ATSPM-in-the-loop Simulation for traffic signal design and operations

An ATSPM digital twin

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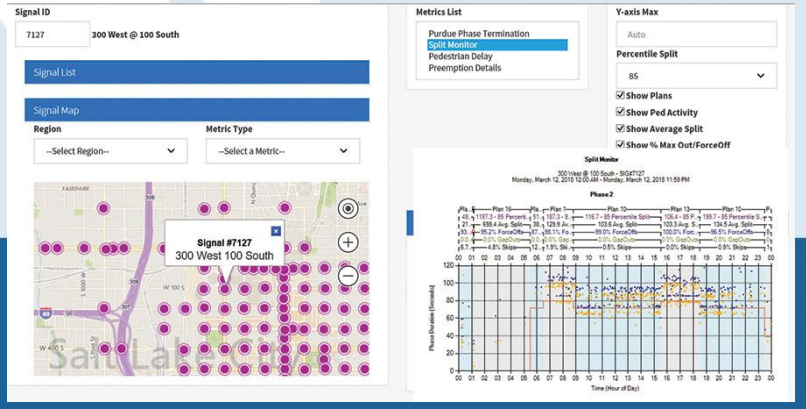
ATSPM system 101

- **Traditional signal performance measures like average control delay cannot take advantages of these new data**
  - **All randomness are averaged out by the control software before becoming available to users**

- **Most traffic controllers record individual control events as a standard function**
  - **Each event include time stamp, event type and event index**
    - **E.g. "vehicle placed a *vehicle call* on NB (det *channel 8)* at *7:01:02.2 AM, May-02-2019*" : *[6, 7:01:02.2 AM, May-02-2019, 82, 8]***

- **Novel ATSPM measures are intended to use these recorded individual events**



Chronicle of ATSPM

- Purdue University first began to retrofit signal controllers to generate such data and tested at individual intersections in the early 2000's.

- Indiana DOT first asked all controllers sold in Indiana to output events for ATSPM later
  - All the major controllers support this function in a few months

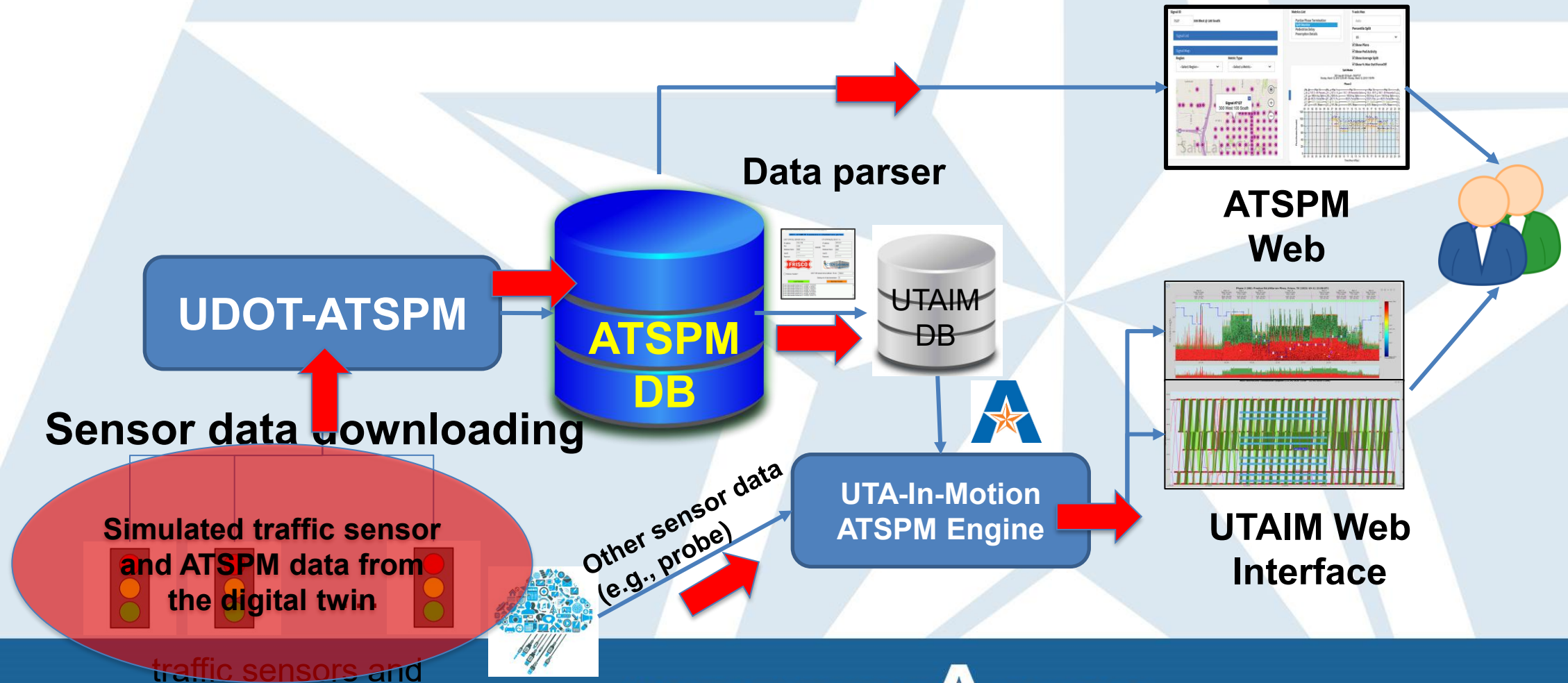
- Utah DOT developed the first ATSPM solution and opened the source code.
  - The ATSPM implementation began to take off. Most commercial solutions derived from the UDOT-ATSPM system

