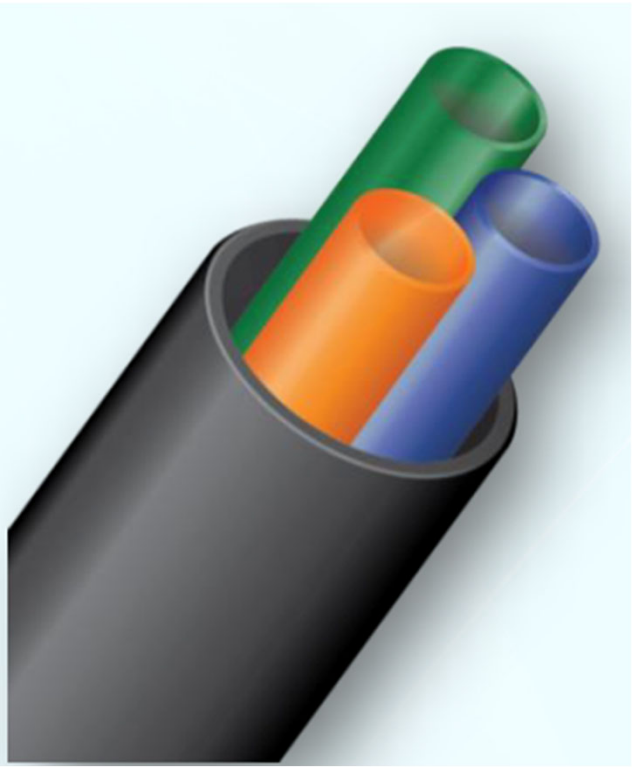
Traffic Monitoring using Fiber Optic Sensing

High performance, economical traffic monitoring using
existing roadside fiber optic networks

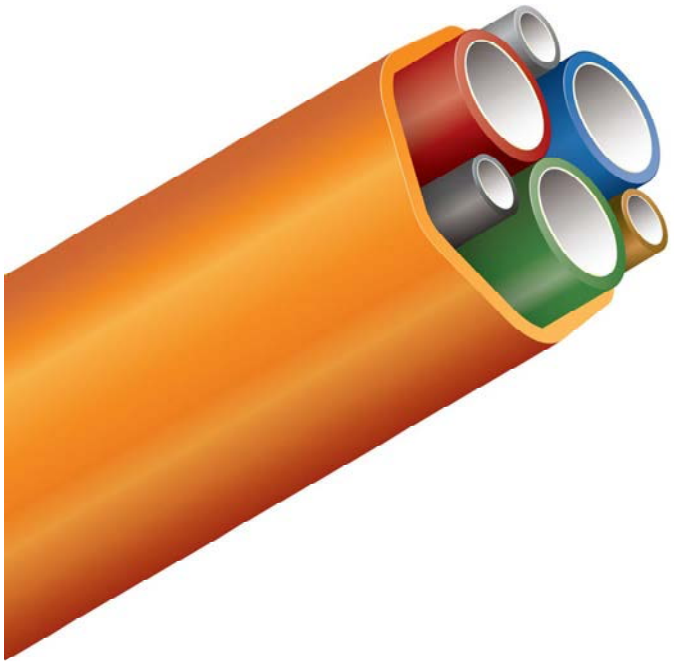
Eric MacGill, Senior Traffic Designer

Traditional Conduit Install



- Labor intensive
  - Conduit Install
  - Fiber Install
- Increased material costs
- Limited space
- Not customizable

Current Future-Proof Install

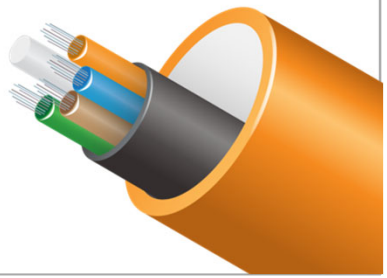


- Labor savings
  - Conduit Install
  - Fiber Install
  - Less workforce
- Reduction in material costs
- Scalable and Flexible
- Customizable for conduit sharing

Smart Conduit Sensing Systems

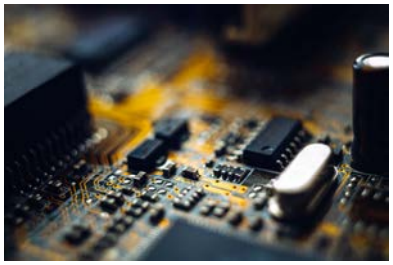
Infrastructure

Fiber cable in conduit



Hardware

Laser / Interrogator Processor



Software

Intelligent monitoring software

Associated installation and support services

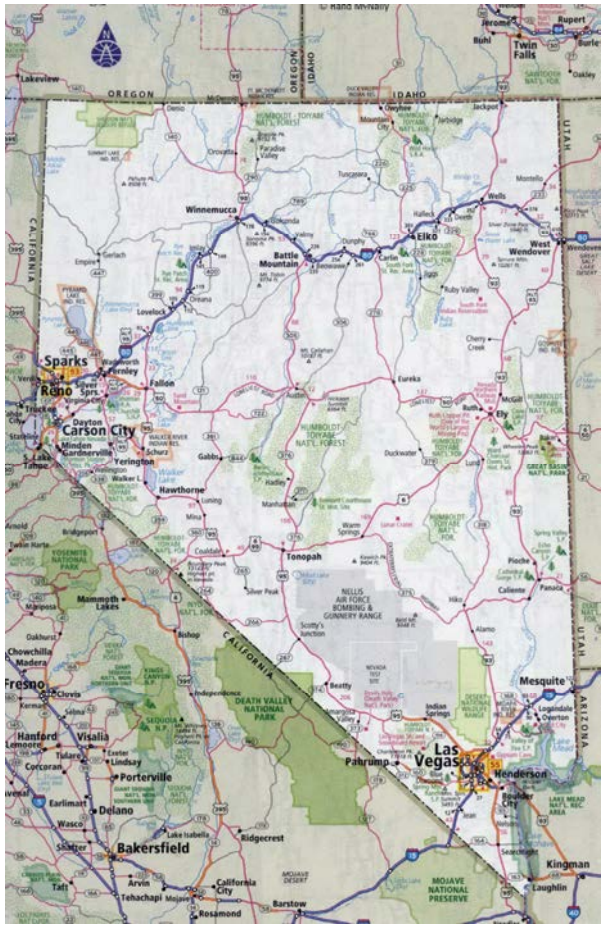
Harnessing the power of optical fiber in conduit as a sensing medium to protect critical assets, improve performance, reduce costs and unlock new commercial opportunities.

Transportation

Traffic flow and incident detection information

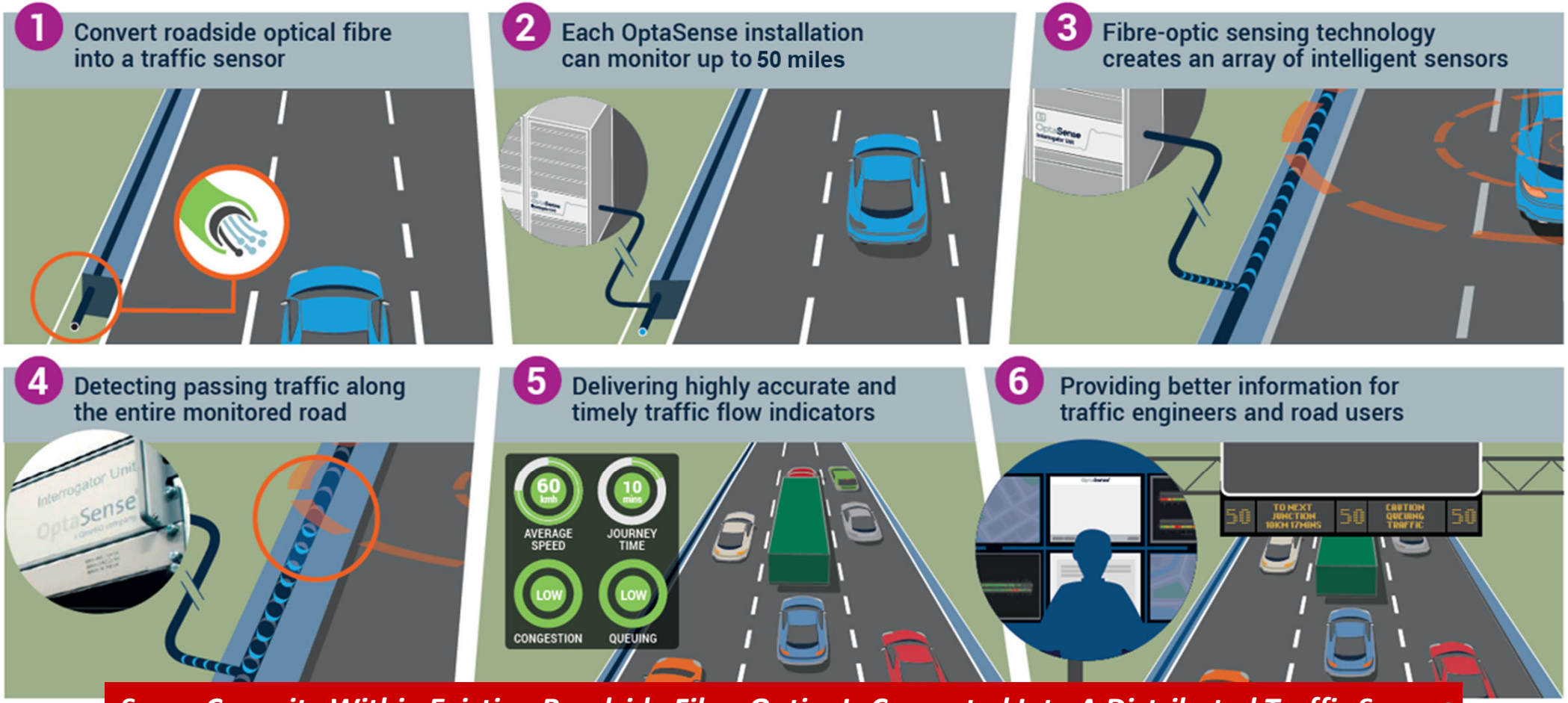
dura-line

Benefits of Leveraging Underground Infrastructure for Traffic Monitoring Purposes



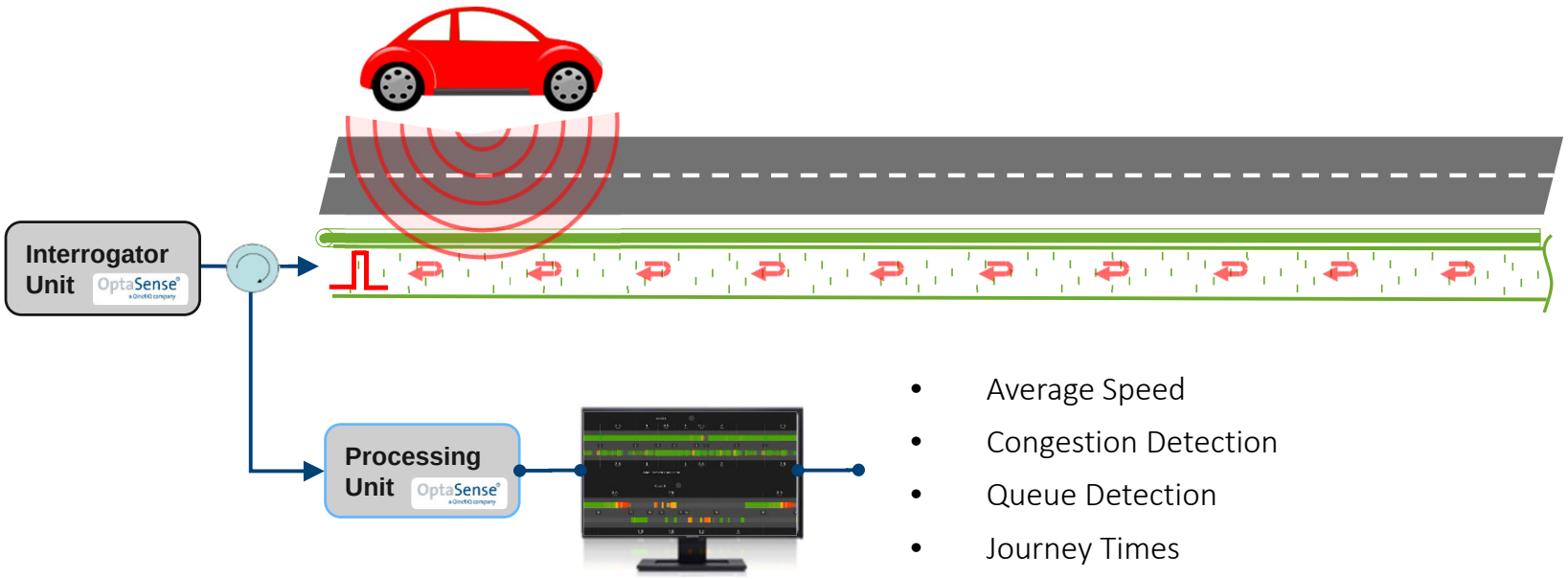
- Leverage buildout of fiber cable and conduit alongside roadways with added functionality
- Continue to improve upon information quality and latency for both traffic engineers and road users
- Enable reduction in equipment cost and maintenance for traffic sensing
- Reduce reliance on legacy point sensor solutions and / or third party probe data
- Provide complimentary traffic data for both urban and rural routes

