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**Deployment and Testing of the Traffic Optimization  
for Signalized Corridors (TOSCo) CV Application in the  
Houston District**




TxDOT 2022 Short Course  
October XX, 2022

1

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## Acknowledgement and Disclaimer

- This material is based upon work supported by the U.S. Department of Transportation under Cooperative Agreement No. DTFH6114H00002.
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2

2

## Purpose and Outline of Presentation

- Purpose
  - Provide an overview of a prototype connected vehicle application tested in the Houston District
- Outline of Presentation
  - What is Traffic Optimization in Signalized Corridors (TOSCo)
  - TOSCo Vehicle and Infrastructure Systems and Processes
  - Deployment Issues and Challenges in Houston District
  - Assessment Summary

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3

3

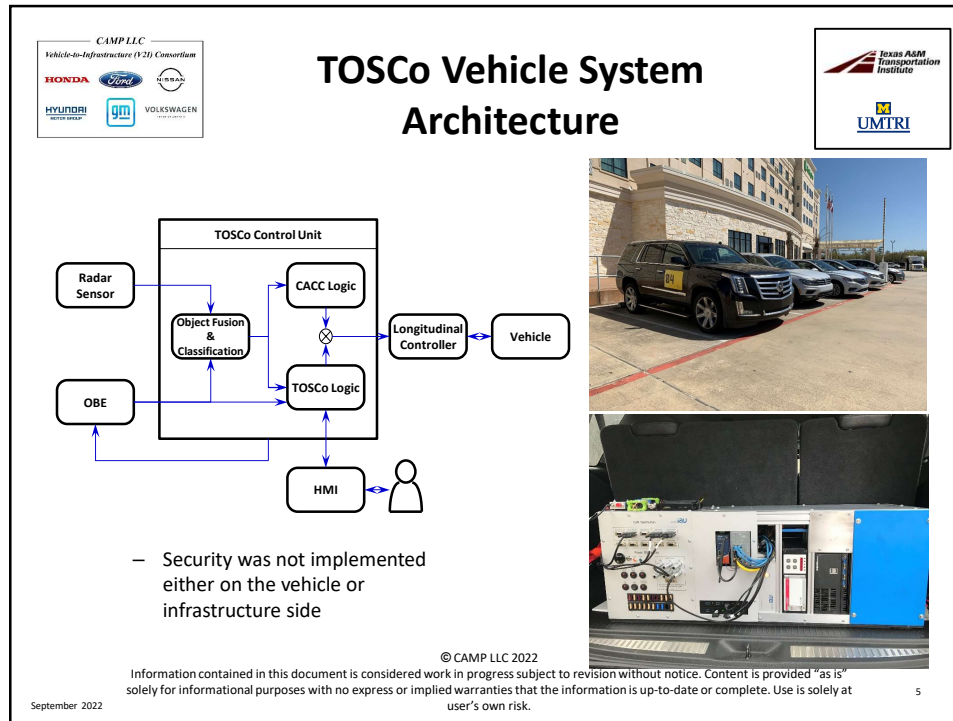
## What is TOSCo?

