

# Smart Work Zone Safety Initiatives

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12/06/2023



# Smart Work Zone Development Motivations

- Work zone safety remains a top priority for VDOT as crashes and injuries remain stubbornly high
- VTTI and VDOT have been working together to improve work zone safety for more than 15 years
- Recent advances in GPS, communications, and automation technologies create opportunities
  - Automated TMA System
  - Work Zone Builder Application
  - Smart Work Zone System





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# AUTOMATED TRUCK MOUNTED ATTENUATOR (ATMA)

MULTI-PHASE DEVELOPMENT PROJECT

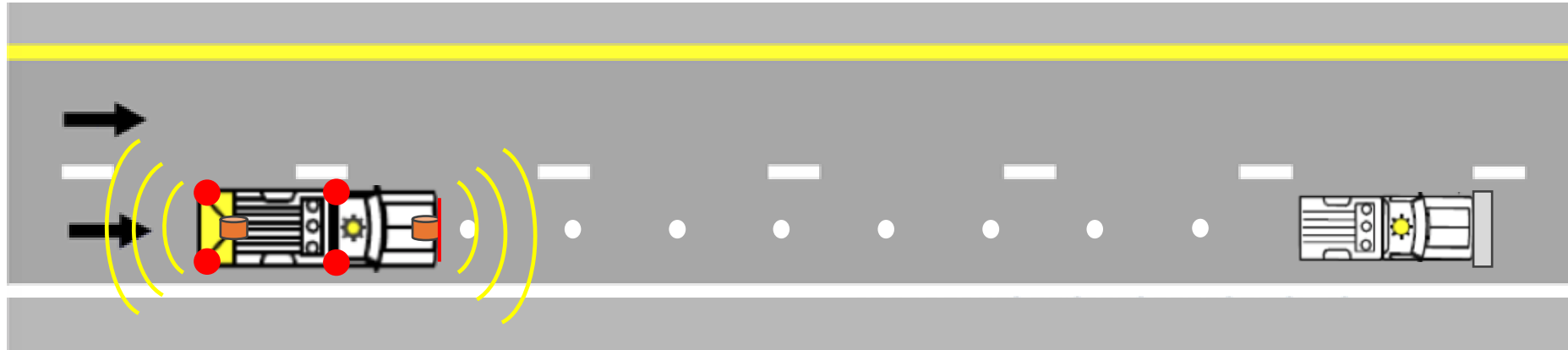


# Automated TMA Program

- Consortia formed to co-fund development of automated TMA prototype
- Multi-phase program
  - Phase 1: Design, build, and demo leader-follower ATMA System (complete)
  - Phase 2: GPS-Denied operations and reduced BOM (fall 2023)
  - **Phase 3: Advanced testing on public roadways (spring 2024)**
- Targeted Outcome
  - IP package suitable for commercialization



# Leader-Follower System Components



## FV Features

- AVR Computer
- HMI tablet
- V2V communications
- GPS with RTK
- IMU
- Machine vision lane line tracking system
- LIDAR
- Forward radar
- Rear radar
- Forward camera
- 4 external e-stop plungers (red)
- Forward e-stop bar
- Internal revert to factory e-stop
- Remote wireless e-stop
- VTTI data acquisition system

## V2V Transmission Content

- System and position status
- GPS path information
- Operational modes
- Commanded headway
- Commanded lane offset
- Lane line offsets
- Waypoint management (hold/release)
- Object detection in safety zone

## LV Features

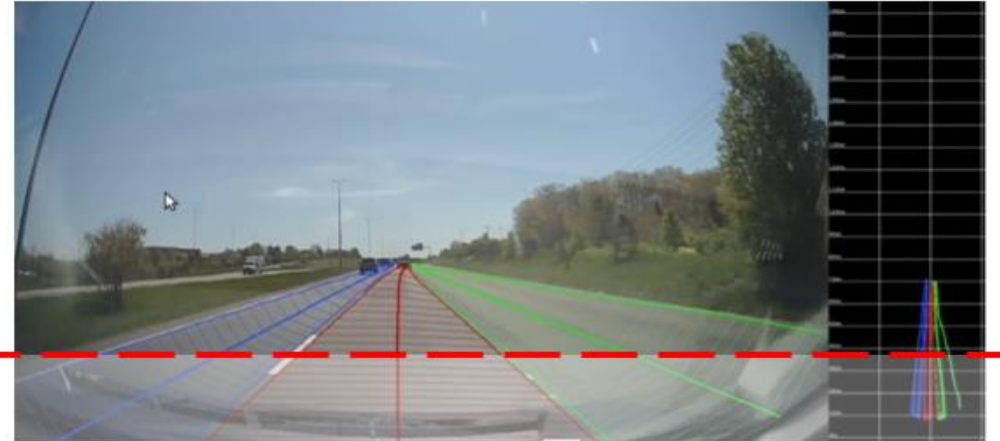
- AVR Computer
- HMI tablet
- V2V communications
- GPS with RTK
- IMU
- Machine vision lane line tracking system

# Phase 2 – Objectives

- Incorporate a machine vision lane line tracking solutions to supplement GPS
- Add safety features to support transition to on-road testing
- Increase operating speeds beyond 15mph
- Reduce BOM and system costs, simplify lead package
- Conduct on-road pilot testing in live operations