Fiber-Optic Traffic Monitoring: Overview



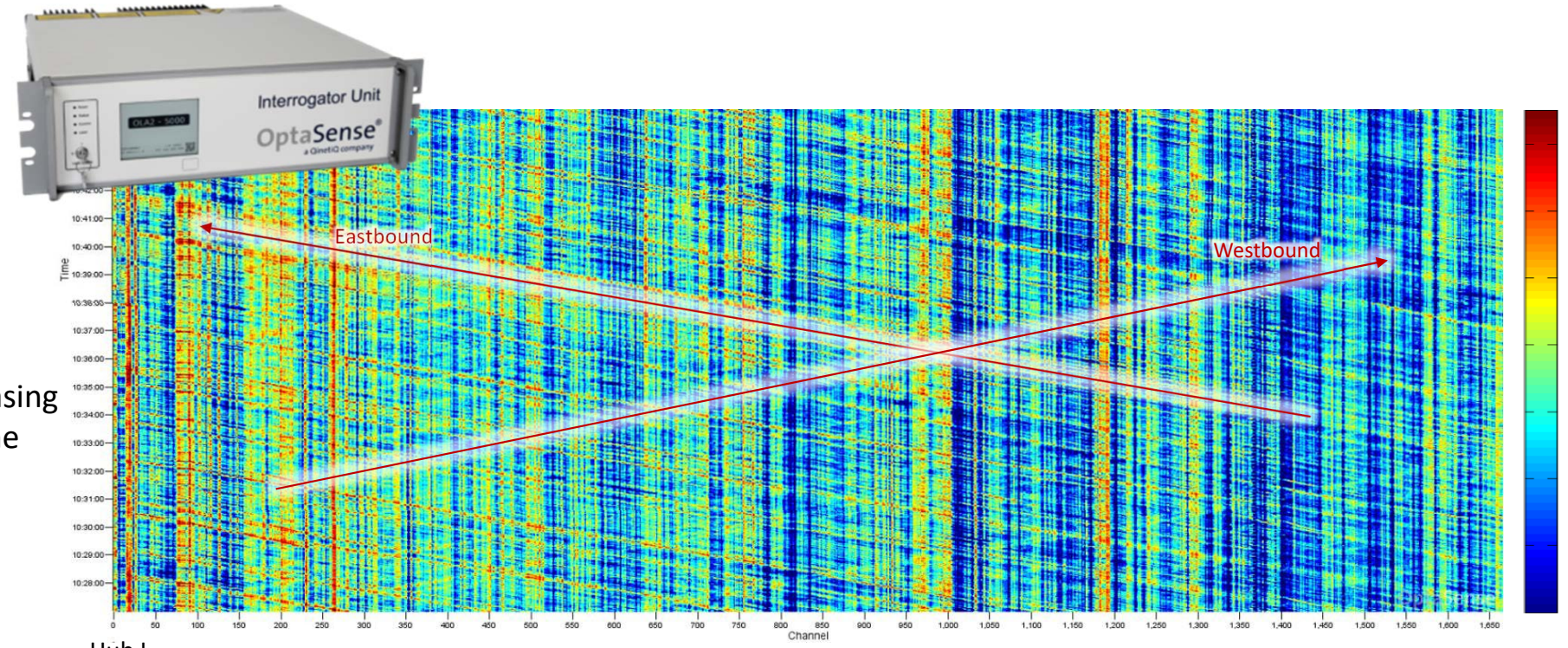
Spare Capacity Within Existing Roadside Fiber Optics Is Converted Into A Distributed Traffic Sensor

How Distributed Fiber Optic Sensing (DFOS) techniques convert a roadside fiber optic cable into a distributed traffic sensor

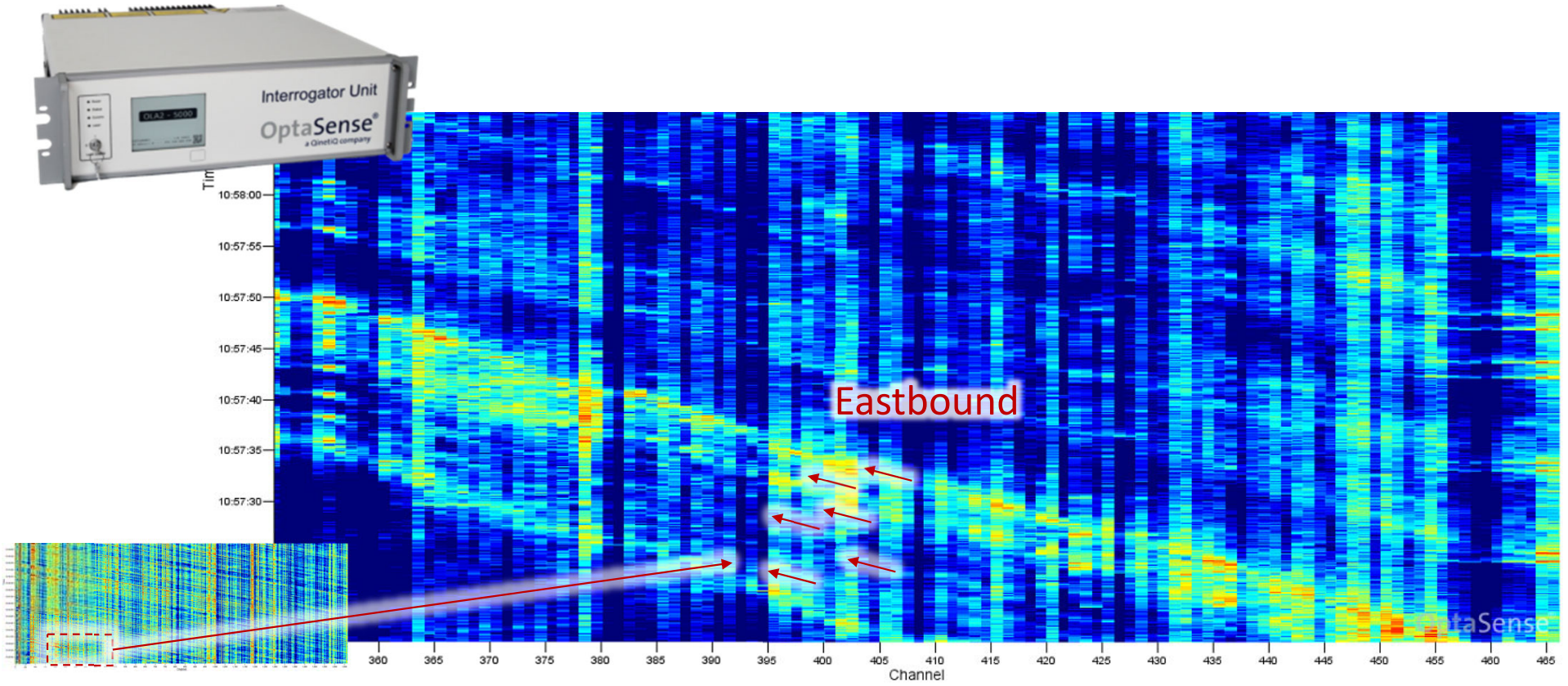


- Average Speed
- Congestion Detection
- Queue Detection
- Journey Times
- Traffic Count
- Flow Rate

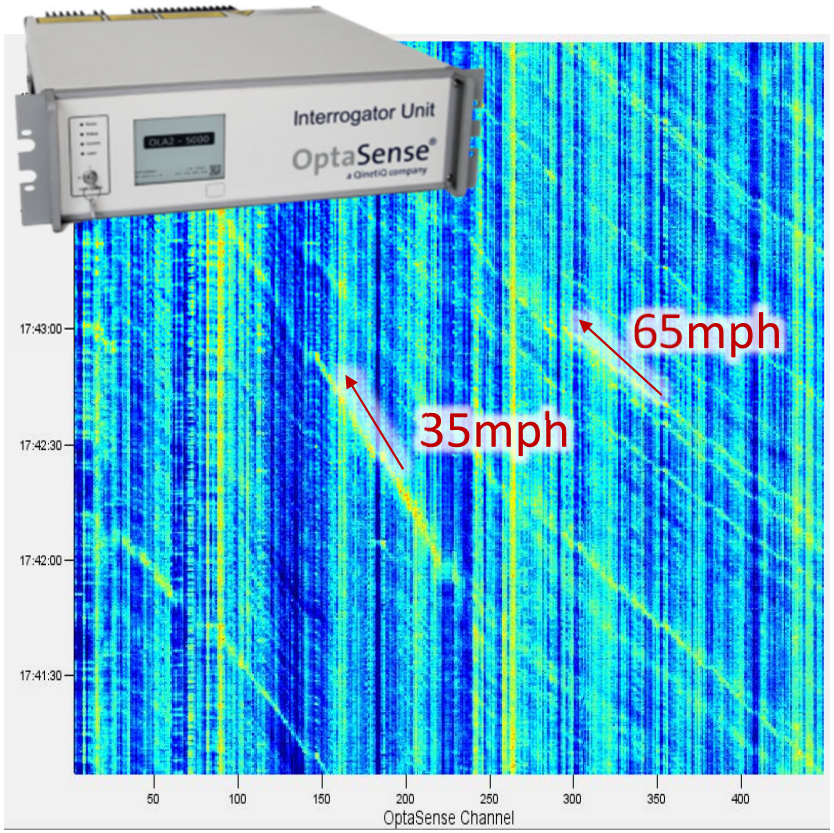
Fiber-Optic Traffic Monitoring: Real-Time Acoustic Data

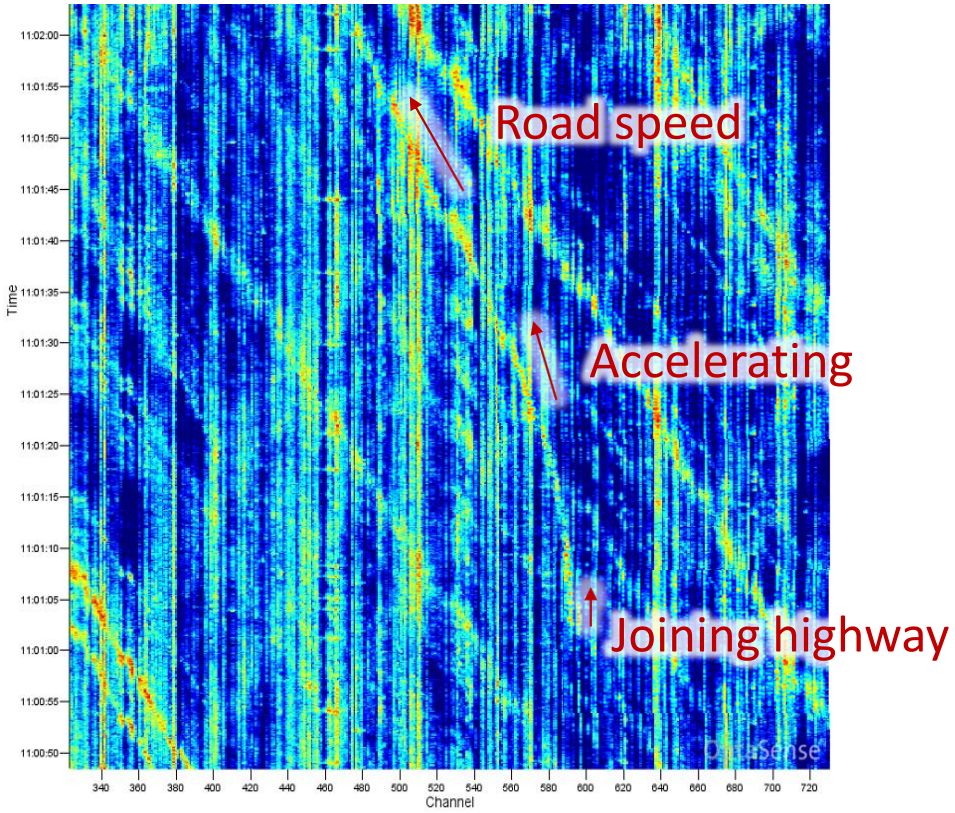


Fiber-Optic Traffic Monitoring: Real-Time Acoustic Data



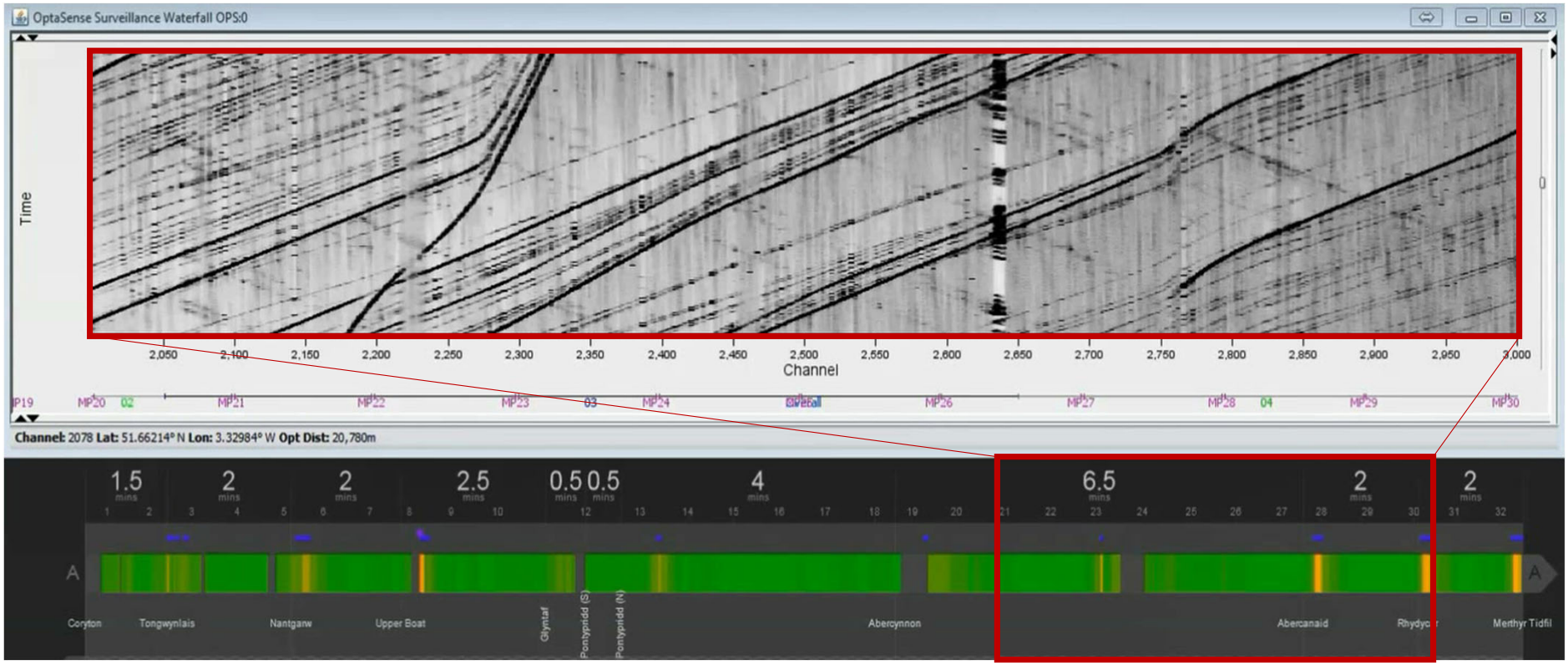
Fiber-Optic Traffic Monitoring: Real-Time Acoustic Data





