Real-Time Traffic Signal System Performance Measurement

Phase II: Data And Functionality Enhancement, Large Scale Deployment, Connected And Autonomous Vehicles Integration

Presentation at

NJDOT Research Showcase

RUTGERS

TCNJ — THE COLLEGE OF NEW JERSEY

Rowan University

Outline

Project Overview

ATSPM Development

- ATSPM Data Sources
- Enhanced ATSPM Functionalities
- NJ ATSPM Platform Demonstration

CAV Application Deployment and Testing

- CAV RSU Integration
- CAV Application Deployment

Project Overview

Project Title: Task Order 368

- Real-Time Traffic Signal System Performance Measurement (Phase II)
- Data And Functionality Enhancement, Large Scale Deployment, Connected And Autonomous Vehicles Integration

Duration:

- 10/21/2019 – 04/31/2022 (24+6 Months)

University Team:

- Rutgers University: Peter J. Jin, Ph.D., Associate Professor, CEE, CAIT
- The College of New Jersey: Thomas Brennan Jr., Ph.D., Professor, CEE
- Rowan University: Mohammad Jalayer, Ph.D., Associate Professor, CEE, CREATES

NJDOT Team:

- Bureau of Research: Priscilla Ukpah
- Mobile Engineering: Wasif Mirza, Kelly McVeigh, Mohamed Elhefnawi, Kateline Barone, LaDanya Friday

FHWA (Federal Highway Administration) Every Day Counts (EDC) Initiative

- State-based model to identify and rapidly deploy proven but underutilized innovations to:
  - Shorten the project delivery process
  - Enhance roadway safety
  - Reduce congestion
- Improve environmental sustainability
- Approximately 40% of vehicle accidents and 20% of fatal crashes occur at an intersection.
- ATSPM (Automated Traffic Signal Performance Measures) is one of the exciting technologies promoted under EDC.

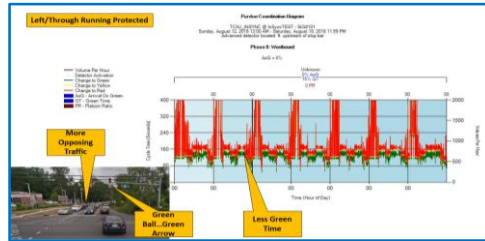https://www.fhwa.dot.gov/innovation/everydaycounts/edc-4.cfm

- ATSPMs: A suit of performance measures, High Resolution Data collection tools, and data analysis tools to support an object and performance-based approach to managing a traffic signal program.

- The traditional project-based signal optimization practices are time-consuming and costly.

- Data-driven ATSPMs provide a means to proactive management and identify problems on a signalized roadway.
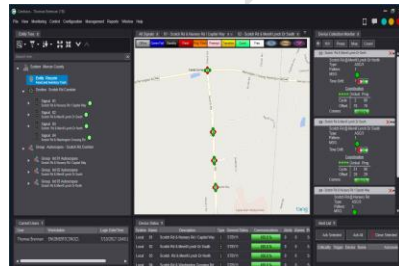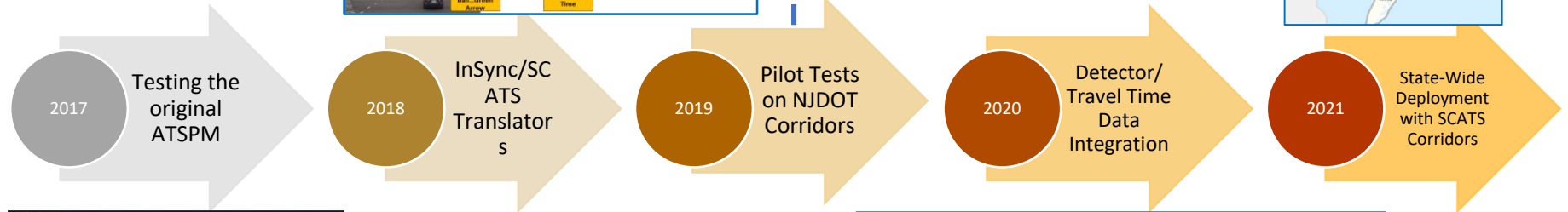
https://ops.fhwa.dot.gov/arterial_mgmt/performance_measures.htm

NJDOT ATSPM Project Timeline

Phase 1

Phase 2

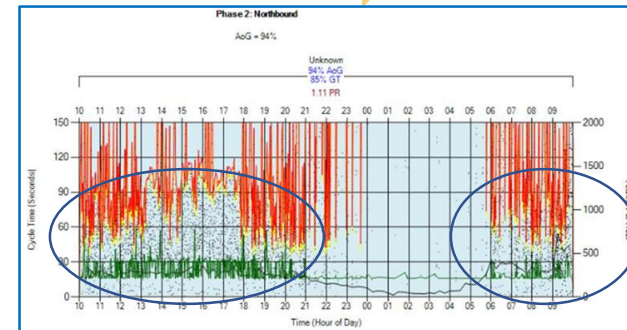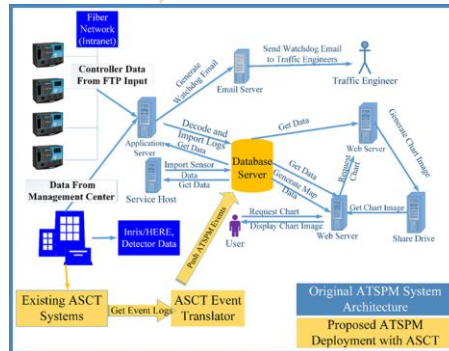| 2017 | Testing the original ATSPM |
2018	InSync/SCATS Translators
2019	Pilot Tests on NJDOT Corridors
2020	Detector/ Travel Time Data Integration
2021	State-Wide Deployment with SCATS Corridors

Scotch Road, Mercer County

Detector data integration

NJDOT Existing Signal Operation

- Over 2,500 NJDOT-maintained signals

- Over 300 signals on Controlled Traffic Signal Systems

- Over 300 more signals optimized (traditional)

- 118 signals on Adaptive Traffic Signal Systems

NJDOT Existing Signal Operation

Full Operation:
NJ-18 (SCATS) = 13 Signals
US-1 (SCATS) = 35 Signals
US-130 (SCATS) = 18 Signals
NJ-73 (SCATS) = 29 Signals
US-130 (InSync) = 12 Signals
NJ-168 (InSync) = 11 Signals

