Lunchtime Tech Talk!

Automating the Traffic Signal Performance Measures for NJDOT Adaptive Traffic Signal Control Systems - Real-Time Signal Performance Measurement (RT-SPM)

June 2021

Outline

- Introduction and NJDOT Perspectives
- Proposed NJDOT ATSPM Platform
- SCATS and Detector Event Conversion
- Deployed ATSPM Performance Metrics
- Case Studies:
  - US 1 @ Carnegie
  - US 1 @ Fisher/Harrison
- Ongoing/Future Works
  - Advanced detection reconstruction
  - Transferring to other ATMS platforms
  - Smart Mobility Testing Ground

NJDOT Research Team

NJDOT Research

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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)**

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.

ATSPM

Automated Traffic Signal Performance Measures

https://ops.fhwa.dot.gov/arterial_mgmt/performance_measures.htm

ATSPMs

How are my signals performing?

How are my signals performing? AND how can I optimize them?

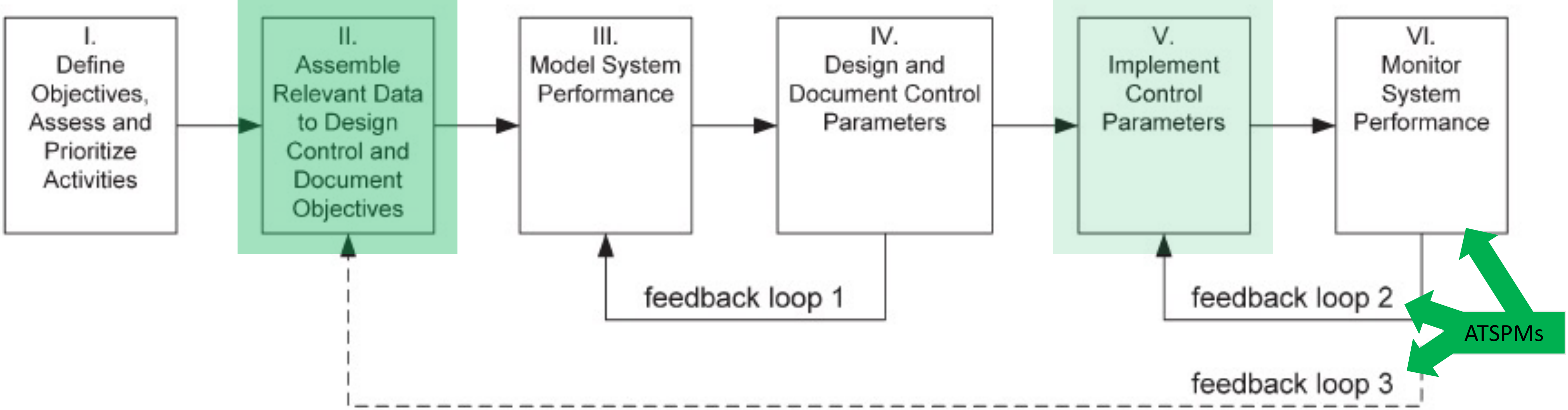
Before

After

ATSPM

Automated Traffic Signal Performance Measures

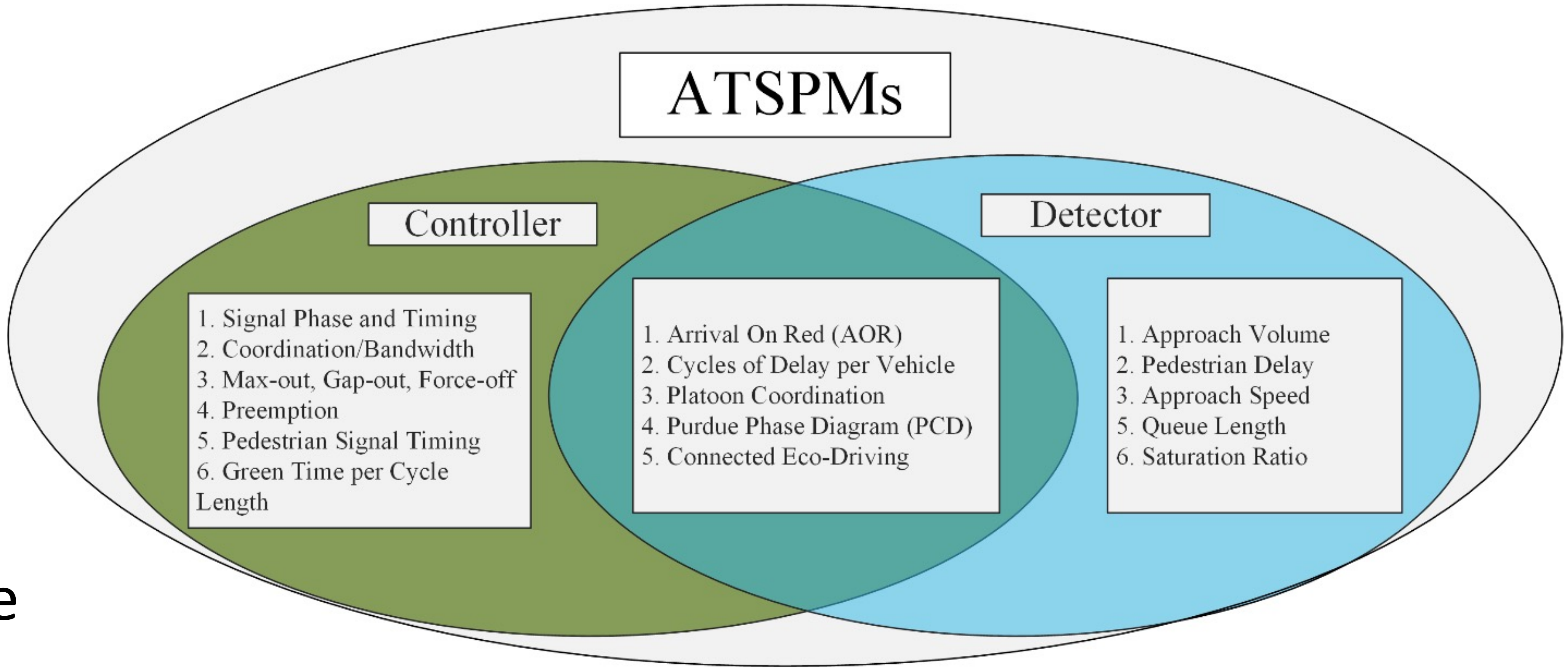
Impact on Traffic Signal (and System) Design



Feedback Loop 2 = Empirical Optimization

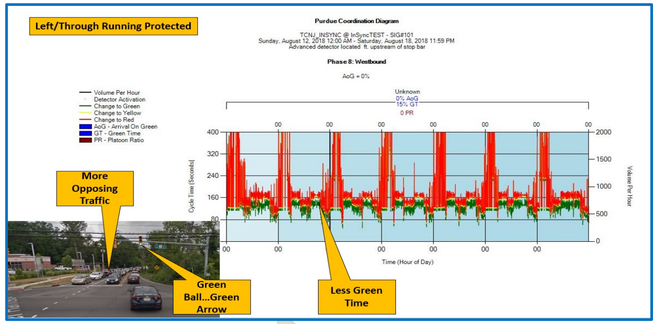
ATSPM Performance Measures and Data input

- ATSPM performance measures include both **controller status and detector data** input.
- The high-resolution controllers log signal functions, while the detection system logs the condition of vehicle arrivals.



Performance Measures from Controller and Detection System

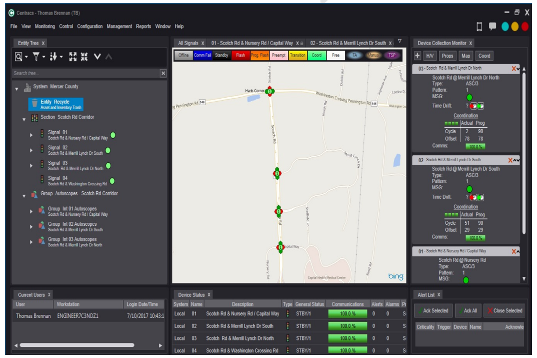
NJDOT ATSPM Project Timeline



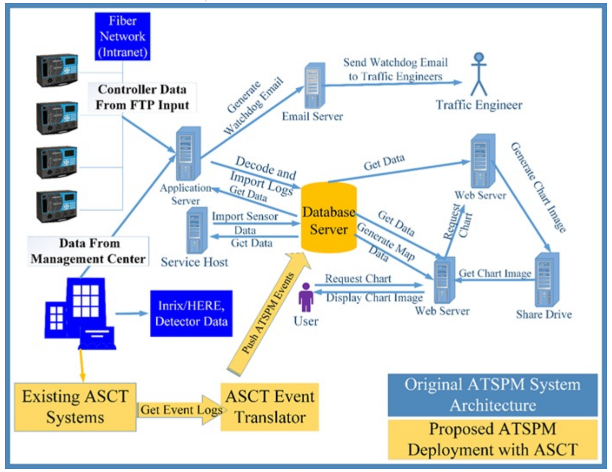
Phase 1

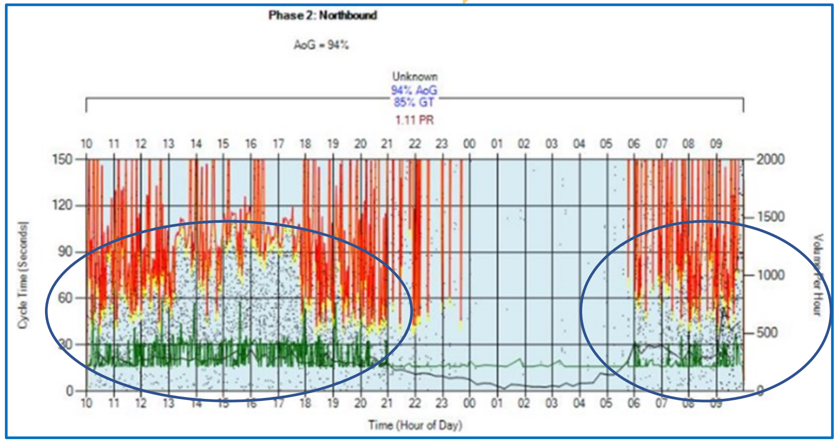
Phase 2

- 2017 — Testing the original ATSPM
- 2018 — InSync/SC ATS 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

