



# Minnesota Autonomous Shuttle

NACV Summit

June 12, 2018



# Presentation Overview

- Project Overview
- Other CAV Projects and Policy Considerations



# Project Goals

## SNOW & ICE

Prepare autonomous vehicle industry for snow & ice conditions

## OPERATIONS

Identify challenges and strategies for safe operation of third party autonomous vehicles on MnDOT's transportation system

## MOBILITY

Prepare for improved mobility services through autonomous vehicles

## INFRASTRUCTURE

Identify the infrastructure that is needed to ensure safe operation of autonomous vehicles

## INFLUENCE

Increase Minnesota's visibility and influence on advancing autonomous & connected vehicles

## PARTNERSHIPS

Enhance partnerships between government and the autonomous vehicle industry

Public Engagement

# Project Timeline

Industry & Regulatory Environment Research  
(February 2017)



Project requirements & RFP development



Industry Outreach (April 2017)



RFP finalized & Advertised



Preferred Vendor Selected/Notice to Proceed  
(September 2017)

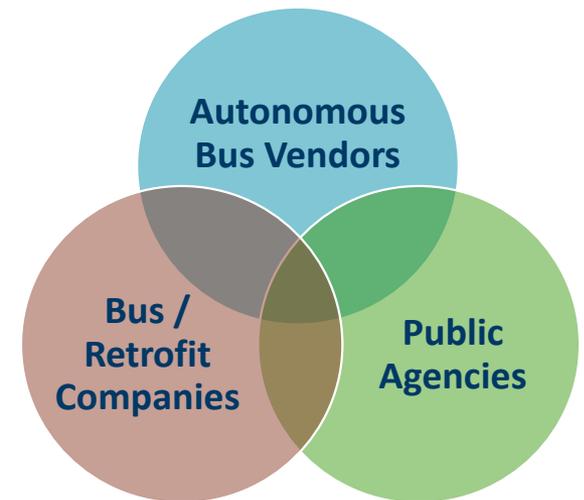
# Industry / Stakeholder Interest

Company
Navya
EasyMile
Local Motors
2getthere
Autonomous Solutions Inc. (ASI)
Romarc Corporation
Velodyne Lidar
New Flyer Industries
Gillig
Hyundai-Kia America Technical Center, Inc. (HATCI)
SB Drive
Yutong
Proterra
DOTs – Colorado, Connecticut
Transit Agencies – RTD (Denver), MVTA & DTA (MN)
Other – Mayo Clinic, FedEx, 3M, University of MN

## April 20 Industry Forum

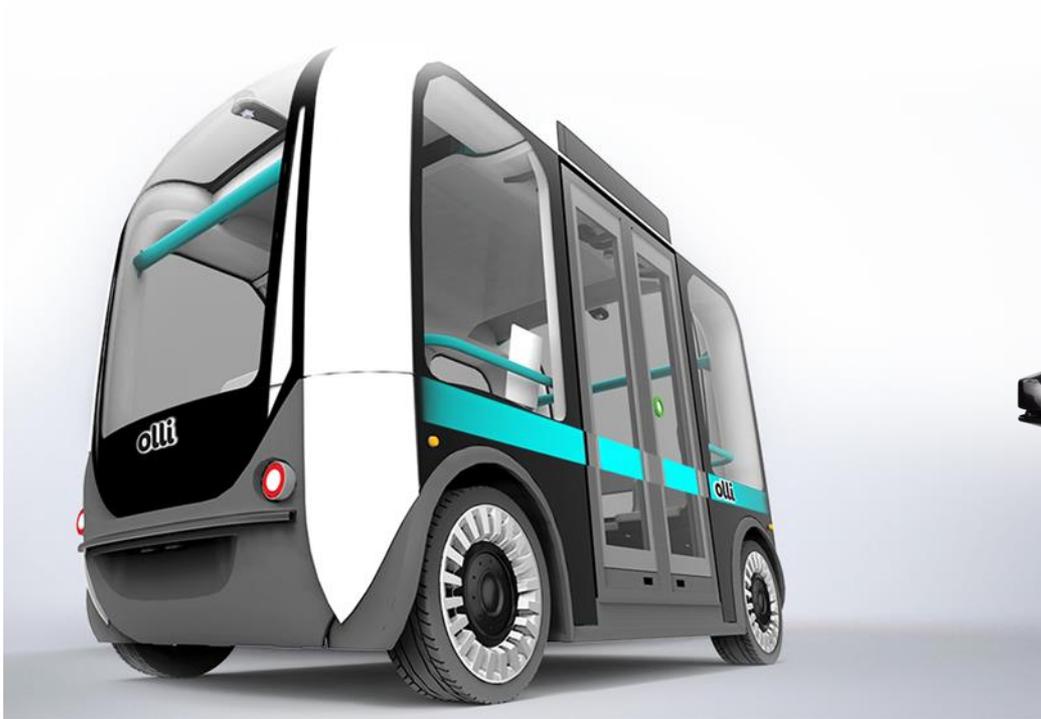
Vendor / Stakeholder Outreach

[www.dot.state.mn.us/autonomous/](http://www.dot.state.mn.us/autonomous/)



# Vendors Responding to RFP

Local Motors



EasyMile

# Project Partners



# About the Easy Mile EZ10 Shuttle



Criteria	EasyMile EZ10 Shuttle
Capacity	12
Speed	Avg. 10-15 mph, up to 25 mph
SAE Level of Autonomy (0-5)	4
Obstacle Detection	Laser (LiDAR)
Route Setup	Pre-mapped/pre-programmed
Navigation	GPS/LiDAR
Accessibility	Wheelchair ramp

