Minnesota Autonomous Shuttle

Alaska Forum on Autonomous Vehicles

June 8, 2018

DEPARTMENT OF TRANSPORTATION

WSB

AECOM

3M

Video

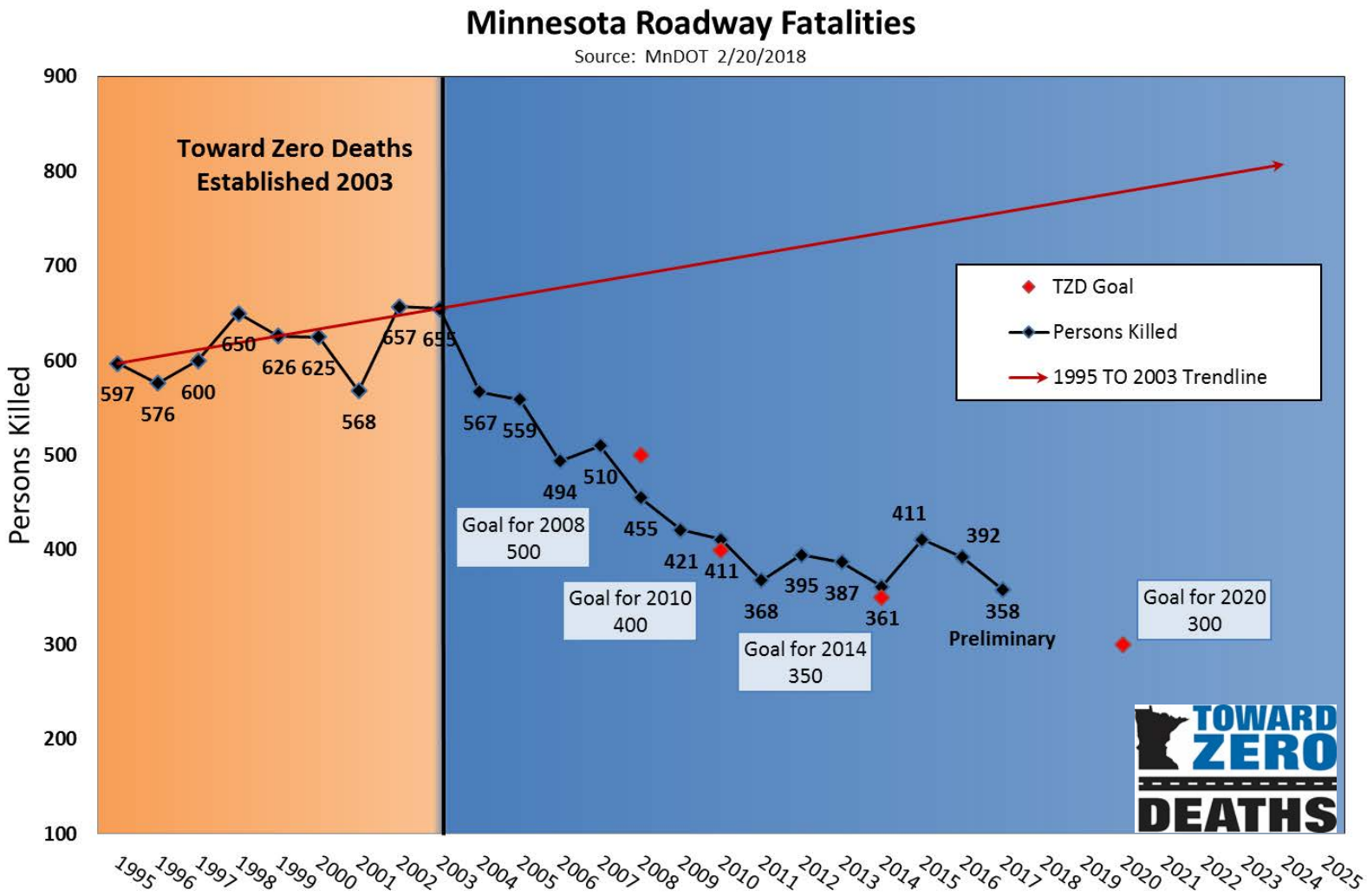
Presentation Overview

- Policy Items in Minnesota
- Why this is important to us
- Project Overview
- Other CAV Projects

Minnesota

- 1/8 Size of Alaska
- Population 5.4 Million
- 139,000 Miles of Road
  - MnDOT: 12,000
  - County: 45,000
  - City: 22,000
  - Township: 60,000

What is the Impact to Minnesota?



What are the Challenges?

Snow / Ice

Salt

Other Challenges

- We are not CA or MI
- What is real, and not real?
- Who do I partner with?
- How much do I invest?
- Timelines

Other Impacts

Parking Impacts

Freight

Cyber Security

Pavement Markings

Geometric Design

Licensing Laws

Bridge Loads

Smart Signs

Pavement Impacts

Traffic Operations

Revenue

Staffing

Mixed Traffic (AV & Non-AV)

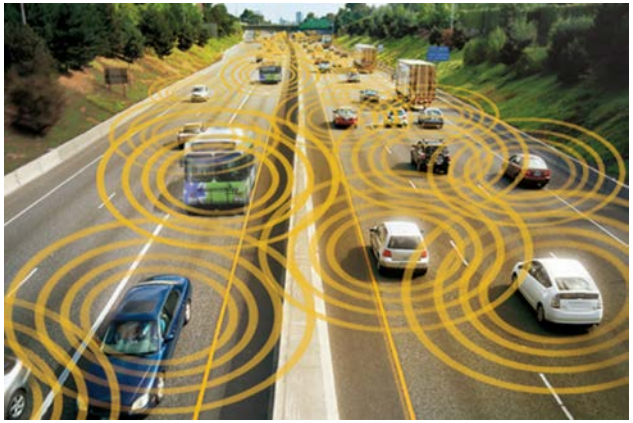
Land Use / Planning

Legal, or Not Legal?

- Driver: *Every Person who drives or is in actual physical control of a vehicle*

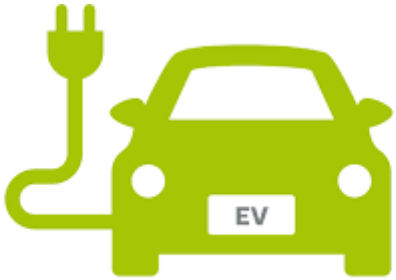
- Person: *Every natural person, firm, co-partnership, association, or corporation*

Items Being Considered



Automated & Connected Vehicles

Truck Platooning



Electric Vehicles

Mobility as a Service (MAAS)

Automated Delivery Services

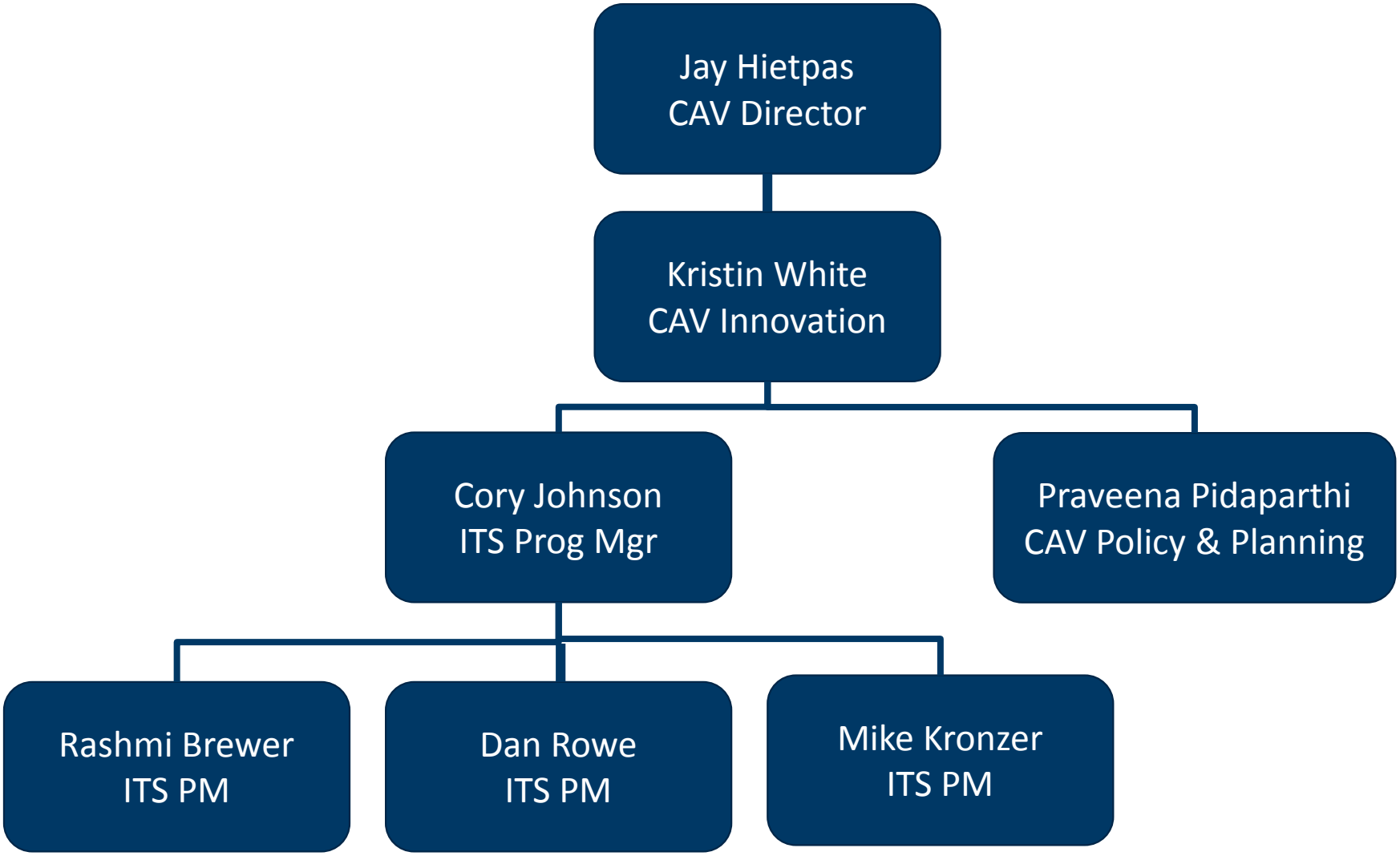
Are We Ready?????