Fiber-Optic Traffic Monitoring: Example Traffic Information Display

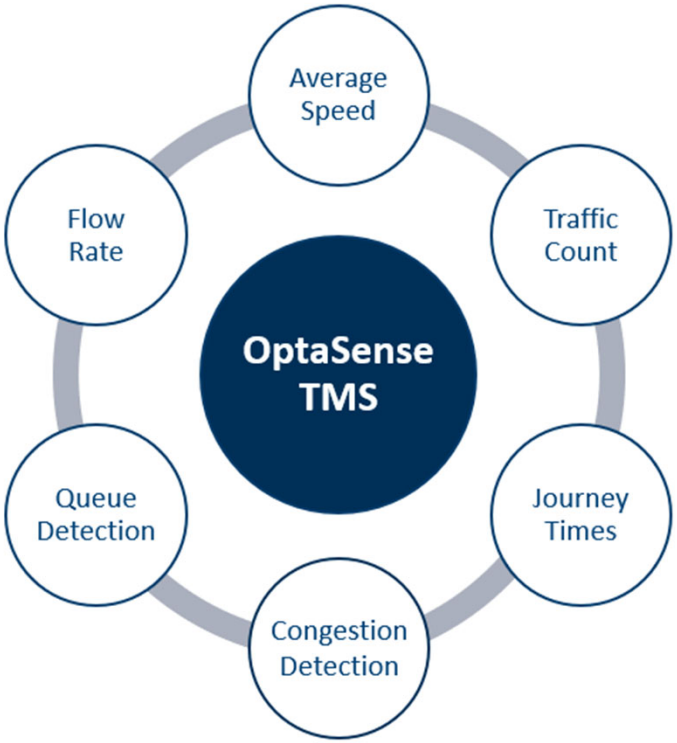
Animation: Converting Acoustic Data into Traffic Flow Information



Fiber-Optic Traffic Monitoring: Information Output

- Speed Variation over 32 foot intervals every second
- Automated Congestion Detection by speed variability analysis
- Automated Queue Detection by measuring traffic slowdowns
- Travel Time along each segment
- Traffic Volumes and Flow Rates

* Aggregated Traffic volume and flows available at fiber optic road crossings only



Spatial Resolution	Update Rate
10 m	1s

Fiber-Optic Traffic Monitoring: Operational Benefits

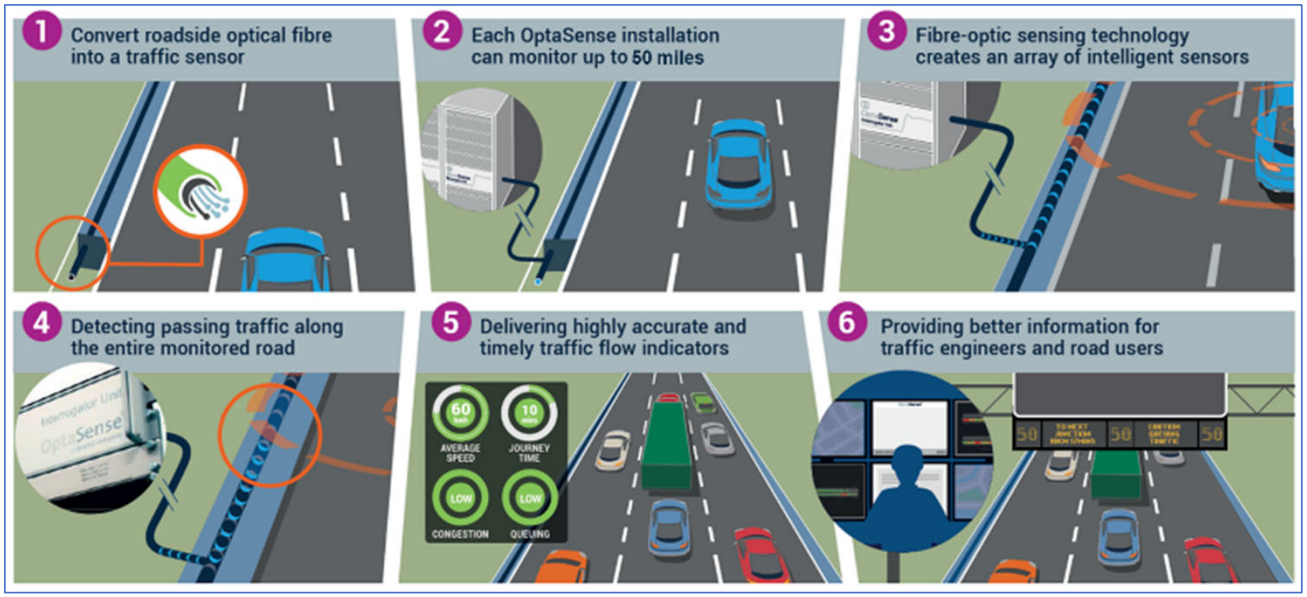
- Efficient route coverage – each installation covers up to 50 miles
- Simple and rapid installation with no requirement for road or lane closures
- Impervious to weather, road maintenance, wear or renewals
- Long life (practical MTBF > 20 years) and ultra-low maintenance burden
- “Per Mile” life-cycle costs (CAPEX & OPEX) significantly less than point sensors alternatives

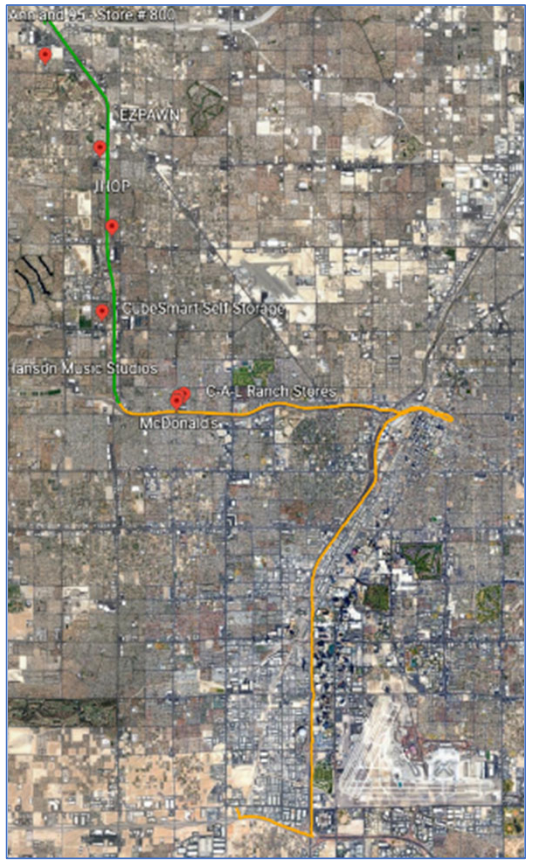
NEVADA DOT PILOT PROJECT 2022

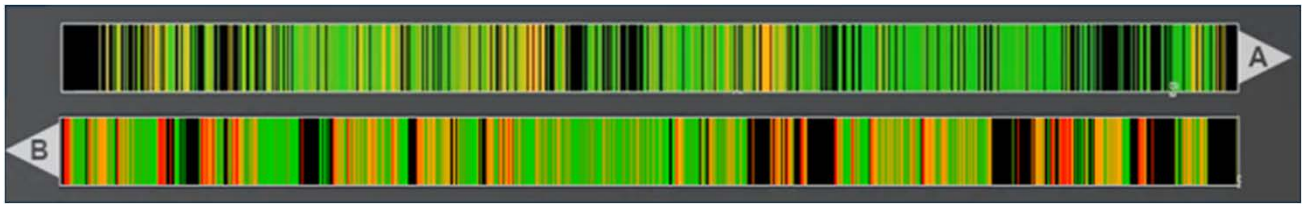
Approx. 25 mile section of I-15 and I-95 in Las Vegas

- Nevada DOT engaged with Dura-Line in 2021 to pilot the OptaSense Traffic Monitoring Solution (TMS)
- Very challenging route intentionally selected
- Despite the intentional challenges, early results are encouraging

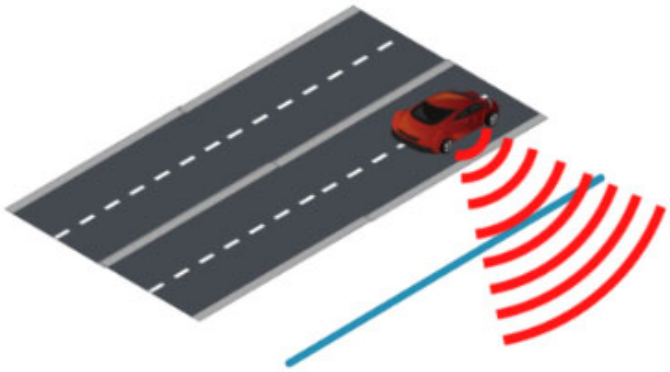
NEVADA DOT PILOT PROJECT OBJECTIVE





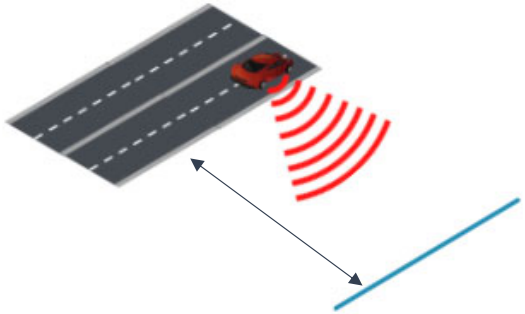


Route Features Which Can Affect Performance

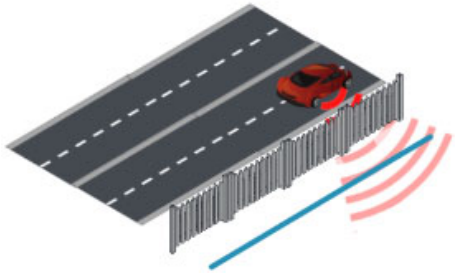


- The OptaSense TMS converts existing road-side fiber into the traffic sensor
- Roadside fiber detects noise and vibration from traffic on the monitored road section and converts into key traffic flow indicators
- Good acoustic coupling between fiber and road section is required

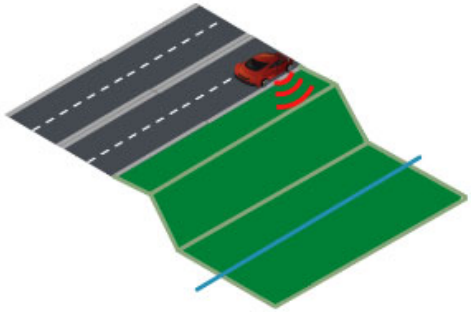
Factors which impact acoustic coupling



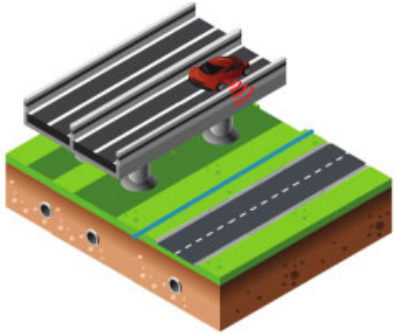
Distance to fiber



Attenuating Structures



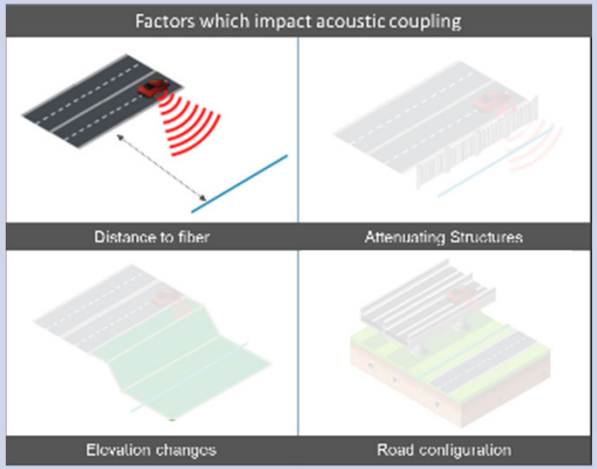
Elevation changes

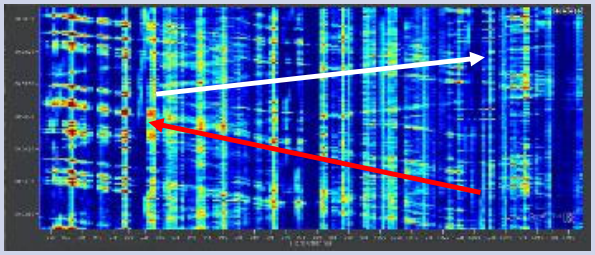


Road configuration

Route Features Which May Affect OptaSense TMS Performance

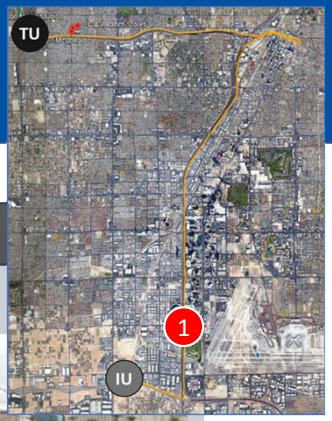
Good Coupling





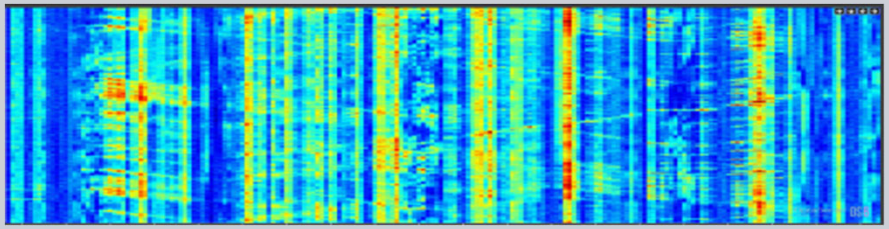
- Traffic detected in both directions

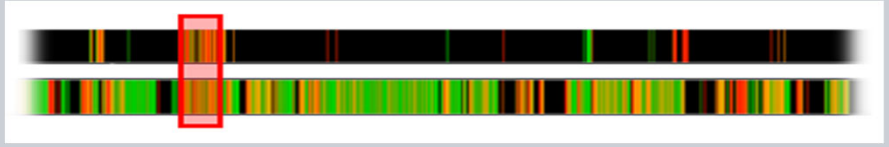
Example 1: Good Fiber Sensing Conditions