# Machine Vision to Support GPS-Denied Operation

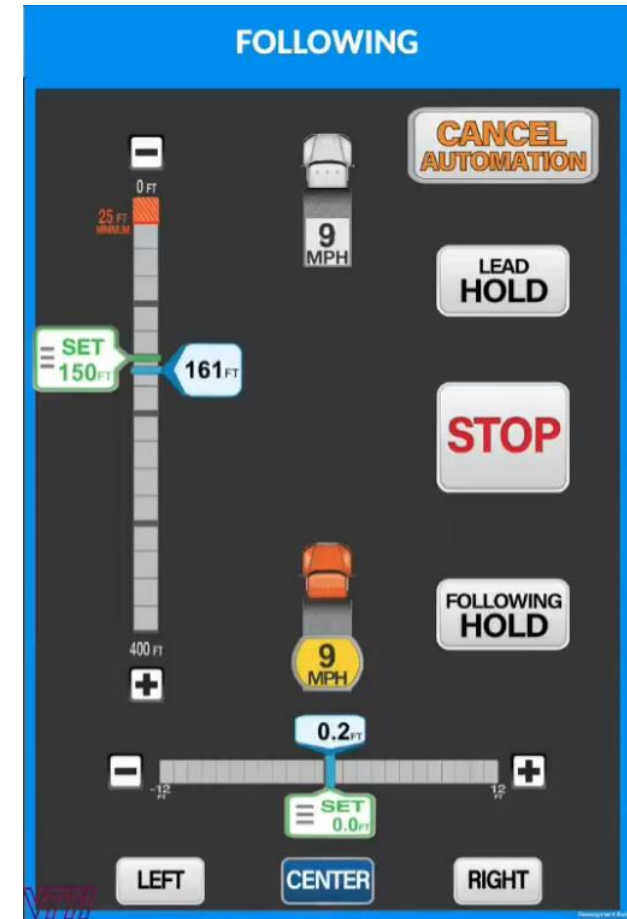


- Video-based lane detection
- Leader offset sent to follower along with longitudinal distance provides future waypoints for follower
- Supports lane-based lateral offset commands



# Current Functionality

- Lead-follower operation with portable lead package
- GPS primary plus supplemental machine vision for GPS-denied operation with smooth transition
- Speeds tested up to 40mph, suggested operation 15mph or less
- Lead vehicle HMI to command operational parameters
- Lateral offsets +/- 12 ft, longitudinal offsets of 50 to 400 ft
- Manual hold and release
- Static and dynamic forward object detection and response
- Left side, right side, center tracking modes
- Integration with remote operation monitoring system

