



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

February 13, 2023



JACOBS[®]

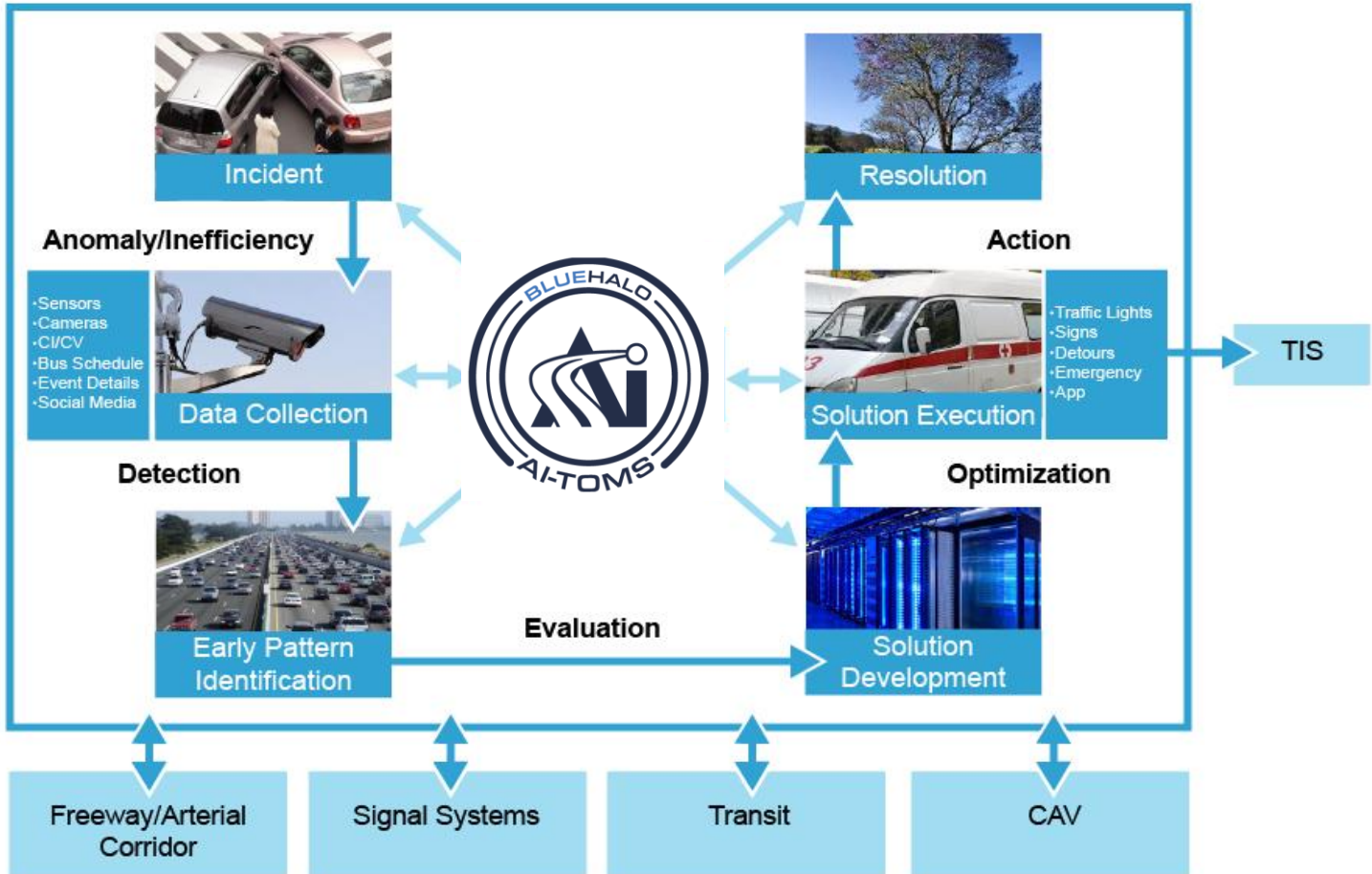
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Outline

- 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)

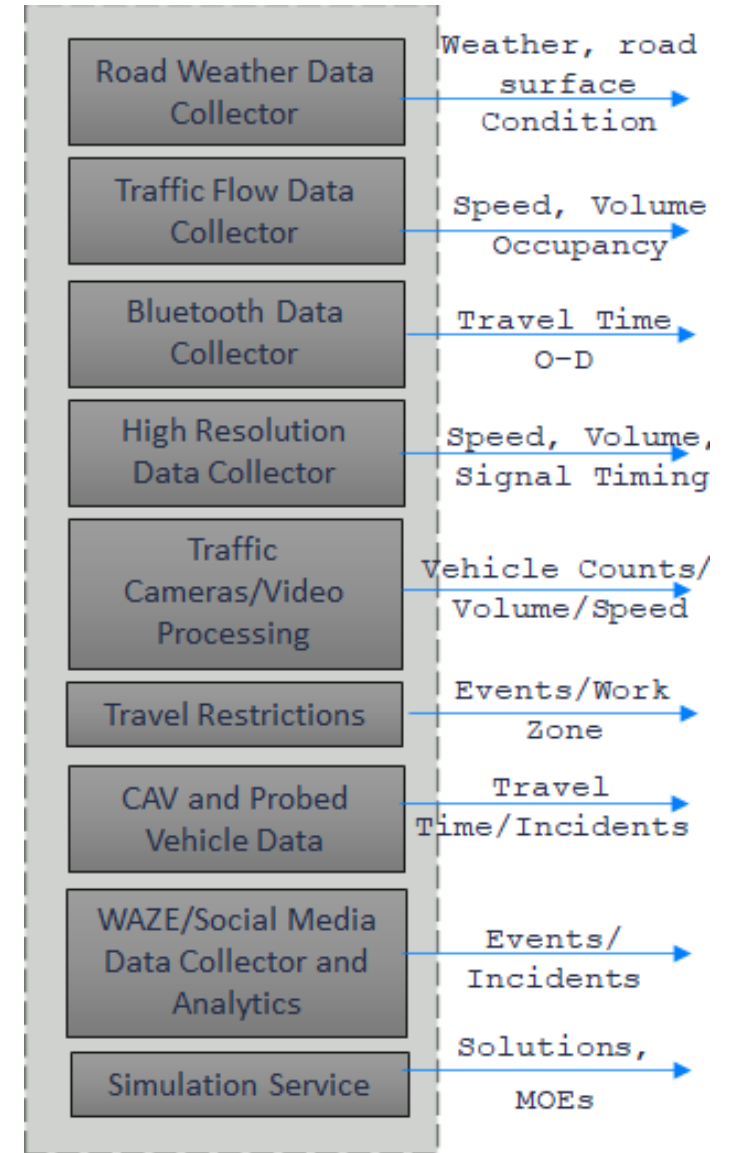
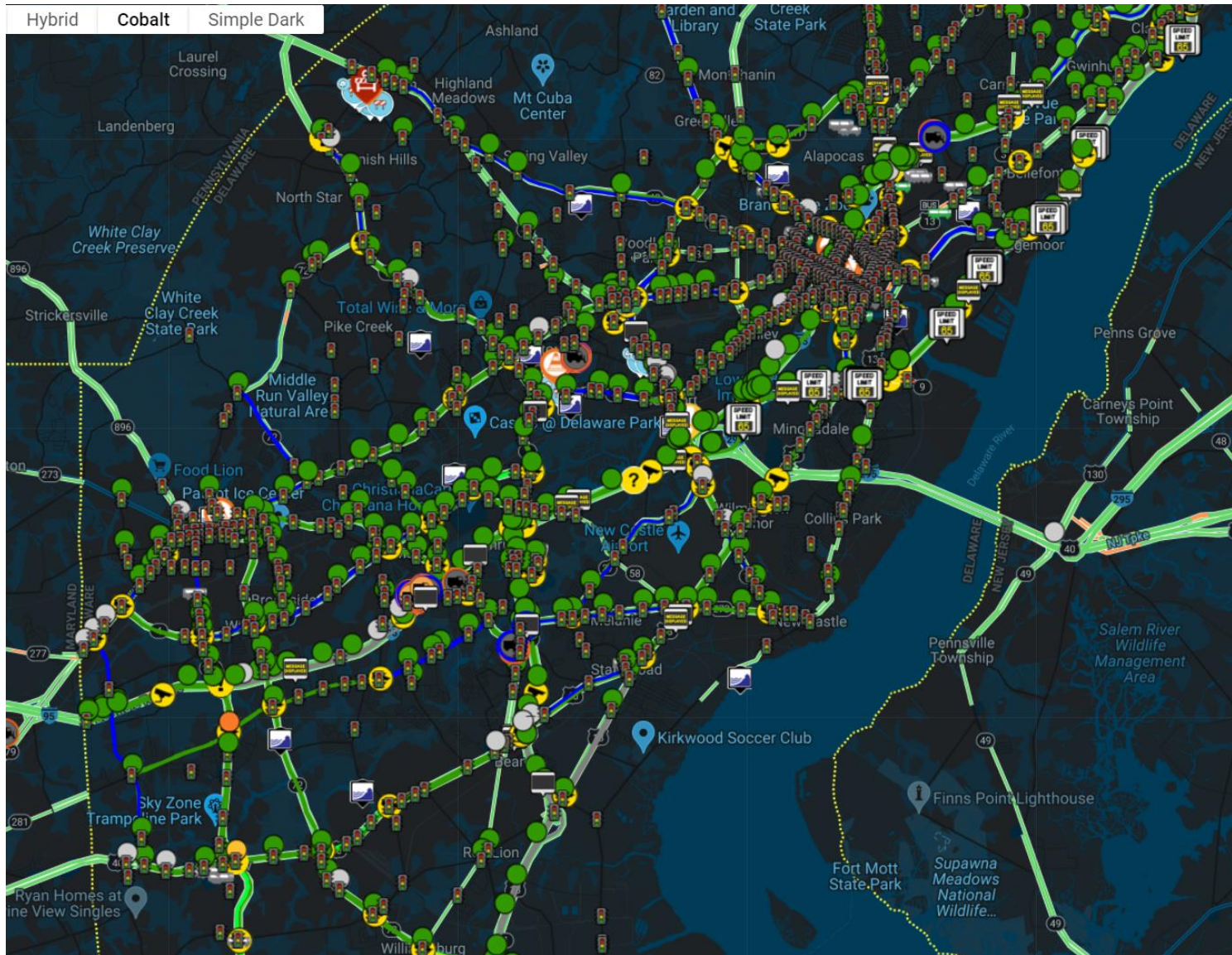


USDOT/DeIDOT “Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD)” grant

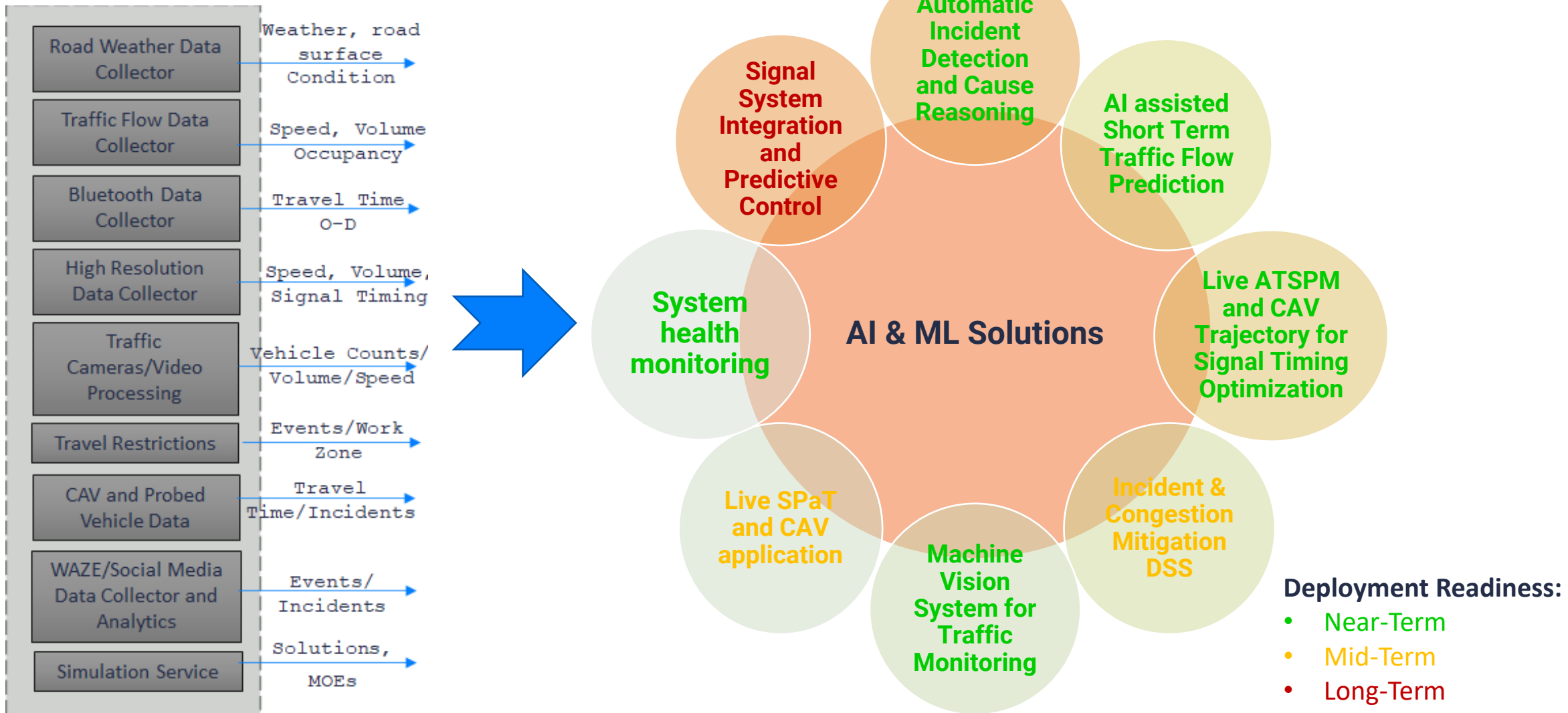
The Vision of AI-ITMS:

- 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)

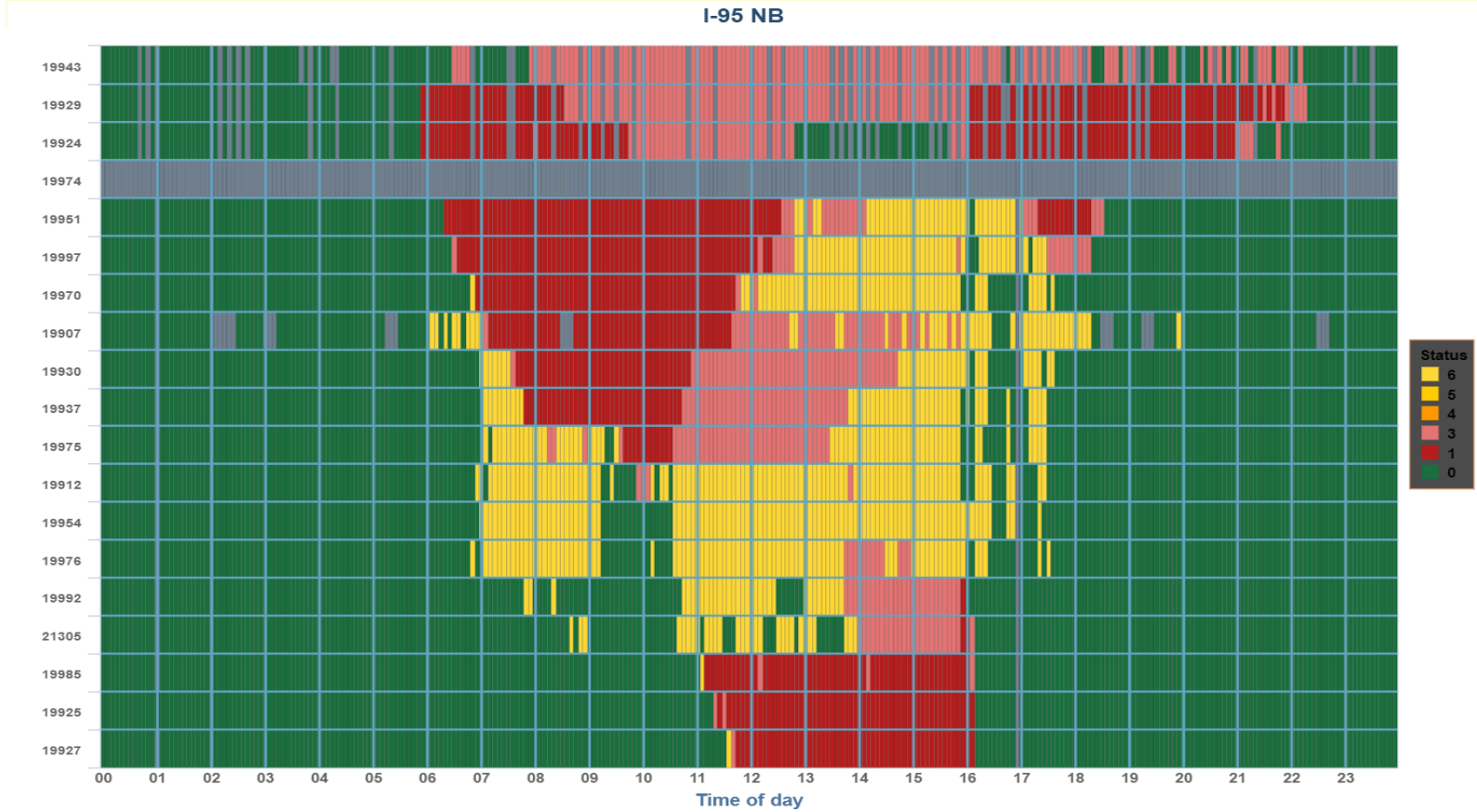


Traffic Anomaly Detection with Data Fusion



Detection Flow Diagram

SPD	VOL	OCC	SPD_C	VOL_C	OCC_C	M	M_H	Cutoff	HQ	LQ	H	L
14	208	48	61	899	16	93.99	3	3.5	432.5	394.5	9.5	5.5



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**)

TIME		LOCATION		TYPE	
Start Time:	7:10 AM	Route:	DE1 NB	Type:	Work Zone
End Time:	7:40 AM	Address:		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.
Duration:	30 min	Detectors		Severity:	42

Incident Localization and Evidence Grouping

AI-TOMS > Traffic Flow Data > TRAFFIC INCIDENTS

September 21, 2021

INCIDENT LIST **TOTALLY 7 INCIDENTS**

ID	Route	Region	Severity	Start Time	End Time	Duration	Evidences	Mitigation
3724	DE1 SB 1	Urban	77	2021-09-20 21:12	2021-09-21 03:20	368 min	89 50 11	
3725	DE1 NB 3	Urban	64	2021-09-20 22:05	2021-09-21 03:54	349 min	172 31	
3726	I-95 NB 3	Urban	89	2021-09-21 07:05	2021-09-21 08:45	99 min	57 70 30 3	
3727	I-95 SB 3	Urban	81	2021-09-21 07:10	2021-09-21 08:20	70 min	29 50 10 2	
3729	DE1 NB 3	Urban	79	2021-09-21 07:43	2021-09-21 08:33	50 min	13 18 26	
3730	DE1 SB 2	CAV	70	2021-09-21 08:00	2021-09-21 09:25	85 min	71 43	
3731	DE1 SB 3	Urban	82	2021-09-21 15:20	2021-09-21 17:50	150 min	54 29 36	

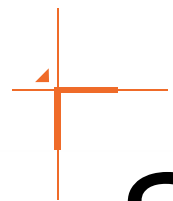
ALL SEGMENTS : SB

TIME	LOCATION	TYPE
Start Time: 8:00 AM	Route: DE1 SB	Type: Incident
End Time: 9:25 AM	Address: 166 Brick Store Landing Rd, Smyrna, DE 19977	Proof: 71 43
Duration: 1 hr 25 min	Detectors: 21266,21744	Severity: 70

Key Features:

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

Traffic Incident Management Interface of AI-TOMS

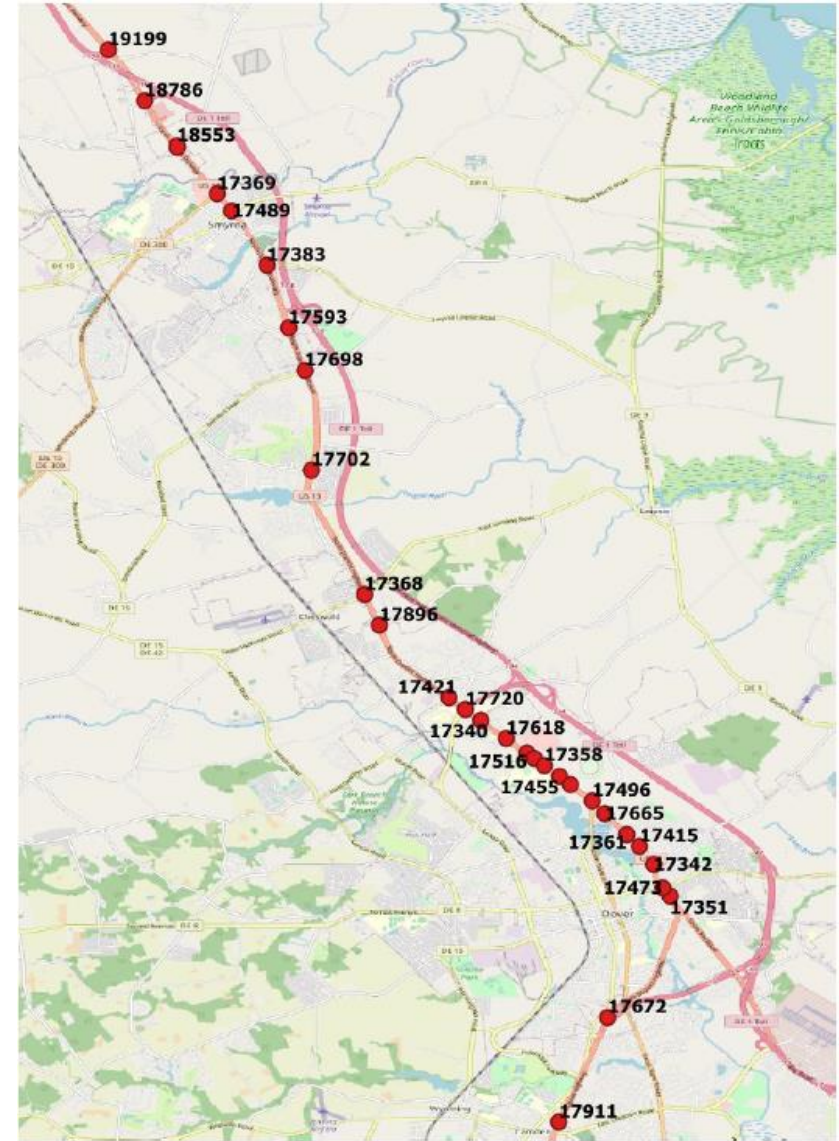


Short-Term Traffic Flow Prediction

1. Robust Long Short-Term Memory (LSTM) Prediction for freeway detectors
2. Graph Structure Learning for Time Series (GTS) for large network

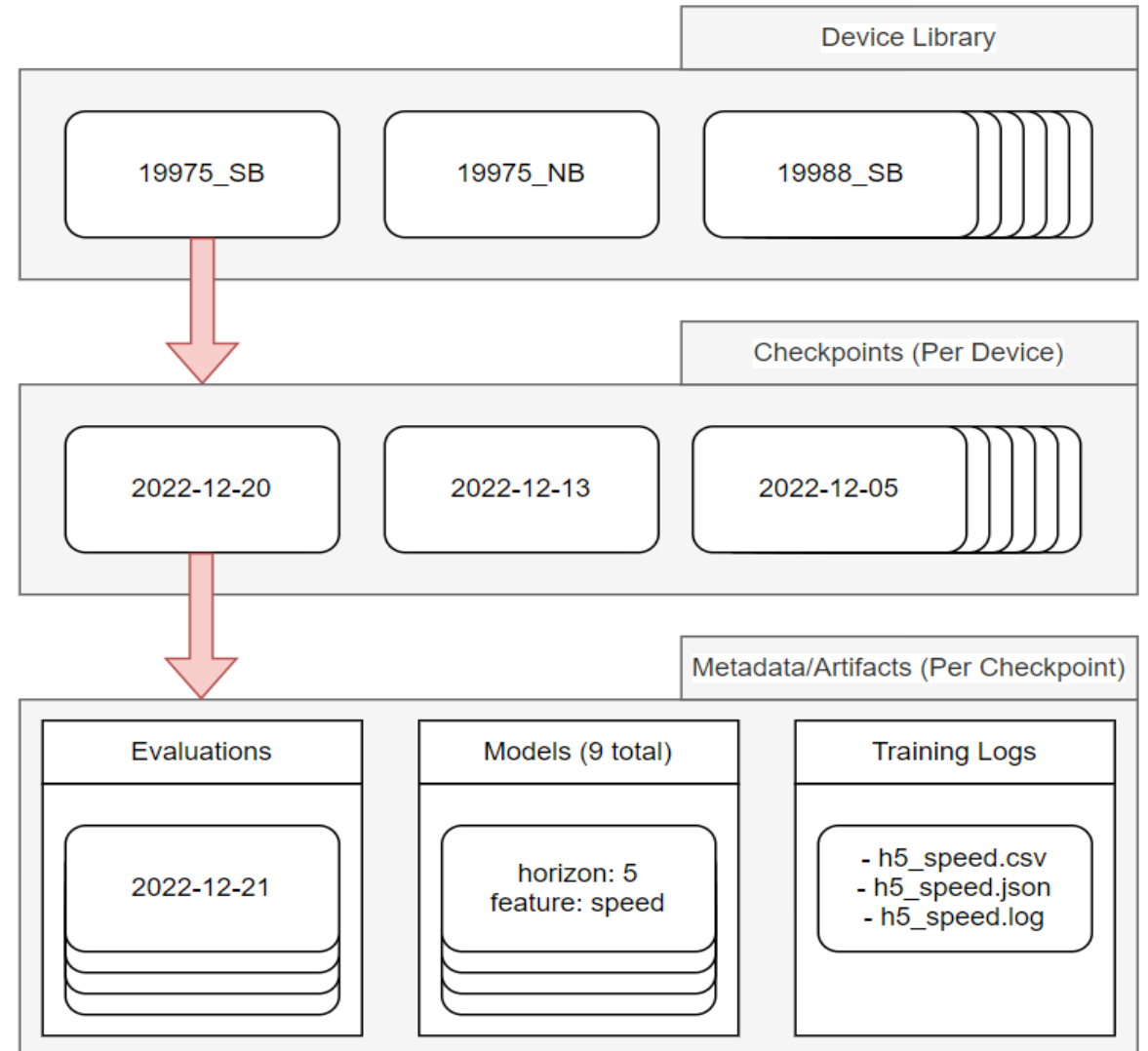
Example Study: CAV Arterials

- 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

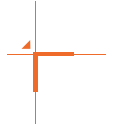
- Prediction models need to update to accommodate seasonal and long-term traffic pattern change
- Library of devices/sensors
- Each sensor has checkpoints
- Each checkpoint has:
 - Models
 - Training logs
 - Dated evaluations