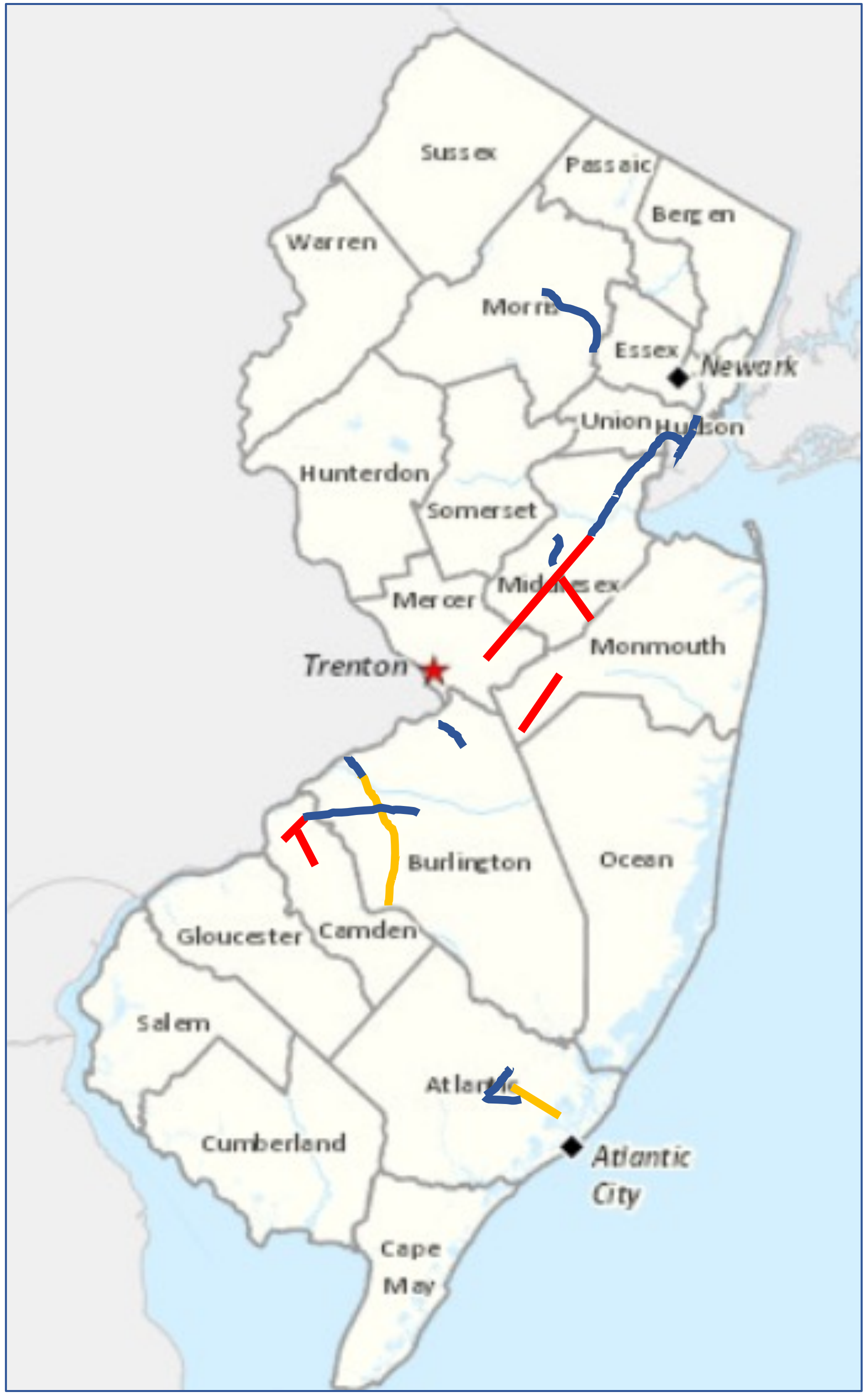
- Over 2,500 NJDOT-maintained signals
- Over 300 signals on Controlled Traffic Signal Systems
- Over 300 more signals optimized (traditional)
- 118 signals on Adaptive Traffic Signal Systems

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



Challenges with Standard ATSPM Deployment

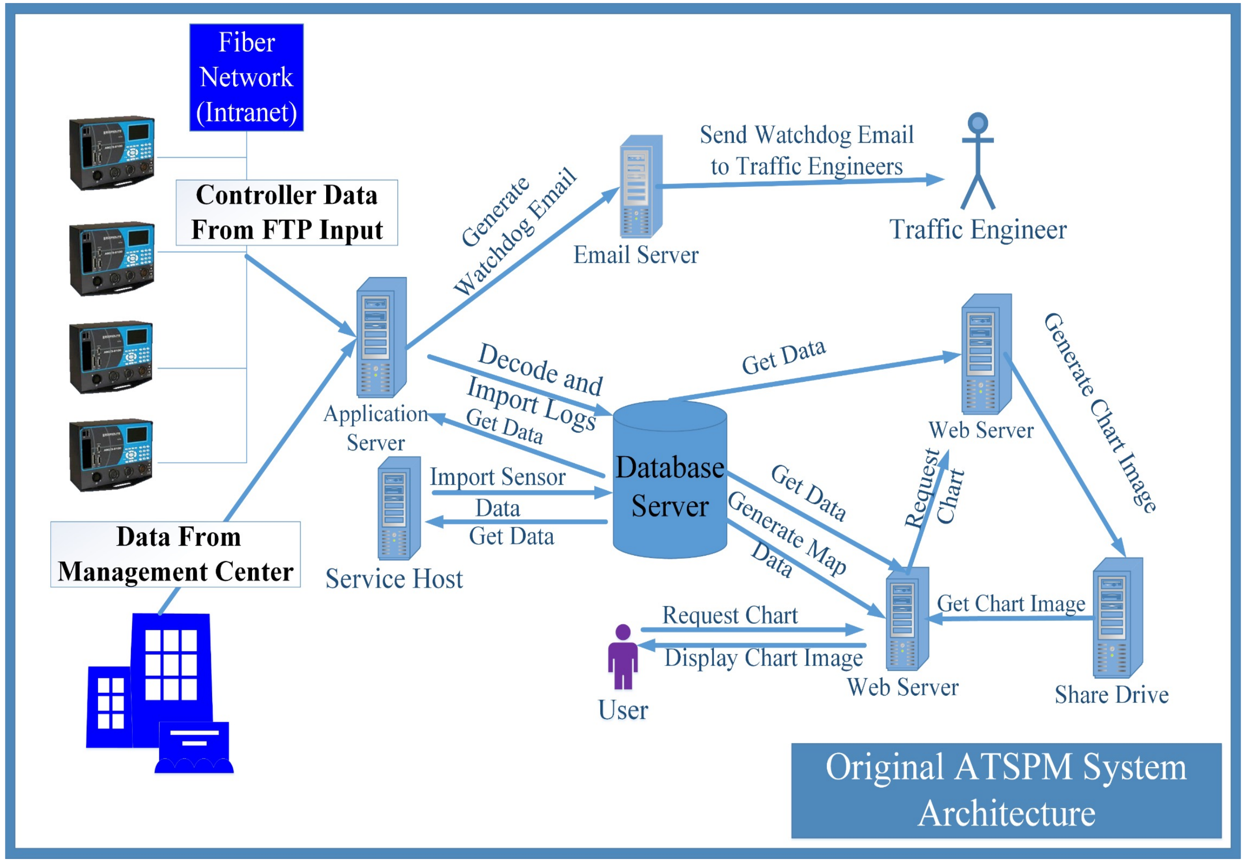
- **Standard ATSPM deployment**: High-resolution controllers, Data Probe and FTP Configuration at Signal Boxes.
- **Challenges**: Upgrading to high-resolution controllers requires significant investment
  - $4000-5000 per intersection.
- **Opportunities**: Centralized event logs of Adaptive Signal Control Technology (ASCT) systems. Rapid expansion of ASCT systems.
- **Objectives**: Integrate ATSPMs and Adaptive Signal Control Technology (ASCT) systems to produce ATSPM performance metrics.
- **Policies**: Dynamically adjust the signal timing in real time in practice. Timing changes (long-term) vs ASCT (real-time/short-term)

Similarities and Relationships between ASCT and ATSPM

Adaptive Signal Control Technology	ATSPMs
Automatic actions based on field data	Performance Measures (PMs) are standardized
Vendors' support is profit-driven (both + &-)	Visualization are data-intensive and comprehensive
PMs are relatively simplistic	Required new skills/efforts to interpret PMs
(Some) can recalibrate on their own	PMs are based on common actuated-coordinated operations
If set properly (some) require less attention than ATSPMs	Open-ended actions – users decide how to use the PMs

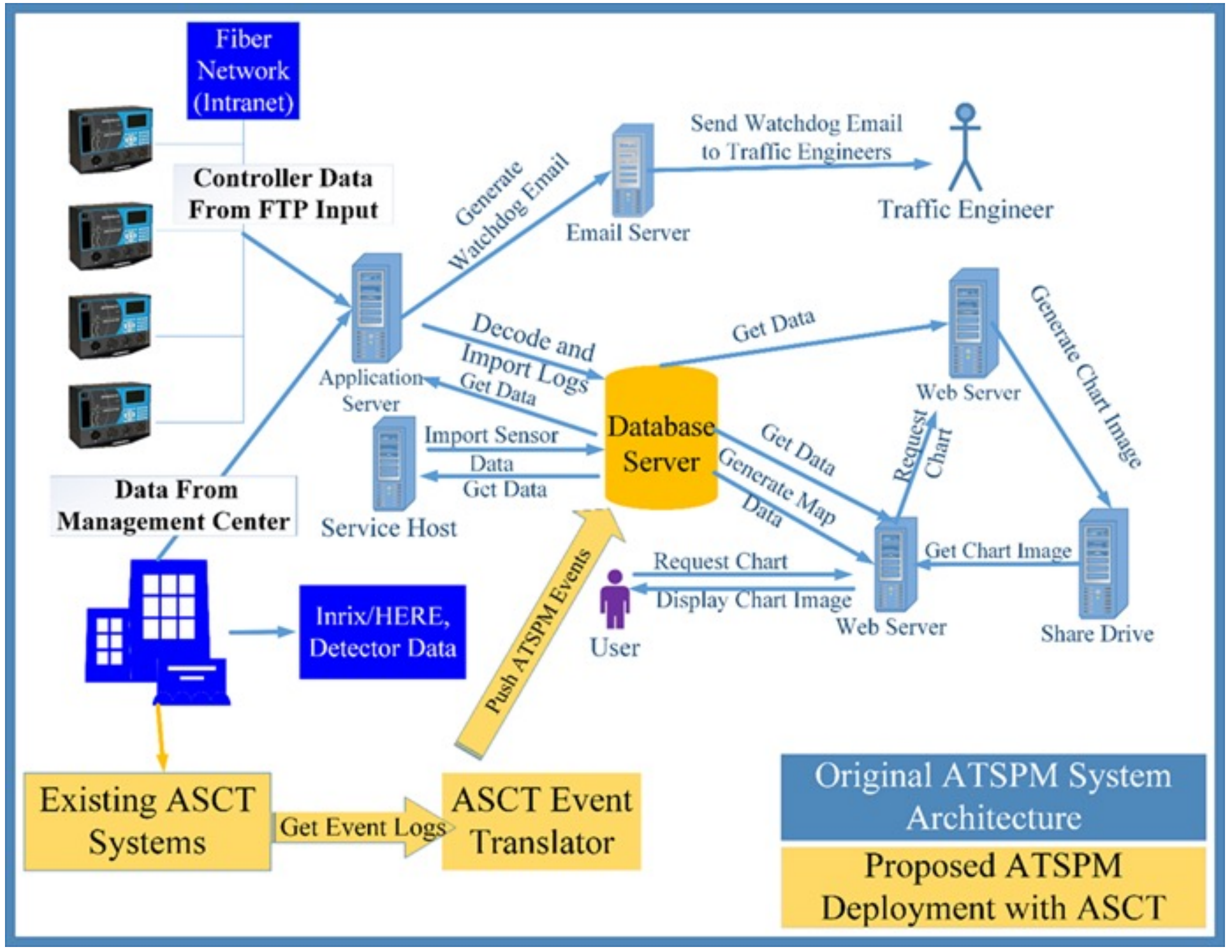
PM: Performance Measures

Original Framework



- The original ATSPMs framework relies on point-to-center communication and high-resolution controller.