Surfacing challenges in the ATSPM deployment

- **ATSPM systems are data-driven: no data, no ATSPM**
  - Requiring a lot of detectors to be fully functional (i.e., extra investment)
  - Does not accept novel big data like vehicle trajectories
- **Limited access: installing and using ATSPM is mostly an exclusive privilege, but more professionals should have access**
- **No possible for signal planning and design with ATSPM:**
  - **Data driven but no data until deployed: a "chick and egg" dilemma**
- **Complex traffic signal operations (vehicle preemption, TSP, Adaptive, peer-to-peer etc.) are common but no good tools for design**
  - Design of such systems is right now heavily based on engineering judgements
  - The effectiveness can be evaluated by the ATSPM after the deployment, but it is **posterior**

An ATSPM digital twin will be able to solve these problems

The ATSPM system and its digital twin

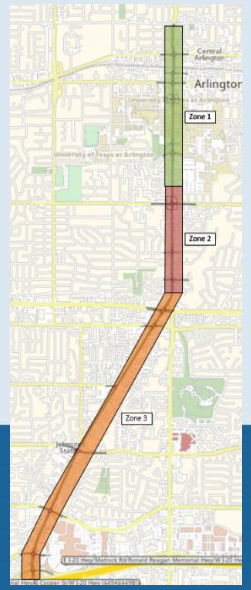


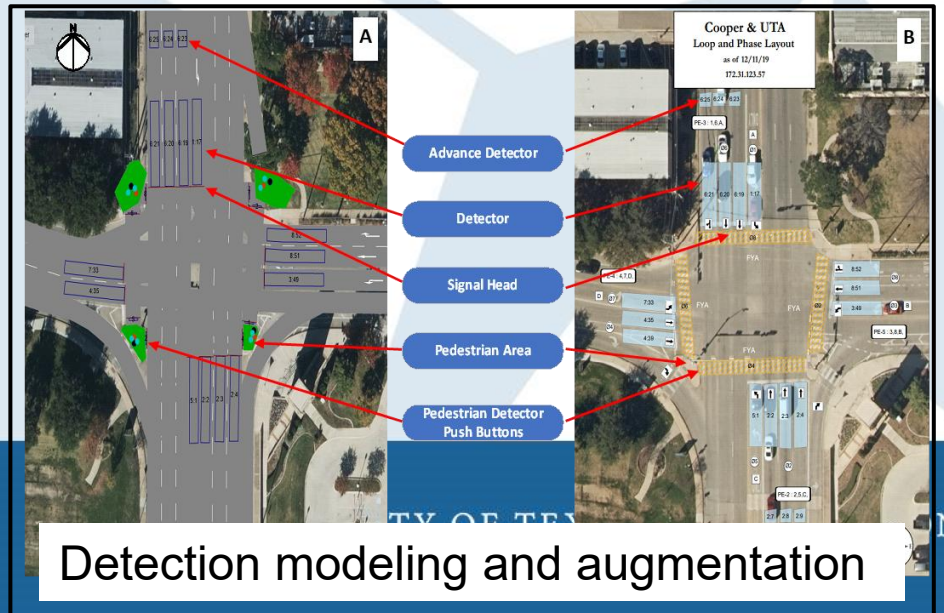
Traffic microscopic simulation engine

- A high-fidelity traffic simulation model (16 intersections along a TxDOT freight corridor) was developed, calibrated and validated