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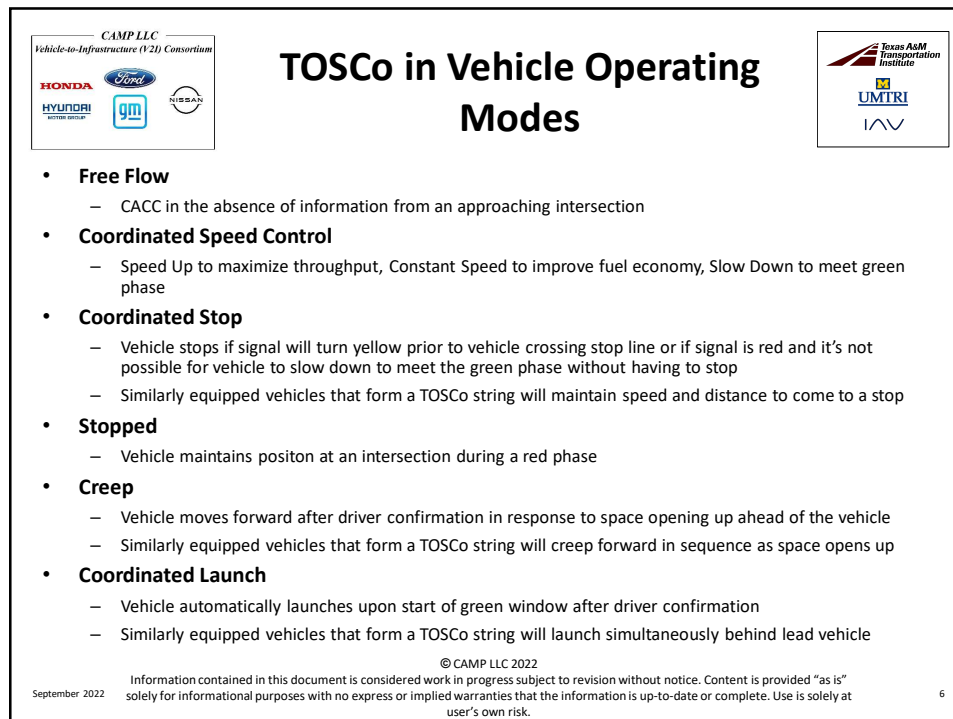
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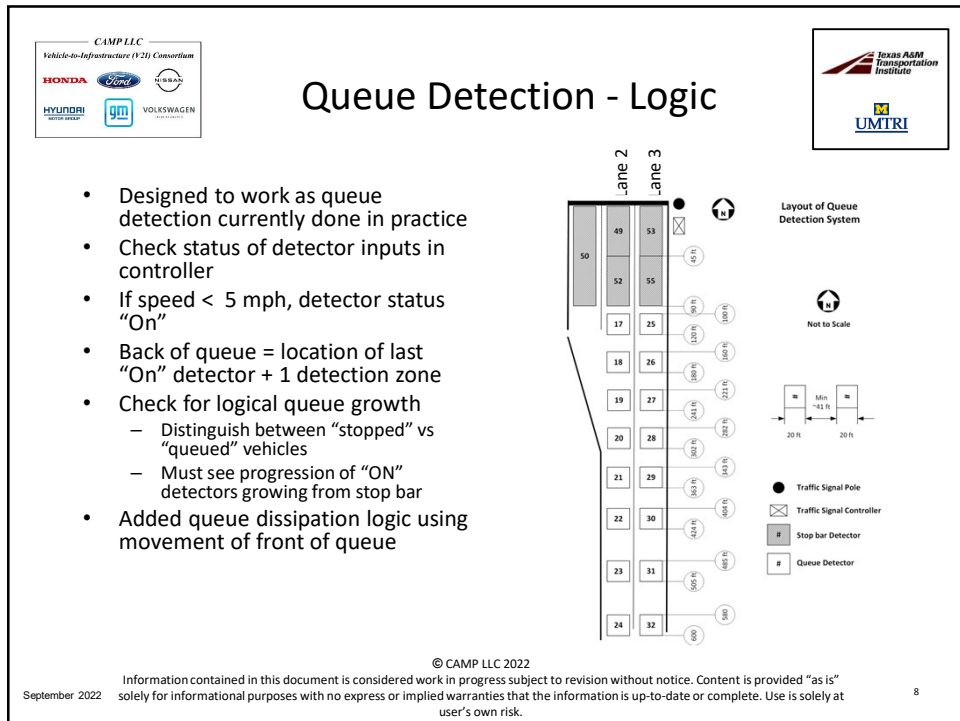
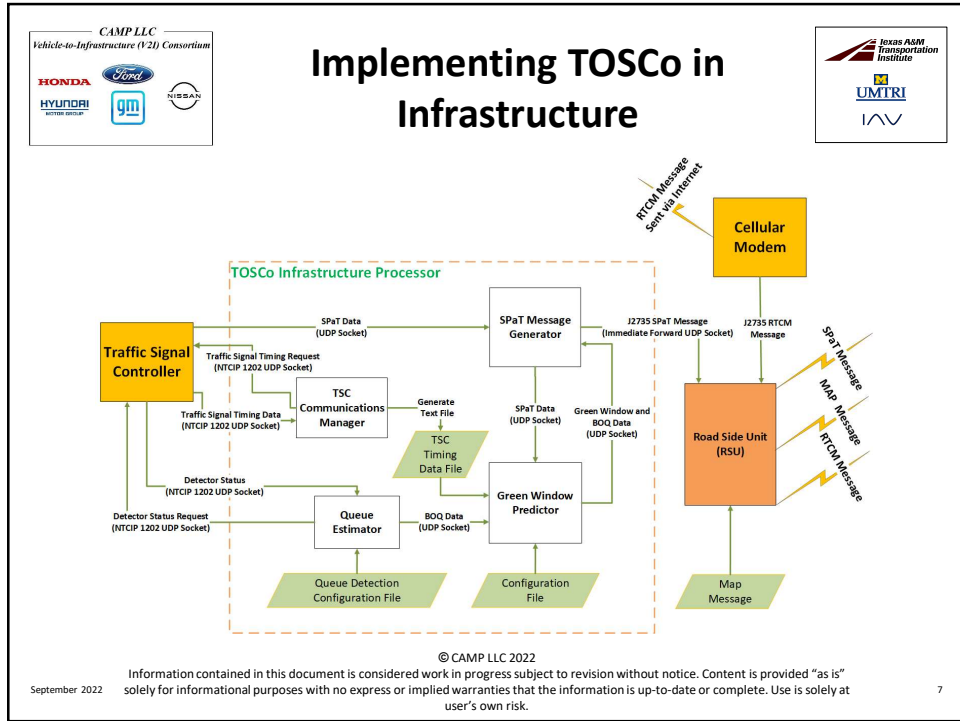
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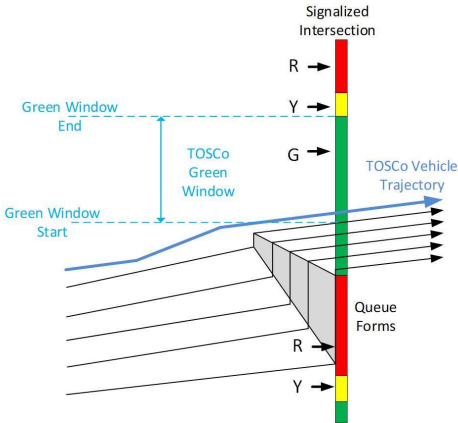