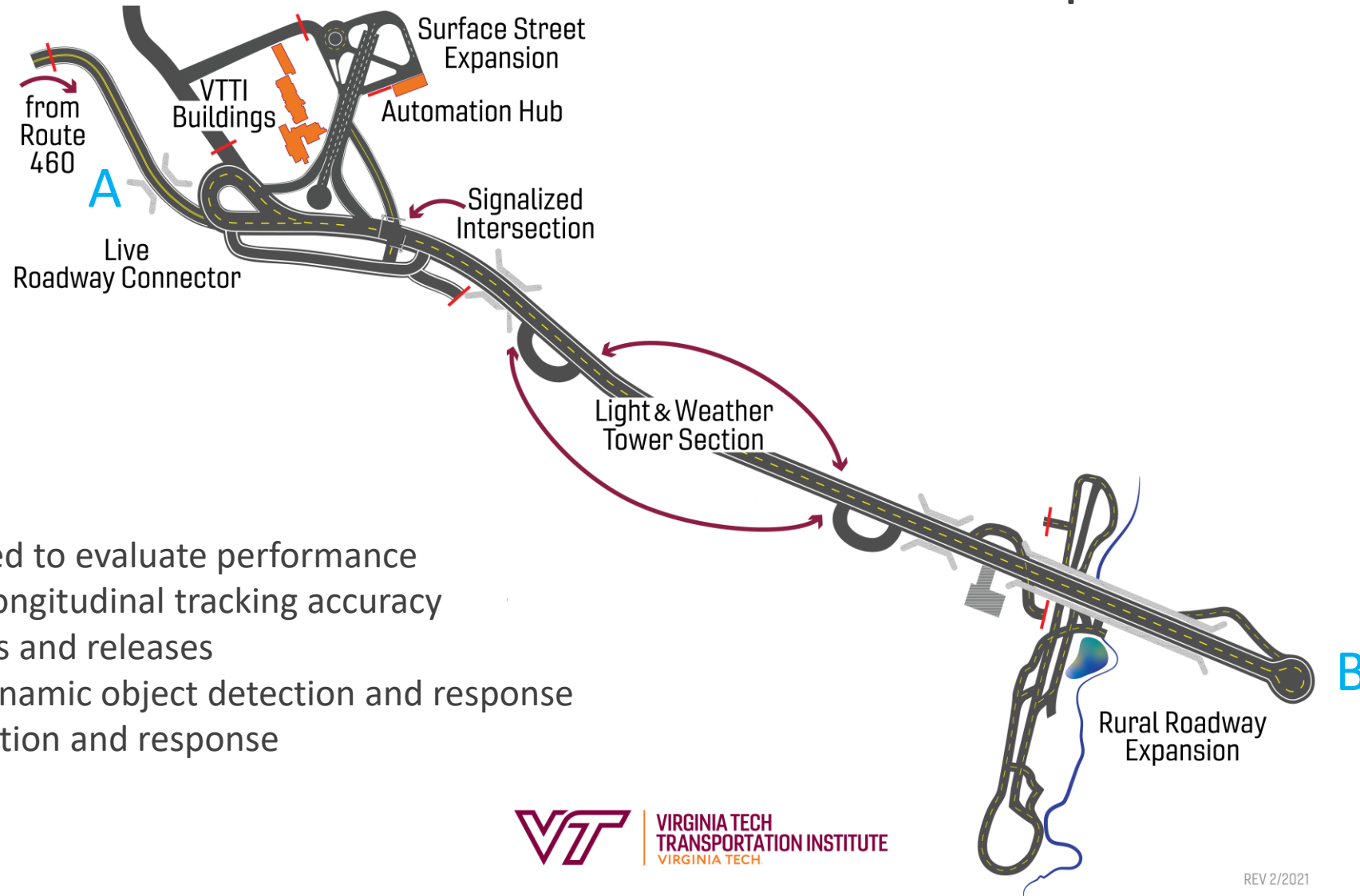




FOLLOWING



# VTTI Smart Road Full 2.2 Mile Loop

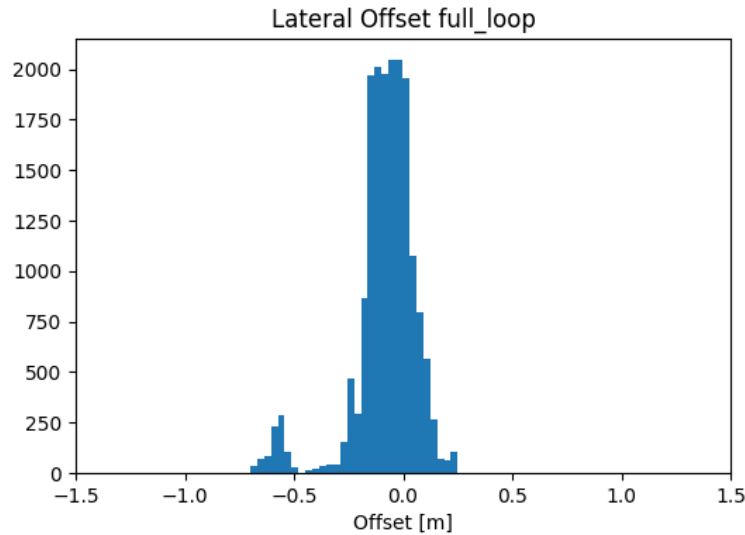


44 Tests executed to evaluate performance

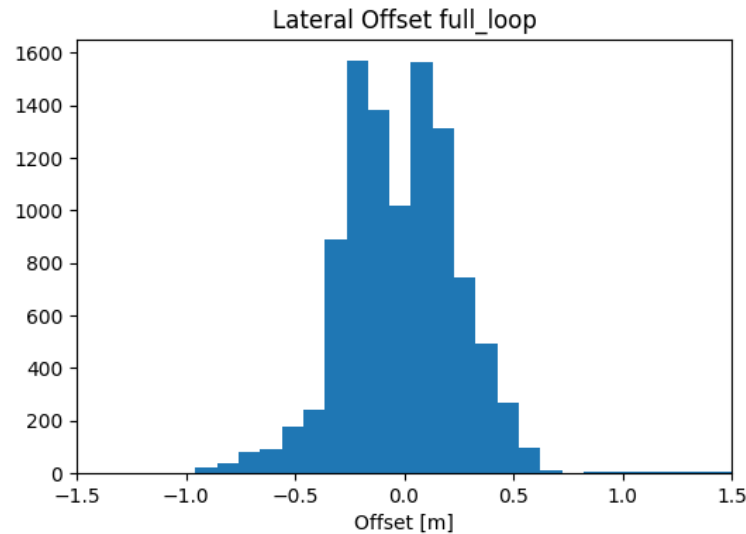
- Lateral and longitudinal tracking accuracy
- Manual holds and releases
- Static and dynamic object detection and response
- E-Stop activation and response

