I-70 TRUCK AUTOMATION CORRIDOR

Purdue Road School

March 15, 2022

- Project Introduction and Overview
  - *Scott Manning, INDOT*
- Project Concept and Architecture
  - *Diane Newton, HNTB*
- I-70 Road Audit
  - *Anmol Sidhu, PhD, TRC*

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Problem Statement

- 88% of freight moves by truck
- Increasing competition
- Driver shortages
- *How can we apply advanced technology to improve both safety and efficiency?*

Truck volumes through and within Indiana and Ohio

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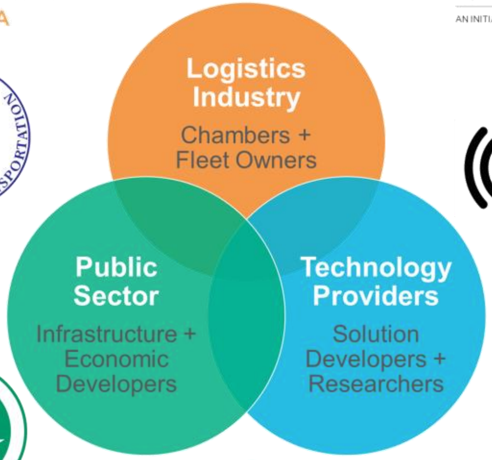
Vision and Goals

- 2019 FHWA ATCMTD Grant Application
  - Agency match
  - Safety, efficiency, environmental impact
- Advance truck automation
- Share Information
- Prepare Infrastructure
- Overcome Institutional Barriers



Approach

- Four-year grant project
- For trucks carrying loads
- Piloting truck automation technologies
    - Platooning
    - Level 2 automation
    - Level 4 automation
- Road Audit
    - Identify deficiencies and recommend changes
    - Create tool to assess roads’ AV readiness
- Automated Vehicle (AV) Readiness Guidebook

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Piloting Truck Automation Technologies

		
Level 1	**Level 2**	**Level 4**
Truck Platooning Automation Connectivity between a convoy of two or more trucks. The lead truck is driven manually. Following trucks use vehicle to vehicle communications and automated driving technology to operate in partially or fully automated mode.	**Partial Automation** Vehicle has combined automated functions, like acceleration and steering but the driver must remain engaged with the driving task and monitor the environment at all times.	**High Automation** The vehicle can perform all driving functions under certain conditions. The driver may have the option to control the vehicle.

Sources: NHTSA, Society of Automotive Engineers

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Outcomes

- **Safety:**
  - *Improve crash avoidance capabilities*
  - *Reduce driver stress*
- **Environment:**
  - *Reduce fuel consumption and emissions output*
- **Efficiency:**
  - *Increase labor productivity*
  - *Positive return on investment*
- **Acceptance:**
  - *Improve fleet and driver acceptance of automated vehicle technology*

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High Level Timeline

Year 1: Systems Engineering	Year 2: Procurement and Route Audit	Year 3: Demonstration and Data Collection	Year 4: Evaluation and Results

MAJOR MILESTONES

- Concept Feb '22
- Requirements Sept '23
- Demonstration Spring '23
- Guidebook Dec '23
- ARRAT Oct '24
- Final Report May '25

Automated Truck Revenue Service Deployment

- Concept: Oct 2021- Feb 2022
- Requirements: Mar 2022 – Sept 2022
- Procurement: Fall 2022
- Demonstration: Spring 2023 to Fall 2024

Route Audit and Repair

- Test Plan: Oct 2021 – Jan 2022
- Route Audit: Spring 2022
- Route Analysis: Summer 2022
- Route repairs: Fall 2022
- Test Report: Fall 2023

Guidebook and Reporting

- AV Readiness Guidebook: Dec 2023
- AV Readiness Roadway Audit Tool (ARRAT): Oct 2024
- Final Report and Results: Spring 2025

Project Management, Communications, Reporting

Project Concept and Architecture

Structured Approach

Systems Engineering V Diagram

- Project Planning Activities with Statewide Documentation
- Project Planning Activities with Project-Specific Documentation

Current Situation

2018-2020	2022-2025	2025-2027	2027 & Beyond
Driver in Each Truck	**Driver in Lead Truck**	**Driver for Pickup & Drop-off**	**Driverless**
Two drivers platooning two trucks, a driver in each. No platooning would take place on non-interstate highways.	Still platooning only on interstate highways, but by this time, there will only be a driver in the lead truck.	Autonomous trucks will traverse interstates without drivers, platooning when possible. Drivers would only be involved for pickup from and drop-off to interstate highways.	Autonomous trucks will drive themselves on all highways, in and out of platoons. Driver involvement would be limited throughout.

AV Pooled Fund Study

US 33 Smart Corridor

Ohio Statewide CV AV Systems Engineering Analysis

Creating the Concept

Engagement

AV Technology Developers

Fleets and OEMs

Logistics Councils

Use Case(s)

Middle Mile

Routes

Scenarios (Work Zones, Inclement Weather, Etc.)

Architecture

National

Statewide (Ohio)