Construction:
US-322 & US-40 = 27 Signals
US-130 = 18 Signals
NJ-70 = 28 Signals

Final Design:
11 Corridors = 122 Signals
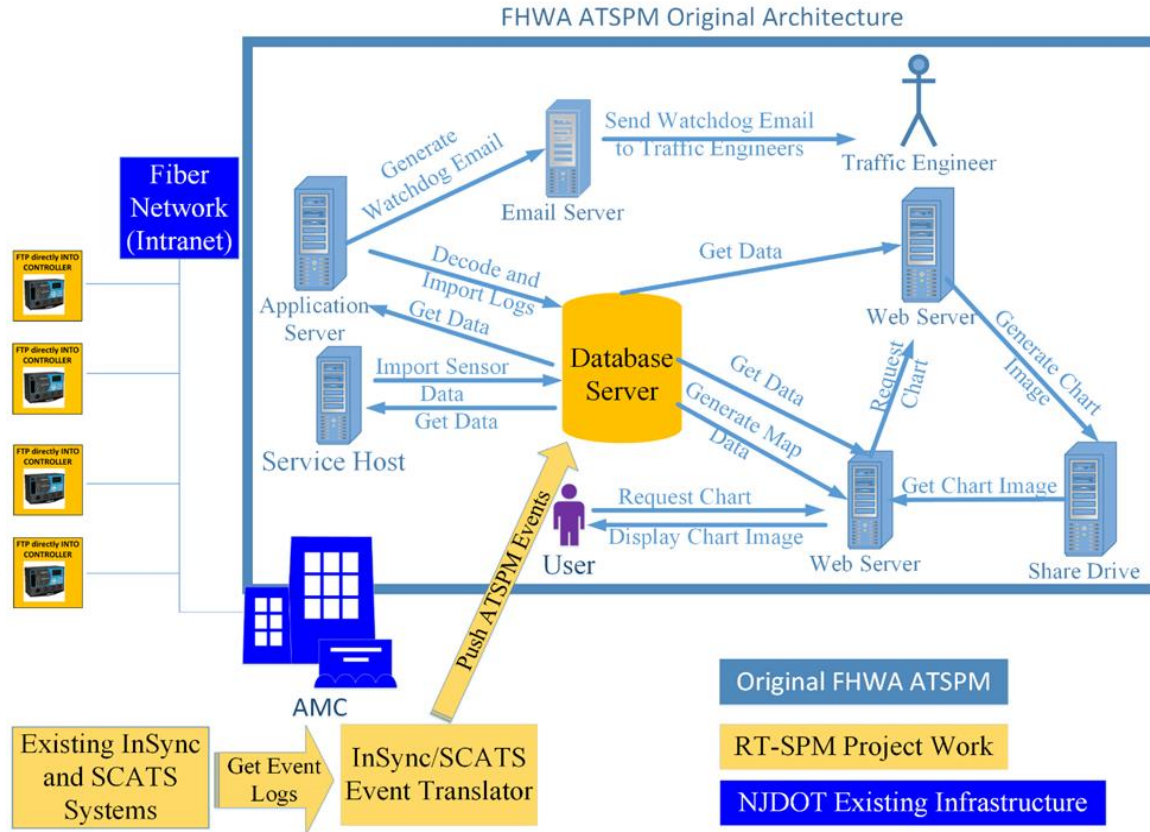
NJDOT Research Project

NJDOT Research Project

- **Objectives:**
  - Development of metrics, guidelines, and implementation strategies for Automated Traffic Signal Performance Measures.
  - Based on the **existing infrastructure** operated and maintained by NJDOT.
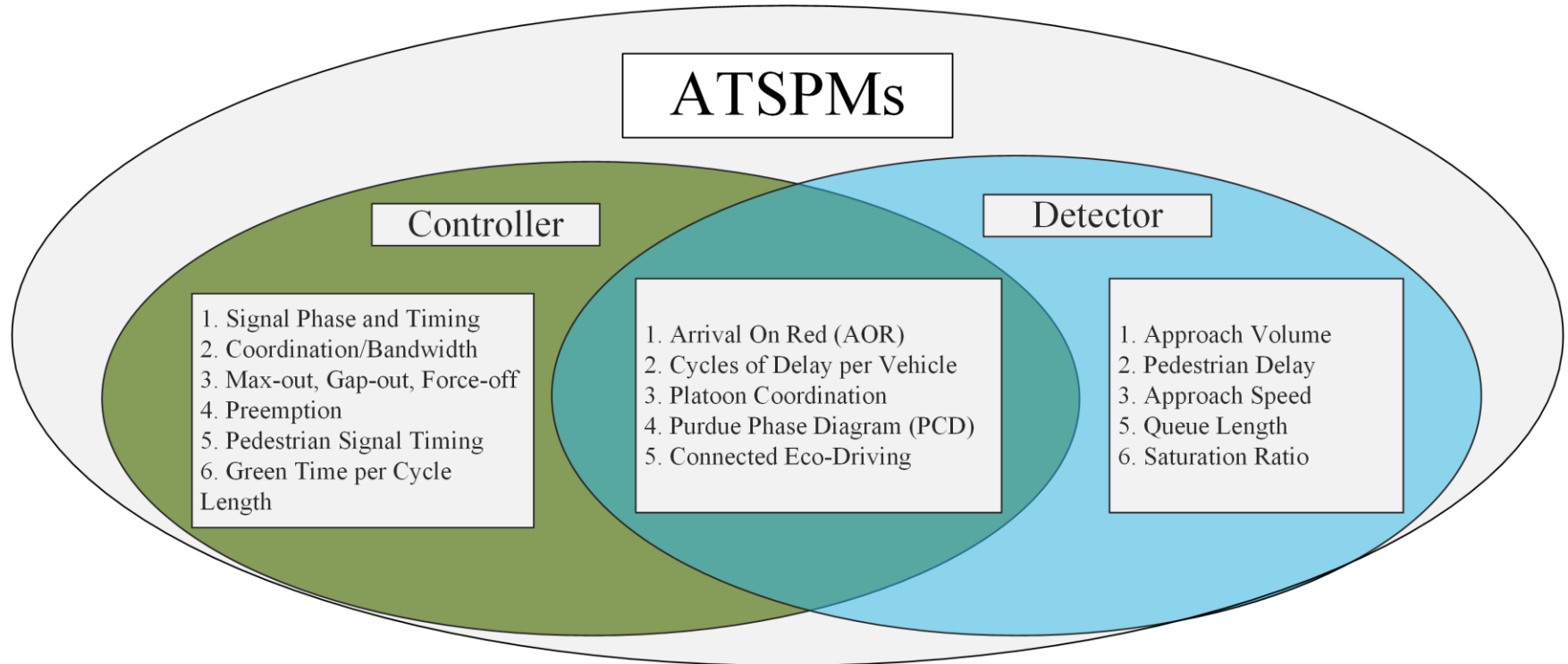 - Develop a prototype ATSPM system.
- **NJDOT Infrastructure:**
  - Centralized control (servers)
  - Fiber-optic communication
  - **Adaptive Signal Control Technology (ASCT)**
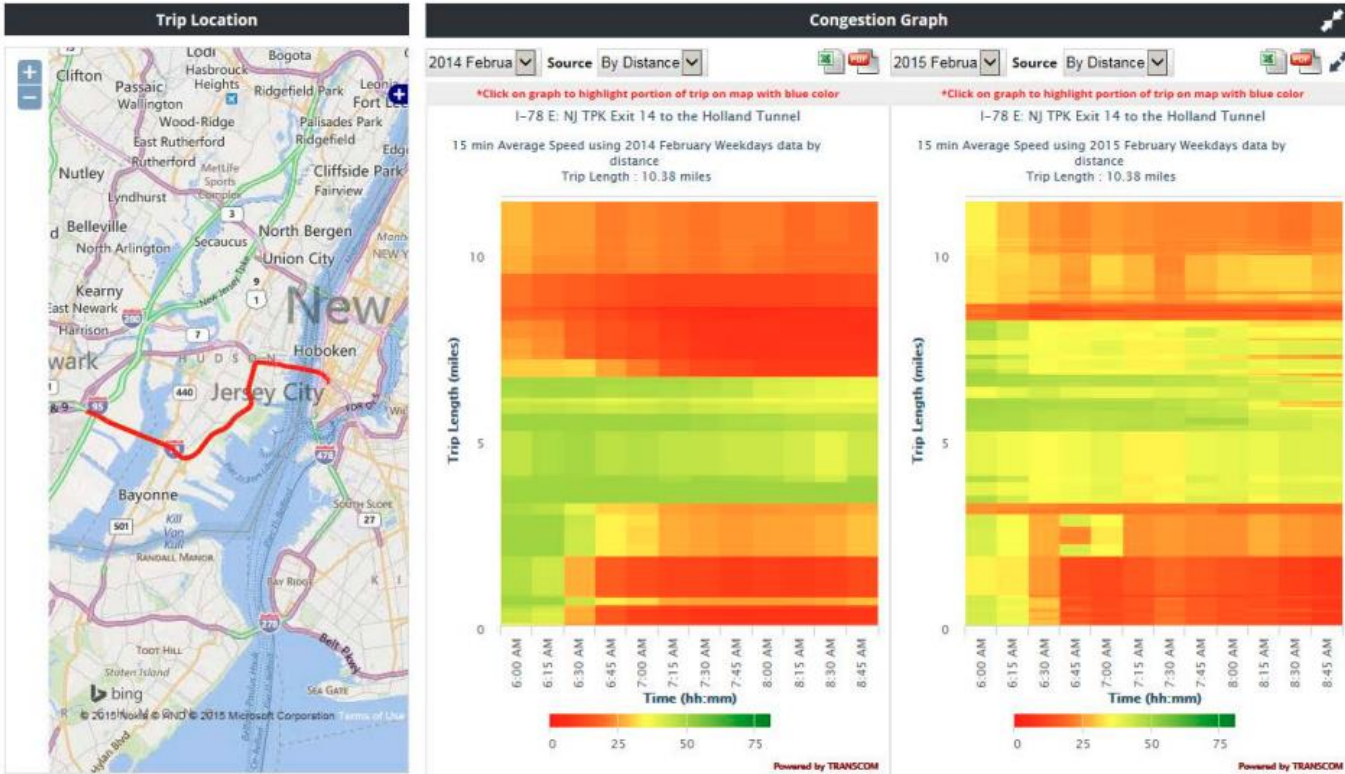
ATSPM Architecture