Location configuration

OptaSense TMS performance

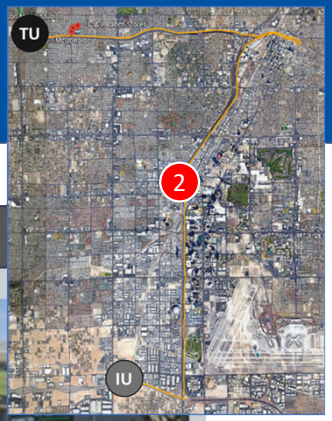




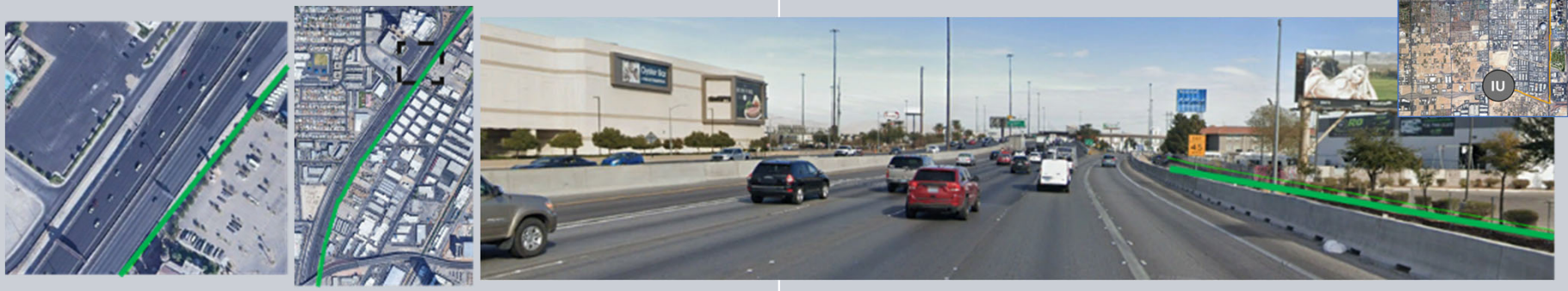
OptaSense assessment

- Monitoring of both directions generally achieved with single OptaSense TMS
- Distance to fiber acceptable (approx. 25 feet or less)
- Fiber installed in monitored road surface
- Fiber and monitored road on same elevation
- Effect of adjacent 3-lane road mitigated

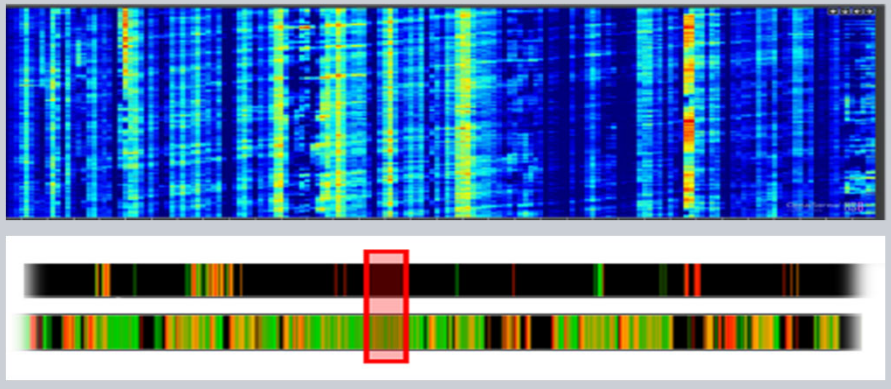
Example 2: Challenging Fiber Sensing Conditions



Location configuration



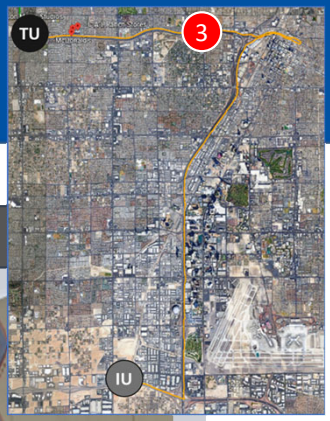
OptaSense TMS performance



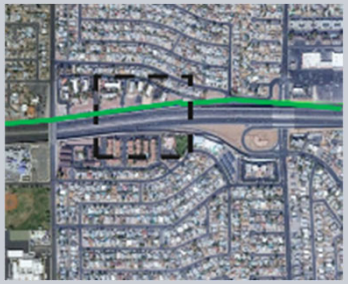
OptaSense assessment

- Monitoring of near-side lanes generally achieved with single OptaSense TMS
- Elevation changes (greater than 2 feet) and concrete barrier between monitored road and fiber attenuate most signal/s from far-side lanes
- Distance to fiber remains within limits

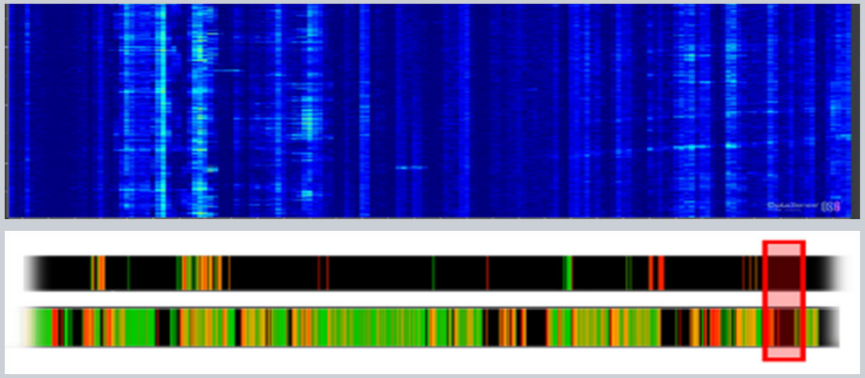
Example 3: Inadequate Fiber Sensing Conditions



Location configuration



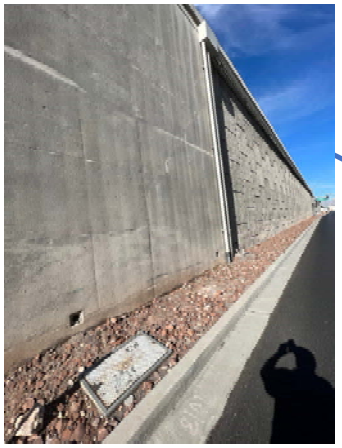
OptaSense TMS performance

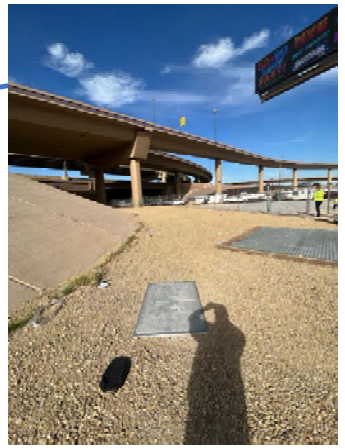


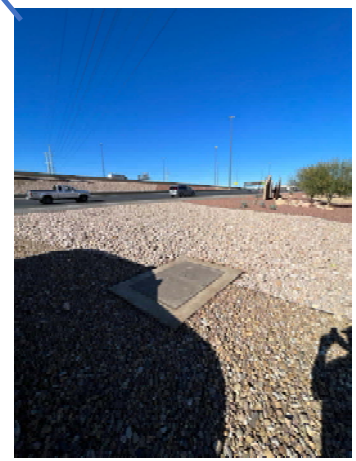
OptaSense assessment

- Fiber installed off monitored road surface
- Huge concrete barrier between monitored road and fiber causes attenuation
- These factors plus distance stop most signal/s from near and far-side lanes resulting in poor coupling and no OptaSense TMS output in these locations

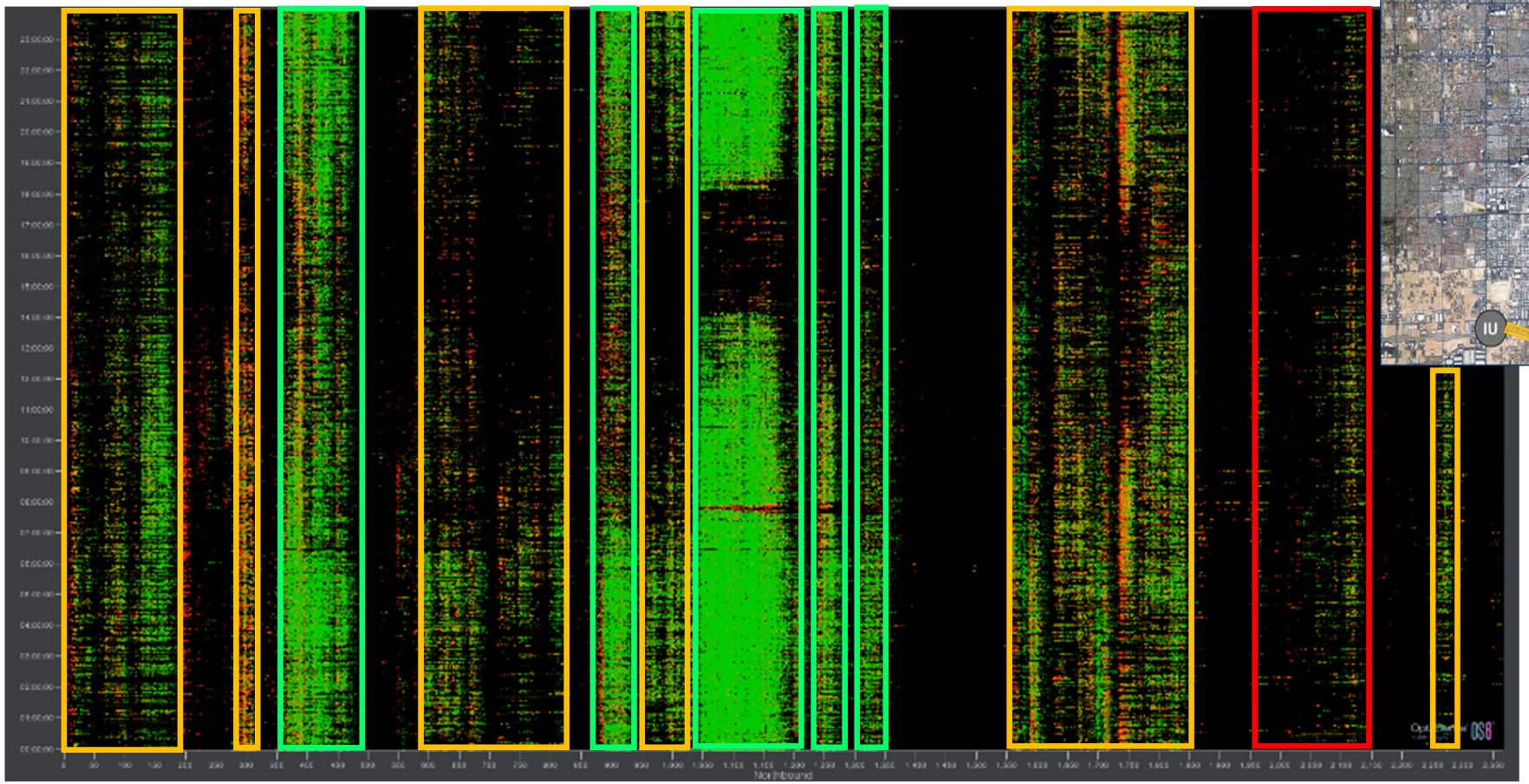
Challenging Fiber Location Examples

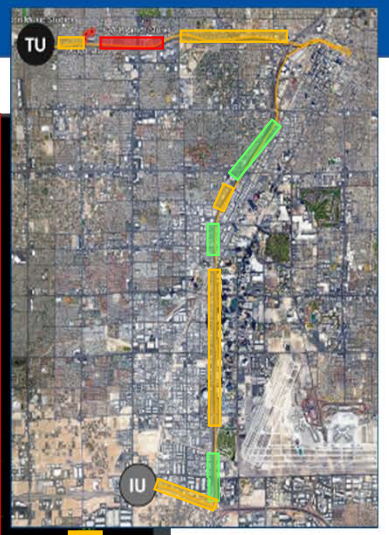






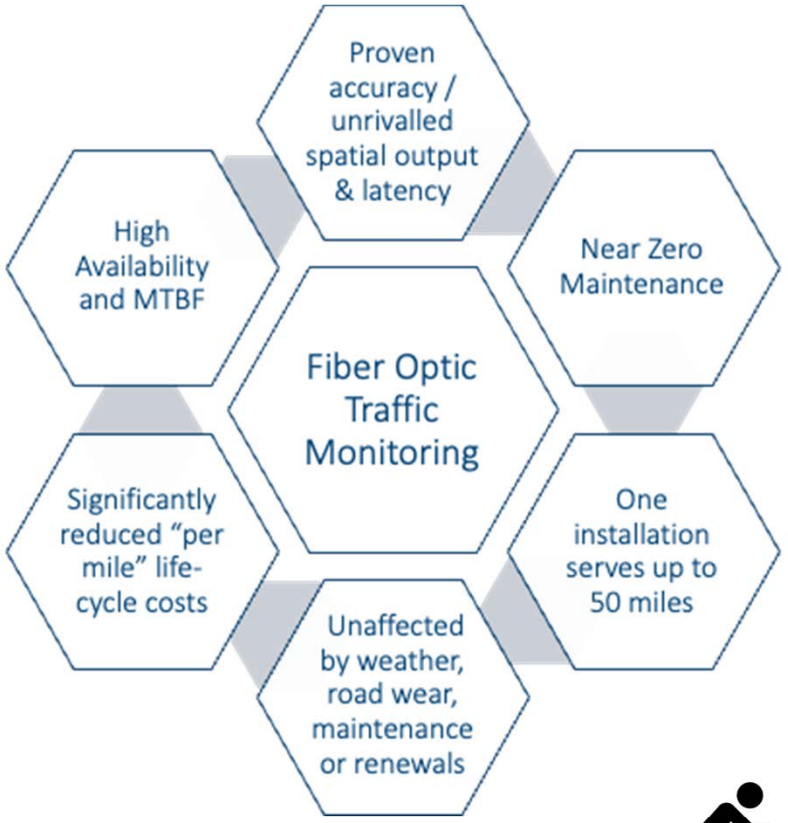
Sample Speed Data over 24 hour period





Fiber Optic Traffic Sensing Tentative Conclusions

- With evaluation of the impact of elevation changes, sound barrier obstructions, and fiber proximity, the pilot is providing valuable info regarding this technology best can be deployed elsewhere within Nevada (and other states)
- In addition to referencing existing technologies, Nevada DOT will evaluate the operational advantages and CapEx/OpEx reductions that can be leveraged for both existing and future fiber installations
- The current pilot concludes during 2022 and it is anticipated the traffic monitoring solution will be useful and scalable to other locations in the state.