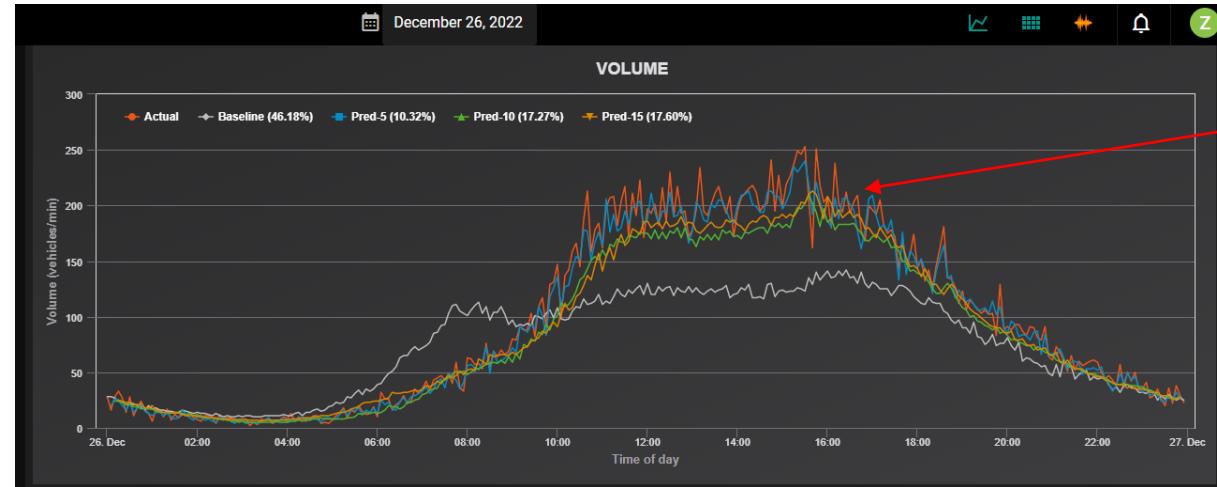
Applications of Traffic Predictions

- 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



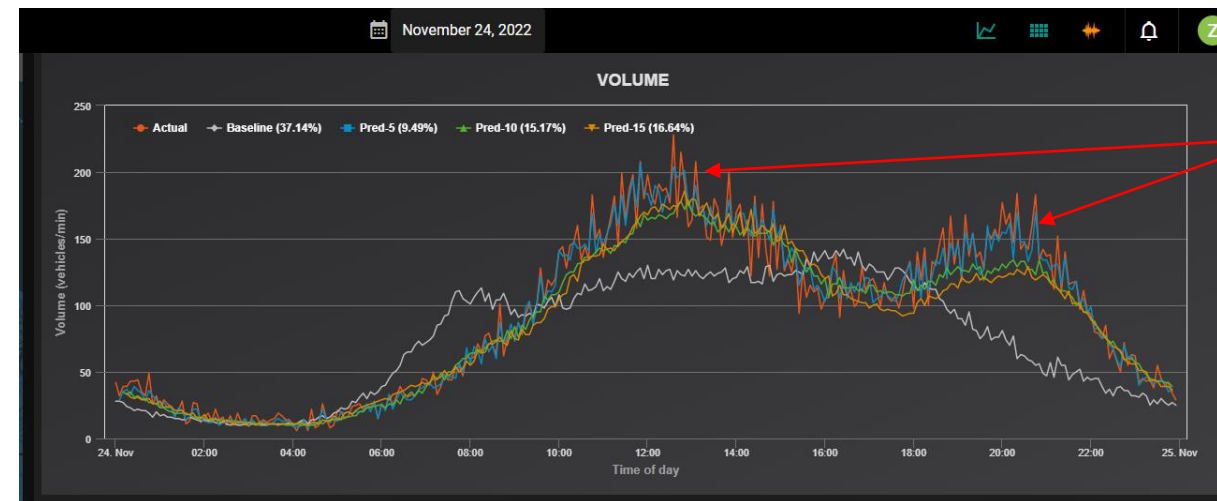
Traffic Flow Prediction Applications

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



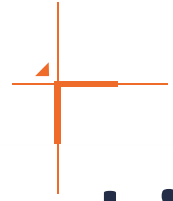
One long peak, with 150-200% traffic demand

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

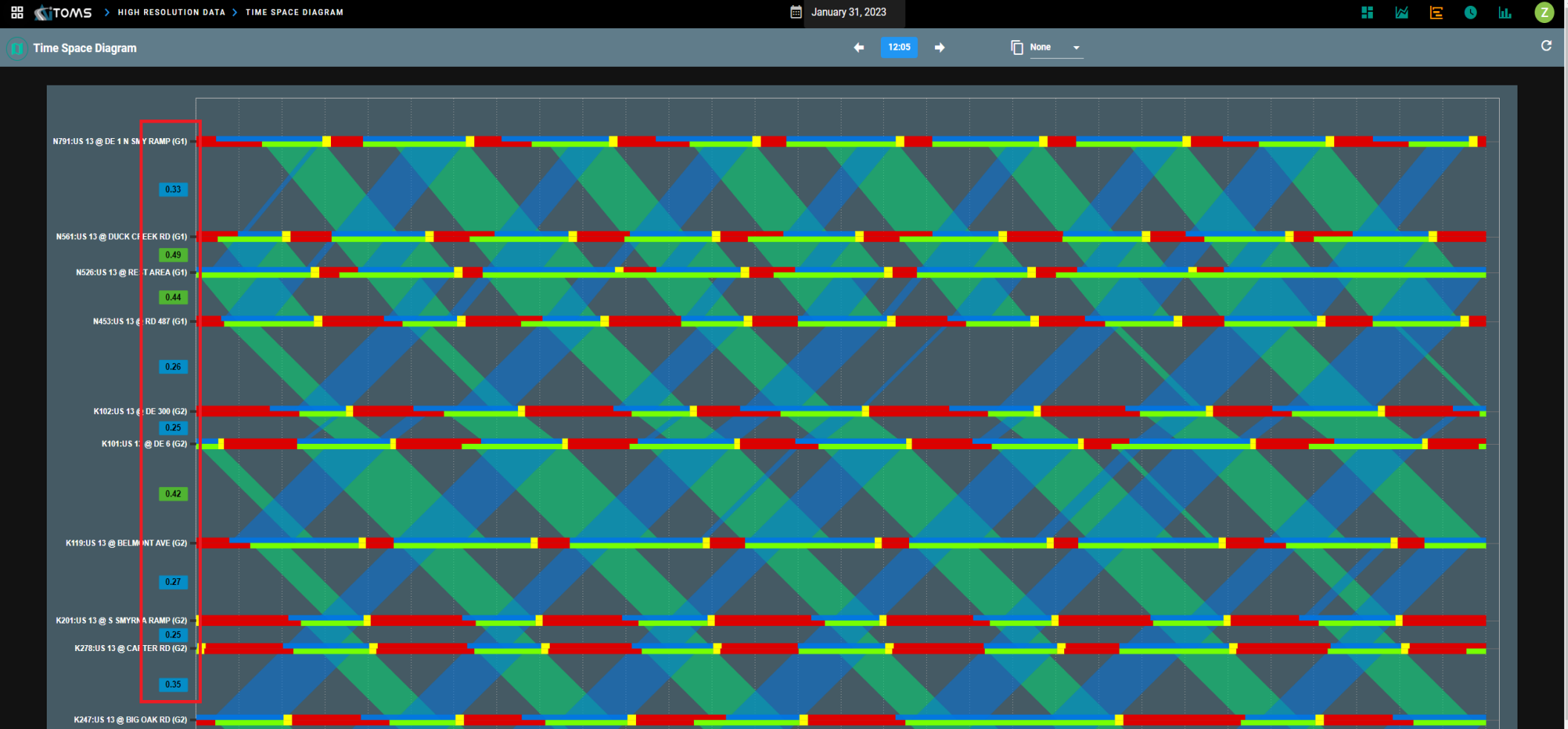
PASSER II EFFICIENCY ASSESSMENT:

0.00 - 0.12: Poor Progression

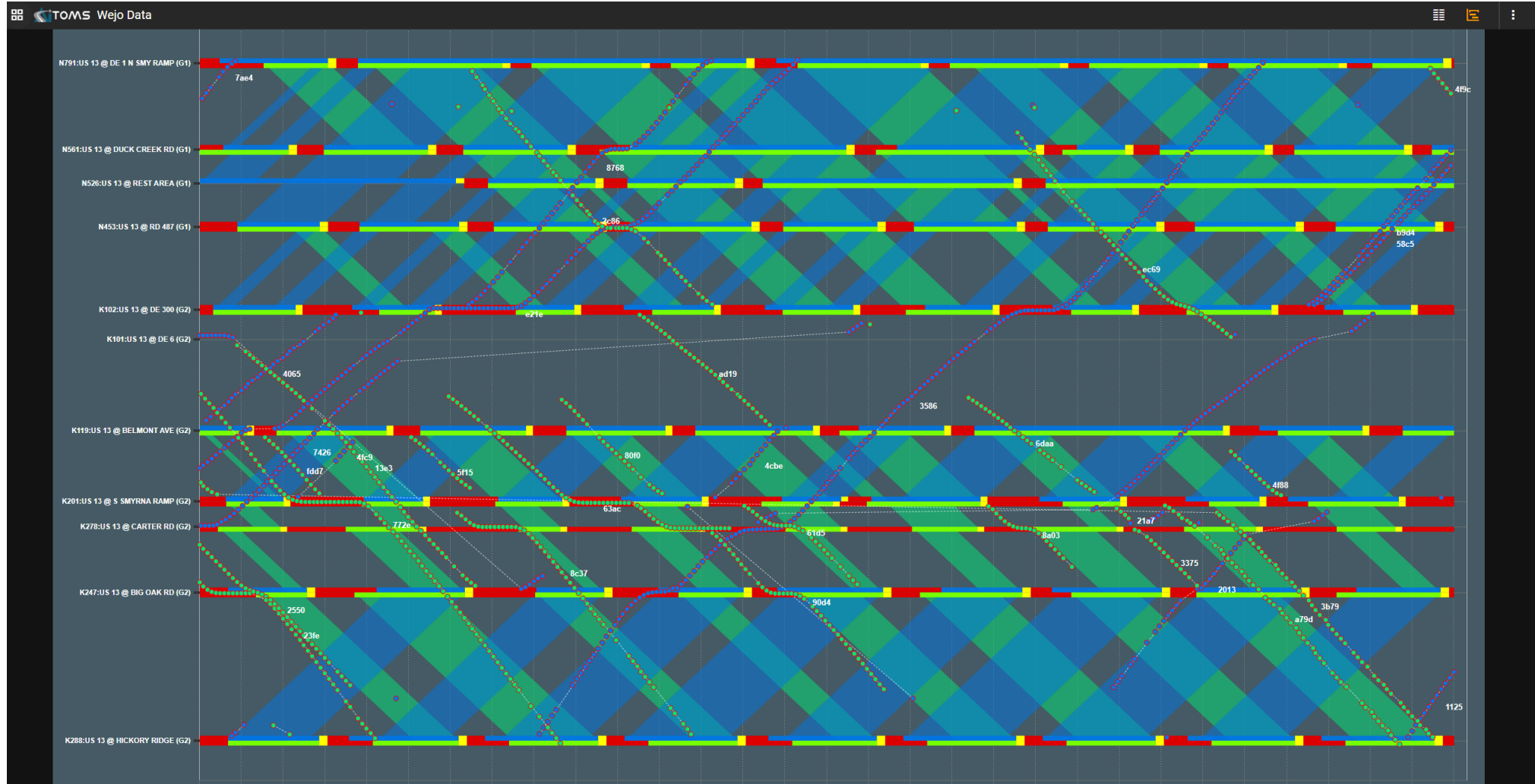
0.13 - 0.24: Fair Progression

0.25 - 0.36: Good Progression

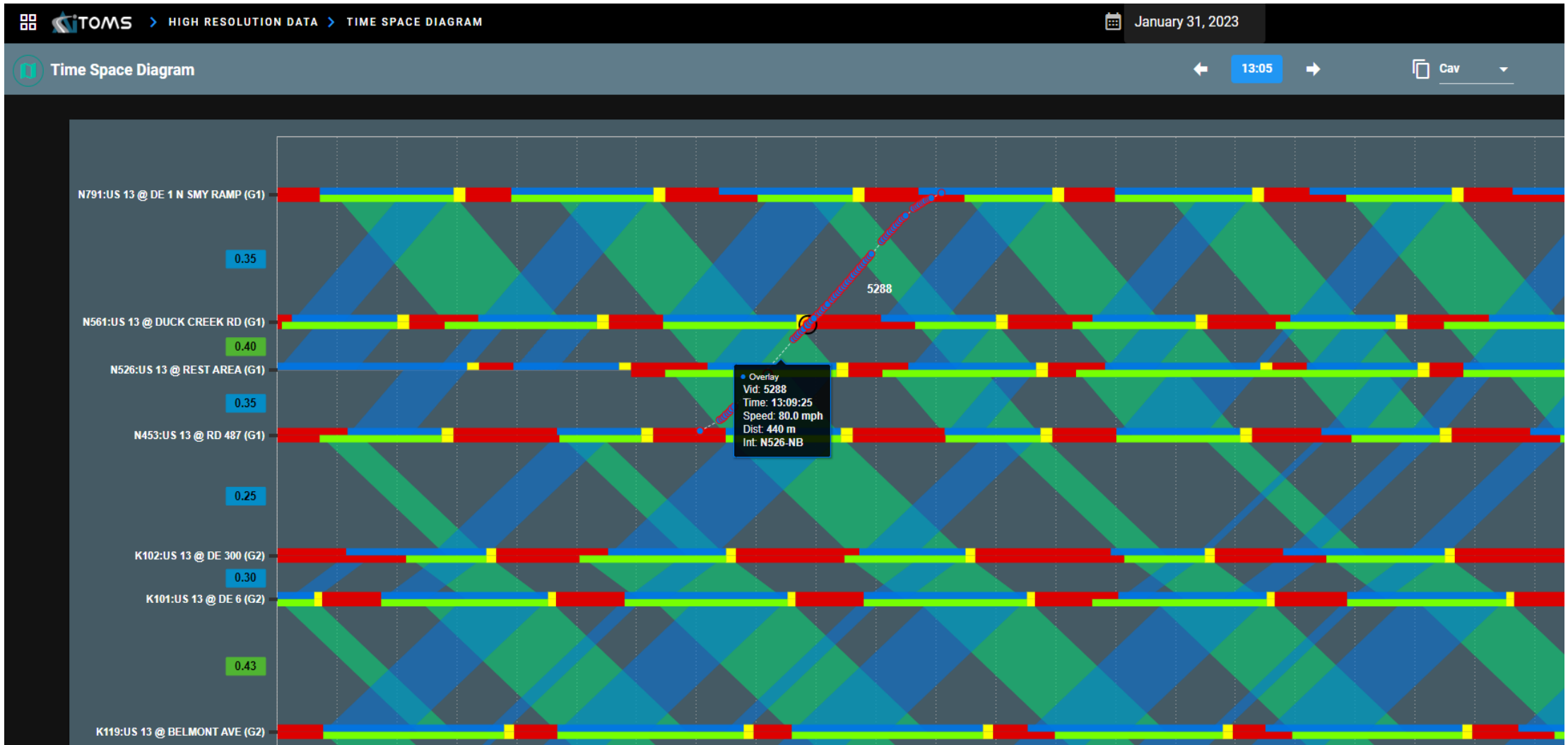
0.37 - 1.00: Great Progression



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

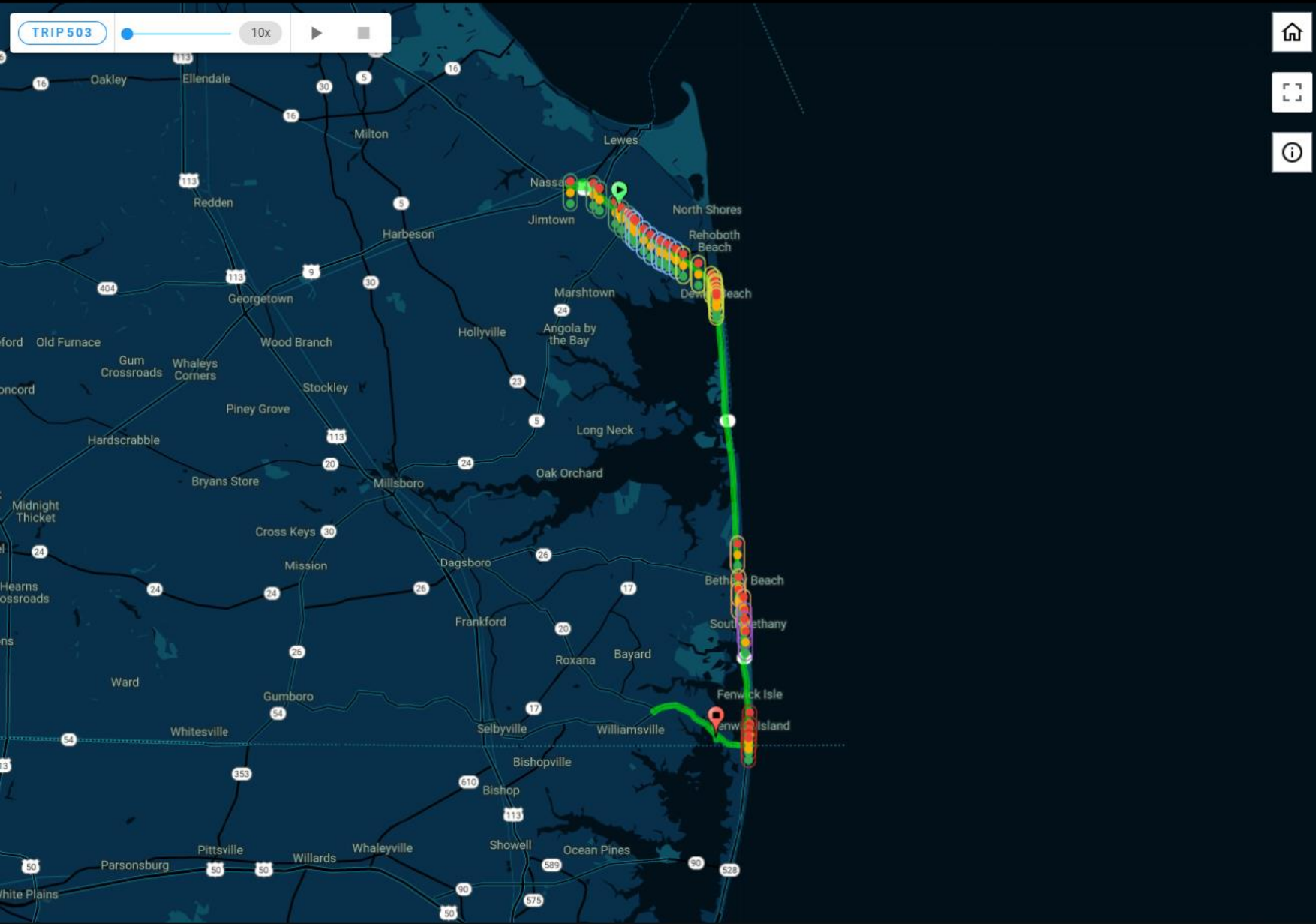


CAN Bus Data Overlay on Time-Space Diagram





CAV/CAN Bus based CSPI



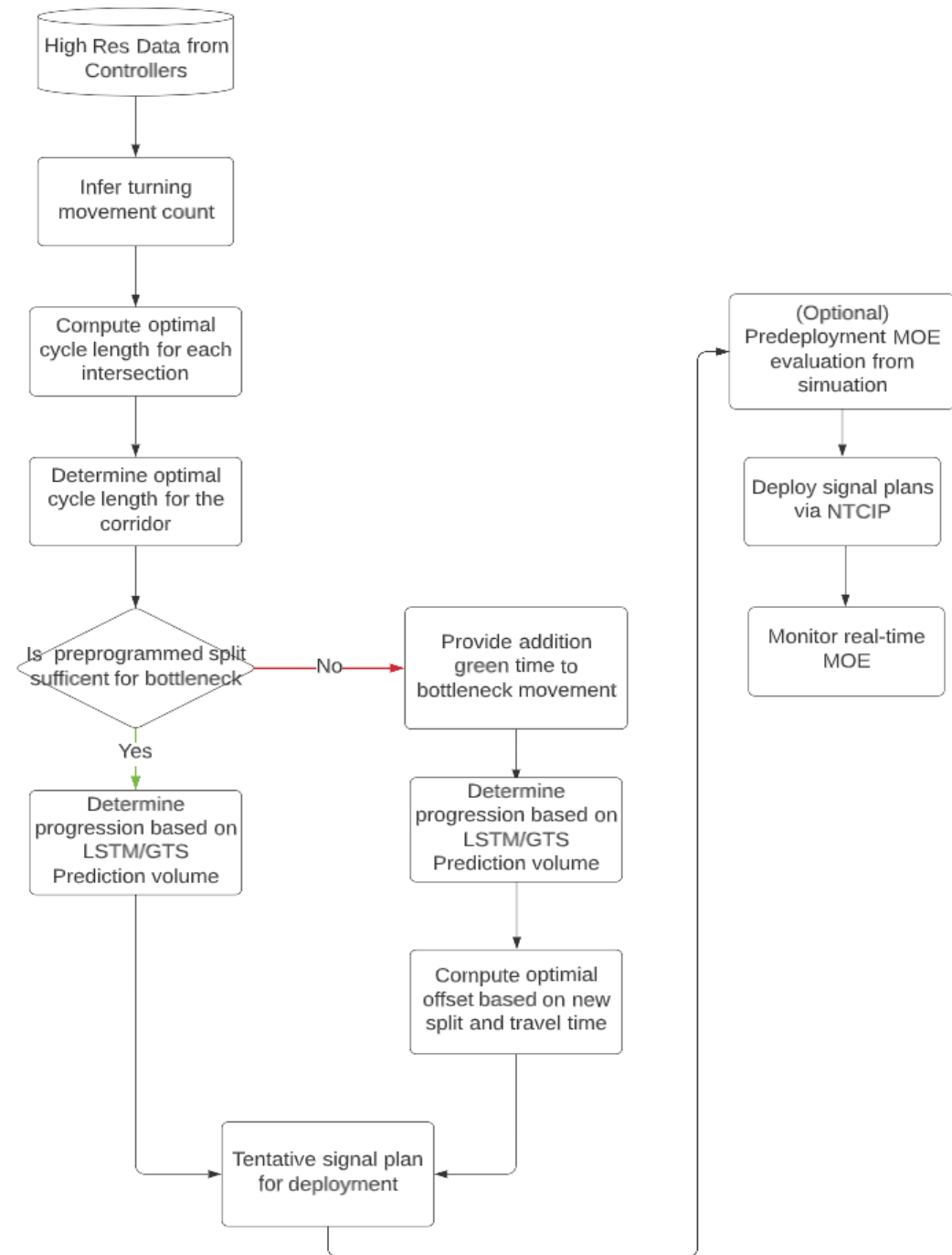
TRIP DATA 🚗 ✕

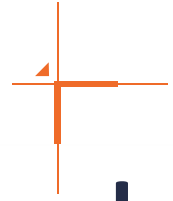
TRIP INFO 🔄

Trip Id:	503
Device Id:	5287
Status:	Completed
Last Updated:	2022-07-08 17:48
Start Time:	2022-07-08 13:31
End Time:	2022-07-08 17:48
Start Location:	Coastal Hwy, Rehoboth Beach, DE 19971
End Location:	Tyler Ave, Selbyville, DE 19975
Distance:	71.3 mi
Duration:	4h 16m
Top Speed:	64.6 mph
Top Rpm:	3957 rpm
Top Accel:	1.35 m/s ²

Signal Group	CSPI Score	Speed Score	Green/Red Score	Stops/Mile Score	# Stops	
S020A	35	8	8	19	6	📄
S020B	35	8	8	19	8	📄
S020C	Average Speed: 12.50 mph			21	9	📄
S018	61	24	8	29	4	📄
S017	109	36	40	33	3	📄
S016	33	8	8	17	4	📄
Average	56	18	15	23		📄