FHWA ATSPM Original Architecture

ATSPM Components

ATSPMs

Controller

Detector

1. Signal Phase and Timing
2. Coordination/Bandwidth
3. Max-out, Gap-out, Force-off
4. Preemption
5. Pedestrian Signal Timing
6. Green Time per Cycle Length

1. Arrival On Red (AOR)
2. Cycles of Delay per Vehicle
3. Platoon Coordination
4. Purdue Phase Diagram (PCD)
5. Connected Eco-Driving

1. Approach Volume
2. Pedestrian Delay
3. Approach Speed
5. Queue Length
6. Saturation Ratio

ATSPM Data Source and Performance Measurements

Potential ATSPM Data Sources

- TRANSCOM Travel Time and SPATEL Data

- INRIX Travel Time Data

- CCTV Traffic Video

- Wavetronics Advanced Detection Data

- Autoscope Stop Bar Detection

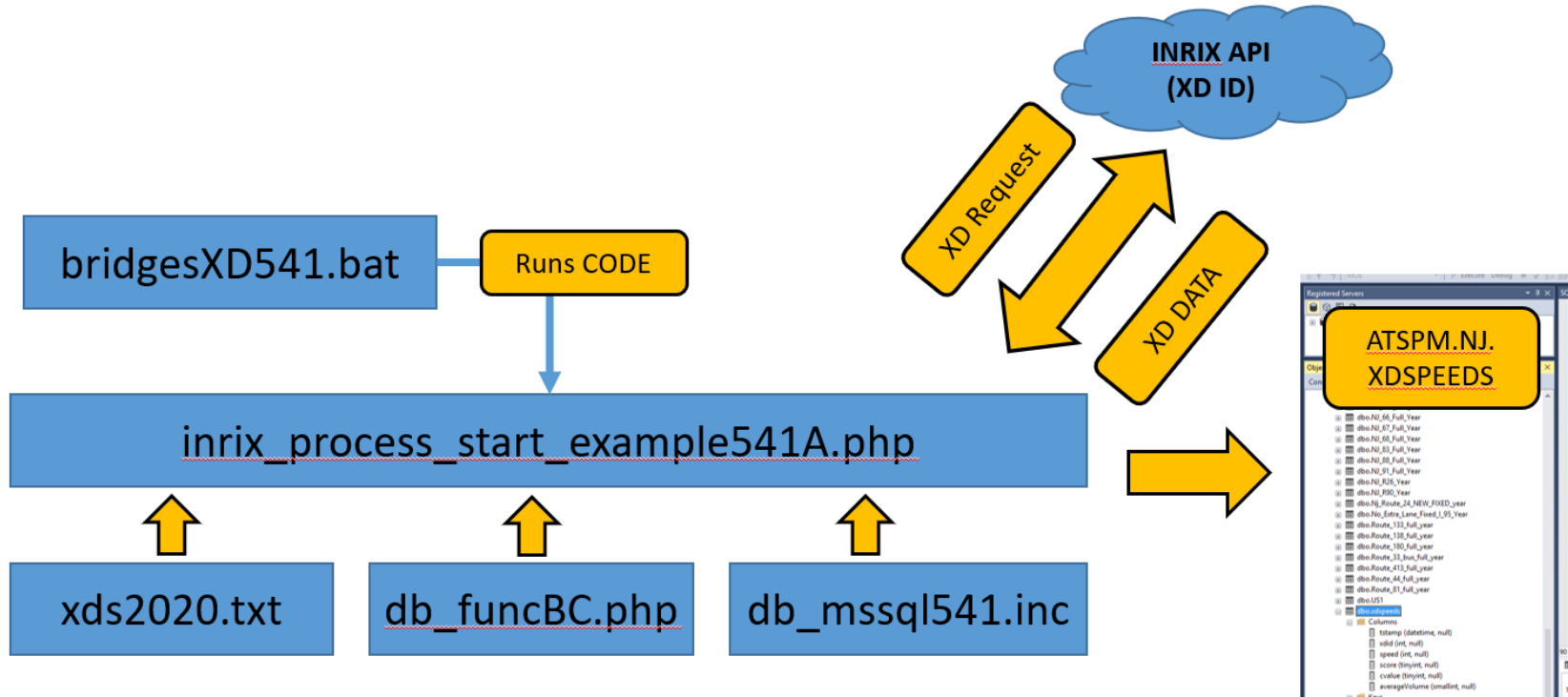# ATSPM Data Sources: TRANSCOM Travel Time Data

