In-Person CV-PFS Meeting

Connected Intersections Message Monitoring Systems Requirements & Prototype Development (CIMMS)

May 7, 2025

Welcome and Review of Meeting Agenda

Agenda

- Welcome and Introductions
- Project Management updates
- Design Updates
- Monitoring System Updates
- Next Steps
- Open Discussion
- Wrap Up

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Designing for the future

Project Management Updates

Background

- Phase I
  - *Design a Connected Intersection Message Monitoring System (CIMMS)*
    - Continually evaluate SPaT and MAP messages for data alignment and consistently
    - Use BSMs to evaluate how well SPaT and Map represent Ground Truth
  - *Develop and deploy CIMMS Prototype*
    - Prototypes deployed in Utah and MCDOT
  - *CIMMS Code is open-source, on the JPO Github*

Scope

- Phase II (current)
  - *Refine existing functionality\features\Algorithms*
  - *Add new functionality\features\Algorithms*
  - *Update Systems Engineering Documents*
  - *Develop CIMMS Installation Guide*
  - *Support other sites in deploying CIMMS*

New and Updated Functionality

Function	Description	Implementation % Complete	Status
Refine Existing Reports	Enhance existing Operator Reports	100%	Completed
Event State Conflict Monitor (account for ped and new event state definitions)	Compare vehicular movement event states against pedestrian movement event states	100%	Completed
Data Management	Investigate and implement methods for reducing storage and overall operational costs	100%	On-going
Message Visualizer	Update as needed	100%	Version 1 deployed
Revision Counter	Verify message content changes when the message revision counter is updated	100%	Completed
Interface with TSC Equip	Integrate CIMMS with TSC or conflict monitor. Compare TSC data with SPaT message	0%	Finalizing Design; comparing SPaT data to ATSPM data from UDOT
Health and Status Monitoring	Include additional RSU manufacturers deployed in UDOT and MCDOT, as applicable, as well as refine the overall functionality of the system.	50%	Initial Design Complete, in the process of deploying to UDOT and MCDOT, working to incorporate additional RSU manufactures
SCMS Attestation	Coordinate with the SCMS Manager to identify CIMMS data and reports that could provide attestation to an SCMS provider	0%	Working with SCMS Manager to identify the data needed and the interface to transfer the data
Event State Transition	Monitor signal group event state transitions to determine if non-permitted transitions are occurring (e.g. Green-to-Red)	75%	Design Complete, in testing
RTCM Messages	Assess RTCM messages utilizing RTCM message types and broadcast rates as defined in CTI 4501	10%	ODE contains ASN.1; completed by others Design Complete. Q2 release starting in May

New and Updated Functionality

Function	Description	Implementation % Complete	Status
Stop Message Broadcast	Issue a “stop broadcasting” command to an RSU if certain events are produced and thresholds are surpassed	0%	Design Complete
Revocable/Enabled Lane	Update existing algorithms to account for revocable/enabled	0%	Design Complete
Performance and Operational Metrics	Generate near real-time and historical aggregated performance and operational metrics visualized on the map user interface	0%	Finalizing Design
Assessment of Vehicle position and speed Plausibility	Plausibility assessment of position and speed data contained in BSMs	50%	Design Complete
SRM\SSM Messages	Assess SRM and SSM message content based on SAE J2945\B or other agreed to specification	0%	Design Complete
RSU Broadcast Validation	Add the capability for CIMMS to validate\verify RSUs are broadcasting	0%	Finalizing Design

Site Support

- Caltrans
- WiDOT
- FDOT
- UMTRI
- Integral Blue
- ISS: setting up CIMMS up the OmniAir PlugFest the week of 05/05/25

2025 Schedule

Task Name	Duration	Start	Finish
NTP	0 days	Mon 12/16/24	Mon 12/16/24
1. PM	250 days	Mon 12/16/24	Tue 12/23/25
2. Document Updates	**190 days**	**Mon 1/20/25**	**Mon 10/20/25**
ConOps	**10 days**	**Mon 1/20/25**	**Fri 1/31/25**
Submit Final (Complete)	10 days	Mon 1/20/25	Fri 1/31/25
Requirements	**10 days**	**Mon 1/20/25**	**Fri 1/31/25**
Submit Final (Complete)	10 days	Mon 1/20/25	Fri 1/31/25
SDD	**30 days**	**Mon 2/3/25**	**Fri 3/14/25**
Submit Draft	10 days	Mon 2/3/25	Fri 2/14/25
Panel Review	10 days	Mon 2/17/25	Fri 2/28/25
Submit Final	10 days	Mon 3/3/25	Fri 3/14/25
Test Plan	**36 days**	**Mon 2/17/25**	**Mon 4/7/25**
Update (Complete)	15 days	Mon 2/17/25	Fri 3/7/25
Submit Draft (Complete)	1 day	Mon 3/10/25	Mon 3/10/25
Panel Review (Complete)	10 days	Tue 3/11/25	Mon 3/24/25
Submit Final (Complete)	10 days	Tue 3/25/25	Mon 4/7/25
Final Report	**36 days**	**Mon 9/1/25**	**Mon 10/20/25**
Update	15 days	Mon 9/1/25	Fri 9/19/25
Submit Draft	1 day	Mon 9/22/25	Mon 9/22/25
Panel Review	10 days	Tue 9/23/25	Mon 10/6/25
Submit Final	10 days	Tue 10/7/25	Mon 10/20/25
3.. Prototype Updates	**189 days**	**Mon 12/16/24**	**Thu 9/25/25**
3.1 Refine Existing Functionality	90 days	Mon 12/16/24	Thu 5/1/25
3.2 Add new Functionality	149 days	Mon 12/16/24	Thu 7/31/25
Testing Phase 1: Existing Functionality	20 days	Mon 5/5/25	Mon 6/2/25
Testing Phase 2: New Functionality	20 days	Fri 8/1/25	Thu 8/28/25
Testing Phase 3: Final	20 days	Fri 8/29/25	Thu 9/25/25
4.0 Code Uptimization	**225 days**	**Mon 12/16/24**	**Fri 11/14/25**
5.0 CIMMS Installation Guide	**10 days**	**Mon 10/20/25**	**Fri 10/31/25**
Submit Final	10 days	Mon 10/20/25	Fri 10/31/25
6.0 Deployment Support	**239 days**	**Mon 1/13/25**	**Tue 12/23/25**
Site Selection	**61 days**	**Mon 1/13/25**	**Mon 4/7/25**
Solicit Sites	20 days	Mon 1/13/25	Fri 2/7/25
Review Site Features	5 days	Mon 2/10/25	Fri 2/14/25
Submit Site Recommendation to Panel	0 days	Fri 2/14/25	Fri 2/14/25
Panel Review	5 days	Mon 2/17/25	Fri 2/21/25
Panel Approval	0 days	Fri 2/21/25	Fri 2/21/25
Notify Sites	1 day	Mon 2/24/25	Mon 2/24/25
Site Preperation	30 days	Tue 2/25/25	Mon 4/7/25
Technical Support	**198 days**	**Tue 3/11/25**	**Tue 12/23/25**
General overview of site requirements Wedinar	1 day	Tue 3/11/25	Tue 3/11/25
Preparing the site for CIMMS deployment Wedinar	1 day	Wed 3/26/25	Wed 3/26/25
CIMMS installation and configuration	30 days	Thu 3/27/25	Wed 5/7/25
CIMMS Troubleshooting	30 days	Thu 5/8/25	Thu 6/19/25
CIMMS Maintenance, Updates, and Expansion	156 days	Thu 5/8/25	Tue 12/23/25

Design Updates

Systems Engineering Documentation

- ConOps
  - *Final submitted for review on 2/19/25*
- System Requirements
  - *Final submitted for review on 2/19/25*
- SDD
  - *About 80% of algorithms have been designed*
  - *Several algorithms still in progress. Currently researching methods*
- Test Plan
  - *Final submitted for review on 2/19/25*

