)
- V2V, V2I, I2V applications alerting drivers to various road conditions
- CV data collection for improved traffic management and traveler information
For More Information

https://wydotcvp.wyoroad.info/
From Planning to Deployment

DEEPAK GOPALAKRISHNA, ICF
The Pilot is comprised of three phases:

- **Phase 1**: Planning (Sept. 2015 – Sept. 2016)
- **Phase 2**: Deployment (Oct. 2016 – April 2018)
- **Phase 3**: Demonstration (May 2018 – Oct. 2019)
Status After Phase 1

- Concept of Operations (ConOps)
- Security Management Operational Concept
- Safety Management Plan
- Performance Measurement and Evaluation Support Plan
- System Requirements Specification
- Application Deployment Plan
- Human Use Approval
- Participant Training and Stakeholder Education Plan
- Outreach Plan
- Comprehensive Pilot Deployment Plan

Notice to Proceed to Phase 2
Phase 2 Activities

- System Architecture Document
- System Design Document

**Build**
- Comprehensive Acquisition Plan
- Comprehensive Installation Plan
- Application Development
- Operational Readiness Plan
- Operational Readiness Testing

**Design**

**Test**
System Architecture Development

Robust systems engineering process followed

<table>
<thead>
<tr>
<th>Phase 1</th>
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<th>Phase 2</th>
<th>Phase 3</th>
<th>Phase 4</th>
<th>Phase 5</th>
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<tbody>
<tr>
<td>Interfacing with Planning and the Regional Architecture</td>
<td>Concept Exploration and Benefits Analysis</td>
<td>Project Planning and Concept of Operations Development</td>
<td>System Definition and Design</td>
<td>System Development and Implementation</td>
<td>Validation, Operations and Maintenance, Changes &amp; Upgrades</td>
<td>System Retirement / Replacement</td>
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Regional Architecture

Cross-Cutting Activities
- Stakeholder Involvement
- Elicitation
- Project Management Practices
- Risk Management
- Program Metrics
- Configuration Management
- Process Improvement
- Decision Gates
- Trade Studies
- Technical Reviews
- Traceability

Concept of Operations
System Requirements
High-Level Design
Subsystem Requirements
Detailed Design
Integration
Unit Testing
System Verification
System Integration
Life Cycle Time Line

Decision Gate

Operations and Maintenance
Changes and Upgrades
Retirement / Replacement
System Architecture Development
Sys. Architecture – Key Outcomes/Challenges

- Planning for security can be a moving target, need to develop architecture plan for research and for deployment (different goals)
- Data collection focus on operations vs. application validation
- Architect TMC network to support CV
  - Security
  - IPv6
  - Bandwidth
  - SCMS access
- Plan for mobile observations data collection and dissemination
- System architecture for weather forecasting and development of roadway alerts and advisories
From Architecture to System Design

SHANE ZUMPF, TRIHYDRO
System Design

- Focus on individual applications
- Develop Interfaces
- Criteria for design
System Design – Applications

- Forward Collision Warning (FCW)
  - Host vehicle receives BSM information from remote vehicles.

- Distress Notification (DN)
  - Rebroadcast Distress message to RSU

- I2V Situational Awareness

- Work Zone Warning (WZW)

- Spot Weather Impact Warning (SWIW)
  - Spot specific weather impacted by WYDOT source
System Design – Work Zone Warning

➢ Work Zone Warning – Behind the Scenes

TMC Application
- Operator Adds Planned Work Zone
- Sends Information to System

Backend Services
- Builds messages
- Determines Affected Area

RSU
- Broadcasts Alerts

Vehicles
- Receive Alerts
System Design – Work Zone Warning

➢ Work Zone Warning in Action
Weather Data
- Remote Weather Stations
- Connected Vehicle Probe Data
- Connected Vehicle CAN Data

Pikalert
- Processes Weather Data
- Issues Weather Alerts and Forecasts

TMC Application
- Operator Receives new Alerts
- Issues Alerts to CV Environment

Backend Services
- Builds messages
- Determines Affected Area

RSU
- Broadcasts Alerts

Vehicles
- Receive Alerts
System Design – Spot Weather Warning

Spot Weather Warning in Action
System Design – Interfaces

[Diagram of system design interfaces]