1. **Are U.S. drivers comfortable with the idea of riding in a self-driving car?**

2. **Are U.S. drivers comfortable with the idea of sharing the road with a self-driving car?**

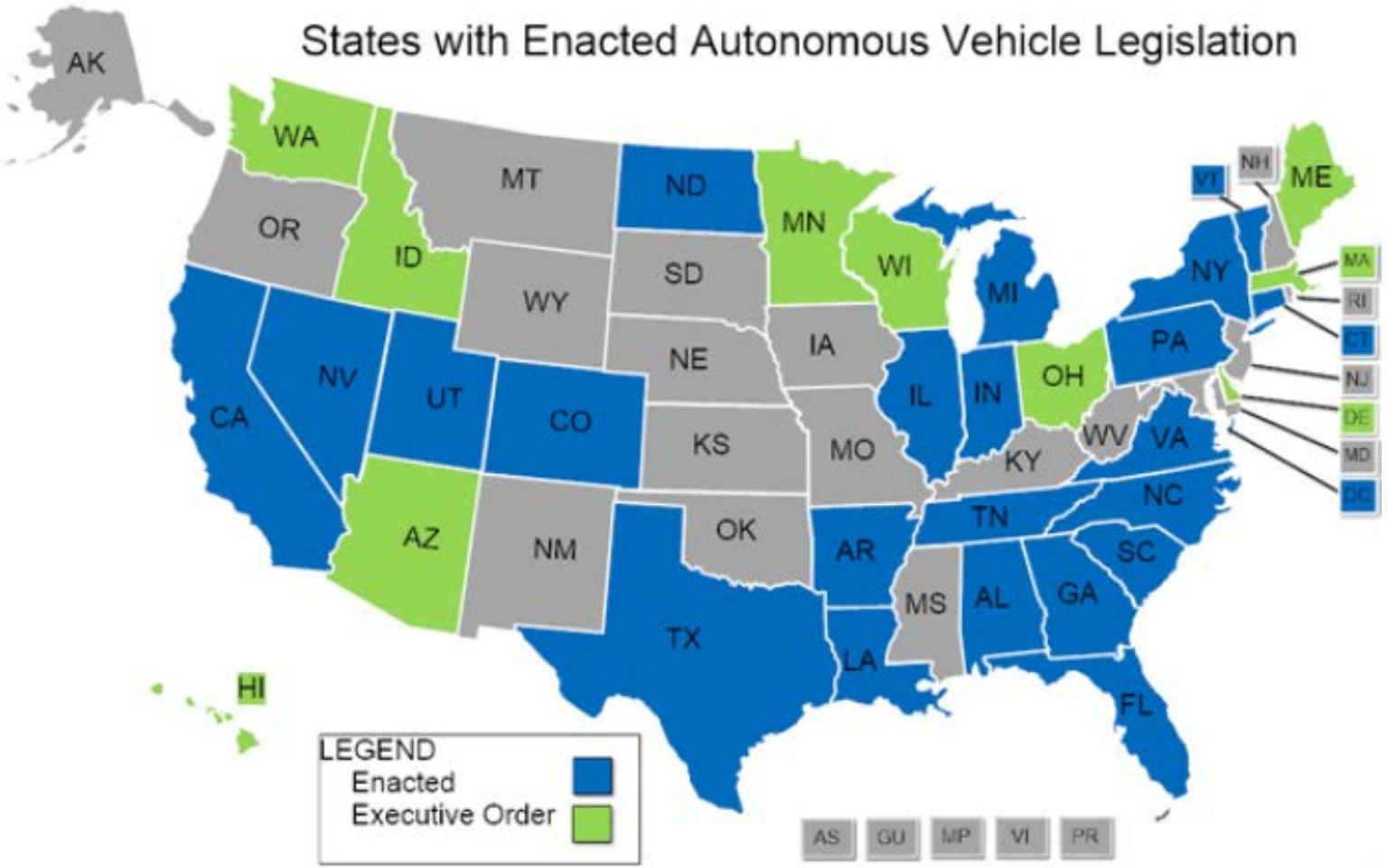
3. **Do U.S. drivers want semi-autonomous technologies in their next vehicle?**

CAV-X


Jay Hietpas
CAV Director
Kristin White
CAV Innovation
Cory Johnson
ITS Prog Mgr
Praveena Pidaparthi
CAV Policy & Planning
Rashmi Brewer
ITS PM
Dan Rowe
ITS PM
Mike Kronzer
ITS PM

MnDOT CAV Strategic Vision

National Items



Executive Order – Expected Outcomes

Advisory Council

- Study, assess, and prepare for the transformation and opportunities associated CAVs
- Develop recommendations for changes in state law
- Submit Report to Legislature by December 1, 2018.
- Establish programs for development, testing, and deployment;

Advisory Council

I-CAV Team

Transportation Infrastructure	Cyber security and data privacy standards	Vehicle Registration, Driving Training, Licensing	Insurance	Traffic Regulations	Economic Development, Business Opportunities, Workforce Development	Accessibility and Equity	Policy and Planning
Stakeholders	Stakeholders	Stakeholders	Stakeholders	Stakeholders	Stakeholders	Stakeholders	Stakeholders