SDD Updates

- The following functions are in process:
  - *Interface with traffic signal controller*
    - preliminary data analysis has been done to compare the timestamps discrepancy between SPaT and ATSPM data.
  - *Nearest Neighbor RSU Validation*
    - Three implementation options are in consideration.
  - *In the process of getting input for:*
    - Performance and operational metrics report

Traffic Signal Controller Data White Paper

- *Potential sources evaluated in this paper:*
  - TSCBM (data feed from controller)
  - Synchronous Data Link Control (SDLC)
  - ATSPM software – signal state transition

- *Pros and cons are broken down for each source under 'Conclusion' section:*

Data Source	Pros	Cons
TSCBM	Most adopted	Known to contain errors; Not fully support CTI 4501; Not actively being updated; Not an independent data source
SDLC	More accurate	Need addition hardware; Need extensive data processing; Only contains current signal state
ATSPM-1	No additional hardware needed; More accurate; Data is standardized	Collect data in batch, limiting the timeliness; Additional resource load is unknown
ATSPM-2	No additional hardware needed; Data is standardized	Collect data in batch, limiting the timeliness; Need agency has an ATSPM server

Meeting with UDOT SMART Grant Team

Held on 3/14/2025

— *SDLC:*

- Pros: closest to ‘ground truth’, highly accurate, reliable, and standardized data
- Cons: requires additional hardware/software at each intersection, complicates scalability, and increases costs

— *ATSPM:*

- Pros: widely available, primarily standardized data, the accuracy level is acceptable
- Cons: concerns regarding timestamps and clock synchronization

— *Time synchronization is critical for comparing data collected from traffic controllers and RSUs.*

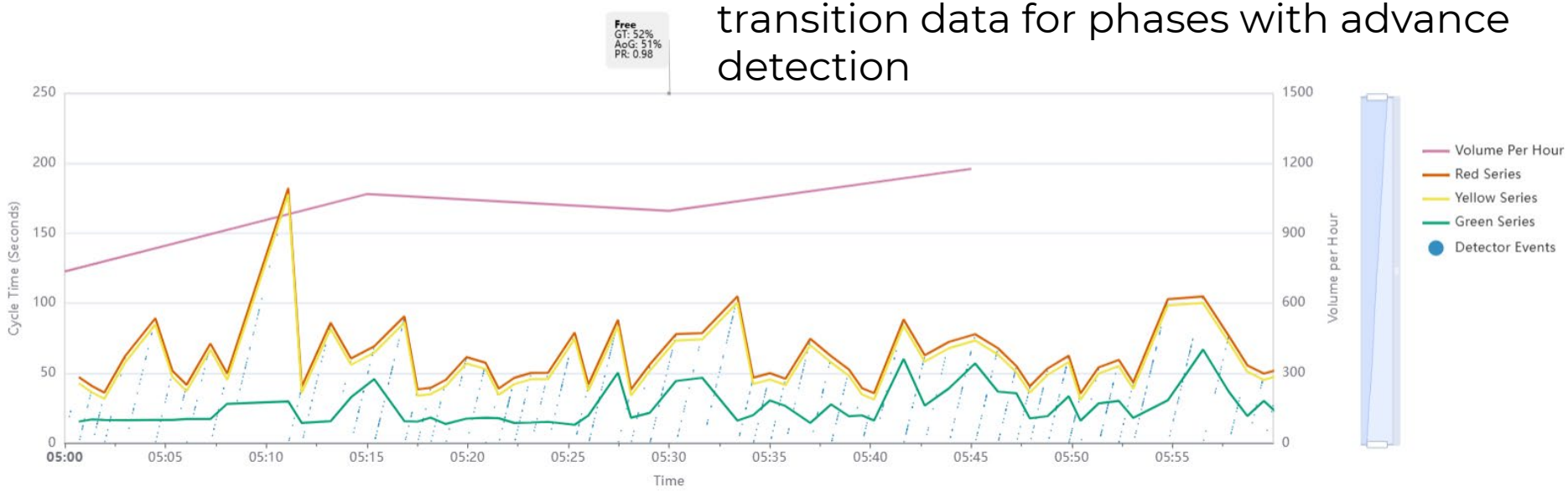
- Utah uses a data acquisition system that collects data from traffic controllers and RSUs and applies GNSS-based timestamps to them.
- Even though ATSPM timestamps might not be perfectly synchronized, the difference could be still acceptable.

UDOT ATSPM Data

Purdue Coordination Diagram
#6311 - State Street & Center Street - NBT Ph2
Tue, March 25, 2025 at 05:00:00 - Tue, March 25, 2025 at 06:00:00

*Arrivals on Green: **51%***

With “normal” access, can only get transition data for phases with advance detection

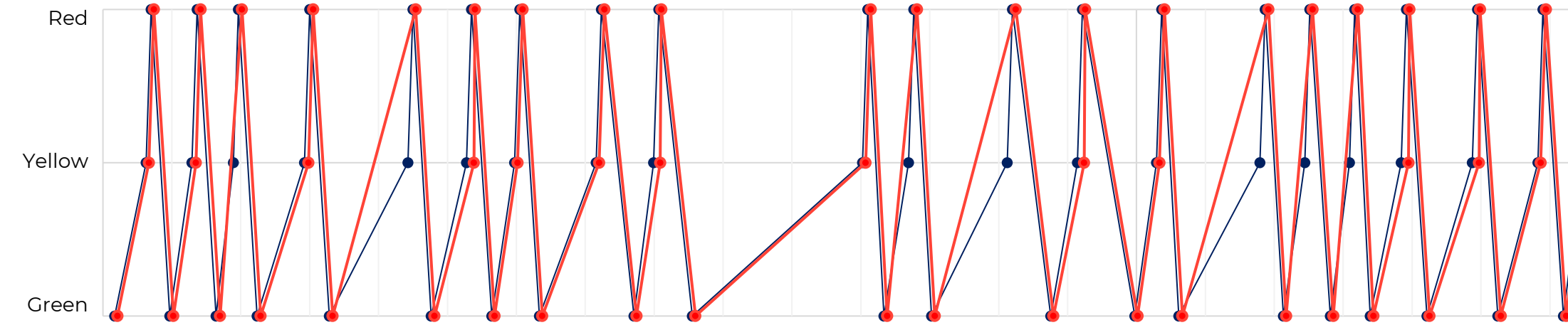


Data View

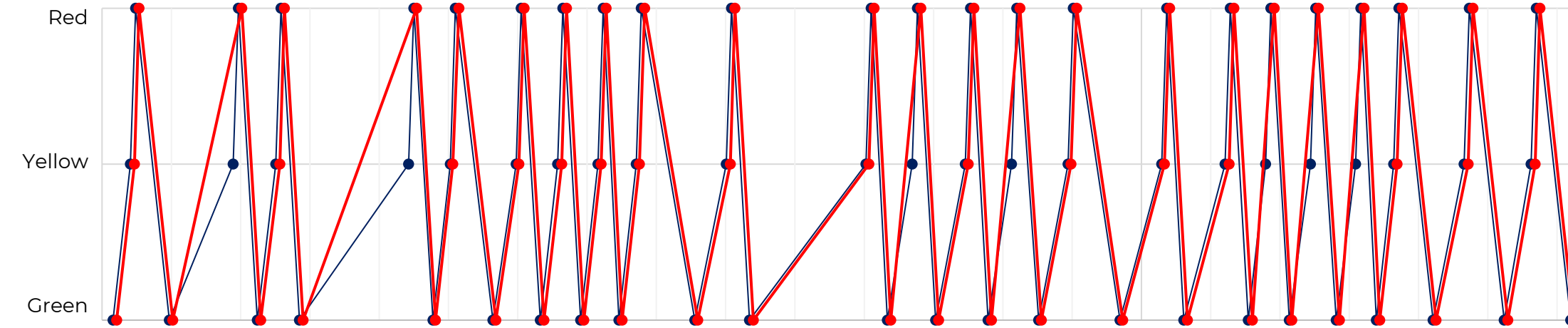
Red Series	Yellow Series	Green Series	Detector Events
1742893242002 47.1	1742893242002 42.6	1742893242002 15.3	1742893214042 18.94
1742893282008 40.6	1742893282008 36.1	1742893282008 16.9	1742893217442 22.34
1742893318008 36	1742893318008 31.5	1742893318008 16.5	1742893217742 22.64
1742893380009 62.1	1742893380009 57.6	1742893380009 16.3	1742893244742 2.54
1742893470001 89.2	1742893470001 84.7	1742893470001 16.4	1742893246842 4.64
1742893521007 51.6	1742893521007 47.1	1742893521007 16.4	1742893251842 9.64
1742893563003 41.6	1742893563003 37.1	1742893563003 17.1	1742893252742 10.54
1742893634004 71.1	1742893634004 66.6	1742893634004 17.1	1742893253942 11.74
1742893684000 49.6	1742893684000 45.1	1742893684000 28	1742893254442 12.24
…	…	…	…