# Lateral Accuracy Full Loop, GPS + Vision

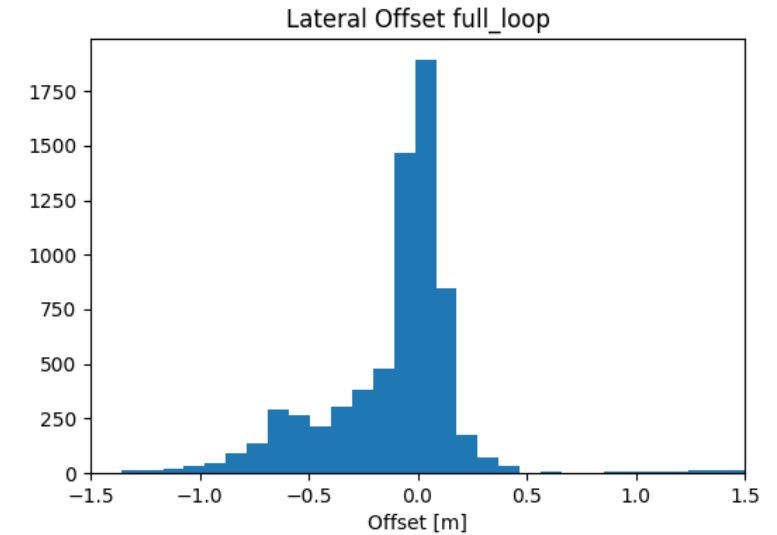
5MPH



15MPH



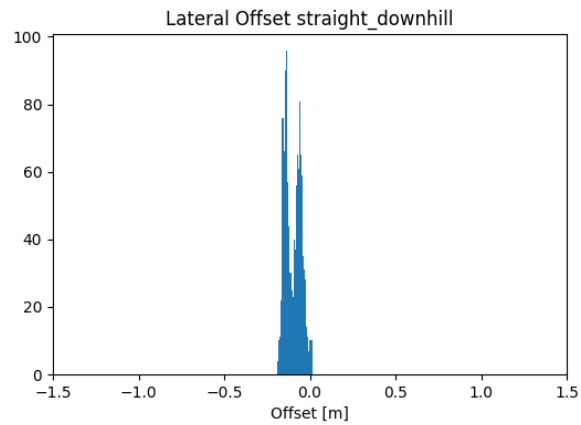
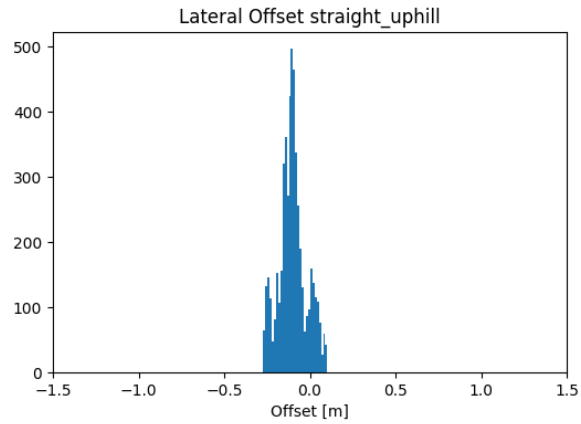
25MPH



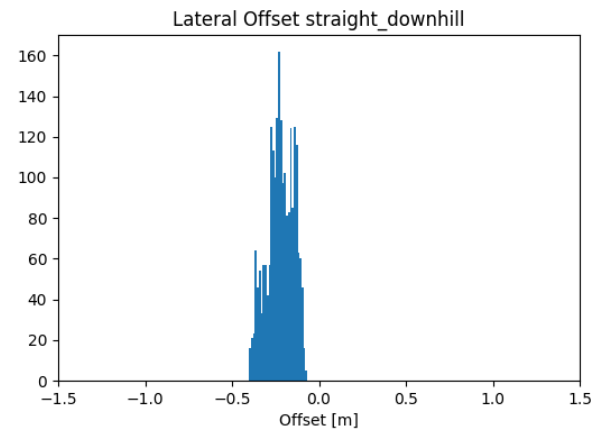
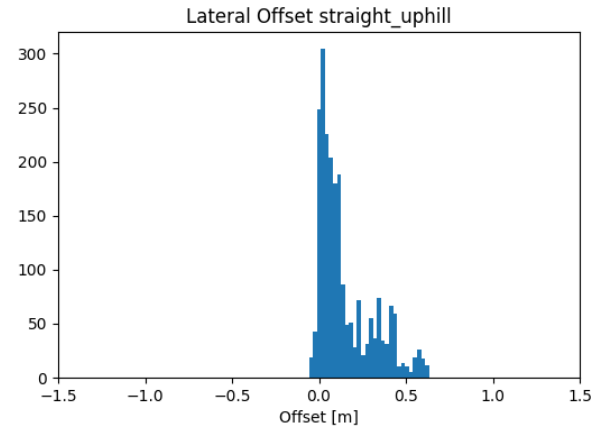
- System biases towards the inside of turns slightly
- Bulk of lateral error at 5mph is under 1 foot
- Bulk of lateral error at 15-25mph is under 2 feet
- Curve radii are 114ft and 262ft, much tighter than planned ODD

# Lateral Accuracy Straights, GPS + Vision

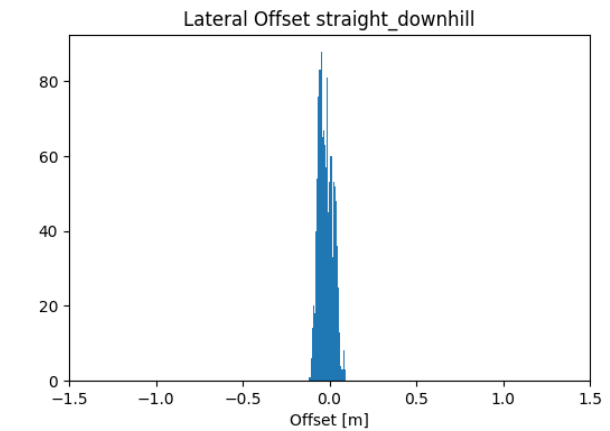
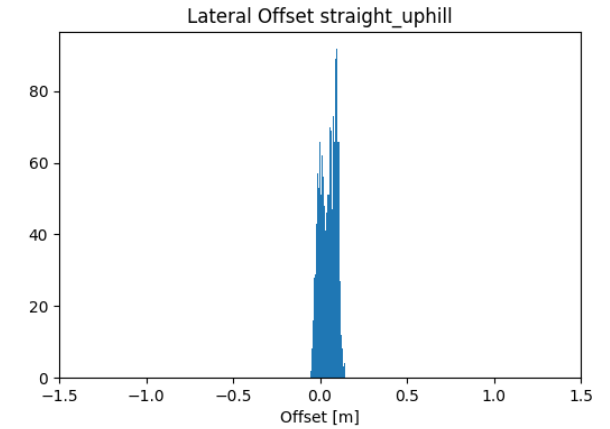
5MPH