Proposed Framework



- The newly developed program can automatically retrieve the controller's logfiles and translate records into standard ATSPM event code.
- This method is agnostic to the controller type.

EVENT TRANSLATOR METHOD

- Converted signal events will be imported into the ATSPM databased.
- Following this, the ATSPM software can generate performance metrics and produce visualization to support maintenance and operations.

ATSPM High-Resolution Active Phase Events and Codes

Event Code	Event Descriptor	Event Code	Event Descriptor
0	Phase On	8	Phase Begin Yellow Clearance
1	Phase Begin Green	9	Phase End Yellow Clearance
2	Phase Check	10	Phase Begin Red Clearance
3	Phase Min Complete	11	Phase End Red Clearance
4	Phase Gap Out	12	Phase Inactive
5	Phase Max Out	21	Pedestrian Begin Walk
6	Phase Force Off	43	Phase Call Registered
7	Phase Green Termination	45	Pedestrian Call Registered
81	Detector Off	82	Detector On

Table shows signal timing and phase-related event and code used by ATSPMs.

SCATS: Event Translator Algorithm

SCATS Log File

Time	Event description
6:56:53	Current running phase=A. Flags=[stretch phase]
6:57:36	Cycle generator: restart
6:58:33	Current running phase=A. Flags=[stretch phase]
6:59:16	Cycle generator: restart
7:00:01	Phase demand: B=On
7:00:02	Phase termination request: next phase=B
7:00:02	Phase termination request confirmation from controller: current phase=A
7:00:03	Phase termination request: next phase=B
7:00:03	Controller request to terminate phase: no request termination for A

ATSPM Standard Code

Results Messages

	SignalID	Timestamp	EventCode	EventParam
3...	103	2018-10-21 06:58:33.000	0	2
3...	103	2018-10-21 06:58:33.000	0	6
3...	103	2018-10-21 06:58:33.000	1	2
3...	103	2018-10-21 06:58:33.000	1	6
3...	103	2018-10-21 07:00:01.000	2	2
3...	103	2018-10-21 07:00:01.000	2	6
3...	103	2018-10-21 07:00:03.000	3	2
3...	103	2018-10-21 07:00:03.000	3	6

Phase On

GreenBegin

SCATS Logfile Translation into ATSPM Standard Code

- Phase A contains Movement 2&6, which is stored in metadata file.
- The **Phase-On Event** and **Green-Begin Event** were created for movements 2&6.
- The translated records are inserted into the database with timestamp information.

SCATS Signal Event Conversion: event #4 GapOut

Translator Output

	SignalID	Timestamp	EventCode	EventParam
97	10015	2020-02-25 00:08:52.000	2	4
98	10015	2020-02-25 00:08:57.000	3	4
99	10015	2020-02-25 00:08:57.000	7	4
100	10015	2020-02-25 00:08:57.000	8	4
101	10015	2020-02-25 00:08:57.000	4	4
102	10015	2020-02-25 00:09:01.000	9	4
103	10015	2020-02-25 00:09:01.000	10	4
104	10015	2020-02-25 00:09:04.000	11	4
105	10015	2020-02-25 00:09:04.000	0	2
106	10015	2020-02-25 00:09:04.000	0	6

SCATS Log

Time	Event
0:08:49	Signal group: SG4=On
0:08:50	Cycle generator: restart
0:08:50	Phase termination: phase=A MX=0 GT=76 CG=0
0:08:50	Phase status flags: [Flag 4 (Mx Ack) = 0 (Off)]
0:08:50	Alarm timer: value=0
0:08:50	Current running phase=C. Flags=[]
0:08:50	Phase status flags: [Flag 9 (Phase Time Calculated) = 1 (On)]
0:08:50	Phase interval: Minimum green
0:08:52	Phase demand: A=On
0:08:56	Phase status flags: [Flag 3 (Phase Gapped) = 1 (On)]
0:08:56	Signal group: SG4=Off
0:08:57	Phase interval: Yellow
0:09:01	Phase interval: All red
0:09:03	Phase demand: A=Off
0:09:03	Signal group: SG6=On SG2=On
0:09:04	Phase termination: phase=C MX=13 GT=14 CG=16
0:09:04	Phase status flags: [Flag 3 (Phase Gapped) = 0 (Off)]
0:09:04	Alarm timer: value=1
0:09:04	Current running phase=A. Flags=[stretch phase]
0:09:04	Phase status flags: [Flag 9 (Phase Time Calculated) = 1 (On)]
0:09:04	Phase interval: Minimum green
0:09:11	Phase interval: Rest or extension green
0:09:11	Controller request to terminate phase: request termination for A

GapOut

Logic

When the record displays *"Phase status flags:[Flag 3 (Phase Gapped)= 0 (Off)]" at the end of the phase,* create *GapOut* event. The Timestamp is the same as GreenTermination.

SCATS Signal Event Conversion: event #5 MaxOut

Translator Output

Results | Messages

	SignalID	Timestamp	EventCode	EventParam
169	10015	2020-02-25 00:16:23.000	2	3
170	10015	2020-02-25 00:16:27.000	3	3
171	10015	2020-02-25 00:16:27.000	7	3
172	10015	2020-02-25 00:16:27.000	8	3
173	10015	2020-02-25 00:16:27.000	5	3
174	10015	2020-02-25 00:16:31.000	9	3
175	10015	2020-02-25 00:16:31.000	10	3
176	10015	2020-02-25 00:16:34.000	11	3
177	10015	2020-02-25 00:16:34.000	0	4
178	10015	2020-02-25 00:16:34.000	1	4
179	10015	2020-02-25 00:16:41.000	3	4

SCATS Log

Time	Event
0:16:20	Phase interval: Minimum green
0:16:23	Phase demand: A=On
0:16:25	Phase status flags: [Flag 7 (Max Due) = 1 (On)]
0:16:25	Phase termination request: next phase=C
0:16:26	Phase termination request: next phase=C
0:16:26	Signal group: SG3=Off
0:16:27	Phase interval: Yellow
0:16:31	Phase interval: All red
0:16:33	Phase demand: C=Off
0:16:33	Signal group: SG4=On
0:16:34	Phase termination: phase=B MX=0 GT=14 CG=16
0:16:34	Phase status flags: [Flag 7 (Max Due) = 0 (Off)]
0:16:34	Alarm timer: value=1
0:16:34	Current running phase=C. Flags=[]
0:16:34	Phase status flags: [Flag 9 (Phase Time Calculated) = 1 (On)]

MaxOut

Logic

When the record displays *"Phase status flags:[Flag 7 (Max Due)= 0 (Off)]" at the end of the phase,* create *MaxOut* event. The Timestamp is the same as GreenTermination.

SCATS Signal Event Conversion: event #6 ForceOff

Translator Output

	SignalID	Timestamp	EventCode	EventParam
196	10015	2020-02-25 00:18:35.000	2	2
197	10015	2020-02-25 00:18:35.000	2	6
198	10015	2020-02-25 00:19:12.000	7	2
199	10015	2020-02-25 00:19:12.000	7	6
200	10015	2020-02-25 00:19:12.000	8	2
201	10015	2020-02-25 00:19:12.000	8	6
202	10015	2020-02-25 00:19:12.000	6	2
203	10015	2020-02-25 00:19:12.000	6	6
204	10015	2020-02-25 00:19:18.000	9	2
205	10015	2020-02-25 00:19:18.000	9	6
206	10015	2020-02-25 00:19:18.000	10	2
207	10015	2020-02-25 00:19:18.000	10	6
208	10015	2020-02-25 00:19:20.000	11	2
209	10015	2020-02-25 00:19:20.000	11	6

SCATS Log

Time	Event
0:19:11	Phase status flags: [Flag 2 (Request Termination) = 0 (Off)]
0:19:11	Phase termination request: next phase=C
0:19:11	Controller request to terminate phase: no request termination for A
0:19:11	Signal group: SG6=Off SG2=Off
0:19:12	Phase interval: Yellow
0:19:18	Phase interval: All red
0:19:19	Phase demand: C=Off
0:19:19	Signal group: SG4=On
0:19:20	Cycle generator: restart
0:19:20	Phase termination: phase=A MX=0 GT=63 CG=0
0:19:20	Phase status flags: [Flag 4 (Mx Ack) = 0 (Off)]
0:19:20	Alarm timer: value=0
0:19:20	Current running phase=C. Flags=[]
0:19:20	Phase status flags: [Flag 9 (Phase Time Calculated) = 1 (On)]

Force Off

Logic

When the record displays *"Cycle generator: restart" before Phase termination, then the MaxOuts should be ForceOff* event. The Timestamp is the same as GreenTermination.

Insync Signal Event Conversion: Event #0 and #1: PhaseOn and PhaseBegin

Insync Log

Date	Time	Movement	Duration
9/23/2018	5:59:25	Tunnel	SouthBoundThrough Tunnel
9/23/2018	5:59:36	WL	7
9/23/2018	5:59:50	ST/NT	32
9/23/2018	6:00:01	Period length c	0
9/23/2018	6:00:19	Tunnel	NorthBoundThrough Tunnel
9/23/2018	6:00:31	WL	9
9/23/2018	6:00:47	ST/NT	125

NEMA Phase 2/6

Translator Output

Results Messages

	SignalID	Timestamp	EventCode	EventParam
5622	101	2018-09-23 05:59:36.000	11	6
5623	101	2018-09-23 05:59:42.000	43	2
5624	101	2018-09-23 05:59:50.000	0	2
5625	101	2018-09-23 05:59:50.000	0	6
5626	101	2018-09-23 05:59:50.000	1	2
5627	101	2018-09-23 05:59:50.000	1	6
5628	101	2018-09-23 06:00:10.000	3	2
5629	101	2018-09-23 06:00:10.000	3	6
5630	101	2018-09-23 06:00:19.000	7	6
5631	101	2018-09-23 06:00:19.000	4	6
5632	101	2018-09-23 06:00:22.000	7	2

Phase on

GreenBegin

Logic

For every movement m in this phase i, if movement m is not in the previous phase, then create PhaseOn and PhaseBeginGreen for movement m

Insync Signal Event Conversion: Event #3 MinGreenComplete

Translator Output

Results | Messages

	SignalID	Timestamp	EventCode	EventParam
5622	101	2018-09-23 05:59:36.000	11	6
5623	101	2018-09-23 05:59:42.000	43	2
5624	101	2018-09-23 05:59:50.000	0	2
5625	101	2018-09-23 05:59:50.000	0	6
5626	101	2018-09-23 05:59:50.000	1	2
5627	101	2018-09-23 05:59:50.000	1	6
5628	101	2018-09-23 06:00:10.000	3	2
5629	101	2018-09-23 06:00:10.000	3	6
5630	101	2018-09-23 06:00:19.000	7	6
5631	101	2018-09-23 06:00:19.000	4	6
5632	101	2018-09-23 06:00:22.000	7	2

Minimum Green Complete

Insync Log

Date	Time	Movement	Duration
9/23/2018	5:59:25	Tunnel	SouthBoundThrough Tunnel
9/23/2018	5:59:36	WL	7
9/23/2018	5:59:50	ST/NT	32
9/23/2018	6:00:01	Period length c	0
9/23/2018	6:00:19	Tunnel	NorthBoundThrough Tunnel
9/23/2018	6:00:31	WL	9
9/23/2018	6:00:47	ST/NT	125

NEMA Phase 2/6

Logic

Do a comparison between phase duration and minimum green time, then create Minimum green complete Event.