Trip Map and Congestion Graphs

ATSPM Data Sources: TRANSCOM SPATEL Data

Event ID	ORC25642301	ORI209302107	ORI207569110	ORI205389107
Facility	NJ 10	NY 32	NY 27	S15N
Event Type	drainage improvements	Construction	Construction	Roadwork
Direction	eastbound	both directions	both directions	northbound
Event Description	NJ DOT - STMC: drainage improvements on NJ 10 eastbound area of Algonquin Pkwy (Hanover Twp) Not currently scheduled	NYSDOT TMC - Albany: Construction, utility work on NY 32 both directions between Clifton Street (Waterford) and Fulton Street (Waterford) alternate lanes closure until 3:00 P.M.	NYSDOT - Region 10: Construction, construction on NY 27 both directions between Exit 38 - Little East Neck Road (Suffolk) and Exit 40 - NY 231; Babylon Northport Expressway (Suffolk) 1 lane closed until 3:00 P.M.	ConnDOT: Road Work on RT15 Northbound between Exits 59 and 60 (3.4 miles) in effect today until 11:14 pm. The right lane is closed. Reported Monday, July 1 at 9:19 am.
State	NJ	NY	NY	CT
County	Morris	Saratoga	Suffolk	New Haven
From City	Hanover Twp	Waterford		New Haven
To City				Hamden
Start Date Time	08/20/2019 9:36:30 PM	08/22/2019 9:01:29 AM	07/31/2019 9:00:19 AM	07/01/2019 9:25:24 AM
Last Update Date	08/21/2019 3:00:14 PM	08/22/2019 9:01:29 AM	07/31/2019 9:00:19 AM	07/01/2019 9:25:24 AM
Close Date	08/21/2019 3:19:00 PM	08/22/2019 3:03:00 PM	07/31/2019 3:01:56 PM	07/01/2019 10:29:55 AM
Duration	0 - 17:43	0 - 06:02	0 - 06:01	0 - 01:04
Recovery Time		0 - 00:01	0 - 00:01	0 - 00:01
From Mile Marker	15.2			
To Mile Marker				
Latitude	40.81690732	42.78161804	40.7133	41.337866
Longitude	-74.40216047	-73.69593859	-73.3519	-72.978399

ATSPM Data Sources: INRIX Travel Time Data

INRIX Data Ingestion to ATSPM

ATSPM Data Sources: CCTV Traffic Video
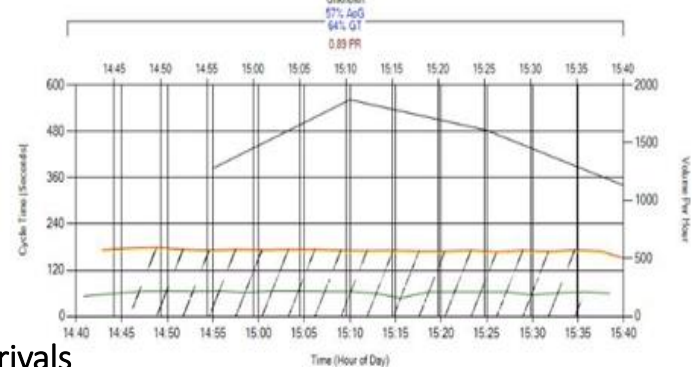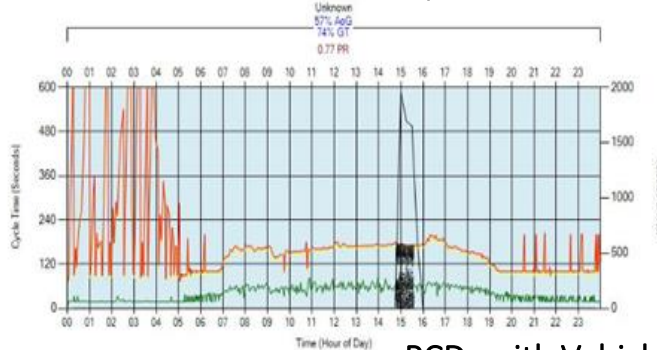
Frame f of Video

STLine from Frame f

(x_{01}, y_{01})
(x_{02}, y_{02})

Pixels Extracted by Spatial-Temporal Line

(x_{0n}, y_{0n})

STMap Generated from CCTV Traffic Video

- Volume Per Hour
- Detector Activation
- Change to Green
- Change to Yellow
- Change to Red
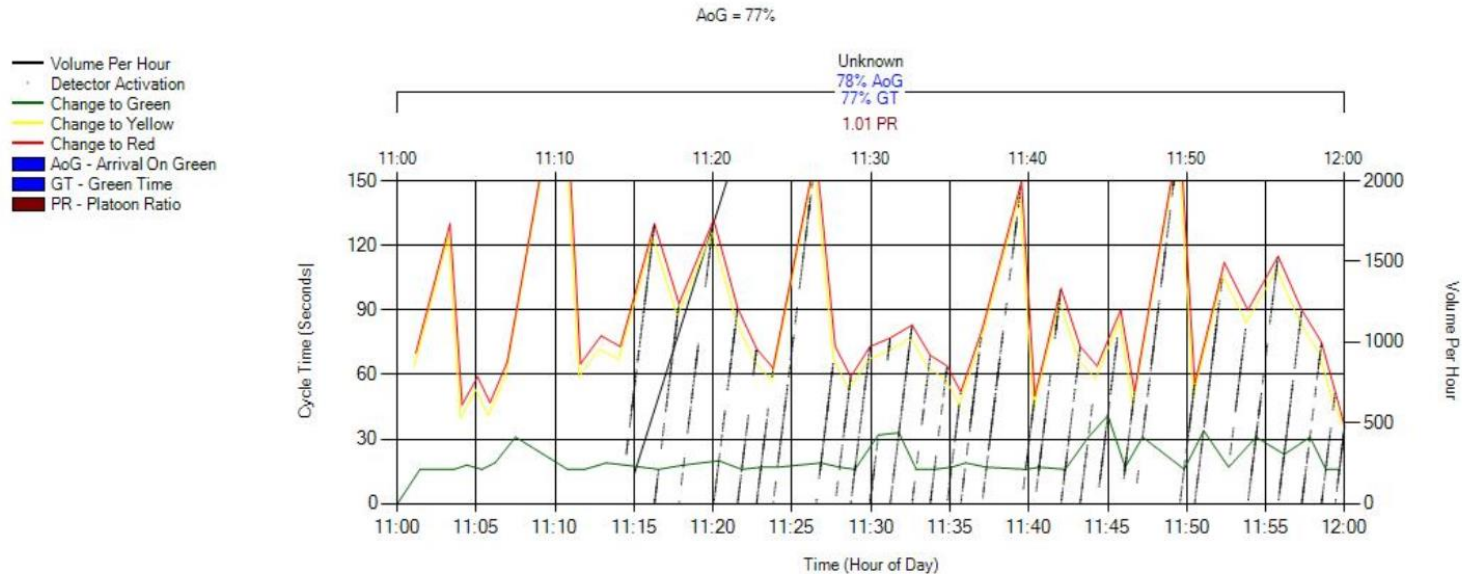- AoG - Arrival On Green
- GT - Green Time
- PR - Platoon Ratio

