Artificial Intelligence and Machine Learning in DelDOT Integrated Transportation Management System (ITMS)

February 13, 2023

DelDOT

U.S. Department of Transportation
Federal Highway Administration

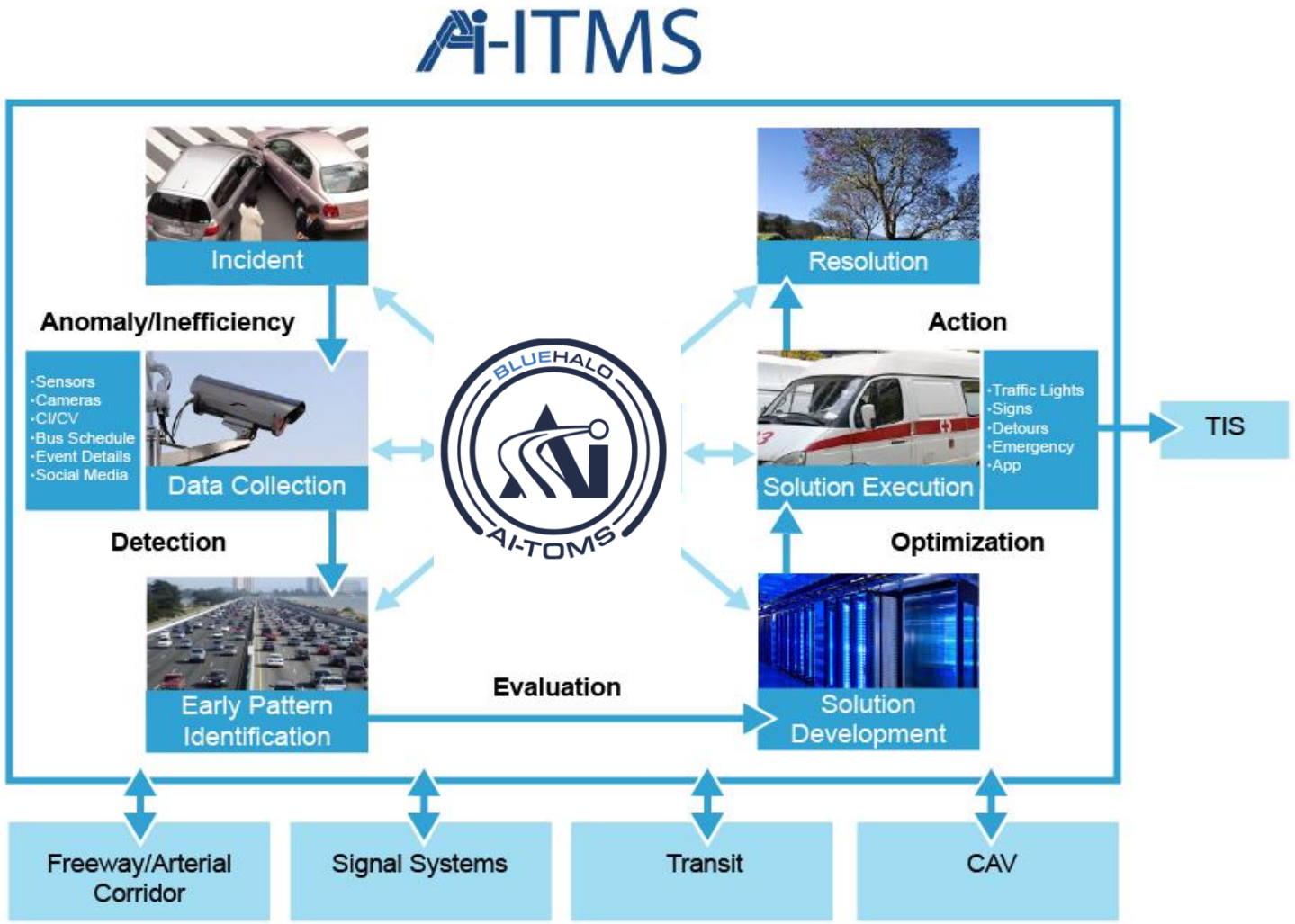
JACOBS

BLUEHALO

Outline

- AI-ITMS Program and Status
- Short Term Traffic Flow Prediction algorithms
  - Robust Long Short-term Memory (LSTM) for freeway detectors
  - Graph Structural Learning for Time Series (GTS) for surface network
- Example Applications
  - Traffic Simulations
  - Congestion/incident impact prediction
  - Incident mitigation
- Vision for the Next Steps

AI Enhanced Integrated Transportation Management System (AI-ITMS)

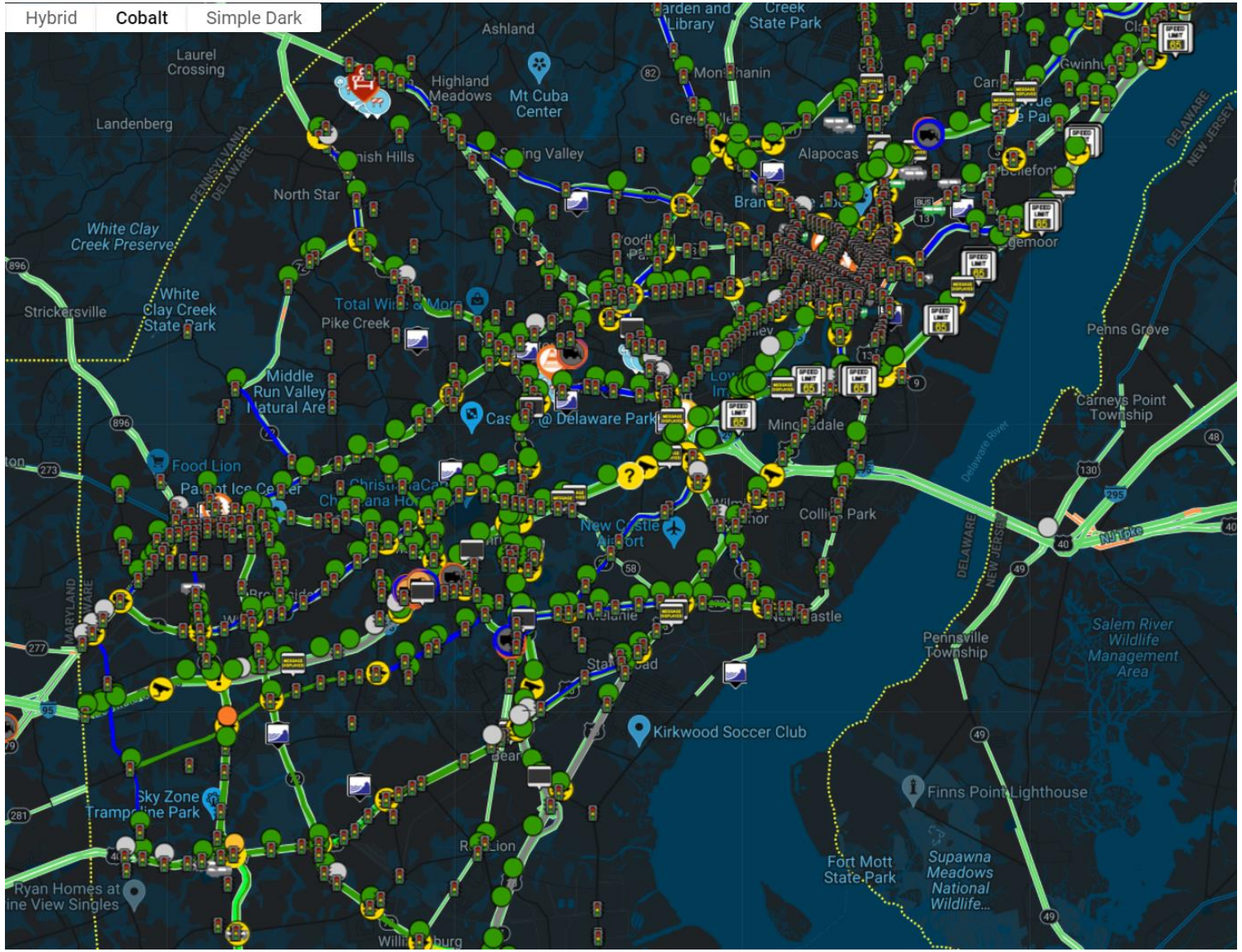


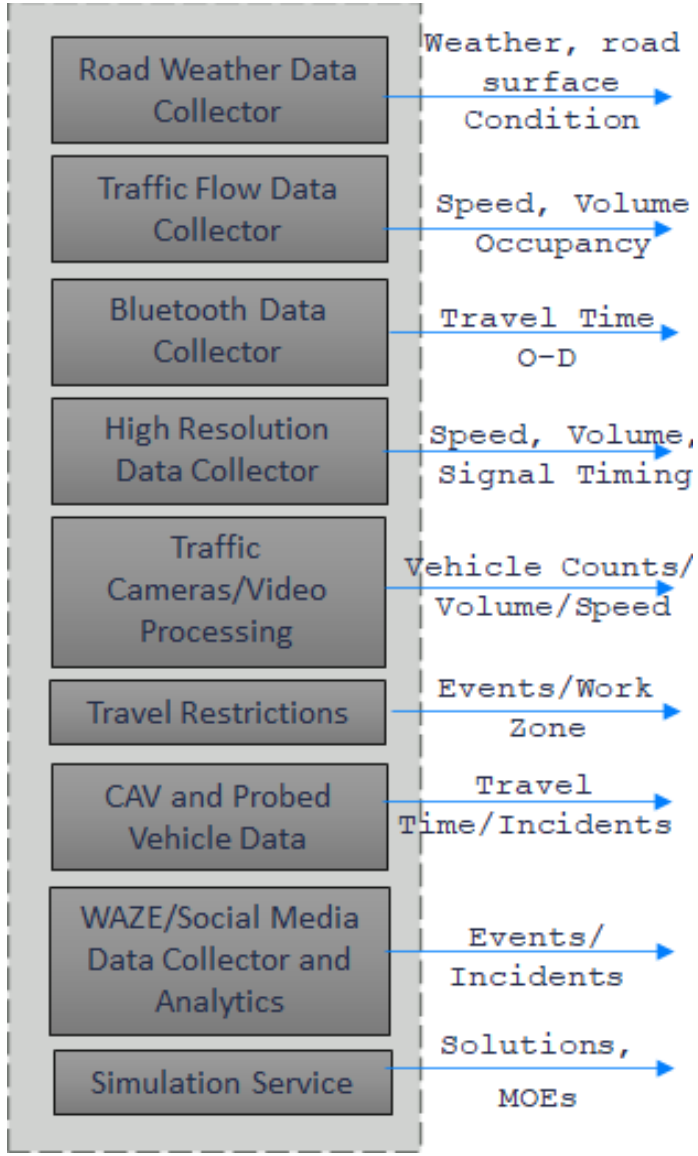
USDOT/DelDOT "Advanced Transportation and Congestion Management Technologies Deployment (**ATCMTD)**"grant

The Vision of **AI-ITMS:**

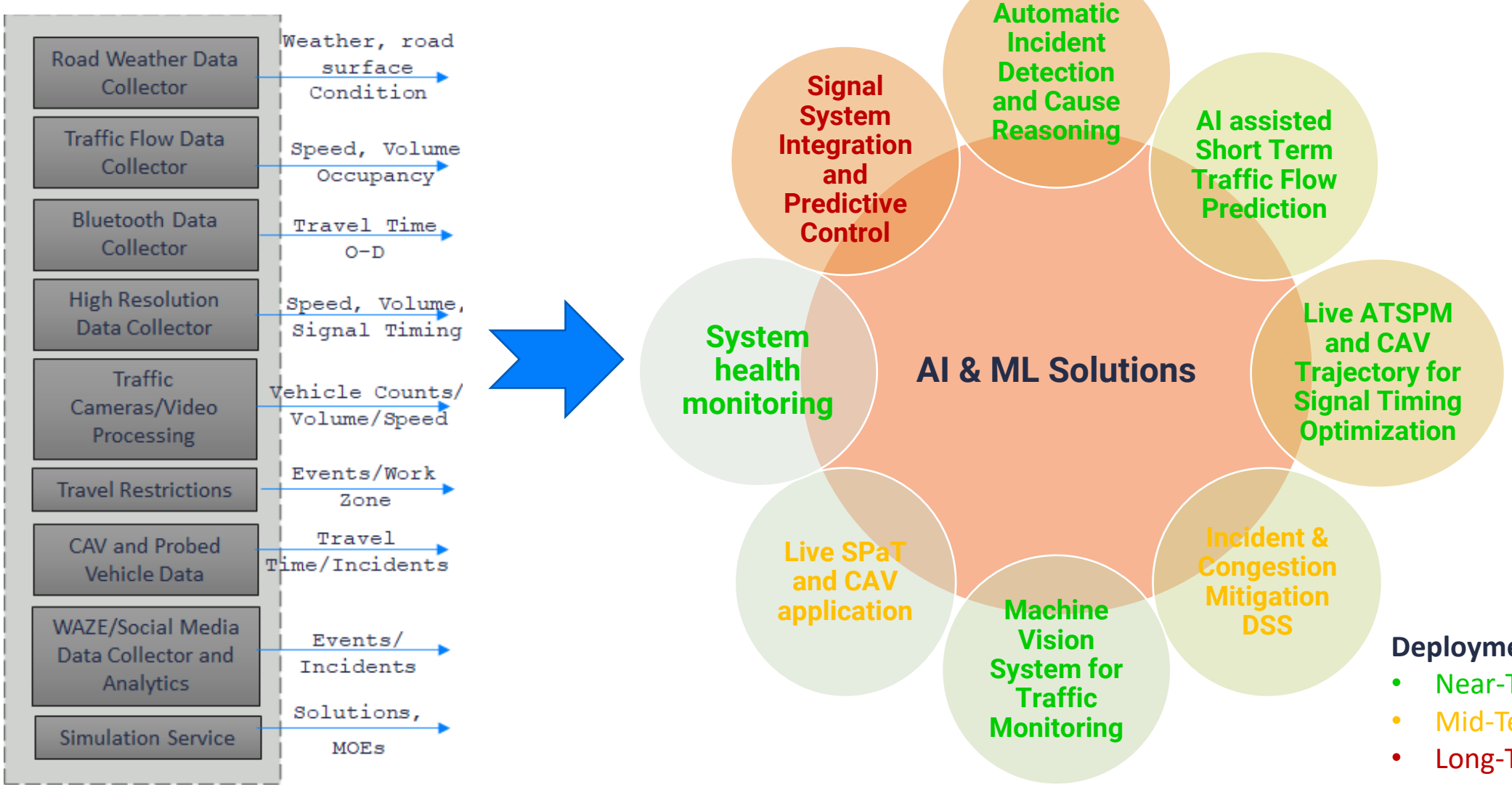
- Automate and optimize transportation systems monitoring and operations
- Early and accurate detection and identification of transportation systems anomalies and inefficiencies,
- Reason the cause and impact of anomaly/inefficiencies,
- Develop corresponding solutions and manage the system proactively

Transportation System “Big Data”





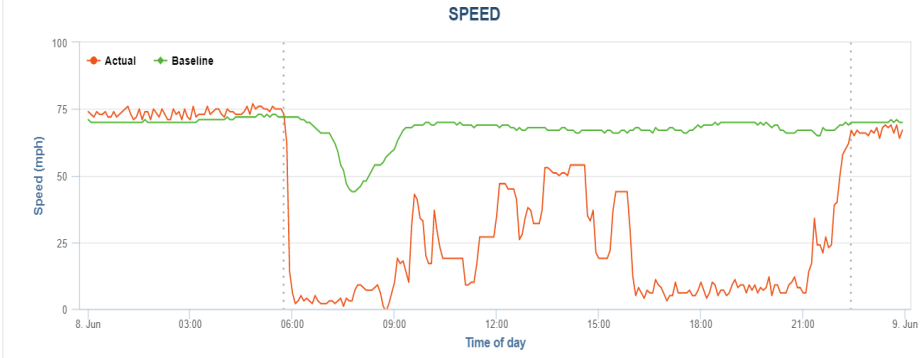
Key Modules of AI-Transportation Operation and Management System (AI-TOMS)