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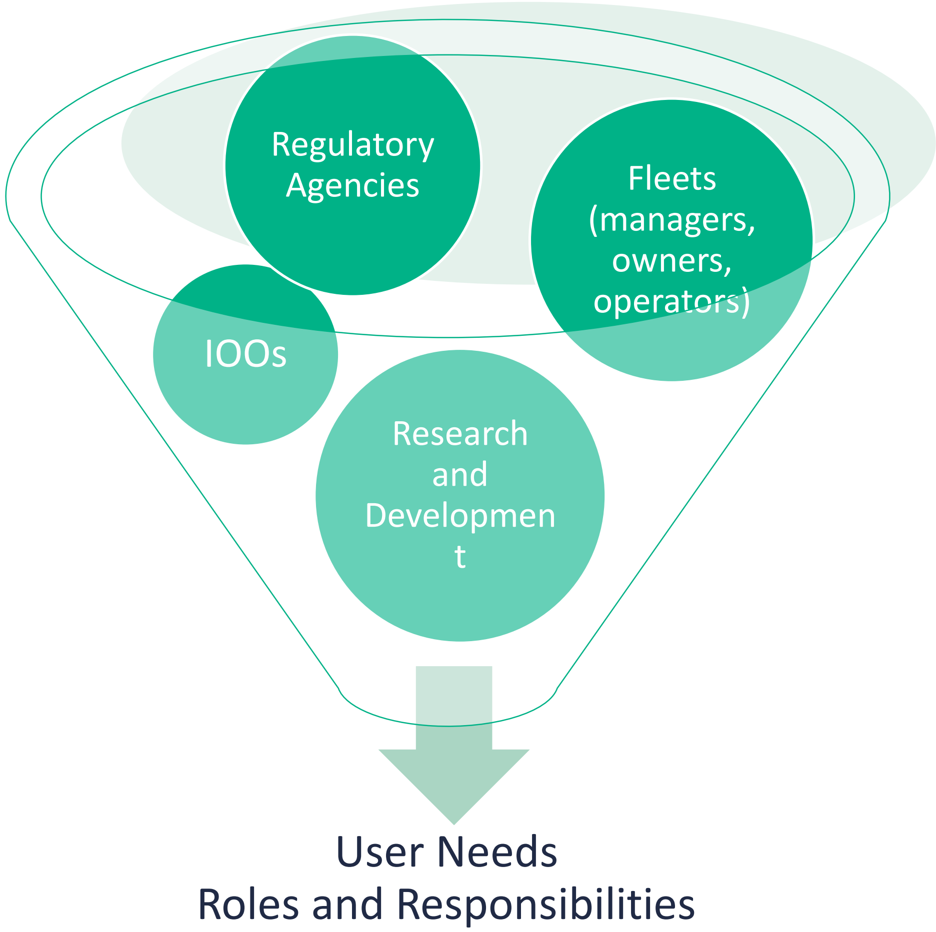
User Needs



Stakeholder	Needs
IOOs	- Improve roadway safety - Reduce transportation sector emissions - Build and strengthen relationships across stakeholders - Identify and prioritize infrastructure investments - Promote economic development
Fleets	- Understand driver responsibility - Ensure technology compatibility with normal operations - Improve driver experience - Achieve positive return on investment - Take manual control of equipped vehicle (if necessary)
Research and Development	- Facilitate technology awareness and adoption - Collect real-world data
Regulatory	- Comply with federal, regional, state and local laws and regulations - Identify which vehicles are using platooning technology - Understand legal framework around AV technology re: compliance and enforcement - Understand inspection and emergency protocols for AVs