PCDs with Vehicle Arrivals

ATSPM Data Sources:
Wavetronics Advanced Detection Data

- Speed data from Wavetronix to vehicle trajectory

Actual Wavetronix data overlaid on PCD indicating a vector speed (1 hour)

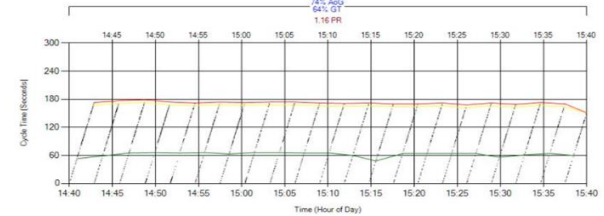# ATSPM Data Sources: Autoscope Stop Bar Detection
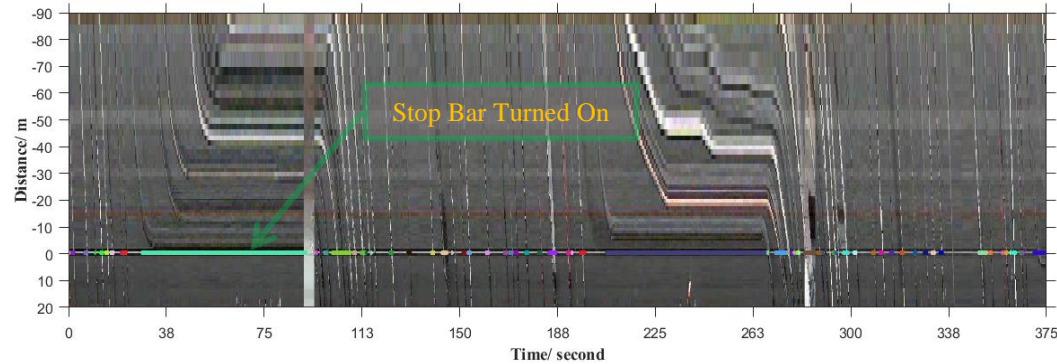
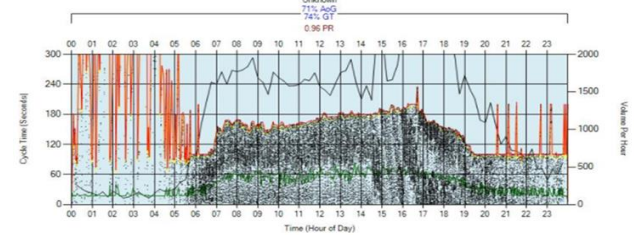Reconstructed Trajectory and Stop-bar Detector Plotted on STMap

Rutgers Coordination Diagram
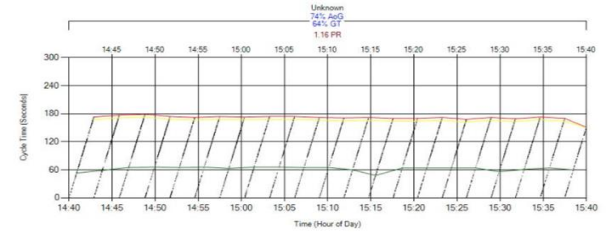
Purdue Coordination Diagram Using Reconstructed Trajectory

Potential ATSPM Data Sources

Potential Data Sources

- TRANSCOM Travel Time and SPATEL Data
- INRIX Travel Time Data
- CCTV Traffic Video
- Wavetronics Advanced Detection Data
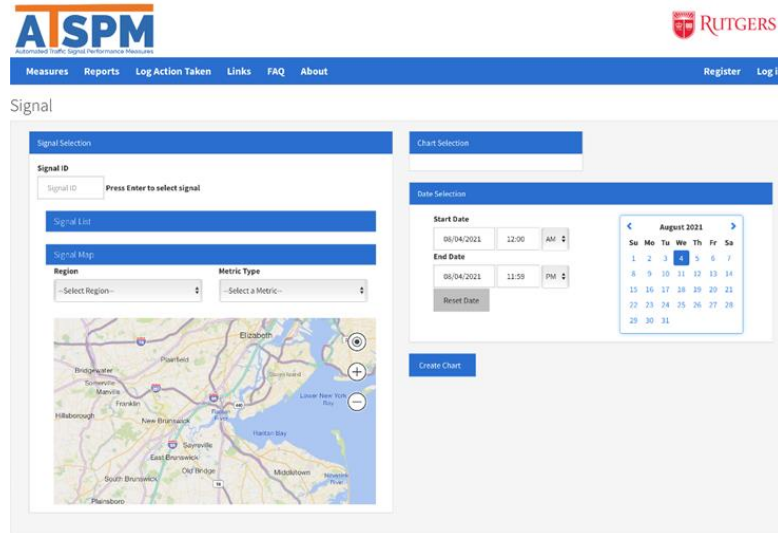- Autoscope Stop Bar Detection

ATSPM Input Data

- **SCATS Signal Event Data**
- **Travel Time Data**
- **Advanced Detection**

Enhanced ATSPM Functionalities

- Purdue Coordination Diagram
- Approach Delay
- Arrival On Red
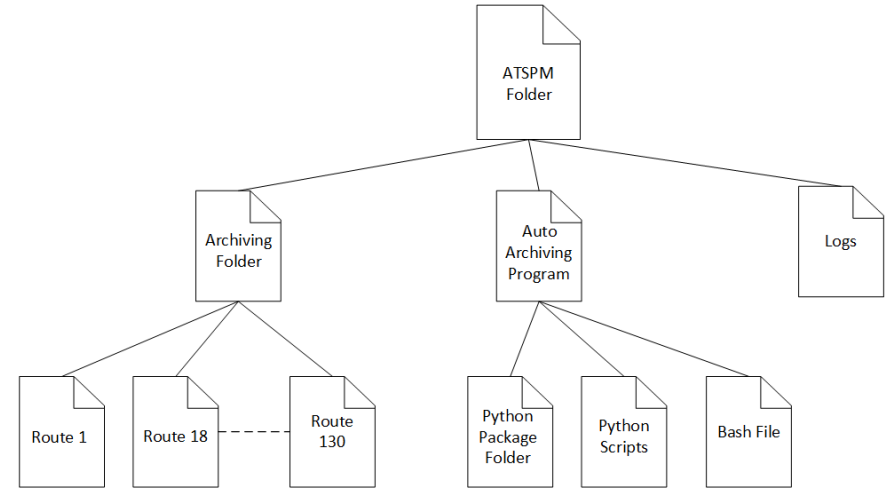- Turning Movement Counts
- Link Pivot