15MPH



25MPH





# Phase 2 Current Status

- Test track performance testing was completed and results shared with Stakeholder group and VTTI Safety Committee
- Plans created for integrating into Dynamic and Short Duration TTC configurations
- Pilot test sites have been selected in Staunton, Hampton Roads, and Salem VDOT Districts
- Initial on-road testing in Blacksburg US460 completed in September
- Staunton piloting completed October 17-18, positive feedback from crews
- VTTI safety driver will remain in ATMA during these pilot tests



# Phase 3 Planning

- Seeking opportunity for broader deployment in Virginia with multiple vehicles and in other districts – demonstrate this success in the Commonwealth
- Feature enhancement to support special cases
- Automated Maintenance Technology PFS interest
- Negotiating commercialization opportunities with an industry partner



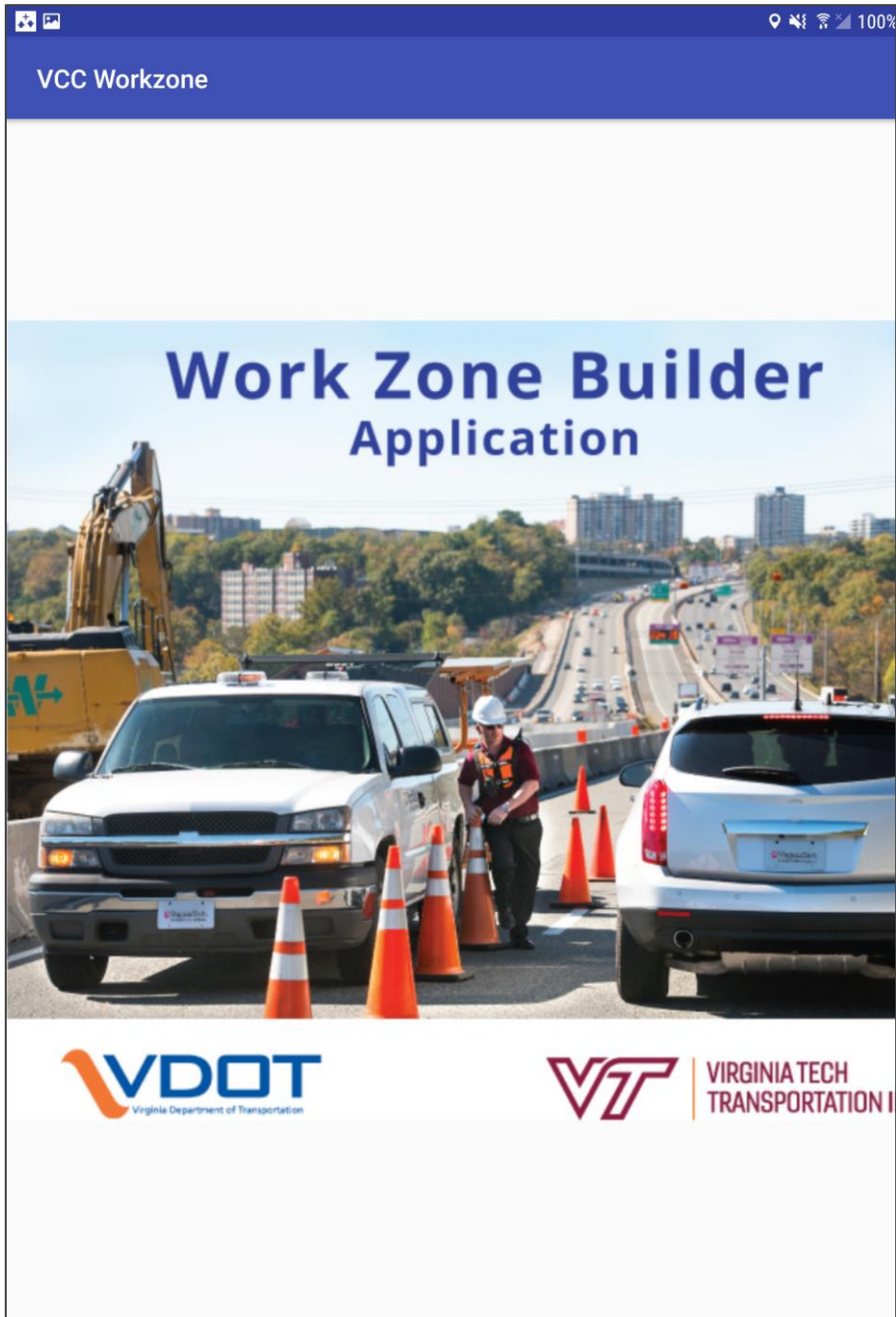


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# WORK ZONE BUILDER

WORK ZONE DESIGN AND DEPLOYMENT APP



# Work Zone Builder Application

- Tablet-based application to create and manage work zone plans
- Produce data that connected and automated vehicles will need to safely navigate work zones
- Streamline submission, review, and approval processes
- Create an app that work zone managers want to use
- Support operations with Design, Field, and Capture modes
- Provide a means to source data for Work Zone Data Exchange and 3<sup>rd</sup> party applications





### Quantal Report

- Area Board - 100' x 100'
- Planning & Survey Station
- Buffer - 100' x 100'
- ▲ Survey
- Way - 1000' x 1000'
- Right-of-Way Station (100' x 100')
- Right-of-Way Station (100' x 100')
- Right-of-Way Station (100' x 100')
- Right-of-Way Station (100' x 100')

Map - 2000' x 2000'

Map - 2000' x 2000'