# Project Phases

## Phase 1

- Testing at MnROAD

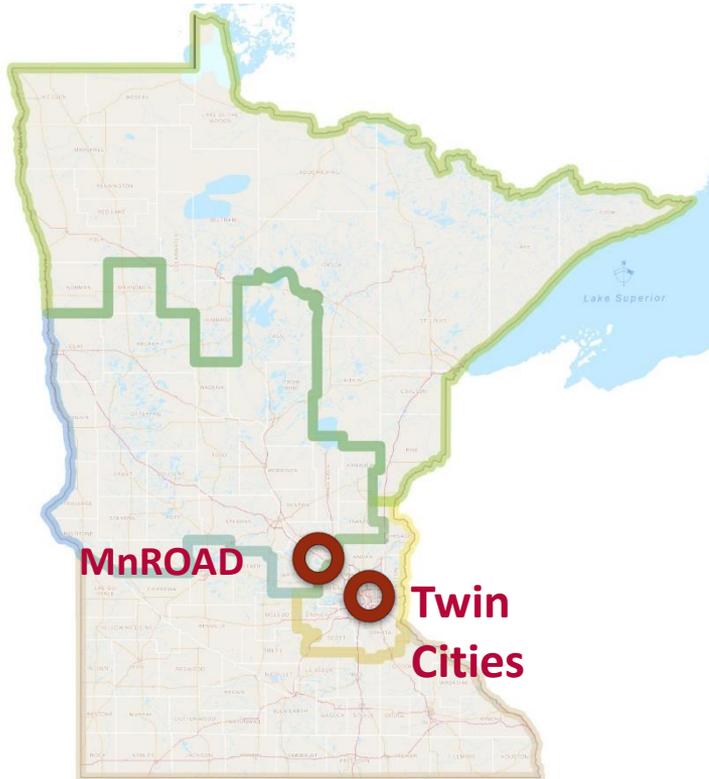
## Phase 2

- Operation during Super Bowl week
- Open to the public

## Phase 3

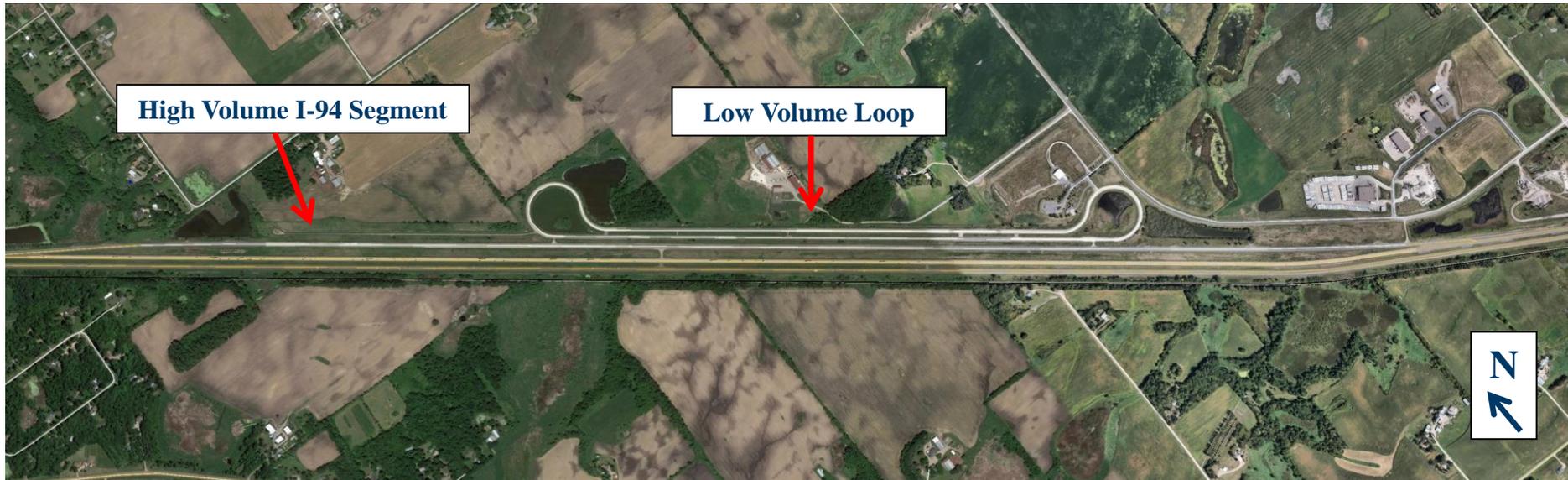
- Additional tests/demonstrations
- Investigating public & private partnerships for demonstrating in an operational setting

# Phase I – MnROAD Testing



# Controlled Test Site

## Minnesota DOT MnROAD Facility

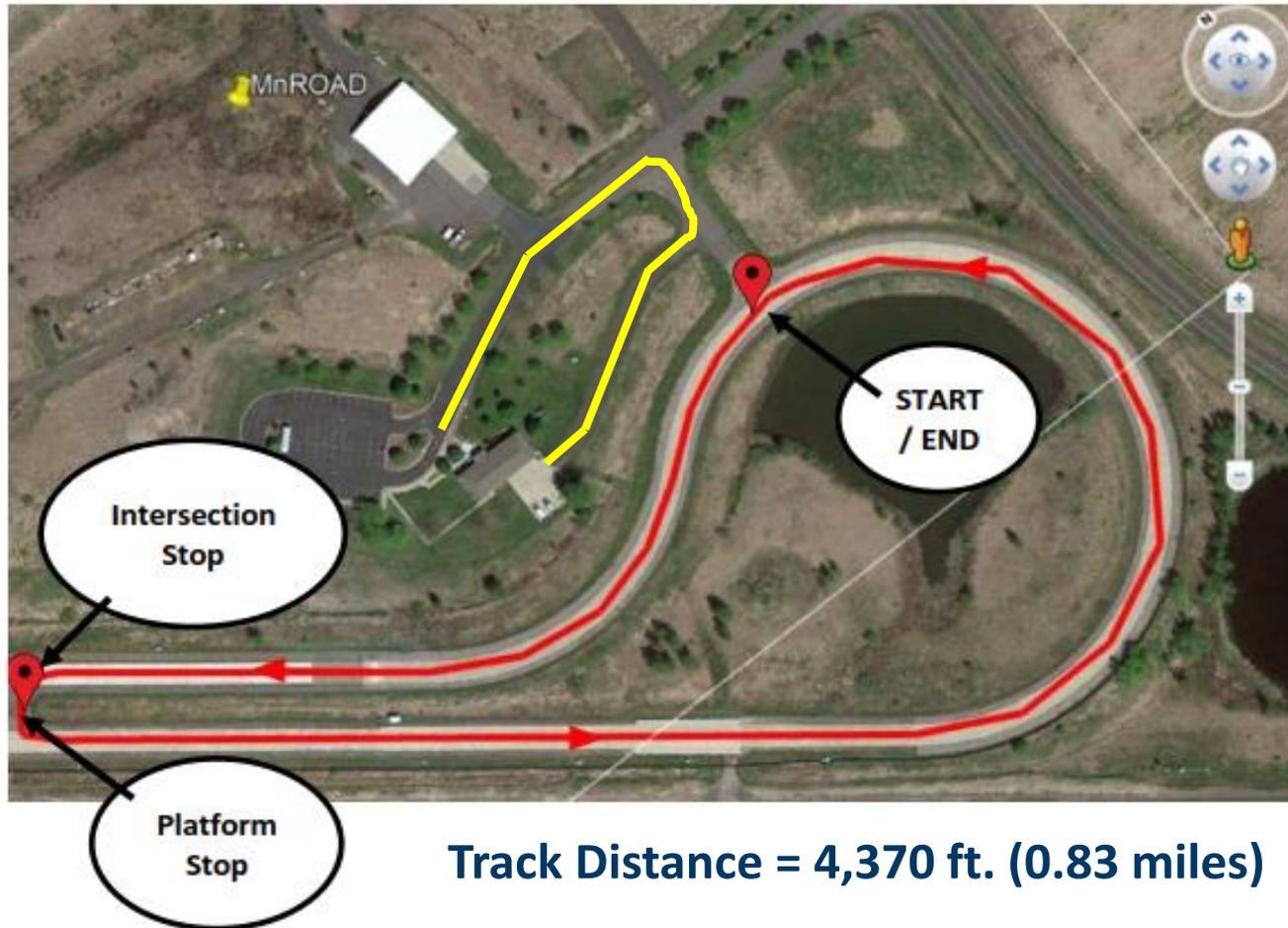


- MnDOT owned and operated
- Low and high speed testing available (30 – 70 MPH)
- Closed loop = 2.5 miles; I-94 high speed segment = 3.0 miles
- Enabling environment, easily accessible and readily available
- Ability to create varying test conditions
- MnDOT designated AV proving ground site