## Green Window Prediction



- Green Window Prediction Components
  - Time to start of green
  - Time for back of queue to start moving
  - Time for back of queue to reach stop line
- Inputs
  - Queue length
  - Signal status
  - Background timing plan
- Outputs
  - Start of green window – time estimate of when last vehicle in queue will clear stop line
  - End of green window – time estimate of when current green will end
- Green window predicted for approach lane
- Updated every second




The diagram illustrates a signalized intersection with a vertical traffic light pole. The light is currently red (R), yellow (Y), and green (G). A blue line represents the 'TOSCo Vehicle Trajectory' starting from a 'Queue Forms' area. A 'Green Window' is defined between 'Green Window Start' and 'Green Window End' points. Arrows labeled R, Y, and G point to the corresponding light colors.


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9



## SPaT Message Generator



- Standard J2735 SPaT message "enhanced" with queue length and green window information
  - Queue length part of per lane movement data
  - Green window information included in regional data elements
- TSC pushes SPaT data every 100 ms
- Merges SPaT data with TOSCo data elements




The photograph shows three individuals in high-visibility safety vests and hard hats standing outdoors. One person is holding a laptop, and they appear to be in a discussion, likely related to the SPaT data mentioned in the text.

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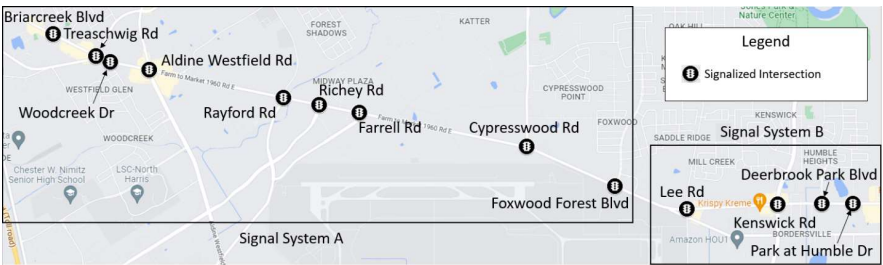
10

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## Deployment – FM 1960






- 13 Signalized intersections on FM 1960 in North Houston
- All intersection operated by Texas Department of Transportation
- Replaced all controllers with Econolite Cobalt controller running ASC/3 software
- Two independent signal systems (Signal System A & B) operating with different timing plans

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11

11

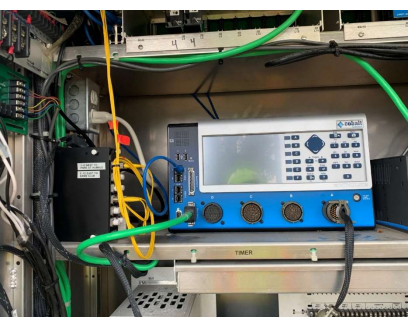
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## Traffic Signal Controller



- Econolite Cobalt Traffic Signal Controller
  - ASC/3 Version 32.67.30
  - EOS version 3.2.10
- Operated in Actuated-Coordinated Mode
- Minimum recall on all minor phases to ensure:
  - Consistent cycle lengths
  - Unused minor movements green times added the TOSCo phase
- Two ethernet ports
  - One used by TXDOT's Traffic Signal Management System
  - Other used for TOSCo operations