- WYDOT Traffic Management Center
  - WYDOT RWIS System
  - WYDOT Data Broker (DB)
  - WYDOT Data Warehouse (DW)

- Pikalert System (PA)
  - National Weather Service (NWS)
  - Location & Time Service (LTS)

- Vehicle System
  - Integrated Comm Vehicle
  - WYDOT Maint Vehicle
  - Retrofit Comm Vehicle
  - Highway Patrol Vehicle

- Roadside Units
  - RSU(s)

- CV Pilot Evaluation Platform (CVPEP)
  - Security Credential Management System (SCMS)
  - USDOT Situation Data Warehouse (SDW)

- Satellite Service Provider

- WYDOT 511 System
- WYDOT Road Condition Reporting System (RCRS)
- WYDOT Incident Console (IC)
- WYDOT Construction Administration (CA)
- WYDOT Trans Reporting and Action Console (TRAC)
- WYDOT Commercial Vehicle Operator Portfolio (CVOP)
- WYDOT ITS Maintenance
- WYDOT Third-Party Interface (TPI)

September 13, 2017
System Design – Interfaces

- I2V DSRC Communications Interface (WE1)
- Location and Time Service (LTS) (WE2 & WE3)
- NWS and RWIS (WE4)
- WYDOT 511 Application (WE5)
- WYDOT RCRS (WE6)
- WYDOT IC (WE7)
- WYDOT Construction Administration (WE8)
- WTI (WE9)
- WYDOT TPI (WE10)
- WYDOT TRAC (WE11)
- WYDOT CVOP (WE12)
- WYDOT ITS Maintenance (WE13)
- Independent Evaluator (IE) / Research Data Exchange (RDE) (WE14, WE18, WE19 and WE20)
- USDOT SDW (WE15)
- USDOT SCMS (WE16 and WE17)
System Design – Interfaces of Note

- CAN bus interface will be a challenge for data definition (J1939 for Heavy-Duty Trucks), also most fleets are protective of CAN interface, could be dangerous to vehicle operation and security. CAN interface is not essential to our system design.

- CV-PEP interface to allow data sharing, in near real time, with evaluator and internal researchers
  - Full data set, highly protected and monitored access, no ability to download data

- RDE interface to allow data sharing, in near real time, with public and external to pilot researchers
  - Sanitized data set (I80 only, normal highway speeds of 5-80 mph)
  - BSM Part II is still under review for sanitization

- Satellite interface to allow Traveler Information Messages (TIMs) to be sent to vehicles outside range of RSU

- HSM in TMC (not yet in design), will be needed to sign TIMs (and MAP messages for other CV deployments)
System Design – Key Outcomes/Challenges

- SCMS integration should not be trivialized, it can be time consuming to get running
- Test log file offloading from OBU and RSU to TMC to validate performance of DSRC and backhaul networks
- Get comfortable with IPv6. Challenges can exist with backhaul routers, firewalls and Internet connections
- Understand how to best work with satellite services for security, numbers of messages and responsiveness expectations
- Do detailed review of in-vehicle networks, tough with snow plows and highway patrol
- Operation Data Environment useful for ASN.1, J2735 encode/decode, 1609.2 validation and signing (with HSM). Offloads much of Connected Vehicle complexities. Open source solution.
- Maturity of mobile environmental sensor collection and communication to TMC is still evolving
From Design to Readiness

DENNY STEPHENS, VITAL ASSURANCE
Operational Readiness Approach

Steps to Achieving Operational Readiness

- Requirements Verification and Acceptance Testing
- Support Systems Readiness Checklist
- Operational Readiness Demonstration

Two Day Event in Cheyenne. Begins our shakedown period with WYDOT fleets ~100 vehicles
Requirements Verification and Acceptance Testing

- Systematic acceptance testing and requirements verification throughout development, integration, installation, and deployment of WYDOT CV Systems:
  - Pilot Subsystem Development, Integration, and Test Readiness
  - Pilot Vehicle End-to-end System Integration and Test Readiness
  - Pilot Acquisition, Installation, and Deployment Readiness