Map - 2000' x 2000'



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# SMART WORK ZONE TECHNOLOGY DEVELOPMENT

MODULAR WORKER PROTECTION SYSTEM

# Smart Work Zone Components

- Main Components:
  - Smart Vest/Helmet
  - Smart Cone
  - C-V2X Base Station
- Work Zone Builder App





# Smart Vest / Helmet / Pocket Devices

- Wireless mesh network integrates to base station
- GPS+RTK module
- Inertial measurement unit
- Redundant modes of warning
  - Vibrating motors
  - Chirping buzzer
  - LED illumination
- 22 hours battery life





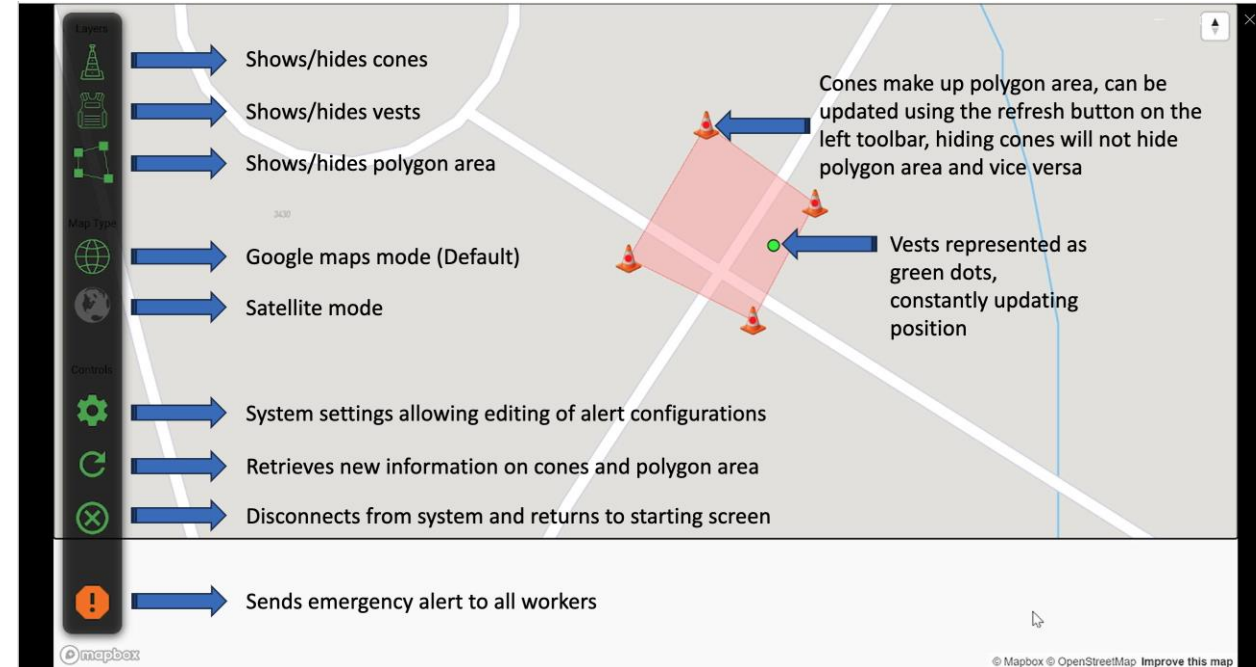
# Base Station

- Communications management and edge processing
- Wireless mesh network integrates with other devices
- 4G module for communications to cloud
- GPS+RTK module
- Can be mounted on vehicle, infrastructure, or temporary trailer
- C-V2X roadside unit functionality broadcasts worker presence and collision warnings to passing connected vehicles