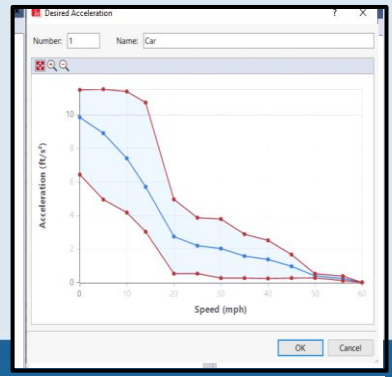
- All available sensor data were considered
  - Traffic signal timings, detector layouts and historical traffic counts: downloaded from the Arlington's ATMS
  - Traffic big data (probe trajectories): Procured from Wejo Data Service Inc.
  - **Detectors were augmented to ensure each intersection is fully ATSPM-compliant**

- Model calibration and validation with the data
  - Turning movement counts; driving behaviors





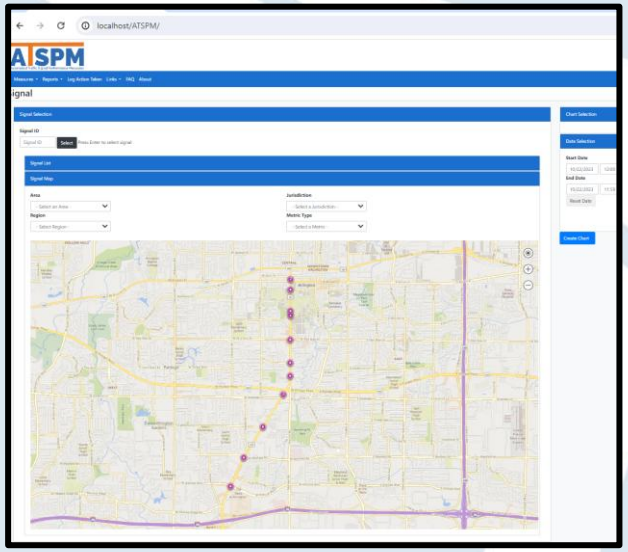
Detection modeling and augmentation

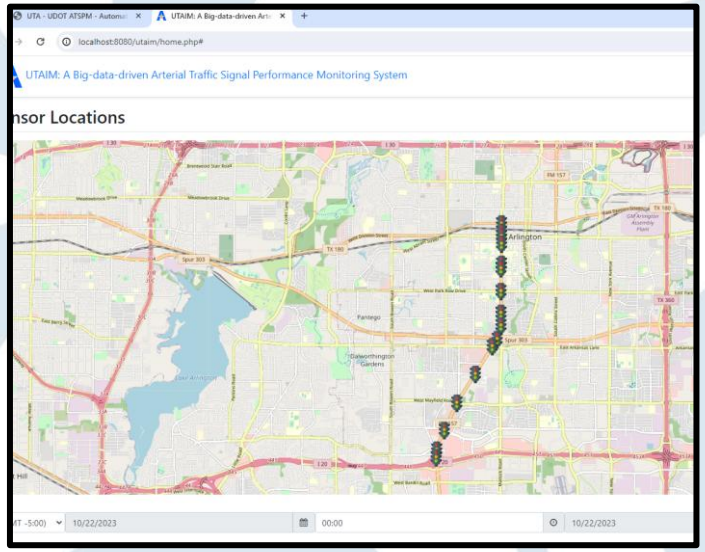


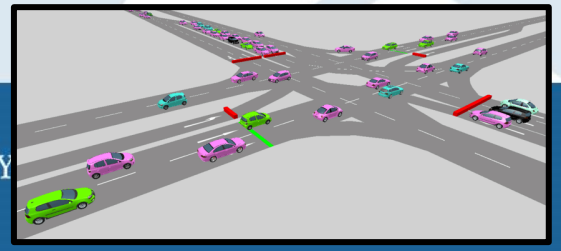
Using Wejo data to calibrate VISSIM vehicle behaviors