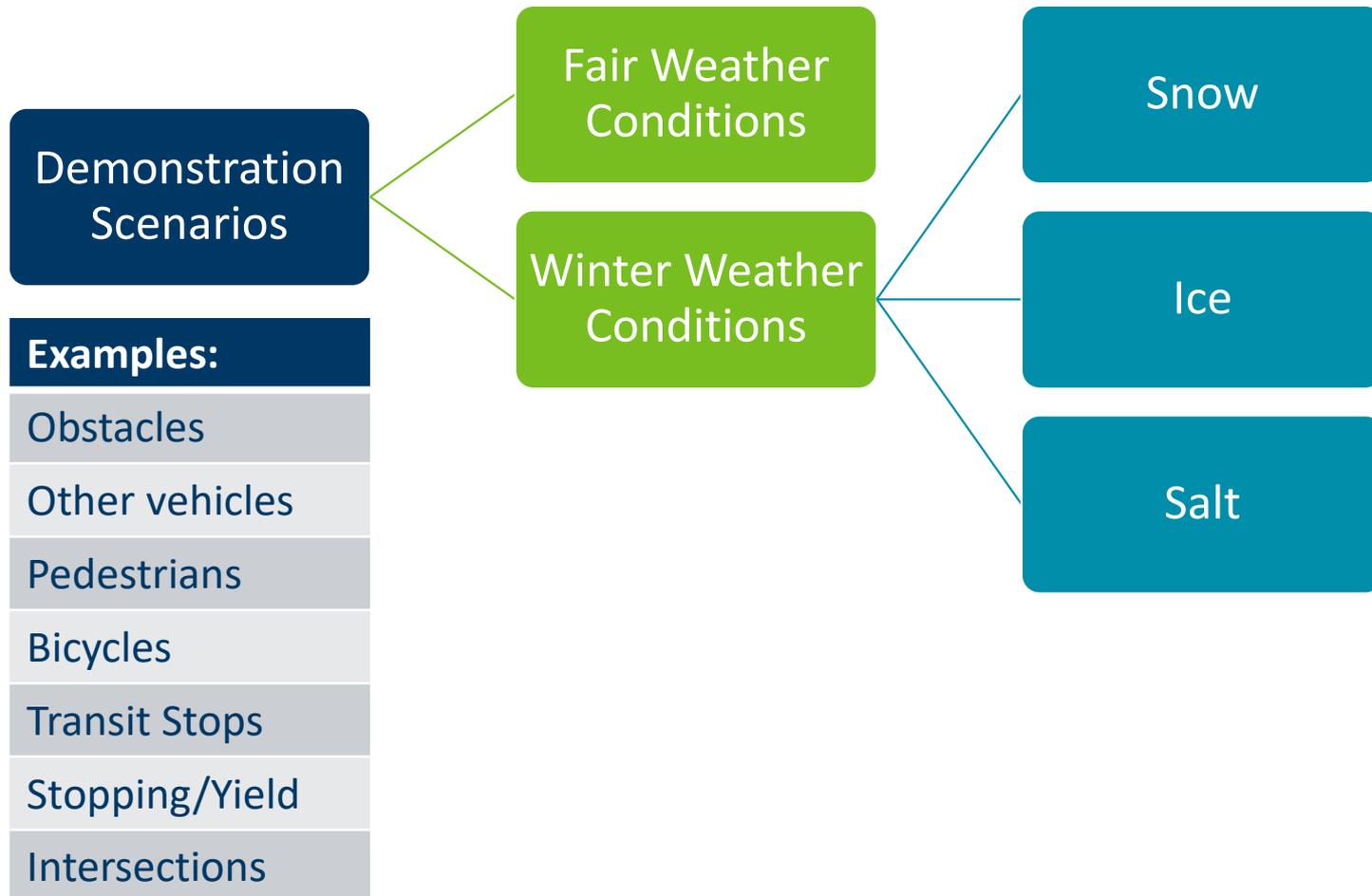
# Demonstration Plan

## Testing Scenarios, Schedule & Responsibilities

- **Clear Weather & Winter Weather - Under Various Conditions**



# Demonstration Concepts



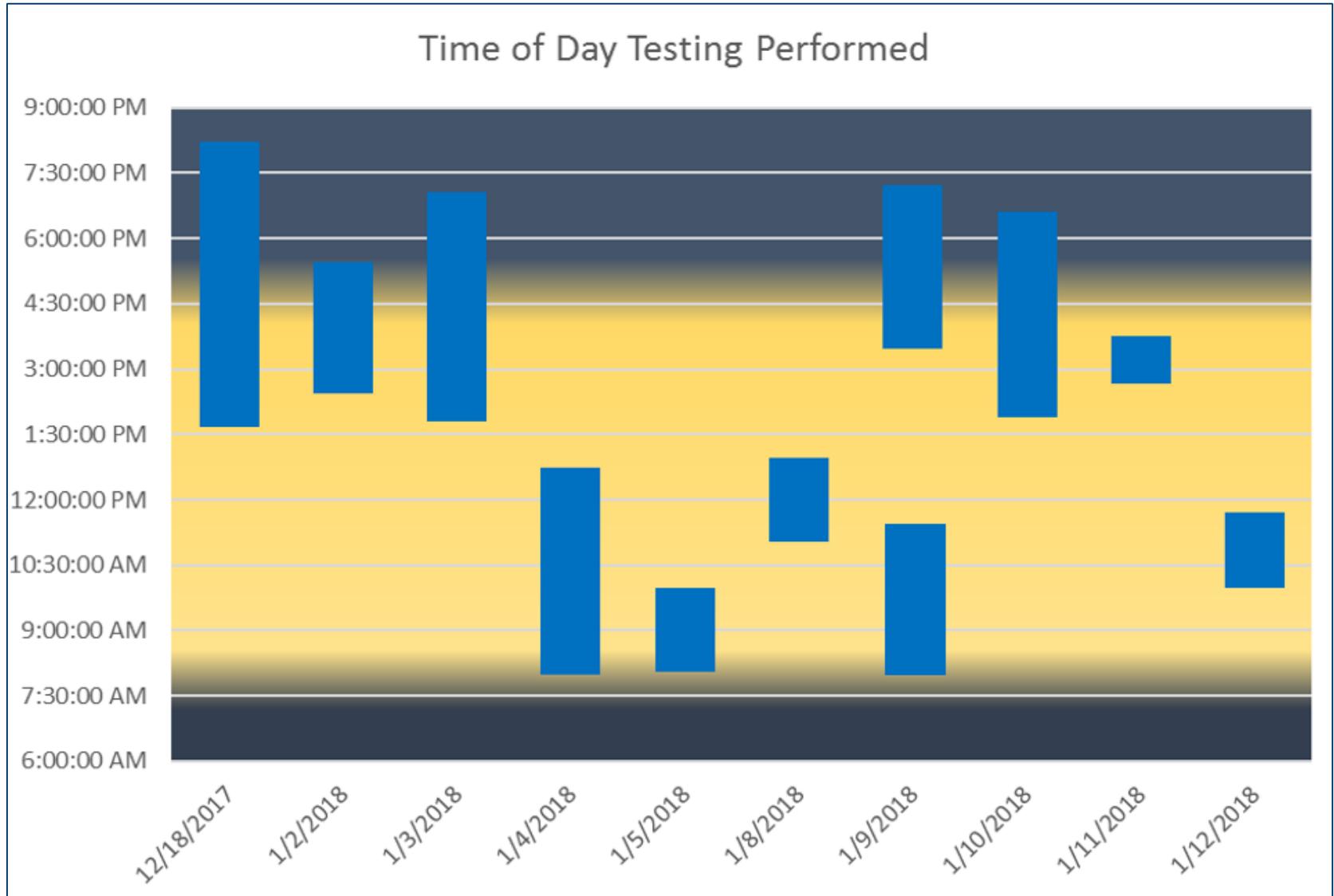


# MnROAD Infrastructure

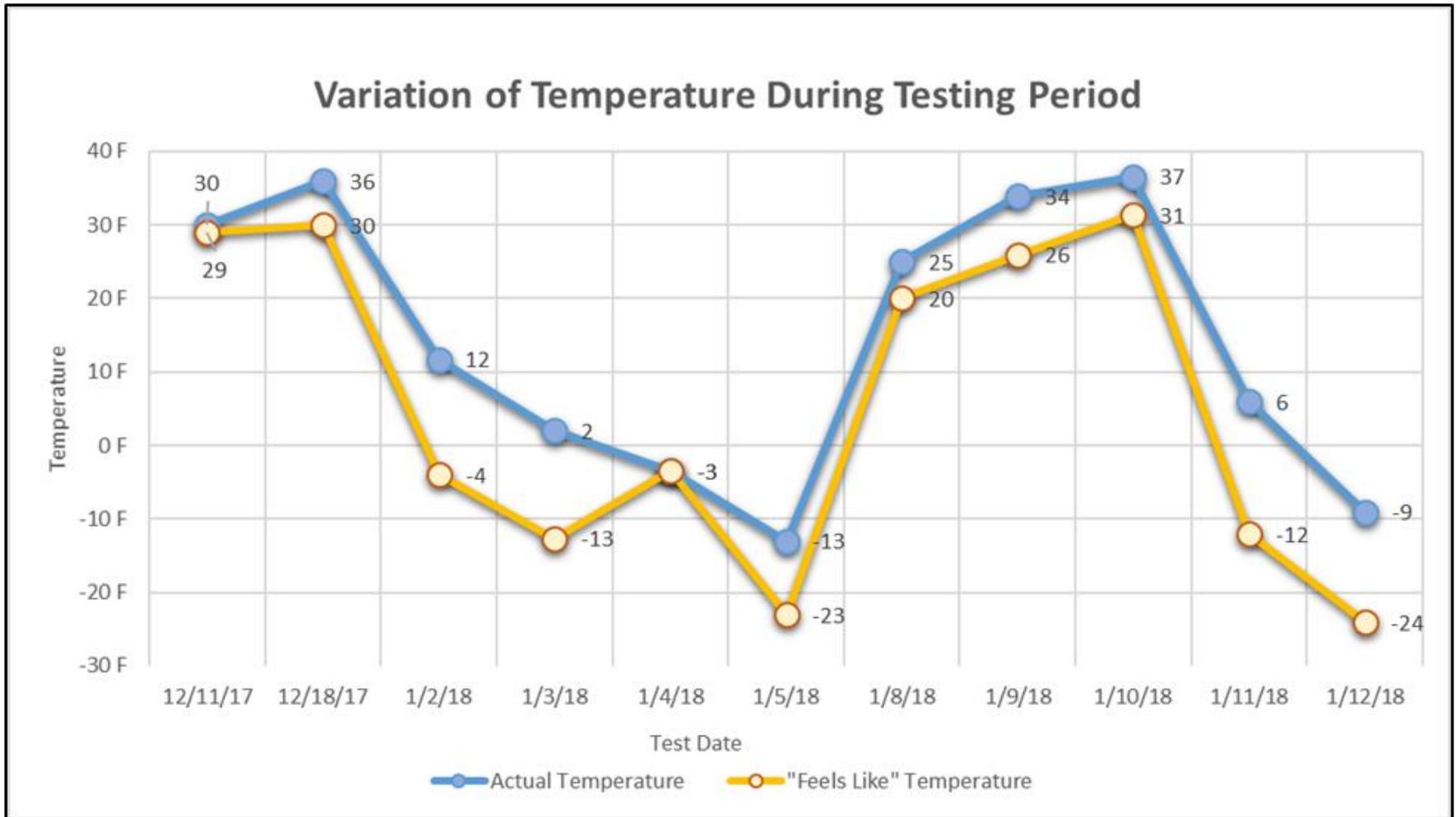




# Observed Sunlight Graph



# Temperature



# Uncontrolled Testing Conditions



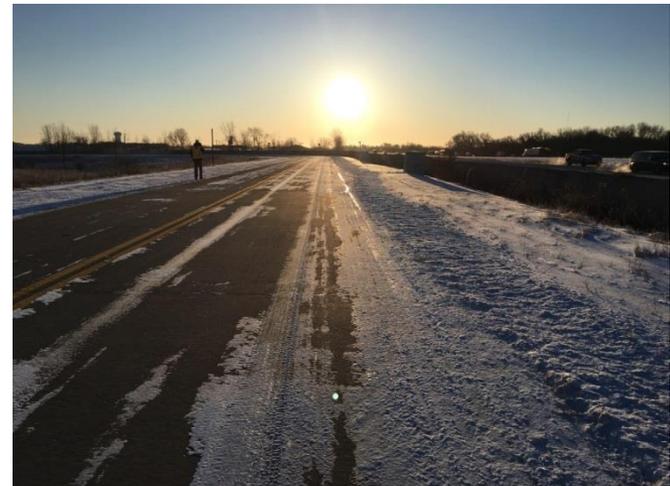
**Bare Pavement**



**Light Misty Rain / Edge of Snow**



**Mostly Bare Pavement**



**Compacted Snow / Icy Spots**

# Uncontrolled Testing Conditions



**Trace - 1 Inch Fresh Snow Cover**



**Loose Snow**



**Low Visibility**



**Blowing / Drifting Snow**

# Controlled Testing Conditions



**Ice for Wheel Path**



**Ice Across Lane**



**Ice at Start / Stop**



**Ice near Intersection**

# Controlled Testing Conditions



**Road Salt**



**Ice**



**Made Snow Trace – 6 Inches**



**Made 3 – 4 Inches of Slush**

# Findings – Bare Pavement / Clear Weather



- Performed Well
- Solid Localization
- Able to Navigate Stops, Starts, Turns, Curves, Intersections
- Good Cars, Peds, Bikes & Obstructions Interaction
- Some Emergency Stops / Slowdowns