State Transition Time - ATSPM vs. SPaT

SG 2 (SPaT) vs. P2 (ATSPM)



SG 6 (SPaT) vs. P6 (ATSPM)



03/25/2025 11:00:00.000 03/25/2025 11:15:00.000

6311: State St @ Center St (Orem, UT) 3/25/25 5:00-5:20 MDT

ATSPM Results

		Phase 2 / SG2	Phase 6 / SG6
All	% match (within 5 s)	82%	90%
	avg Δt (s)	2.698	2.878

ATSPM Results

		Phase 2 / SG2	Phase 6 / SG6
All	% match (within 5 s)	82%	90%
	avg Δt (s)	2.698	2.878
Red	% match (within 5 s)	100%	100%
	avg Δt (s)	2.692	2.869
Yellow	% match (within 5 s)	47%	71%
	avg Δt (s)	2.692	3.007
Green	% match (within 5 s)	100%	100%
	avg Δt (s)	2.707	2.796

ATSPM Results - mismatch

		Phase 2 / SG6	Phase 6 / SG2
All	% match (within 5 s)	47%	44%
	avg Δt (s)	2.582	2.678
Red	% match (within 5 s)	48%	44%
	avg Δt (s)	2.512	2.869
Yellow	% match (within 5 s)	22%	19%
	avg Δt (s)	2.314	2.629
Green	% match (within 5 s)	71%	68%
	avg Δt (s)	2.715	2.684

UDOT ATSPM (v5)

- Website in development
- Allows Users (with access) to download raw ATSPM data
- Able to get first hour of day

Event Code	Event Descriptor	Parameter	Description
Active Phase Events:			
1	Phase Begin Green	Phase # (1-255)	Set when either solid or flashing green indication has begun. Do not set repeatedly during flashing operation.
7	Phase Green Termination	Phase # (1-255)	Set when phase green indications are terminated into either yellow change interval or permissive (FYA) movement.
8	Phase Begin Yellow Change	Phase # (1-255)	Set when phase yellow indication becomes active and interval timer begins.
9	Phase End Yellow Change	Phase # (1-255)	Set when phase yellow indication becomes inactive.
10	Phase Begin Red Clearance	Phase # (1-255)	Set only if phase red clearance is served. Set when red clearance timing begins.
11	Phase End Red Clearance	Phase # (1-255)	Set only if phase red clearance is served. Set when red clearance timing concludes. This may not necessarily coincide with completion of the phase, especially during clearance of trailing overlaps, red revert timing, red rest, or delay for other ring terminations.

eventCode	eventParam	timestamp
7	6	4/28/2025 00:00:29.600
8	6	4/28/2025 00:00:29.600
9	6	4/28/2025 00:00:34.100
10	6	4/28/2025 00:00:34.100
1	5	4/28/2025 00:00:35.600
11	6	4/28/2025 00:00:35.600
7	5	4/28/2025 00:00:42.400
8	5	4/28/2025 00:00:42.400
9	5	4/28/2025 00:00:46.000
10	5	4/28/2025 00:00:46.000
11	5	4/28/2025 00:00:50.000
1	6	4/28/2025 00:00:50.000
7	2	4/28/2025 00:01:05.100
8	2	4/28/2025 00:01:05.100
7	6	4/28/2025 00:01:05.100
8	6	4/28/2025 00:01:05.100
9	2	4/28/2025 00:01:09.600
10	2	4/28/2025 00:01:09.600
9	6	4/28/2025 00:01:09.600
10	6	4/28/2025 00:01:09.600
11	2	4/28/2025 00:01:11.100
1	4	4/28/2025 00:01:11.100
11	6	4/28/2025 00:01:11.100

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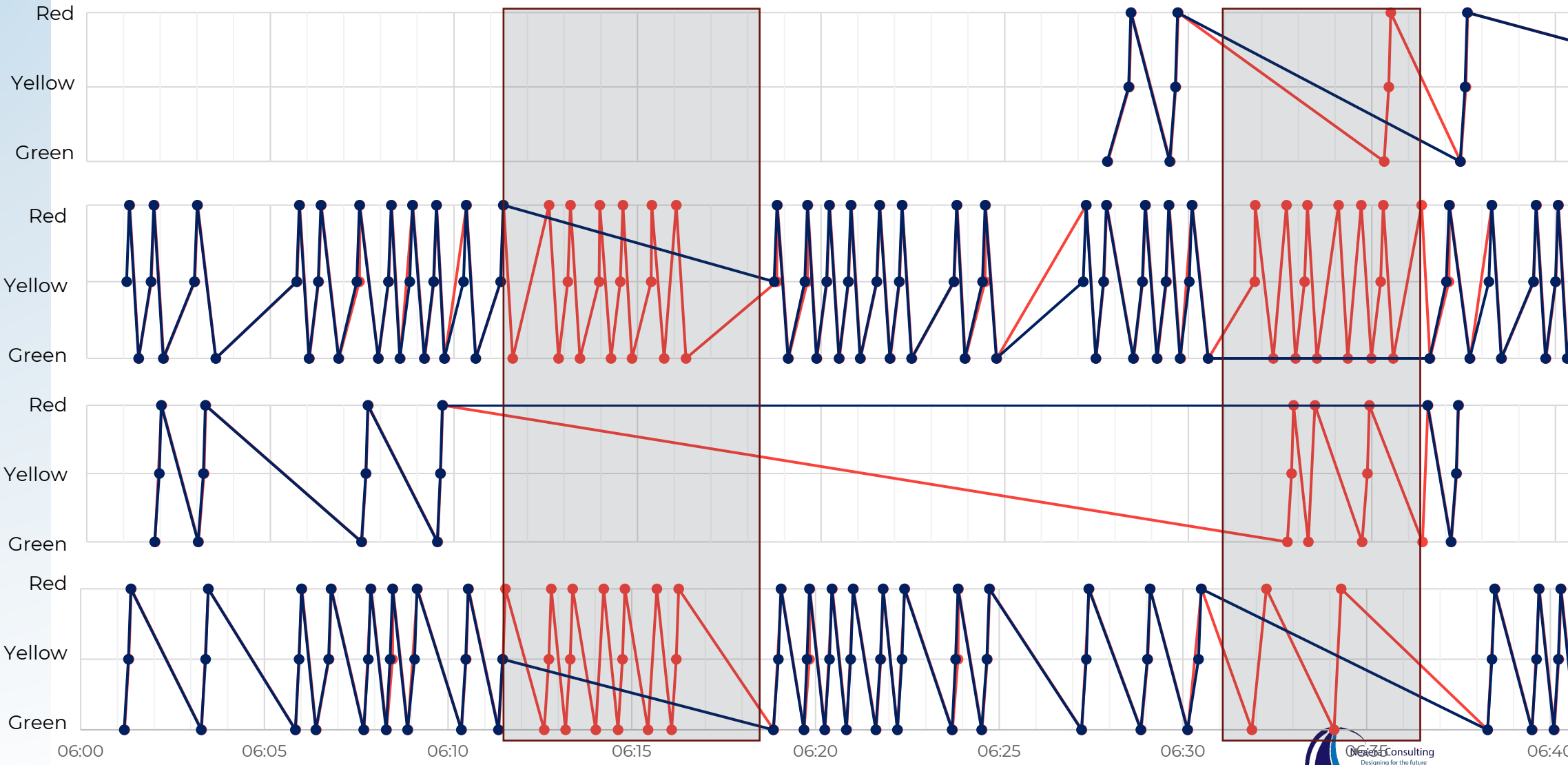
State Transition Time - ATSPM vs. SPaT