Signal Timing Recommendation Flowchart

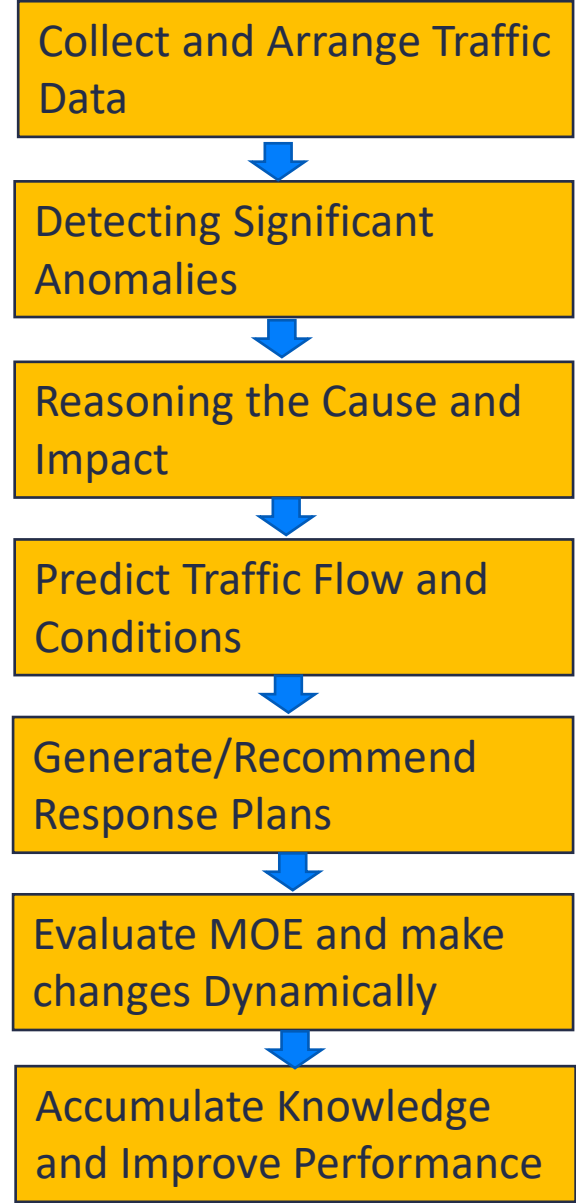
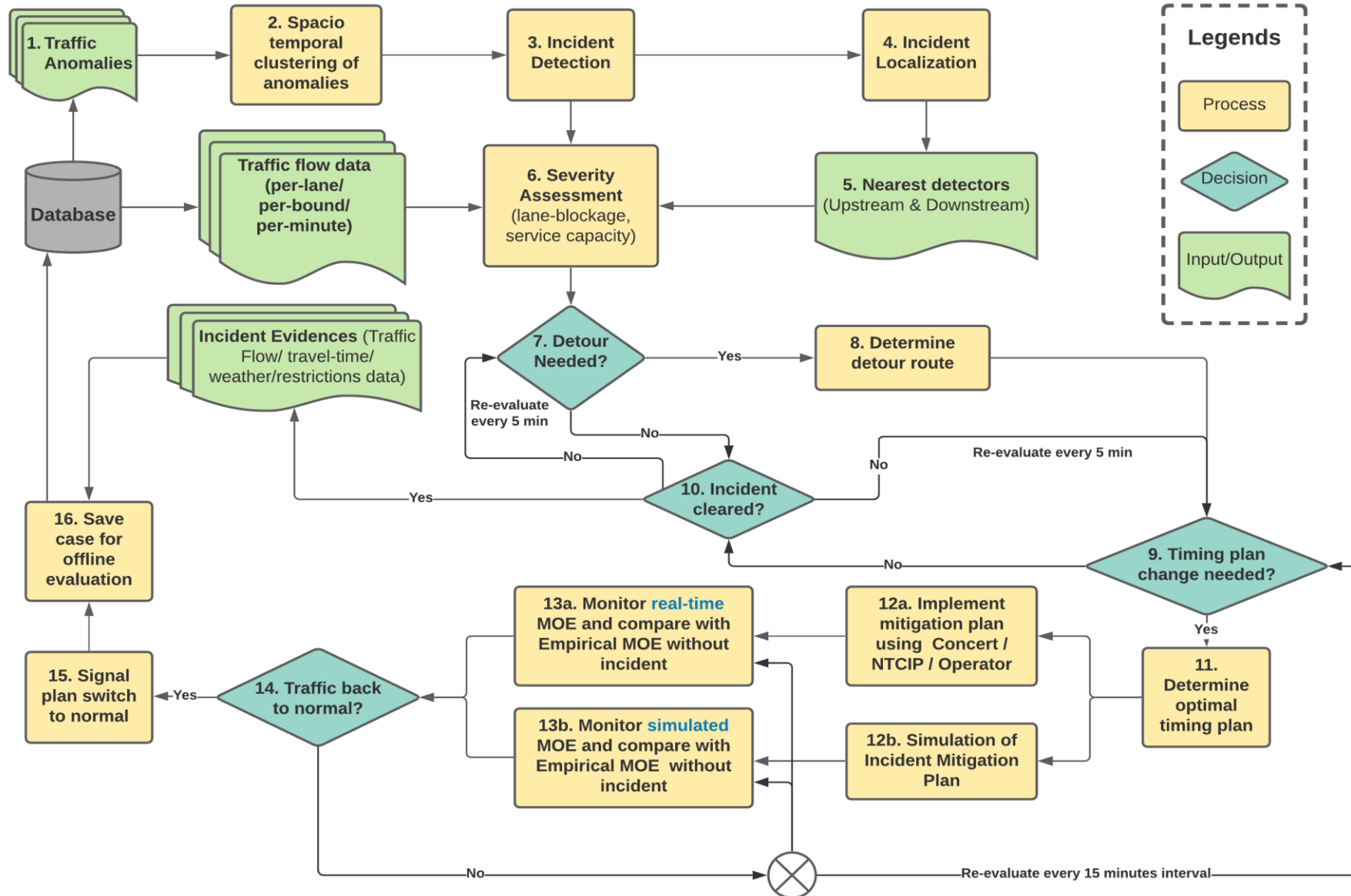




Incident & Congestion Mitigation Decision Support

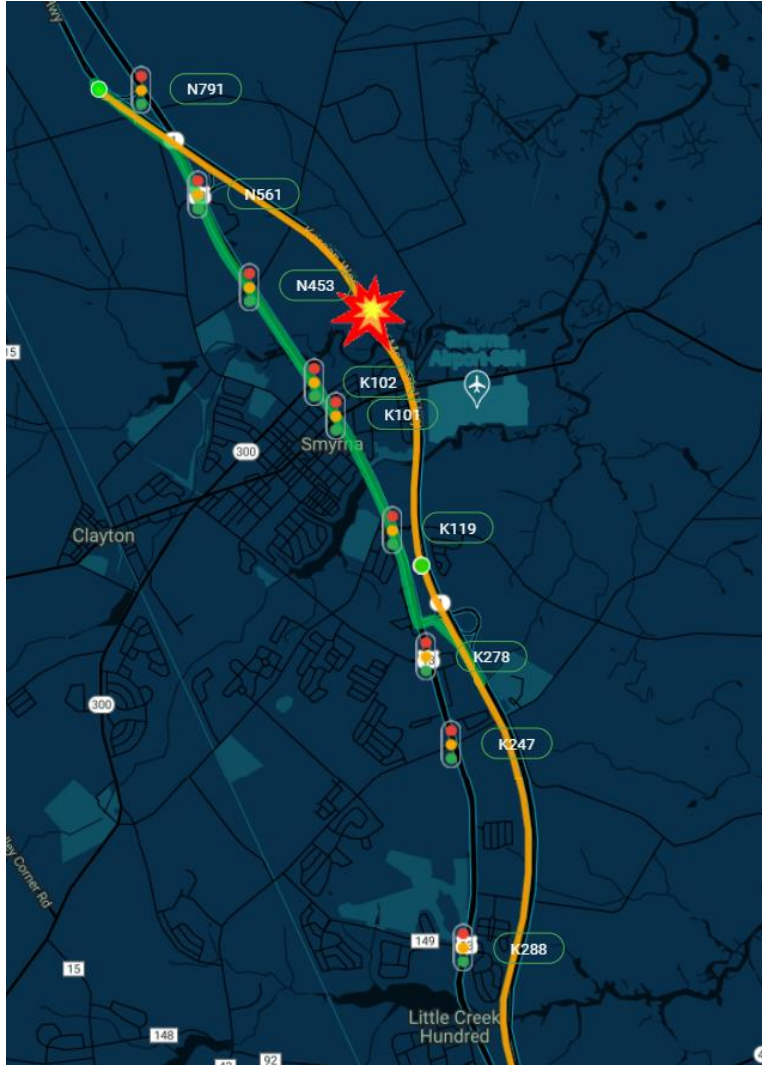


Traffic Incident Management Workflow



Example Incident Management Scenario

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

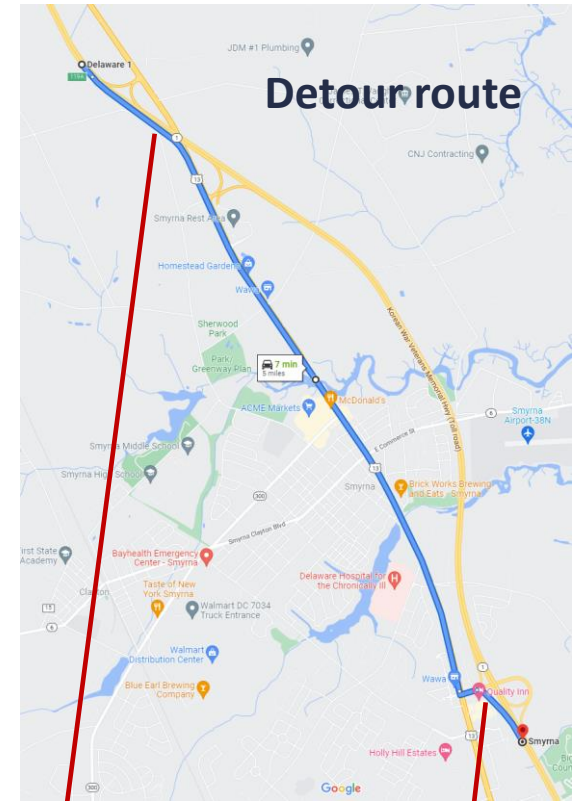
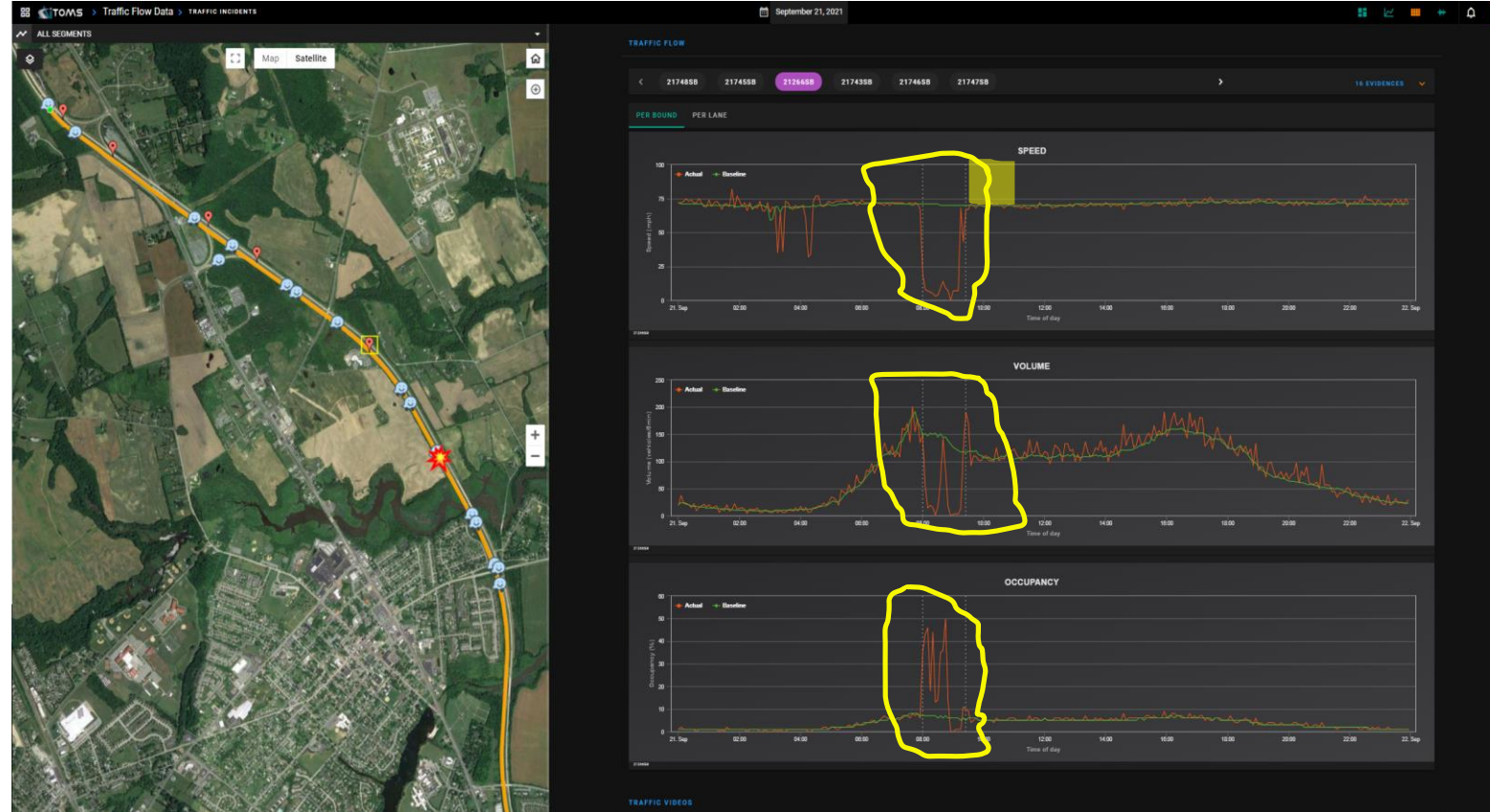