Set up two ATSPM systems in the laboratory

- Set up two complete ATSPMs on the VISSIM host computer in the laboratory: UDOT-ATSPM; ***UTA-In-Motion*** by U of Texas Arlington

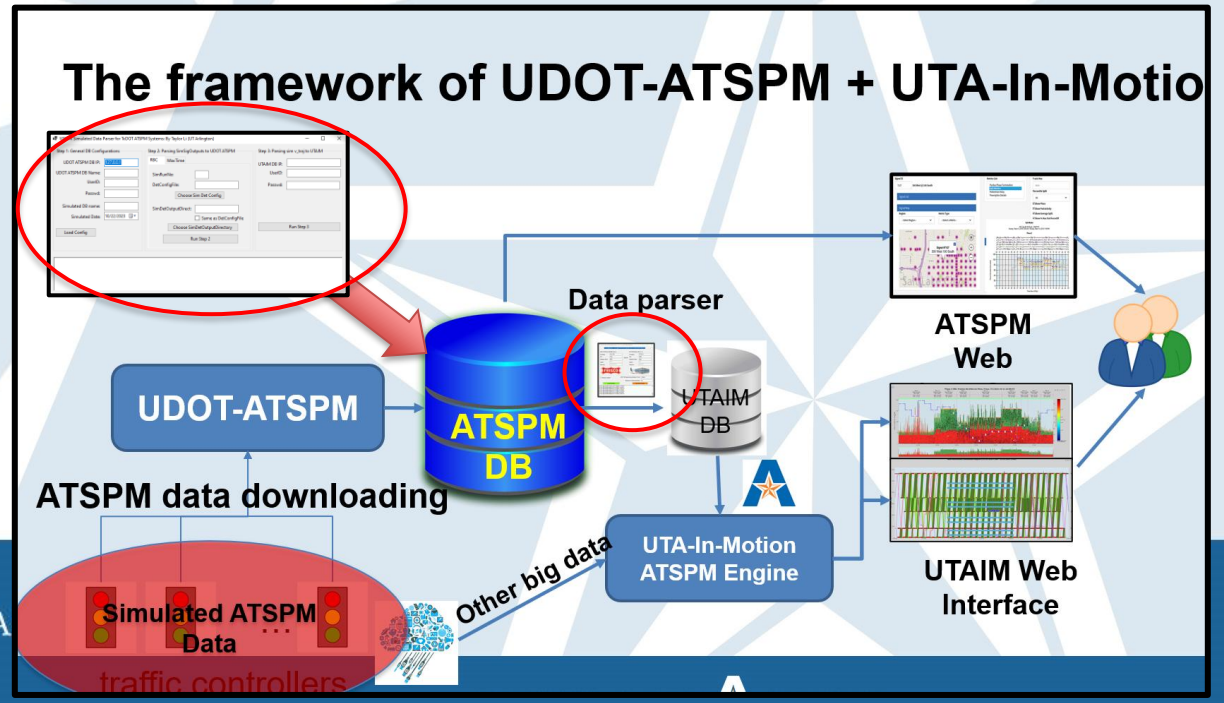


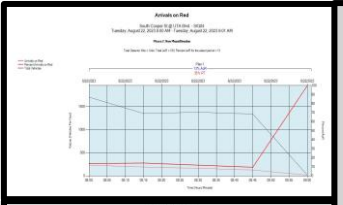


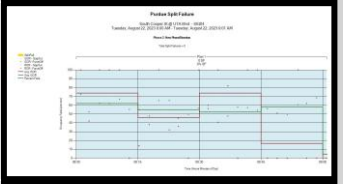


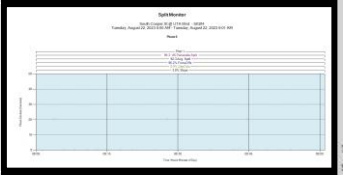
Software to emulate infrastructure sensor data