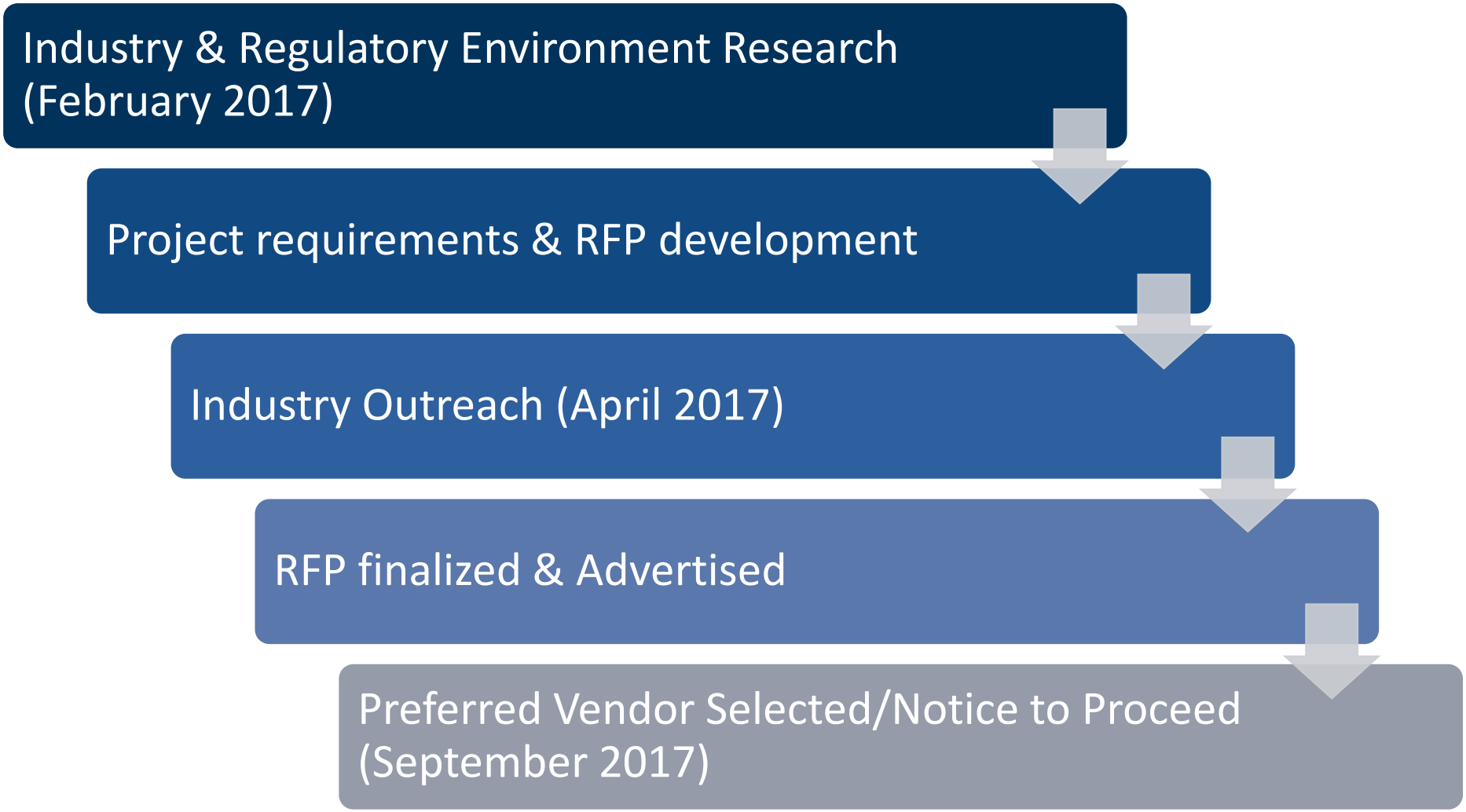

EASY
MILE
3M
Science.
Applied to Life.™

Project Goals

SNOW & ICE	OPERATIONS	MOBILITY	INFRASTRUCTURE	INFLUENCE	PARTNERSHIPS
Prepare autonomous vehicle industry for snow & ice conditions	Identify challenges and strategies for safe operation of third party autonomous vehicles on MnDOT's transportation system	Prepare for improved mobility services through autonomous vehicles	Identify the infrastructure that is needed to ensure safe operation of autonomous vehicles	Increase Minnesota's visibility and influence on advancing autonomous & connected vehicles	Enhance partnerships between government and the autonomous vehicle industry

Public Engagement

Project Timeline



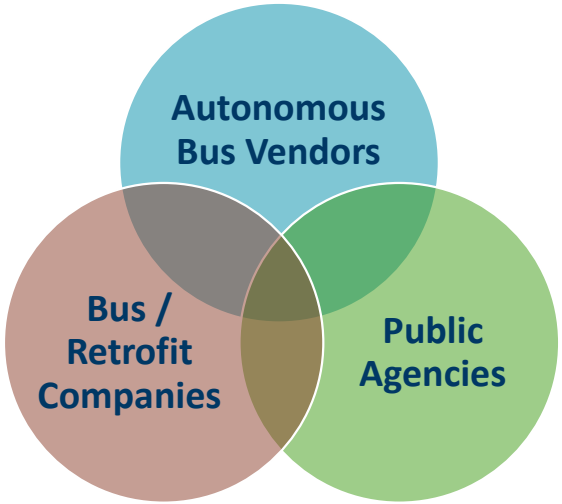
Industry / Stakeholder Interest

Company
Navya
EasyMile
Local Motors
2getthere
Autonomous Solutions Inc. (ASI)
Romaric 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/