Significant Detour from RT 1

Delays on US 13







Example of Incident Mitigation

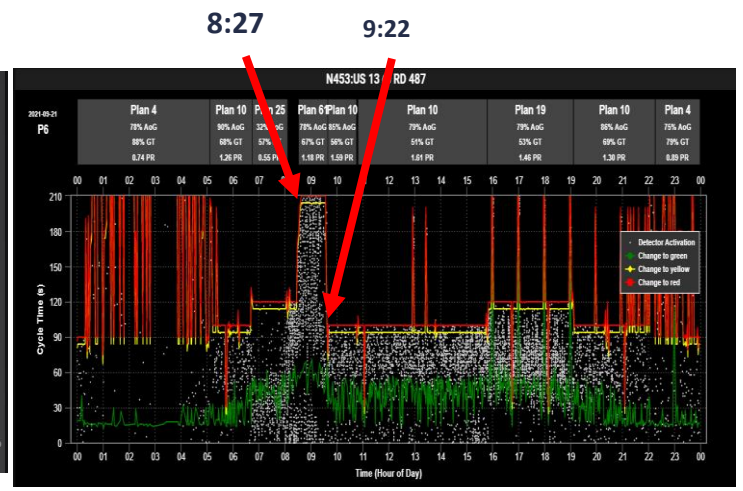
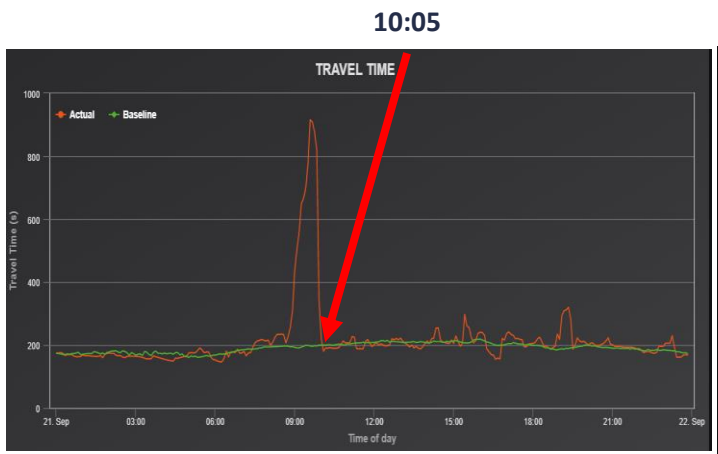
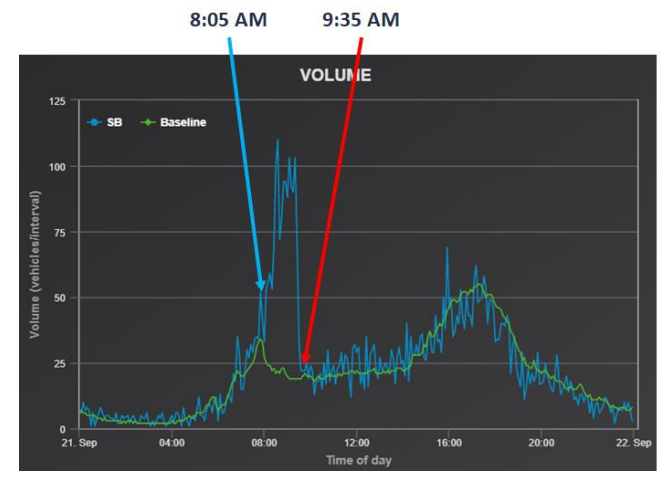
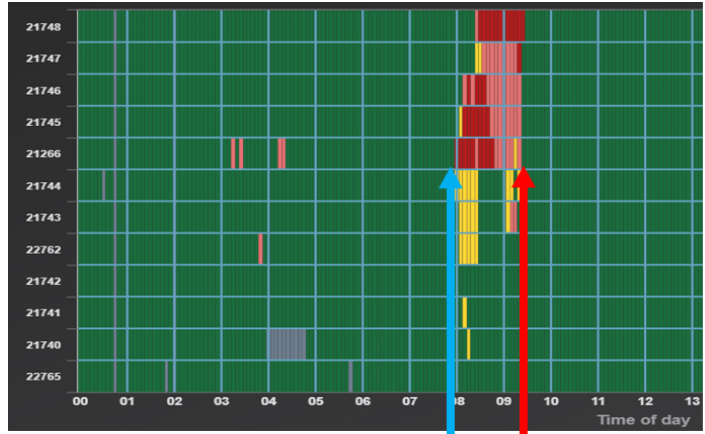
DE-1 SB Incident on September 21, 2021



Incident Management/Mitigation Timeline

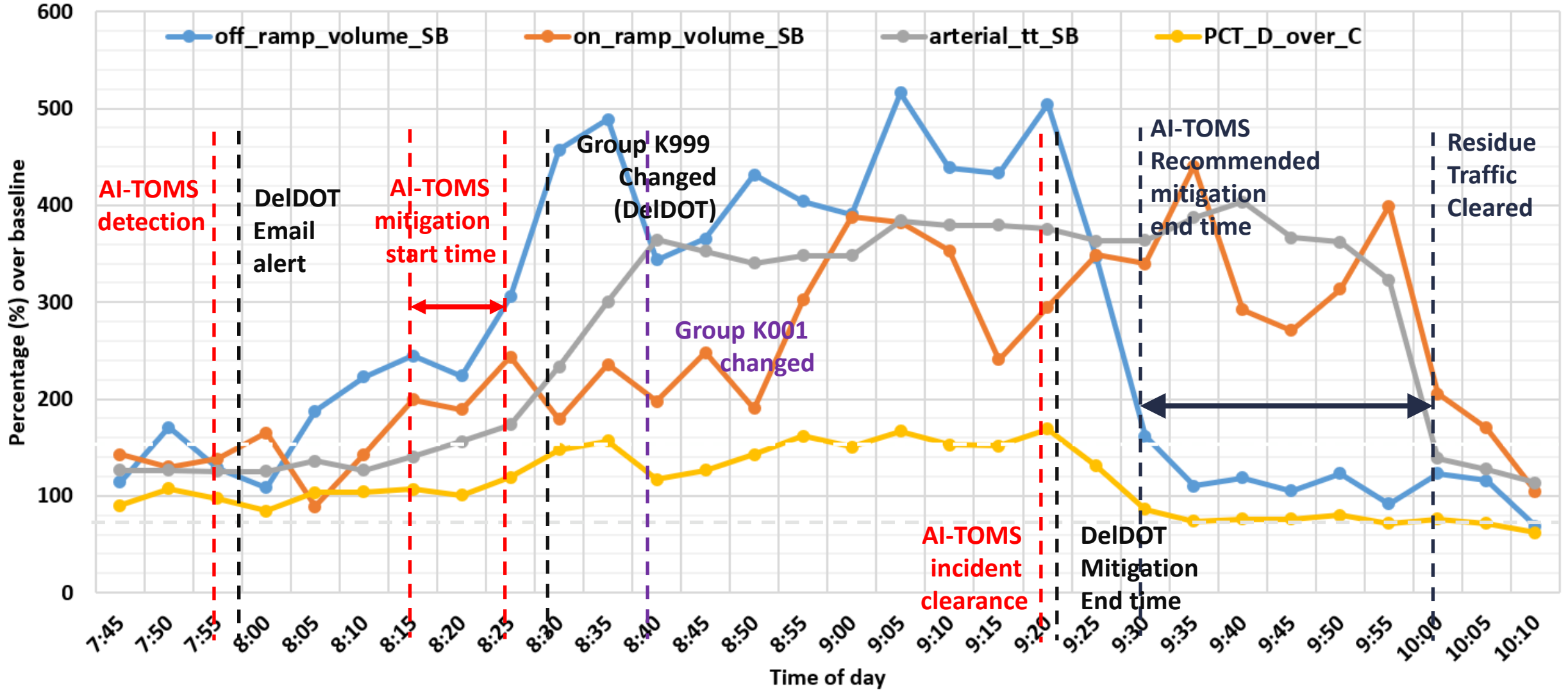
TIMELINE

- 
07:38 AM
First waze alert received
- 
07:55 AM
Incident start
- 
08:00 AM
M-dist anomaly detector detected an incident
- 
08:53 AM
Last waze alert received
- 
09:30 AM
M-dist anomaly detector indicates incident is cleared
- 
09:30 AM
Incident end



Incident Mitigation Timeline

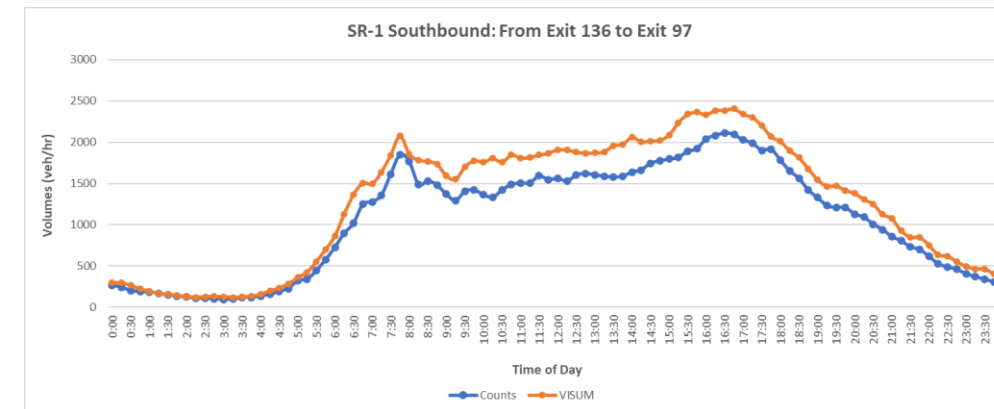
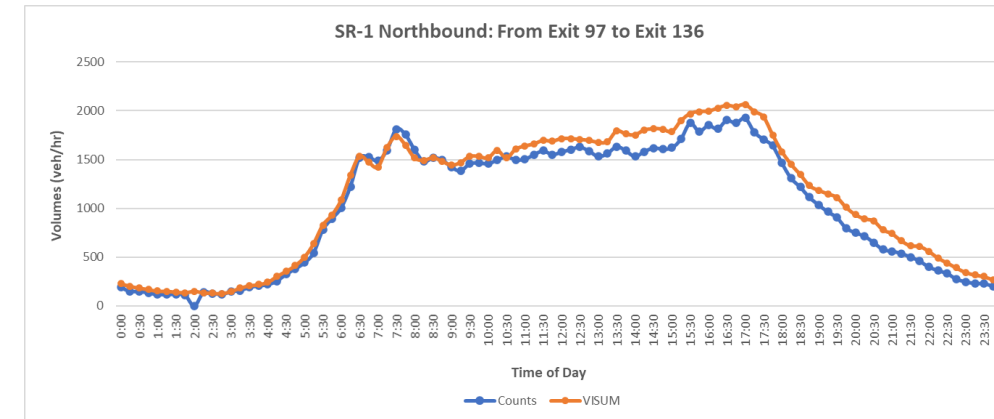
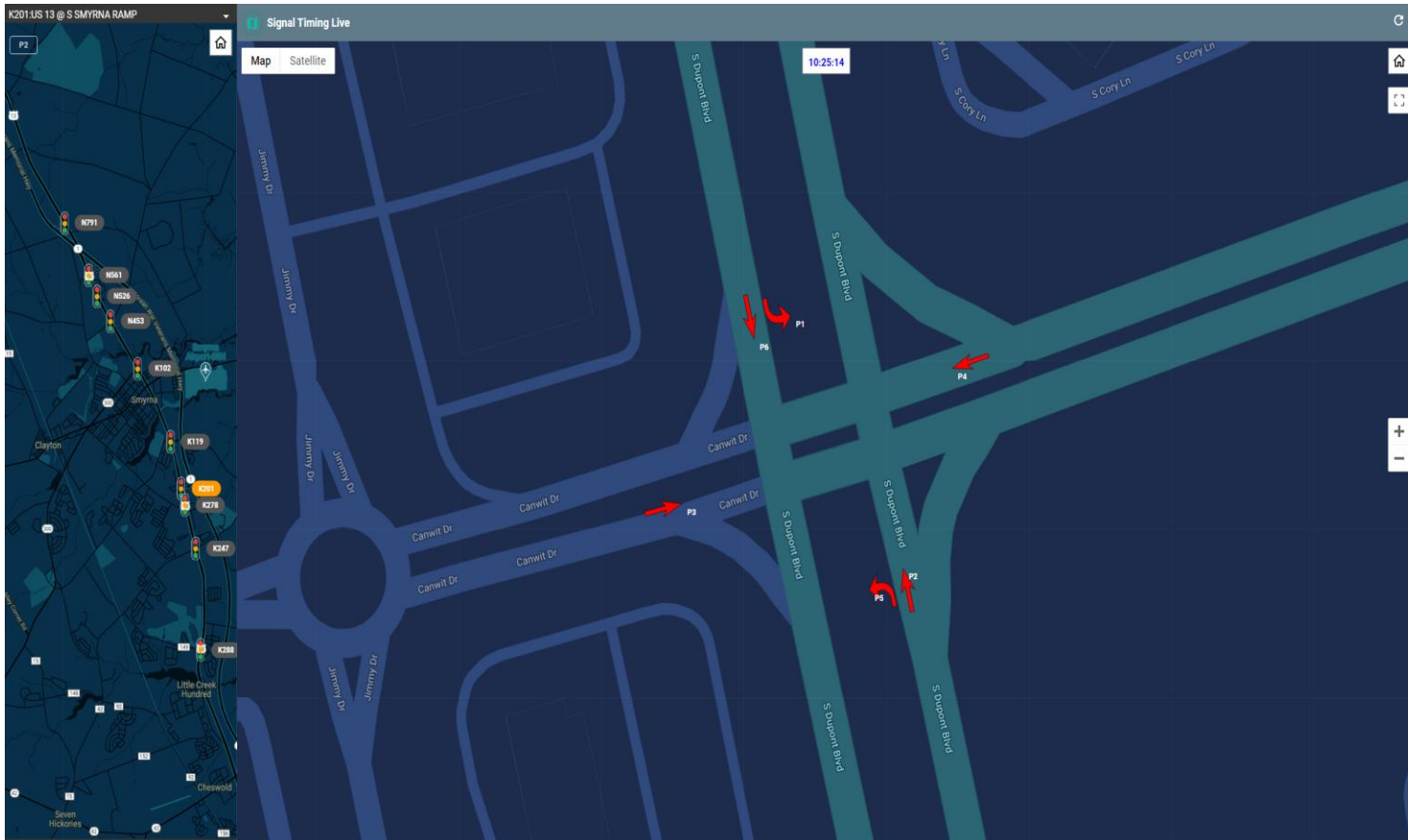
September 21 Incident on DE-1