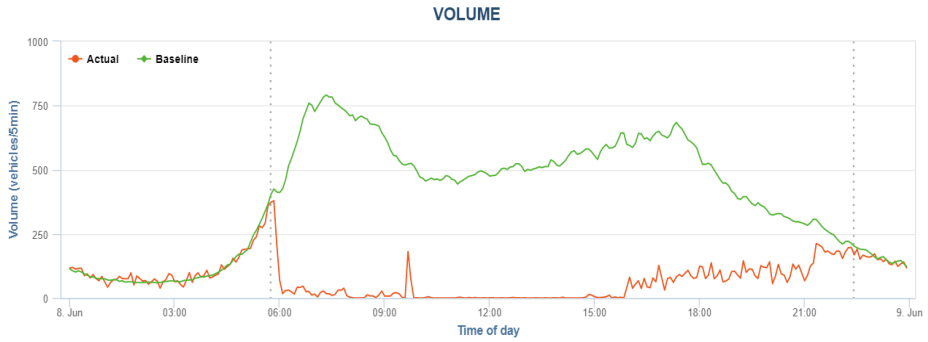


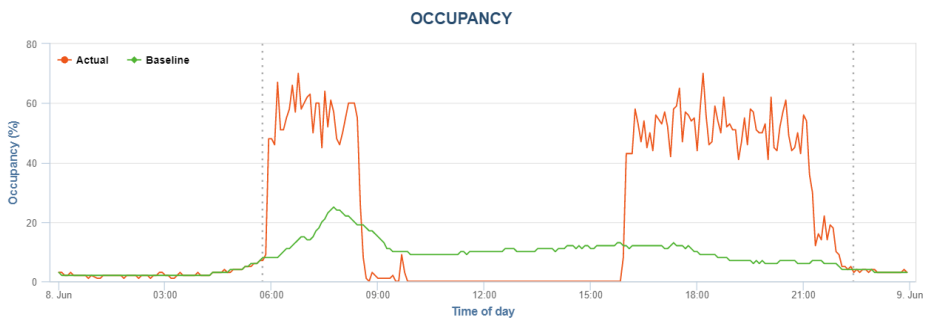
Deployment Readiness:

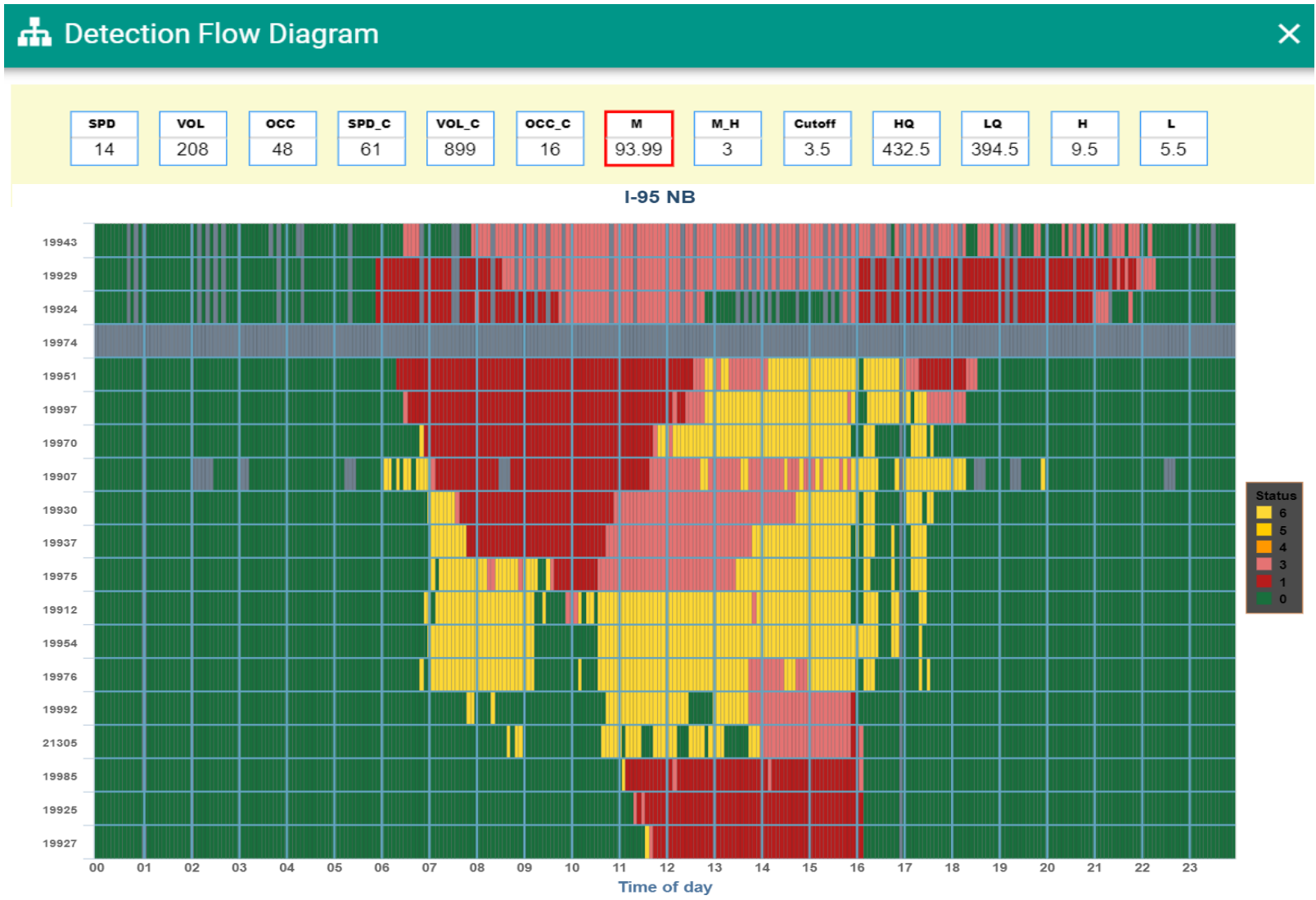
- Near-Term
- Mid-Term
- Long-Term

Traffic Anomaly Detection with Data Fusion





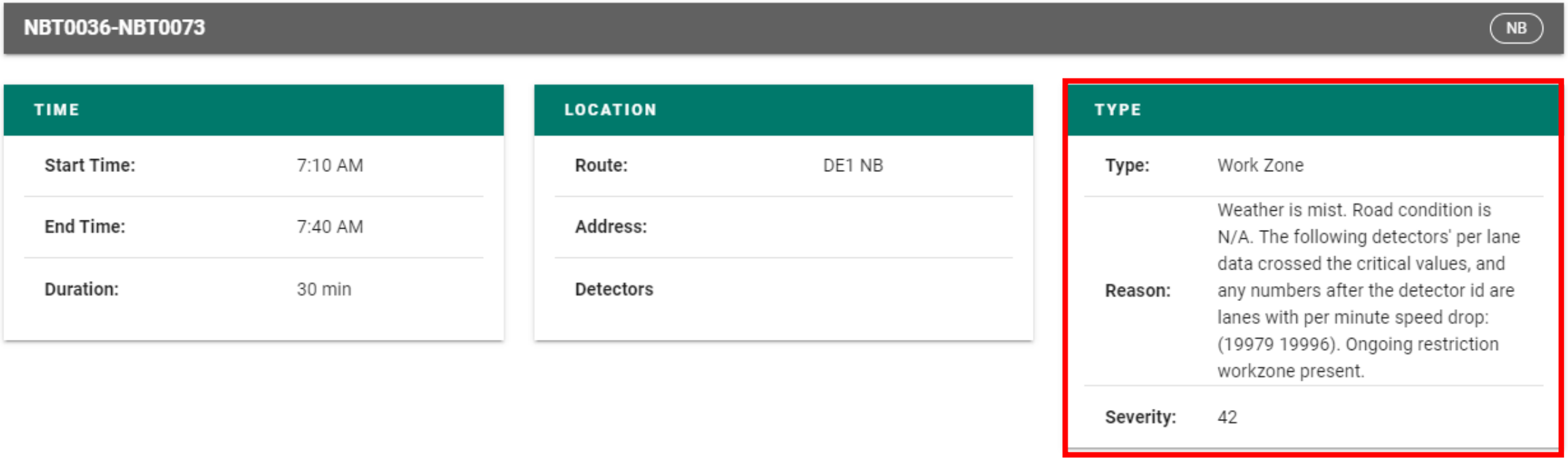




Traffic Anomaly Reasoning and Classification

- What is the type of incident and cause?
- Data input includes Bluetooth, M-dist. values, Waze, restrictions, weather, and flow data

- The service classifies each incident as
  - Work zone (**WZN**)
  - Incident (**INC**)
  - Severe Weather (**SWE**)



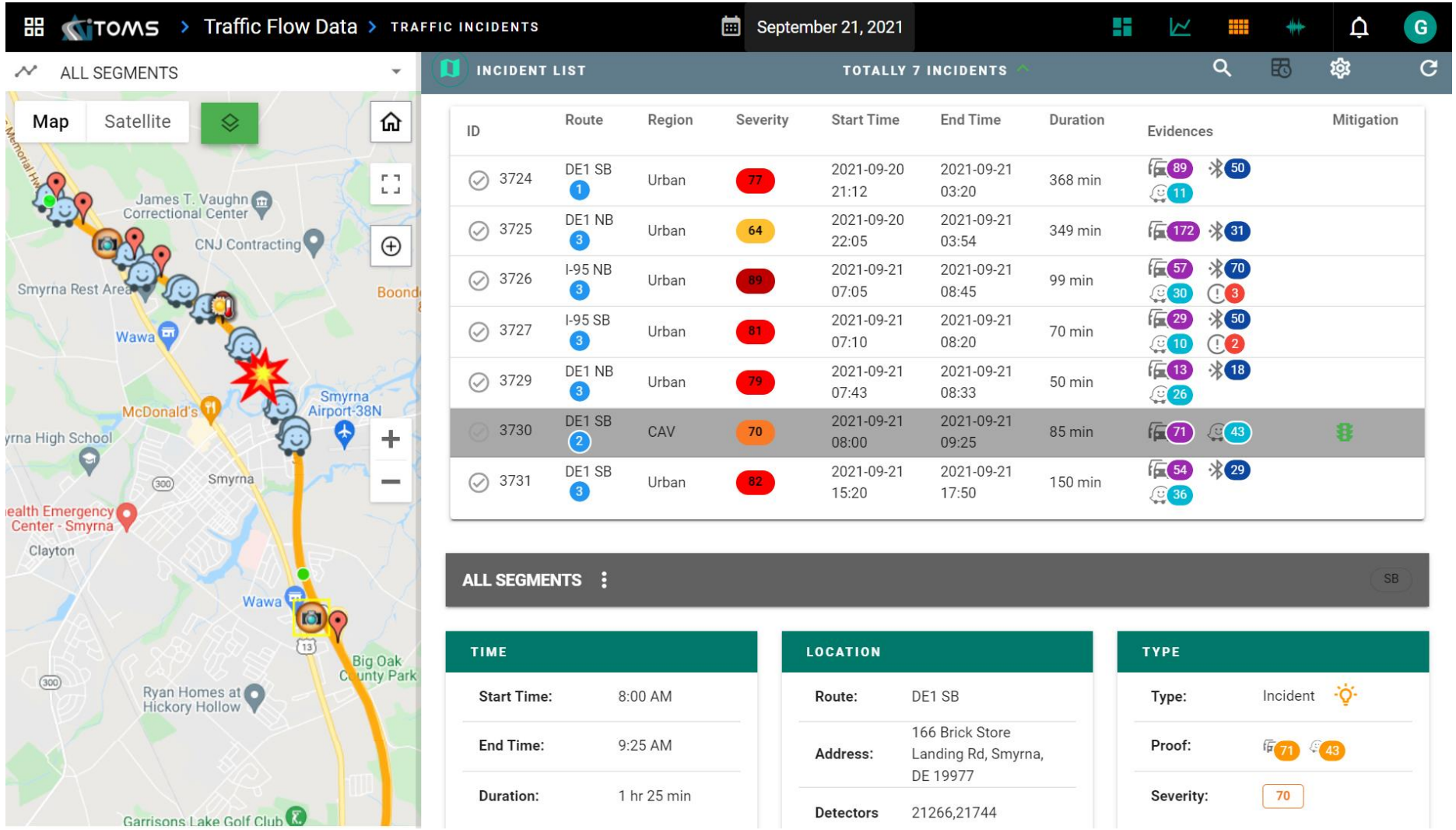
NBT0036-NBT0073 NB

TIME	
Start Time:	7:10 AM
End Time:	7:40 AM
Duration:	30 min

LOCATION	
Route:	DE1 NB
Address:	
Detectors	

TYPE	
Type:	Work Zone
Reason:	Weather is mist. Road condition is N/A. The following detectors' per lane data crossed the critical values, and any numbers after the detector id are lanes with per minute speed drop: (19979 19996). Ongoing restriction workzone present.
Severity:	42

Incident Localization and Evidence Grouping



Traffic Incident Management Interface of AI-TOMS

Key Features:

- Collect and analyze network-wide, multiple sources of data
- Detect, locate, reasoning, and impact assessment of incidents

Short-Term Traffic Flow Prediction

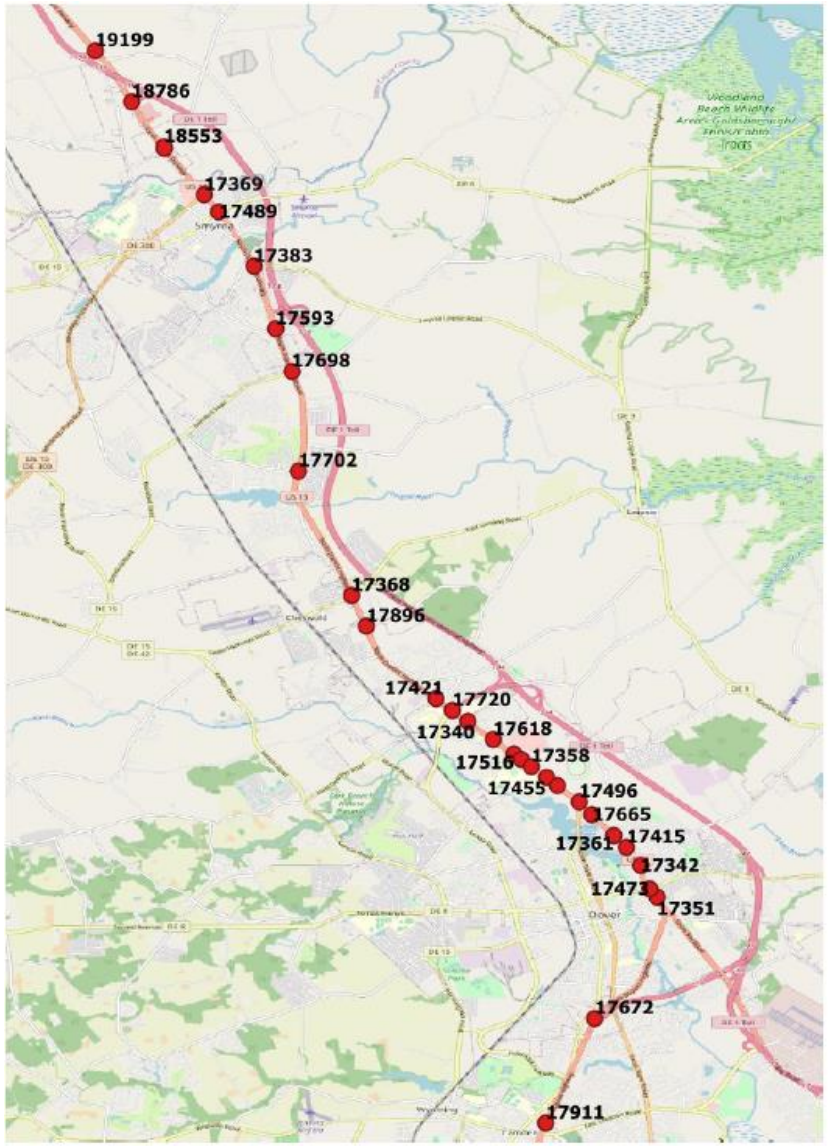
1. Robust **L**ong **S**hort-**T**erm **M**emory (LSTM) Prediction for freeway detectors
2. **G**raph Structure Learning for **T**ime **S**eries (GTS) for large network