SG 1 (SPaT) vs. P1 (ATSPM)

SG 2 (SPaT) vs. P2 (ATSPM)

SG 3 (SPaT) vs. P3 (ATSPM)

SG 4 (SPaT) vs. P4 (ATSPM)



6311: State St @ Center St (Orem, UT) 4/28/25 0:00-0:35 MDT

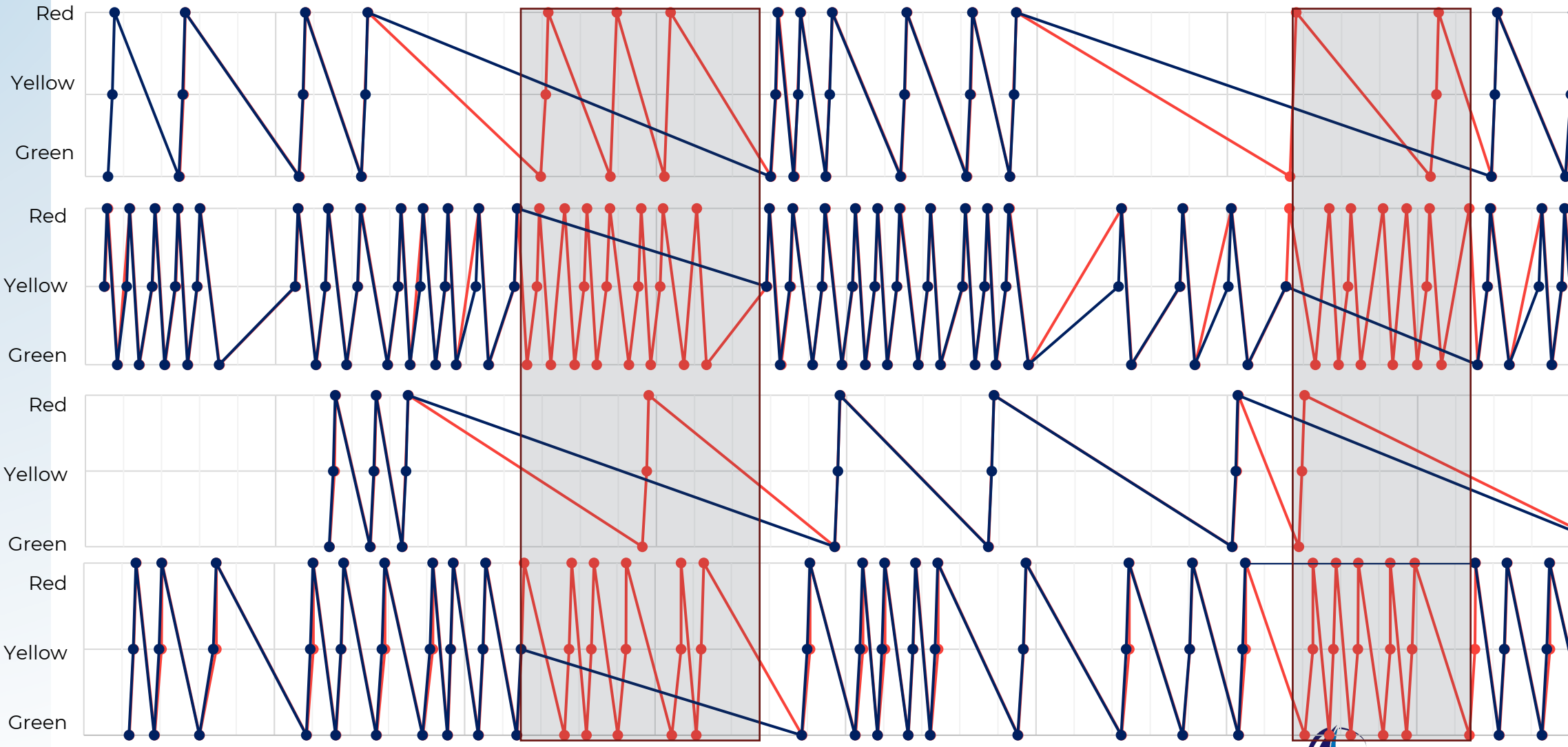
State Transition Time - ATSPM vs. SPaT

SG 5 (SPaT) vs. P5 (ATSPM)

SG 6 (SPaT) vs. P6 (ATSPM)

SG 7 (SPaT) vs. P7 (ATSPM)

SG 8 (SPaT) vs. P8 (ATSPM)



6311: State St @ Center St (Orem, UT) 4/28/25 0:00-0:35 MDT

ATSPM Next Steps

- If we can get raw ATSPM data for other times, would like to assess protected-permissive turns
  - *Would help to confirm algorithm design details*
- Consider alternative ATSPM vs. SPaT “matching” methods
  - *E.g. linear nearest neighbor*
- Determine how to identify and handle missing ATSPM data

Nearest Neighbor RSU Validation

NTCIP 1218 rsuReceivedMsgTable

Parameter	What It Means
PSID (`rsuReceivedMsgPsid`)	What type of message to forward (e.g., SPaT, MAP)
Start/Stop Time (`rsuReceivedMsgDeliveryStart`, `rsuReceivedMsgDeliveryStop`)	What time of day to start and stop forwarding
Interval (`rsuReceivedMsgInterval`)	Forward every Nth message (e.g., 3 = every third message)
RSSI Threshold (`rsuReceivedMsgRssi`)	Only forward messages that are received strongly (signal strength filter)
RowStatus (`rsuReceivedMsgRowStatus`)	Whether the forwarding rule is currently active

Nearest Neighbor RSU Validation

🔘 Option 1: User-Initiated Button

- Click a button to activate forwarding rules via SNMP on all RSUs.
- Message forwarding starts immediately and ends after a short interval (e.g., 10 minutes).
- Optional filters (message type, RSSI threshold, message sampling).

🔁 Option 2: Periodic Automation

- Same mechanism as Option 1, but triggered automatically at scheduled times (e.g., every hour).
- Requires a server-side script or scheduler to issue SNMP commands.

⚙️ Option 3: Always-On Static Filters

- Each RSU is configured once with filters (PSID, RSSI, interval).
- Forwarding happens continuously for all matching messages.
- No time window control, but filters help reduce data volume.

