# PA Turnpike Connected Work Zone Pilot


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# Agenda

- PA Turnpike CAV Roadmap – Selection of CV Pilot
- Connected Work Zone Pilot
  - Architecture
  - Evaluation Metrics
  - Installation and Integrations
  - Evaluation Preliminary Findings
  - Lessons Learned

# CAV Roadmap

# CAV Roadmap Project

- Project executed February 2016
- Prime – AECOM
- Subs – Information Logistics and TTI
- Roadmap Tasks:
  - Research current standards and best practices
  - Identify potential projects for short/mid/long term
  - Align with capabilities of PTC infrastructure readiness, planned projects, and in-house capabilities
  - Develop Implementation plan, starting with a “Quick Win” project
- Roadmap completed April 2017
- Executed CV pilot project December 2017

# Application Areas

## V2I Safety

- Red Light Violation Warning
- Curve Speed Warning
- Stop Sign Gap Assist
- Spot Weather Impact Warning
- Reduced Speed/Work Zone Warning
- Pedestrian in Signalized Crosswalk Warning (Transit)

## V2V Safety

- Emergency Electronic Brake Lights (EEBL)
- Forward Collision Warning (FCW)
- Intersection Movement Assist (IMA)
- Left Turn Assist (LTA)
- Blind Spot/Lane Change Warning (BSW/LCW)
- Do Not Pass Warning (DNPW)
- Vehicle Turning Right in Front of Bus Warning (Transit)

## Road Weather

- Motorist Advisories and Warnings (MAW)
- Enhanced MDSS
- Vehicle Data Translator (VDT)
- Weather Response Traffic Information (WxTINFO)

## Environment

- Eco-Approach and Departure at Signalized Intersections
- Eco-Traffic Signal Timing
- Eco-Traffic Signal Priority
- Connected Eco-Driving
- Wireless Inductive/Resonance Charging
- Eco-Lanes Management
- Eco-Speed Harmonization
- Eco-Cooperative Adaptive Cruise Control
- Eco-Traveler Information
- Eco-Ramp Metering
- Low Emissions Zone Management
- AFV Charging / Fueling Information
- Eco-Smart Parking
- Dynamic Eco-Routing (light vehicle, transit, freight)
- Eco-ICM Decision Support System

## Agency Data

- Probe-based Pavement Maintenance
- Probe-enabled Traffic Monitoring
- Vehicle Classification-based Traffic Studies
- CV-enabled Turning Movement & Intersection Analysis
- CV-enabled Origin-Destination Studies

## Mobility

- Advanced Traveler Information System
- Intelligent Traffic Signal System (I-SIG)
- Signal Priority (transit, freight)
- Mobile Accessible Pedestrian Signal System (PED-SIG)
- Emergency Vehicle Preemption (PREEMPT)
- Dynamic Speed Harmonization (SPD-HARM)
- Queue Warning (Q-WARN)
- Cooperative Adaptive Cruise Control (CACC)
- Incident Scene Pre-Arrival Staging Guidance for Emergency Responders (RESP-STG)
- Incident Scene Work Zone Alerts for Drivers and Workers (INC-ZONE)
- Emergency Communications and Evacuation (EVAC)
- Connection Protection (T-CONNECT)
- Dynamic Transit Operations (T-DISP)
- Dynamic Ridesharing (D-RIDE)
- Freight-Specific Dynamic Travel Planning and Performance
- Drayage Optimization