Example Study: CAV Arterials

- Number of detectors on US-13 used for prediction:
  - **NB:** 25 detectors
  - **SB:** 26 detectors

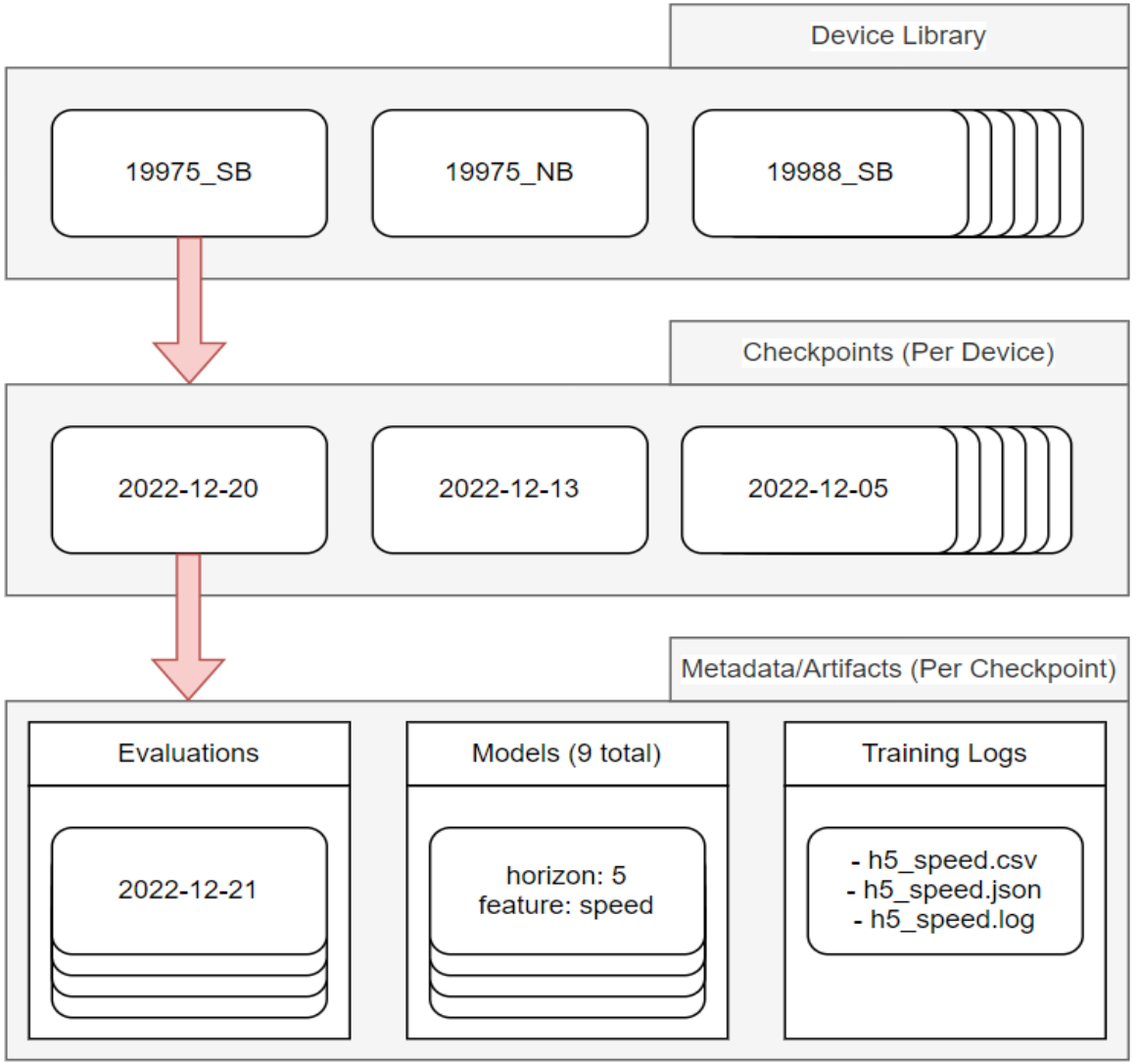
- **Training:** 2019-03-01 to 2021-07-31 (all data including incidents)
- **Testing:** 2021-08-01 to 2021-10-01 (2 months)

- Features used in the model:
  - Adjacent matrix of detectors
  - Volumes of all detectors (last 1 hour data)
  - Surface condition
  - Weekday information
  - Month information



Automatic Traffic Prediction Model Updating

- Prediction models need to update to accommodate seasonal and long-term traffic pattern change
- Library of devices/sensors
- Each sensor has checkpoints
- Each checkpoint has:
  - Models
  - Training logs
  - Dated evaluations

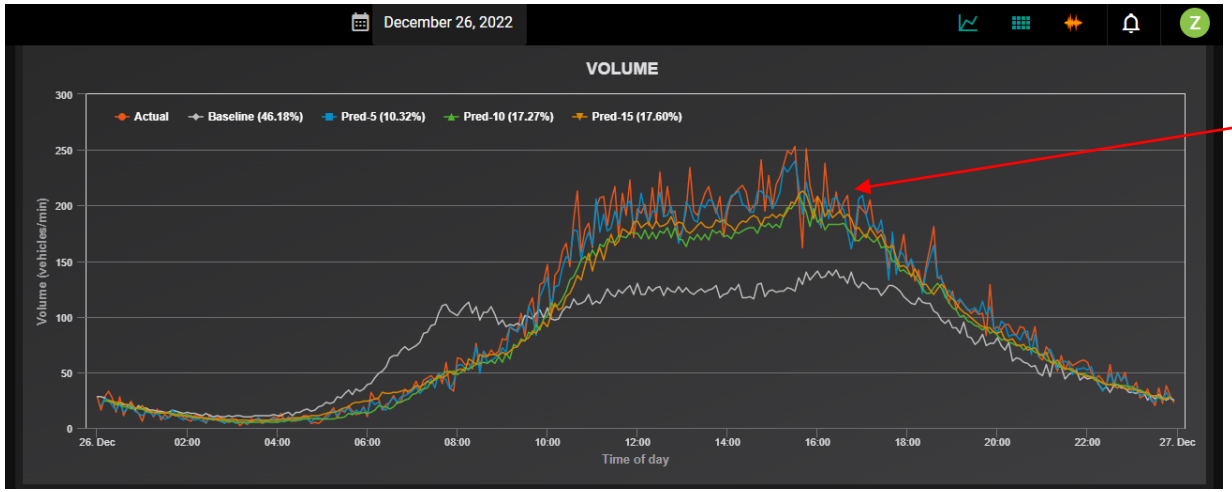


Applications of Traffic Predictions

- Simulation Model Accuracy Improvement
  - Replace historical baselines with predicted demands
  - Compare with live traffic data to calibrate and evaluate the improvements
- Traffic Congestion Prediction
  - Using predicted demand and known "operational capacity", we can predict the possibility of congestion for certain links
- Traffic Anomaly/Incident Impact Prediction and Mitigation
  - Use LSTM models for demand forecasting on freeways
  - Use GTS models for arterial demand forecasting before the incident
  - Detours + original arterial demand → signal plan changes faster than Traffic responsive ahead of congestion

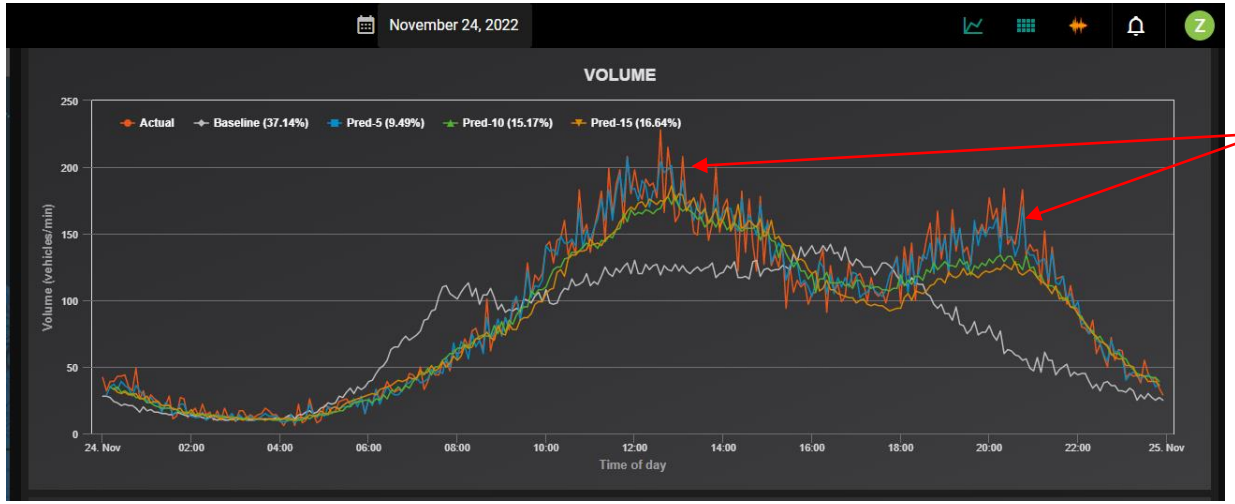
Traffic Flow Prediction Applications

Traffic prediction is extremely effective in handling non-incident related traffic pattern abnormalities



One long peak, with 150-200% traffic demand

Day after Christmas (12/26/2022)



Two peaks, one in midday and one in the late evening

Thanksgiving (11/24/2022)

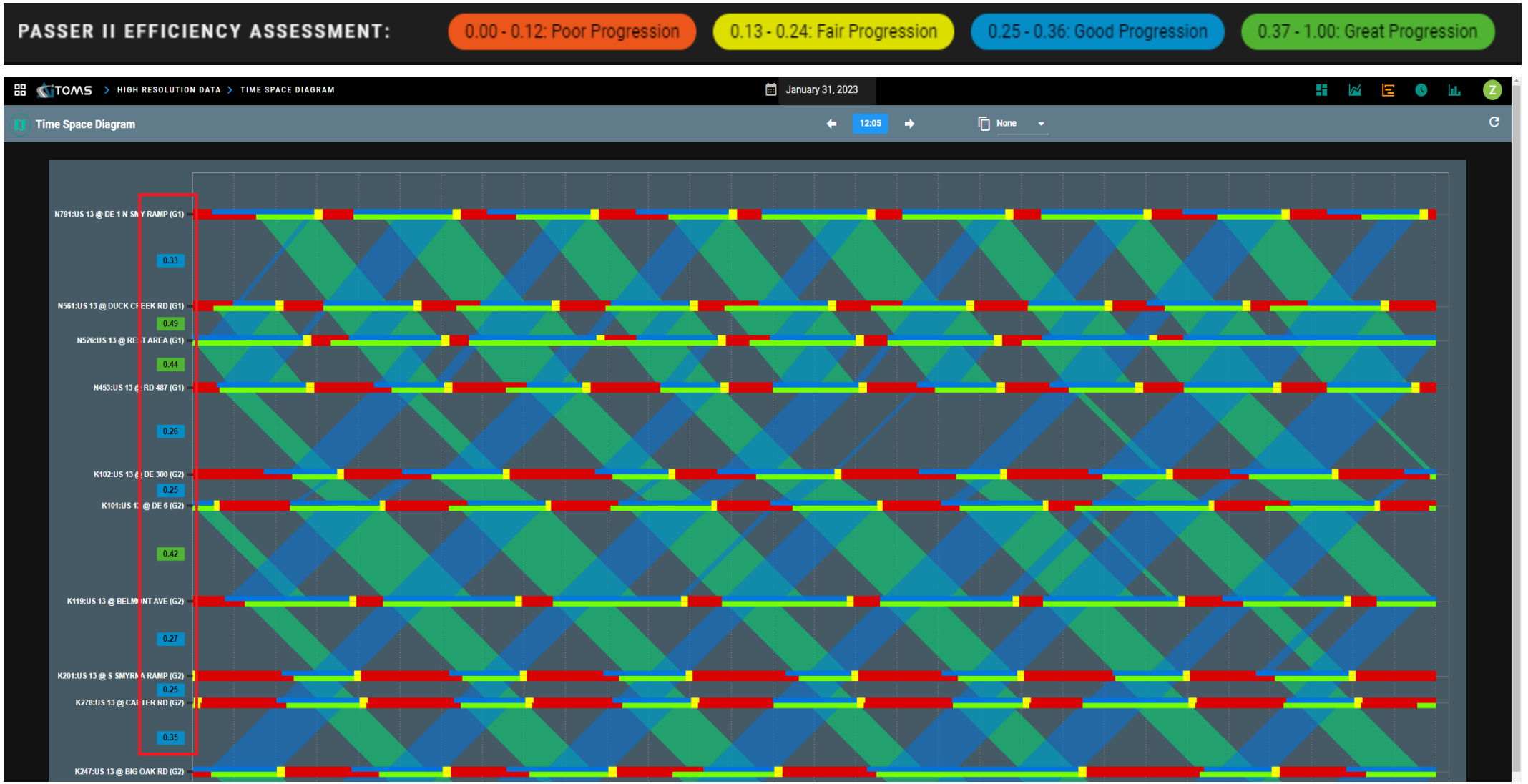
Live Automated Traffic Signal Performance Measure (ATSPM) and Connected Automated Vehicle (CAV) Trajectory for Traffic Signal Timing Optimization

