SPE WORKSHOP

Putting Theory Into Practice: Field Trial of DFOS on a Pipeline

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Background and Objectives

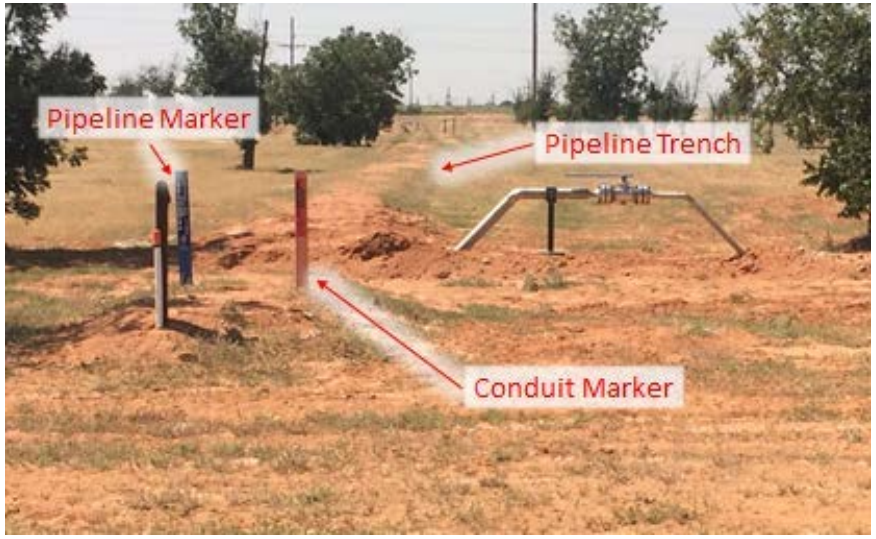
- Distributed fiber optic sensing (DFOS) is an emerging technology for real-time pipeline monitoring, specifically for leak detection and third party interference

- ExxonMobil conducted a 90 day DFOS field trial on a West Texas pipeline with the following objectives:
  - Evaluate technical readiness of for future commercial applications
  - Assess performance in a real-world environment including accuracy, repeatability, false positives, and leak detection thresholds

- High-Fidelity Dynamic Sensing system assessed
  - Combined DAS/DTS/DSS DFOS system