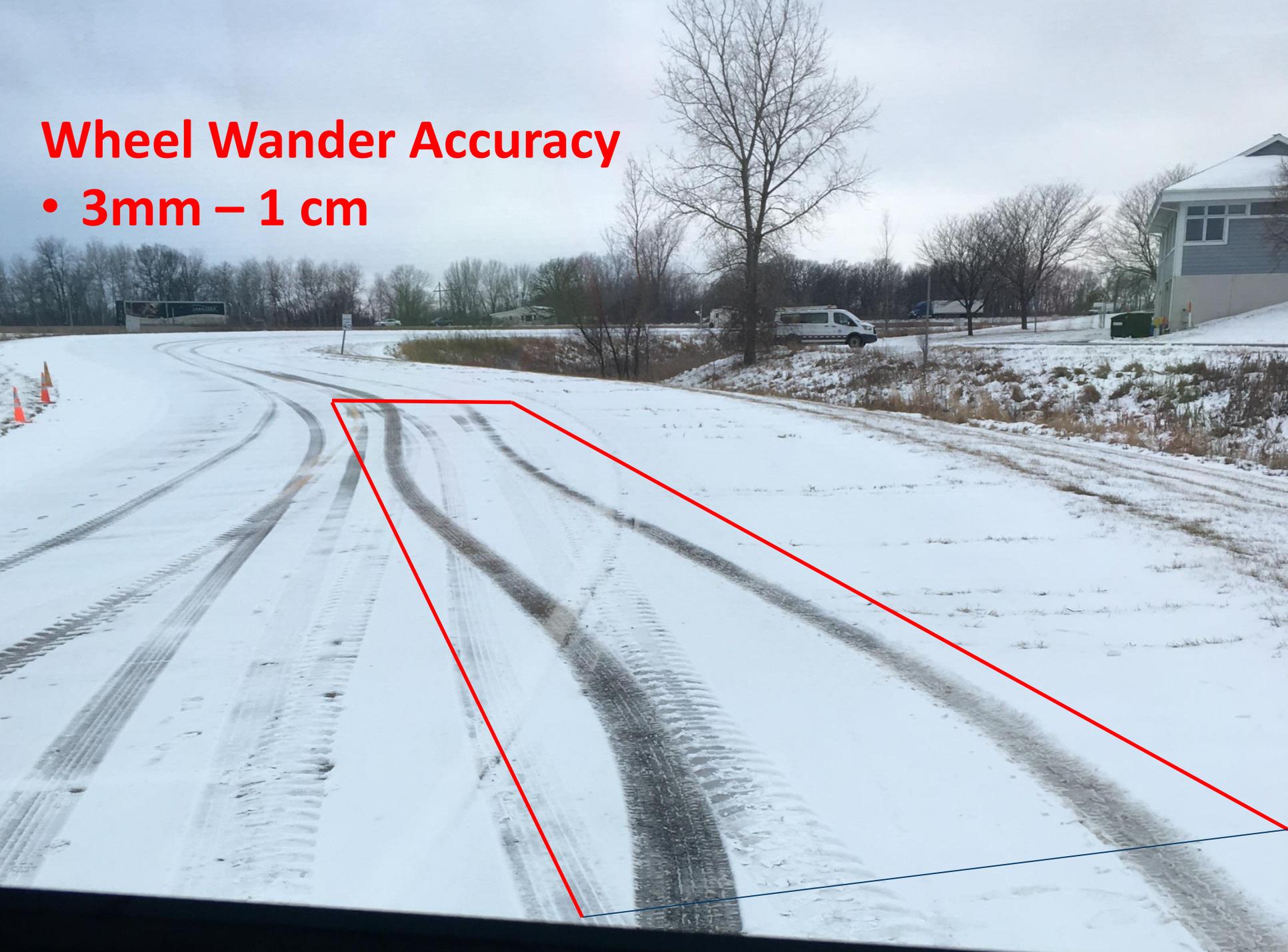
# Findings – 1 Inch Fresh Snow



- Calm Wind / Low 30s
- Performed Well - Similar to Bare Pavement
- Some Emergency Stops / Slowdowns
- Nice Interaction with Work Zone Barrel Obstructions
- Wheel Wander Observations

# Wheel Wander Accuracy

- 3mm – 1 cm



# Interaction with Other Cars



# Bus & Car Intersection Interaction



**Stop Impact from Car Creep = 5.6 Feet  
(Bumper to Bumper)**

# Interaction with Other Cars – Exhaust?



# Interaction with Bicycles and Pedestrians



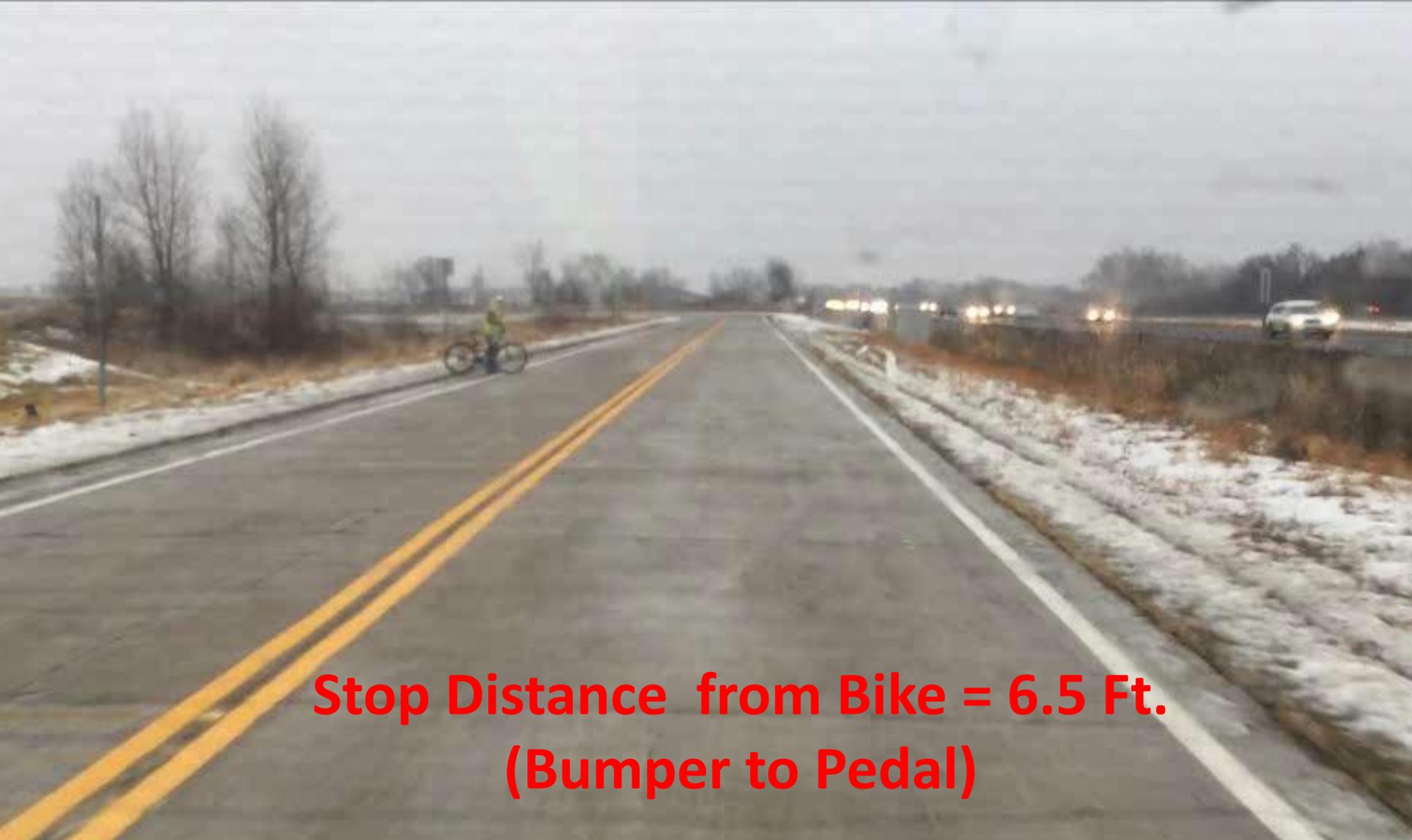
# Interaction with Pedestrians

**More conservative with higher speeds**



**Front Stop Distance = 5.3 – 6.6 Ft. (Bumper to Shins)**  
**Side of Bus = 1.6 – 1.8 Ft. (off Wheel Path)**

# Interaction with Bicycles



**Stop Distance from Bike = 6.5 Ft.  
(Bumper to Pedal)**



**Bus Performed Well in Ice**



**Snow Accumulation in Sensor Housing**

# Findings – Compacted, Loose & Blowing Snow



- Compacted Snow – Slippage and Localization Issues (Greater with Higher or Variable Speeds)
- Loose & Blowing Snow – Became Obstructions
- Plowed Road - Reduced Blowing Snow but Increased Slippage
- Cold Temps & Compacted Snow Increased Slippage