Live ATSPM for Signal Performance Monitoring

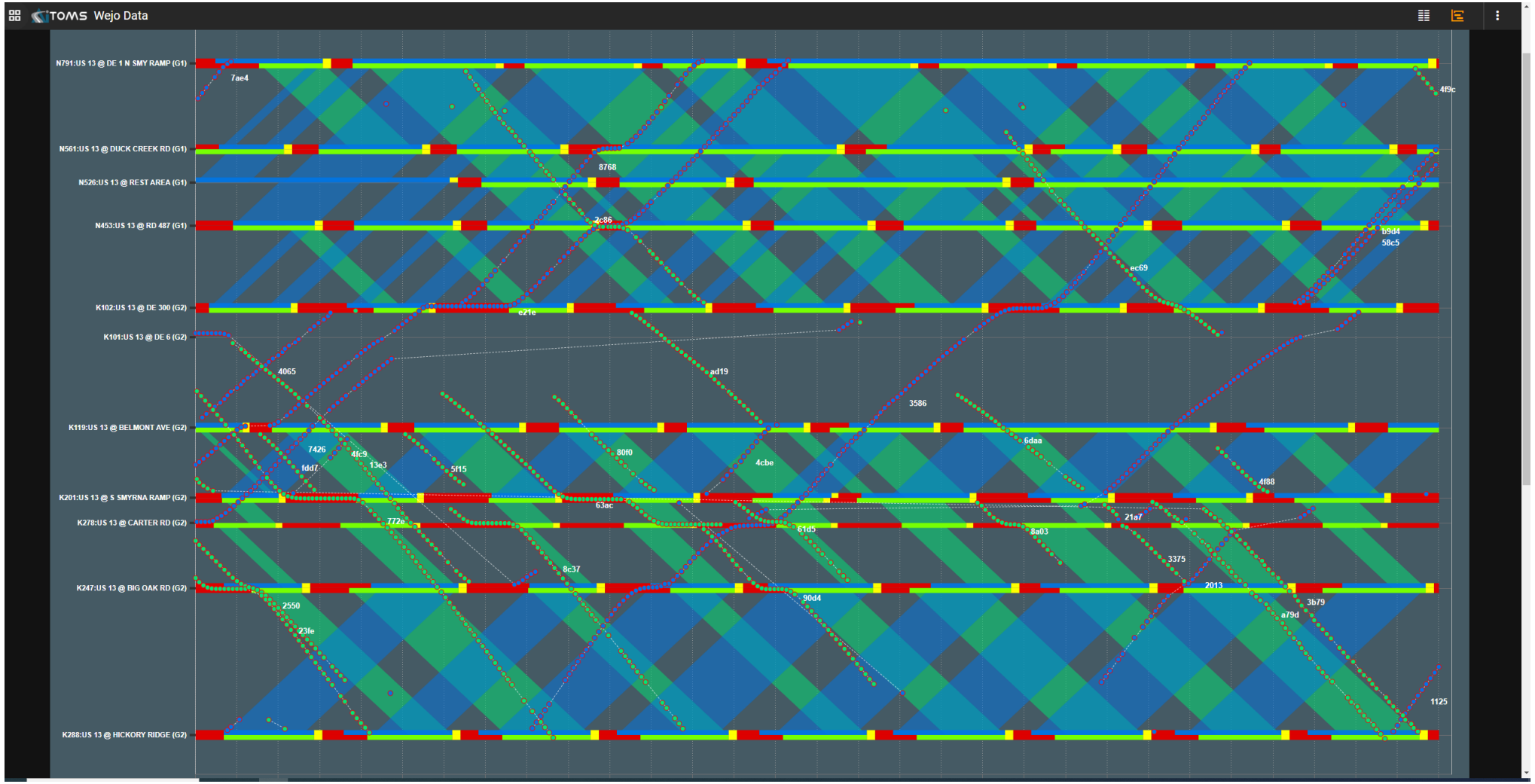
AI-TOMS monitors traffic signal and corridor performance, and recommends signal plan and parameter change based on live High Res and vehicle trajectory data

- Collect and visualize High Resolution Signal controller log data in near real time (5 minutes interval)
- Monitor signal performances and corridor progression

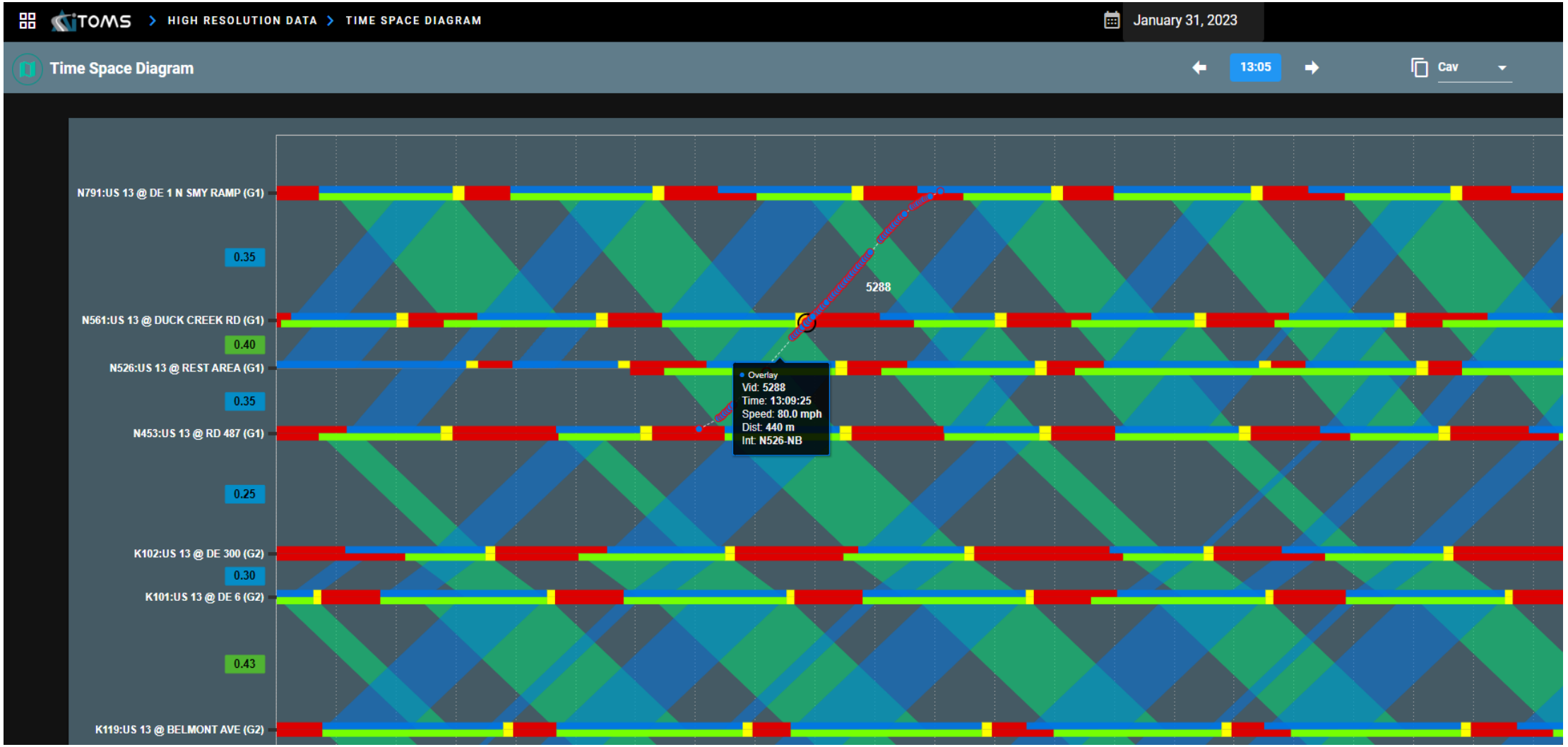
Progression Bandwidth Efficiency Calculation



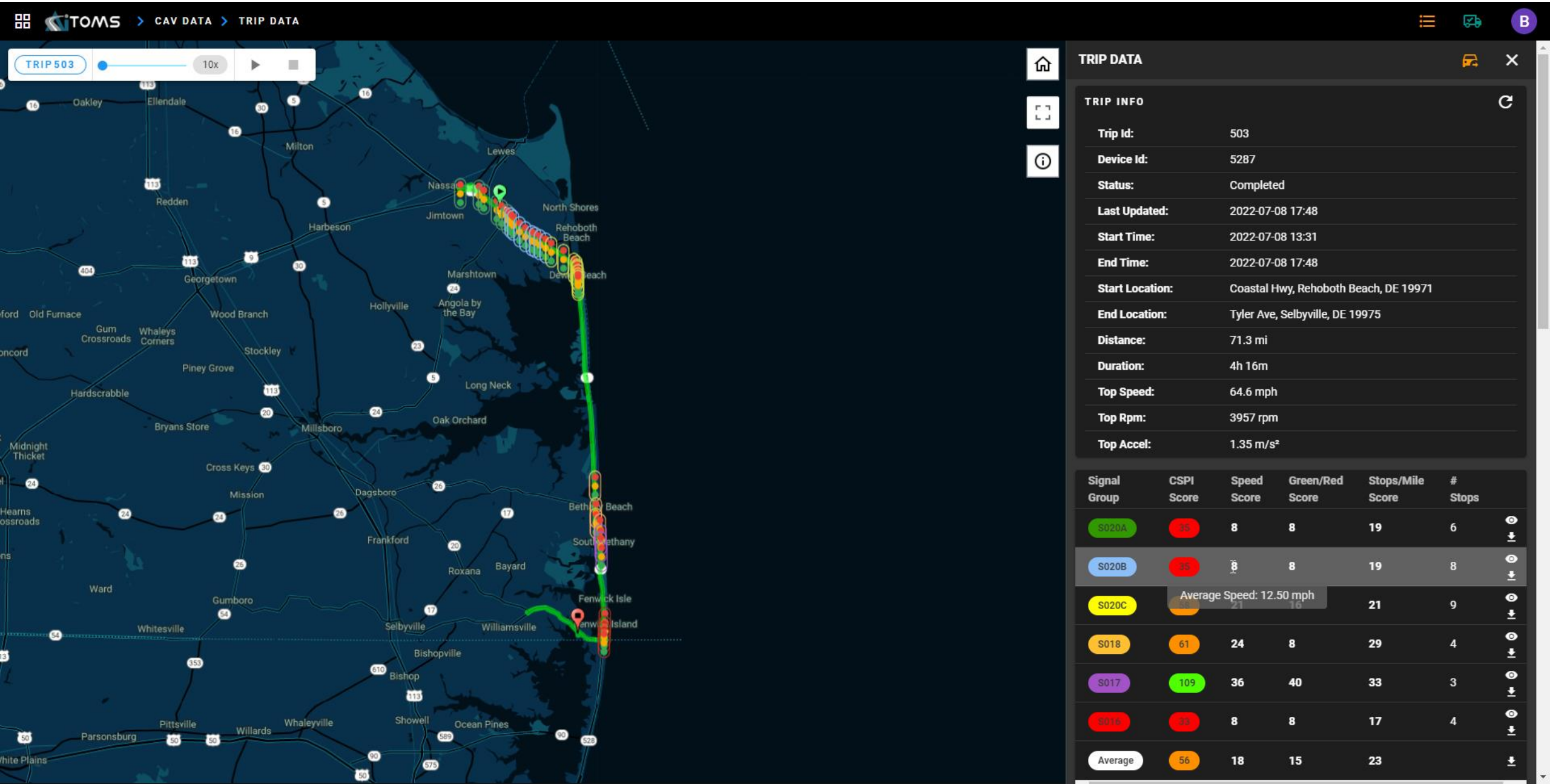
Vehicle Trajectory Data (from Wejo) Overlay on Time-Space Diagram



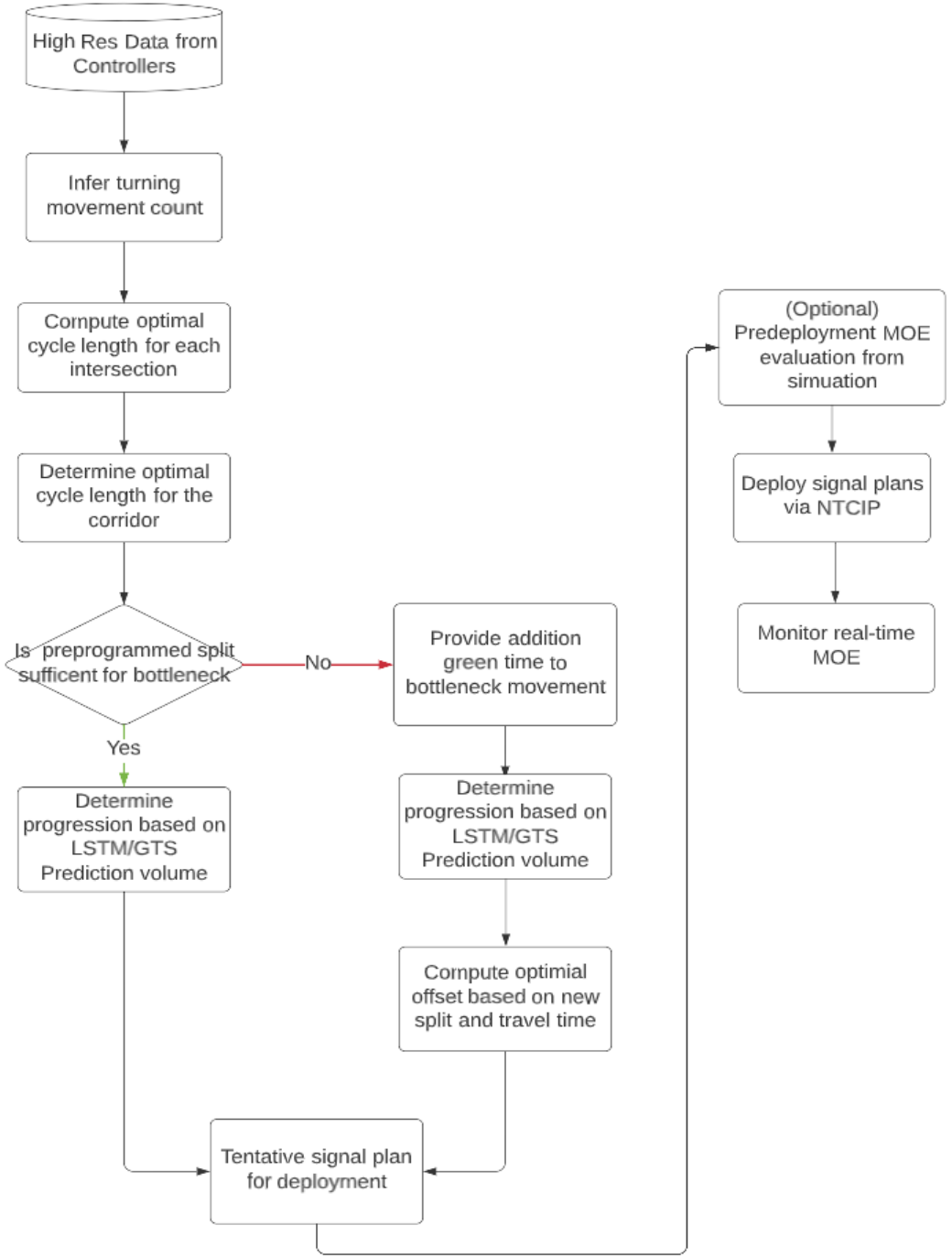
CAN Bus Data Overlay on Time-Space Diagram