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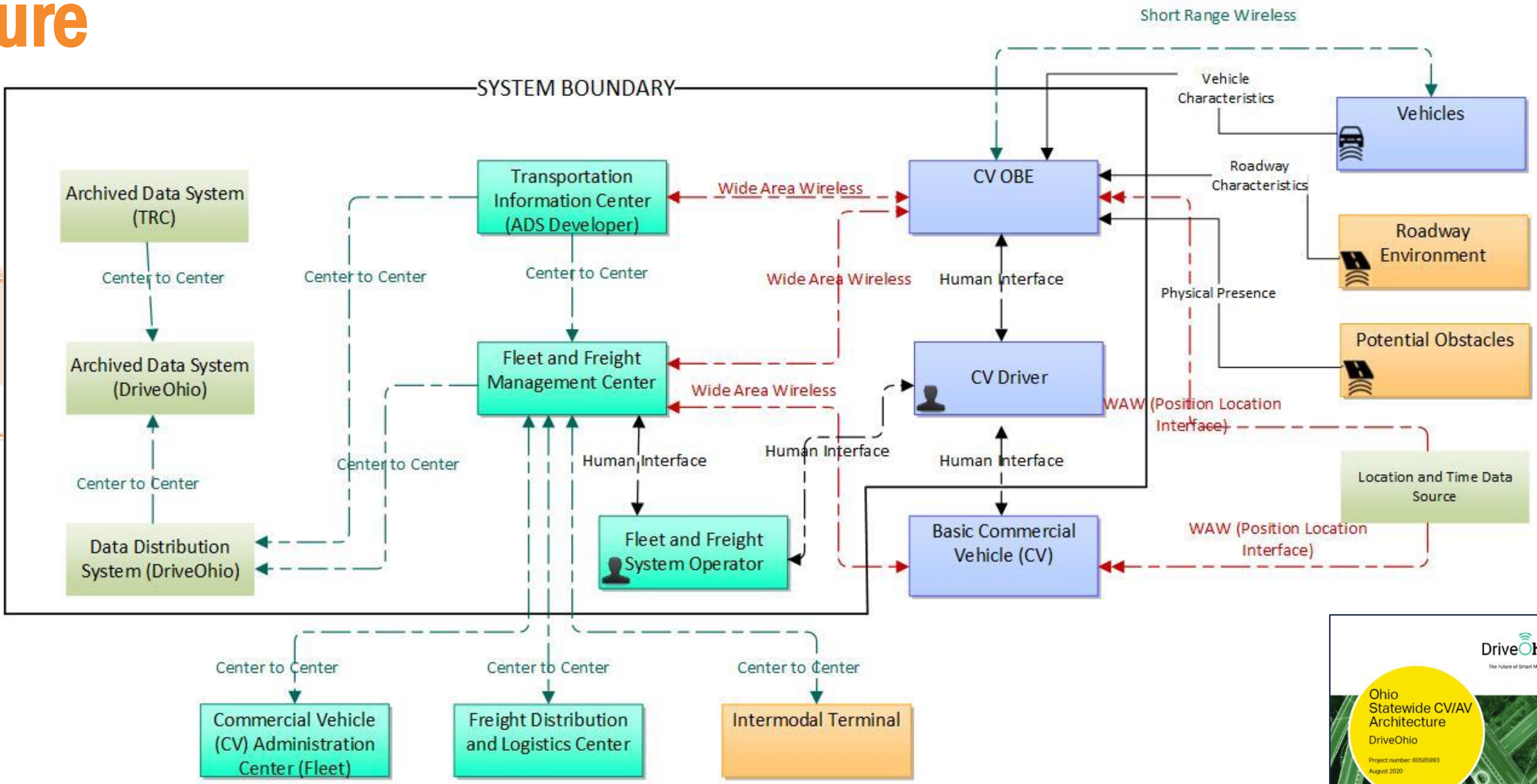
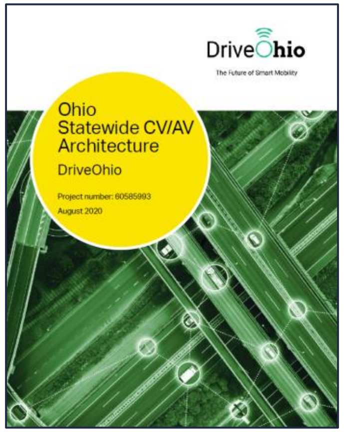
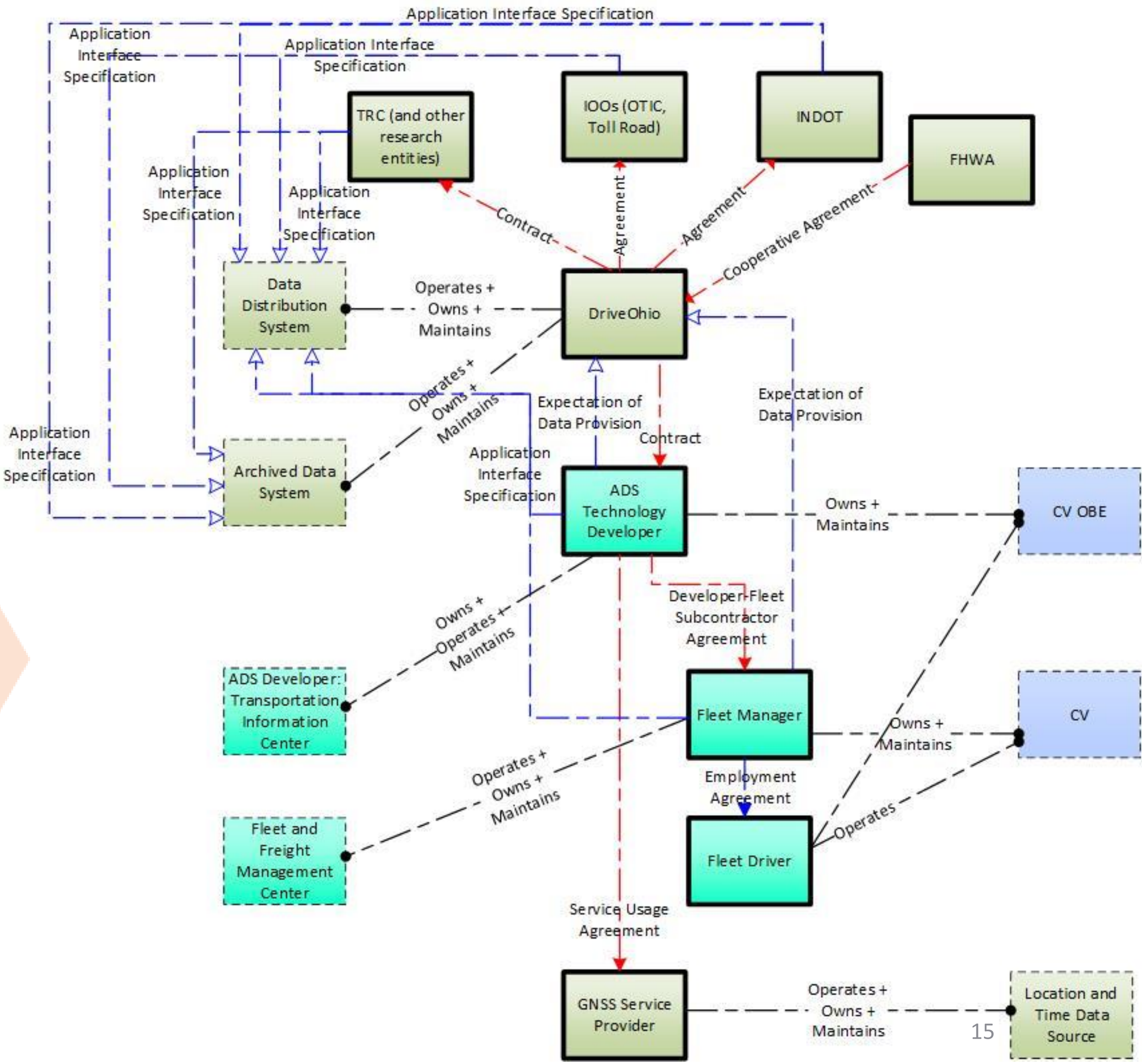
Architecture





ARC-IT Version 9.0
The National ITS Reference Architecture

Roles and Responsibilities



Operational Scenarios

ITEM	DEFINITION
Operational Scenario	An instance of a use case describing a sequence of events, activities carried out by the user, the system and the environment.
Data	Recorded information that is needed to address or facilitate the given operational scenario.
Resources	Anything available to a system that can support the achievement of objectives and has some role, offers services, and performs some action within a system. The primary focus here is on resources that provide data.
Users	The data end-users and/or ultimate beneficiaries or participants in the scenario.
Existing Systems	Existing systems that are used to collect, capture, or act on the data.
Interactions	Interactions needed between those that have data and those that need data.
Potential Use Cases	Examples of the multiple ways in which this scenario can be demonstrated.
Additional Capabilities and Challenges	Additional capabilities or challenges that would be created by technology application in this scenario.
User Needs	Uniquely identifiable, solution-free statements that describe a major desired capability, including the rationale or intent as to why the capabilities are needed in the system.
Service Packages	A combination of ITS architecture components tailored to provide a specific ITS service.

Operational Scenarios

Scenario: A truck equipped with automated technology (platooning, L2 or L4) safely enters and exits the interstate.