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

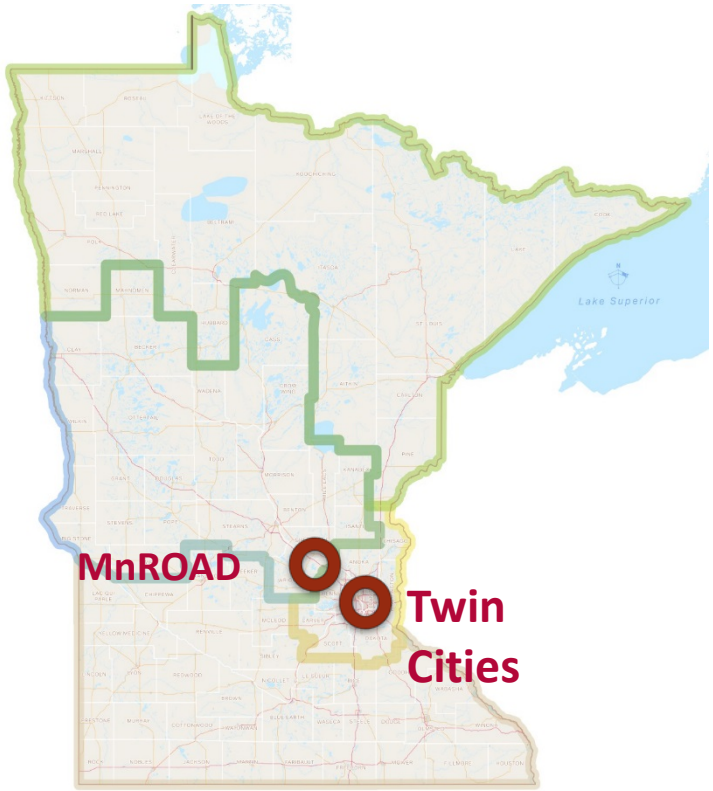
Phase 2

- 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

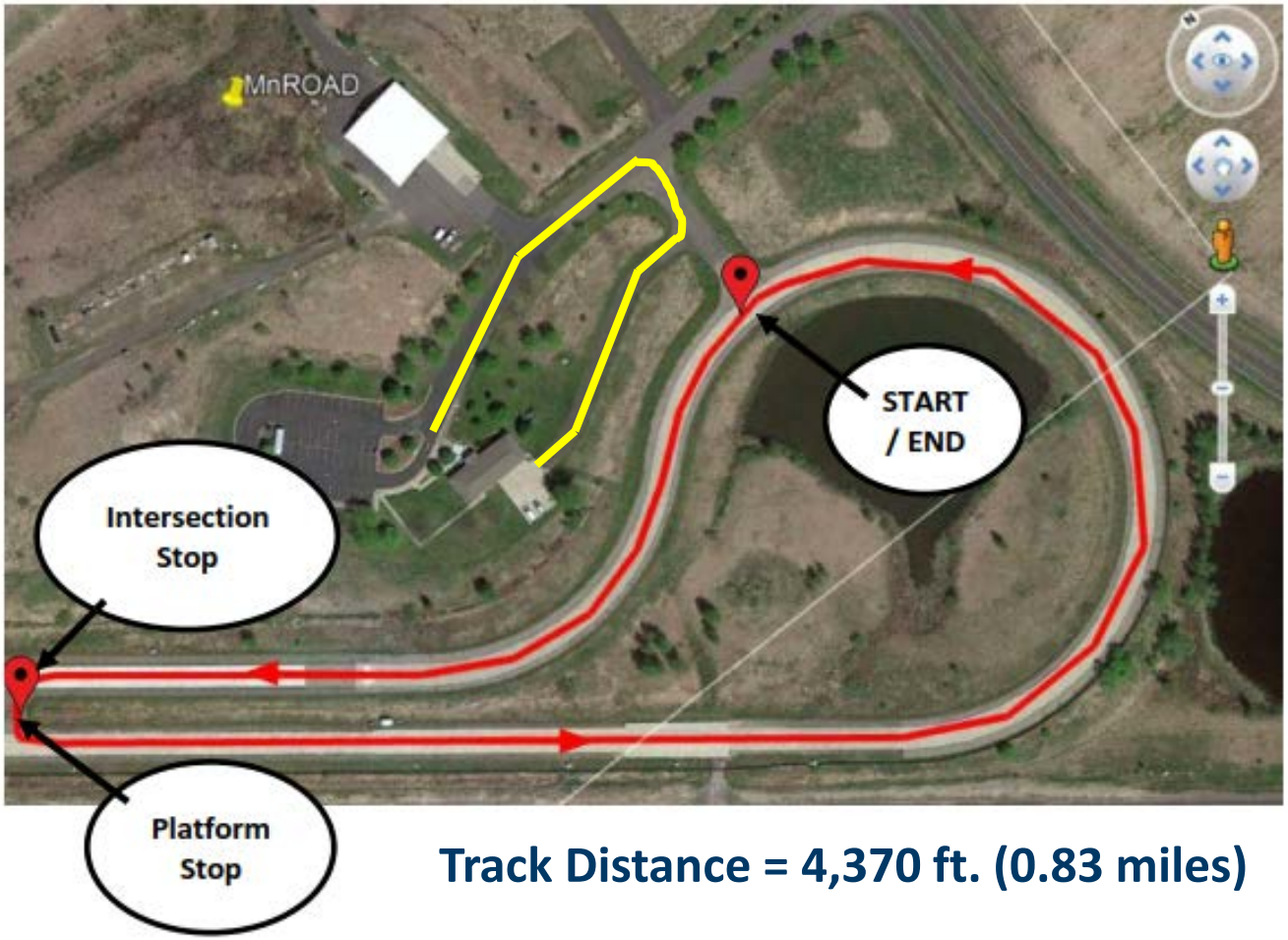
Minnesota DOT MnROAD Facility

- 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

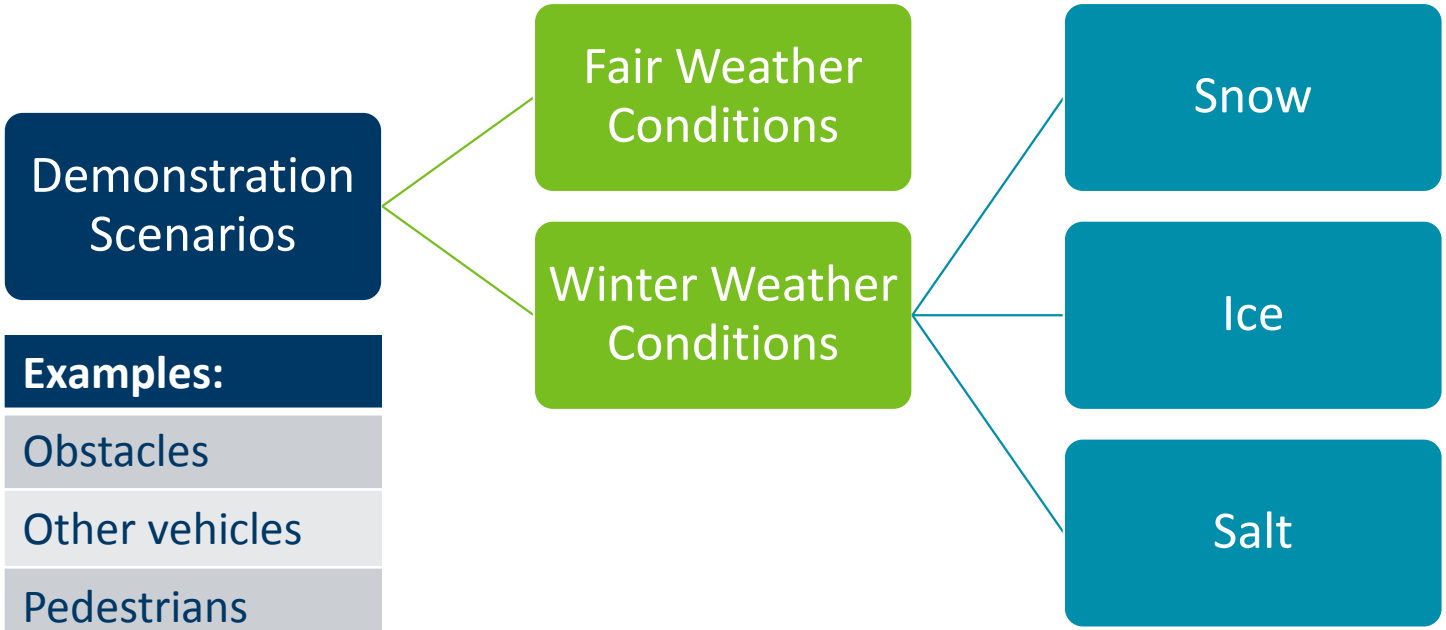
Testing Scenarios, Schedule & Responsibilities

- Clear Weather & Winter Weather – Under Various Conditions



Track Distance = 4,370 ft. (0.83 miles)

Demonstration Concepts



Examples:
Obstacles
Other vehicles
Pedestrians
Bicycles
Transit Stops
Stopping/Yield
Intersections


easy
MILE
3M
Science.
Applied to Life.

Observations / Conditions

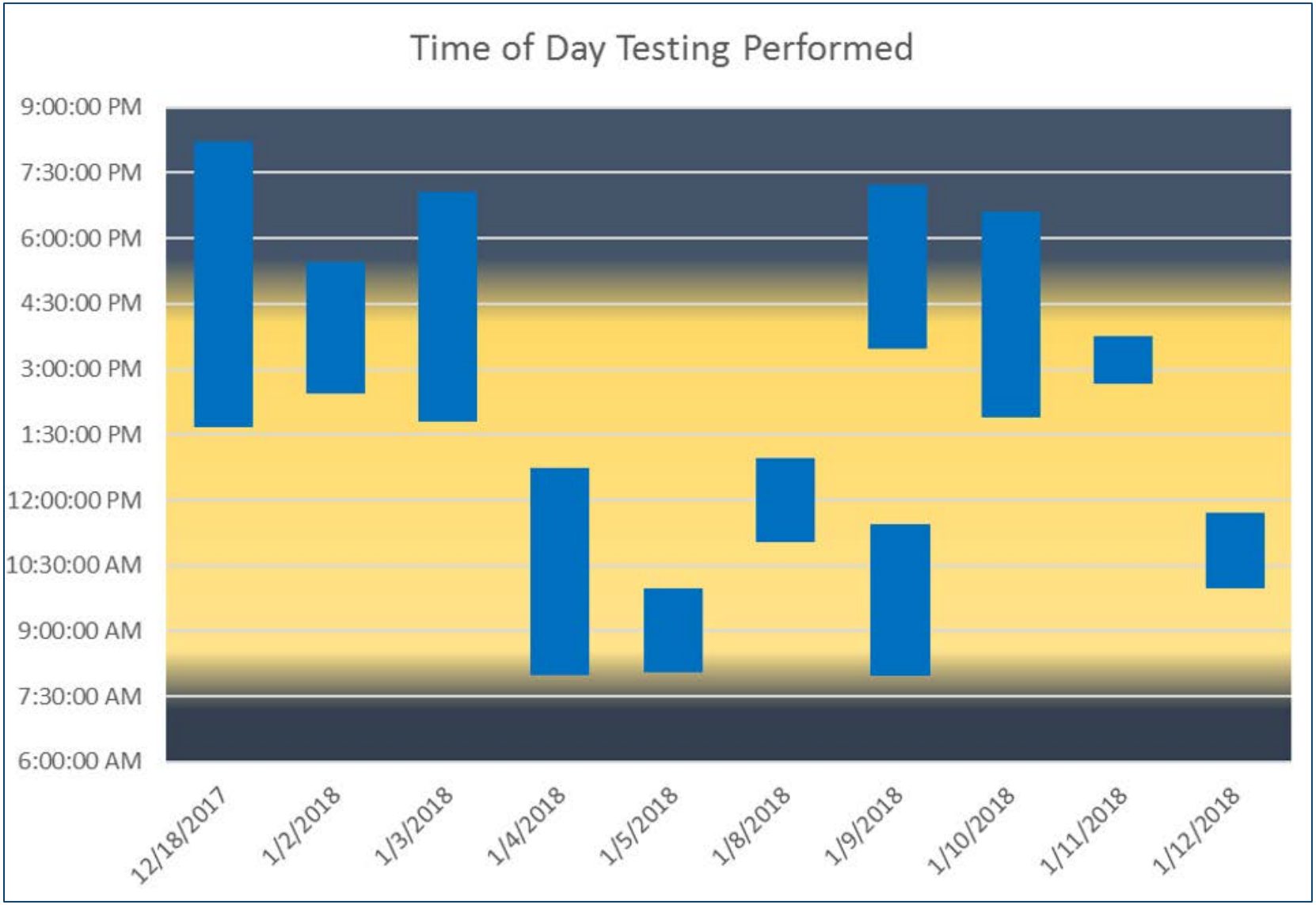
Observations / Conditions

Dry / Mild Weather	Winter / Cold Weather	Snow / Rain / Fog
Loose / Compacted Snow	Slush / Ice / Road Salt	Bare Pavement
Varying Visibility	Various Lighting	Obstacles
On-coming Vehicles	Slow / Stopped Vehicles	Car In Front / Following
Intersection Turns	Stop / Yield Signs	~~Traffic Signals~~
Pedestrians	Bicycles	Right-of-Way Decisions
Parking	Transit Stops	Pick-up / Drop-off Passengers