# Road Salt







**Made Snow: Trace to > 5 Inches**  
**Made Slush up to 3 Inches**  
**Coverage = 500+ Feet**



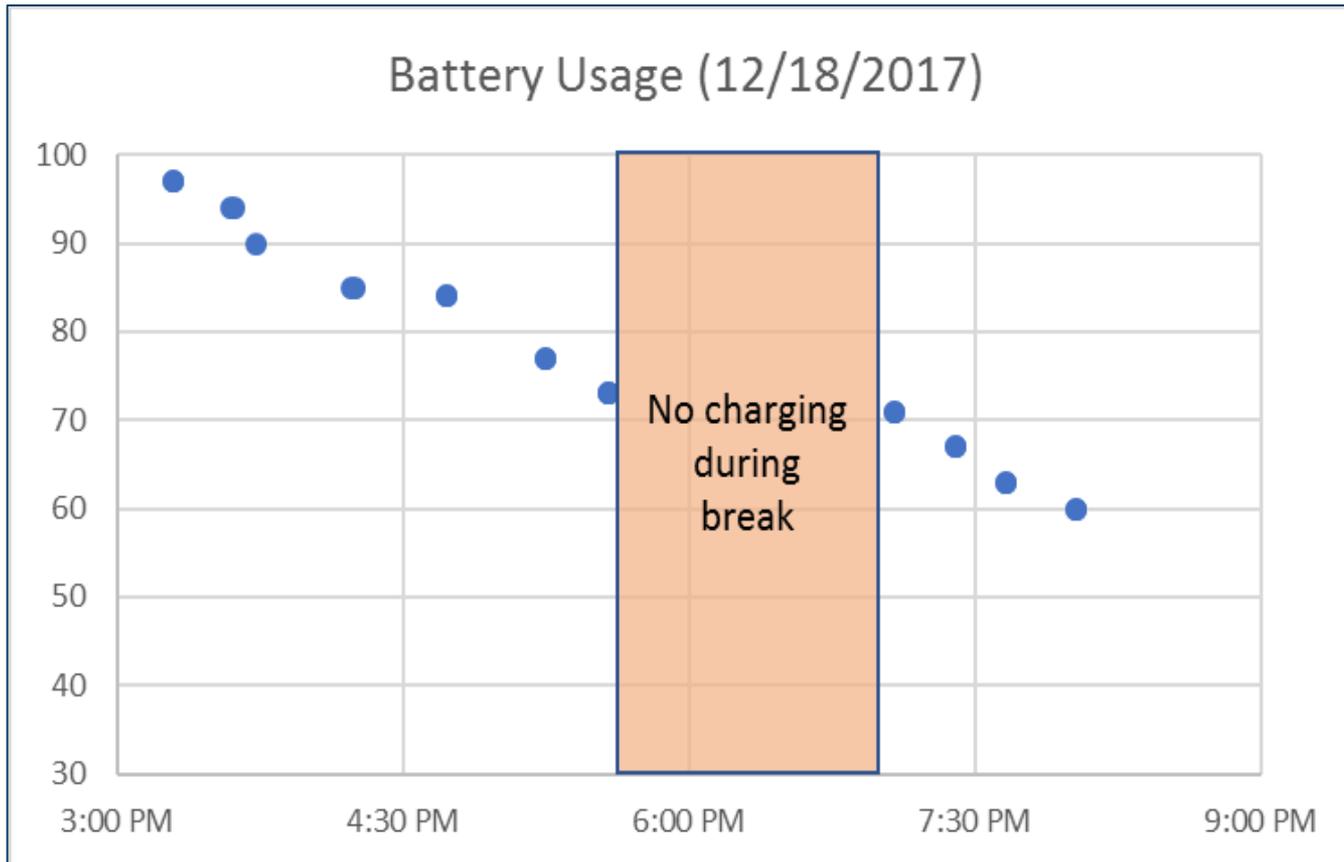
# Snow Cloud



# Snow Cloud

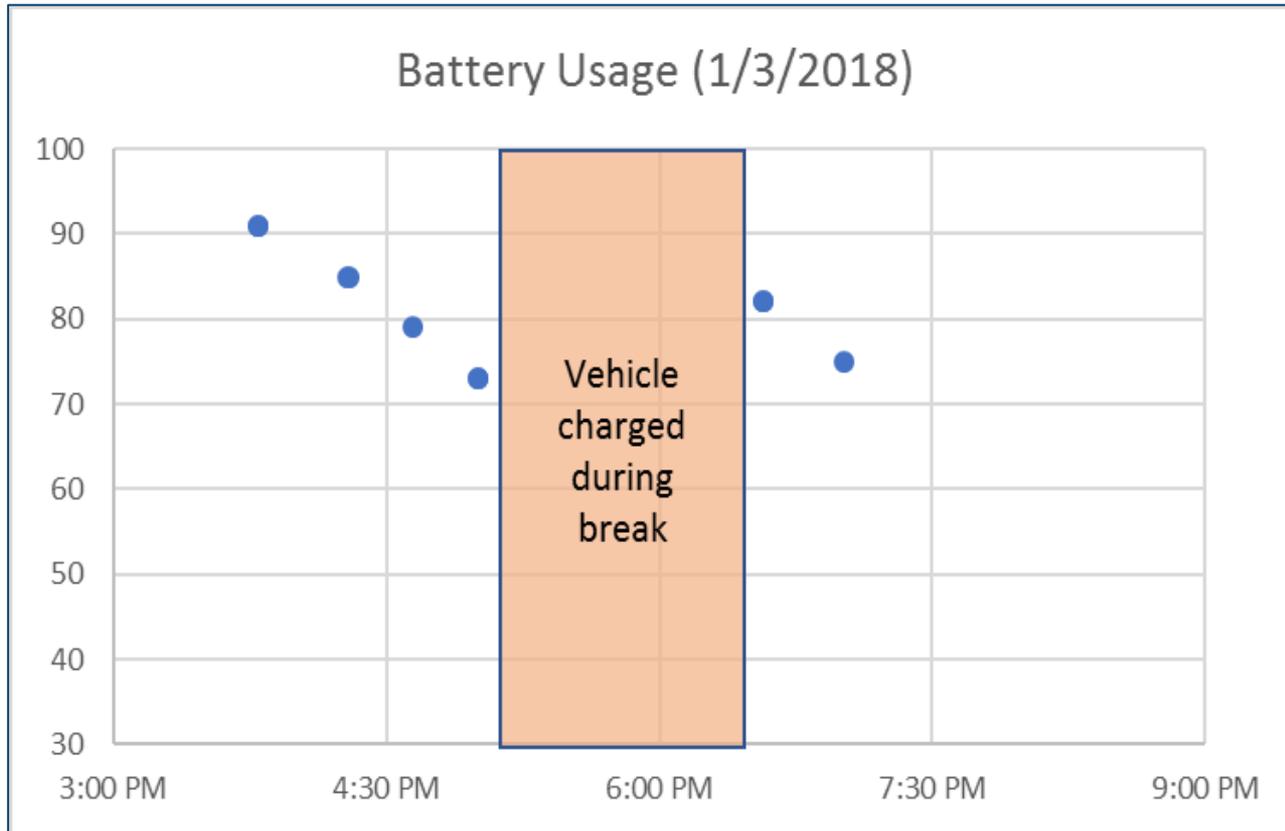


# Battery Usage – Mild Weather



Dec. 18<sup>th</sup>, 2017 Battery Charge Readings  
Start Temp.: 36° F ; Wind: S 7 mph

# Battery Usage – Cold Weather



Jan. 3<sup>rd</sup>, 2018 Battery Charge Readings

Start Temp.: 3° F; (-13° F windchill); Wind: WNW 11 mph

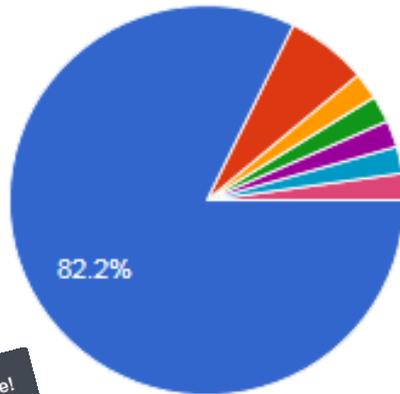
# Downtown Minneapolis - Nicollet Mall Demo



# Downtown Minneapolis- Public Demonstrations

Are you looking forward to having driverless vehicles operate on all roadways in the future?

45 responses



- Yes
- No
- Possibly, if all the bugs can be worked out.
- Unsure about it
- Need own laned
- Some. Not all.
- Not sure if the transition with some driverless and others not is safe