Fiber Optic Traffic Monitoring Summary

- Fiber optics sensing is an exciting technology which enables spare capacity within existing roadside fiber-optics to be used for Traffic Monitoring
- Going forward with new fiber cable & conduit installations, NDOT will consider how best to install to take advantage of both multiduct conduits & traffic monitoring sensing

DOT installs in the future to leverage multi-use

Eric MacGill, Senior Traffic Designer
emacgill@dot.nv.gov| (775) 888-7561

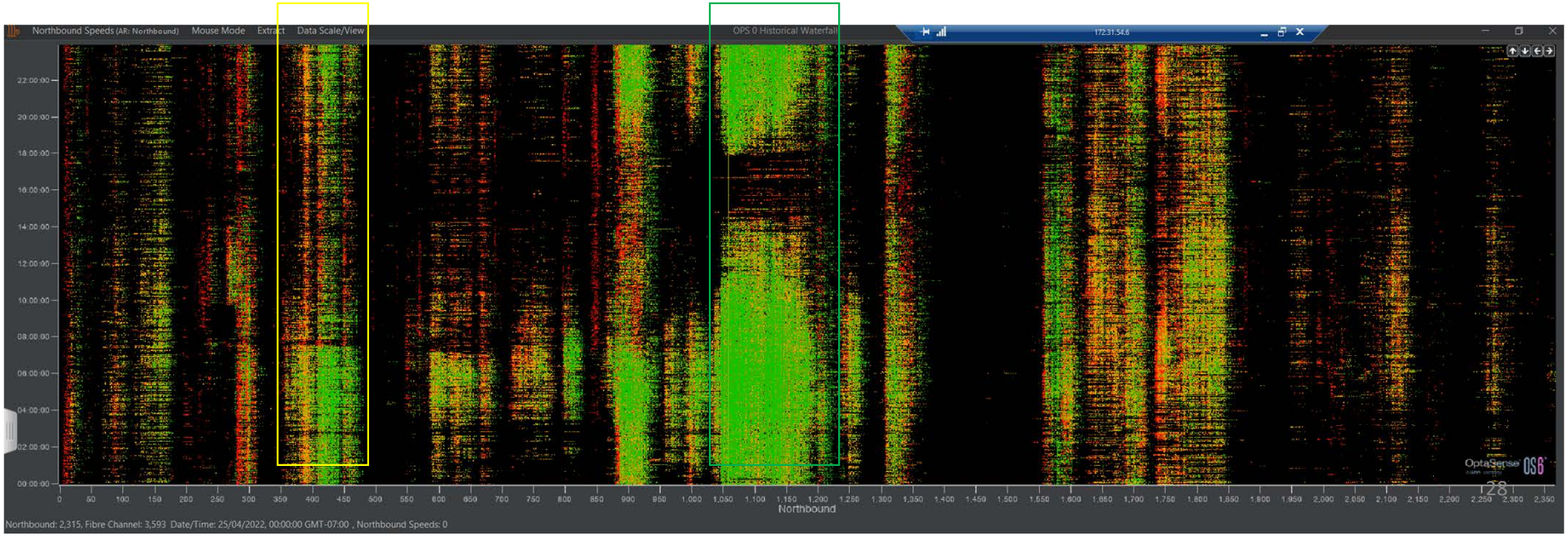
Traffic Monitoring using Fiber Optic Sensing

Data Evaluation

Jeff Bickett, Network Analyst

CONSIDERATIONS FOR EVALUATION

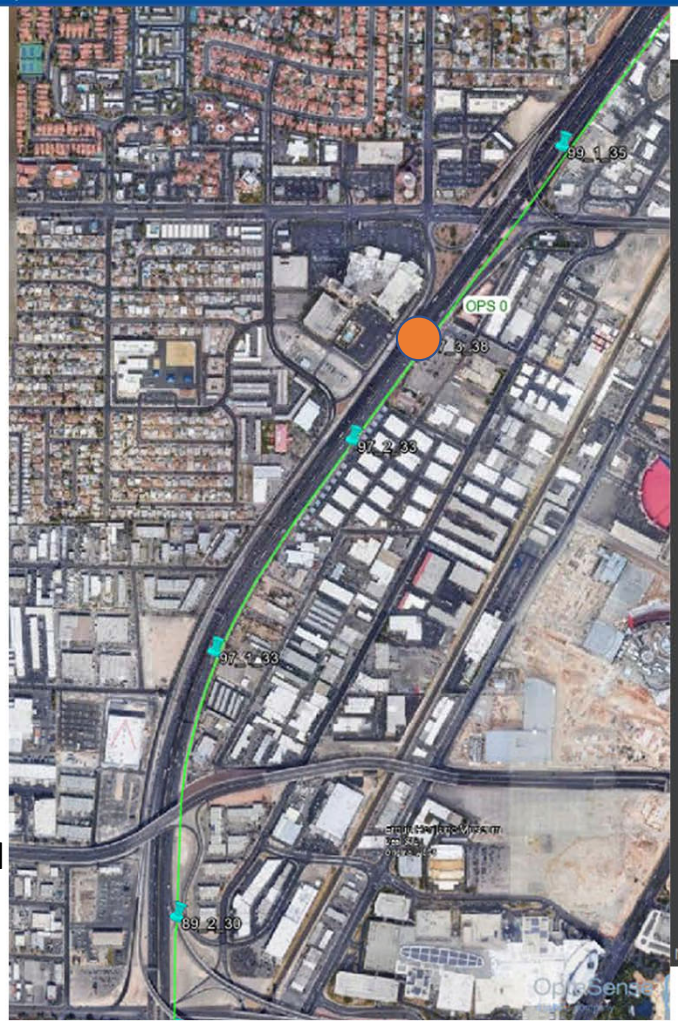
- Elevation, sound walls, and distance from roadway to fiber play a major role in how the system performs.
- Evaluation locations were screen based on the Optasense coupling.
- Regions with good coupling were further screened for the presence of ramps and frontage roads that induce ‘noise’ to the system.
- The yellow rectangle below represents a region with decent coupling. However, the system is detecting vibrations from a nearby frontage road and not the mainline.
- NDOT sensors within the green region were selected for the optimal comparison zone where the vendor specified the system will be accurate.