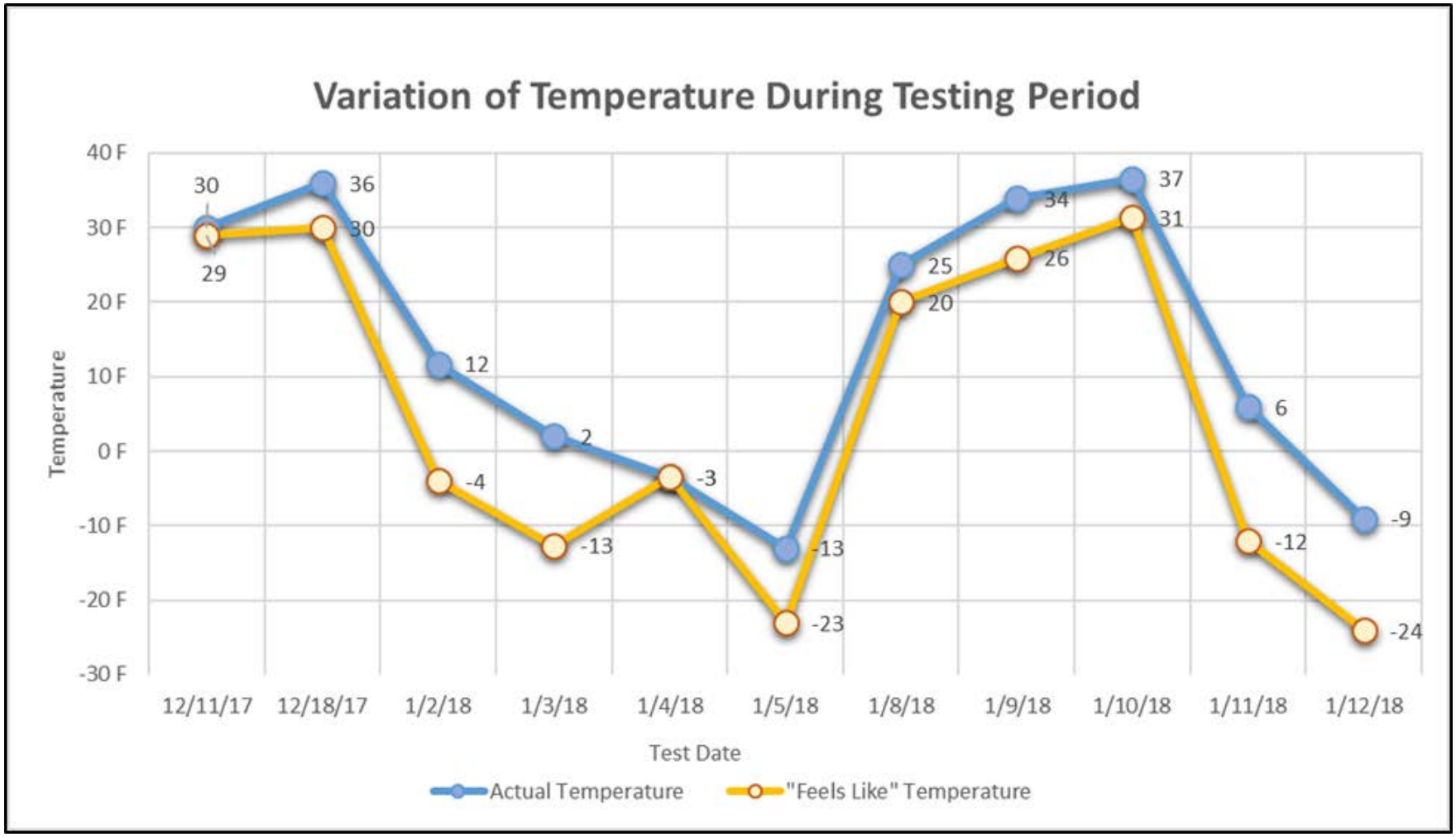
MnROAD Infrastructure


AUTONOMOUS
VEHICLE
TESTING AREA
15 MPH

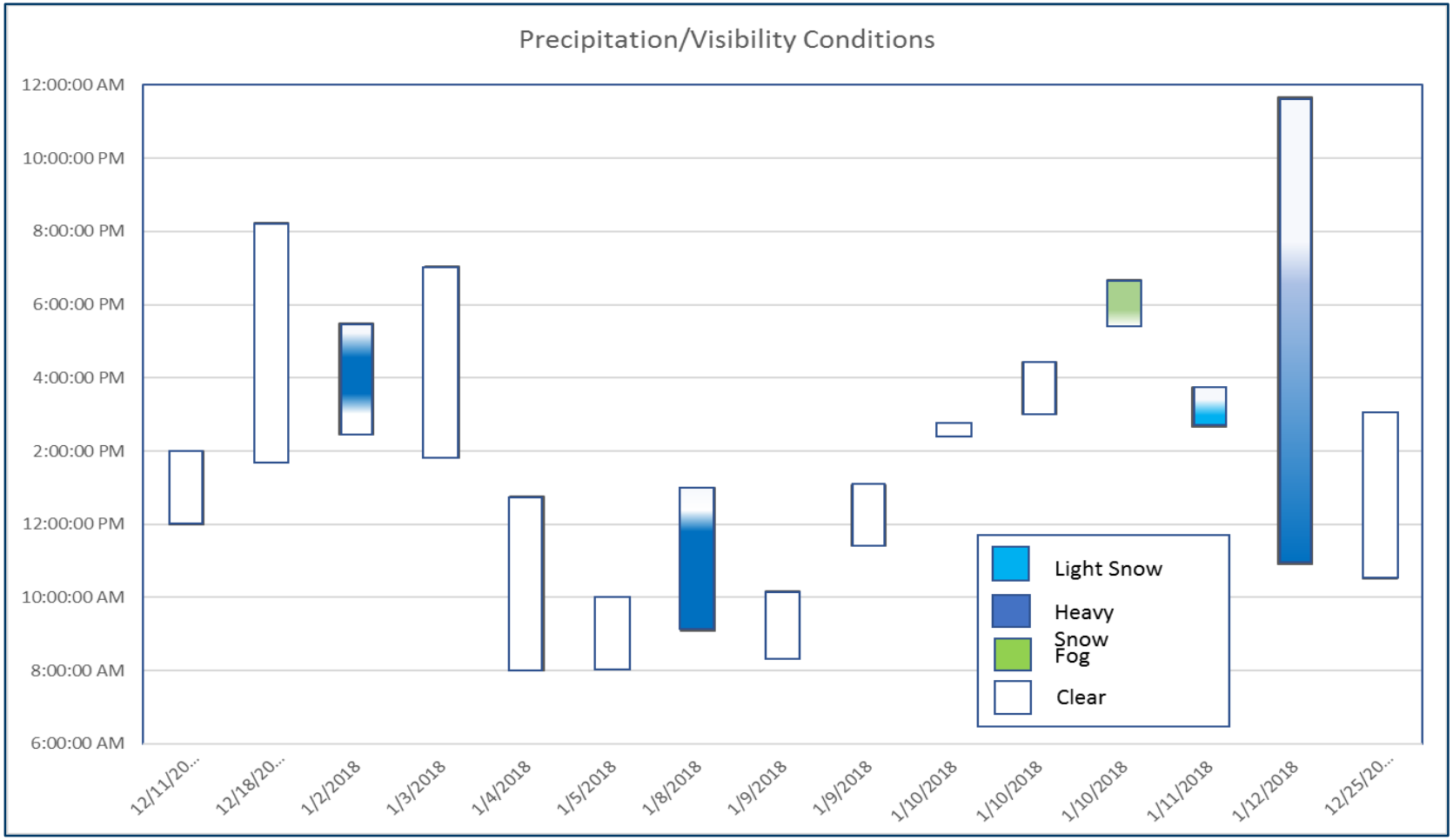
Observed Sunlight Graph



Temperature



Precipitation



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

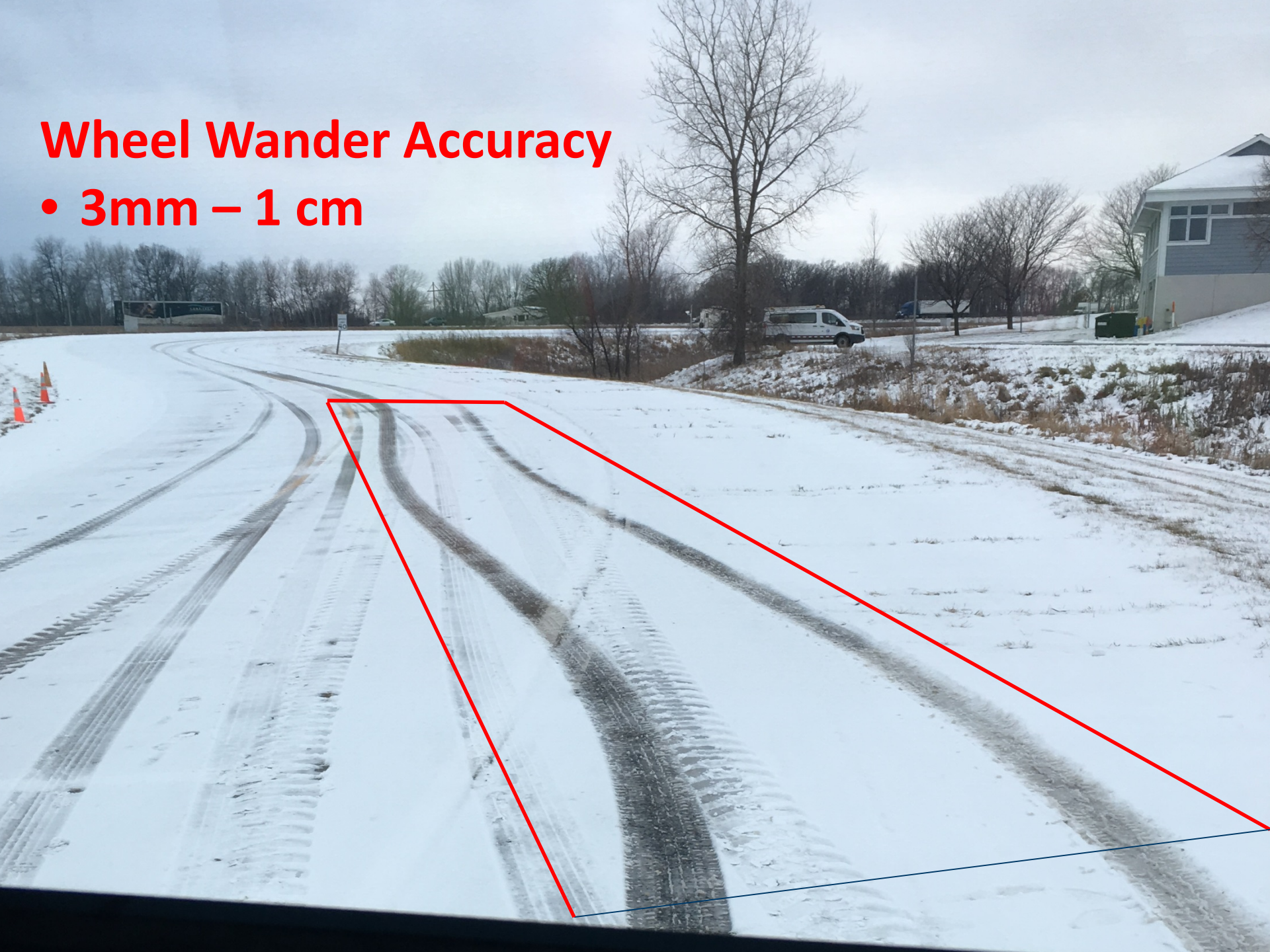