Data
- Quantitative AV system data and driver perception data to evaluate interactions with other equipped or unequipped vehicles
- Quantitative fleet/truck operational data

Resources
- Technology developers
- IOOs
- Drivers/participating fleets

Users
The end users of such data include:
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- Fleets
- Technology developers
- Commercial logistics/ Freight companies

Existing Systems
The data is collected by the various fleet operators and/or technology providers

Interactions
The Resources must actively and regularly be engaged throughout deployment to share data and discuss outcomes (quality, perceptions and technology performance)

Potential Use Cases
- Truck approaching a signalized ramp versus a merged ramp
- Truck coming to a stop sign or traffic signal
- Truck speeding up to traffic upon entry or down to ramp speed
- Truck entering interstate without room to move into merge lane

Additional Capabilities and Challenges
- Creation of data for state agencies on legislation and regulatory needs to support AV program development
- Assessing level of automated operation
- AVs could increase the safety of truck travel on the interstate
- AVs may face challenges integrating with unequipped vehicles on the interstate

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Operational Scenarios

1. [Equipped] trucks entering/exiting the interstate
2. Trucks interact with other vehicles and users
3. Truck navigates around a roadway obstacle and/or accommodates a stopped vehicle
4. Truck responds to a dramatic change in weather conditions
5. Truck responds to dramatic change in traffic conditions
6. Truck traverses an interstate work zone

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Road Audit

Overall Route Audit Goals

1. Collect Data on I-70 interstate freeway
2. Assess readiness for automated vehicles
3. Propose infrastructure remedies
4. Inform development of the Guidebook

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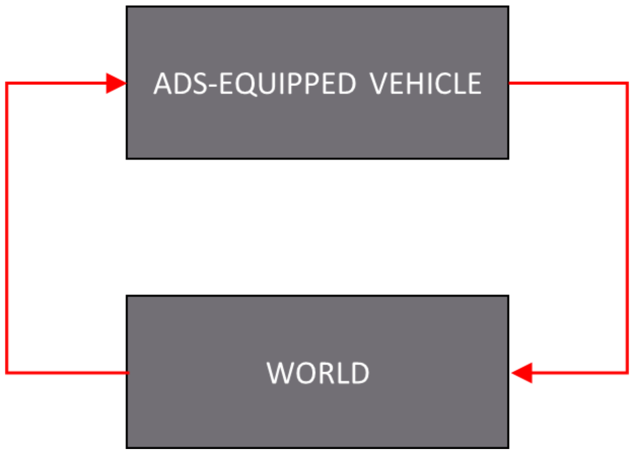
Technical Challenges

1. ADS technology exists on a spectrum (SAE Levels)
2. Continuous evolution of ADS as well as infrastructure
3. Varieties of sensor suites that sense the environment
4. Establishing link between infrastructure elements and ADS performance



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Partial Automation (SAE Level 2) Features Under Focus

Feature Set 1

- Automatic Emergency Braking
- Adaptive Cruise Control
- Lane Keeping Assist

Feature Set 2

- Automatic Emergency Braking
- Adaptive Cruise Control
- Lane Centering
- Navigation and Route Planning
- Lane Changes

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Identified Infrastructure Needs

Type of SAE Level 2 Driving Automation Features			Feature Set1	Feature Set2
Infrastructure needs to enable Driving Automation System Performance		Speed Limit Information (Signage)	Y	N
		Road Geometry - Curvature	Y	Y
		Signage relevant to Longitudinal Control	Y	Y
		GPS Signal to enable Speed limit information lookup from a database	N	Y
	For Lateral Control			
		Road Geometry - Curvature	Y	Y
		Signage relevant to In-lane control	Y	Y
		Signage relevant to lane-change operation	N	Y
		GPS signal to enable lane-change necessitated by a route plan feature	N	Y
	Weather	Environment Weather Information	Supp.	Supp.
		Road-weather Information	Supp.	Supp.
	Localization	GPS signal to enable navigation planning features	N	Y

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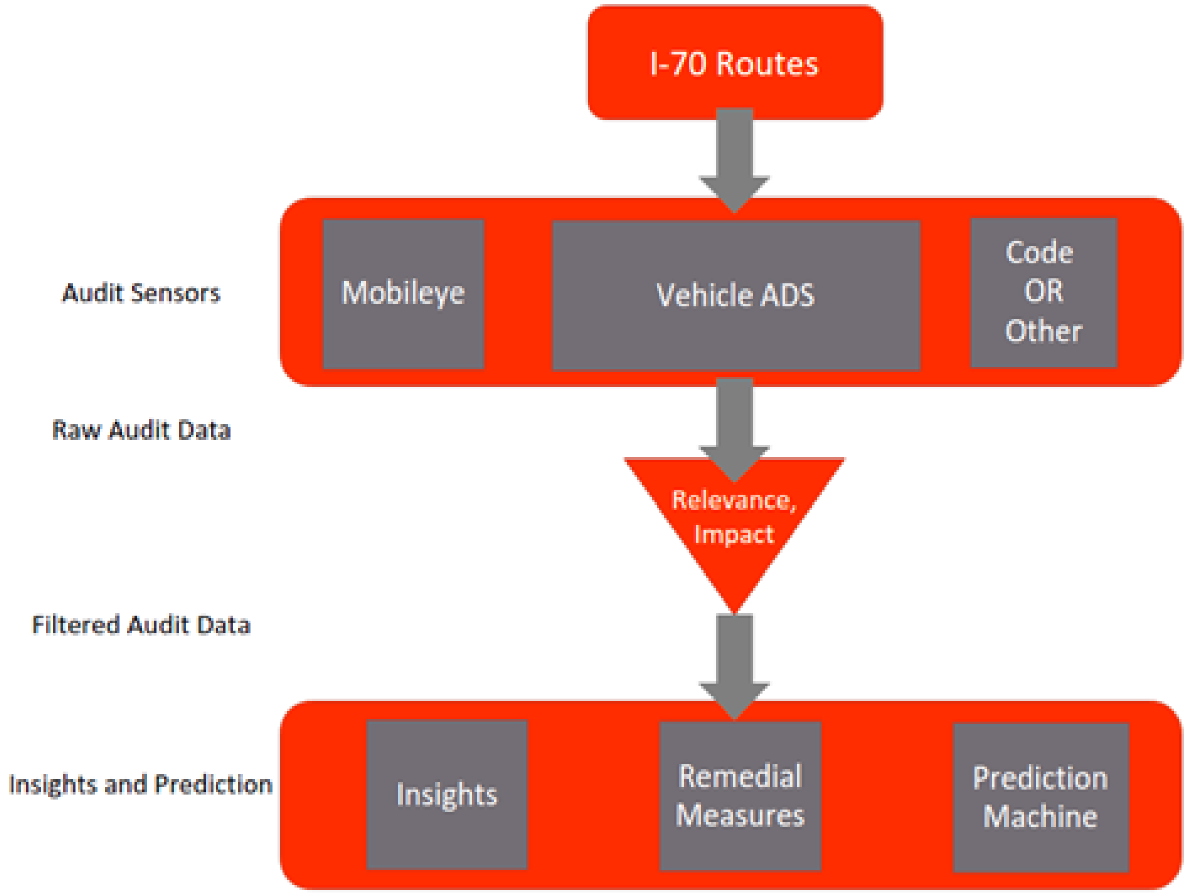
Road Audit Scheme