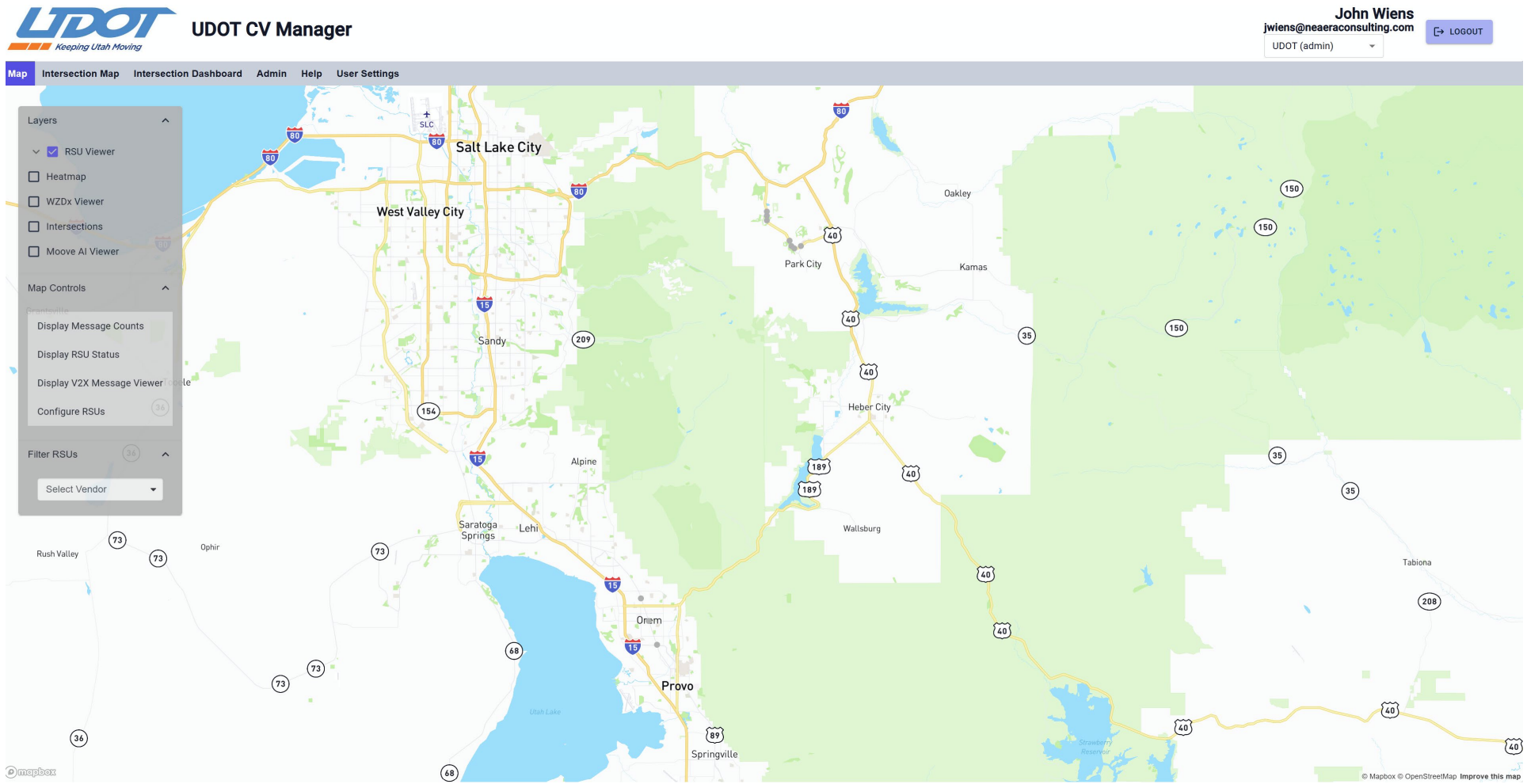
Nearest Neighbor RSU Validation- Comparison

Feature	Option 1: User-Initiated	Option 2: Periodic Automation	Option 3: Static Filters
Activation Trigger	Manual button click	Scheduled script	One-time static setup
Flexibility	High – user chooses when	Moderate – based on time intervals	Low – always on once configured
Data Volume	Low – short time burst	Moderate – periodic windows	High – continuous flow
Maintenance Effort	Low – single click, no schedule	Moderate – script upkeep	High – must configure each RSU manually
System Impact / Stability	Burst traffic; may affect stability	Repeated bursts; risk depends on frequency	Most stable; predictable continuous flow