Real Life Circumstances

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


Other Car Tests
Following, Ahead, Parallel Lane, Passing,
Opposing Direction, Intersections

Interaction with Other Cars

Bus & Car Intersection Interaction

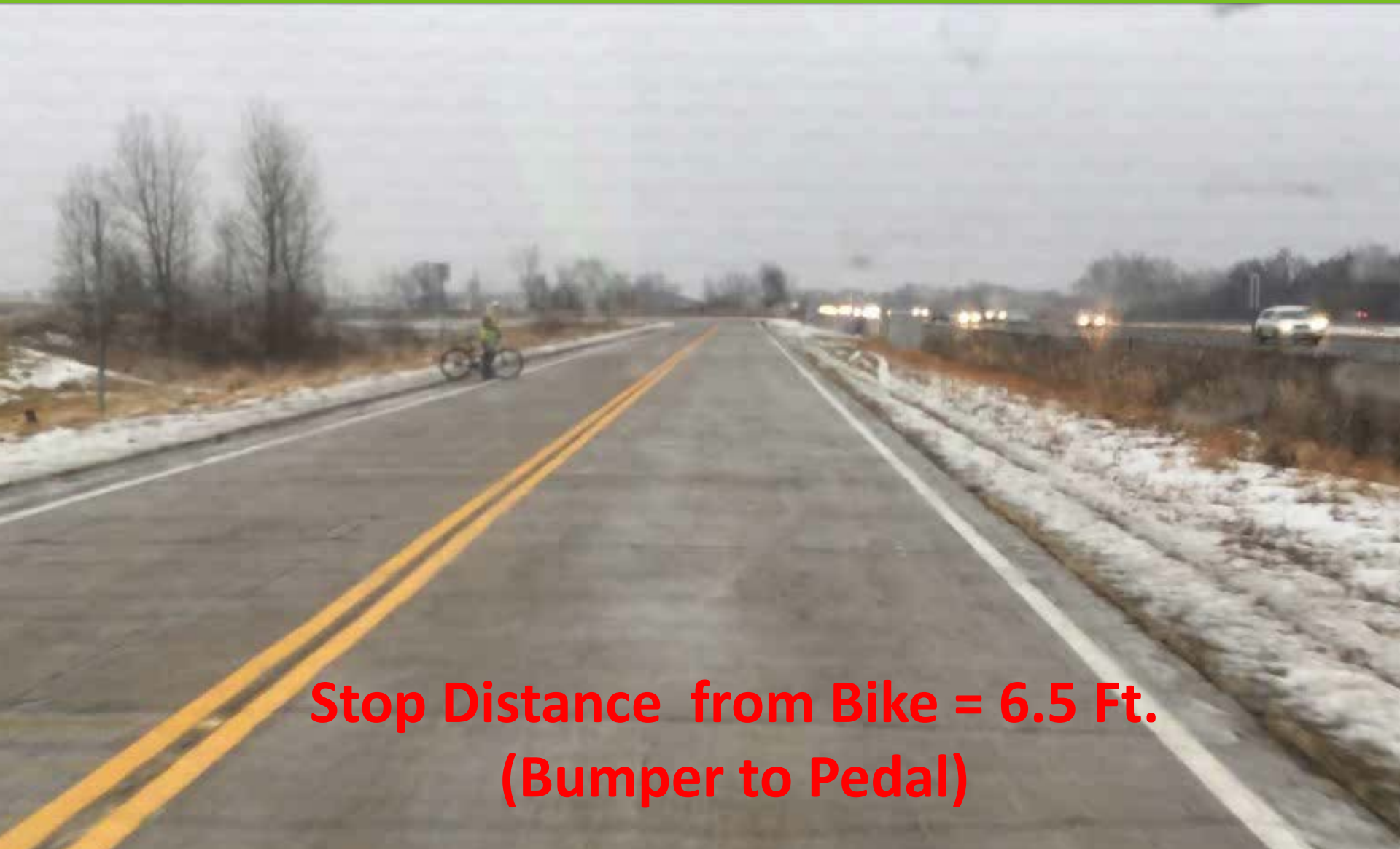
Interaction with Other Cars – Exhaust?