Elements of Interest – Lane Lines

Priority	Roadway Location	Color	Type	Description
1	Driving Lane	White	Broken	Right side of left lane, Left side of right lane, On both sides of center lanes
2	Ramp Merge and Diverge	White	Dotted[a]	Non taper area of on-ramp merge and off-ramp diverge
3	Lane Shift and Narrow Lanes	Various	Solid	In Work Zones
4	Shoulder and Stay-in-Lane Areas	White/Yellow	Solid	Yellow on left edge of roadway, White on right edge of roadway
5	Ramp Taper	White	Dotted[b]	Optional lane marking upstream of off-ramp diverge or downstream of on-ramp merge

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Elements of Interest – Signs

Priority	Signage Group	MUTCD Category	Relevance to Driving Automation Systems	Notes
1	Speed Limit and variants	Regulatory	Longitudinal control	Some Driving Automation Systems detect select signage.
2	Advisory Speed and Truck Rollover	Warning	Longitudinal and In-lane lateral control	Not detected
3	Do-not-pass, Stay-in-lane	Regulatory	In-lane lateral control	Not detected
4	Keep right except to pass, Trucks use right lane	Regulatory	Lane-change or lane-choice control	Not detected
5	Lights On and variants	Regulatory	Other system behavior	Not detected

Other Elements of Interest

Road Geometry

- Horizontal and vertical curvature
- Line of sight issues
- Infrastructure issues vs. vehicle limitations

Work Zones

- Types of work zones and impact on ADS performance
- Narrowing lane-widths, lane-shifts, non-standard striping, etc.
- Obstacles such as barriers, cones, barrel, etc.
- Ability of ADS to recognize peculiar signage

Road Audit Vehicles and Sensors

Two Audit Vehicles

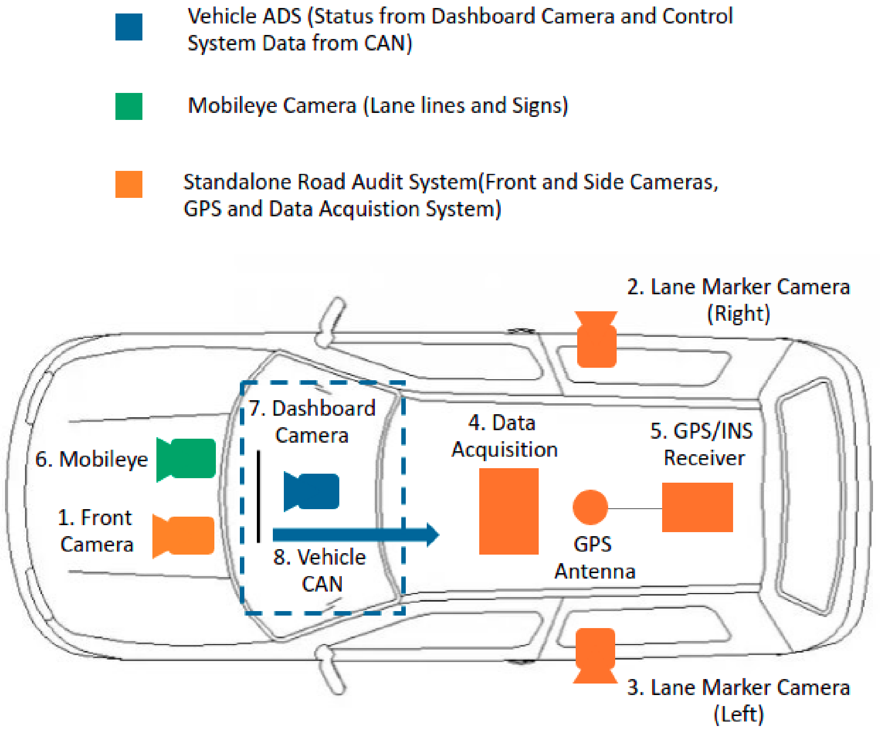
- Honda Insight (Feature Set 1) - Primarily a Machine Vision and RADAR based Driving Automation System.
- Tesla Model 3 (Feature Set 2) - SAE Level 2 features such as Lane Centering, Adaptive Cruise Control, and Traffic Sign Recognition capabilities.

Mobileye

A machine vision based sensor that offers select lane-line and traffic sign detection ability.

TRC's Sensor Suite

- Machine vision cameras with cutom software
- GPS/INS fusion sensor



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Sensor Descriptions and Purpose

Front Cameras

- Context of driving scene
- Lane lines and road sign detection
- Lane marker type and quality
- Lane line curvature
- Sign type
- Sign location

Dashboard Camera

Events reported by vehicle HMI related to ADS status and performance

Mobile Eye

Determine transfer functions between lane line and road sign quality and ADS performance

GPS/INS

- Identify hotspots of infrastructure issues
- GPS satellite coverage
- RTK corrections availability
- Identify anomalies in vehicle behavior attributable to ADS performance issues
- Aid machine vision algorithms

Vehicle Controller Area Network (CAN) Data

Correlation between ADS performance issues due to infrastructure and environment perception vs merely control system limitations

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Analysis Layers

Where is lane-detection performance poor as indicated by the sensor?

Where does detection of identified signage fail?

Where does failed detection negatively influence driving behavior?

What is bad about an observed scene that leads to poor lane-line detection as observed by the audit sensors?

Why is the lane-line detection poor?

What is bad about an observed scene that leads to poor signage detection as observed by the audit sensors?

Why does a sign show poor detection performance?