Enhanced Functionality: Interface, File Architecture

ATSPM Interface
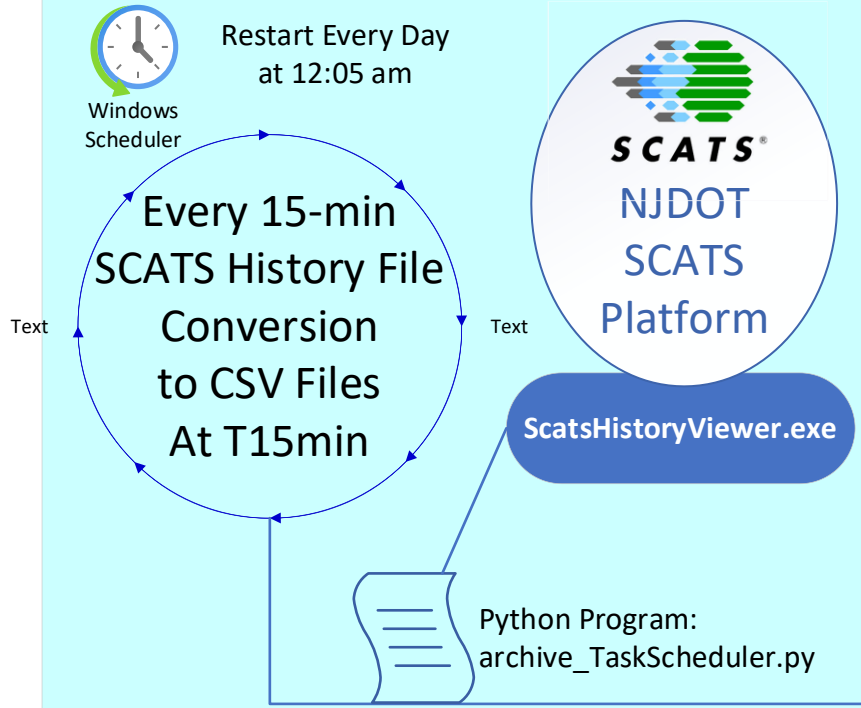

ATSPM File Architecture on SCATS Server

SCATS Event Live Archiving Program
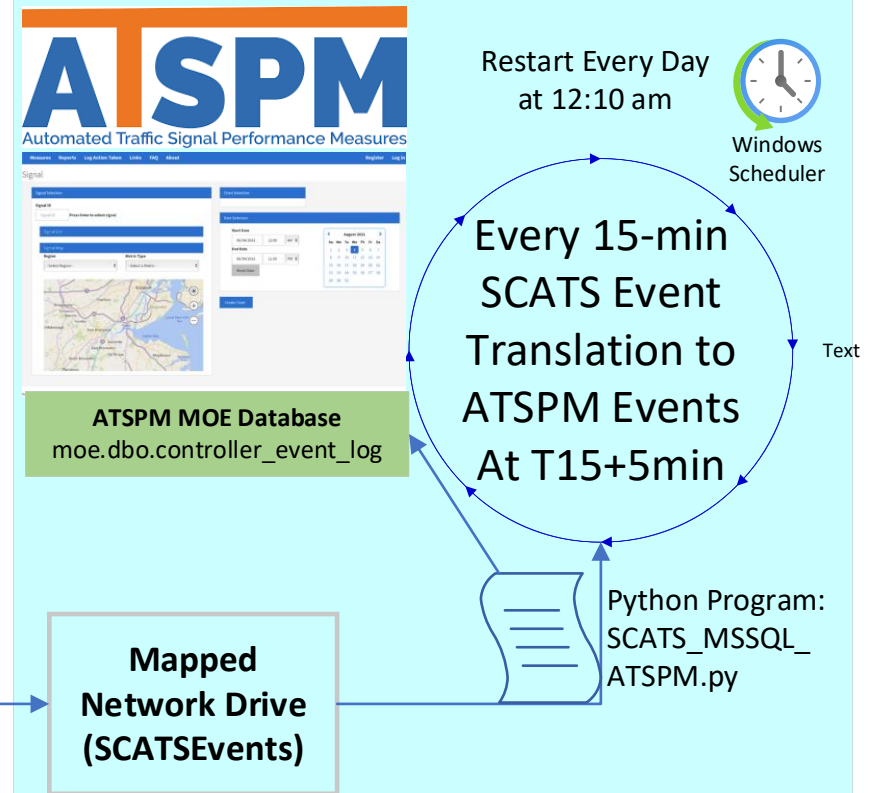
SCATS Event Historical Archiving Program