CAV/CAN Bus based CSPI

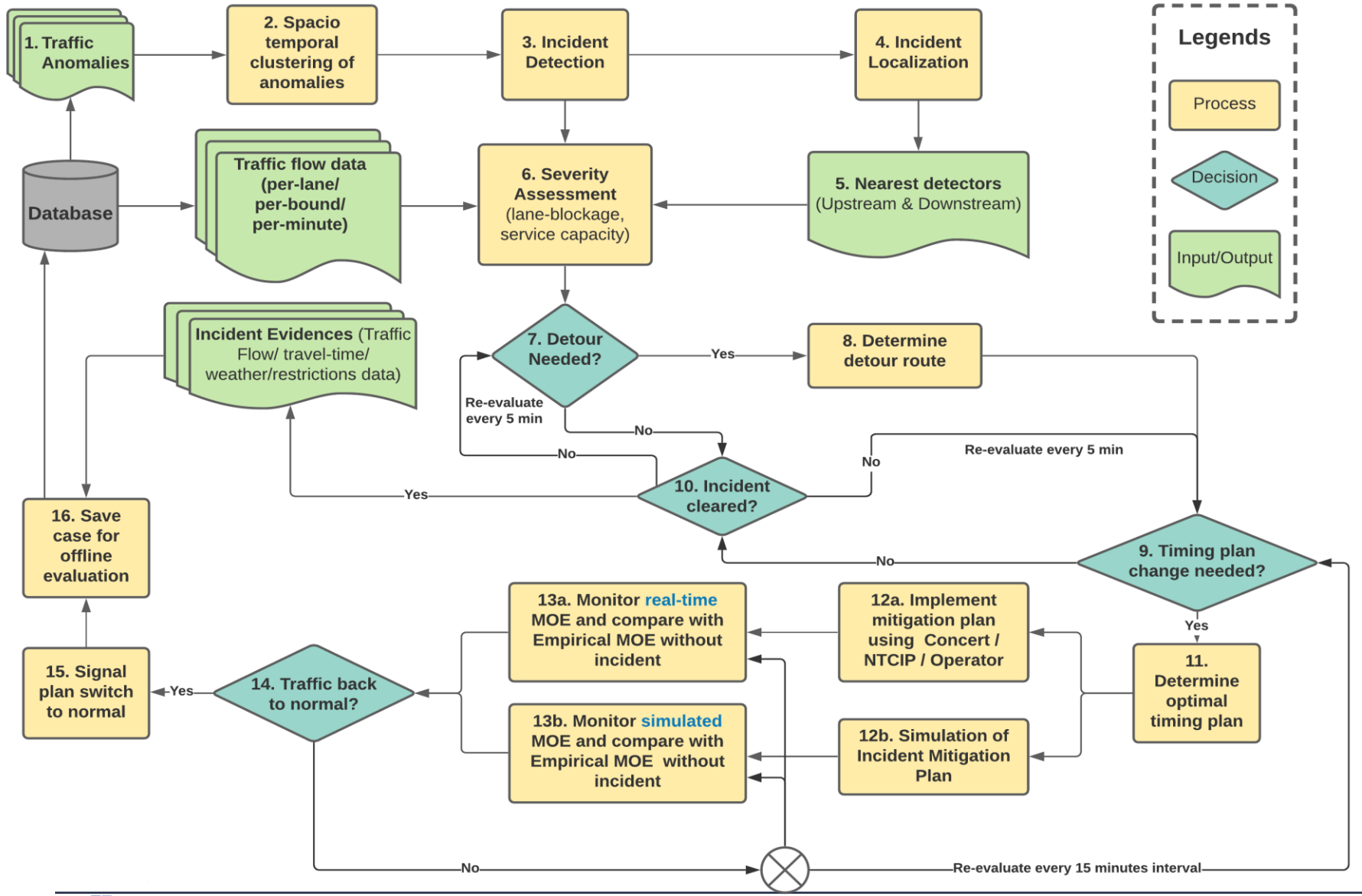


Signal Timing Recommendation Flowchart



Incident & Congestion Mitigation Decision Support

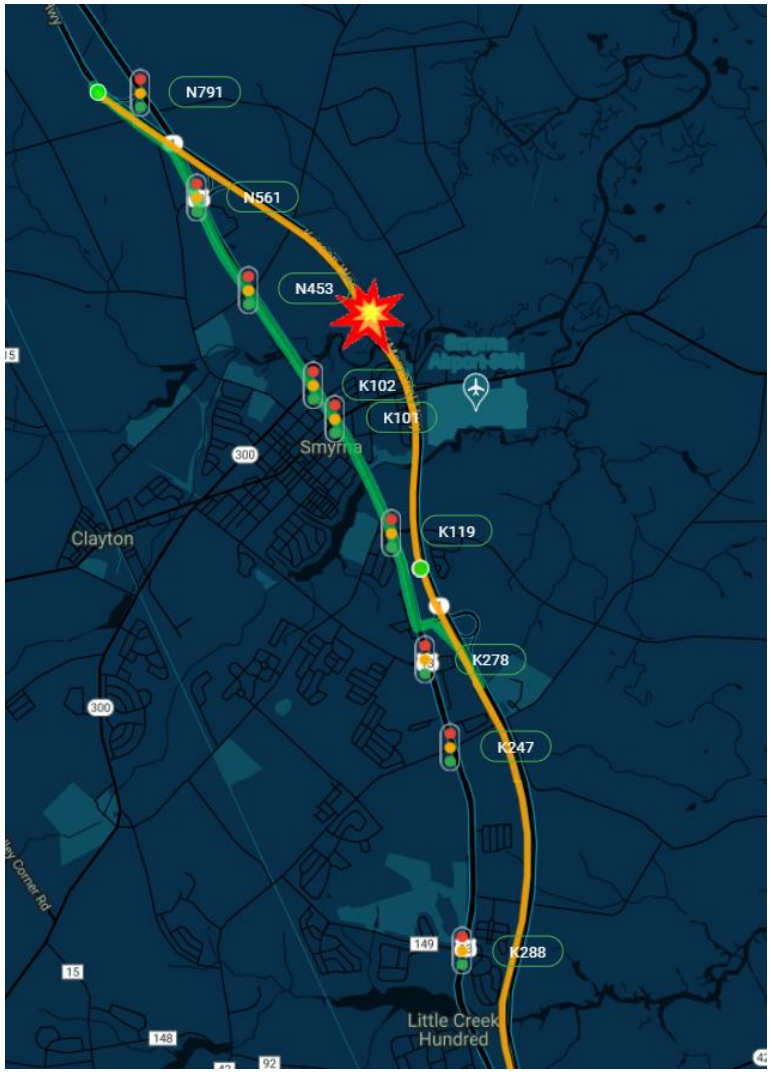
Traffic Incident Management Workflow



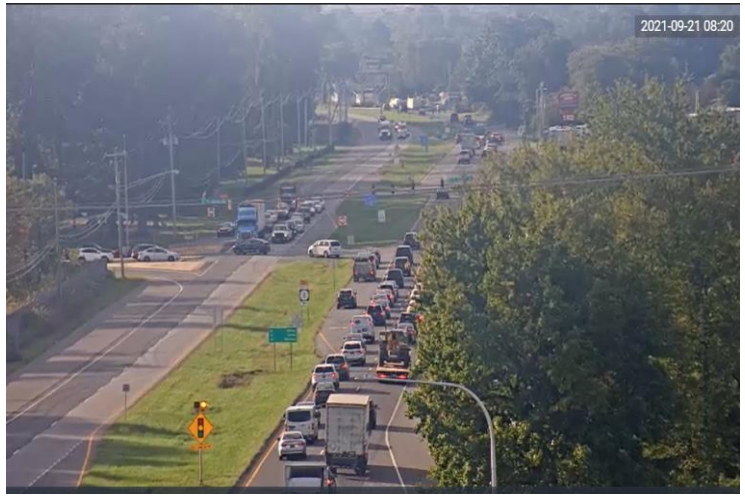
- Collect and Arrange Traffic Data
- Detecting Significant Anomalies
- Reasoning the Cause and Impact
- Predict Traffic Flow and Conditions
- Generate/Recommend Response Plans
- Evaluate MOE and make changes Dynamically
- Accumulate Knowledge and Improve Performance