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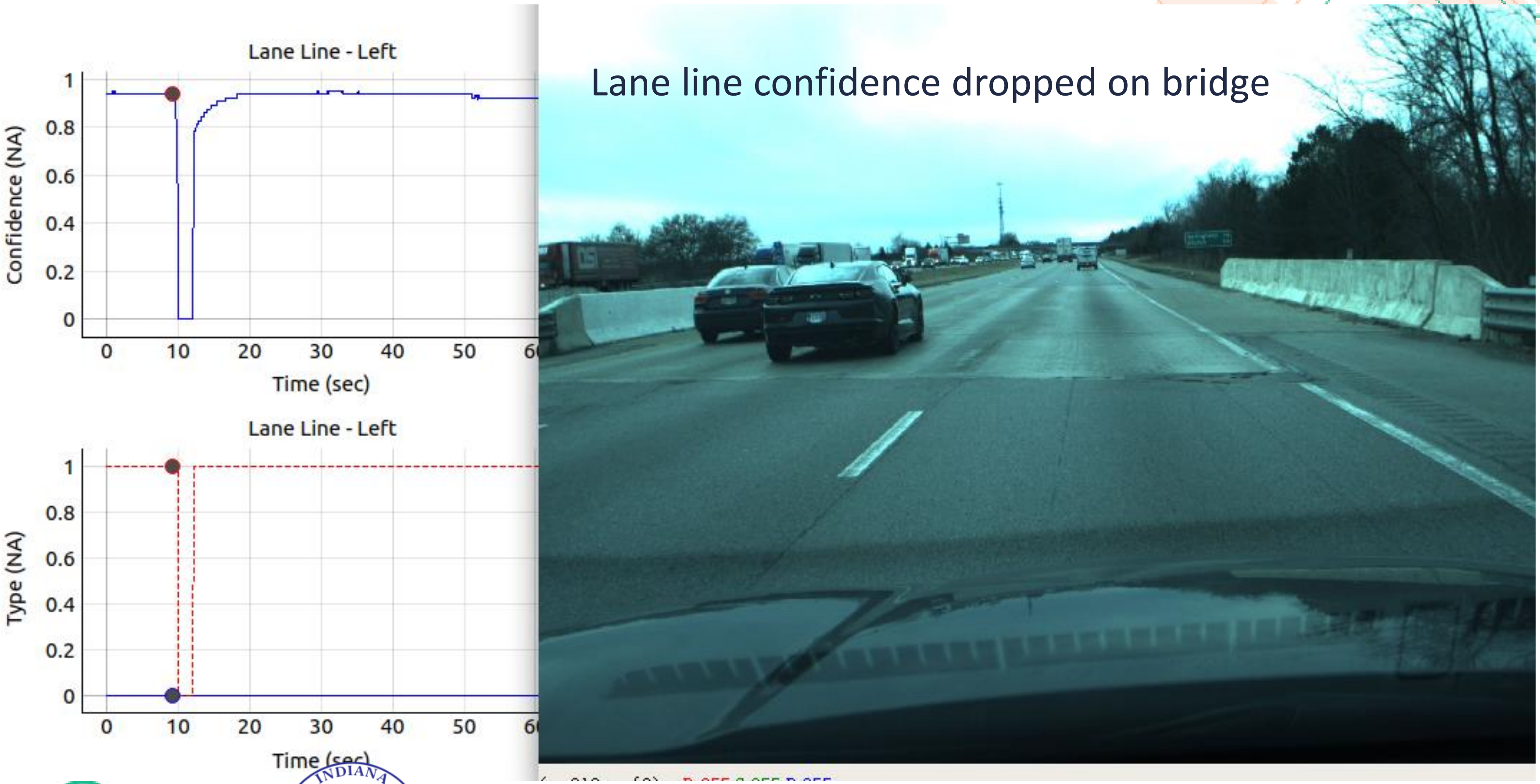
Sample Data