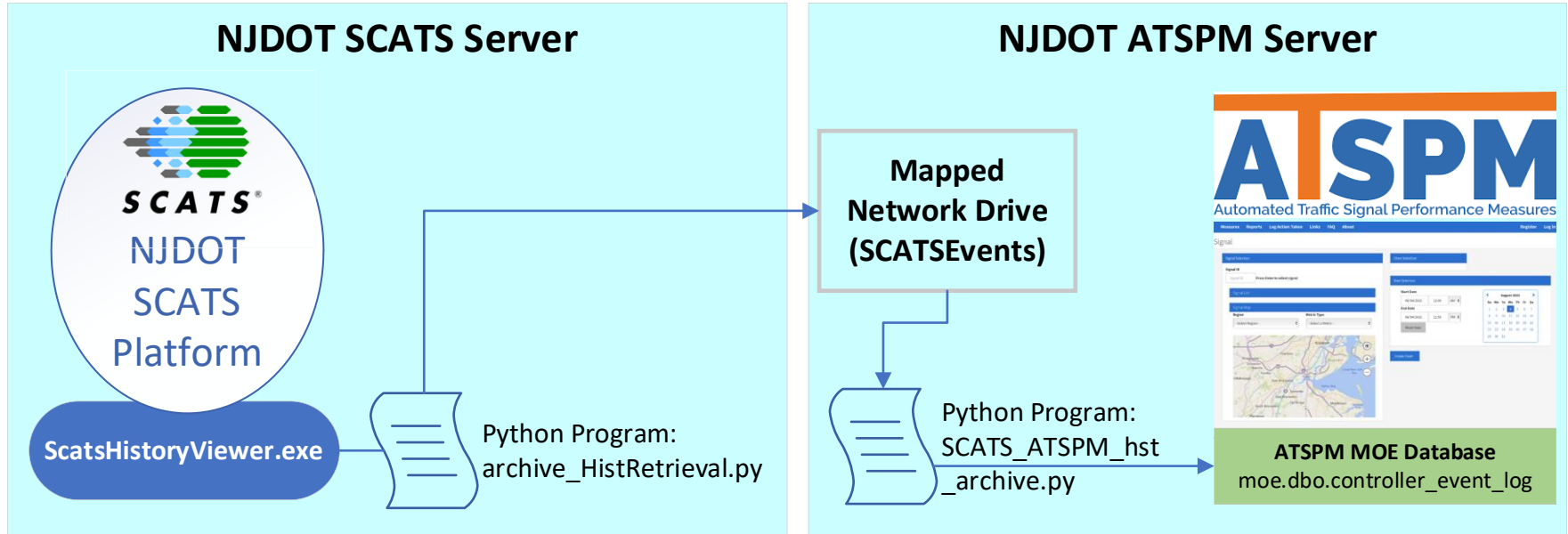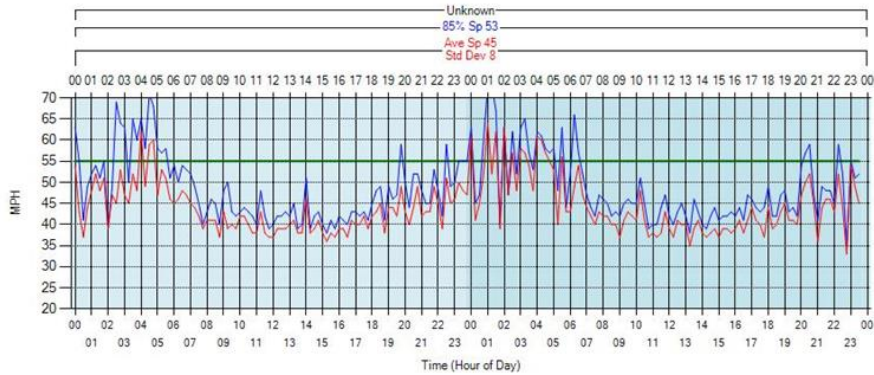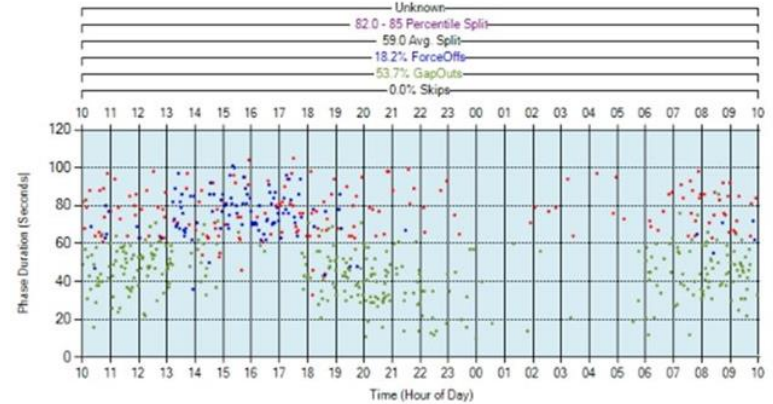
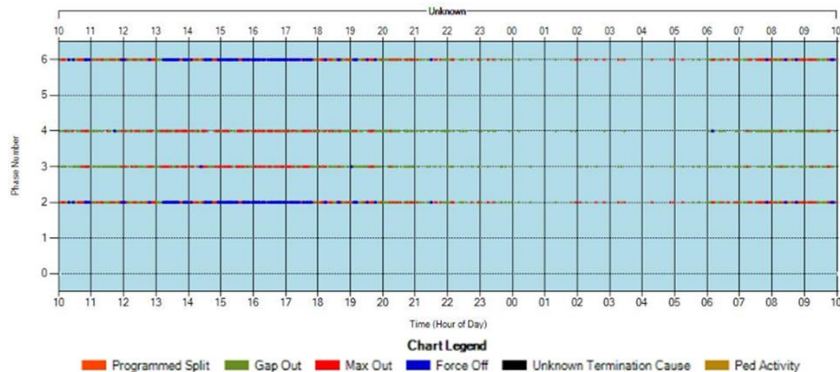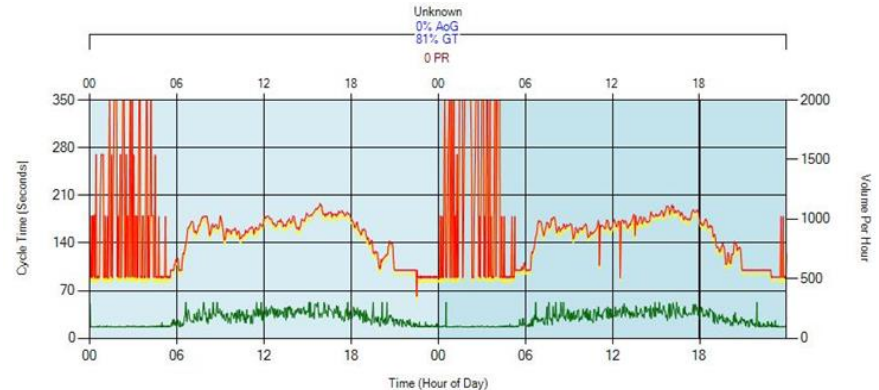# AutoScope Detection Event
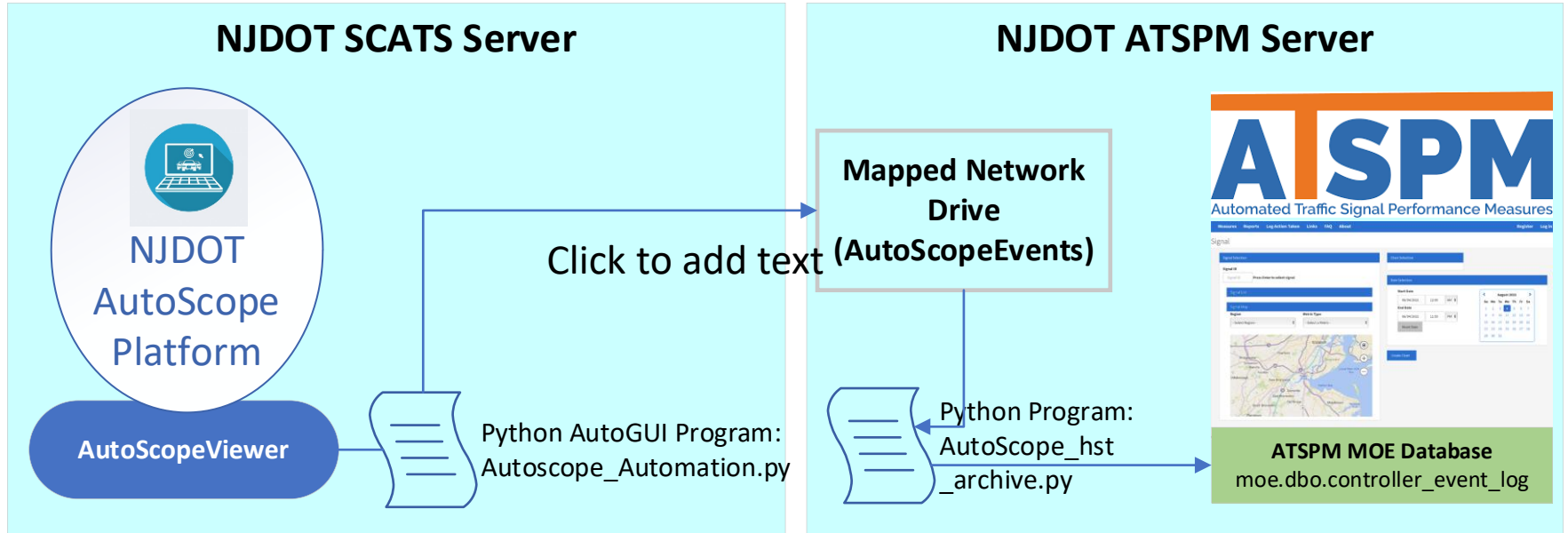
Enhanced Functionality