## Smart Roadside

- Wireless Inspection
- Smart Truck Parking

# Connected vs Autonomous

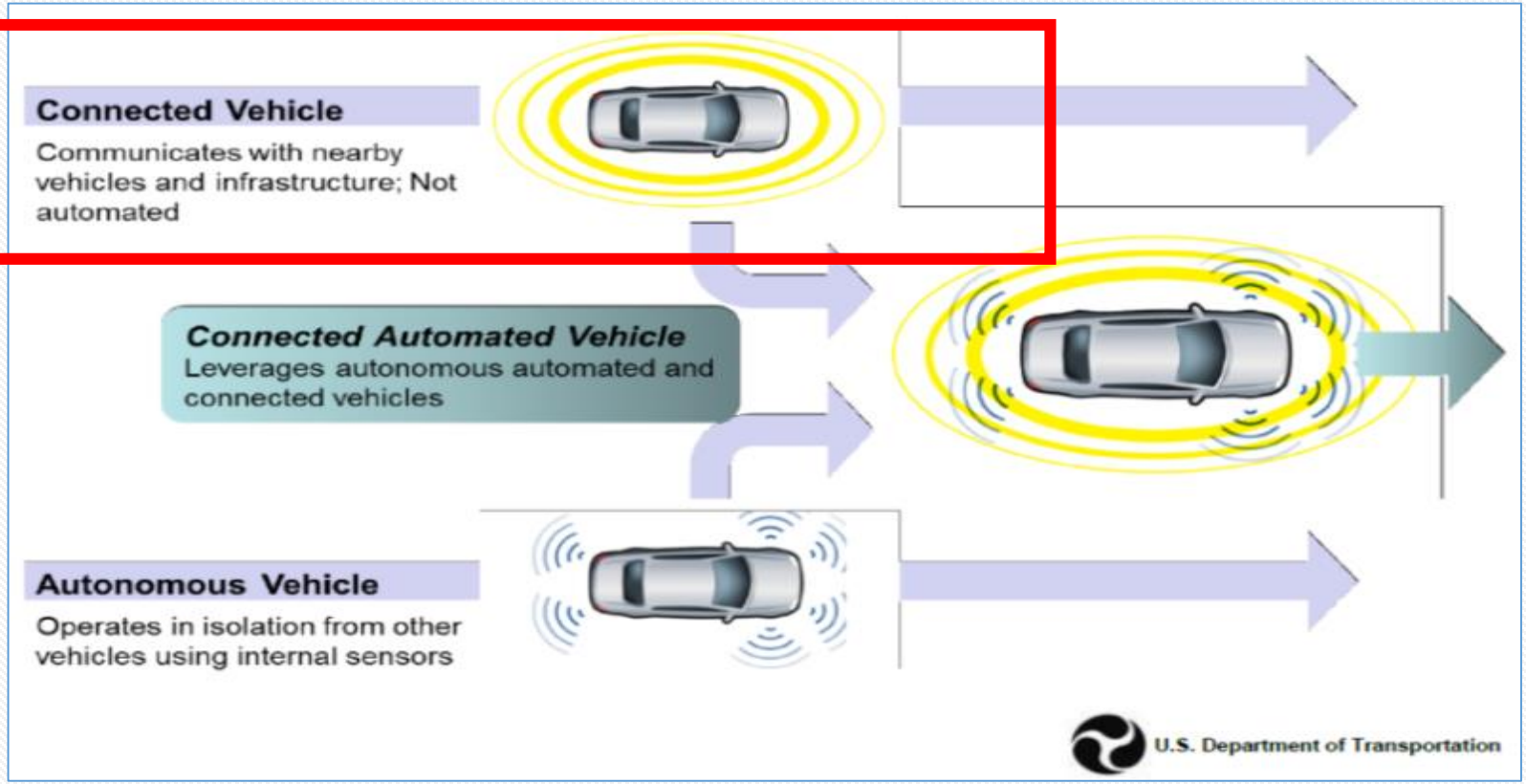
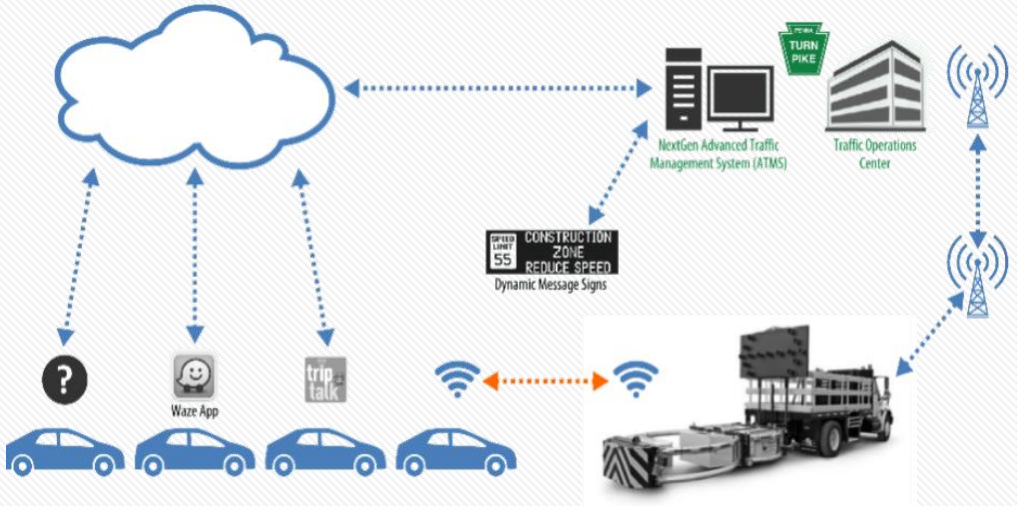