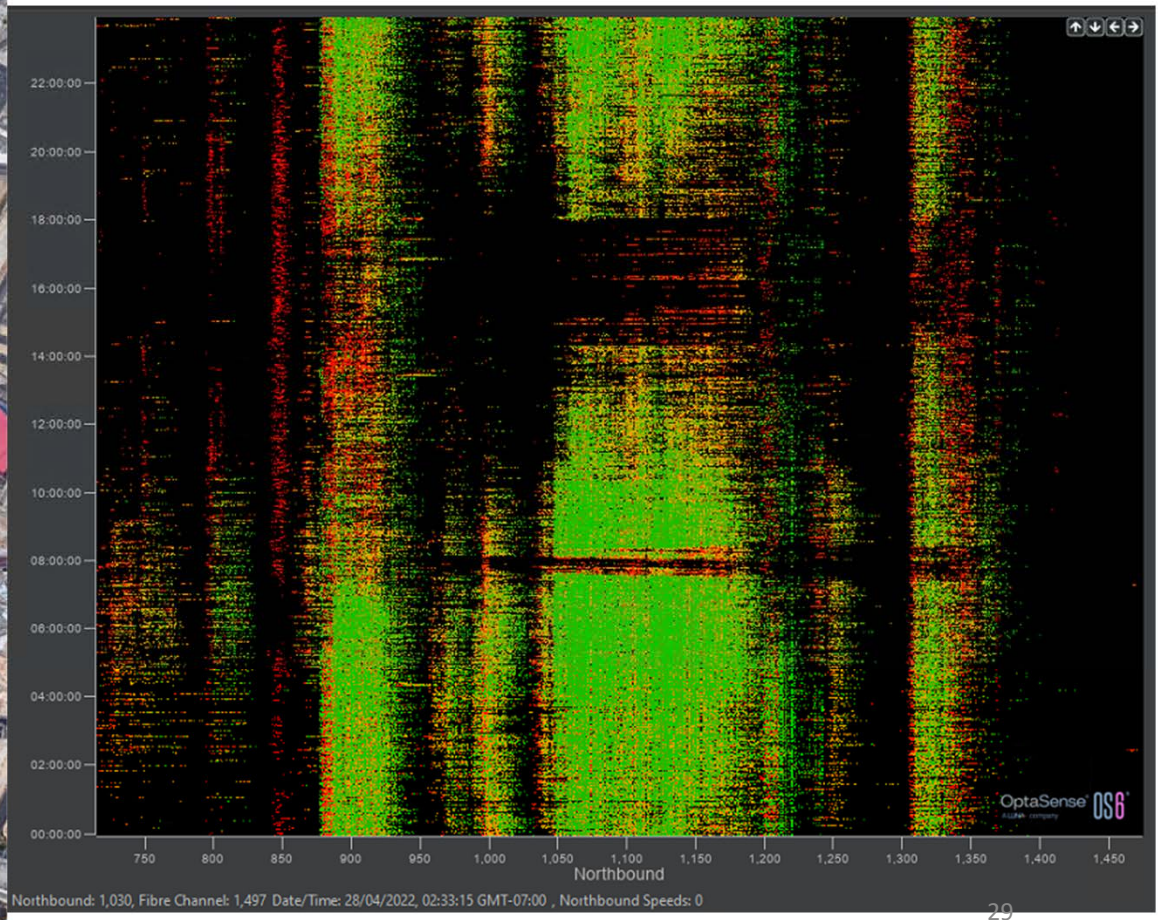


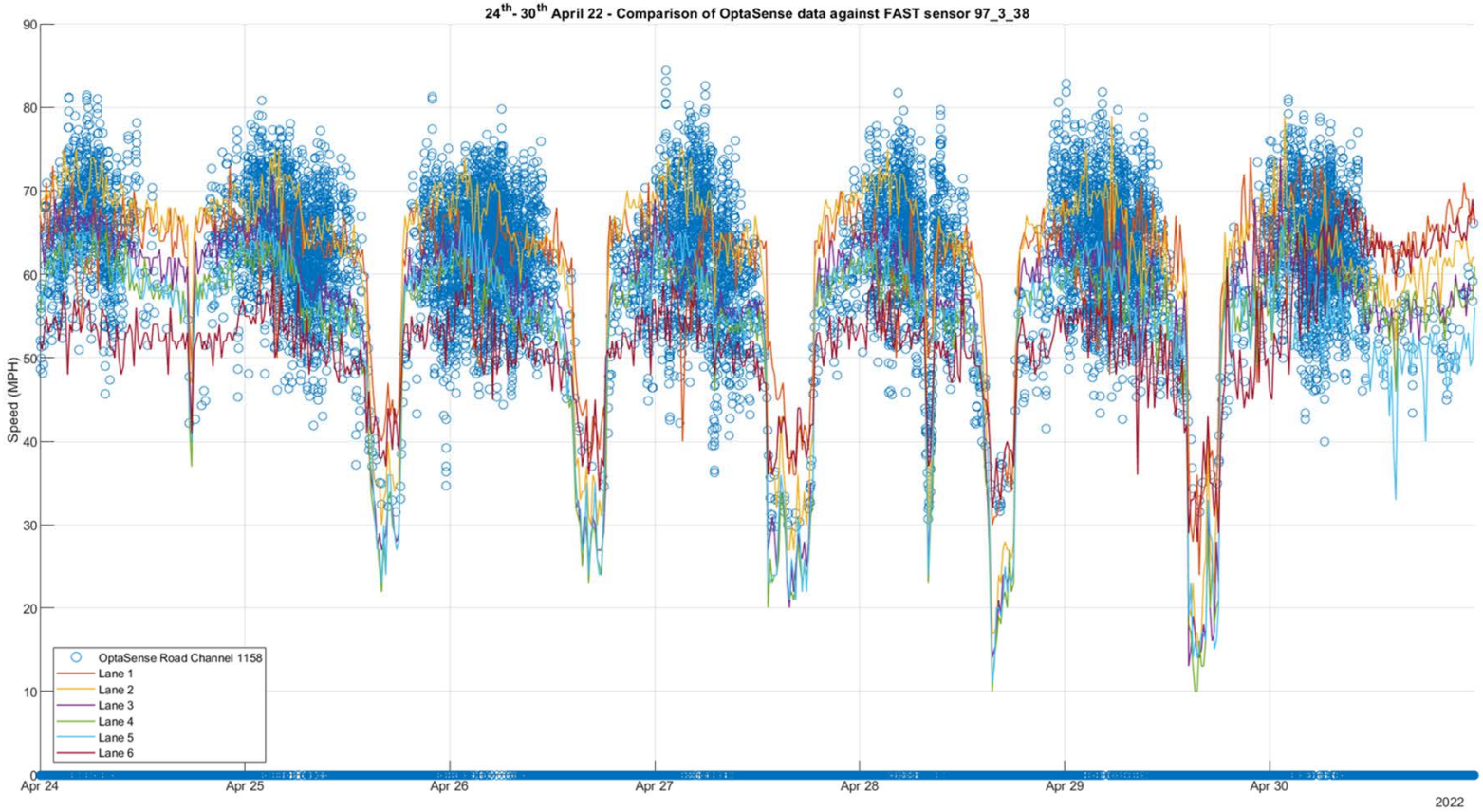
Comparison Region

W Sahara Av

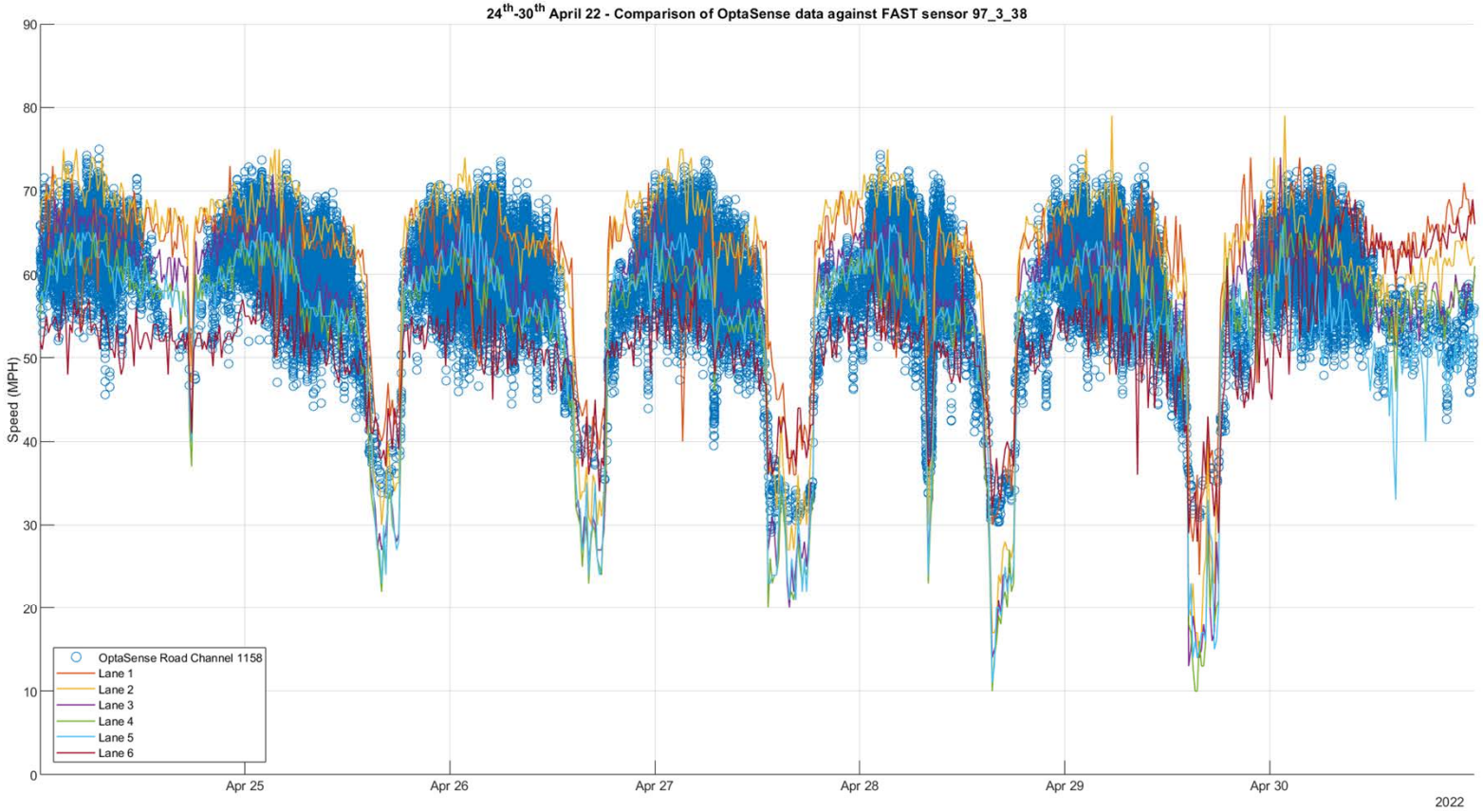
W Desert Inn Rd



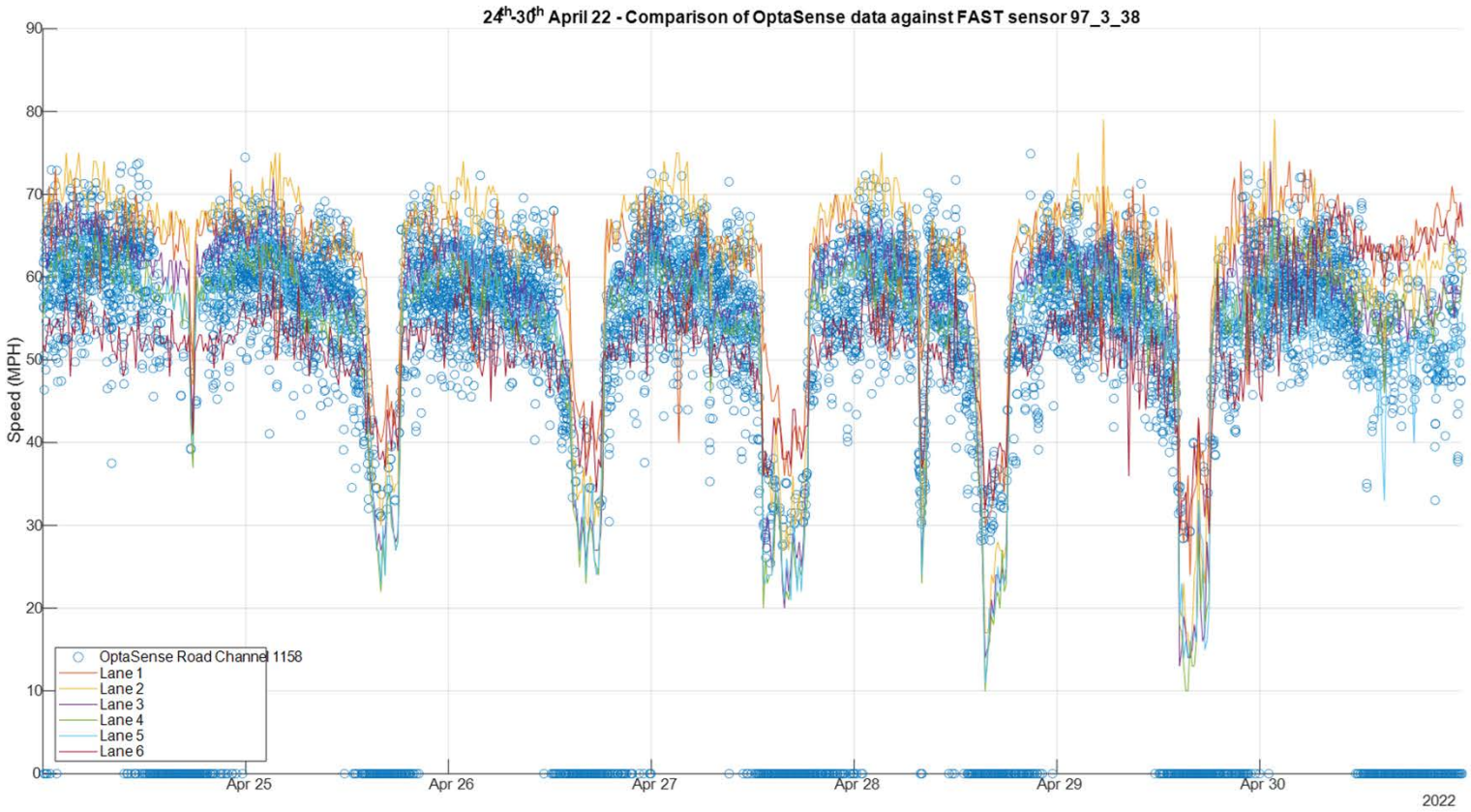




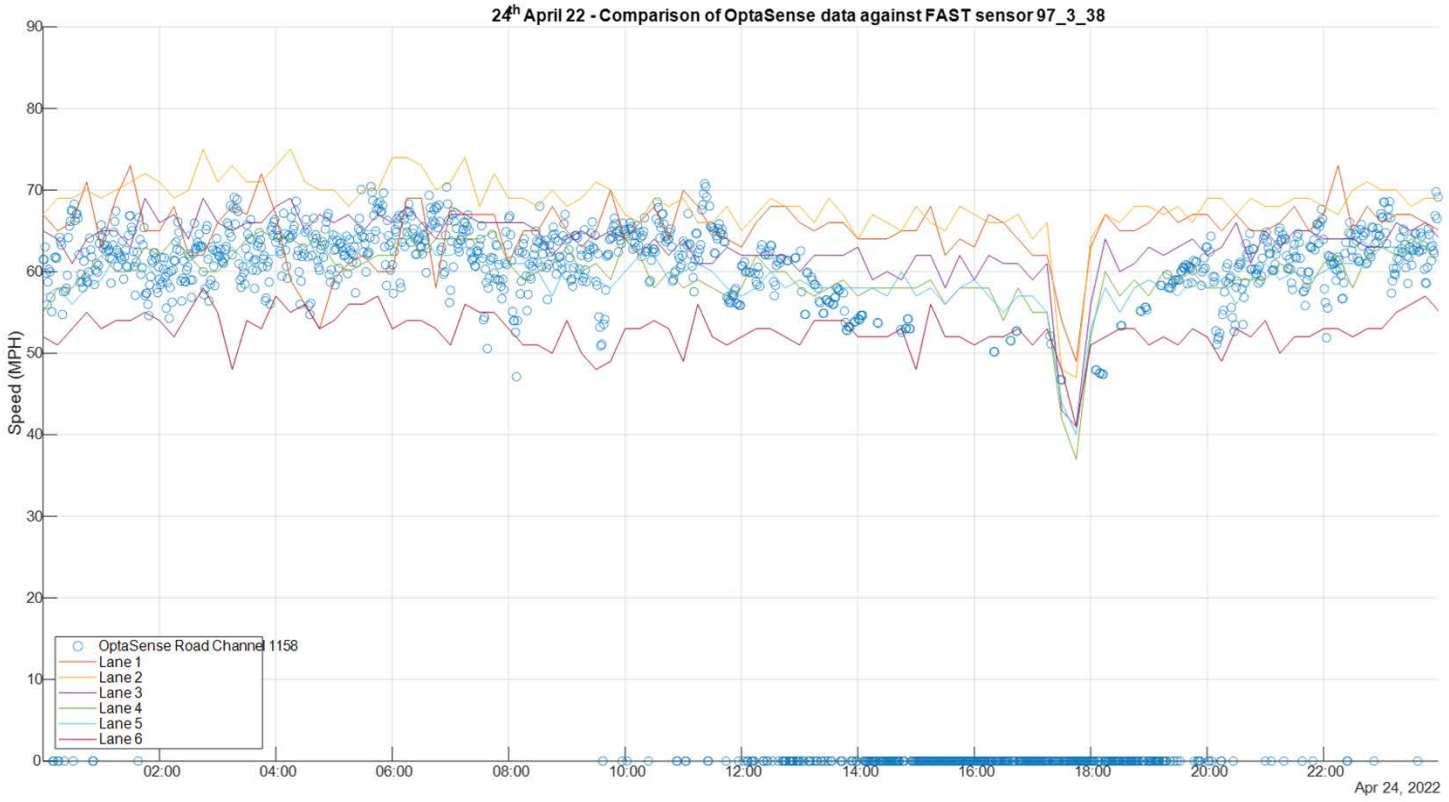
Smoothed Road Speed Data (Kalman) for Channel 1158 plotted against FAST sensor 97-3-38