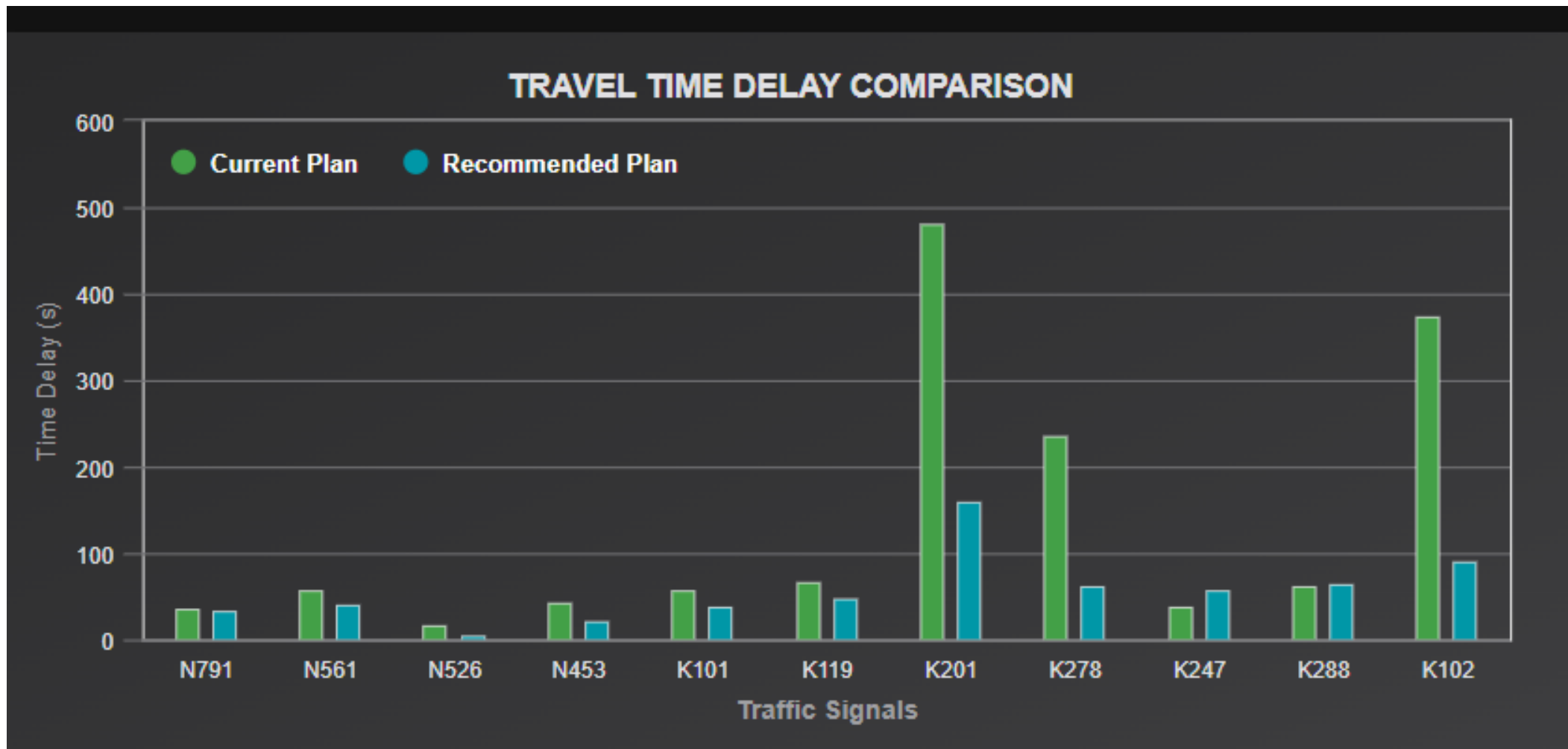
Mitigation Solution Development

- 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

TOMS > Traffic Flow Data > INCIDENT MITIGATION | September 21, 2021

INCIDENT LOCATION AND SIGNALS | MITIGATION SOLUTION | INCIDENT 3730

RECOMMENDED TIMING PLAN

08:00 | TIME OFFSET: 0 MIN

Current Plan & MOE

Group	Time Plan #	Cycle Length	LOS	Delay	Bottleneck Volume	Travel Time
K999	231	120	D	38	358	1468
K001	231	120	E	188	358	1468

Recommended Plan & MOE | CYCLE LENGTH: 120 S | IMPLEMENTED

Group	Time Plan #	Cycle Length	LOS	Delay	Bottleneck Volume	Travel Time
K999	231	120	C	20	358	1218

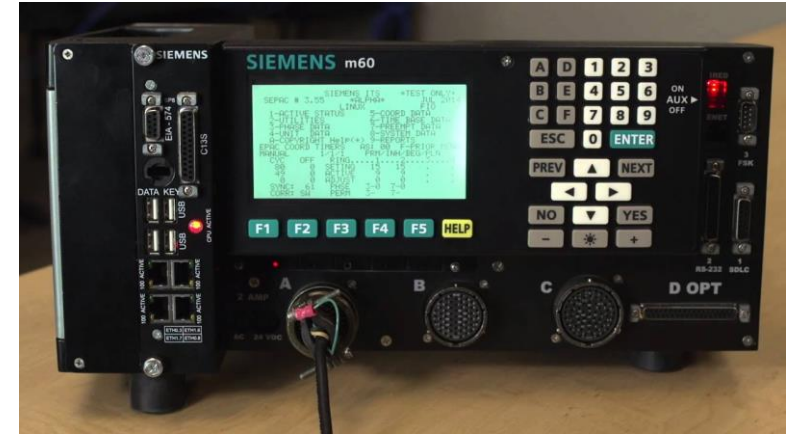
Permit	Offset	LOS	Delay	P1	P2	P3	P4	P5	P6	P7	P8
N791	95	C	23	/	106	/	10	70	33	/	/
N561	0	C	31	22	53	11	25	9	66	/	/
N526	115	A	6	9	96	/	9	9	96	/	/
N453	12	B	19	10	76	15	10	10	76	/	/

K001 231 120 C 69 358 1218

- 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 DeIDOT 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



MITIGATION SOLUTION INCIDENT 3730

RECOMMENDED MITIGATION SOLUTION

08:15 08:30 08:45 09:00 TIME OFFSET: 0 MIN CYCLE LENGTH: 120 S

Permit	Group	Offset	LOS	Delay	BN Volume	Travel Time	P1	P2	P3	P4	P5	P6	P7	P8
N791	K999	95	C	24	282	403	/	75	/	25	25	50	/	/
N561	K999	95	F	146	282	403	27	37	23	13	17	47	/	/
N526	K999	78	C	29	282	403	25	60	/	15	16	69	/	/
N453	K999	16	F	305	282	403	15	44	30	24	15	44	/	/
K101	K001	0	F	102	282	403	30	30	30	30	30	30	30	30
K119	K001	13	F	116	282	403	14	64	/	22	14	64	/	22
K201	K001	85	F	1454	282	403	18	42	20	20	18	42	/	/
K278	K001	25	D	37	282	403	20	42	19	19	25	37	21	17
K247	K001	79	D	54	282	403	25	28	22	25	15	38	/	/