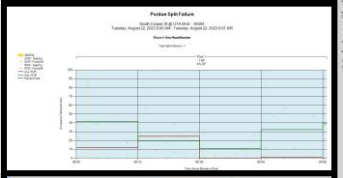
- Three software tools has been developed to transform the simulation output to the real-world data format for those real-world ATSPM systems (e.g., Signal event numbering, (lat, lon) location, etc.)
  - To ensure the simulated sensor data has the same format as the real sensor data
- Software is planned to be uploaded to Github after the project is finished, contingent on institutional approvals

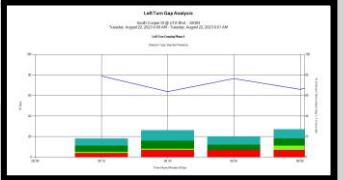


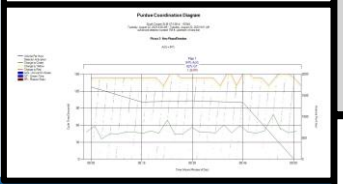


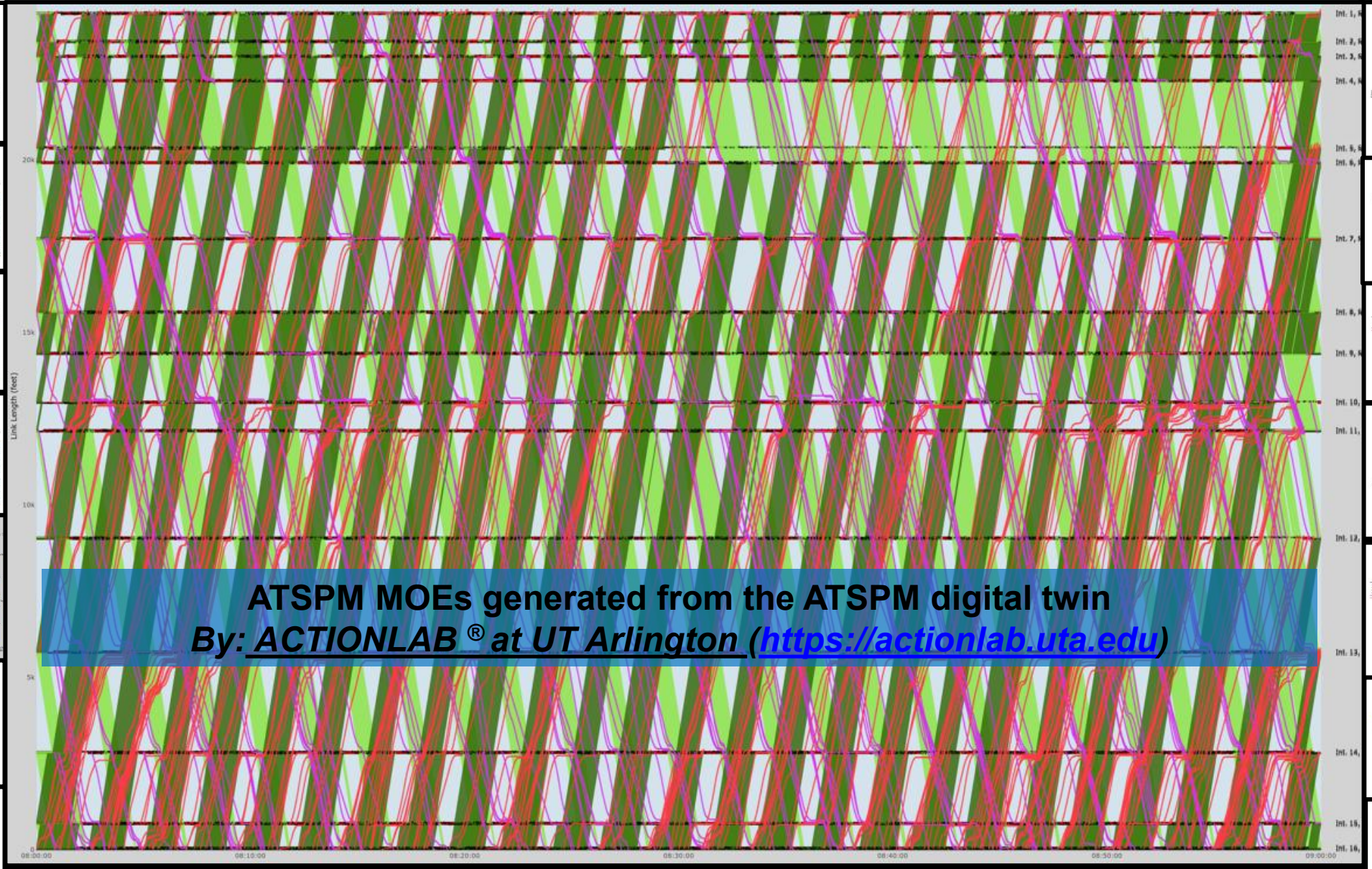






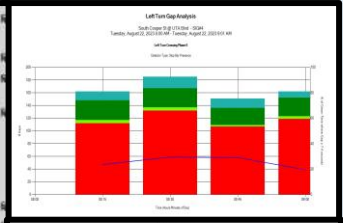


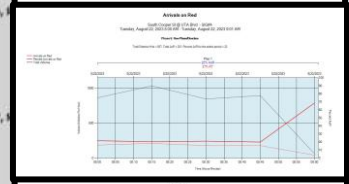


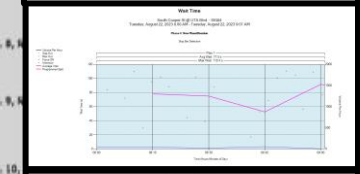


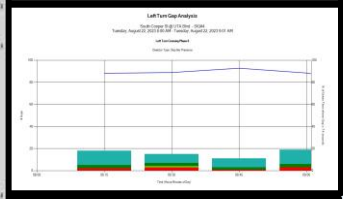
ATSPM MOEs generated from the ATSPM digital twin

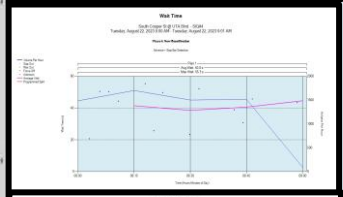
By: ACTIONLAB ® at UT Arlington (https://actionlab.uta.edu)