**Figure 1. What are Connected and Automated Vehicles?**

# CV Top Priorities

- Weather
- Traffic Incident Management
- Safety
- Work Zones



# CV Deployment Plan

| Short-Term<br>0-4 Years | Mid-Term<br>4-10 Years | Long-Term<br>Beyond 10 Years |
|---|---|---|
| • Warnings about Upcoming Work Zone (Work Zone Safety)<br>• Advanced Traveler Information Systems (Traveler Information)<br>• Incident Scene Work Zone Alerts for Drivers and Workers (Traffic Incident Management)<br>• Electronic Toll Collection (Tolling)<br>• Reduced Speed Zone Warning/Lane Closure (Work Zone Safety)<br>• Traveler Information-Smart Parking (Traveler Information)<br>• Curve Speed Warning (Roadway Safety)<br>• Spot Weather Impact Warning (Road Weather Safety) | • Incident Scene Pre-Arrival Staging Guidance for Emergency Responders (Traffic Incident Management)<br>• Road Weather Information for Maintenance and Fleet Management Systems (Road Weather Safety)<br>• Variable Speed Limits for Weather-Responsive Traffic Management (Road Weather Safety)<br>• Road Weather Motorist Alert and Warning (Road Weather Safety)<br>• In-Vehicle Signage (Traveler Information)<br>• Queue Warning (Roadway Safety)<br>• Warnings about Hazards in a Work Zone (Work Zone Safety) | • Speed Harmonization (SPD-HARM) (Traffic Network)<br>• Road Use Charging (Congestion Pricing)<br>• Vehicle Data for Traffic Operations (Traffic Network)<br>• Performance Monitoring and Planning (Traffic Network)<br>• Enhanced Maintenance Decision Support System (Traffic Network)<br>• Advanced Automatic Crash Notification Relay (EVAC) (Traffic Incident Management)<br>• Road Weather Information and Routing Support for Emergency Responders (Traffic Incident Management) |

# Short Term Projects – Quick Wins

| CAV Safety Core Focus Areas | CV Applications | "Quick Win" Projects |
|---|---|---|
| Work Zone Safety<br>Traffic Incident Management<br>Roadway Safety<br>Road Weather Safety | ▶ Warnings about Upcoming Work Zone<br>▶ Incident Scene Work Zone Alerts for Drivers and Workers<br>▶ Reduced Speed Zone Warning/Lane Closure<br>▶ Curve Speed Warning<br>▶ Spot Weather Impact Warning | **Option 1 (Pick One):**<br>Mobile and Maintenance Patterns Warning (Line Painting; MP 319-326; MP 202-206)<br>Curve and Ramp Warning Systems (Breezewood Interchange)<br>Road Weather Information Systems (Mile Marker 288)<br>**Option 2:**<br>Connected Truck Mounted Attenuator Pilot |

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# Why Pilot CV for Work Zone?

## Work Zone Crash Summary

### Fiscal Year - Total*

| Fiscal Year | Work Zone Total Crashes | | | Work Zone Fatal Crashes | | Vehicle Miles Traveled (Crashes per MVMT) | | Capital Spending (Crashes per Million) | |
|---|---|---|---|---|---|---|---|---|---|
| | Total | Injury | PDO** | Total | Person | MVMT | Rate | Cost (M) | Rate |
| FY2014 | **214** | 70 | 141 | 3 | 3 | 6,143.3 | **0.035** | $422.7 | **0.51** |
| FY2015 | **267** | 100 | 162 | 5 | 5 | 6,296.4 | **0.042** | $547.3 | **0.49** |
| FY2016 | **327** | 103 | 220 | 4 | 4 | 6,504.0 | **0.050** | $684.4 | **0.48** |
| FY2017 | **283** | 86 | 197 | 0 | 0 | 6,562.0 | **0.043** | $564.9 | **0.50** |
| FY2018 | **173** | 50 | 122 | 1 | 1 | 6,600.8 | **0.026** | $527.4 | **0.33** |
| FY2019*** | **89** | 36 | 53 | 0 | 0 | 3,040.0 | **0.029** | $226.6 | **0.39** |
| **5 Yr Average** | **253** | **82** | **168** | **3** | **3** | **6,421.3** | **0.039** | **$549.3** | **0.46** |

* June 1st through May 31st

** Property Damage Only

*** June 1st through Oct 31st

# Why Pilot CV for Work Zone?

- Maintenance on board with Pilot – willing to test technology on maintenance vehicle
- Quick deployment
- Open communications among stakeholders
- Easy access to troubleshoot equipment throughout pilot
- Effective coordination of work zone vehicle operations and evaluation vehicle

# Connected Work Zone Pilot

# Connected Work Zone Pilot Overview

- Project Team
  - Gannett Fleming, Iteris, Information Logistics, Drive Engineering
- Project Objectives
  - Evaluate DSRC mobile (OBU) technology
  - Evaluate Vehicle data feed for alerts into Waze and TripTalk
  - Operate with "**No interaction needed from Operator**"
- Operational Scenarios
  - Stationary Work Zone
  - Mobile Work Zone