Interaction with Other Cars

Interaction with Bicycles and Pedestrians

Interaction with Pedestrians

Interaction with Bicycles




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

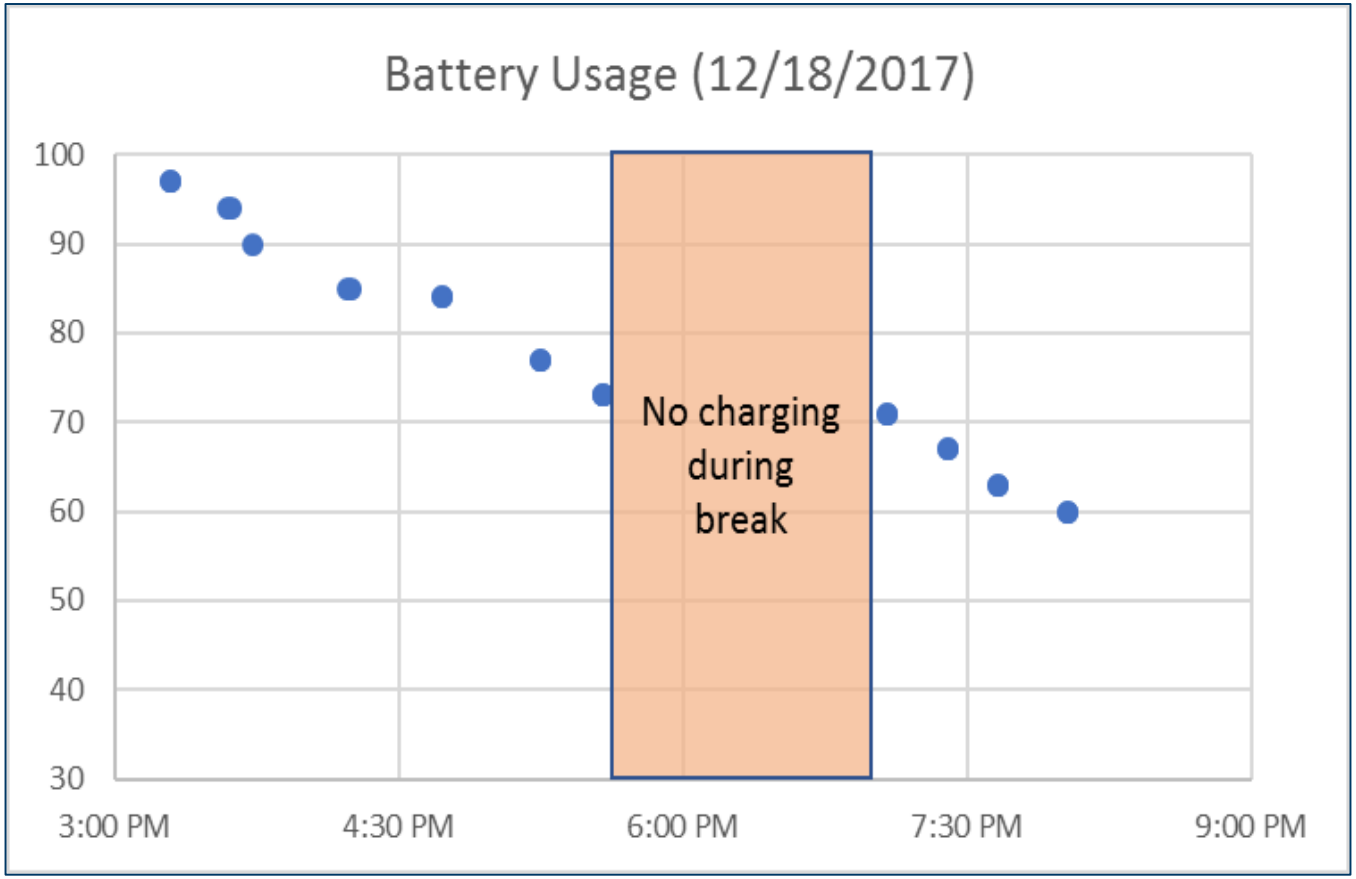
Snow Making


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

Snow Cloud

Snow Cloud

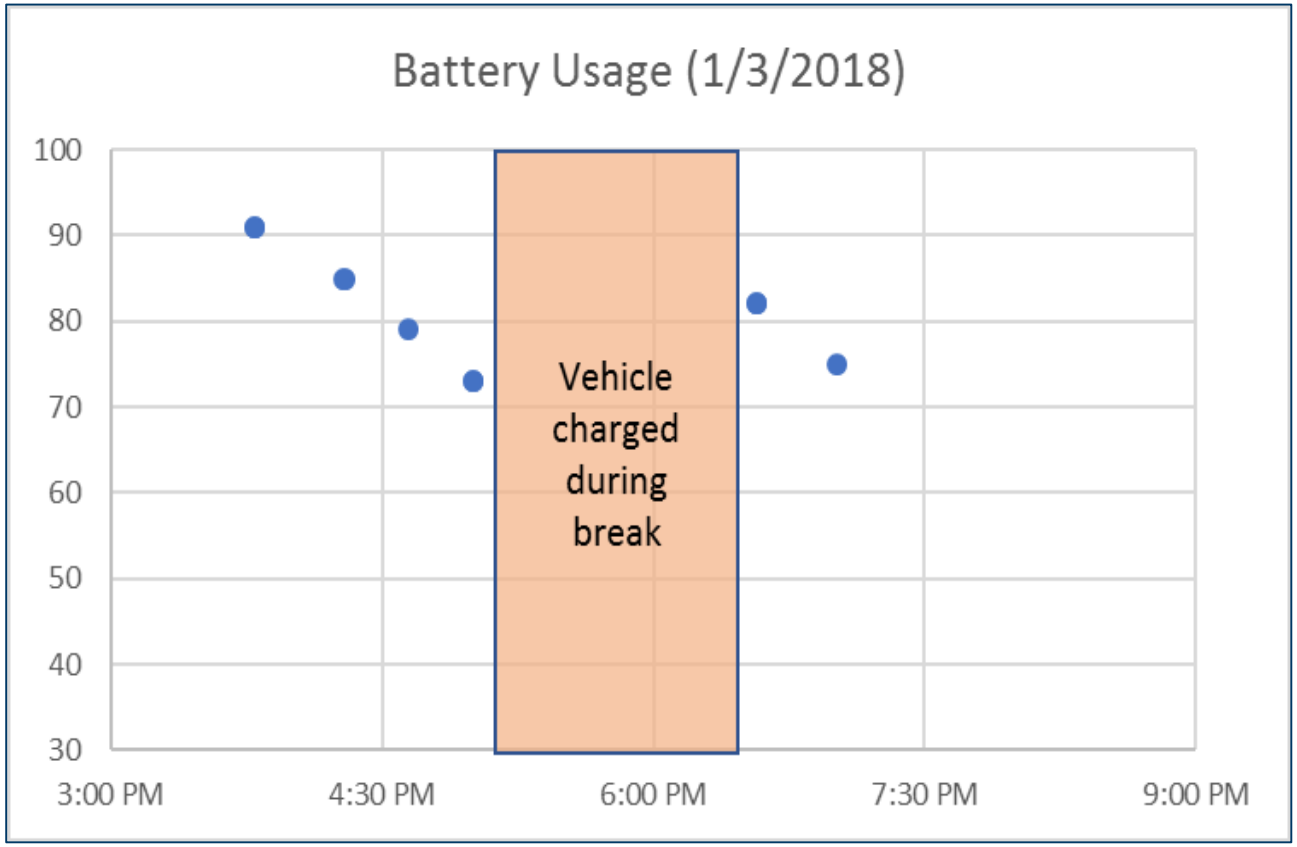
Battery Usage – Mild Weather



Dec. 18th, 2017 Battery Charge Readings

Start Temp.: 36° F ; Wind: S 7 mph

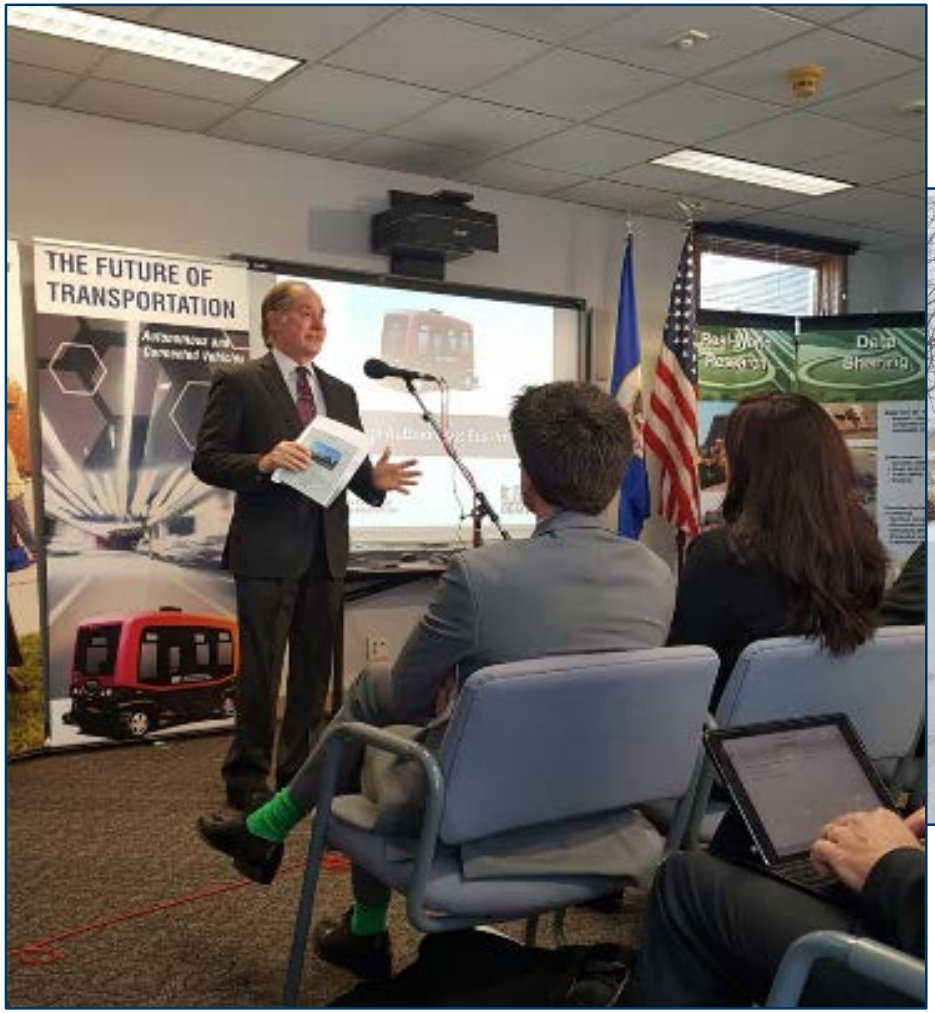
Battery Usage – Cold Weather



Jan. 3rd, 2018 Battery Charge Readings
Start Temp.: 3º F; (-13º F windchill); Wind: WNW 11 mph