Insync Signal Event Conversion: Event #7 GreenTermination

Insync Log

Date	Time	Movement	Duration
9/23/2018	5:59:25	Tunnel	SouthBoundThrough Tunnel
9/23/2018	5:59:36	WL	7
9/23/2018	5:59:50	ST/NT	32
9/23/2018	6:00:01	Period length c	0
9/23/2018	6:00:19	Tunnel	NorthBoundThrough Tunnel
9/23/2018	6:00:31	WL	9
9/23/2018	6:00:47	ST/NT	125

NEMA Phase 2/6

Results Messages **Translator Output**

	SignalID	Timestamp	EventCode	EventParam
5622	101	2018-09-23 05:59:36.000	11	6
5623	101	2018-09-23 05:59:42.000	43	2
5624	101	2018-09-23 05:59:50.000	0	2
5625	101	2018-09-23 05:59:50.000	0	6
5626	101	2018-09-23 05:59:50.000	1	2
5627	101	2018-09-23 05:59:50.000	1	6
5628	101	2018-09-23 06:00:10.000	3	2
5629	101	2018-09-23 06:00:10.000	3	6
5630	101	2018-09-23 06:00:19.000	7	6
5631	101	2018-09-23 06:00:19.000	4	6
5632	101	2018-09-23 06:00:22.000	7	2

GreenTermination

Logic

For each movement in current phases, if it does not show in next record, then create "PhaseGreenTermination" for that movement

Insync Signal Event Conversion: Event #4 or #5 GapOut / Maxout

Insync Log

Date	Time	Movement	Duration
9/23/2018	5:59:50	ST/NT	32
9/23/2018	6:00:01	Period length c	0
9/23/2018	6:00:19	Tunnel	NorthBoundThrough Tunnel truncated 18 second(s) early.
9/23/2018	6:00:31	WL	9
9/23/2018	6:00:47	ST/NT	125
9/23/2018	6:02:50	Tunnel	NorthBoundThrough Tunnel truncated 22 second(s) early.

NEMA Phase 2/6

Translator Output

	SignalID	Timestamp	EventCode	EventParam
243	101	2018-09-23 05:59:50.000	0	6
244	101	2018-09-23 05:59:50.000	0	2
245	101	2018-09-23 05:59:50.000	1	6
246	101	2018-09-23 05:59:50.000	1	2
247	101	2018-09-23 05:59:50.000	44	3
248	101	2018-09-23 06:00:01.000	43	3
249	101	2018-09-23 06:00:19.000	7	6
250	101	2018-09-23 06:00:19.000	4	6
251	101	2018-09-23 06:00:22.000	7	2
252	101	2018-09-23 06:00:22.000	5	2
253	101	2018-09-23 06:00:22.000	8	6
254	101	2018-09-23 06:00:22.000	8	2
255	101	2018-09-23 06:00:29.000	9	6

GapOut

MaxOut

Logic

We assume every movement will be MaxOut when current phase terminates, unless it has truncated record. If it has truncated log, then create GapOut for the movement.
When the record displays *"Tunnel truncated"*, create GapOut events. Otherwise it will be MaxOut.

Insync Signal Event Conversion: Event #8 and #9 YellowBegin/ YellowEnd

Insync Log

NEMA Phase 2/6

Date	Time	Movement	Duration
9/23/2018	5:59:50	ST/NT	32
9/23/2018	6:00:01	Period length c	0
9/23/2018	6:00:19	Tunnel	NorthBoundThrough Tunnel truncated 18 secc
9/23/2018	6:00:31	WL	9
9/23/2018	6:00:47	ST/NT	125
9/23/2018	6:02:50	Tunnel	NorthBoundThrough Tunnel truncated 22 secc

Translator Output

	SignalID	Timestamp	EventCode	EventParam
225	101	2018-09-23 05:59:50.000	0	6
226	101	2018-09-23 05:59:50.000	1	2
227	101	2018-09-23 05:59:50.000	1	6
228	101	2018-09-23 06:00:01.000	43	3
229	101	2018-09-23 06:00:19.000	7	6
230	101	2018-09-23 06:00:19.000	8	6
231	101	2018-09-23 06:00:19.000	4	6
232	101	2018-09-23 06:00:22.000	7	2
233	101	2018-09-23 06:00:22.000	5	2
234	101	2018-09-23 06:00:22.000	8	2
235	101	2018-09-23 06:00:25.000	9	6
236	101	2018-09-23 06:00:25.000	10	6
237	101	2018-09-23 06:00:28.000	9	2

YellowBegin for Phase 6

YellowBegin for Phase 2

Logic

For each movement that ends with current phase, we create yellow begin event. The yellow interval duration is read from meta data.

Because Phase 6 was truncated, the two approaches were asynchronized.

Insync Signal Event Conversion: Event #11 RedEnd

Translator Output

SignalID	Timestamp	EventCode	EventParam
101	2018-09-23 06:00:22.000	8	2
101	2018-09-23 06:00:25.000	9	6
101	2018-09-23 06:00:25.000	10	6
101	2018-09-23 06:00:28.000	9	2
101	2018-09-23 06:00:28.000	10	2
101	2018-09-23 06:00:31.000	11	2
101	2018-09-23 06:00:31.000	11	6
101	2018-09-23 06:00:31.000	0	3
101	2018-09-23 06:00:31.000	1	3
101	2018-09-23 06:00:38.000	3	3
101	2018-09-23 06:00:40.000	7	3

RedEnd for Phase 2

RedEnd for Phase 6

Insync Log

NEMA Phase 2/6

Date	Time	Movement	Duration
9/23/2018	5:59:50	ST/NT	32
9/23/2018	6:00:01	Period length c	0
9/23/2018	6:00:19	Tunnel	NorthBoundThrough Tunnel truncated 18 seco
9/23/2018	6:00:31	WL	9
9/23/2018	6:00:47	ST/NT	125
9/23/2018	6:02:50	Tunnel	NorthBoundThrough Tunnel truncated 22 seco

Logic

For each movement that ends with current phase, then create red clearance after yellow interval.
The red clearance duration is read from Metadata.

Insync Signal Event Conversion: Event # 21, and #45 PedestrianBeginWalk/ PedestrianCallRegistered

Insync Log

NEMA Phase 2/6

Date	Time	Movement	Duration
7/16/2018	2:51:07	WT/ET	7
7/16/2018	2:51:20	ST/NT	58
7/16/2018	2:51:52	Pedestrian Called (Phase 6)	0
7/16/2018	2:51:52	Pedestrian Called (Phase 2)	0
7/16/2018	2:52:20	Pedestrian Sent (Phase 6)	0
7/16/2018	2:52:20	Pedestrian Sent (Phase 2)	0
7/16/2018	2:52:26	WT/ET	7
7/16/2018	2:52:39	ST/NT	58

Translator Output

SignalID	timeStamp	eventCode	parameter
1001	02:51:20	21	6
1001	02:51:20	21	2
1001	02:51:52	45	6
1001	02:51:52	45	2
1001	02:52:39	21	6
1001	02:52:39	21	2

PedCallRegistered

PedestrianBeginWalk

Logic

Look for Pedestrian log event and parse the message to extract movement and timestamp. If historical log event i contains string $\text{Pedestrian Called(Phase m)}$, then create event #45 for movement m.

If movement $\boldsymbol{m}$ has been registered for event #45, and when the movement $\boldsymbol{m}$ *starts*, create event #21.

SCATS Autoscope Detection Event Translator

AutoScope

CPU Identifier	Autoscope Description	Detector ID	Detector Title	Date	Time	Duration	Status	Ticks (millisec.)	State
0C050DFF9A676E28	3 -- 2020,02,24 9:09:33 -- 10.5.0 -- 0	125		2/26/2020	4:38:19 PM	00:00:00	207 (ISSCLAPI_POLL_STATUS_CREATING_POLL_ON_AUTOSCOPE)		
0C050DFF9A676E28	3 -- 2020,02,24 9:09:33 -- 10.5.0 -- 0	127		2/26/2020	4:38:19 PM	00:00:00	207 (ISSCLAPI_POLL_STATUS_CREATING_POLL_ON_AUTOSCOPE)		
0C050DFF9A676E28	3 -- 2020,02,24 9:09:33 -- 10.5.0 -- 0	129		2/26/2020	4:38:19 PM	00:00:00	207 (ISSCLAPI_POLL_STATUS_CREATING_POLL_ON_AUTOSCOPE)		
0C050DFF9A676E28	3 -- 2020,02,24 9:09:33 -- 10.5.0 -- 0	125		2/25/2020	2:42:28 PM		100	1578161124	0
0C050DFF9A676E28	3 -- 2020,02,24 9:09:33 -- 10.5.0 -- 0	127		2/25/2020	2:42:28 PM		100	1578161124	32769
0C050DFF9A676E28	3 -- 2020,02,24 9:09:33 -- 10.5.0 -- 0	129		2/25/2020	2:42:28 PM		100	1578161124	0
0C050DFF9A676E28	3 -- 2020,02,24 9:09:33 -- 10.5.0 -- 0	129		2/25/2020	2:42:46 PM	00:00:18	100	1578179210	1
0C050DFF9A676E28	3 -- 2020,02,24 9:09:33 -- 10.5.0 -- 0	127		2/25/2020	2:42:57 PM	00:00:29	100	1578191156	0
0C050DFF9A676E28	3 -- 2020,02,24 9:09:33 -- 10.5.0 -- 0	129		2/25/2020	2:42:59 PM	00:00:13	100	1578192791	0
0C050DFF9A676E28	3 -- 2020,02,24 9:09:33 -- 10.5.0 -- 0	125		2/25/2020	2:43:23 PM	00:00:55	100	1578217150	1
0C050DFF9A676E28	3 -- 2020,02,24 9:09:33 -- 10.5.0 -- 0	125		2/25/2020	2:44:43 PM	00:01:20	100	1578297001	0
0C050DFF9A676E28	3 -- 2020,02,24 9:09:33 -- 10.5.0 -- 0	125		2/25/2020	2:44:44 PM	00:00:01	100	1578297335	1
0C050DFF9A676E28	3 -- 2020,02,24 9:09:33 -- 10.5.0 -- 0	125		2/25/2020	2:44:45 PM	00:00:01	100	1578298470	0
0C050DFF9A676E28	3 -- 2020,02,24 9:09:33 -- 10.5.0 -- 0	127		2/25/2020	2:46:25 PM	00:03:28	100	1578398809	1
0C050DFF9A676E28	3 -- 2020,02,24 9:09:33 -- 10.5.0 -- 0	127		2/25/2020	2:46:26 PM	00:00:01	100	1578399777	0
0C050DFF9A676E28	3 -- 2020,02,24 9:09:33 -- 10.5.0 -- 0	127		2/25/2020	2:47:14 PM	00:00:48	100	1578447627	1
0C050DFF9A676E28	3 -- 2020,02,24 9:09:33 -- 10.5.0 -- 0	127		2/25/2020	2:47:59 PM	00:00:45	100	1578492341	0
0C050DFF9A676E28	3 -- 2020,02,24 9:09:33 -- 10.5.0 -- 0	127		2/25/2020	2:48:16 PM	00:00:17	100	1578509493	1
0C050DFF9A676E28	3 -- 2020,02,24 9:09:33 -- 10.5.0 -- 0	129		2/25/2020	2:48:35 PM	00:05:36	100	1578528647	1
0C050DFF9A676E28	3 -- 2020,02,24 9:09:33 -- 10.5.0 -- 0	129		2/25/2020	2:49:43 PM	00:01:08	100	1578596652	0
0C050DFF9A676E28	3 -- 2020,02,24 9:09:33 -- 10.5.0 -- 0	127		2/25/2020	2:49:45 PM	00:01:29	100	1578599054	0
0C050DFF9A676E28	3 -- 2020,02,24 9:09:33 -- 10.5.0 -- 0	125		2/25/2020	2:50:09 PM	00:05:24	100	1578622646	1
0C050DFF9A676E28	3 -- 2020,02,24 9:09:33 -- 10.5.0 -- 0	125		2/25/2020	2:51:33 PM	00:01:24	100	1578706468	0