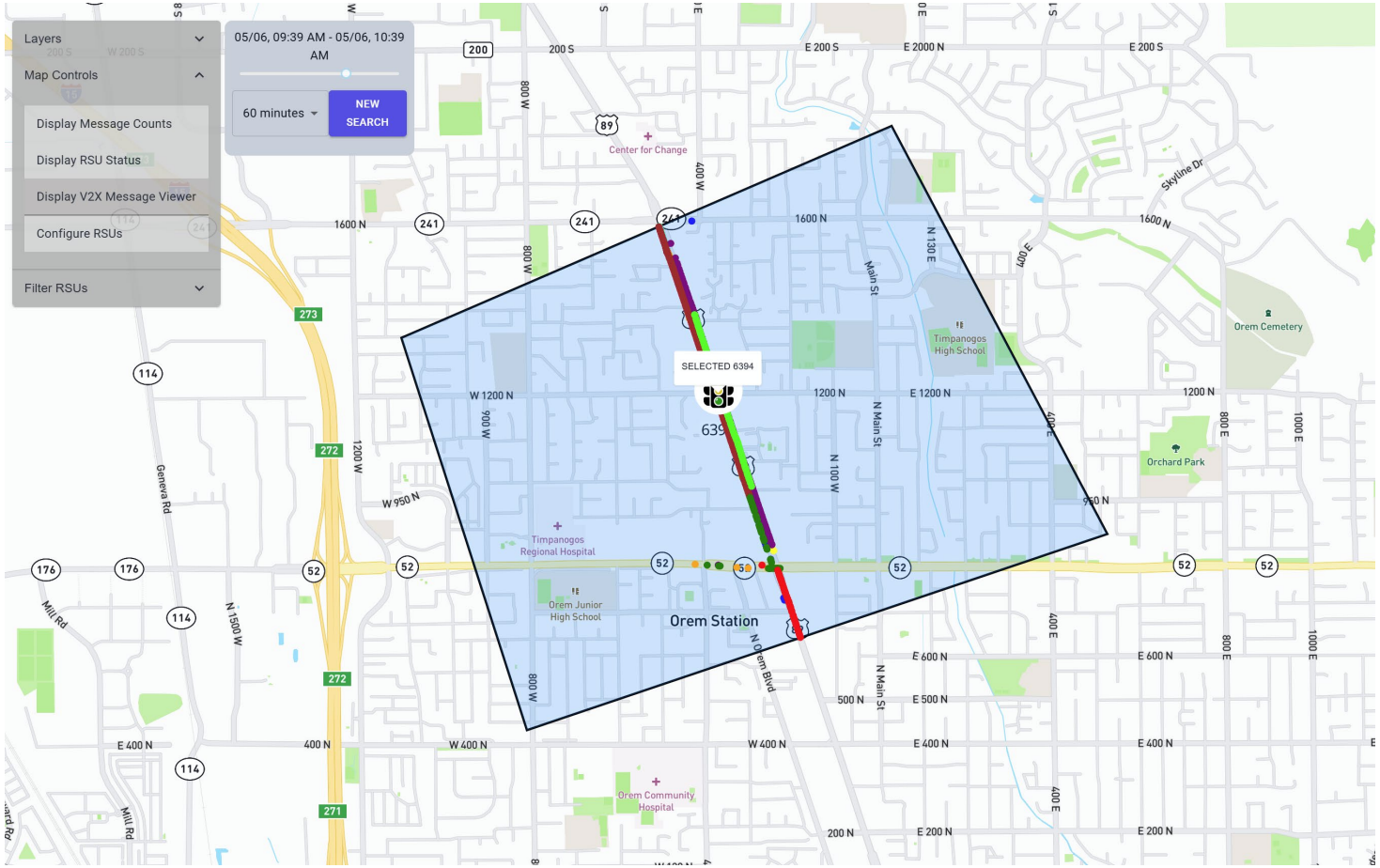
Monitoring System

CIMMS System Demo

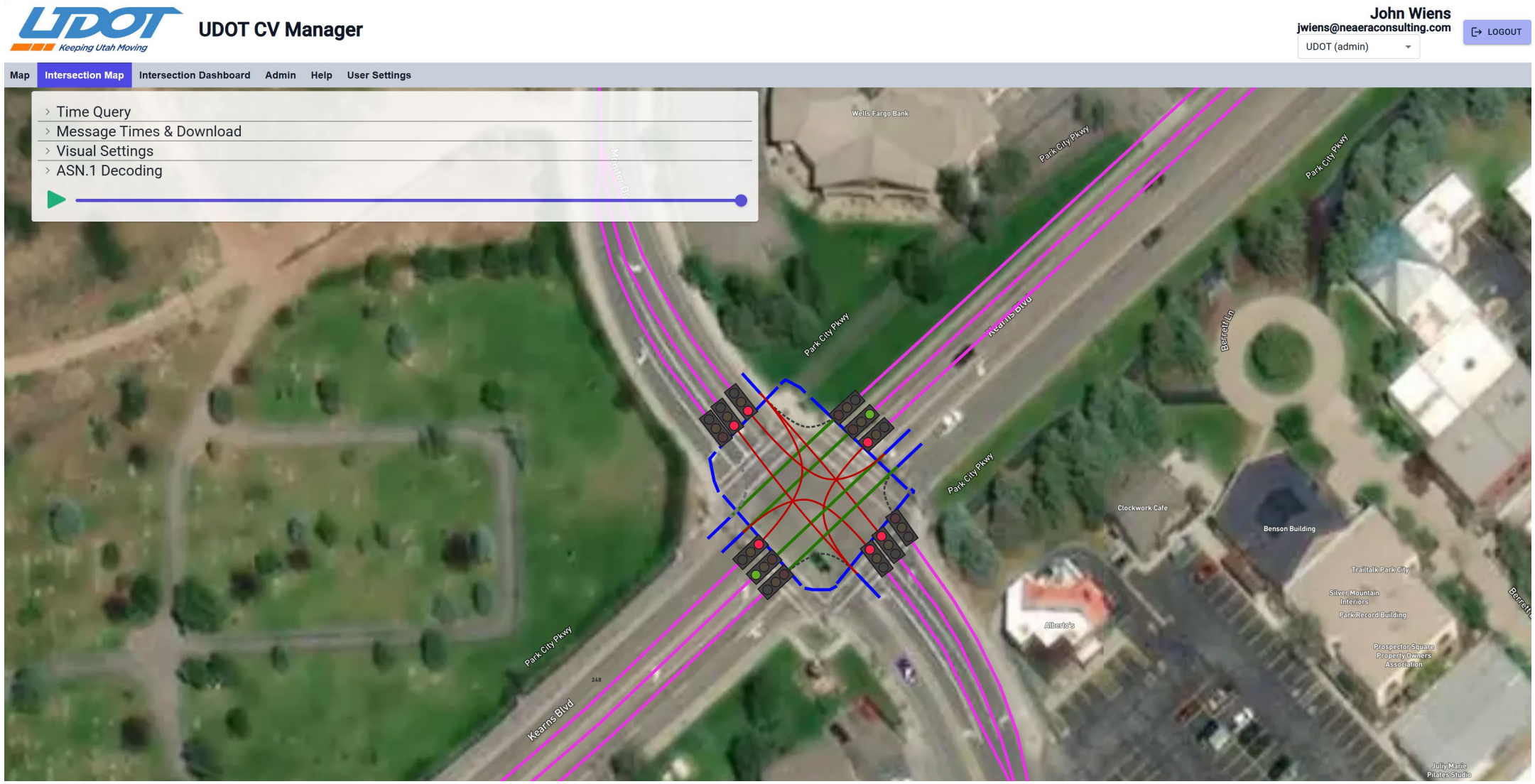
CV Manager – RSU Status Screen



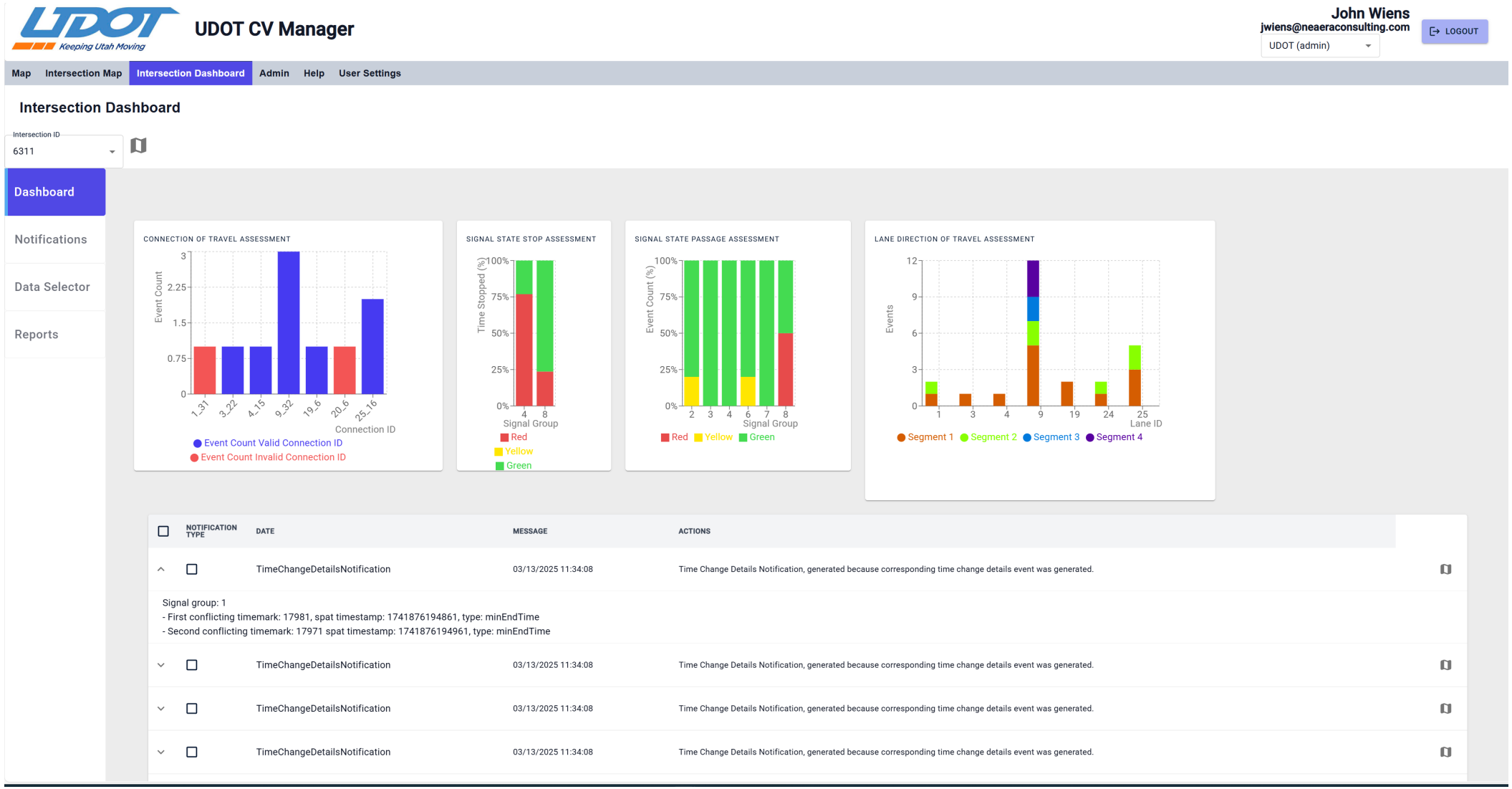
BSM Spatial Query



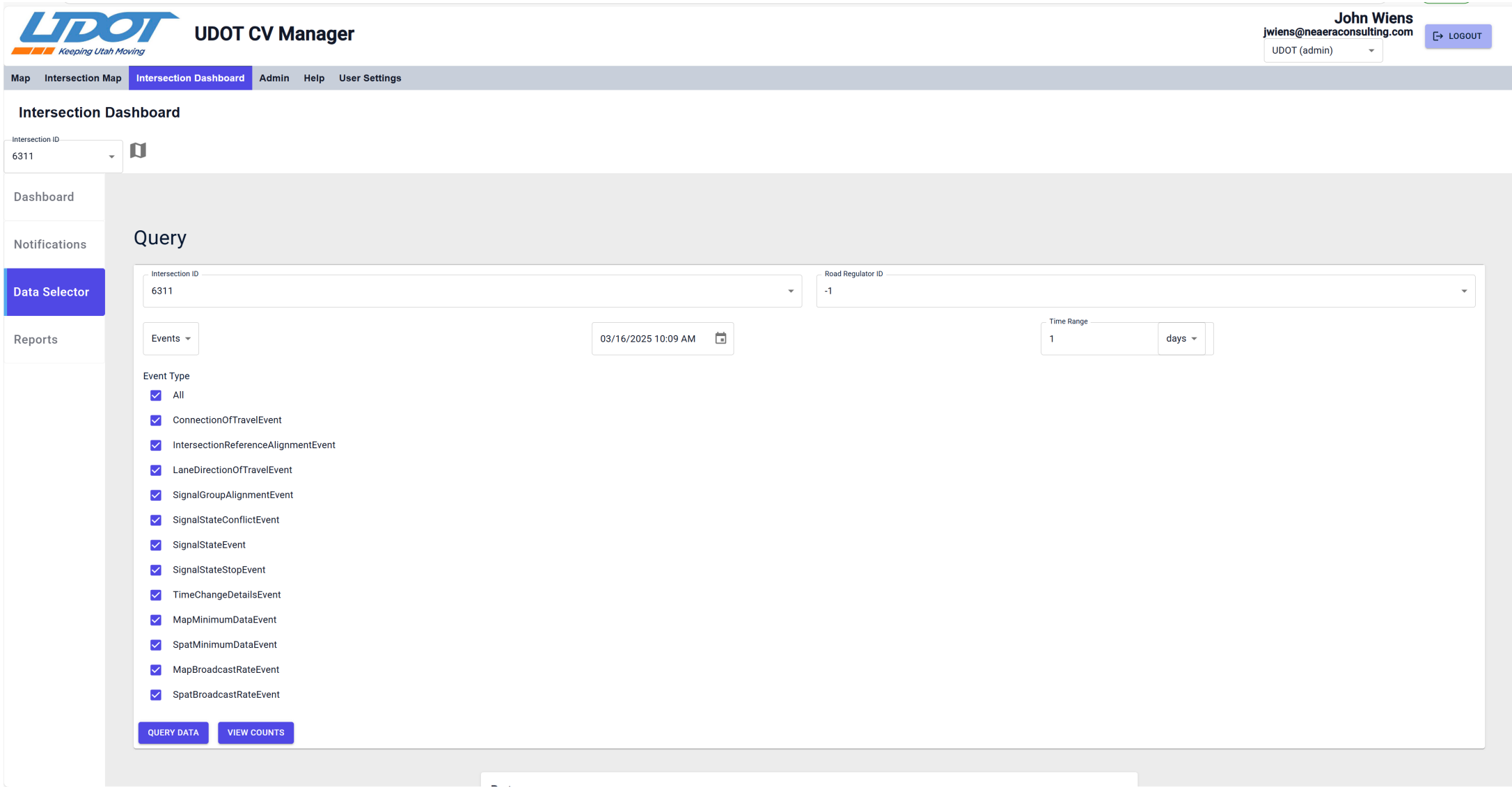
CV Manager - Intersection



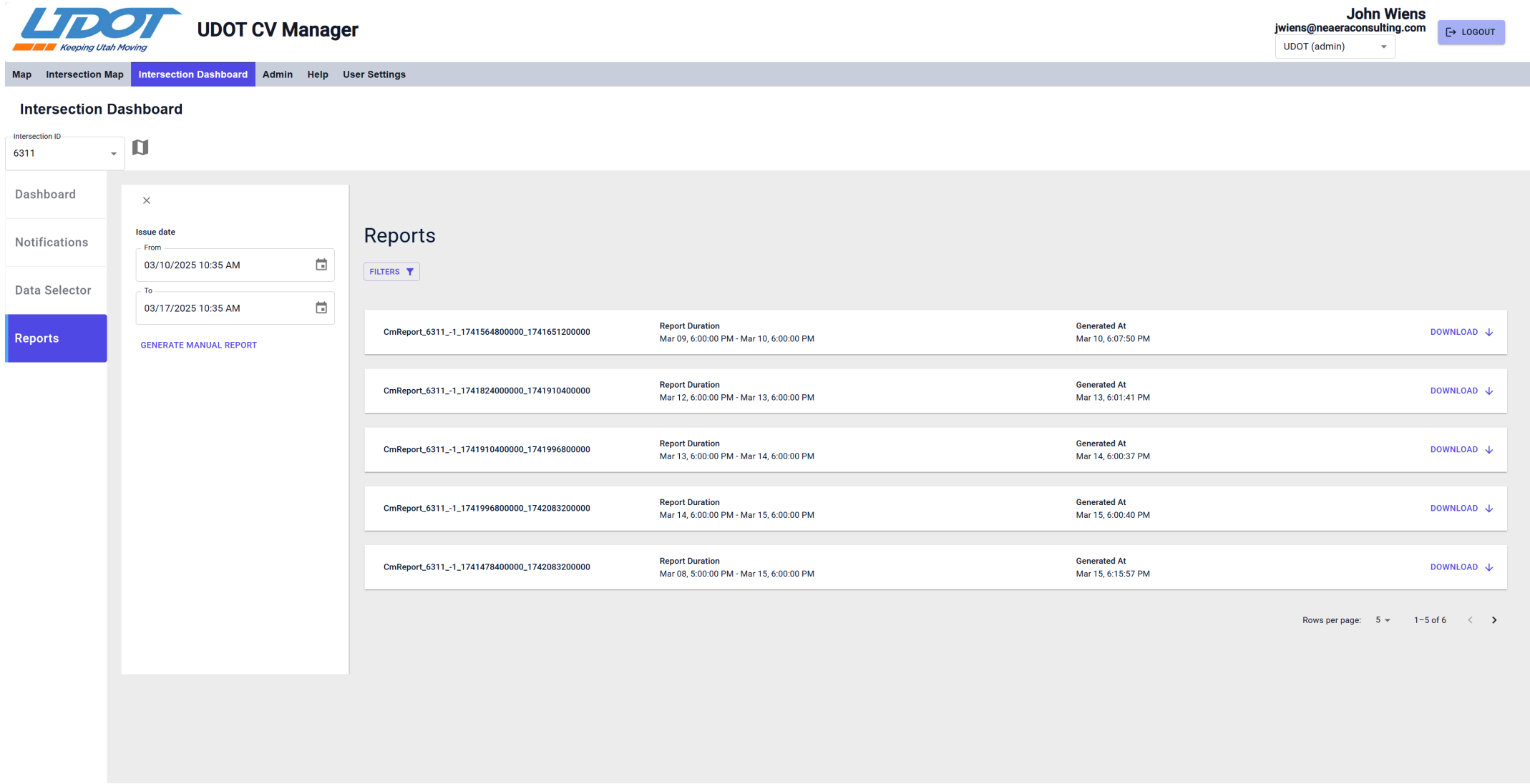
CV Manager – Intersection Dashboard



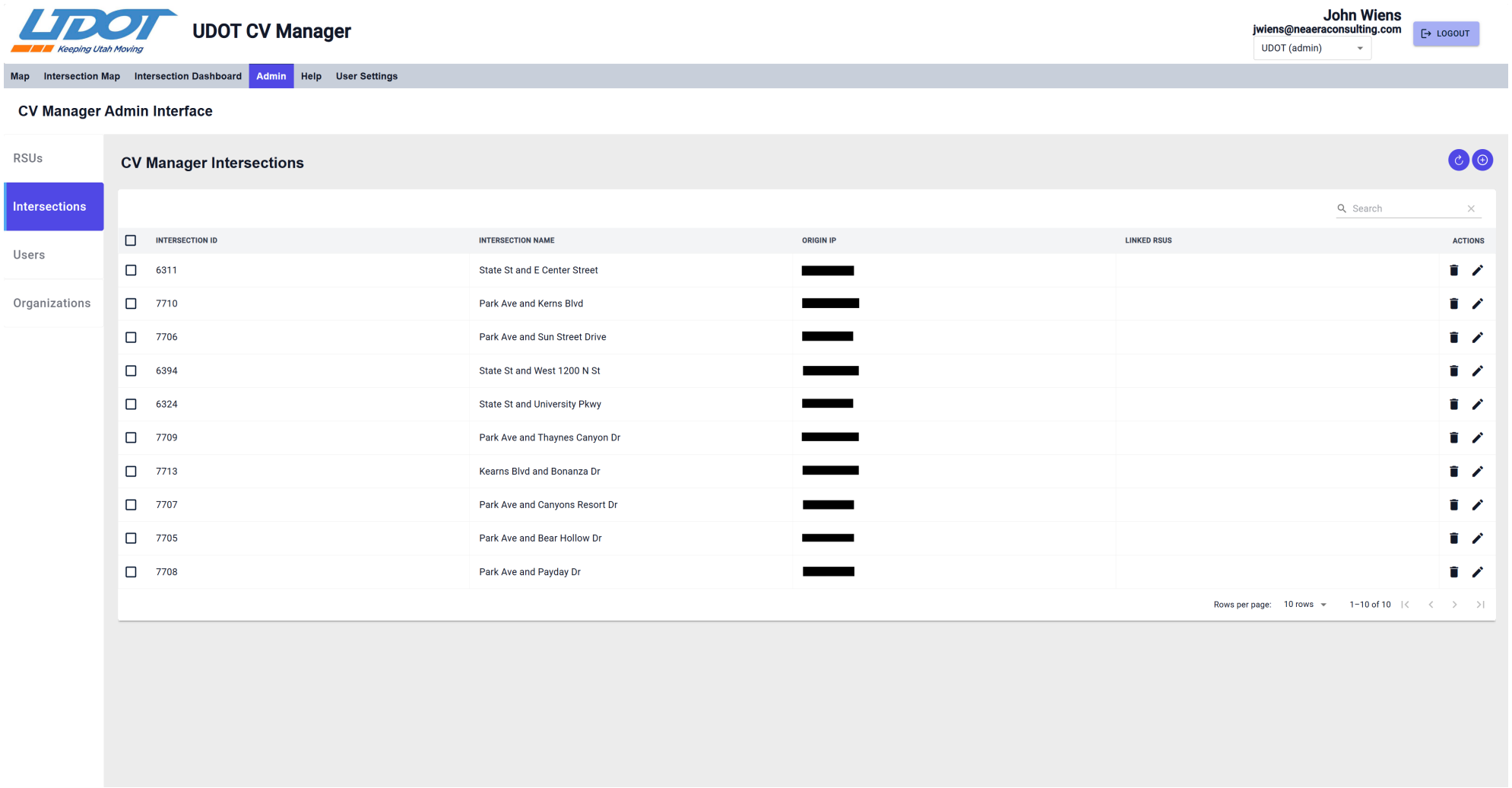
CV Manager – Data Download Page



CV Manager – Report Generation



CV Manager – Intersection Management



Next Steps

Next Steps

- Finalize Traffic Signal Controller interface design
- Finalize RSU broadcast verification design
- Continue working with the SCMS Manager to enable CIMMS to send data
- Continue integrating CV Manager

Next Meetings

— The next Panel meeting is scheduled for Friday 05/16/25 at 2pm ET

Thank you!

Questions?

Please contact :

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Connected Intersections Message Monitoring Systems Requirements and Prototype Development

March 2025

Backup

Traffic Signal Controller Data White Paper

Summary of meeting on 3/14/2025

- *SDLC:*
  - Pros: closest to 'ground truth', highly accurate, reliable, and standardized data
  - Cons: requires additional hardware/software at each intersection, complicates scalability, and increases costs

- *ATSPM:*
  - Pros: widely available, primarily standardized data, the accuracy level is acceptable
  - Cons: concerns regarding timestamps and clock synchronization

- *Time synchronization is critical for comparing data collected from traffic controllers and RSUs.*
  - Utah uses a data acquisition system that collects data from traffic controllers and RSUs and applies GNSS-based timestamps to them.