MnROAD – Stakeholder Tours

Media Day



Jon Koznick
@Jonkoznick

The future maybe coming. Today I checked out a driverless bus. They are testing them in winter conditions. Watch for them in MPLS durring Super Bowl, to get your ride. #mnleg

12:21 PM · 14 Dec 17

4 Likes

Tom Emmer
@RepTomEmmer

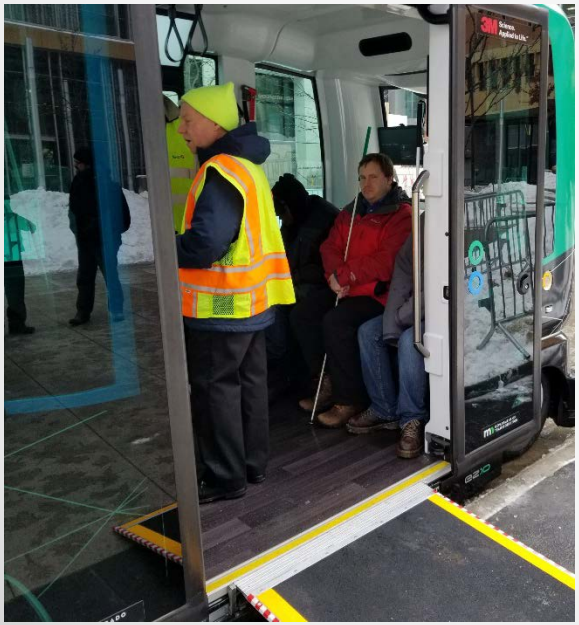
Had a great ride on the 12-passenger autonomous easy mile bus today! Thank you @MnDOTnews for having me out to your MNRoad facility in Monticello! This technology is transportation for the future and I enjoyed learning more about it!

5:12 PM · 12 Jan 18

Downtown Minneapolis - Nicollet Mall Demo

Downtown Demonstration Planning - Route

National Federation of the Blind – Minnesota Chapter visit



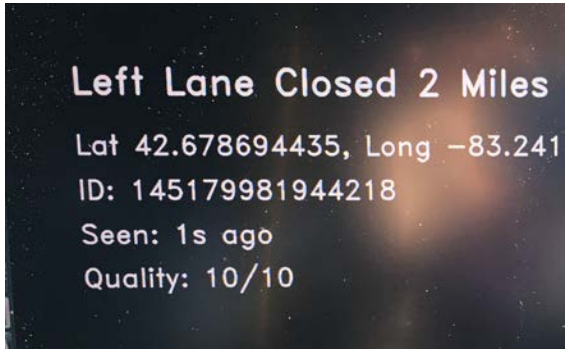
Downtown Minneapolis – National Federation of the Blind – MN Chapter


Welcome to
DEPARTMENT OF TRANSPORTATION
Autonomous Shuttle Demo Rides
DEPARTMENT OF TRANSPORTATION
e2.10
First Transit

3M™ Smart Code: Enabling Machine Readable Signage

Solutions providing more reliable sign detection and classification
and increased situational awareness

Visible Image



Computer Vision Image and
Associated Meta-Data

- High data density messaging
- Encoded error recovery
- Digitally certain results
- Ground truth verification

- Authenticatable
- Redundant classification confirmation
- Potential for dynamic messaging
- Maintains exceptional human visibility

MnDOT EasyMile – Nicollet Mall demonstration

3M Connected Roads - Smart Sign

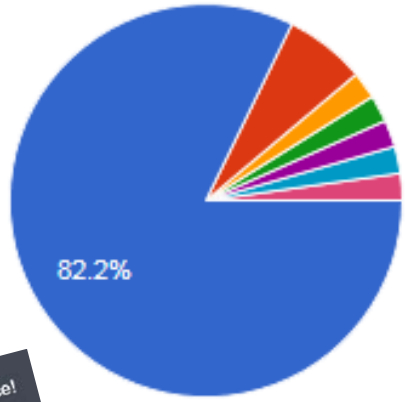

3M Science. Applied to Life.™
max. 350 kg
BRAVO
ez10


DEPARTMENT OF TRANSPORTATION
EASY MILE
3M Science. Applied to Life.™
First Transit
e210
e210

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

Downtown Minneapolis- Public Demonstrations

Hurry up and get these things in our city!!! Can't wait for the future

This was really fun and enjoyable. I can't wait to see more operational in MN!

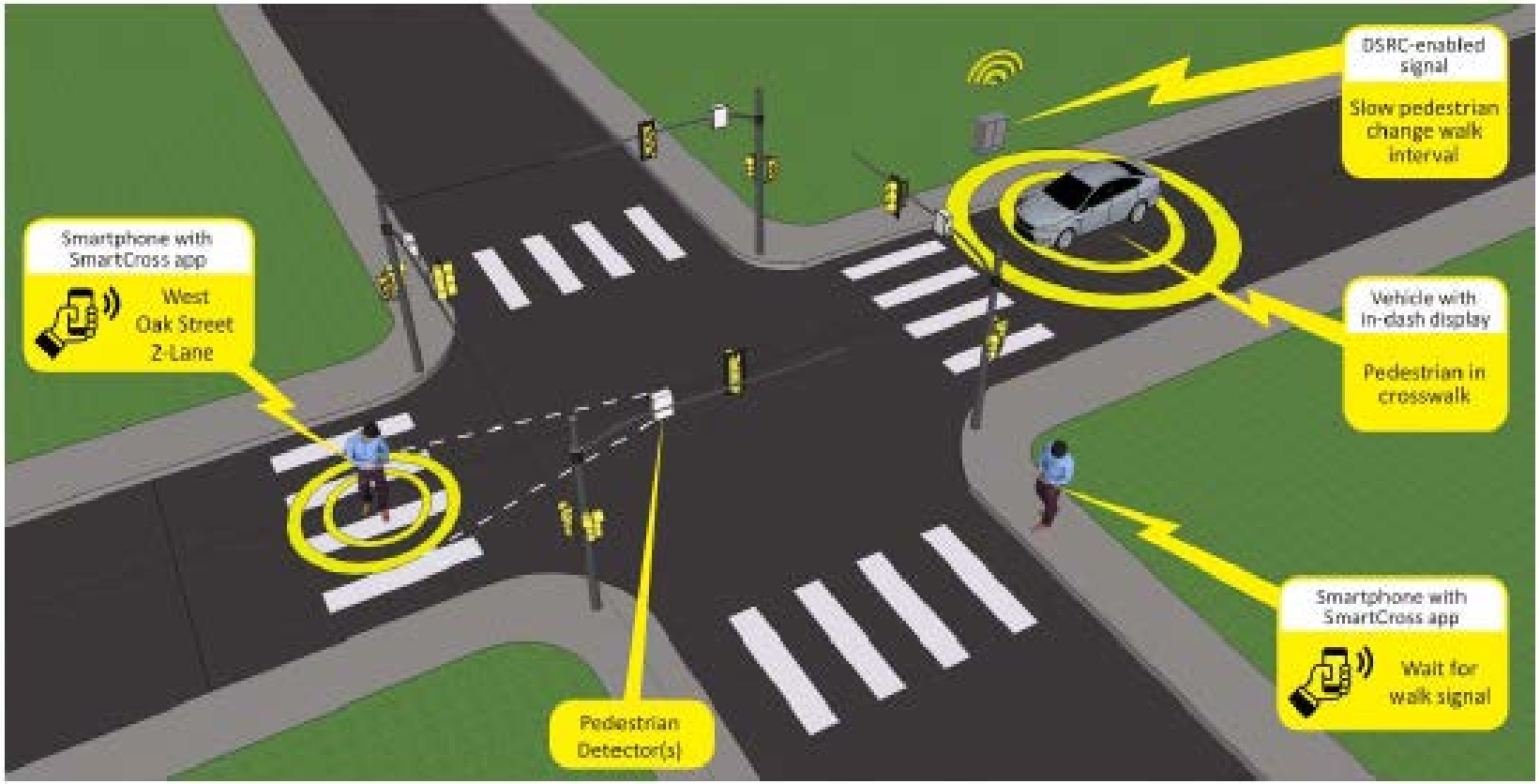
Thank you city of Minneapolis for setting up events like this to help the public experience future growth projects.

I am concerned about malicious hacking of driverless vehicles, which would be extremely dangerous for everyone sharing the road with them.

It was a good demo and the people explaining it were very good

Next Steps for CAV In Minnesota

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!