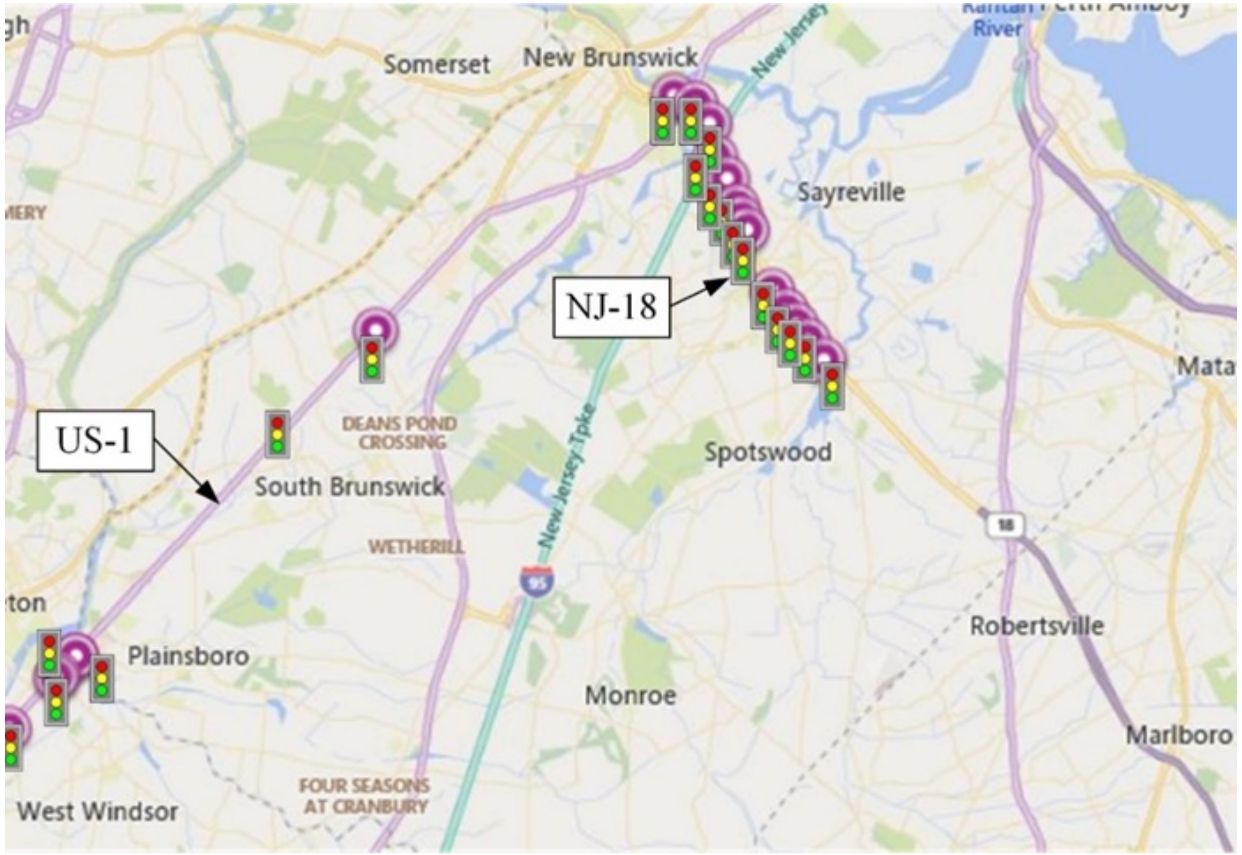
Wavetronix

30-Jul-20	SS126 U10	Site 5 SB	Rt 1 NB MI	North	
LANE	LENGTH	(MPH)	CLASS	RANGE	YYYY-MM-DD HH:MM:SS.sss
#2_Lane2	13	68	2	85	07/30/2020 11:14:29.9
#1_Lane1	16	75.2	2	70	07/30/2020 11:14:30.0
#3_Lane3	11	66	2	96	07/30/2020 11:14:31.1
#2_Lane2	13	61.4	2	83	07/30/2020 11:14:34.7
#1_Lane1	16	61	2	71	07/30/2020 11:14:42.9
#3_Lane3	13	60.4	2	96	07/30/2020 11:14:43.1
#2_Lane2	15	65.9	2	82	07/30/2020 11:14:43.5
#2_Lane2	14	64.9	2	84	07/30/2020 11:14:48.3
#3_Lane3	18	54.6	2	95	07/30/2020 11:14:48.8
#3_Lane3	17	54.7	2	96	07/30/2020 11:14:51.1
#1_Lane1	9	60.4	1	74	07/30/2020 11:14:51.4
#2_Lane2	18	60.1	2	82	07/30/2020 11:14:51.9
#1_Lane1	18	65.3	2	69	07/30/2020 11:14:53.1
#2_Lane2	14	63.7	2	86	07/30/2020 11:14:55.1
#1_Lane1	14	66.3	2	70	07/30/2020 11:14:55.2
#3_Lane3	20	56.7	3	96	07/30/2020 11:14:56.5
#2_Lane2	15	64.6	2	84	07/30/2020 11:14:59.8
#3_Lane3	18	53.9	2	96	07/30/2020 11:15:00.4
#3_Lane3	10	52.7	2	96	07/30/2020 11:15:02.3
#2_Lane2	13	66.2	2	83	07/30/2020 11:15:02.9
#2_Lane2	15	63.6	2	83	07/30/2020 11:15:05.0
#2_Lane2	66	55.9	7	80	07/30/2020 11:15:12.6
#3_Lane3	13	49.8	2	98	07/30/2020 11:15:13.1
#1_Lane1	17	66.5	2	71	07/30/2020 11:15:13.5
#3_Lane3	16	50.2	2	96	07/30/2020 11:15:14.3
#2_Lane2	70	55.6	7	83	07/30/2020 11:15:15.6
#1_Lane1	16	67	2	74	07/30/2020 11:15:17.9
#1_Lane1	9	67.9	1	70	07/30/2020 11:15:19.3

Vehicle Occurrence Data: Detector data events conversion into ATSPM Events (#82, On) and (#81, Off)

Speed trajectory slices: Wavetronix data event converted into short speed trajectories ➔ a series of ATSPM Events (#82 On)

PILOT STUDY SCOPE



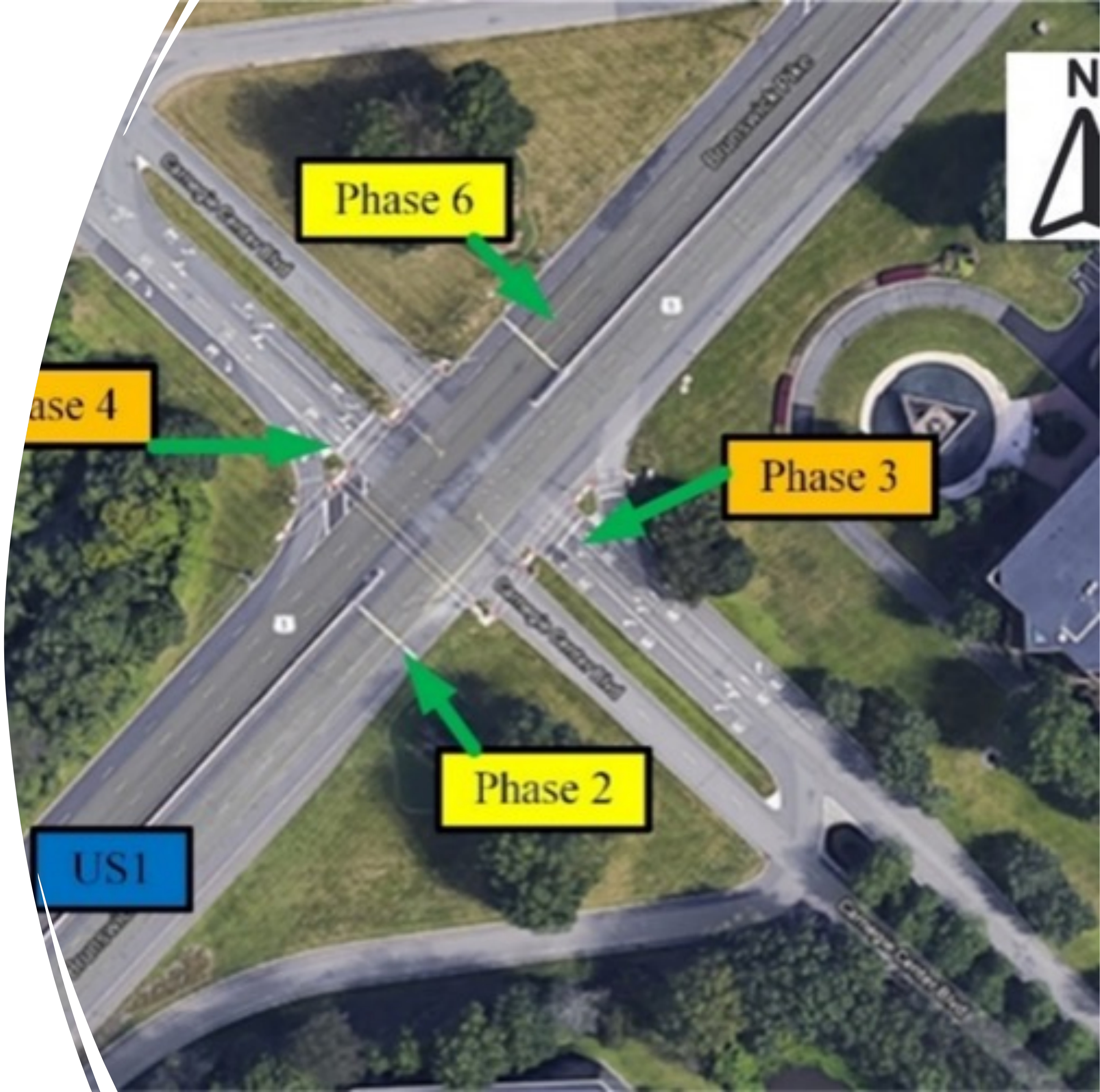
- Two ASCT managed corridors in New Jersey were selected as pilot testing corridors. 13 SCATS controlled intersections were tested along NJ-18 highway during 2019.
- Four newly installed SCATS intersections along US1 were tested during 2020.
- Two InSync managed intersections on US1 were tested during 2019.