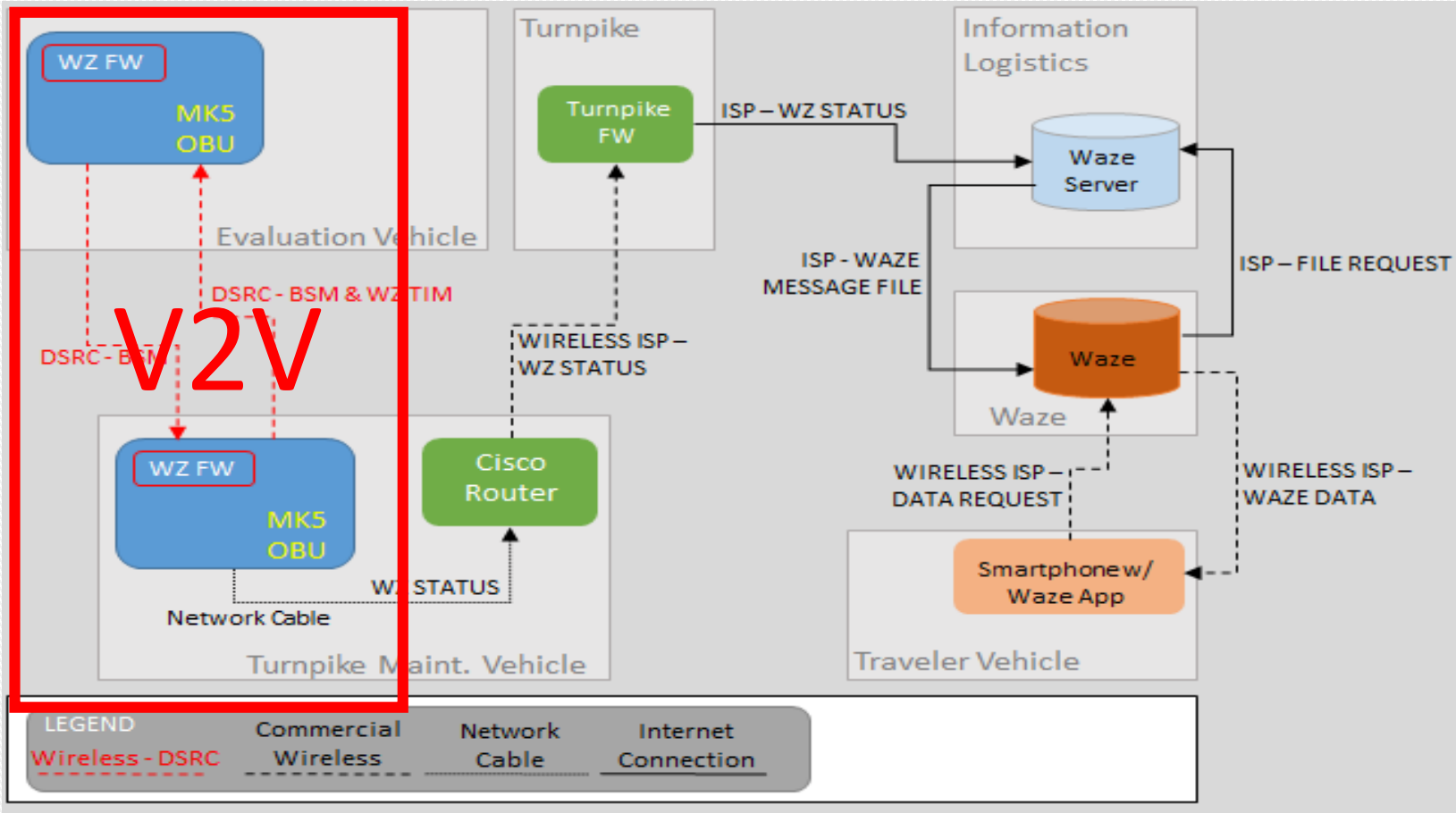
# Pilot Primary Tasks

- Develop Conops, Requirements, System Design, Evaluation Plan
- Software / Firmware development
- Waze / TripTalk Application Integrations
- Hardware procurement / Installation
- Integration and Testing
- Evaluation

# Evaluation Metrics

- What % of transmitted messages were received V2V, Waze & TripTalk?
- Distance from TMA that messages were disseminated V2V, Waze & TripTalk?
- Was messaging provided for relevant direction of travel?
- Message Latency?
- Number of vehicles equipped with DSRC capable devices on PTC that transmitted BSM?