Example Incident Management Scenario

Sept. 21, 2021 Incident, RT-1 Southbound all lane closed due to a crash



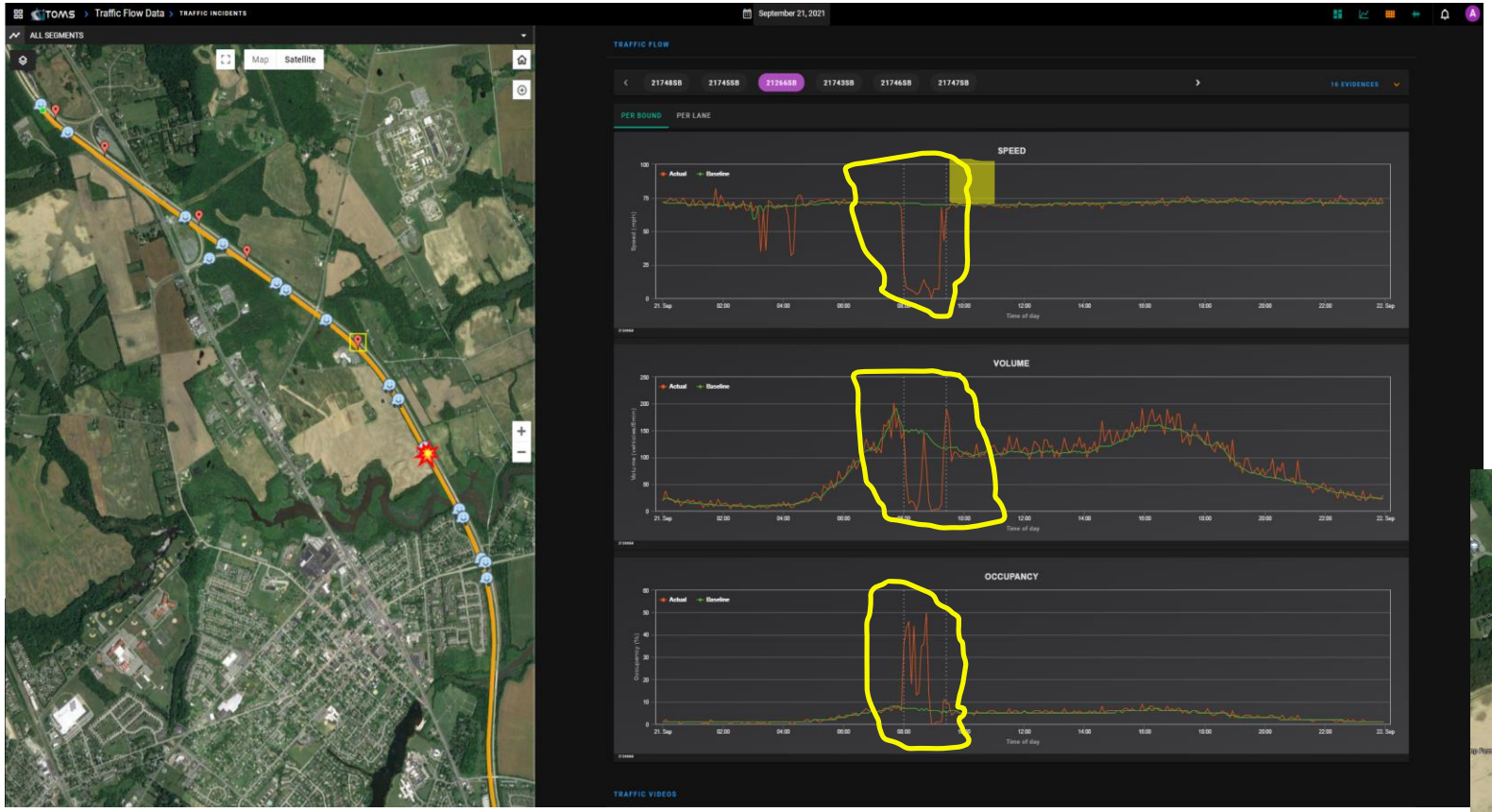
Significant Detour from RT 1

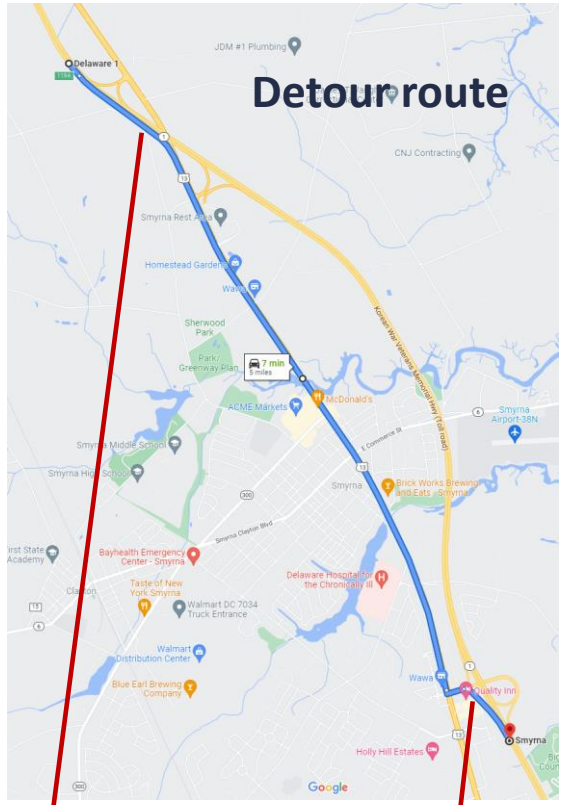


Delays on US 13

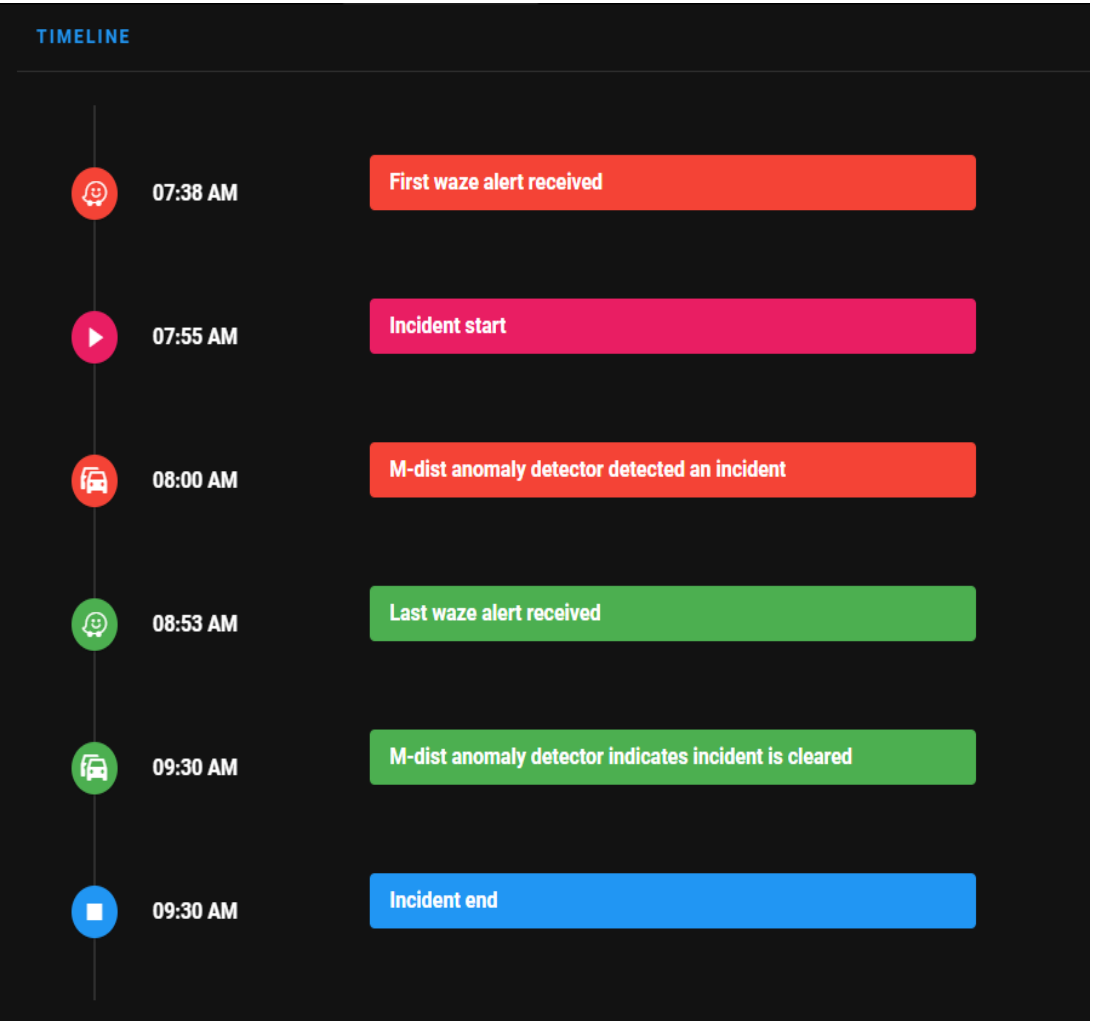
Example of Incident Mitigation

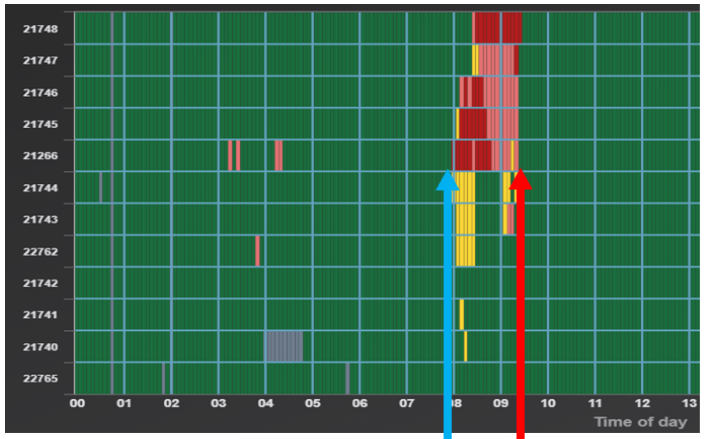
DE-1 SB Incident on September 21, 2021

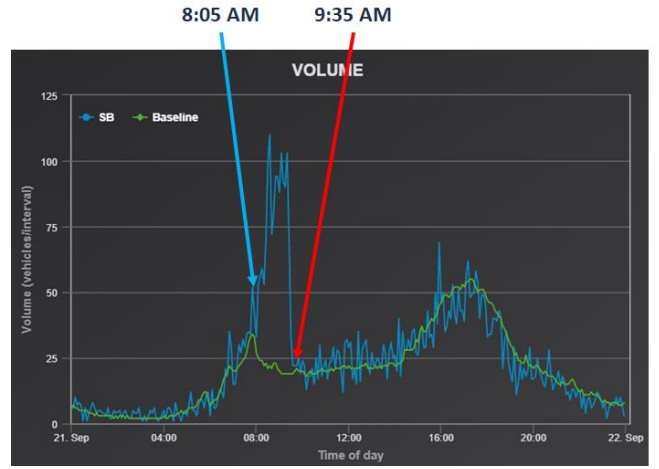


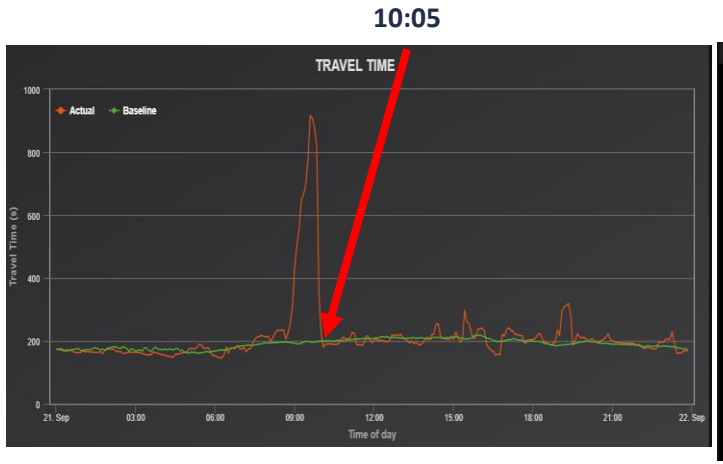


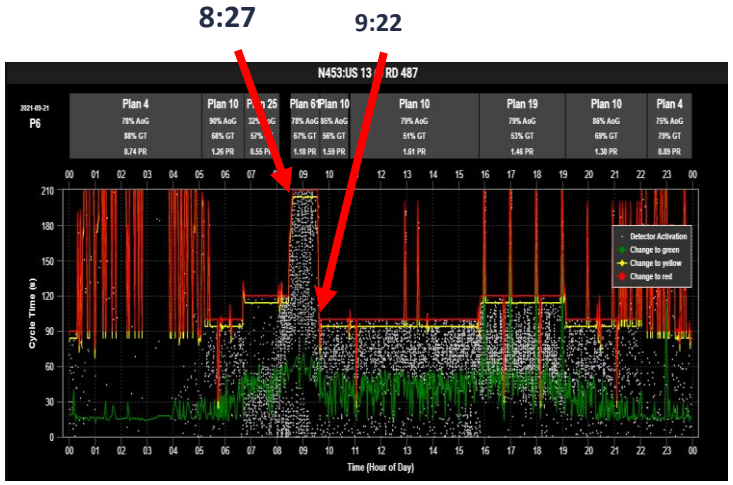
Incident Management/Mitigation Timeline



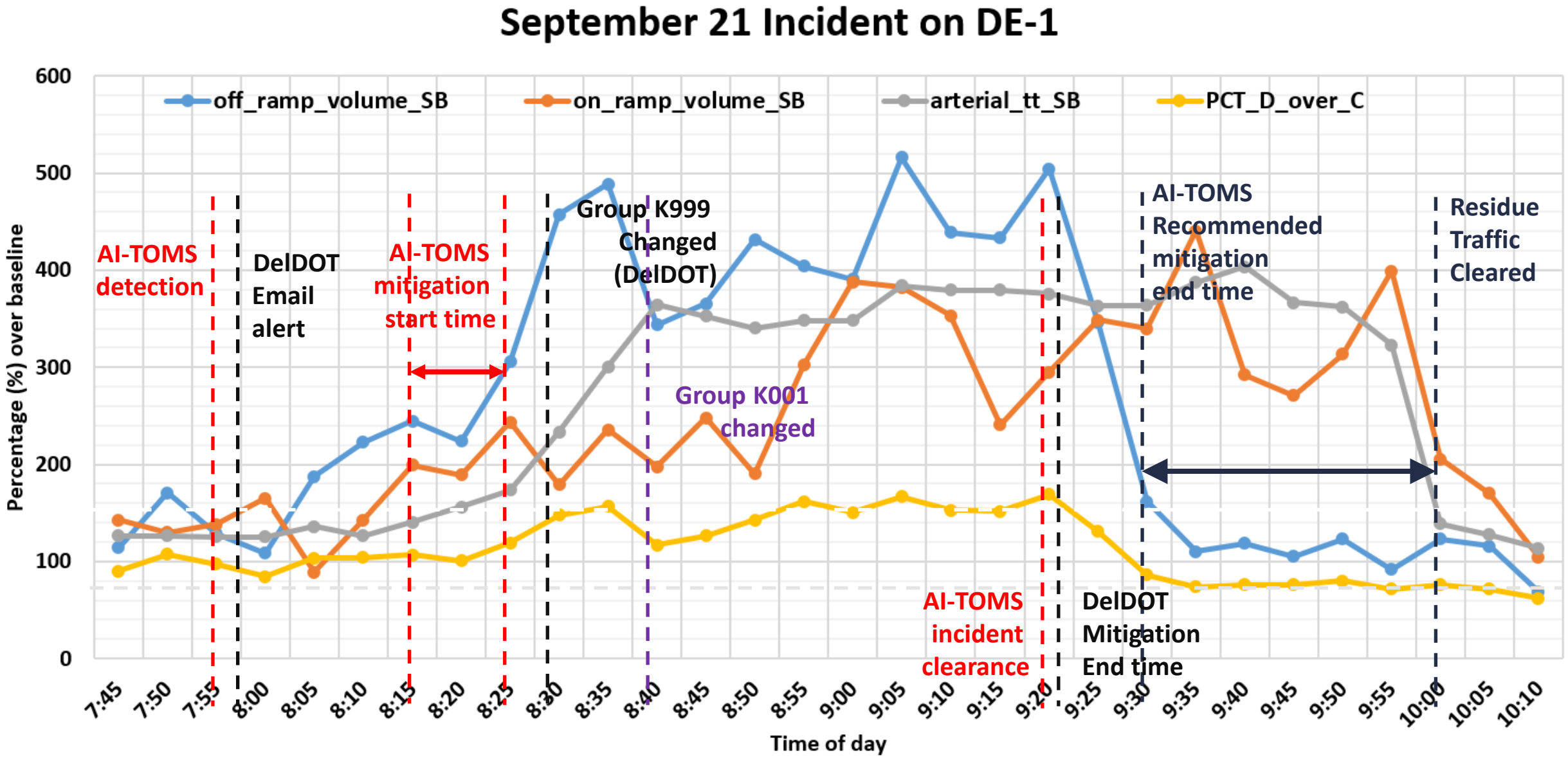






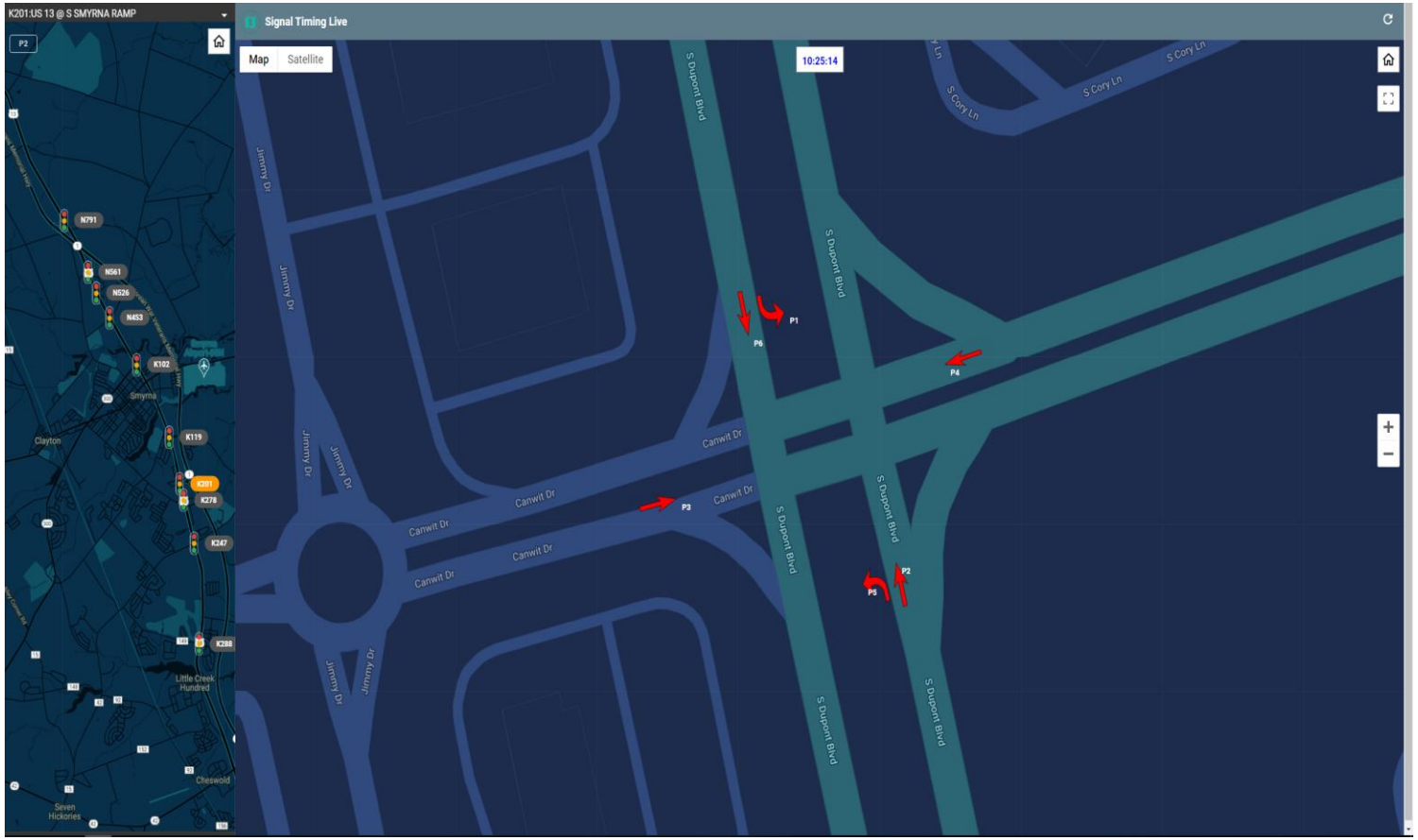


Incident Mitigation Timeline

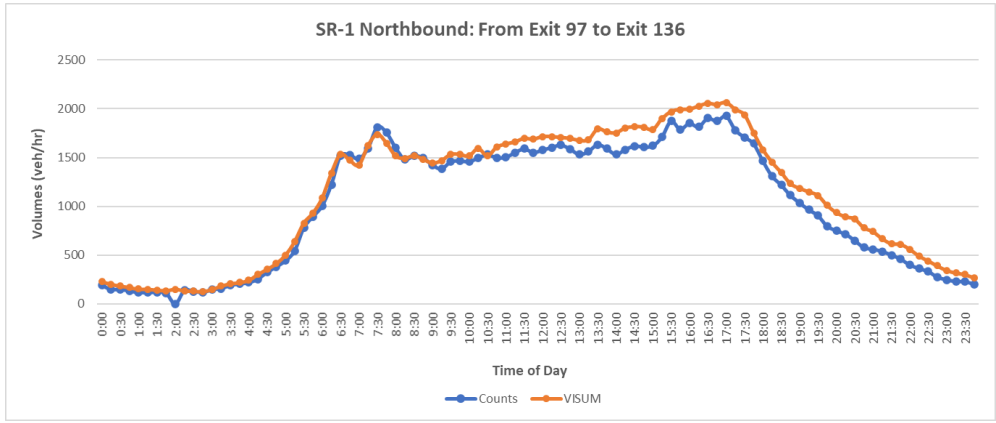


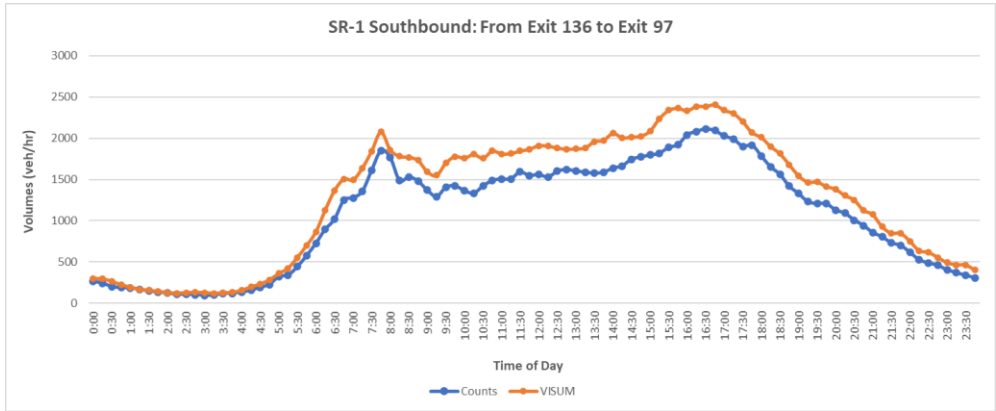
Mitigation Solution Development

- In VISUM, we use HCM6 and the predicted volumes to optimize signals
- We attempt to optimize phase splits at different cycle length
- Example: K201 – US13 @ S SMYRNA RAMP