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12

12



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## Roadside Unit (RSU)

Texas A&M  
Transportation  
Institute

- Cohda Wireless DSRC RSU
- Broadcasts
  - MAP – Store-and-forward mode
  - SPaT – Immediate-forward mode
  - RTCM – Immediate-forward mode
- Assumed Operational Range = 1000 feet
  - Actual range over 1 mile
  - Receive messages from multiple RSUs at each intersection
- Power over Ethernet (POE) powered









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13

13



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## TOSCo Computer

Texas A&M  
Transportation  
Institute

- Field-hardened Edge Computing PC running Windows 10
  - 16GB RAM
  - 1 TB SSD Hard disk
  - 3 Ethernet ports
    - One connects to TSC
    - One connects to RSU
    - One to cell modem (to provide remote access)
  - Multiple USB & serial port
  - HDMI video output
- 3 separate applications running in real-time
- Each application generates its own logs






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14

14





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## Queue Detection

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Transportation  
Institute

- Combination radar / video detection unit
  - One unit for each supported TOSCo approach
  - Configured to provide per lane detection
  - Two video detection zones 45 feet and 90 feet from stop line
  - Six speed detection zones
    - Trailing edge of closest detection zone place 100 feet from stop line
    - 40 feet detection zone length with 40-foot gap between detection zones
    - Maximum range of radar detection = 600 feet from stop line
  - Programmed to provide standard detection inputs into traffic signal controller
  - Limited to 16 detection channels per sensor



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## Infrastructure Deployment

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Detector Installation on Mast Arm




Detector Installation on Span Wire


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## Deployment Challenges—Queue Detection





**Detector Facing  
Correct Direction**

**Detector on Mast Arm  
Nearside Approach**


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17

17

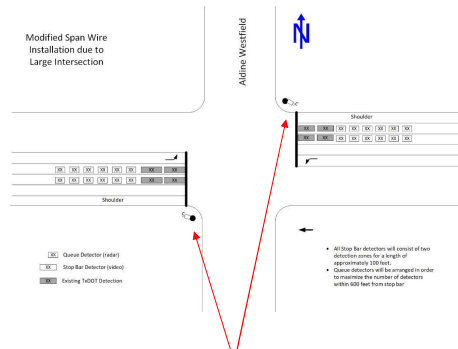
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## Deployment Issues – Nearside Placement



Modified Span Wire Installation due to Large Intersection



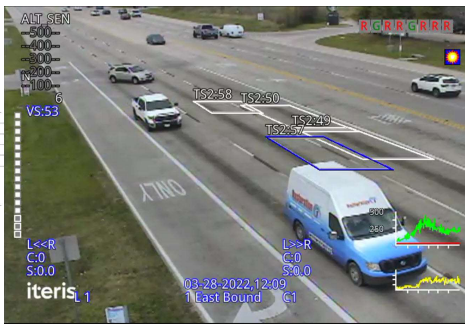
Adaptive Westfield

Shoulder

Shoulder

Legend:  
 Queue Detector (red)  
 Stop Bar Detector (yellow)  
 Facing 180° Detection

• All Stop Bar detectors will consist of two detection zones for a length of approximately 100 feet.  
 • Queue detectors will be arranged in order to maximize the number of detectors within 500 feet from stop bar.



**Nearside Placement of Detectors on  
Span Wire Intersections**

**False Detections of Queue**

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18

18

## Slide 18

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**JH0** In the bulleted text that starts with "All Stop bar detectors . . . ," The word should Bar should be capitalized so that it read "Stop Bar." Also, the phrase "detection zone" should be "detection zones"

Jill Herbert, 2022-06-08T15:43:56.196


**JH1** Map requires attribute.

Jill Herbert, 2022-06-08T15:44:11.192


**FD1 0** Not a map. We took this picture. Do we need to source the picture?

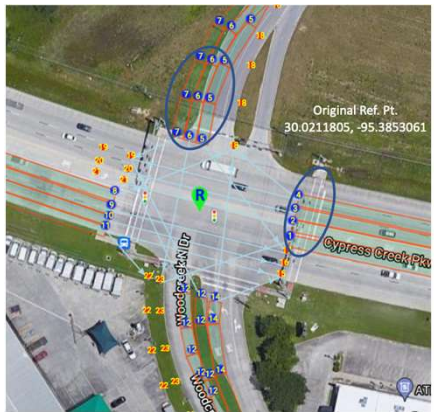
Florence, David, 2022-06-08T20:19:05.996