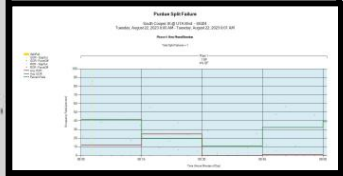


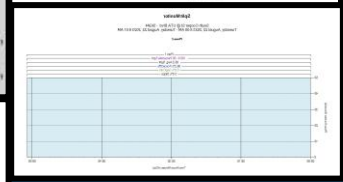




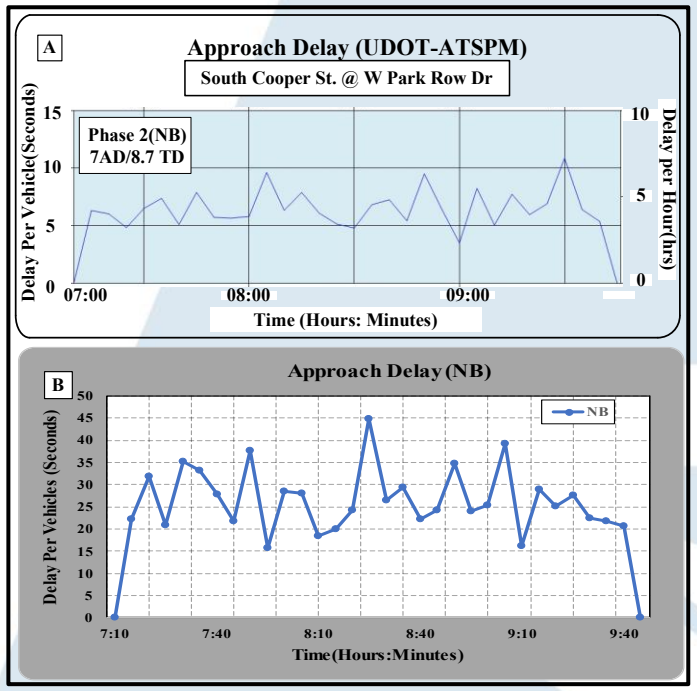


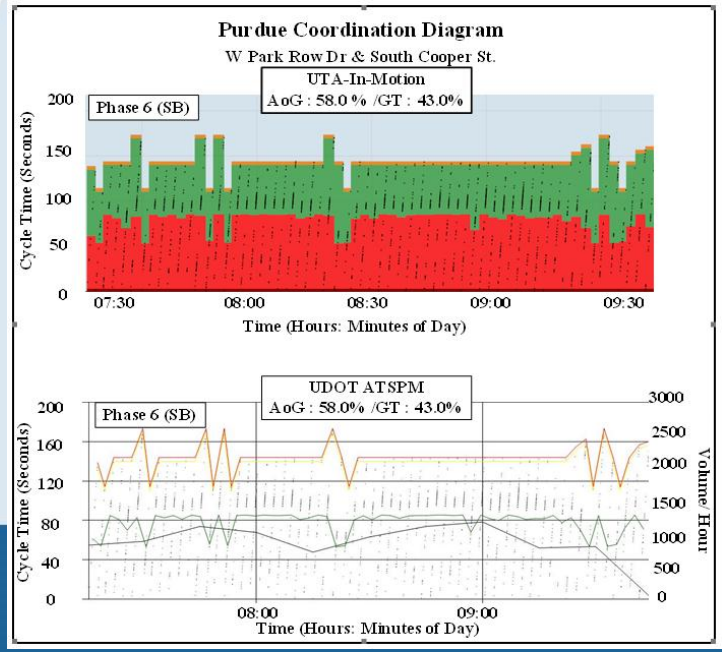


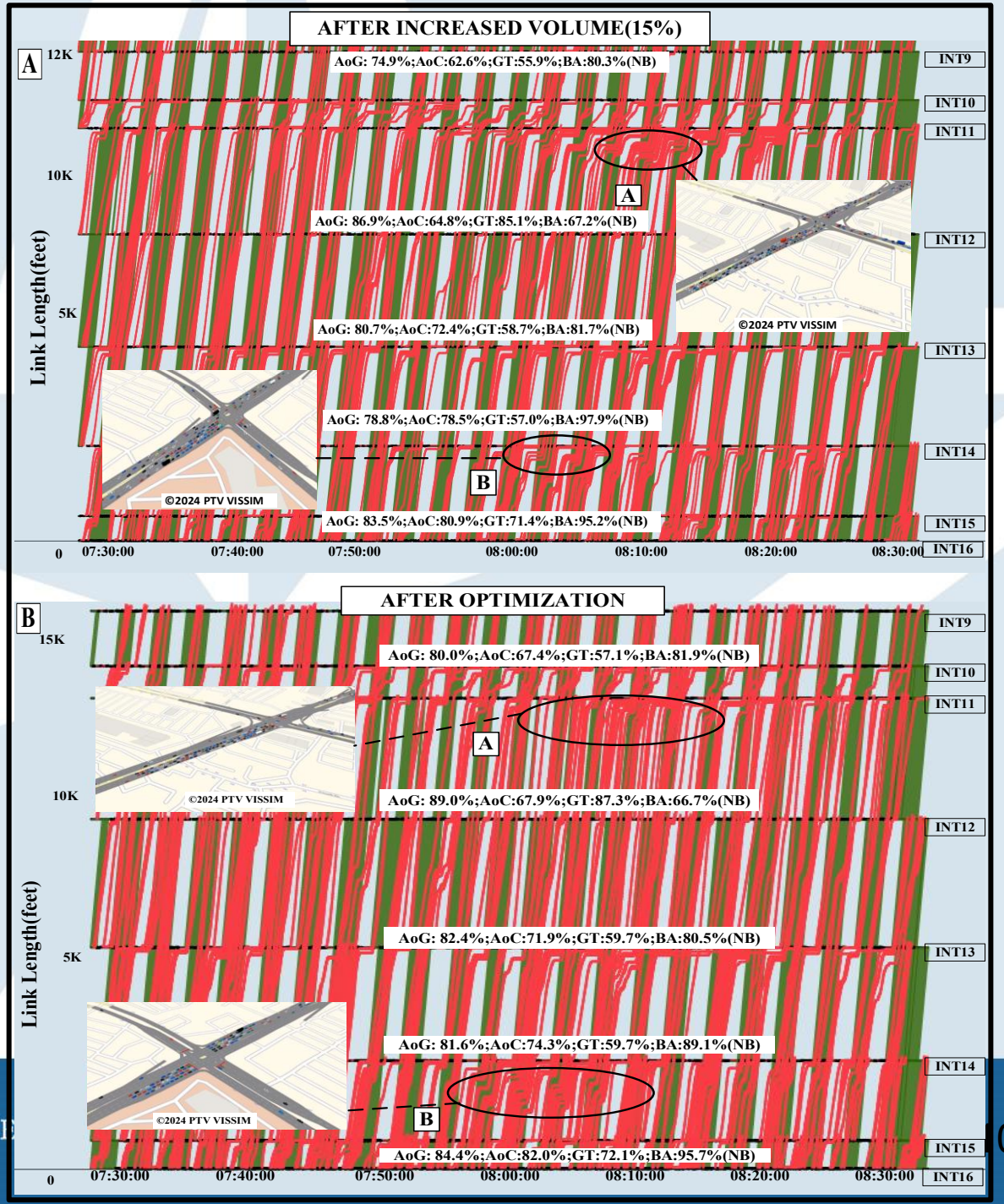




Case study


A
Approach Delay (UDOT-ATSPM)
South Cooper St. @ W Park Row Dr
Phase 2(NB)
7AD/8.7 TD
Delay Per Vehicle(Seconds)
Delay per Hour(hrs)
Time (Hours: Minutes)
B
Approach Delay (NB)
NB
Delay Per Vehicles (Seconds)
Time(Hours:Minutes)


Purdue Coordination Diagram
W Park Row Dr & South Cooper St.
UTA-In-Motion
AoG : 58.0 % /GT : 43.0%
Phase 6 (SB)
Cycle Time (Seconds)
Time (Hours: Minutes of Day)
UDOT ATSPM
AoG : 58.0% /GT : 43.0%
Phase 6 (SB)
Volume/ Hour


AFTER INCREASED VOLUME(15%)
AoG: 74.9%;AoC:62.6%;GT:55.9%;BA:80.3%(NB)
AoG: 86.9%;AoC:64.8%;GT:85.1%;BA:67.2%(NB)
AoG: 80.7%;AoC:72.4%;GT:58.7%;BA:81.7%(NB)
AoG: 78.8%;AoC:78.5%;GT:57.0%;BA:97.9%(NB)
AoG: 83.5%;AoC:80.9%;GT:71.4%;BA:95.2%(NB)
©2024 PTV VISSIM
Link Length(feet)
AFTER OPTIMIZATION
AoG: 80.0%;AoC:67.4%;GT:57.1%;BA:81.9%(NB)
AoG: 89.0%;AoC:67.9%;GT:87.3%;BA:66.7%(NB)
AoG: 82.4%;AoC:71.9%;GT:59.7%;BA:80.5%(NB)
AoG: 81.6%;AoC:74.3%;GT:59.7%;BA:89.1%(NB)
AoG: 84.4%;AoC:82.0%;GT:72.1%;BA:95.7%(NB)

Additional notes

OR?

- We are building a “Space-X”, not a “Saturn-V”
  - Cost-aware, easy to repeat.

- Therefore, the project team and TxDOT panel carefully evaluated the expected deliverables, not only the capability but also the economic feasibility for the stakeholders (agents, consultants, etc.)
  - **Does it increase project budget (a lot), like software, hardware, etc.?**
  - **Can it be picked up and accepted by stakeholders quickly? (learning curves)?**
  - **Generality?**

- Holding these thoughts, the following options were adopted during the system design and software development

Software/Hardware options in the ATSPM digital twin

- *Traffic simulation software*: PTV VISSIM with RBC and external signal controller API support
  - Widely adopted for traffic signal projects in Texas
- *Developed software tools*
  - Graphic user interface
  - After the regular traffic simulation modeling effort, it takes 10~15 mouse clicks to get the data transferring
- Free Database engines and Windows 10/11
  - *Free and common*
- **For complex conditions** (adaptive, preemption, transit signal priority, etc.)
  - We adopted Q-free's MAXTIME's software-in-the-loop (SILS) solution
  - Other brands of controllers are also supported through a universal control interface software (CIS) with hardware controllers (developed at UTA)