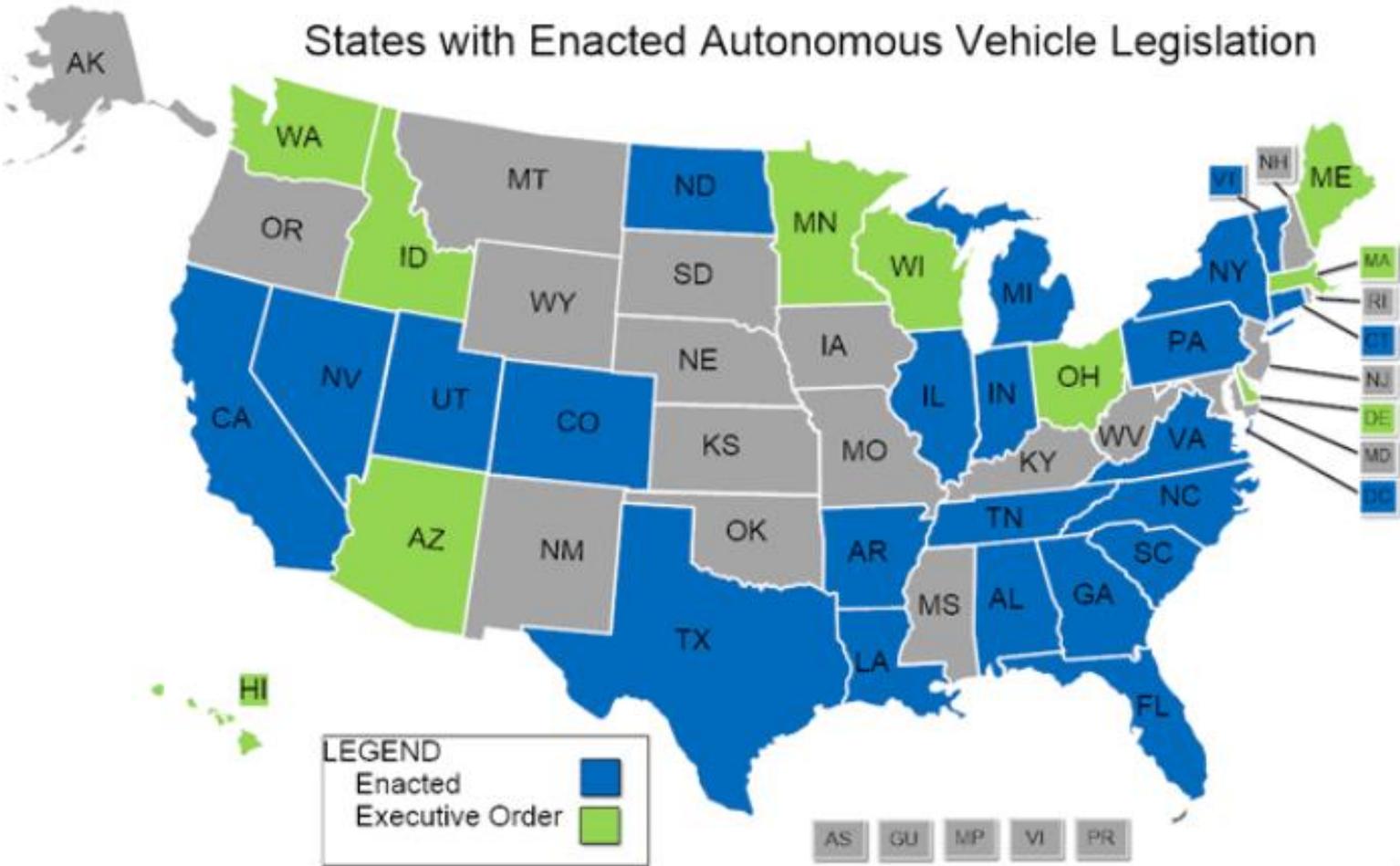
# Next Steps for CAV In Minnesota

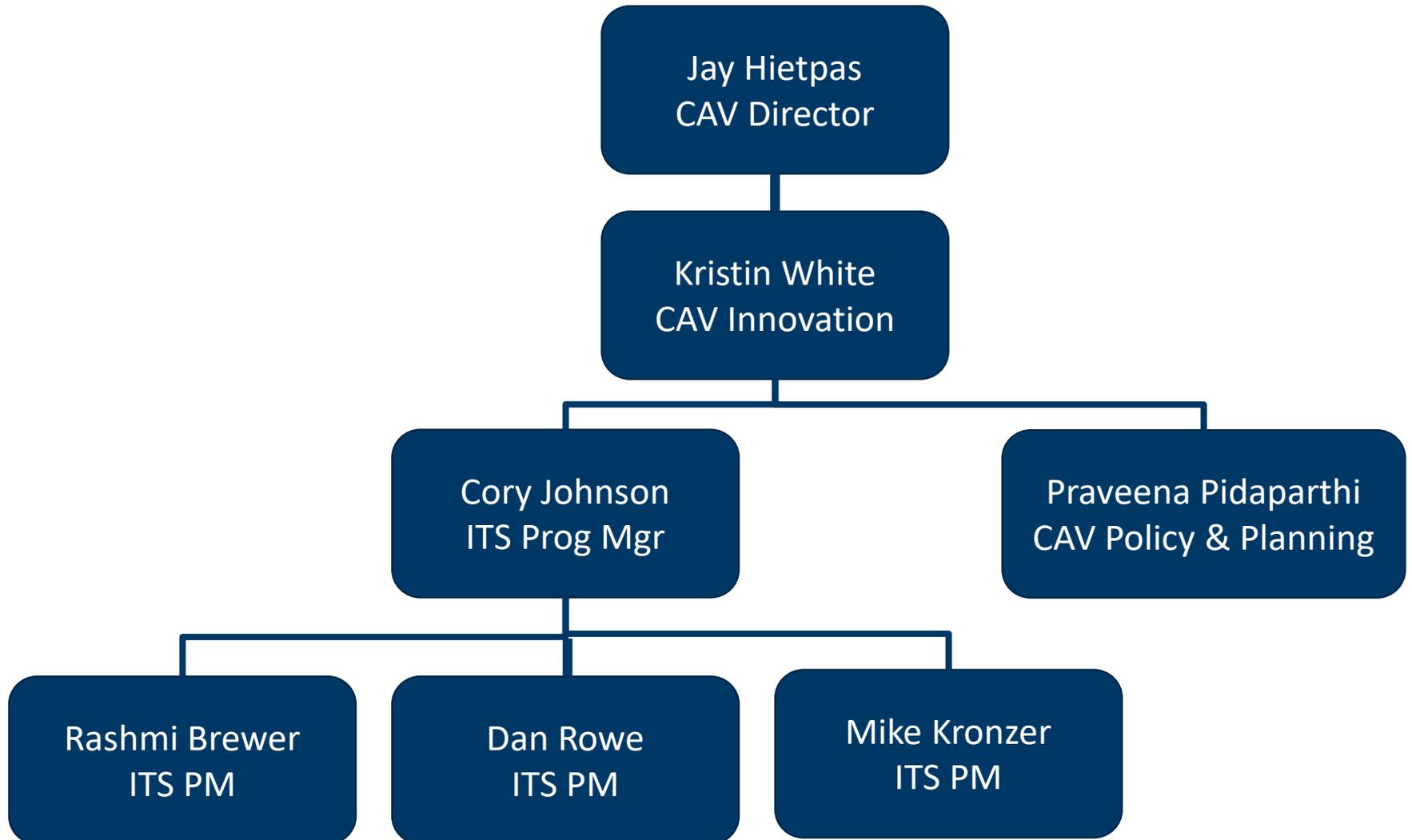


# MnDOT CAV Strategic Vision

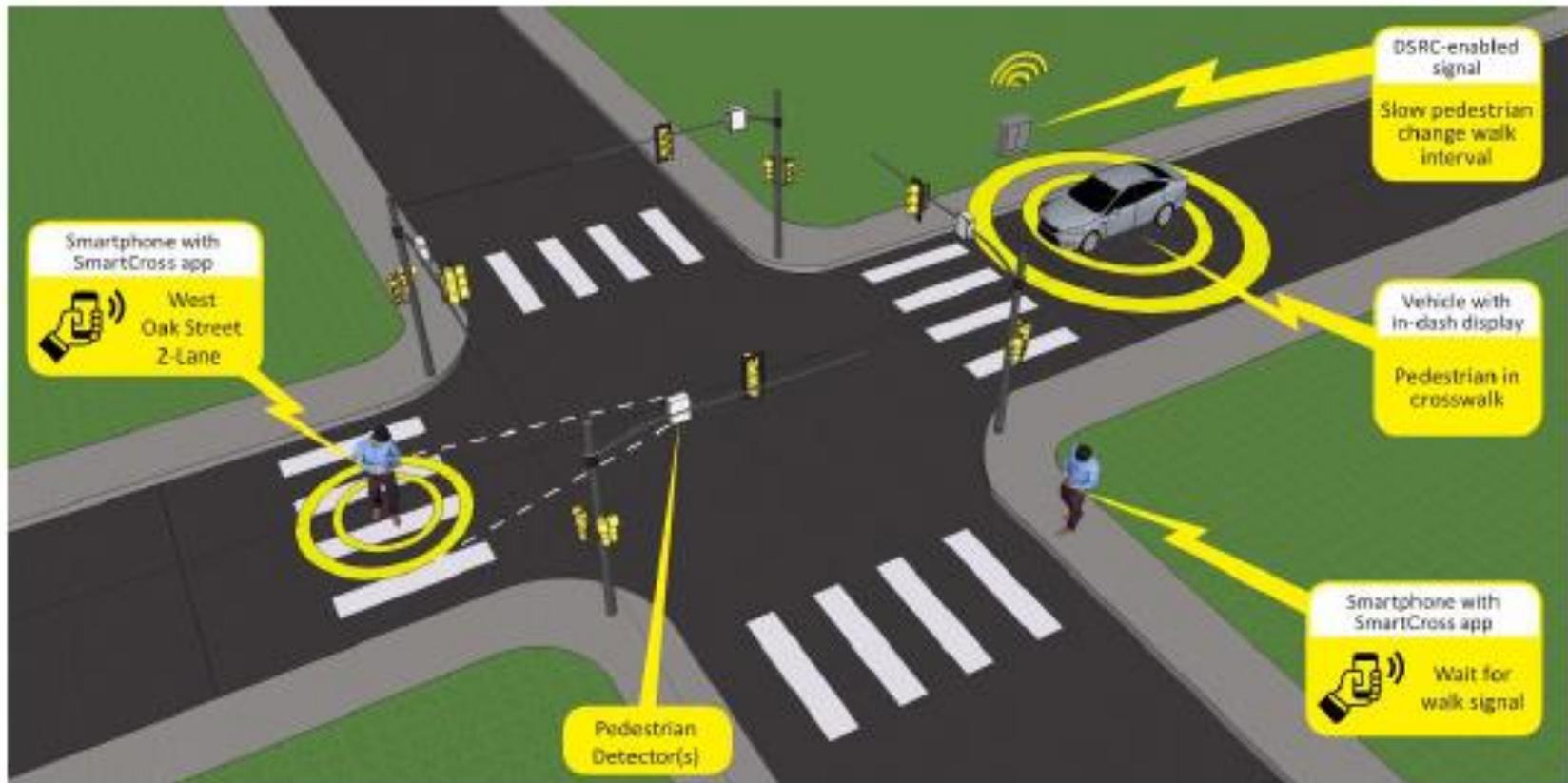


# National Items





# SPaT Challenge



# Minnesota Connected Vehicle Corridor



# Smart Corridor Concepts

- Secure Signal Phasing and Timing (SPaT)
- Vehicle – Pedestrian Conflict Warning System
- Snow Plow Signal Priority
- Data Management
  - Basic Safety Messages (in from vehicles)
  - Traffic Signal Data (our to third party vendors)
- Mobile Work Zone

# Other Concepts Being Considered

- Automated Truck at MnROAD Site
- Final Four Demonstration
- Truck Platoon Demonstration
- Innovative Ideas Funding
- Automated Truck Mounted Attenuator



# Questions & Answers

## Thank You!