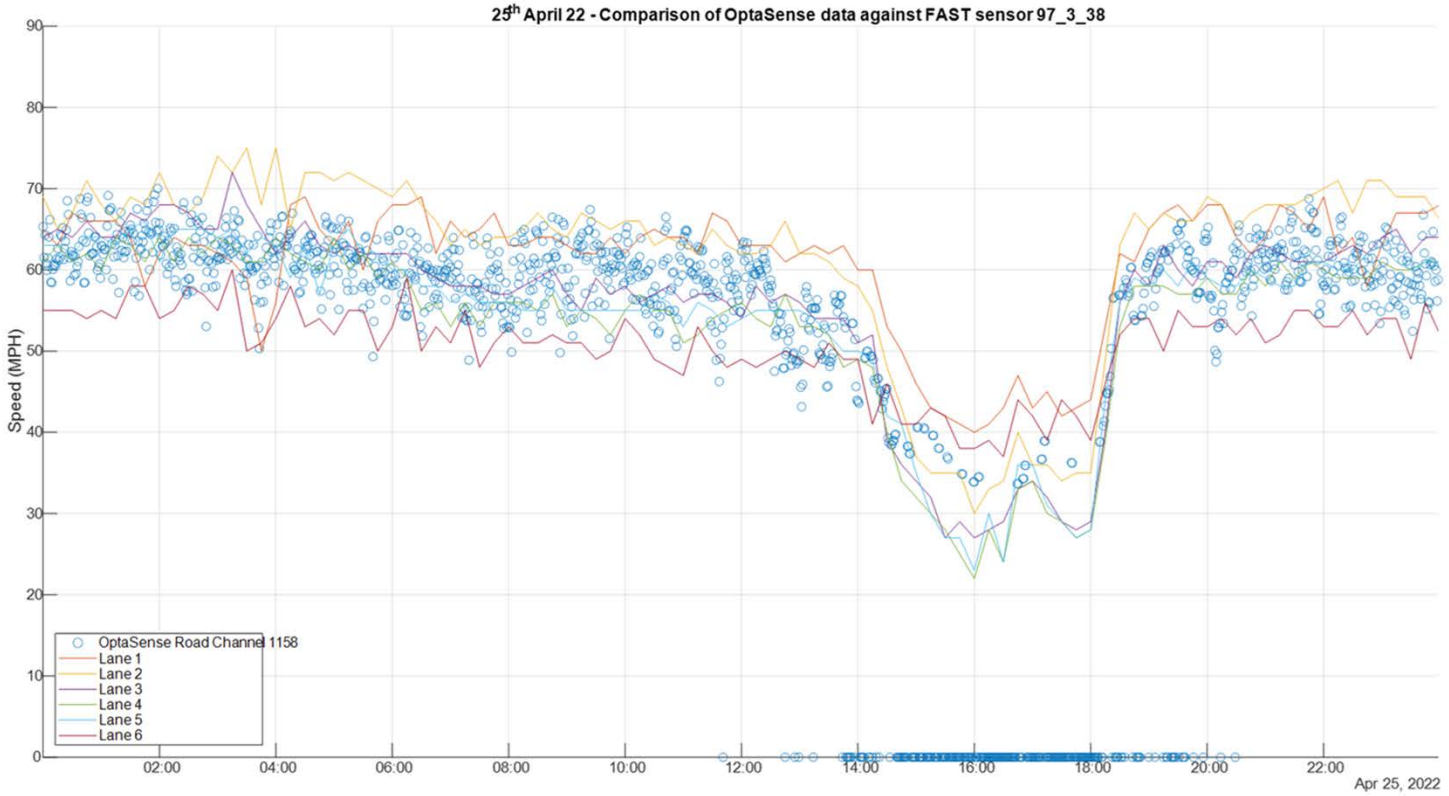
Smoothed Road Speed Data (Kalman using 5 channel window) for Channel 1158 plotted against FAST sensor 97-3-38



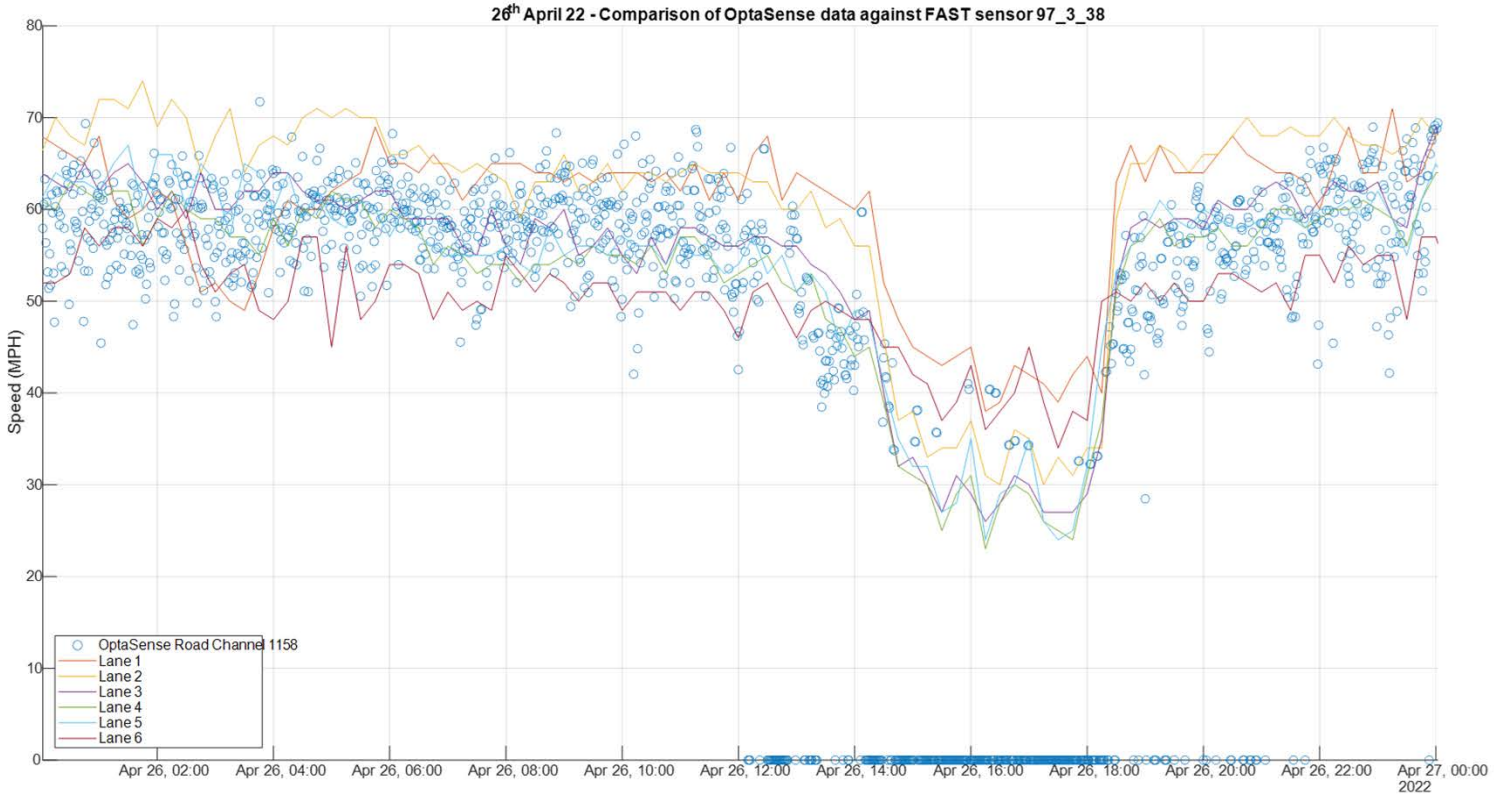
Smoothed Road Speed Data (Kalman using 5 channel window) for Channel 1158 plotted against FAST sensor 97-3-38
Mean of Smoothed speeds from 60 second chunk



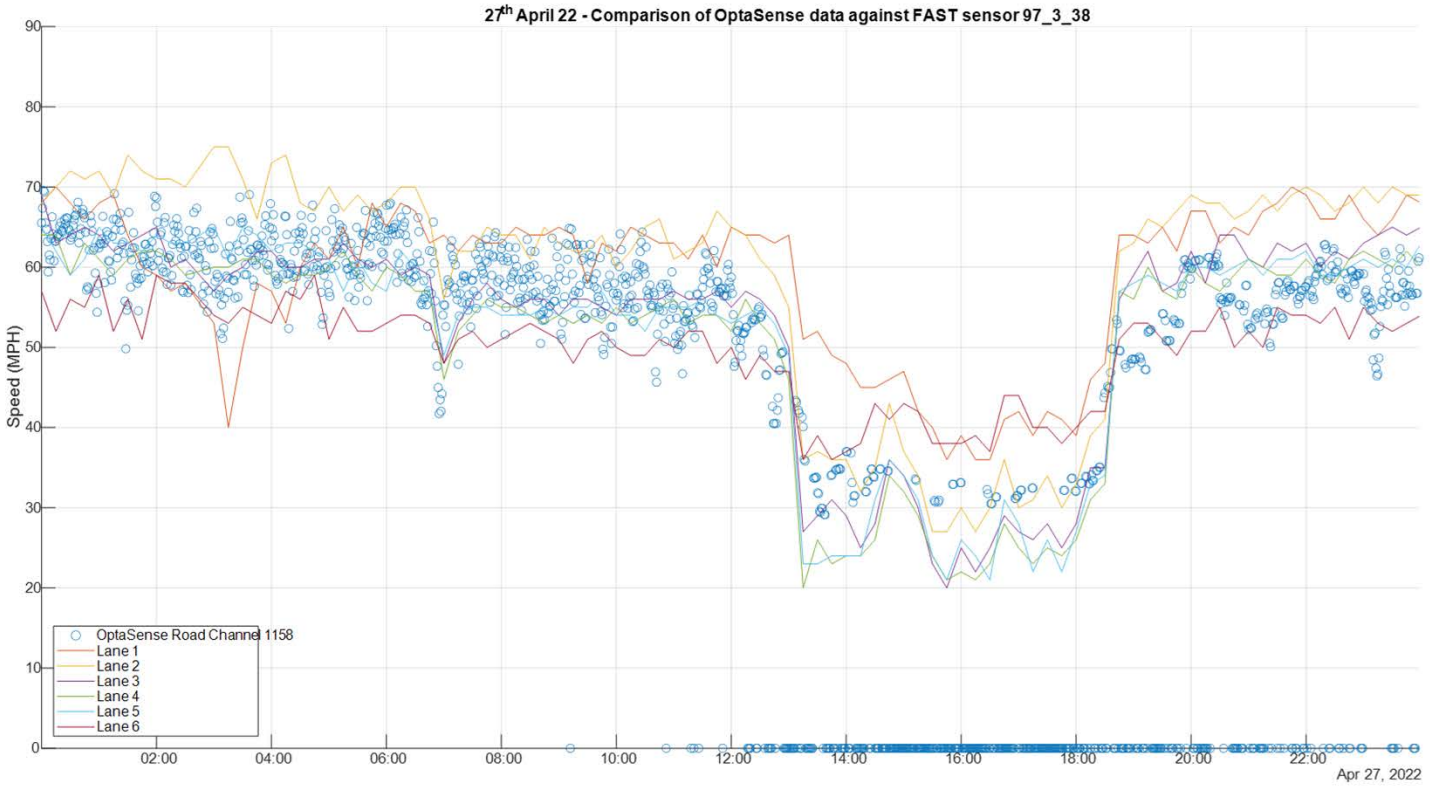
Smoothed Road Speed Data (Kalman using 5 channel window) for Channel 1158 plotted against FAST sensor 97-3-38
Mean of Smoothed speeds from 60 second aggregation



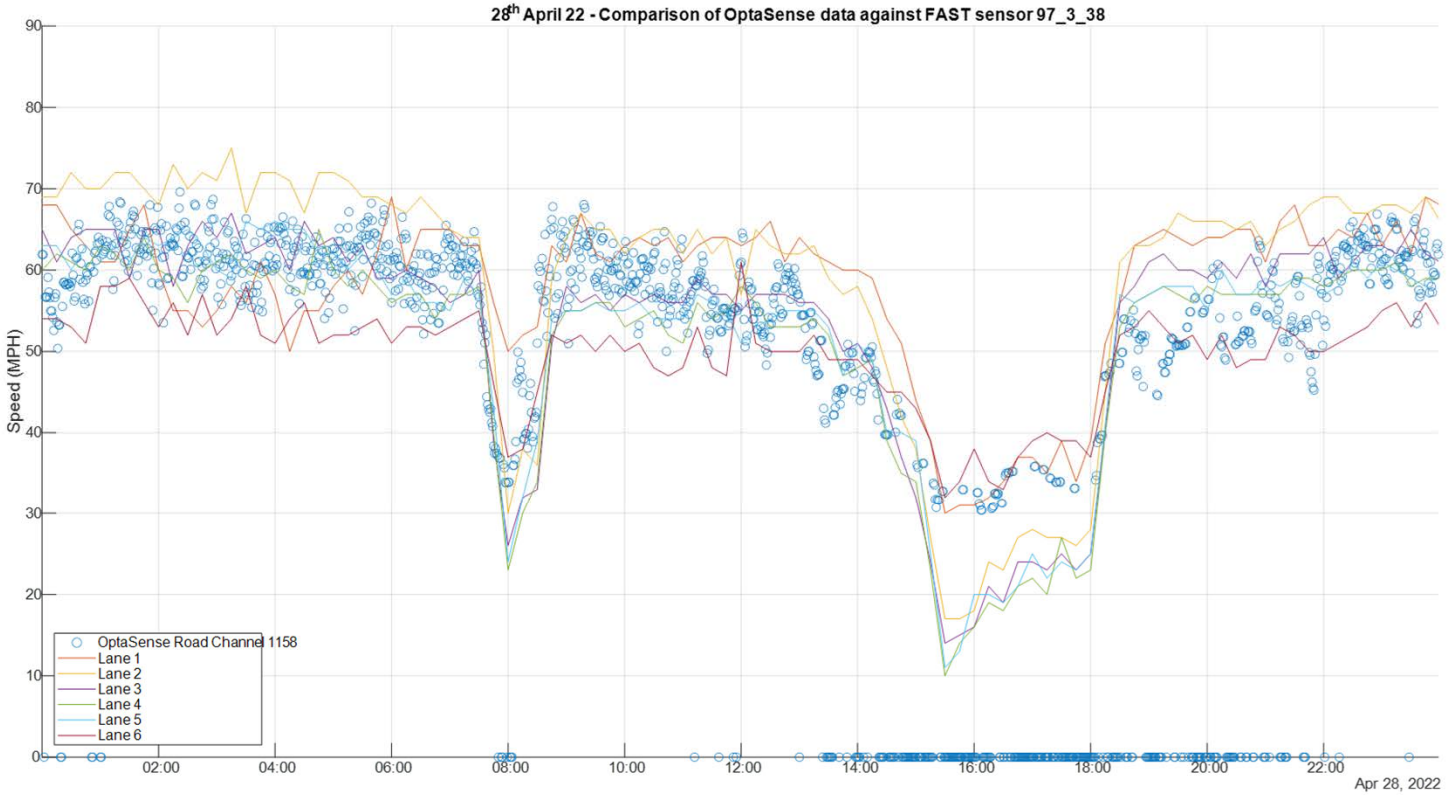
Smoothed Road Speed Data (Kalman using 5 channel window) for Channel 1158 plotted against FAST sensor 97-3-38
Mean of Smoothed speeds from 60 second aggregation