Ingested ATSPM Speed Records

Split Monitor

Phase Termination

PCD
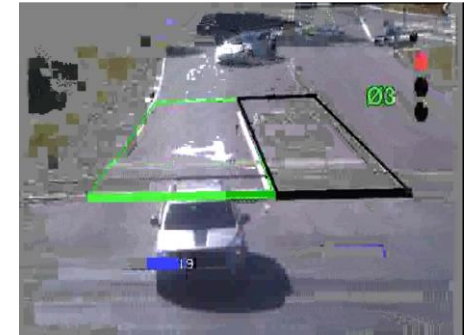
Enhanced Functionality:
SCATS Signal Event Conversion

Event Code	Event	SCATS Translator Logic
0	Phase On	"Current Phase" in SCATS message
1	Phase Begin Green	" Current Phase" in SCATS message
2	Phase Check	"Phase demand" in SCATS message
3	Phase Min Complete	calculate the phase min complete using the minimum green value from the metadata file
4	Phase Gap-Out	Green Duration < Maximum Green
5	Phase Max-Out	Green Duration > Maximum Green
7	Phase Green Termination	"Phase interval: Yellow" in SCATS message
8	Phase Begin Yellow Clearance	"Phase interval: Yellow" in SCATS message
9	Phase End Yellow Clearance	"Phase interval: All Red" in SCATS message
10	Phase Begin Red Clearance	"Phase interval: All Red" in SCATS message
11	Phase End Red Clearance	keyword: "Phase termination"
12	Phase Inactive	If a movement does not exist in a certain cycle, then create Phase Inactive
21	Pedestrian Begin Walk	keywords: "Walk" + "Active=On"
22	Pedestrian Begin Clearance	Keywords: "Walk" + "Active=Off"
45	Pedestrian Call Registered	keywords: "Walk" + "Demand=On"

Safety Performance Metrics Evaluation

- Task 4: ATSPM Enhanced Functionality Development

  - Purdue Phase Termination

  - Split Monitor

  - Pedestrian Delay

Safety Performance Metrics Evaluation

- Task 4: ATSPM Enhanced Functionality Development

  - Yellow and Red Actuations
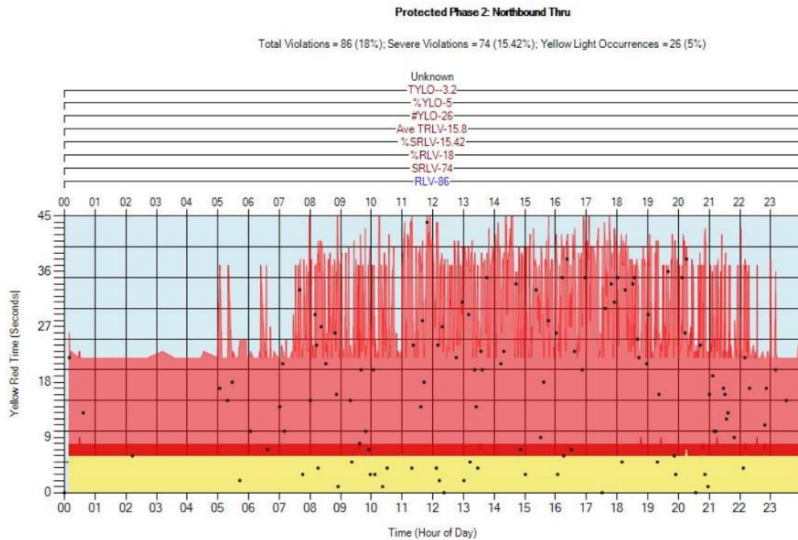
The events that activated the detectors during the beginning of the red phase (i.e., 2 seconds from the start of the red phase) were the actual red light running events

Safety Performance Metrics Evaluation

- Task 4: ATSPM Enhanced Functionality Development
  - Red Actuations (Validation)

Direction	Detector id	24 Hrs. Red light Running Detector Count	Video Timing	Red light Running Detector Count	Red light Running from Video	Relative Accuracy
SB	127	8	8:00 AM-10:00 AM	3	3	100%
NB	127	15	8:00 AM-10:00 AM	3	3	100%
EB	101	8	9:00 AM-10:00 AM	1	1	100%
WB	122	17	9:00 AM-10:00 AM	5	2	40%

Safety Performance Metrics Evaluation

- ## Task 4: ATSPM Enhanced Functionality Development
  - ### Time interval thresholds based on the level of service (LOS)

Level of Service (LOS)	Time Interval Threshold (sec)		
	FFS = 65mph	FFS = 60mph	FFS = 55mph
A	5.07	5.45	6.00
B	1.58	3.33	3.64
C	2.21	2.31	2.52
D	1.77	1.79	1.89
E	1.53	1.57	1.60

Based on NJDHTS recommendation, in good weather, at a minimum of 2-second time interval is considered a safe distance between vehicles. If the road and/or weather aren't good, increase the distance to 4 or 5-seconds. *(Source: NJDHTS)*

(Note: Thresholds have been calculated based on the Highway Capacity Manual 2010)

Date	Time Interval ≤ 1sec	Time Interval ≤ 2sec	Time Interval ≤ 3 sec	Time Interval ≤ 4 sec	Time Interval ≤ 5 sec	Time Interval ≤ 6 sec
12-03-2020	2380	3179	3665	3985	4230	4372
12-04-2020	1748	2494	2983	3309	3532	3711

(Note: Total Detector Count: 12-3-2020: 5152 & 12-4-2020: 4751 for SB:127 at US-1 @ Harrison)