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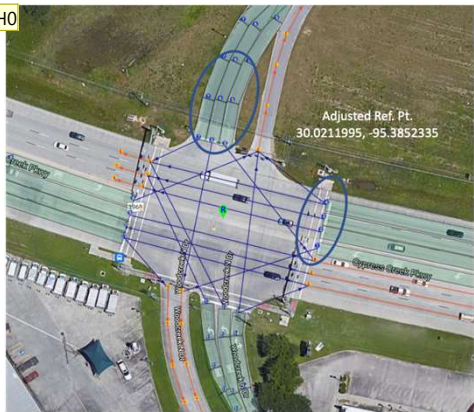
# MAP Matching Issues





Source: CAMP, 2021. Google Maps 2021.

**Initial MAP with Offset Reference Point**



Source: CAMP, 2021. Google Maps 2021.

**Realignment of Reference Point to Correct MAP Matching Issues**


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19

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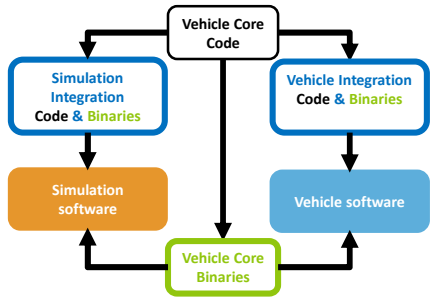
# Testing and Evaluation



- **Field Testing**
  - Deployed in actual corridors under live traffic conditions
  - Refinement of algorithms and assess vehicle performance

- **Simulation and Modeling**
  - Incorporate the actual vehicle logic into the simulation environment for benefits assessment
  - Utilize Software in the loop simulation of the ASC/3 Controller with VISSIM 9





```

graph TD
    VCC[Vehicle Core Code] --> SIB[Simulation Integration Code & Binaries]
    VCC --> VIB[Vehicle Integration Code & Binaries]
    SIB --> SS[Simulation software]
    VIB --> VS[Vehicle software]
    SS --> VCB[Vehicle Core Binaries]
    VS --> VCB
    VCC --> VCB
    
```

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20

**JH0** Need Map attributions

Jill Herbert, 2022-06-08T15:35:00.274



## Assessing TOSCo Performance




- **Mobility and Environmental Benefits**
  - As volumes increased, TOSCo was able to reduce stops on the approach from many stops (stop and go in queue) to less than one stop on the approach
    - Indicates an increase in capacity at the intersection
  - TOSCo was able to achieve reductions in stop delay and number of stops with both TOSCo settings
    - Stop delay decreased by around 50% on average across the corridor as TOSCo Market Penetration Rate (MPR) increases
    - Average stops per vehicle increased initially in simulation with the introduction of TOSCo because Non-TOSCo vehicles stopped more times as TOSCo vehicles finished their speed profiles
    - TOSCo vehicles had lower number of stops than the baseline traffic in simulation
  - TOSCo reduced total delay in the westbound direction of FM 1960 with both TOSCo settings and the eastbound direction with the revised TOSCo settings
    - These reductions were greater with the revised TOSCo settings


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21

21



## Assessing Market Penetration Impacts




- **Mobility and Environmental Benefits**
  - High TOSCo MPR scenarios experienced increases in total delay relative to the baseline and the 90% MPR scenarios with the revised TOSCo configuration because of increased range and signal timing causing the TOSCo vehicles to enter CREEP early
  - TOSCo showed improved performance for each respective vehicle class, TOSCo-equipped as well as non-equipped, in total delay, stop delay, as market penetration increased on most of the approaches
    - Improvements were most noticeable with the revised TOSCo settings
  - TOSCo did not cause substantial changes in the total travel time for vehicles on the FM 1960 network
  - TOSCo increased fuel consumption initially and then reduced fuel consumption gradually as TOSCo MPR increased


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22

22



## Project Summary




- The Project Team successfully:
  - Deployed TOSCo functionality on FM 1960 Corridor in Houston, Texas
  - Demonstrated TOSCo functionality by operating four automation level 1 vehicles equipped with TOSCo functionality
    - Vehicles responded to information broadcast from intersections to either speed up, slow down or stop at an intersection and automatically launch
    - Vehicles were able to interact with non-equipped vehicles to maintain TOSCo functionality
  - Implemented RTCM corrections to improve map matching capability
  - Developed and utilized simulation tools to help refine and evaluate TOSCo
- Recommendations
  - Investigate infrastructure capability to interact with TOSCo-equipped vehicles
  - Investigate methods to improve TOSCo functionality when intersections fall out of coordination due to signal preemption or pedestrian calls


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## Questions



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