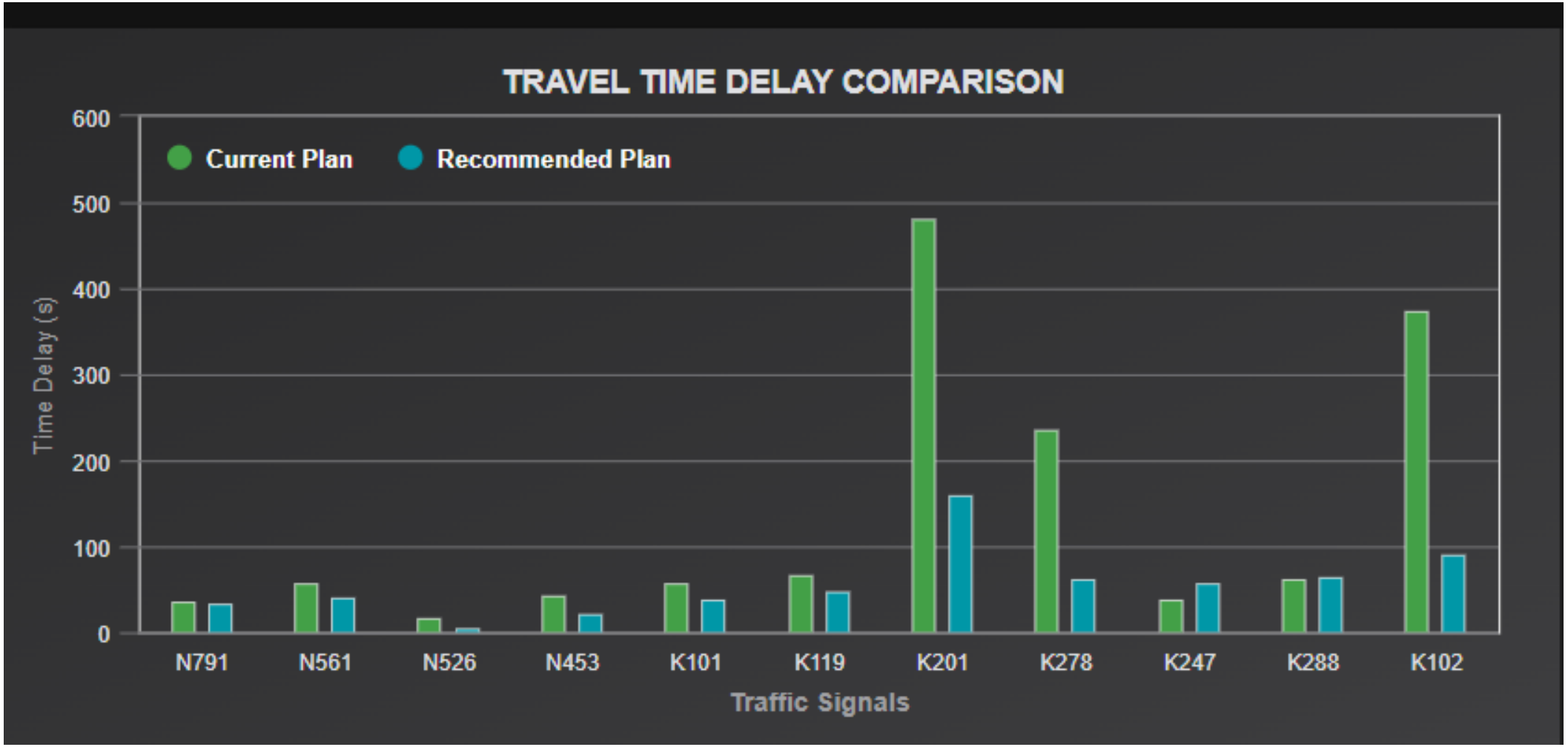


VISUM Model Calibration (Volume)

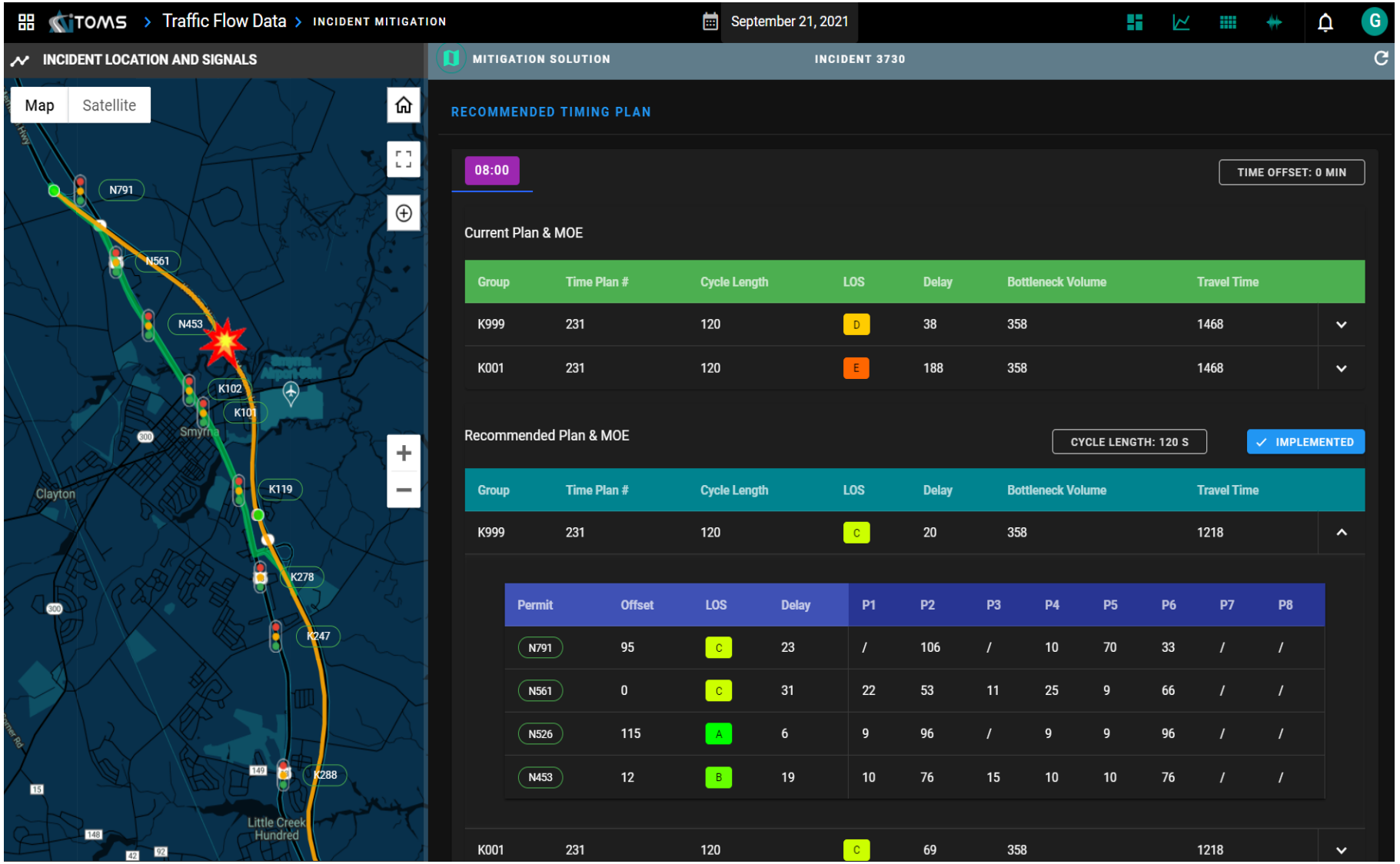




Solution Performance Prediction



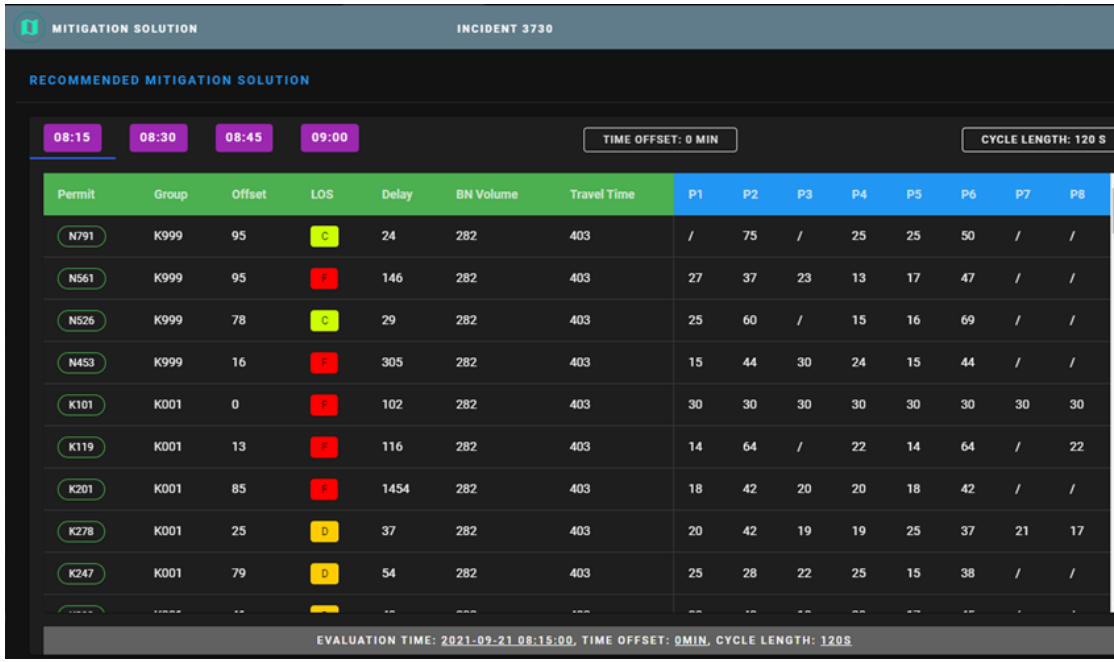
Mitigation Solution Recommendation



- Recommended signal timing is better than the current plan with reduced delay and travel time
- The detailed split and offset are optimized and ready for deployment

Signal Timing Change via NTCIP

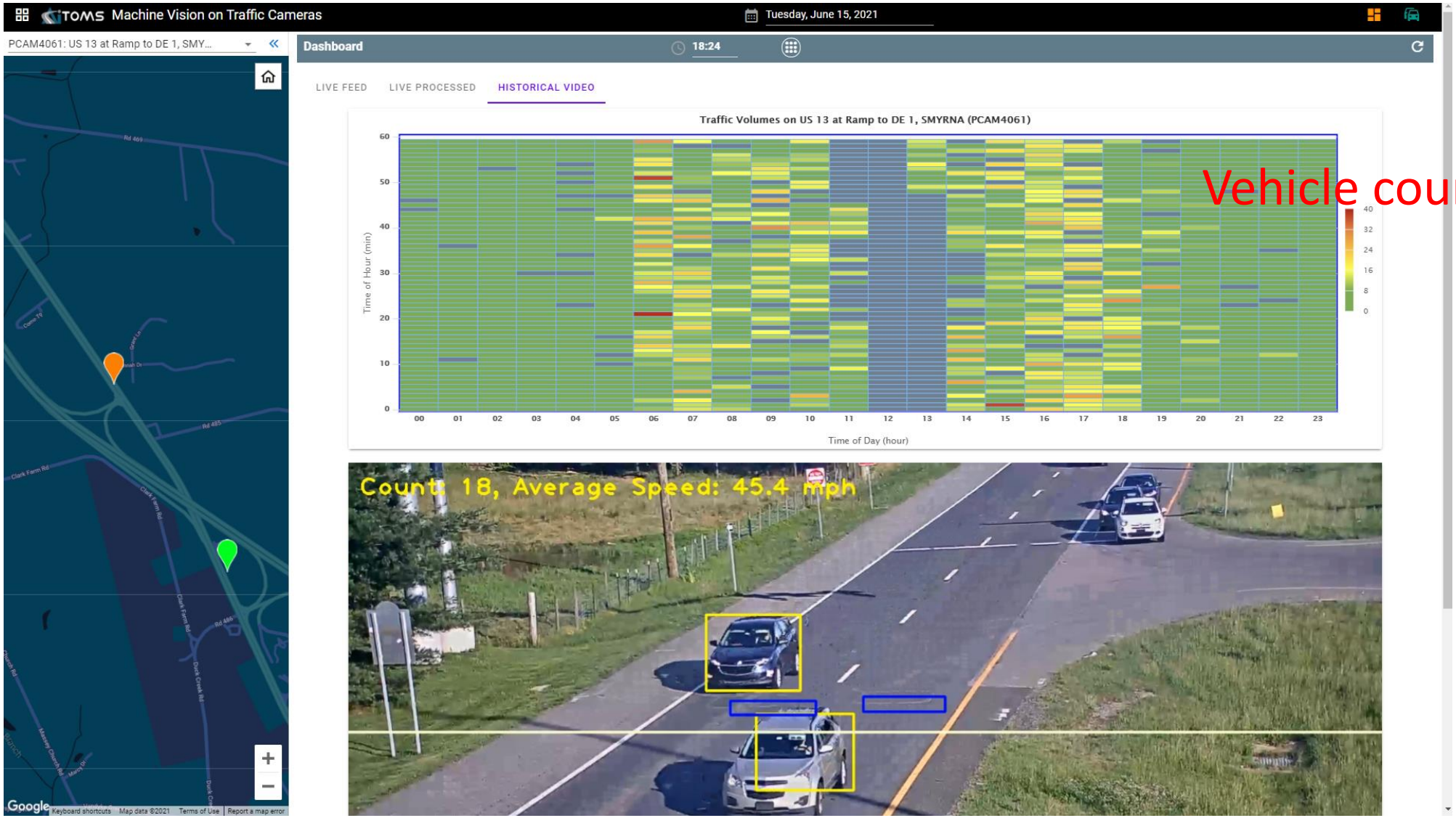
- Implemented a NTCIP software to interface AI-TOMS and a M60 controller in DelDOT TMC
  - Retrieve current configuration
  - Change signal parameters
    - Phase parameter: minimum green, max green, red time, etc.
    - Coordination parameter: phase split, cycle time, offset, etc.
    - Phase data bank
    - System operation mode, etc.



- Use test controllers in the TMC for initial testing (connected to TACTICS)
  – AI-TOMS switch Tactics to operation in “Manual Mode”
  –NTCIP switch to another signal plans or changing timing parameters

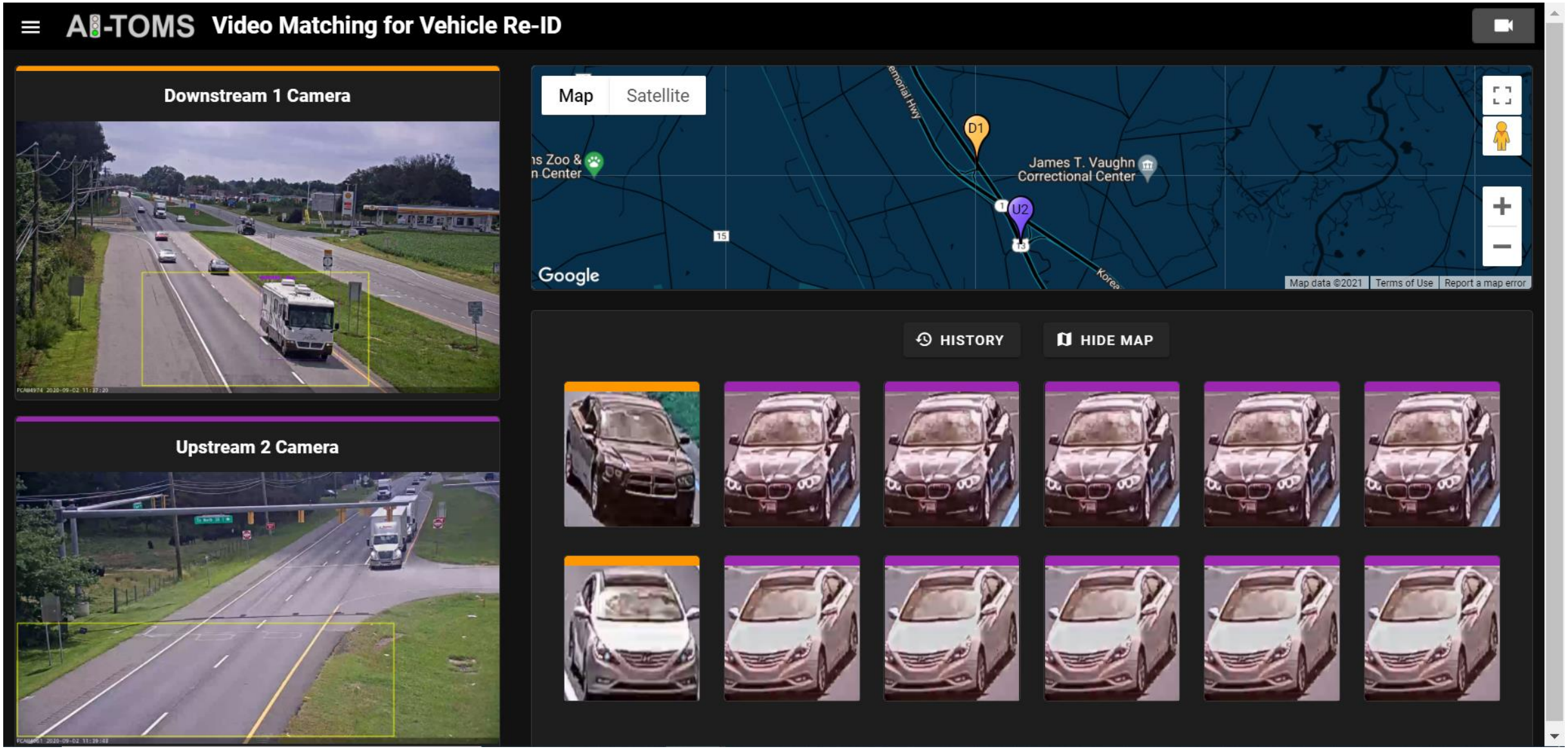
Machine Vision for Traffic Condition Monitoring and Vehicle Re-identification