Rt 1 at Carnegie Center

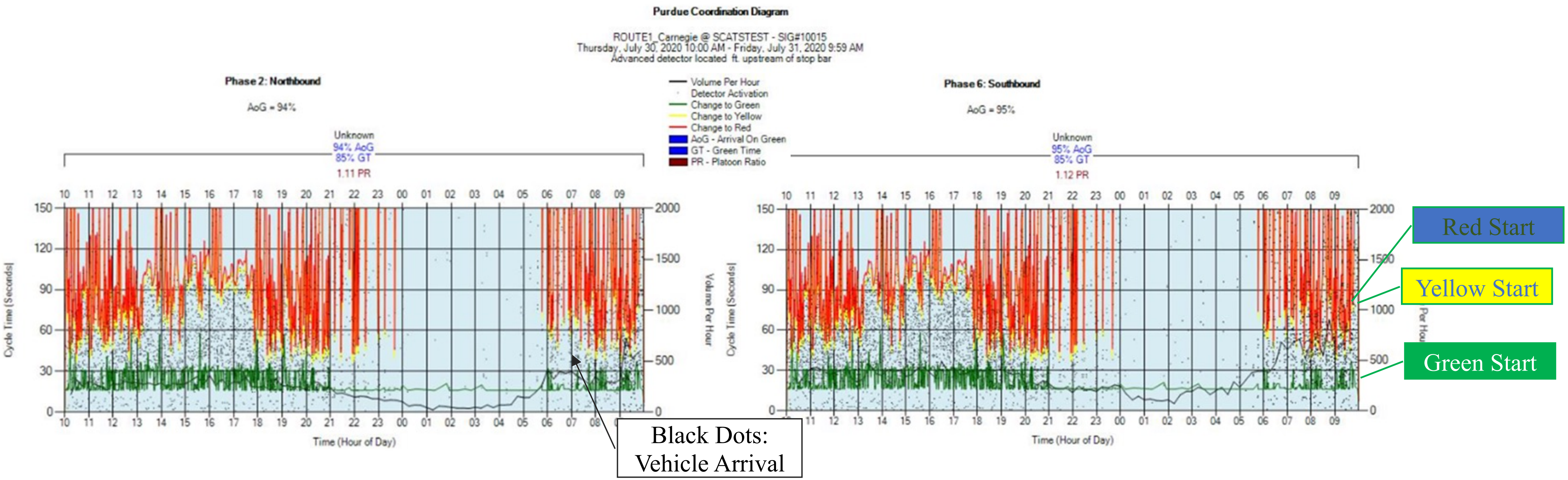
SCATS ATSPMs Results

SCATS ATSPM Analysis at US-1 and Carnegie Center

- Two groups of movements with phases from the same group running simultaneously.
  - Group A is for northbound (phase 2), and southbound (phase 6)
  - Group B is for the westbound (phase 3), and Eastbound (phase 4).
- Performance metrics:
  - **PCDs**
  - **Phase termination**
  - **Split Monitor**
  - **Detector** performance measurements, were applied to SCATS.



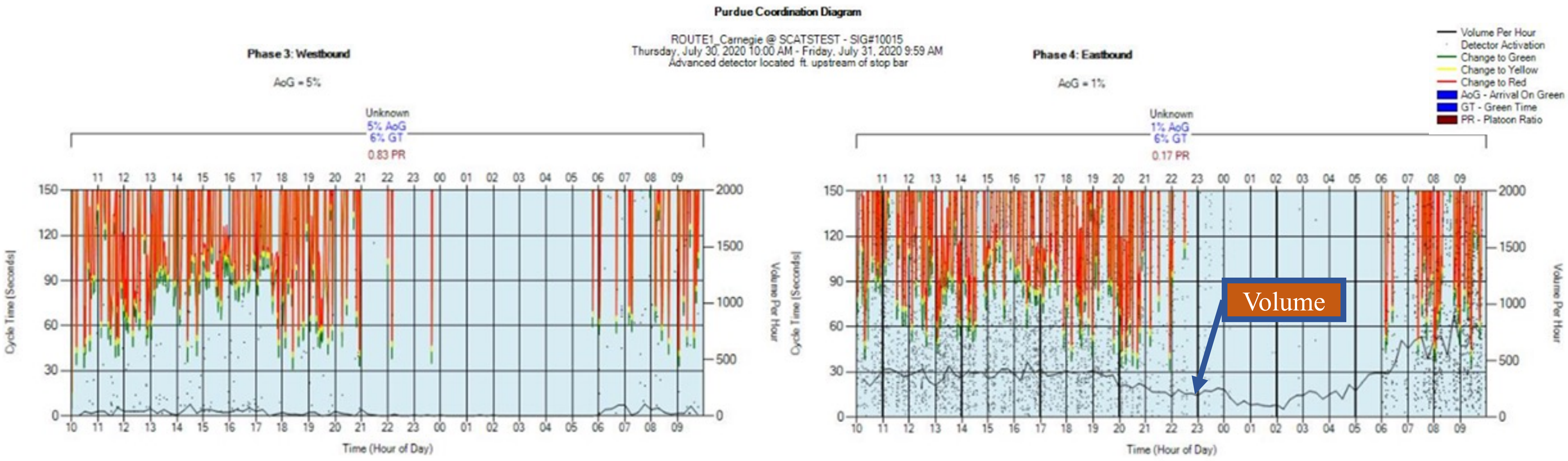
Purdue Phase Diagram (PCDs)



After 20:00, the SCATS server extends the cycle length to adjust to the reduction of traffic. From midnight to 6:00 A.M. in the morning the SCATS controller usually rests on the mainline.

It is worth to note that the testing data is collected during the COVID-19 pandemic period, the vehicle volume is very light due to work-from-home policy.

Purdue Phase Diagram (PCDs)



Minor approach (Phase 3&4) PCD with 6% green time allocated to the minor approach

Phase 4 has higher volume than phase 3

GOING LIVE

http://atspm.lions.tcnj.edu/atspm

ATSPMs with Stop-bar Detector

- When integrating ATSPMs with current traffic control systems, there is a lot of locations that are not properly equipped with advanced detectors ready for signal performances (e.g., Arrival on Red, Cycles of Delays, Platoon Coordination and Purdue Coordination Diagram).

- Wavetronix Detector is not particularly installed for intersection data collection purpose

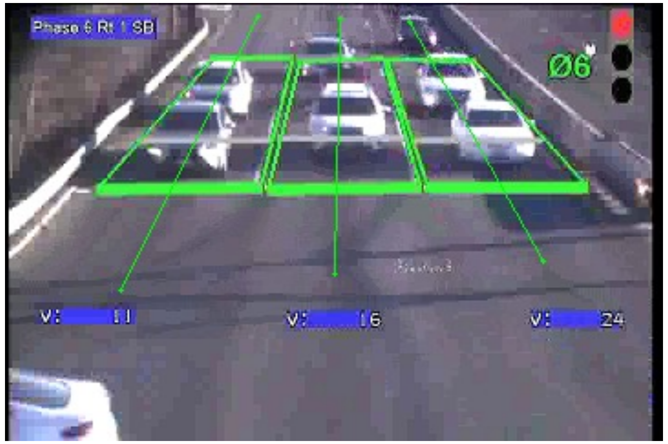
Wavetronix Detector's Location is too faraway from Intersection

Trajectory Reconstruction with Stop-bar Detector

In practice, many adaptive signal control systems are equipped with the stop-bar vehicle detection system, which allows real-time signal timing adjustment.

In the 2nd phase of this project. The team has developed algorithm to utilize the commonly-seen stop-bar detector for vehicle trajectory reconstruction and estimate the advanced location detection.

To evaluate the trajectory reconstruction results, we also use the CCTV camera as ground truth data to validate the trajectory results



AutoScope Stop-Bar Detector

NJ 511 CCTV Camera

Scanline Method for Vehicle Detection and Tracking

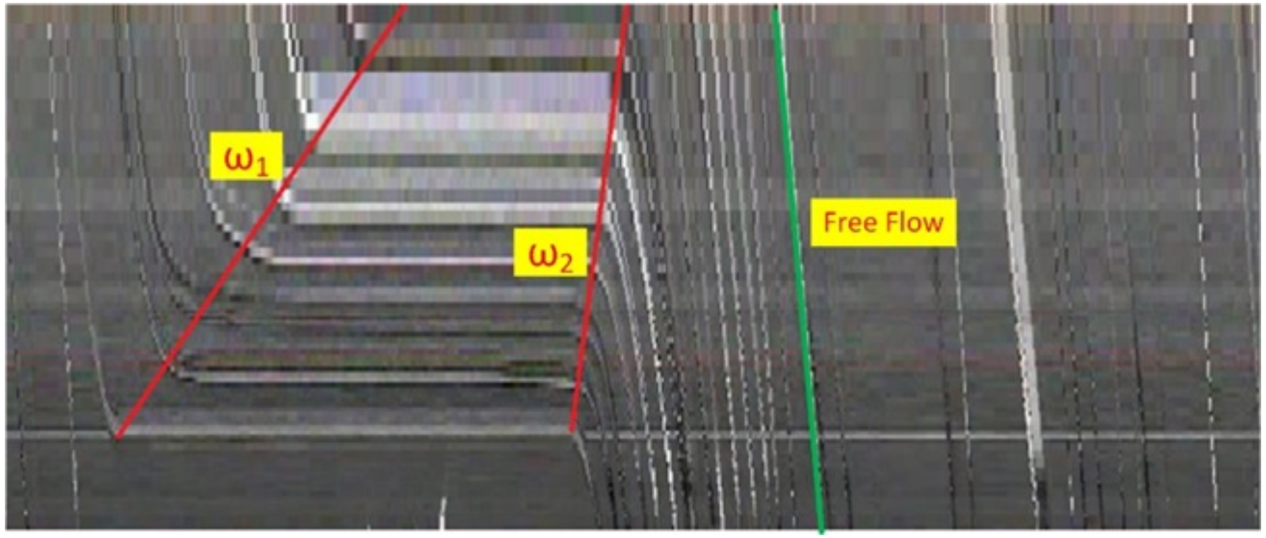
- Scanline method is a video analytic method in traffic-related research, which has adopted broadly for traffic detection to address vehicle tracking problem of multi-camera network.
- The research team implemented scanline method to extract high-resolution vehicle trajectories from high-angle traffic video to collect high-resolution trajectories for both highway segment and urban signalized intersection (30).