  - Even though ATSPM timestamps might not be perfectly synchronized, the difference could be still acceptable.

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Connected Intersections Message Monitoring Systems Requirements and Prototype Development

March 2025

Site Criteria

Site Selection Criteria

- Assumptions
  - *Site has an operational CV system broadcasting J2735 SPaT and MAP messages based on ITE CTI 4501*
  - *Prototype will need to store a revolving 1 to 2 months' worth of project data*
- Hosting the Prototype in a Cloud Service
  - *An estimated cost of $2k-5k/month will be required for a cloud-based service meeting the Server Requirements stated below*
- Hosting the Prototype at a TMC
  - *TMC must be able to perform daily backups of all relevant servers hosting the prototype and its data.*

Site Selection Criteria

- Server Requirements
  - *2-4 terabytes of data storage will be required over the life of the project*
  - *3 to 6 Linux Virtual Machines, with each VM having:*
  - *16-32 GB RAM*
  - *2-4 2GHz Cores*
  - *> 50 GB Disk, > 1TB Disk for Database VM*

- General IT Requirements
  - *Ability to support Firewall configurations between RSUs and Prototype*
  - *A bandwidth of 6 to 10 Mb/s to each intersection*
  - *Ability to configure Ports between Server VM's*
  - *Access to SNTP Server, or a 3rd party email service (SendGrid, Postmark)*

Site Selection Criteria

- General IT Requirements (cont.)
  - *Access to the following online repositories for building the Conflict Monitor*
    - Docker Download: https://download.docker.com/
    - Docker Images: https://hub.docker.com/
    - Ubuntu Packages: http://archive.ubuntu.com/ubuntu/