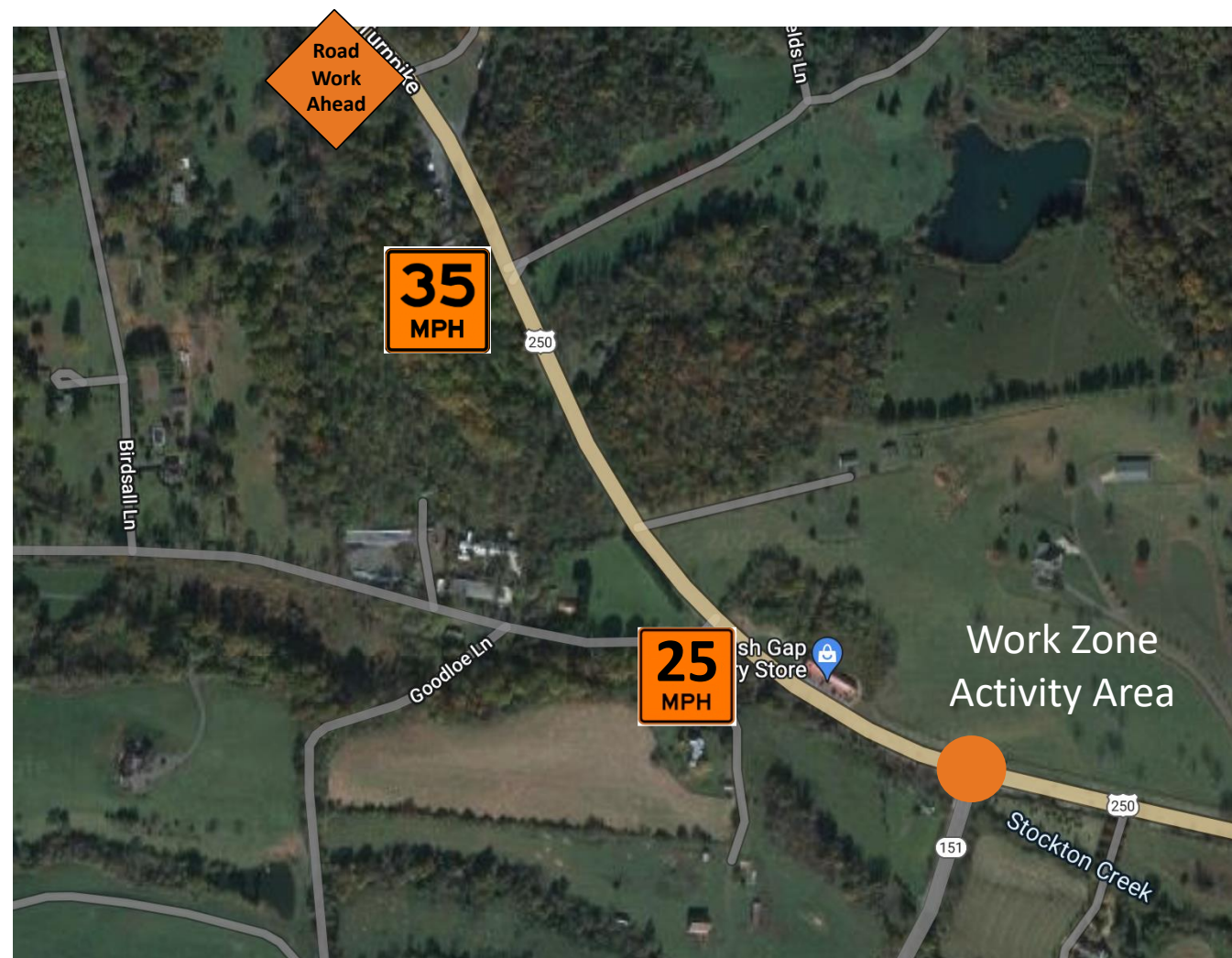
# Situation Awareness Application

- Provides overview of work zone layout over map
  - Locations of smart cones, vests, helmets, equipment
  - Adjust boundaries
  - Send warnings to workers
- Expanding functionality based on pilot deployment feedback
- Will support plug and play sensor addition in future



# Field Trial – VA Rt 250/151 Roundabout

- Requested trial in dangerous intersection project
- 3 incursions in 2 months with equipment being hit
- Desired advanced warning of high-speed approaches
- System provides 8s warning when vehicles detected greater than 55 mph in 35 mph zone



# Field Trial – VA Rt 250/151 Roundabout

- Steep descent grade: 8%
- Multiple runaway trucks during construction – loss of brakes
- Previous intersection allowed trucks to go straight through to reestablish control at the bottom straightaway
- Issued Air Horns to field personnel as a measure of safety
- VDOT team was introduced to VTTI in Blacksburg, VA
  - Introduction to Move Over Law (MOL) System: 09/29/2022
  - System Testing: 10/28/2022
  - Field Implementation: 11/09/2022 (41 days after learning about the system!)