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Sample Data

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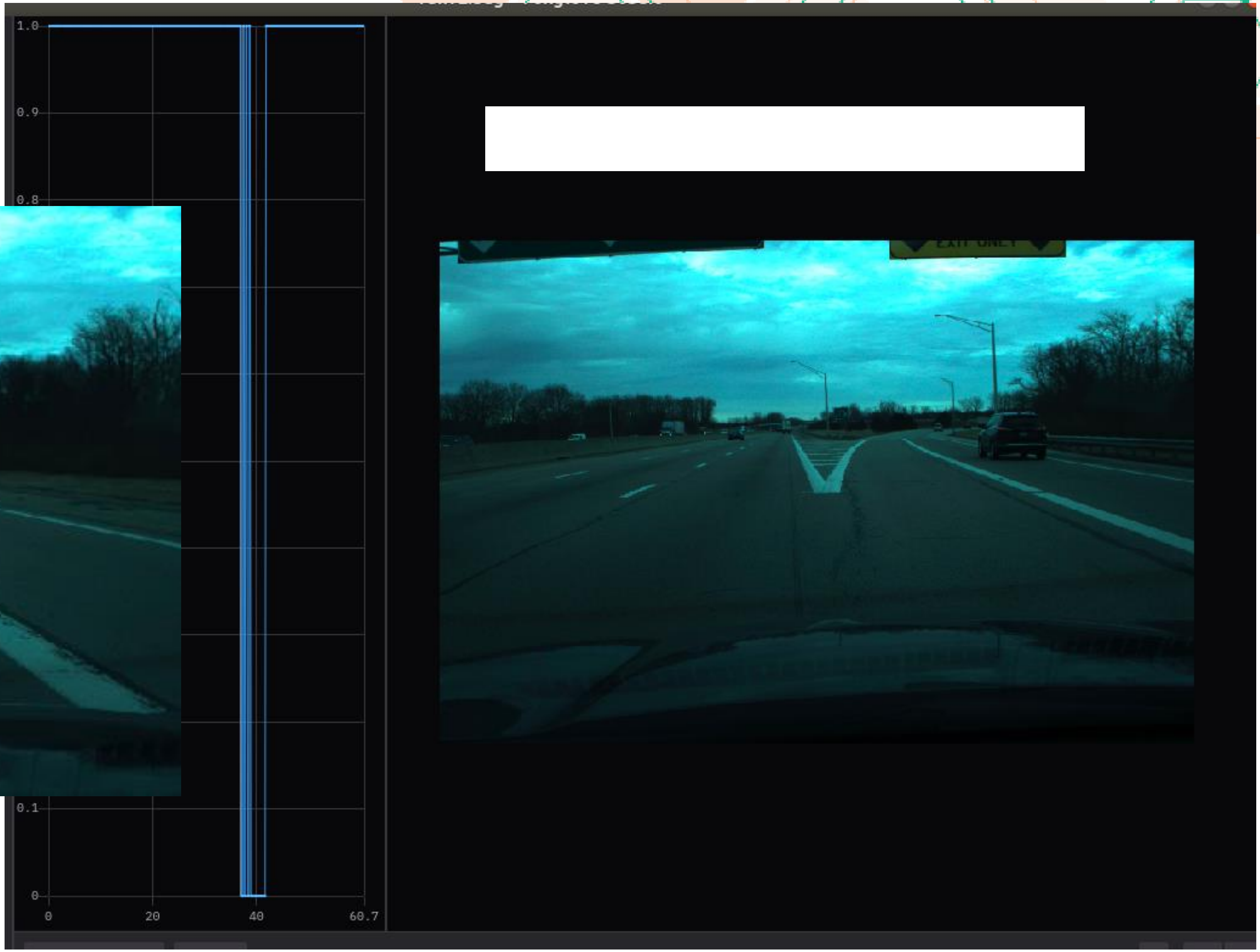
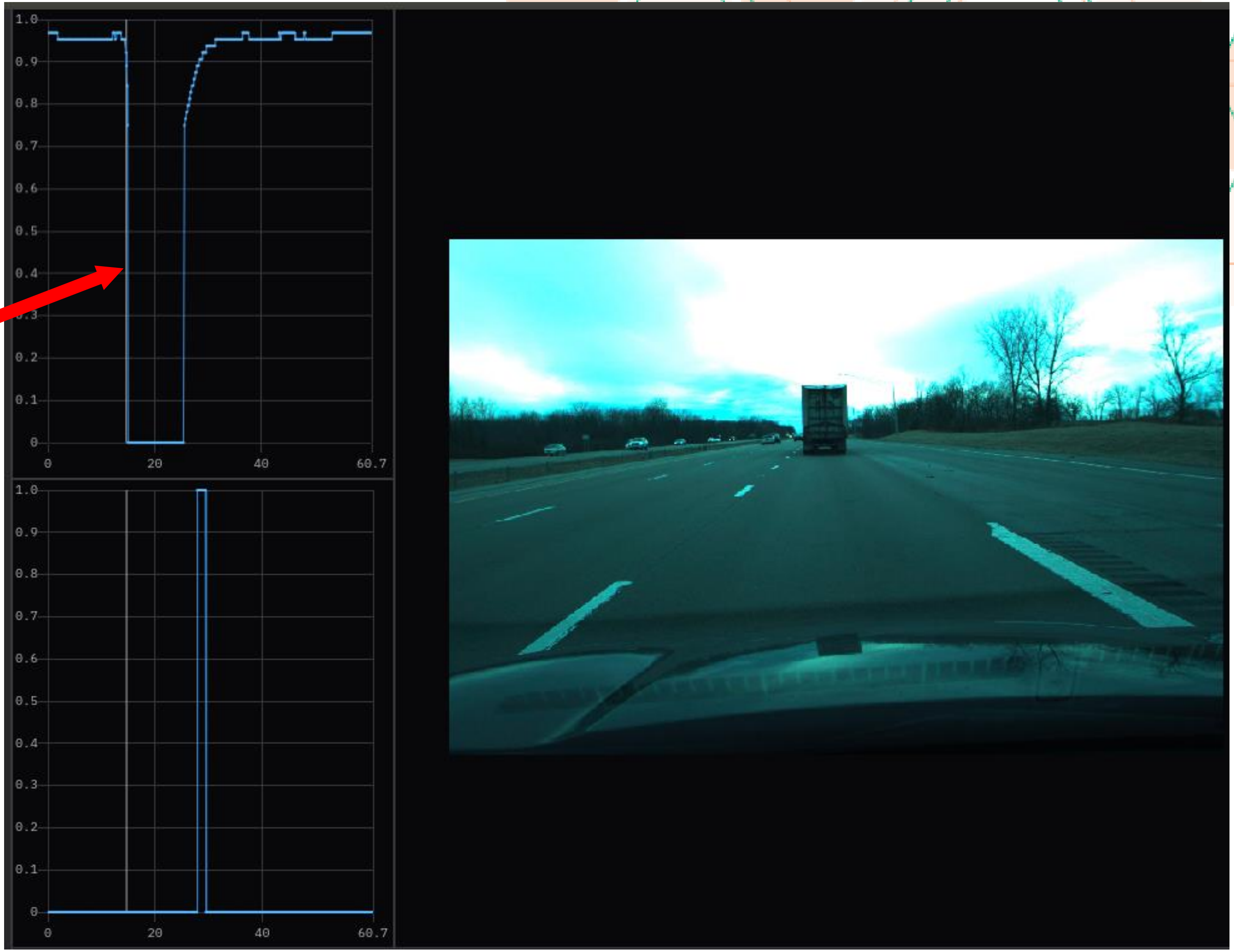
Sample Data