    - Ubuntu Packages: http://security.ubuntu.com/ubuntu/
    - Source Code: https://github.com/
    - Node Packages: https://registry.npmjs.org/
    - Java Maven Packages: https://mvnrepository.com/
    - Python Packages: https://pypi.org/
    - Keycloak: https://quay.io/

Site Selection Criteria

- Intersection Requirements
  - *3 or more 4 leg intersections should be available*
  - *Intersection types should range in operation\timing plans (Permissive turns, Protected turns, through lanes, etc.)*

- Vehicle Penetration Requirements
  - *A minimum of 10 equipped vehicles should pass through each intersection on a given weekday*

Site Selection Criteria: MAP Message

- timeStamp: MinuteOfTheYear (desired)
- layerType: LayerType
- layerID: LayerID
- intersections: IntersectionGeometryList
  - *id: IntersectionReferenceID*
    - region: RoadRegulatorID
    - id: IntersectionID
  - *refPoint: Position3D*
  - *laneWidth: LaneWidth*
  - *laneSet: LaneList*
    - laneID: LaneID
    - laneAttributes: LaneAttributes
      - directionalUse: LaneDirection
    - nodeList: NodeListXY
      - nodes: NodeSetXY
    - connectsTo: ConnectsToList
      - connectingLane: ConnectingLane
        - lane: LaneID
      - signalGroup: SignalGroupID

Site Selection Criteria: SPaT Message

- intersections: IntersectionStateList
  - *id: IntersectionReferenceID*
    - region: RoadRegulatorID
    - id: IntersectionID
  - *moy: MinuteOfTheYear (desired)*
  - *timeStamp: DSecond (desired)*
  - *states: MovementList*
    - signalGroup: SignalGroupID
    - state-time-speed: MovementEventList
      - eventState: MovementPhaseState
      - timing: TimeChangeDetails
        - minEndTime: TimeMark
        - maxEndTime: TimeMark