# System Architecture



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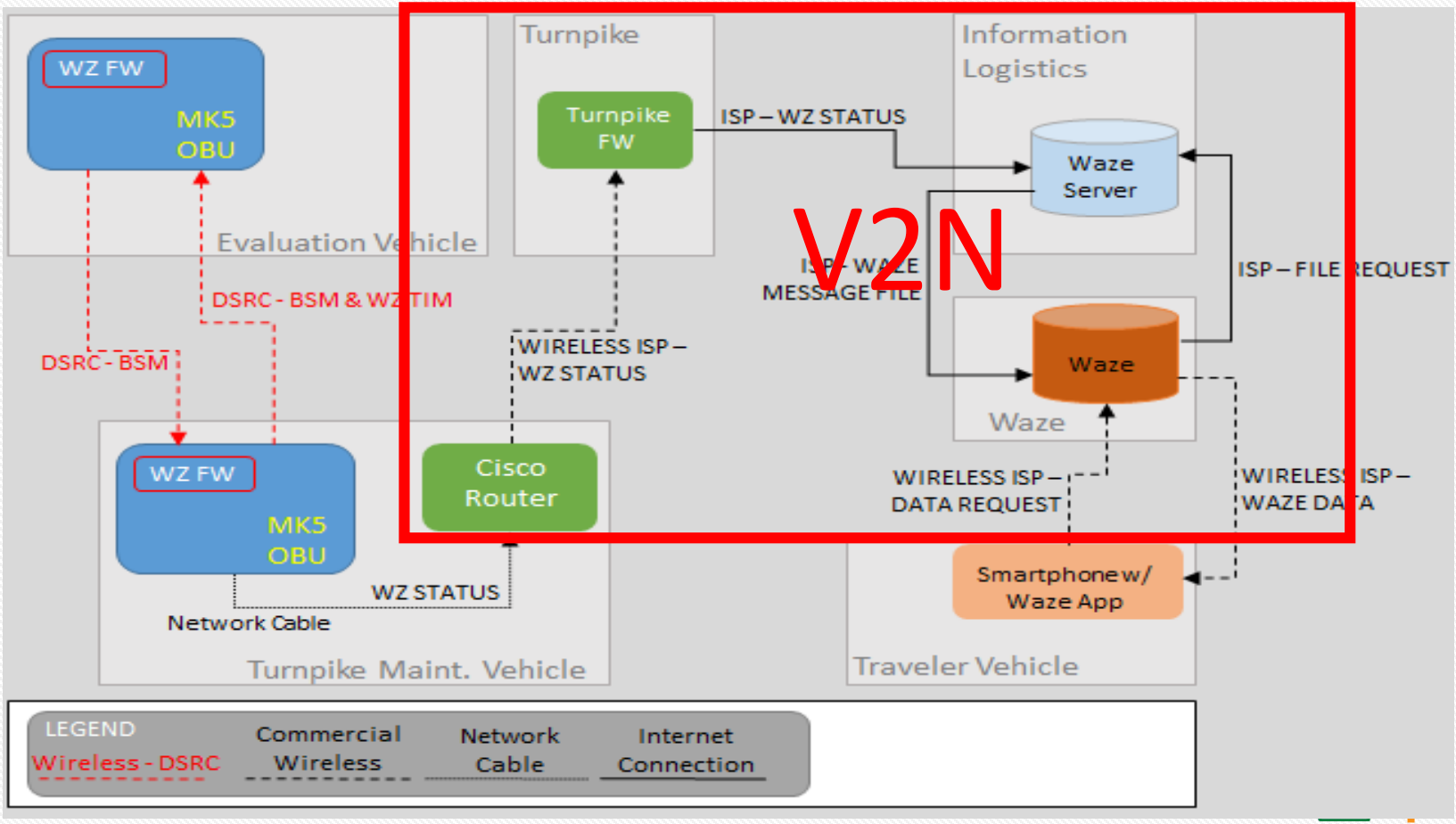