d for Vehicle Detection and Tracking

by Matching Video image with Google Map to measure real world distance

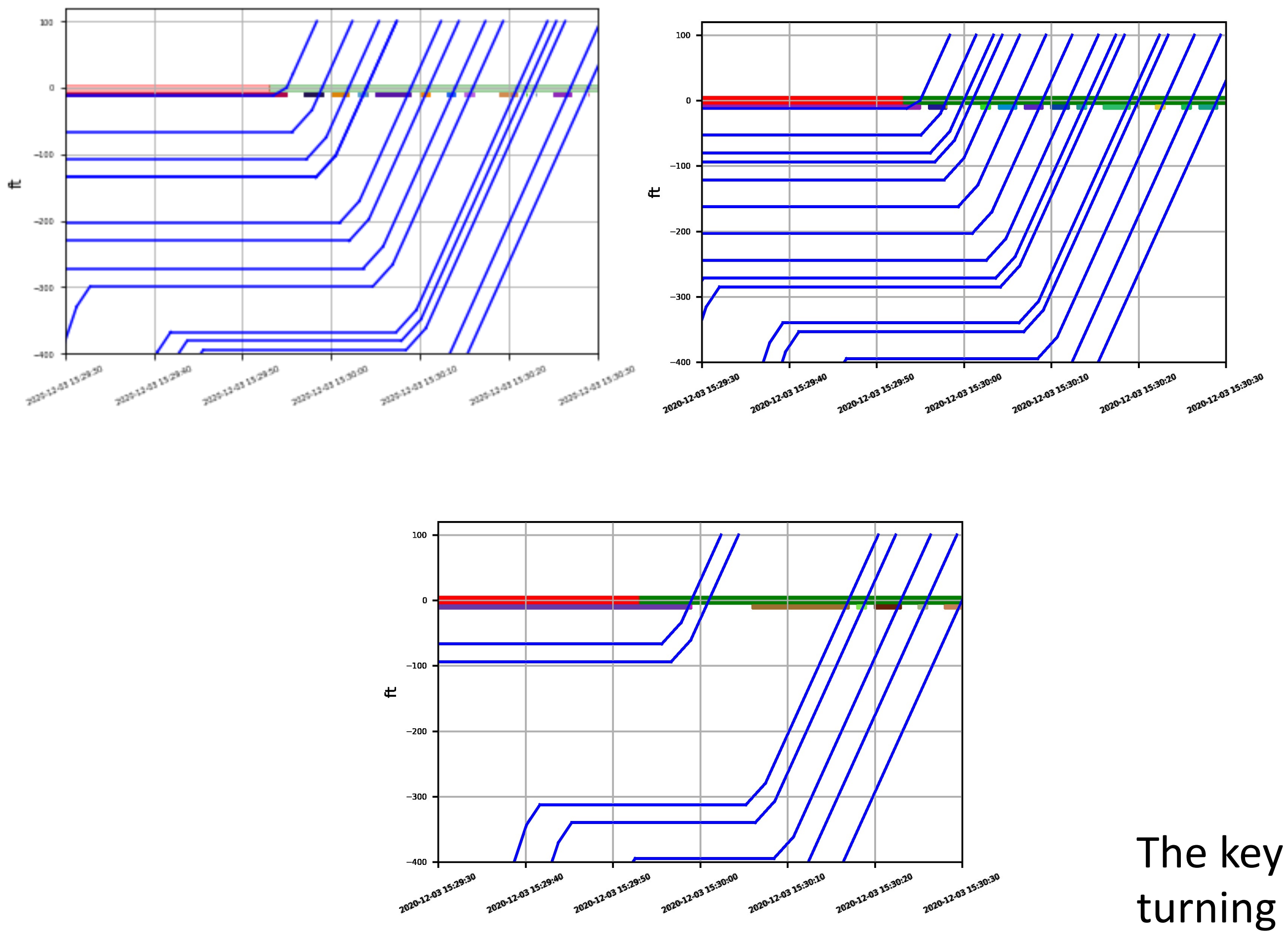
A Feature Matching Google Map and CCTV Video

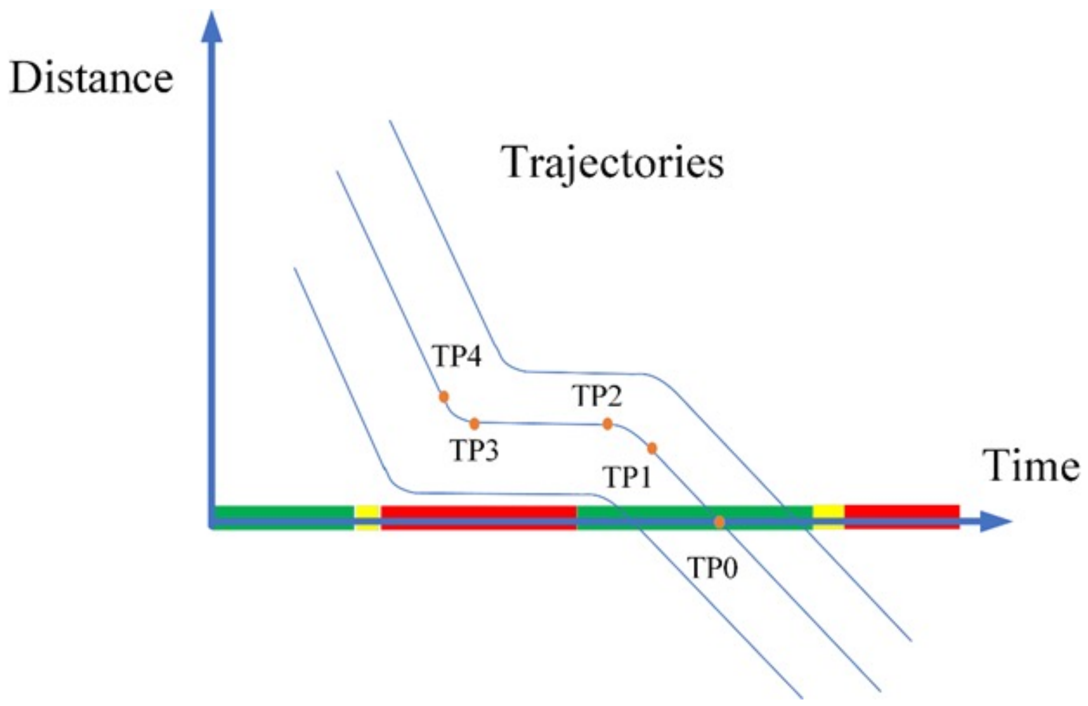
B Rectified Spatial Temporal Map to Overcome Perspective Distortion



Shockwave Measurements from STmap (ω_1: Queuing Shockwave; ω_2: Discharging Shockwave)

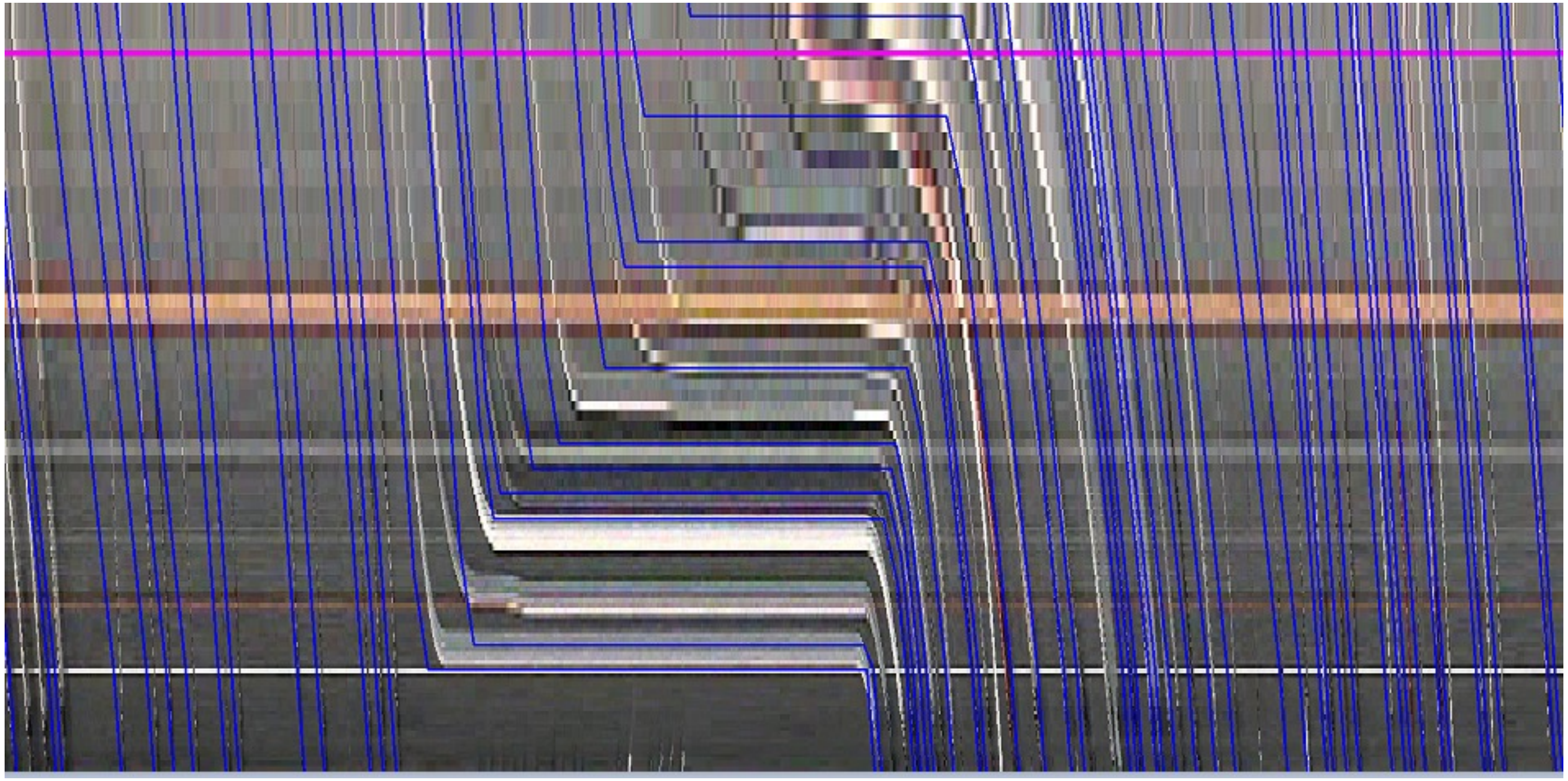
Reconstruct Vehicle Trajectory





The key to reconstruct the vehicle trajectories is to identify all turning points of the piece-wise linear trajectory model.