EVALUATION TIME: 2021-09-21 08:15:00, TIME OFFSET: 0MIN, CYCLE LENGTH: 120S



Machine Vision for Traffic Condition Monitoring and Vehicle Re-identification



Machine Vision for Vehicle Count, Speed and Occupancy



Video based Vehicle Re-ID

AI-TOMS Video Matching for Vehicle Re-ID

Downstream 1 Camera



Upstream 2 Camera



HISTORY

HIDE MAP



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

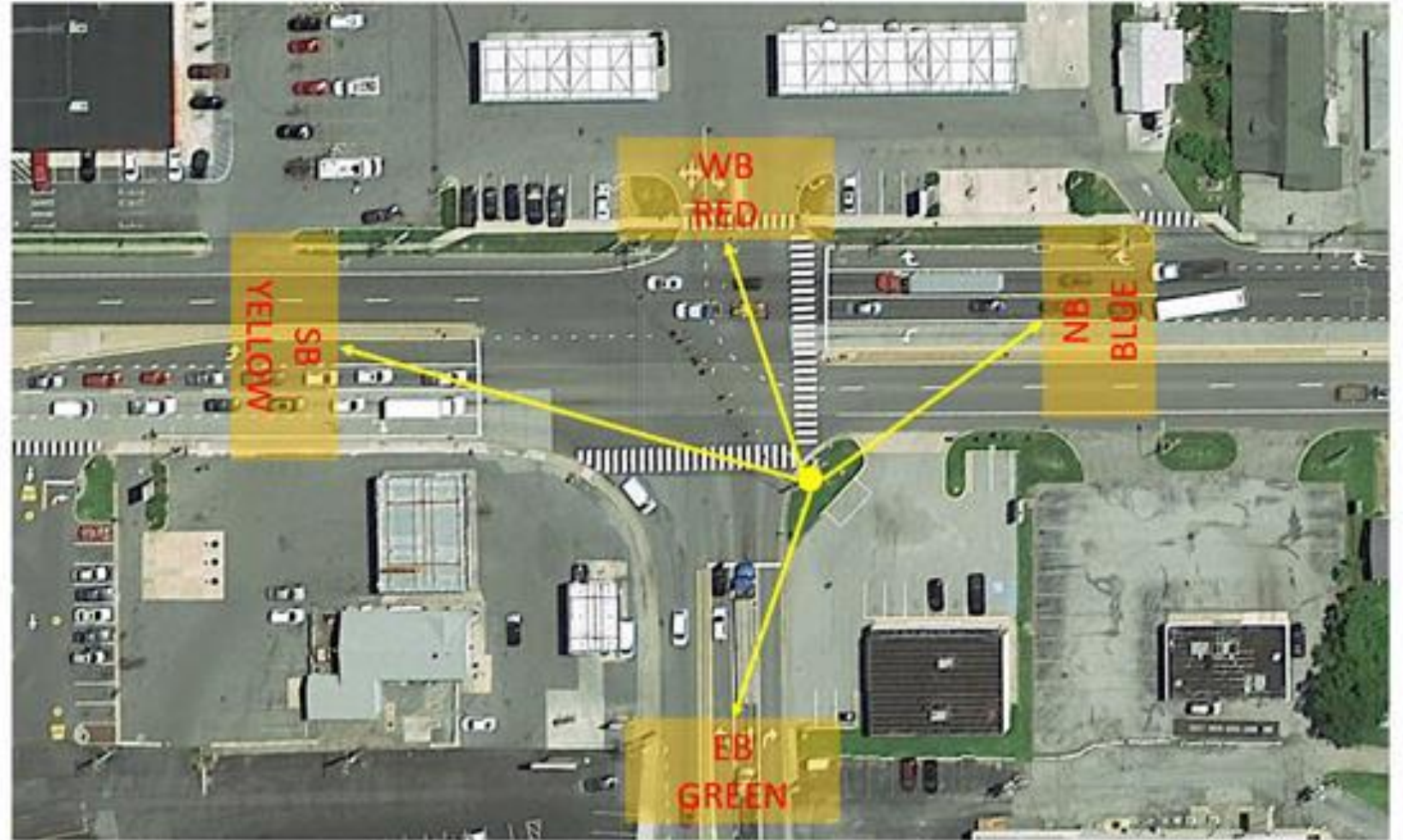
COLOR CODE

NB: BLUE

SB: YELLOW

WB: RED

EB: GREEN



Machine Vision Hub Software Interface

TOMS > Machine Vision > TRAFFIC CAMERAS

November 13, 2022

JCAM17121006: US13 at DE 300 SB

JCAM17121006

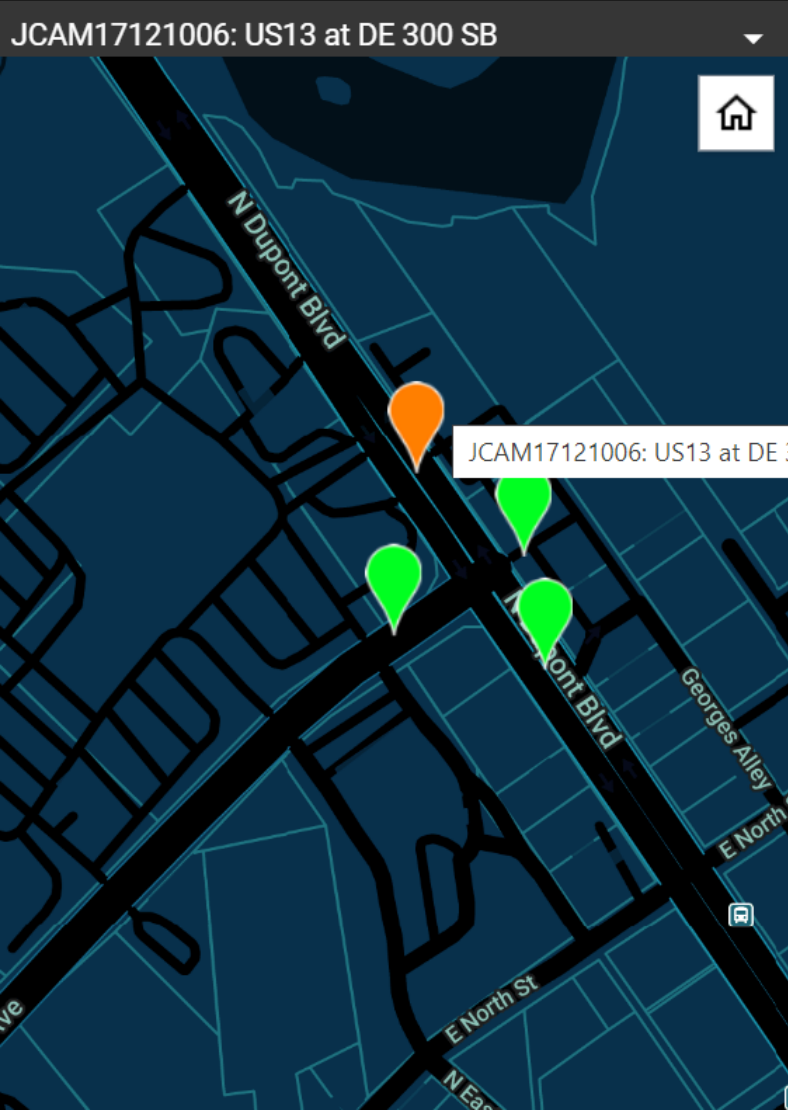
LIVE FEED **HISTORICAL VIDEO** TRAFFIC FLOW

Speed: 41.4, Vol: 2, Occ: 35 (update in 20 s)

People Detected

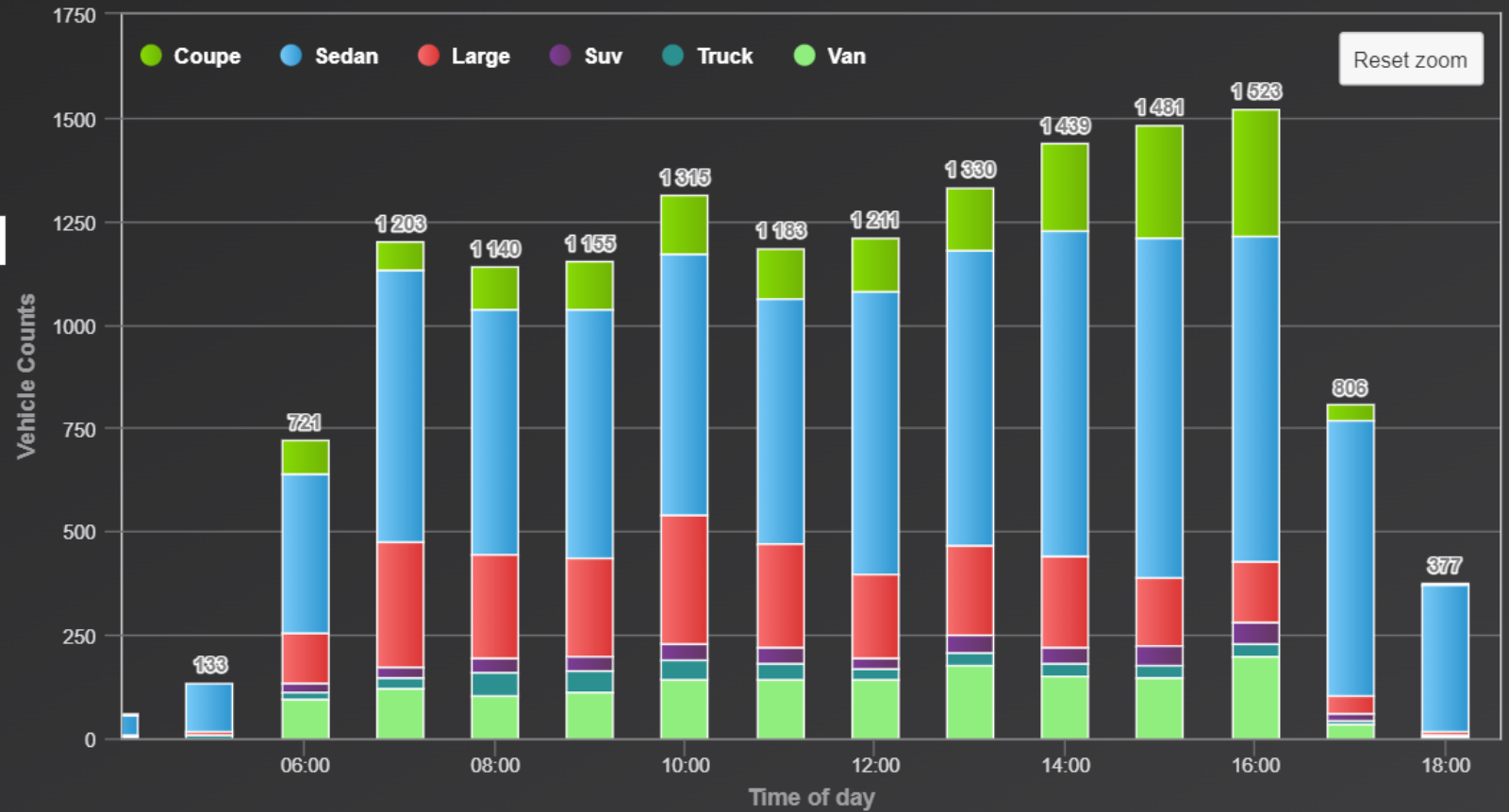
43944	36.9	Black	Chevrolet	Large
43904	14.8	White	Mercedes	Large
43091	15.1	White	Ford	Van
43817	8.0	White	Bmw	Sedan
43888	24.2	White	Chevrolet	Large
43756	6.0	Black	Chevrolet	Sedan
43822	24.0	White	Mercedes	Large
43828	11.0	Silver	Mercedes	Sedan
43513	2.0	White	Mercedes	Sedan
43732	45.8	Silver	Mercedes	Sedan

Machine Vision Vehicle Count and Classification

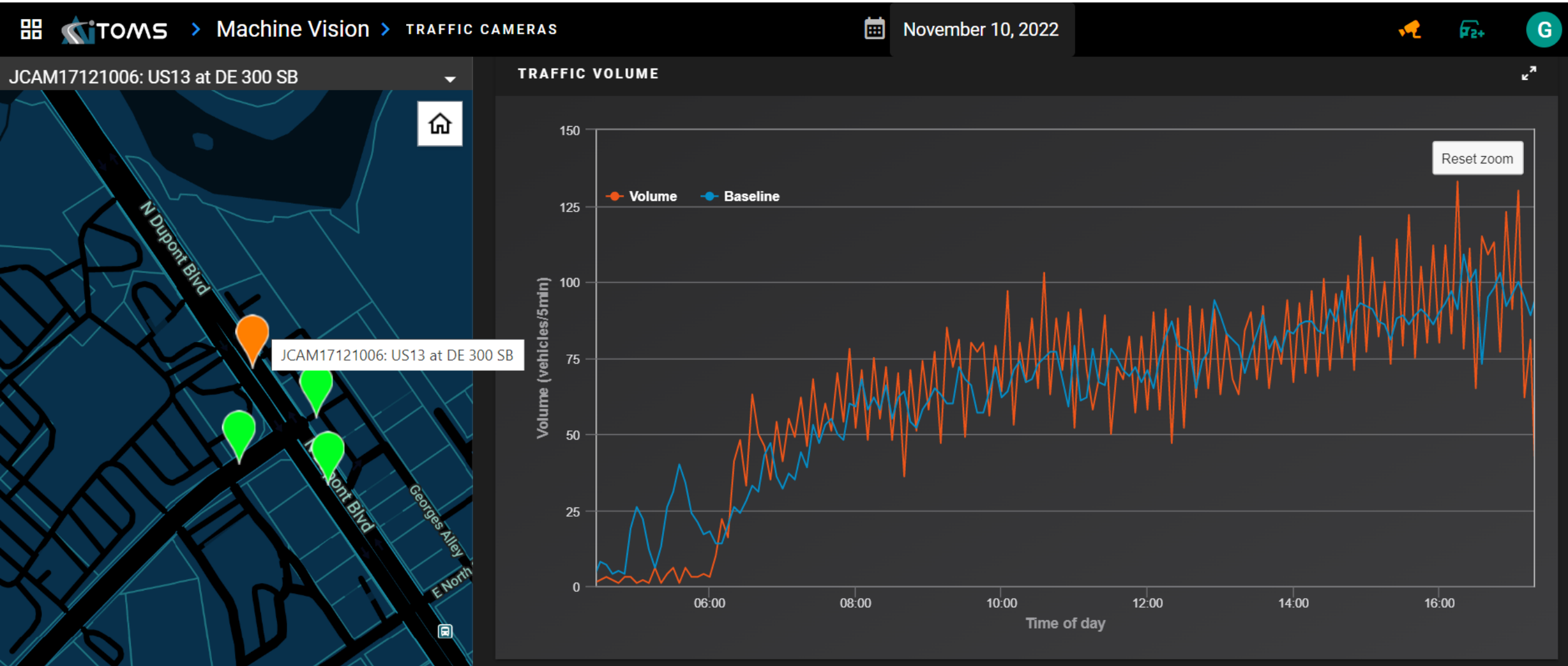


TRAFFIC COUNTS

🕒 1 Hour



Cross Check of Vehicle Count with System Loop Data



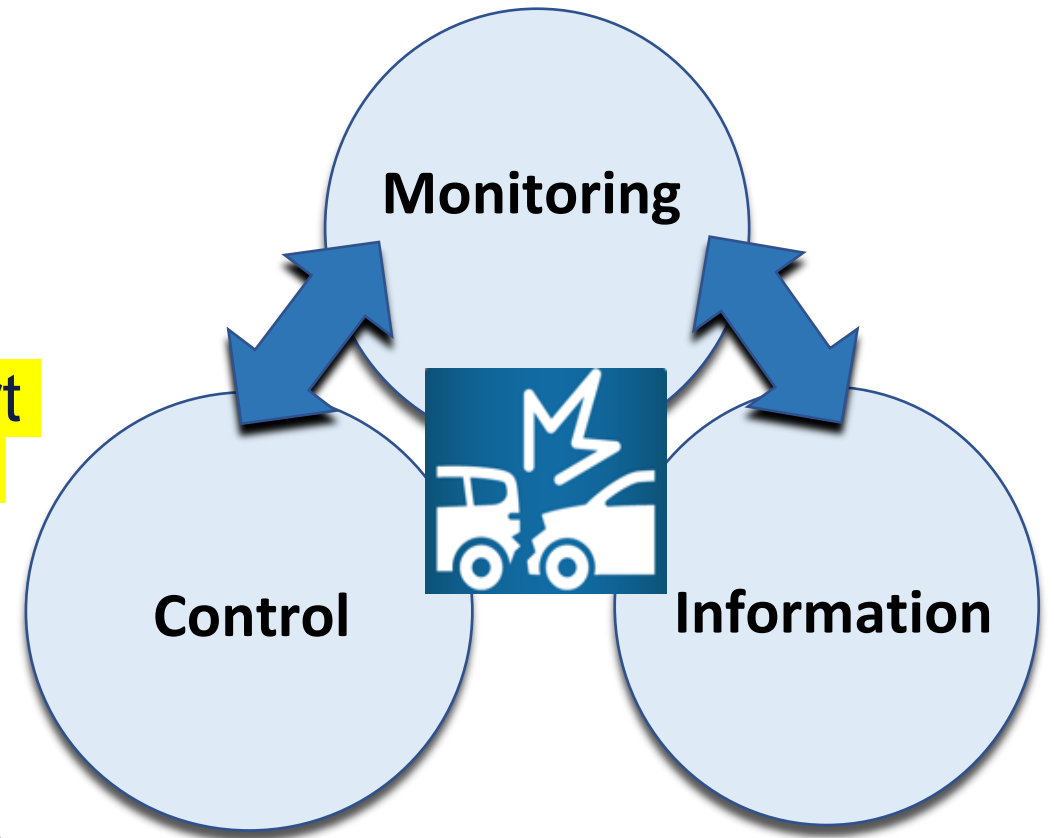


Key Findings and Lessons Learned

- 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



<https://deldot.gov/Programs/itms/>

<https://deldot.gov/Programs/itms/>

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