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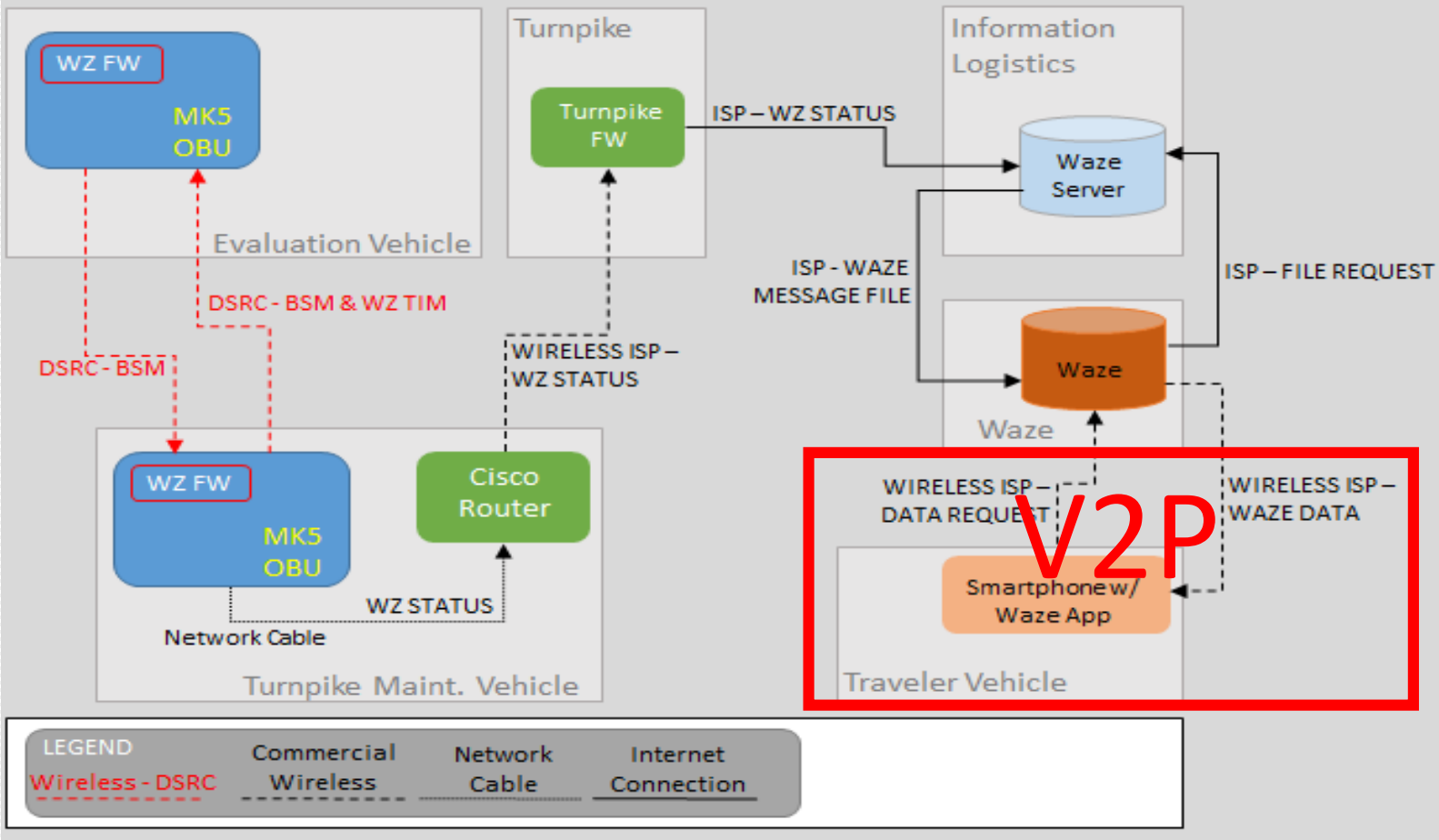


# CV WZ implementation, Evaluation, Lessons Learned

# Key Requirements

- OBU application is on at all times in maintenance zone
- OBU application sends simple messages when
  - Vehicle in preconfigured geofence of maintenance zone
  - Vehicle moving slowly or stopped
  - ~~Time during preconfigured construction schedule~~
- V2V Communication between maintenance vehicle and evaluation or OBU-equipped vehicle (via DSRC)
  - Implemented using Roadside Alert
- Communication to ILog for Waze via wireless ISP over Internet*
  - OBU application provides alert information to servers
  - Servers generate CIFS 2.0 message every 30 seconds
  - Servers terminate message with comm failure from OBU