# Old vs New Intersections: Cause for Concern

• Old Intersection



**New Intersection**

**Notice the overturned truck?**



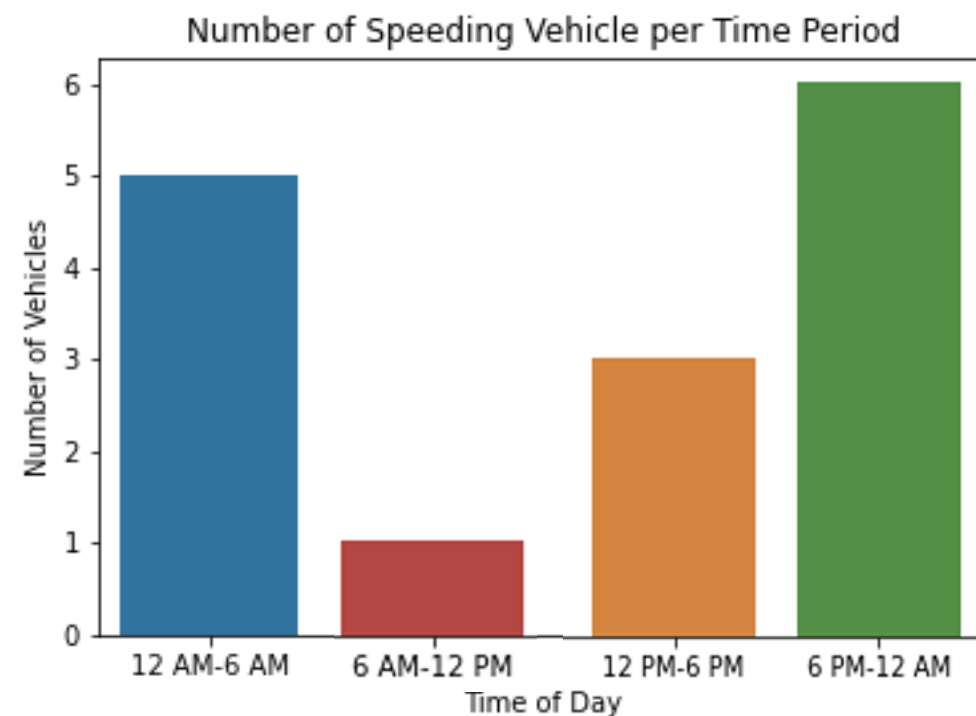
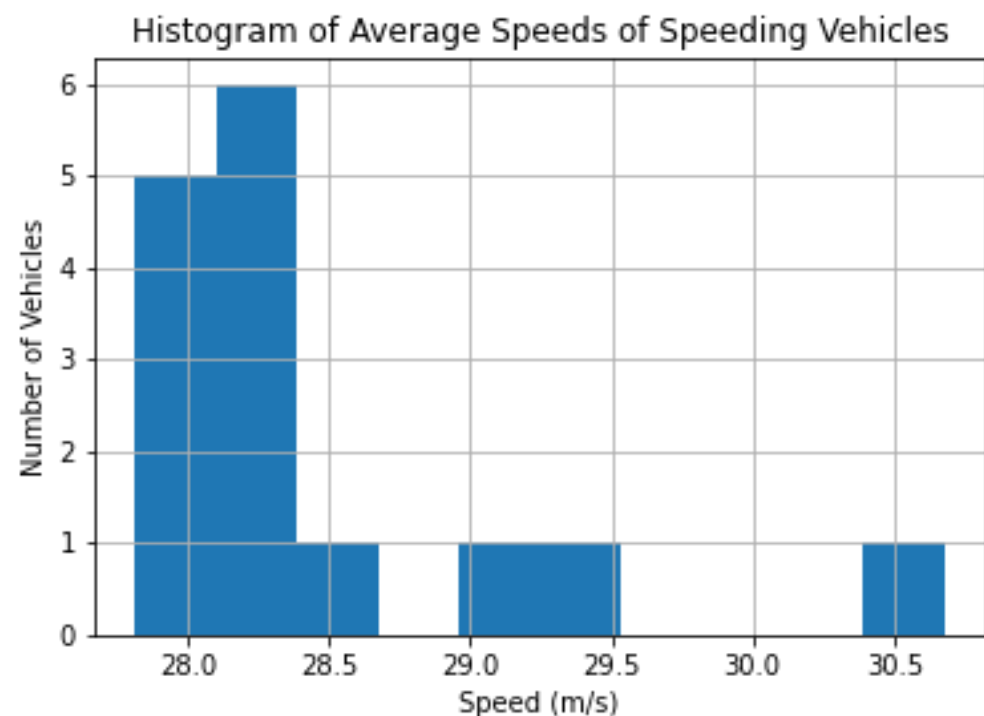
# Field Trial Setup







# Sample Frequency Data

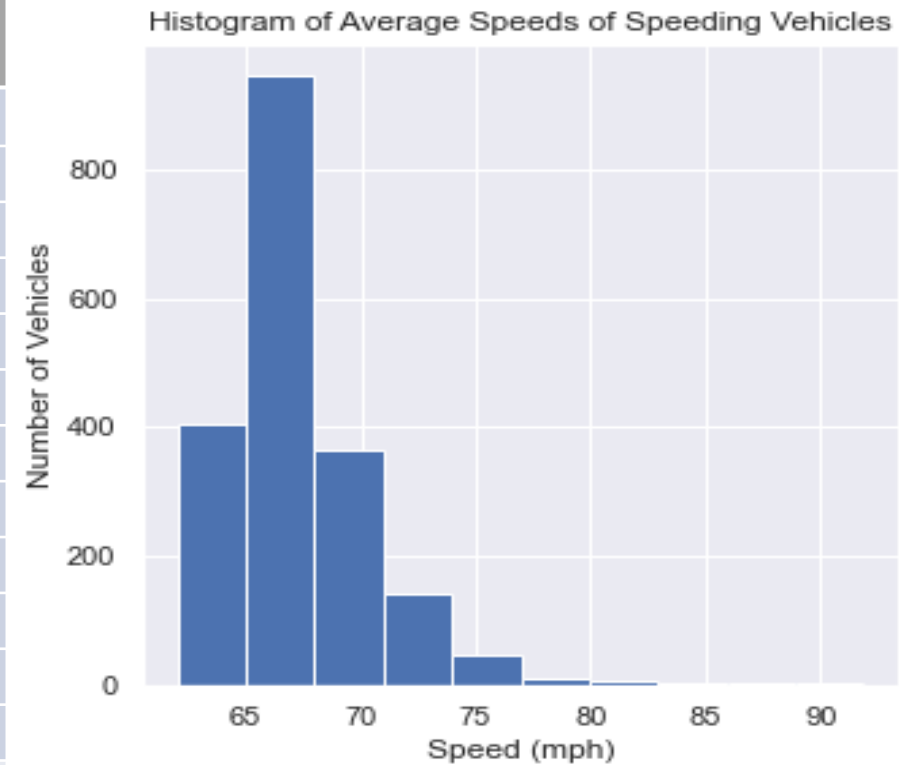


Number of vehicles observed at greater than 60mph



# Data Metrics Combined

Date Range	Total Number of Speeding Vehicles				
05/03-05/09	135				
05/10-05/16	142				
05/17-05/23	212				
05/24-05/30	139				
05/31-06/06	148				
06/07-06/13	72				
06/14-06/20	200				
06/21-06/27	197				
06/28-07/04	255				
07/05-07/11	154				
07/12-07/18	192				
07/19-07/26	83				
<b>Total</b>	<b>1929</b>				
Date Range	12 AM - 6 AM	6 AM - 12 PM	12 PM - 6 PM	6 PM - 12 AM	Total
05/03-07/26	315	572	491	551	1929



> 65 mph in a 45 mph zone



# Questions?

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