Smoothed Road Speed Data (Kalman using 5 channel window) for Channel 1158 plotted against FAST sensor 97-3-38
Mean of Smoothed speeds from 60 second chunk with a 5 channel wide window

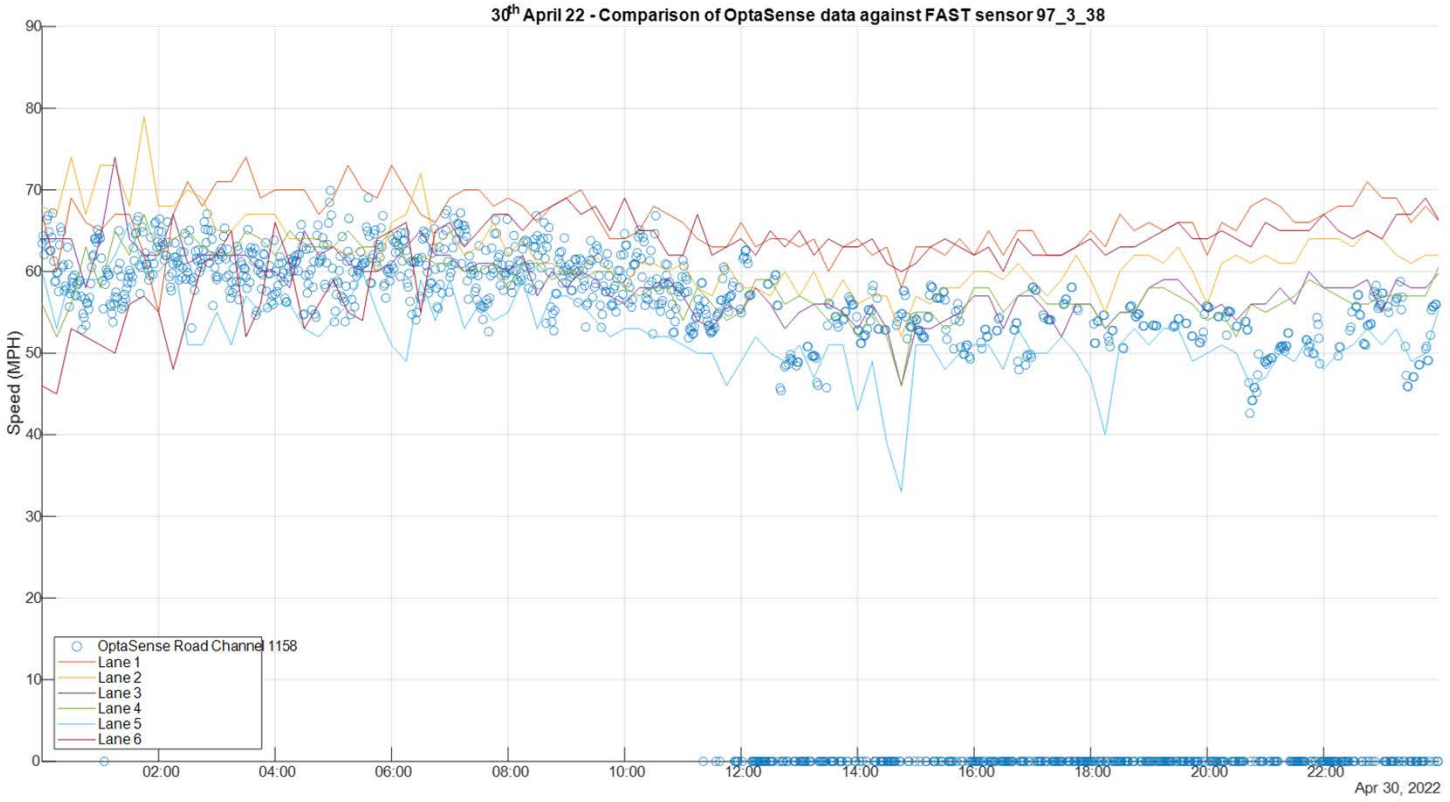


Smoothed Road Speed Data (Kalman using 5 channel window) for Channel 1158 plotted against FAST sensor 97-3-38
Mean of Smoothed speeds from 60 second aggregation

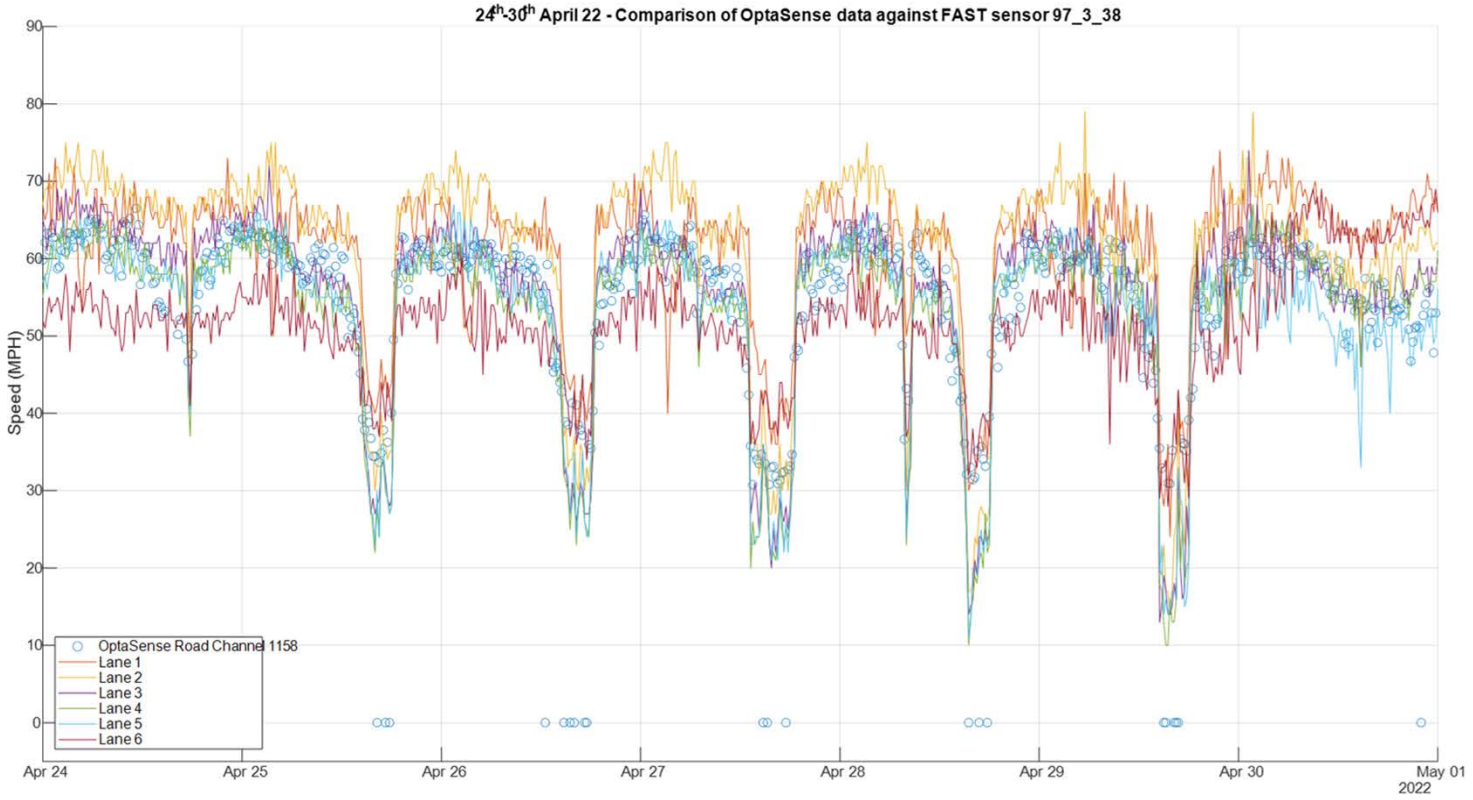


Smoothed Road Speed Data (Kalman using 5 channel window) for Channel 1158 plotted against FAST sensor 97-3-38
Mean of Smoothed speeds from 60 second aggregation

Smoothed Road Speed Data (Kalman using 5 channel window) for Channel 1158 plotted against FAST sensor 97-3-38
Mean of Smoothed speeds from 60 second chunk

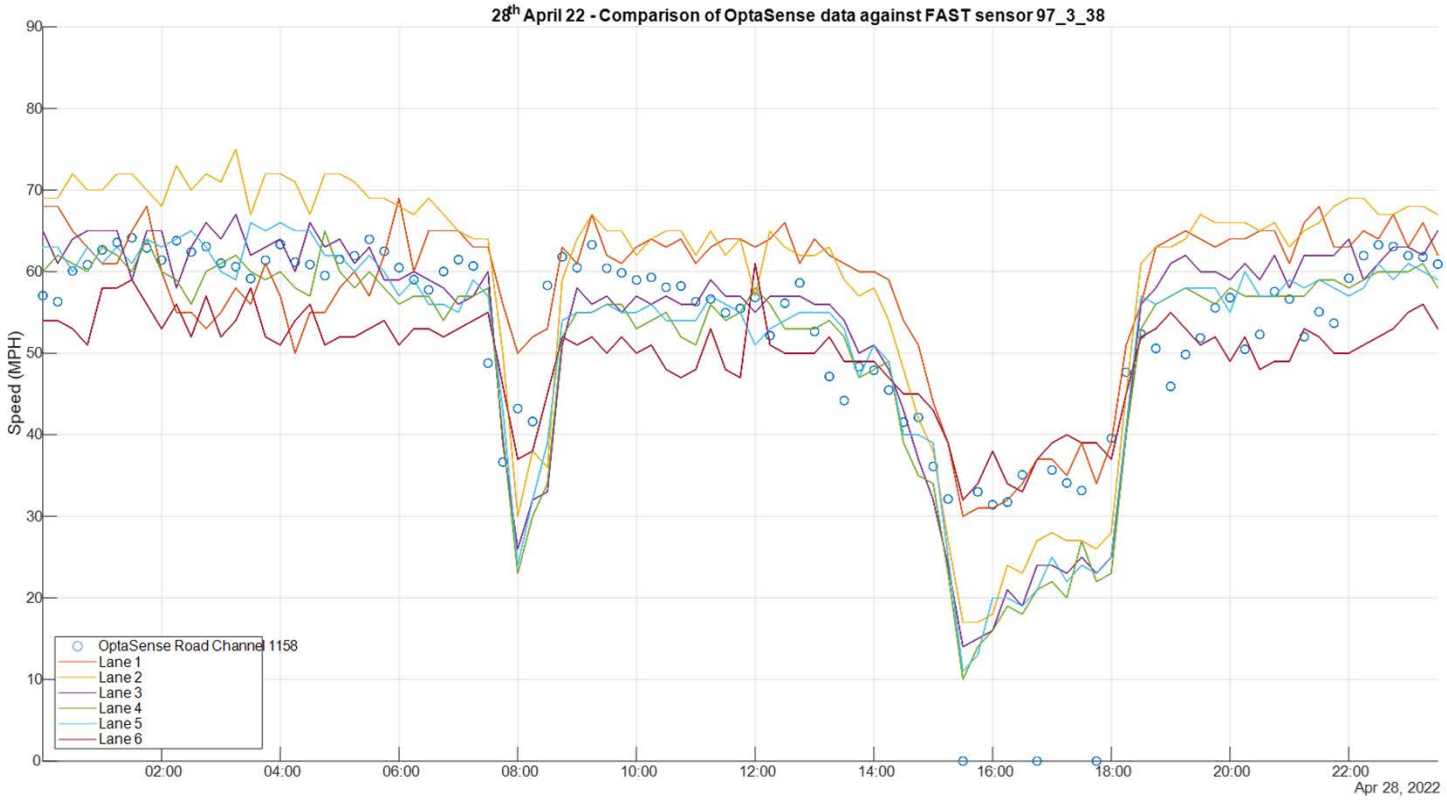


Smoothed Road Speed Data (Kalman using 5 channel window) for Channel 1158 plotted against FAST sensor 97-3-38
Mean of Smoothed speeds from 60 second aggregation



Smoothed Road Speed Data (Kalman using 5 channel window) for Channel 1158 plotted against FAST sensor 97-3-38
Mean of Smoothed speeds from 900 second aggregation

Smoothed Road Speed Data (Kalman using 5 channel window) for Channel 1158 plotted against FAST sensor 97-3-38
Mean of Smoothed speeds from 900 second aggregation



Smoothed Road Speed Data (Kalman using 5 channel window) for Channel 1158 plotted against FAST sensor 97-3-38
Mean of Smoothed speeds from 900 second aggregation

FINDINGS

PROS:

- Strong trending between the NDOT and Optasense speed data sets.
- Optasense outlier speeds and null further mitigated when aggregated over 15 minutes, matching NDOT binning.
- While detection is diminished, the systems incident detection algorithm will flag the segment of roadway, notifying users of the change. This function allows for the identification of bottlenecks and accidents.

CONS:

- Under breakdown conditions (~<35 mph) the system begins to lose detection coupling and speed reporting capabilities.
- On multilane facilities, Optasense speeds track better with the lane closest to the fiber.

Additional Considerations:

- The current pilot project was not able to evaluate how the Optasense system performs with two directional traffic given the width, geometric constraints, and fiber location of the pilot freeway segment.
- The Optasense system ability to count vehicles where fiber crosses the roadway was unable to be evaluated as all mainline fiber crossings occurred on elevated structures and ramp crossings did not have an NDOT sensor available.
- Deployment in Rural settings with fiber crossing the mainline road is recommended for further evaluation.