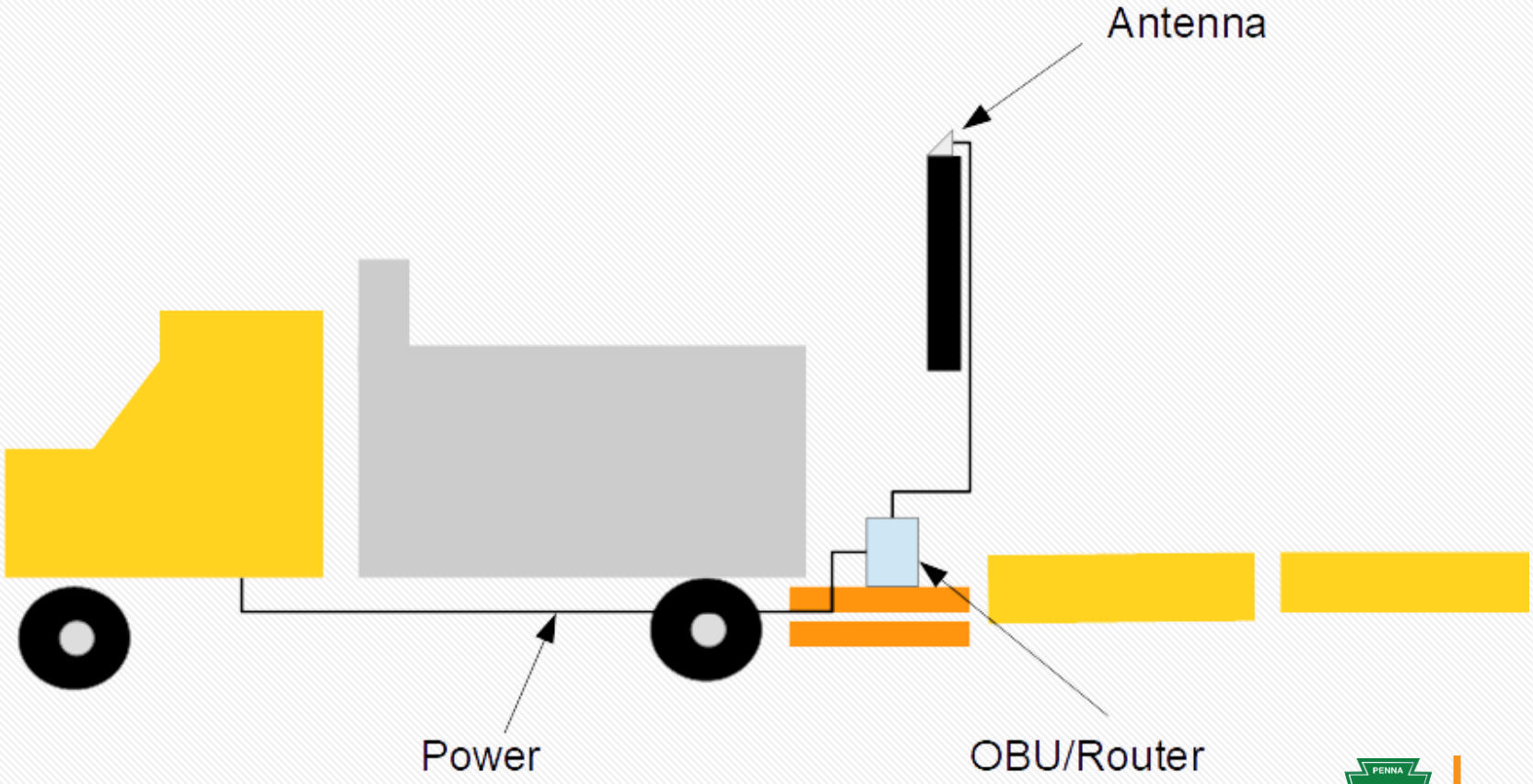
* Communication for Trip Talk App added

# Project Hardware

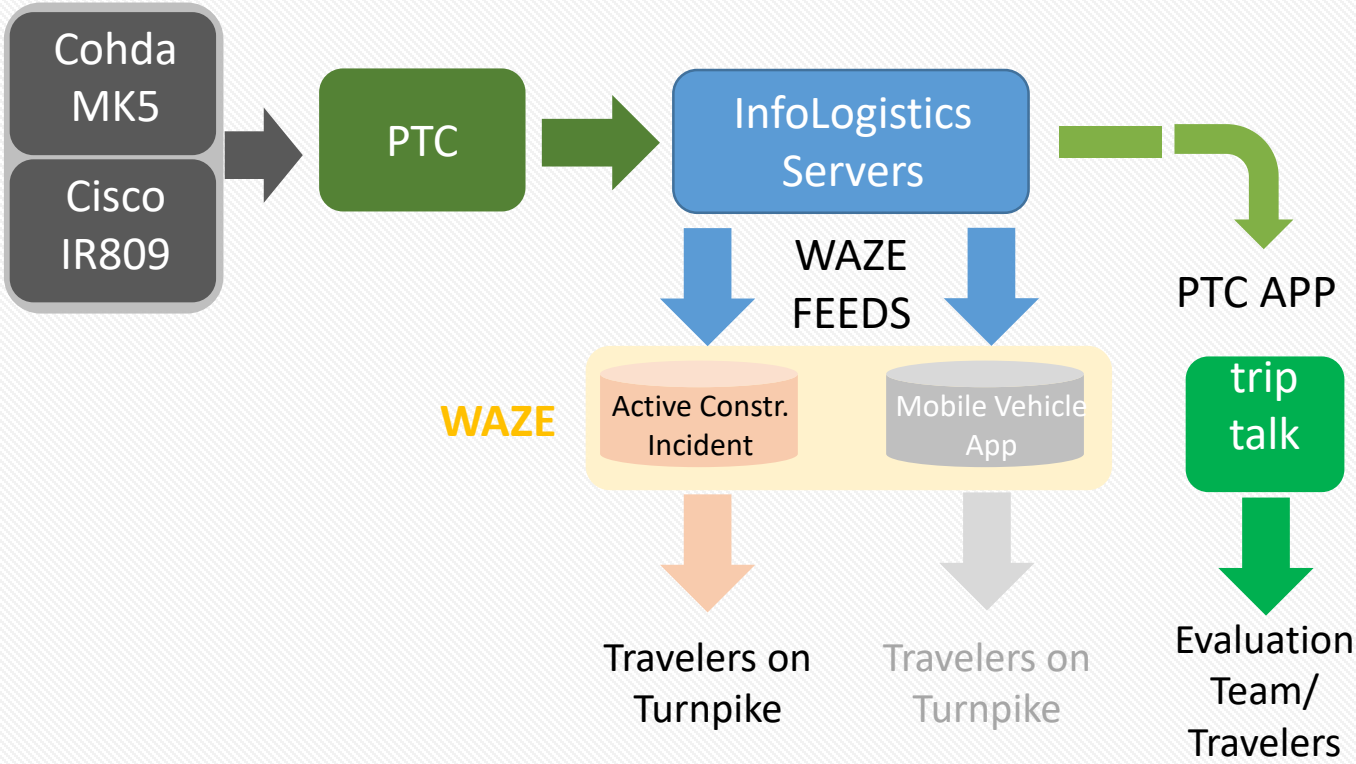


Enclosure Design/ Equipment Install by Gannet Fleming

# OBU Installation



# Task 4.3 Operational Evaluation (WAN feeds)



# Evaluation Hardware

# Project Status

- Initiated December 2017
- OBU and router installed on maintenance vehicle in June 2018
- OBU firmware last updated in August 2018
- System in operation during routine maintenance activities starting in August
- Notification via Waze incomplete
  - Alerts being retrieved by Waze servers
  - Alerts not displayed on Waze app or website map
- Evaluation of information display using mobile phone app using Trip Talk in place of Waze
  - Alerts successfully displayed on Turnpike's Trip Talk app

# Evaluation Metrics

- What % of transmitted messages were received V2V, Waze & TripTalk?
  - V2V - 100%
  - TripTalk - 83%
  - Waze - 0%
  - No false alarms
- Distance from TMA that messages were disseminated V2V, Waze & TripTalk?
  - V2V – 0.1 - 0.2 miles
  - TripTalk – 0.4 - 1.2 miles
  - Waze – N/A
- Was messaging provided for relevant direction of travel?
  - V2V – 100% for moving WZ, unreliable for stationary
  - TripTalk – >90%
  - Waze – N/A

# Evaluation Metrics (Cont.)

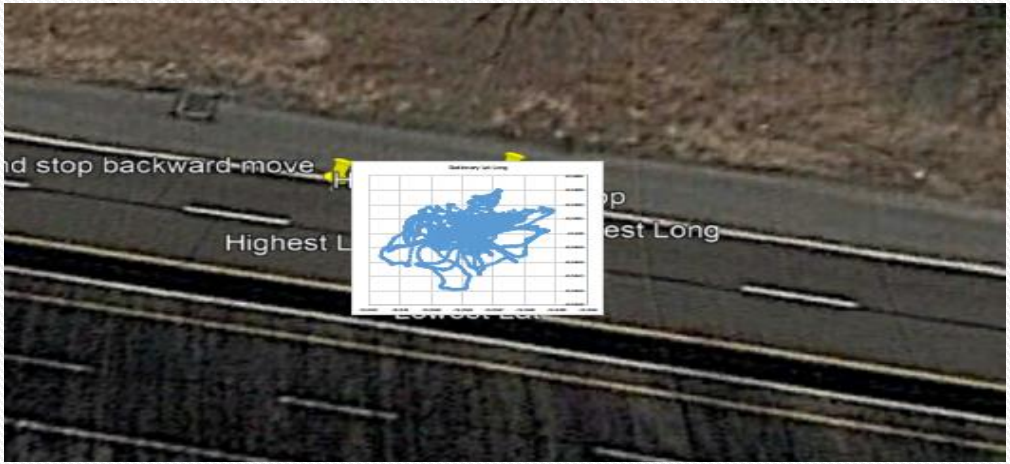
- Message Advance Warning?
  - V2V – ~15 seconds prior to encounter
  - TripTalk – ~60 seconds prior to encounter
  - Waze – N/A