- Systems Readiness (at each level of development and integration) is measured by completion and internal approval of:
  - Test Cases and Procedures
  - Requirements Verification
  - Pass Acceptance Test
  - Test Results Report
Support Systems Readiness Checklist

- Operational Readiness Checklist tracks the completion and internal approval “✓“ of the following Operational Readiness Measures:
  - Planning and Design Readiness
  - Pilot Performance Measures Readiness
  - Pilot Operations and Maintenance Readiness
  - Pilot Procedures, Documentation and Training Readiness
  - Pilot Institutional, Staff and Financial Readiness
  - Pilot Other Topics Readiness - Safety, Security and Privacy

Requirements Verification and Acceptance Testing  Support Systems Readiness Checklist  Operational Readiness Demonstration
Operational Readiness Demonstration

- System level functionality and performance test cases verify achievement of project goals and objectives through:
  - Repeated Acceptance Tests to demonstrate end-to-end readiness for deployment
  - Demonstrated readiness of system components, functions, apps, and scenarios
  - Demonstrated safety-, security-, privacy-, and performance measure-focused readiness elements
Lessons Learned

TONY ENGLISH, TRIHYDRO
Lessons Learned

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<tr>
<th>Lessons Learned</th>
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<tbody>
<tr>
<td>Developing a robust and scalable data design for CVs is a challenge</td>
<td>Different requirements add significant data needs for storage and throughput which may or may not be possible technically in the real-world.</td>
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<td>Approaches to manage for security are still in development</td>
<td>Evolving SCMS integration plan and outside cred management require flexibility in development of associated interfaces.</td>
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<td>Utilize existing standards as a part of the system architecture and design process.</td>
<td>The use of standards helped create a solid deployment effort in Phase 2, simplified technical documentation, and assisted with interoperability.</td>
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<td>Reserve an appropriate amount of time in the schedule to account for testing, both test planning and test execution.</td>
<td>Detailed test planning is dependent on many other factors including equipment availability, so the development of detailed test plans can be a lengthy process while uncertainties are nailed down.</td>
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<td>Detailed testing is required for OBU and RSU software.</td>
<td>Much of the software is not yet created or not created completely.</td>
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## Lessons Learned (contd.)

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<td>Wireless connection between equipment can be unreliable and finding a solution can take time</td>
<td>Bluetooth connection can present its challenges.</td>
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<td>Early enthusiasm may not be matched by reality</td>
<td>Trucking partners backed out after determining they do not have the assets or dispatch availability required to support the program.</td>
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<td>DOT Firewalls can hinder CV integration</td>
<td>Firewalls can be a problem when connecting existing components to new ones—e.g., a new external modelling tool with an in-house data source.</td>
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<td>Partnerships between different disciplines enhances system development</td>
<td>Combining fields of expertise can expedite the background research process—e.g., combining weather and vehicle crash expertise improves the blowover algorithm development.</td>
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Technical Issues

- Currently Being Resolved
  - DSRC Antenna Positioning on Trucks
  - Basic Safety Message for Trucks
  - Application Algorithms for Trucks
  - Bluetooth/WiFi linkage in-vehicle
  - Weather sensor quality and robustness
  - Event logging
  - Integration with security credentialing management system (SCMS)
  - IPv6
  - Traveler Information Message (TIM) formats
  - Adherence to standards
  - Back-office Transportation Management Center integration
  - Over The Air (OTA) updates
  - TBD

- Already Resolved
  - DSRC licensing
  - Roadside Units (RSU) installation
  - Third party interface
Institutional Issues

➢ Currently Being Resolved
  • Memorandums of Understanding (MoUs) with fleet partners
  • Independent evaluation needs
  • Operations & Maintenance procedures
  • Training
  • Human subjects/privacy

➢ Already Resolved
  • IRB initial approval
  • Initial procurements
  • Procurement & installation plans
Next Steps

VINCE GARCIA, WYDOT
Next Steps

- Operational Testing – Underway
- Operational Readiness Demonstration – November 2017
- Wyoming DOT Fleets in operations – Winter of 2017
- Phase III Begins – May 2018
Q&A