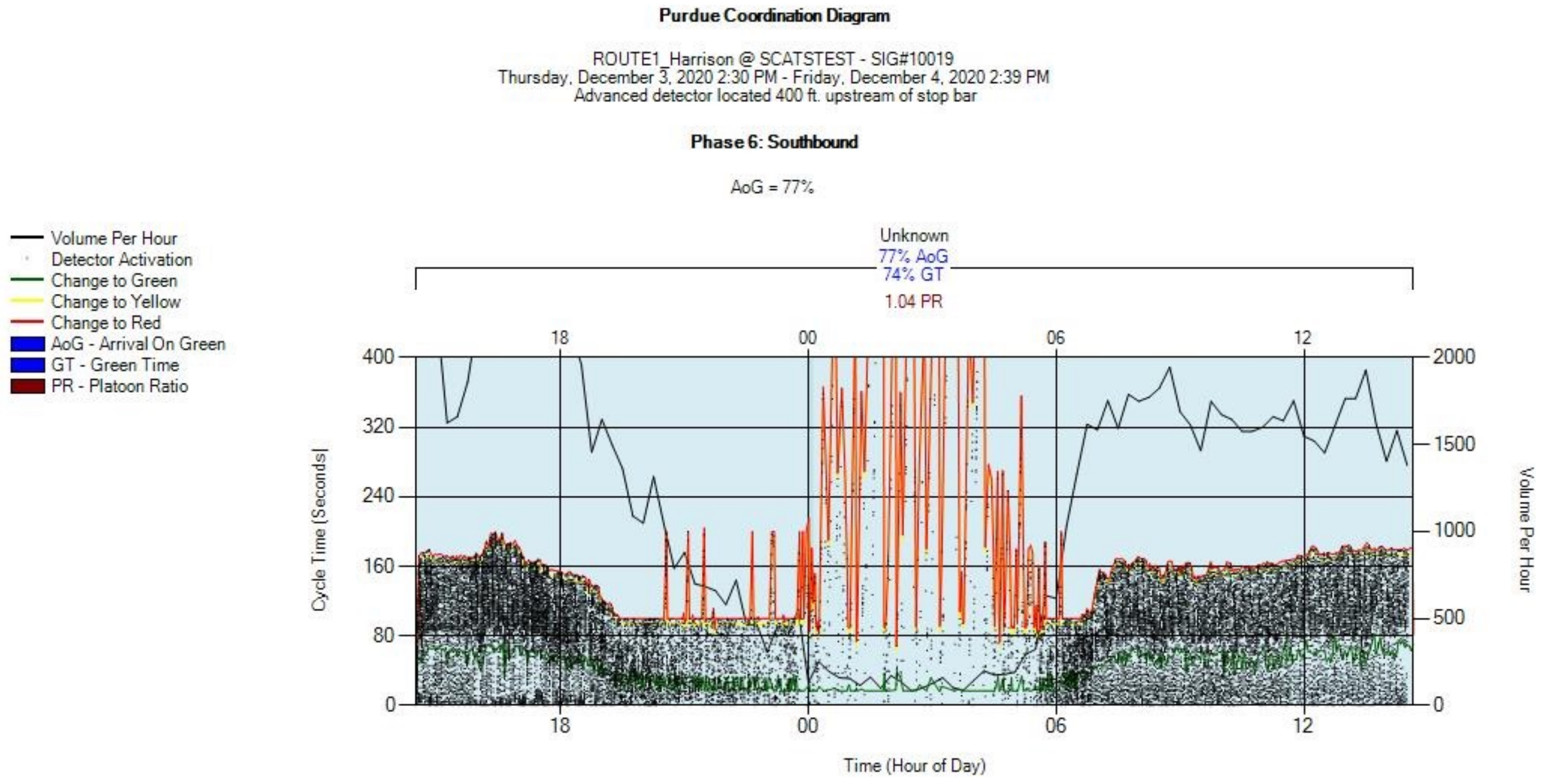
Reconstructed Vehicle Trajectories on STMap



400-ft Location for Advanced Detector

Stop-Bar Detector

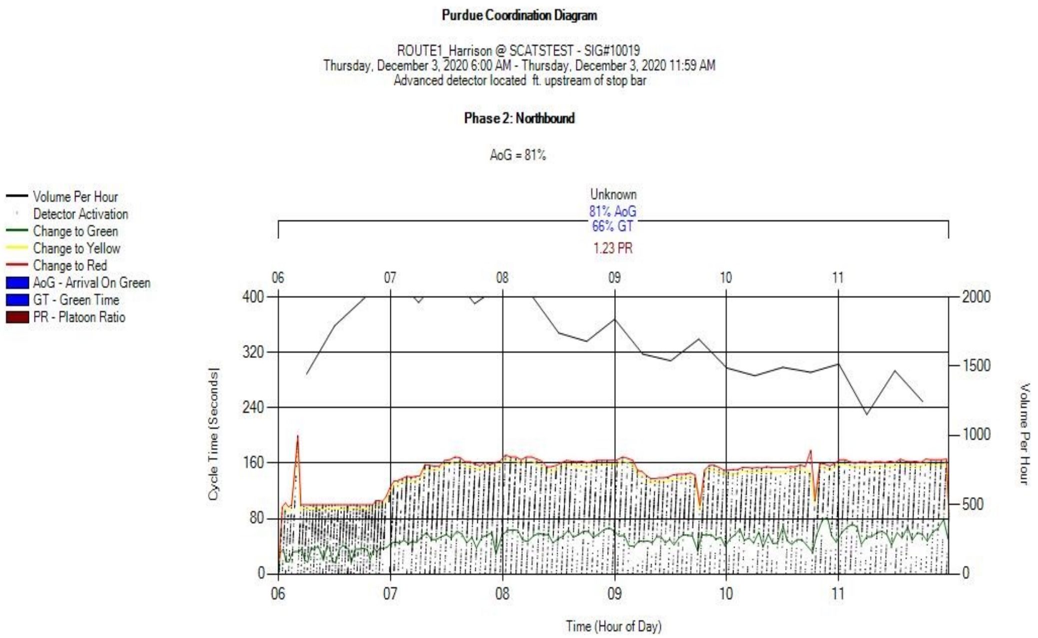
Purdue Phase Diagram (PCDs) From Reconstructed Trajectory



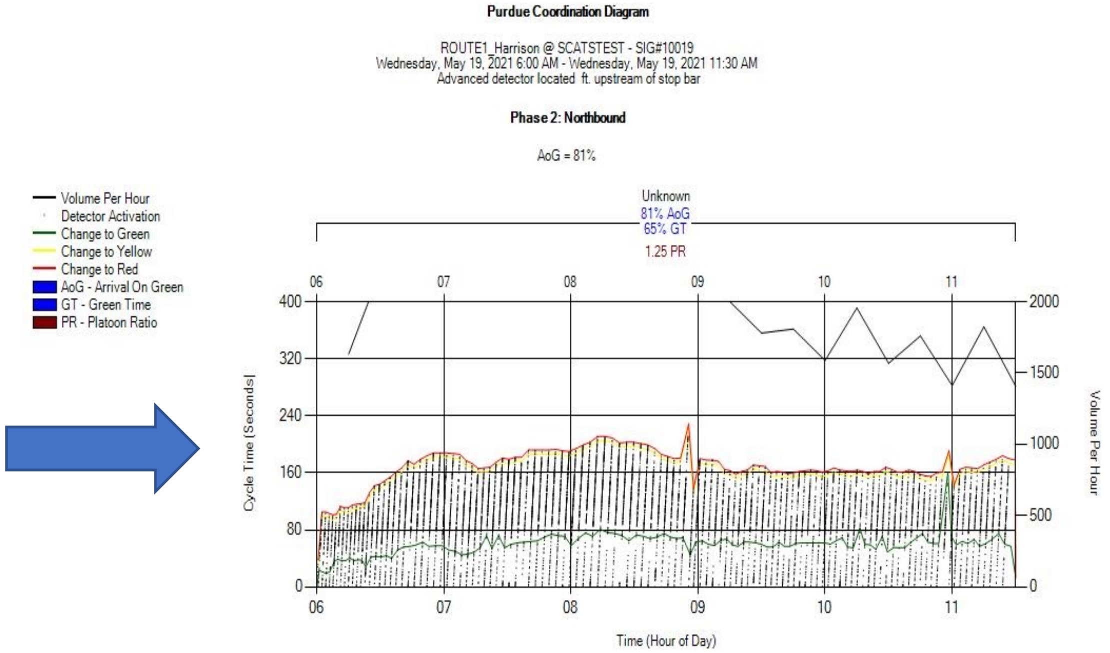
Rt 1 at
Fisher/Harrison

ATSPM-based Before/After Studies – Offset Optimization

Before-After Comparison



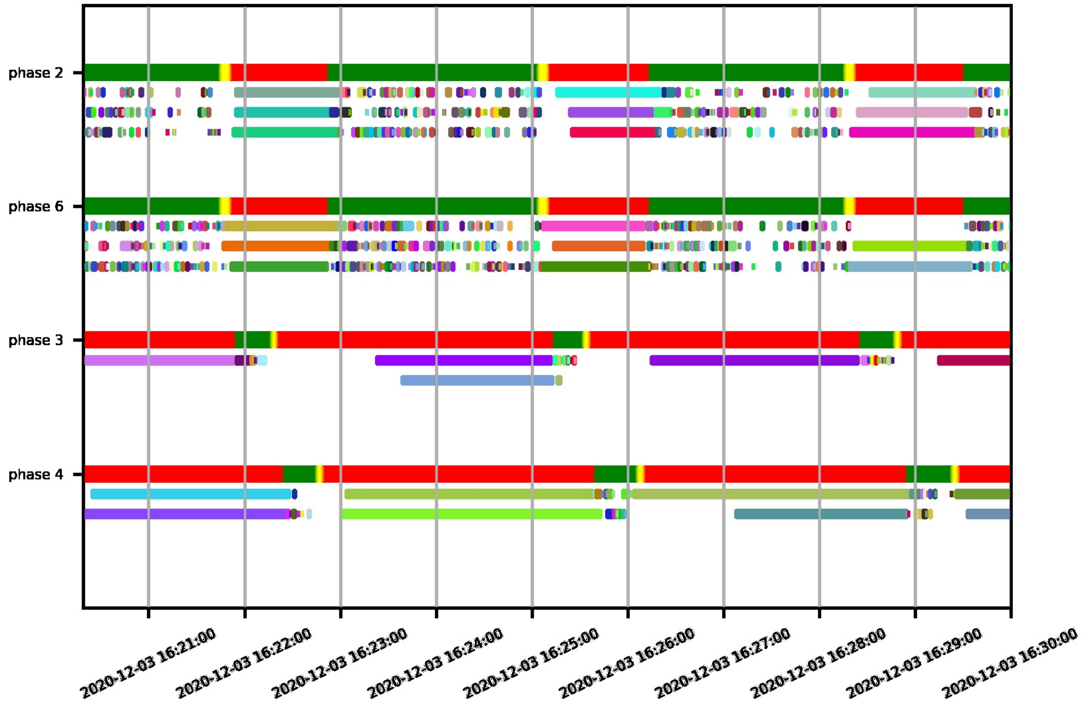
2020-12-03



2021-05-19

1. Higher Volume
2. Longer Cycle Length

Stop-Bar Coordination Diagram



- Does not have Queue-Over-Detector (QOD) phenomena compared to advanced detector.
- Does not have privacy concerns compared to the mobile sensor data.
- Detect all vehicles instead of sampled vehicle trajectories and provide lane-by-lane based performance measurement.
- Detection zone length is the main impacting factor of accuracy, which is easy to calibrate.

Summary

- Addressed the gap to build ATSPM for adaptive signal control systems by utilizing existing data sources instead of upgrading the current infrastructure.
- Signal and detector information in the ASCT that can be used to produce additional performance measures in the ATSPMs.
- The proposed approach can avoid the intensive infrastructure investment for the adaptive system to build ATSPMs.
- In practice, many adaptive signal control systems equipped with the stop-bar vehicle actuation system, which allows real-time signal timing adjustment.
- The reconstructed vehicle trajectories can extend the capability of fixed location detectors for signalized corridor management and real-time monitoring of road network for signal optimization.

Reference:

- Day, C. M., Langdon, S., Stevanovic, A., Tanaka, A., Lee, K., Smaglik, E. G., ... & Phillips, S. (2019). Traffic Signal Systems Research: Past, Present, and Future Trends. Centennial Papers.
- Remias, S., Waddell, J., Klawon, M., & Yang, K. (2018). Signal Performance Measures Pilot Implementation (No. SPR-1681).
- Brennan Jr, T. M., Day, C. M., Sturdevant, J. R., & Bullock, D. M. (2011). Visual Education Tools to Illustrate Coordinated System Operation. Transportation research record, 2259(1), 59-72. (Traffic Signal Systems: Exceptional Paper Award 2011)
- https://ops.fhwa.dot.gov/publications/fhwahop20002/index.htm