- Number of vehicles equipped with DSRC capable devices on PTC that transmitted BSM?
  - 2 on Penn Turnpike in ~20 hours of TMA operation during evaluation
  - 2 additional off Penn Turnpike by evaluation vehicle en route

# Lessons Learned

- Initial implementation handles vast majority of work zone situations correctly
- CV-DSRC stable platform for providing near real-time moving vehicle/ work zone status
- CV-DSRC-based system reliably provides data for use by mobile phone travel apps
- CV-DSRC can be integrated with commonly used wireless gateway for wide area communications
- Cohda OBU powerful Linux computer
  - Capable of mapping applications not included in pilot

# Lessons Learned (Cont.)

- Installation approach (system on when ignition on) highly reliable
  - No resistance from operations
- GPS solutions not sufficiently reliable at lane level (as configured for this pilot)
  - GPS solution confidence may be able to determine when insufficiently accurate



# Lessons Learned (Cont.)

- Need to evaluate design trade-offs with regard to work crew intervention
  1. No intervention (this pilot)
     - More sophisticated logic required for some situations
       - Maintenance vehicle on overpass
       - Maintenance vehicle in nearby service area
       - Maintenance vehicle reversing to stop
  2. Crew/Driver Activation
     - Adds one more thing for crew to do
     - Less risk of errors due to omissions in programming

# Questions??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