Machine Vision for Vehicle Count, Speed and Occupancy



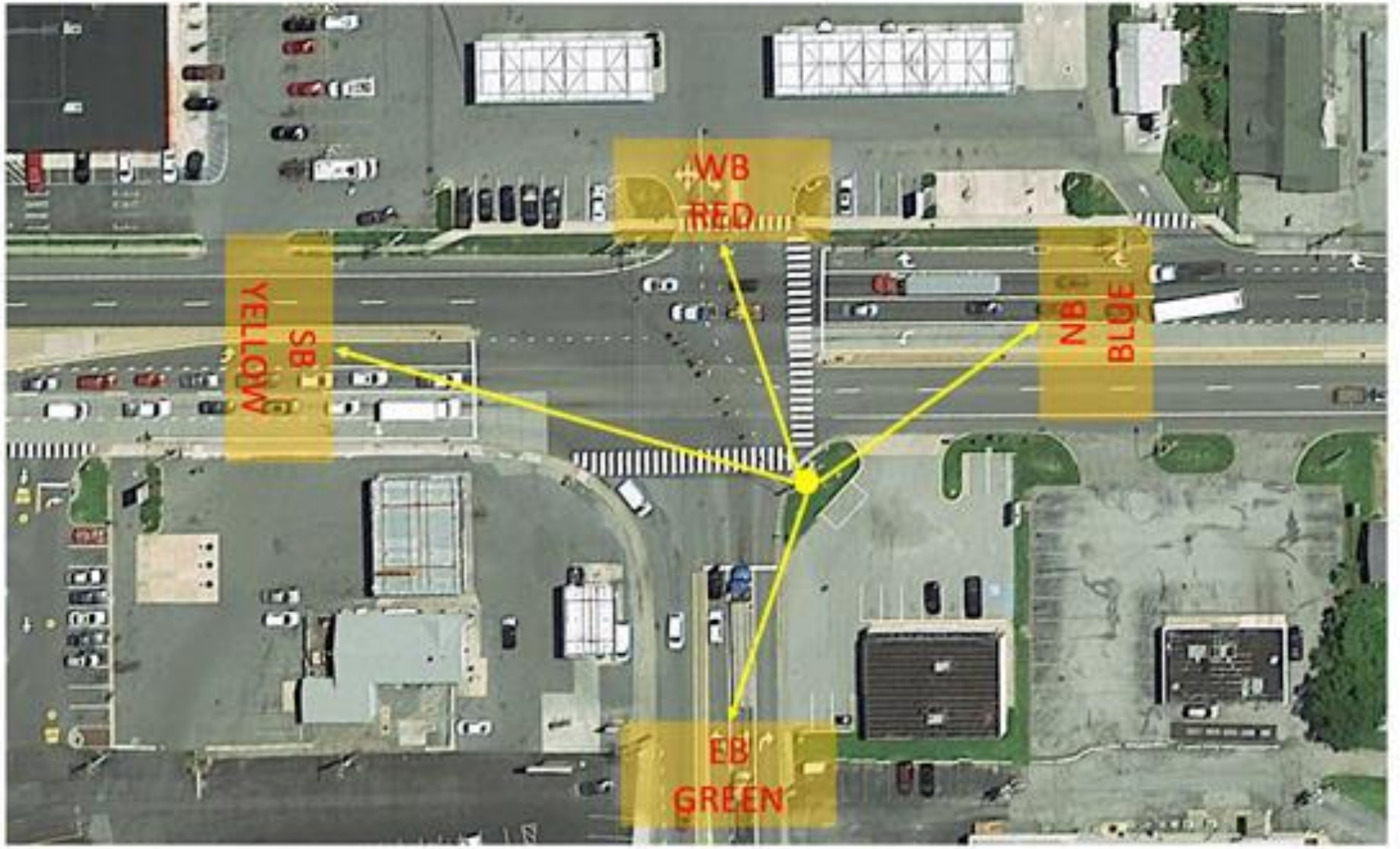
Vehicle count data

Video based Vehicle Re-ID

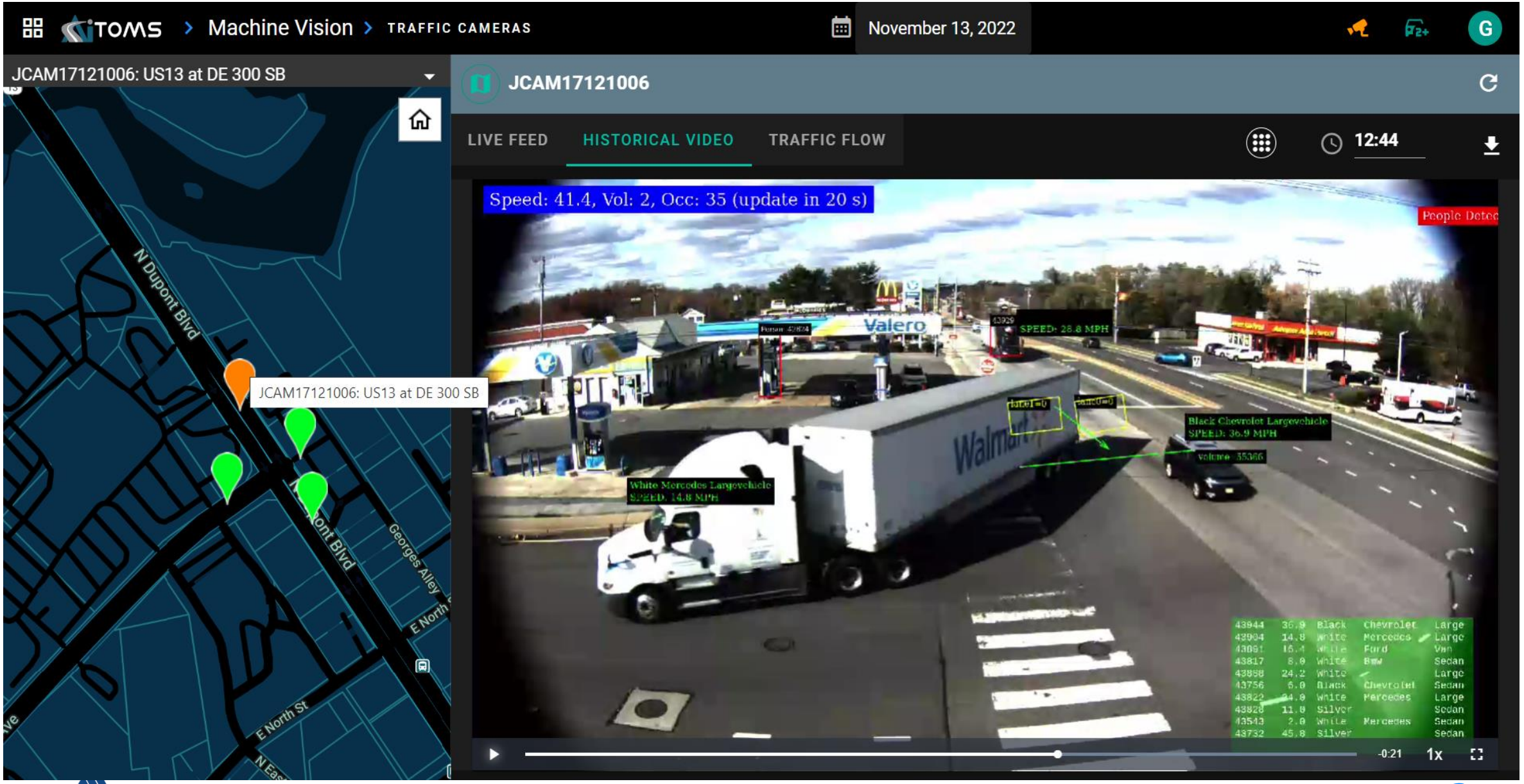


MV HUB: US 13 at DE 300, Smyrna DE (As Built)

COLOR CODE
NB: BLUE
SB: YELLOW
WB: RED
EB: GREEN

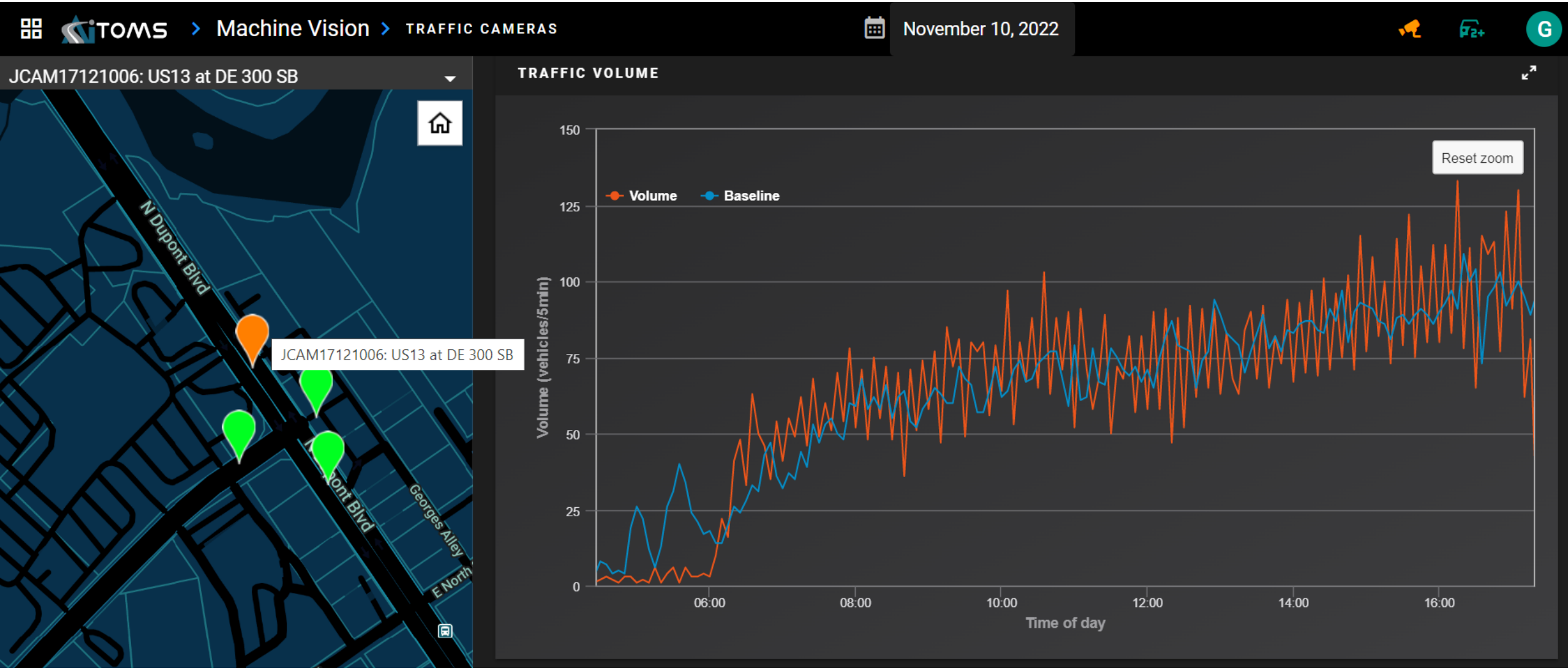


Machine Vision Hub Software Interface



Machine Vision Vehicle Count and Classification

Cross Check of Vehicle Count with System Loop Data

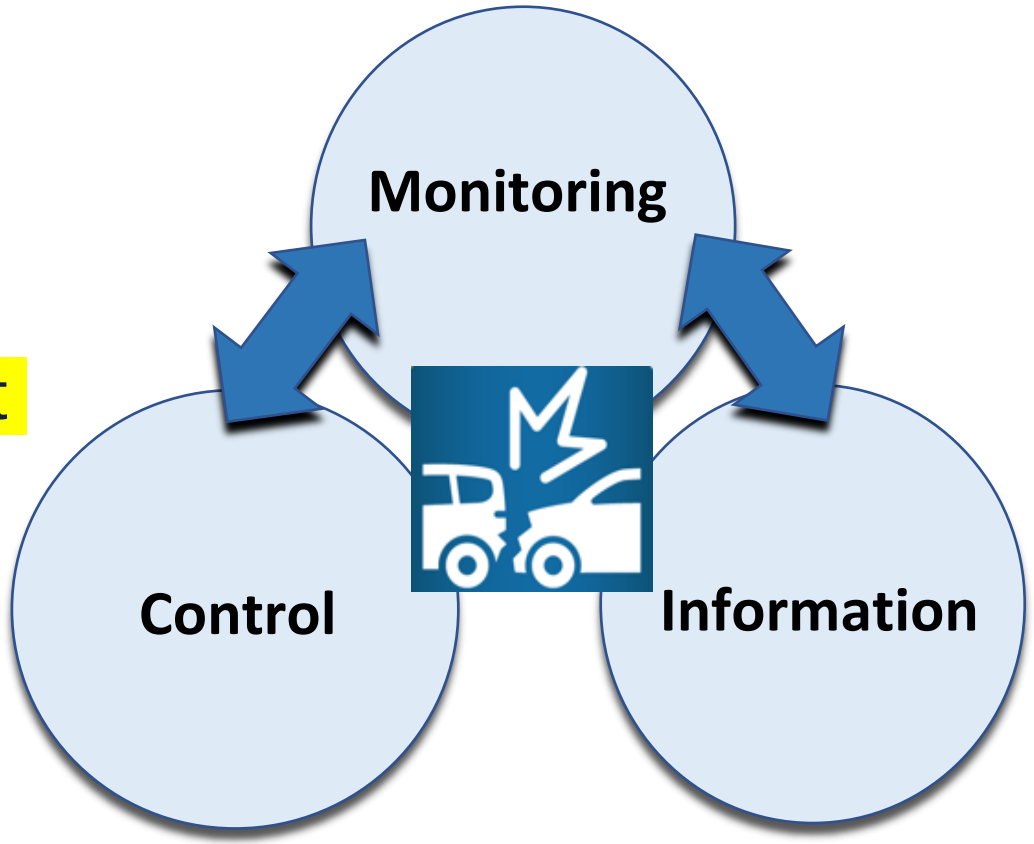


Key Findings and Lessons Learned

- AI and Machine Learning demonstrated potential to improve TSMO with automated big traffic data analysis/fusion, traffic flow prediction, proactive incident management and multimodal decision support
- Challenges of implementing and deploying AI/ML for TSMO
  - Data availability and data quality
  - Validation of the outcomes of AI/ML
  - Integration with existing TMC hardware/software tools: most vendors may not provide API or open interfaces
  - Security, networking configuration, Linux/open-source software support issues could cause roadblocks when deploying the system in the state network
  - Testing, Operation, Maintenance and Support requires long term commitment

Next Steps

- Continuous enhancement – system will continuously learn, as a traffic engineer would, and automate operations
- Understanding what it takes to support this advanced system – need support of staff/team with the required knowledge, skills and abilities
- Detection system of today – enhancements with ML and AI
- Enhance mobility not only in Delaware, but for transportation systems everywhere



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