Sample Data

Merging lane

Right line confidence drops

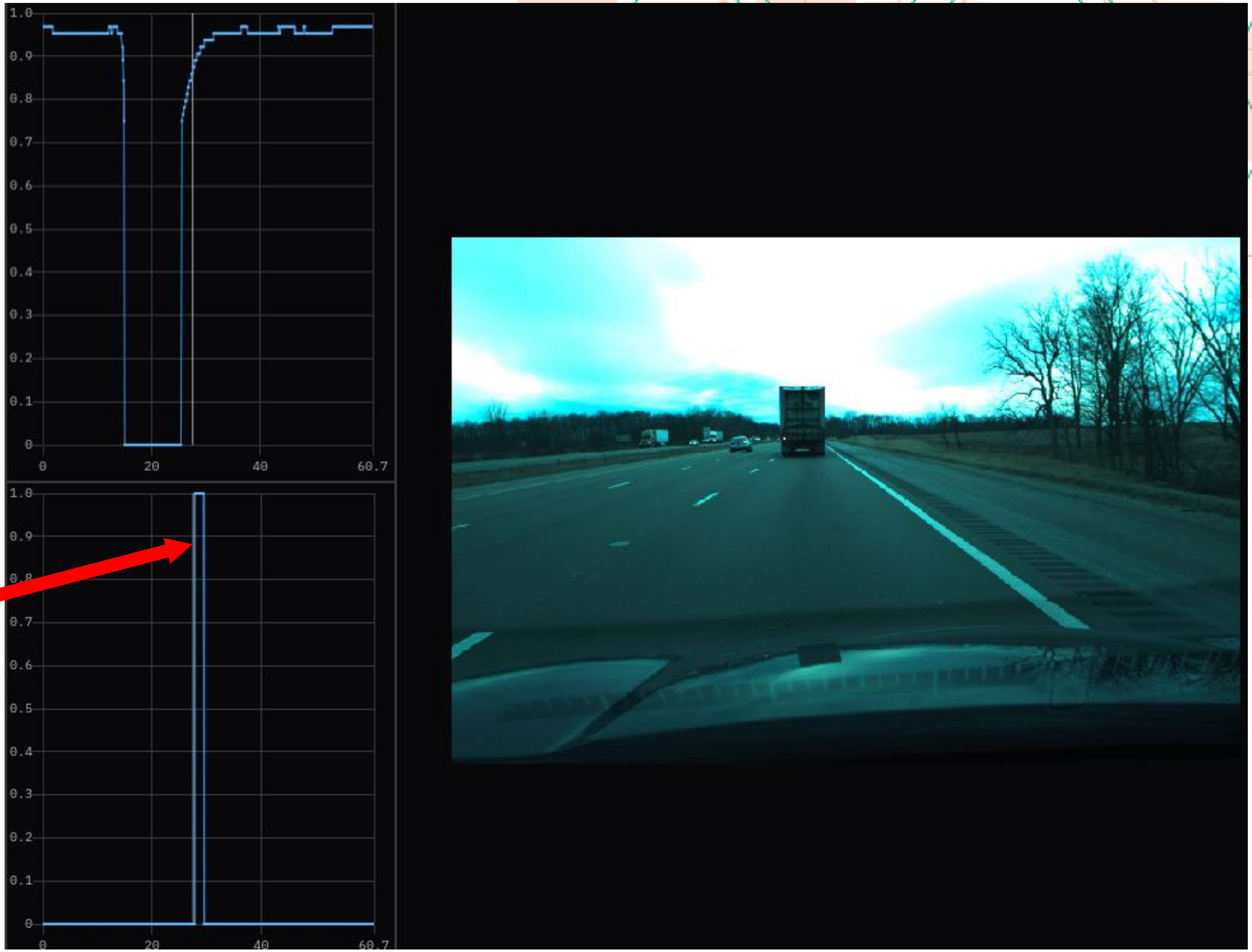


Sample Data

Merging lane

Right line confidence drops

Ends in lane departure



Logistics

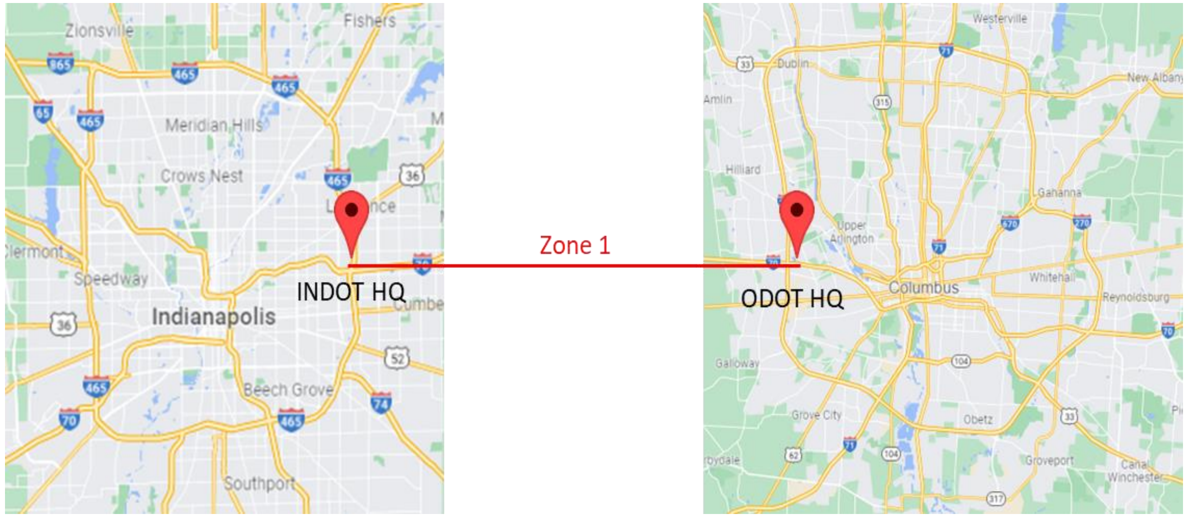
Key Route Audit Activities	Phases of Route Audit Deployment			
	Phase 1: Early Winter – Peak Winter		Phase 2: Peak Winter – Early Summer	
Deployment 1	Feb'22-Apr'22	Data Analysis	Apr'22-June'22	Data Analysis
Insights	Infrastructure insights begin July '22 and continue to facilitate roadway improvements			
Analysis	Continued Engineering to conduct Guidebook Process Development			
Deployment 2	Feb'23-Apr'23	Data Analysis	Apr'23-June'23	Data Analysis

Major freight corridor b/w Ohio and Indiana.

Conditions

- Full-sun
- Night-time

165 miles x 2 directions x 2 conditions x 2 vehicles = 1,320 miles



Wrap-Up

Next Steps

- **Spring 2022:**
  - Road Audit
  - RFI
  - Requirements
- **Summer 2022:**
  - RFP and award
  - Deployment plan

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Project Resources

I70@drive.ohio.gov

www.Drive.ohio.gov/70truckautomation

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Questions?

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