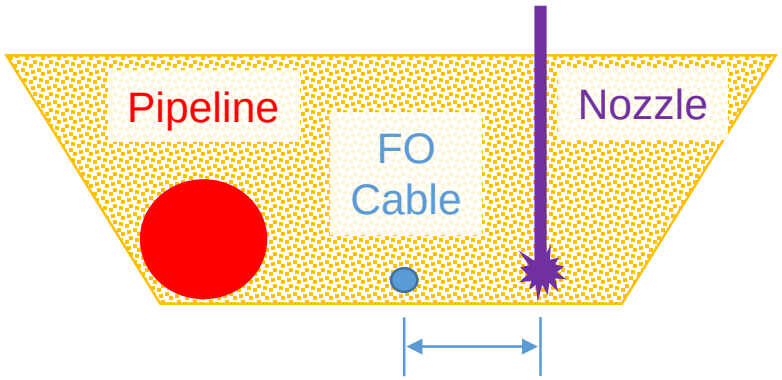
Fiber Installation Process

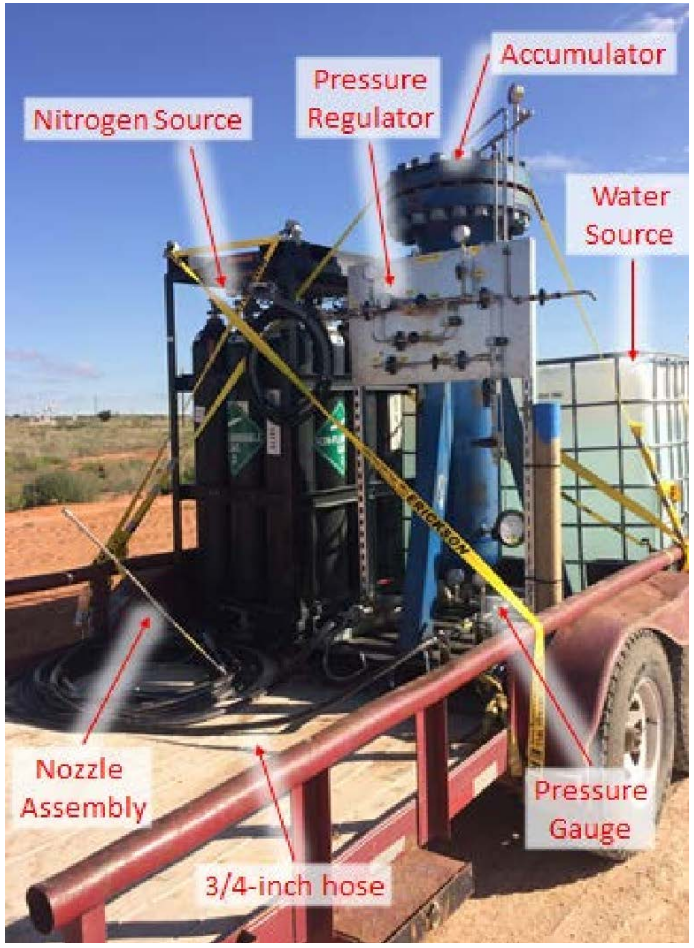
- High-Fidelity Dynamic Sensing system installed during construction of new 6” produced water pipeline in West Texas
  - Uncontrolled operating environment
  - Multiple intersecting pipelines and roads, nearby pump jacks, normal operations and traffic
- Duraline 2-way conduit placed in trench, FO cables blown in after burial
  - Microduct 1 – High fidelity sensing fiber
  - Microduct 2 – SM telecom fiber
- Average distance from conduit to pipe 3 ft
- Monitored section 1.1 miles plus 16 mile long lead in fiber



Leak Simulation Apparatus

- Water or nitrogen used to simulate liquid or gas leaks
- Compressed nitrogen pressure source
- Accumulator vessel used to pressurize water
- Flexible hose used to connect accumulator to buried nozzle
- 20 buried nozzles pre-installed along monitored section
  - Distance from nozzles to FO cable: 1 to 8 feet
- Simulated leak duration ~1 minute



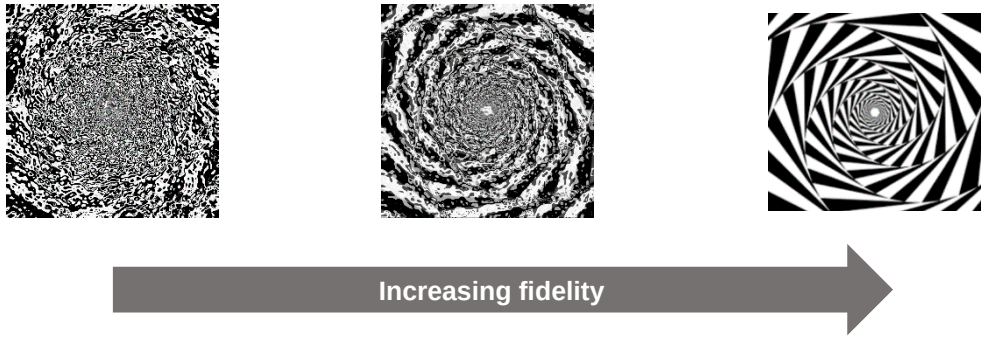


Test Program

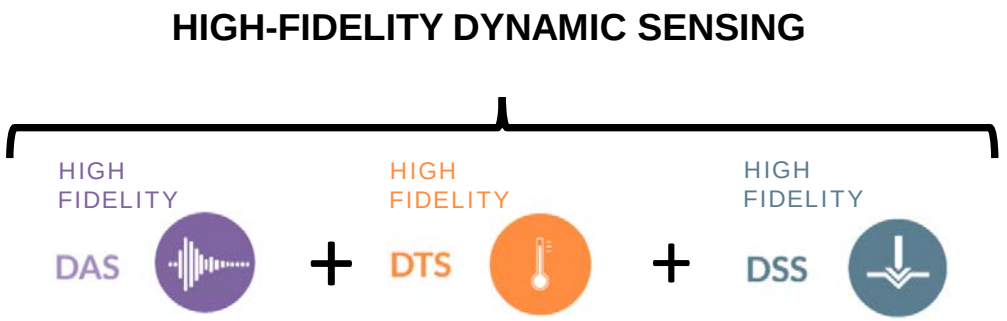
- Total of 134 simulated leaks conducted during test program
- Nozzle orifice size: 1/8 to 1/4”
- Pressure: 100 to 1,200 psi
- Corresponds to the following flow rates
  - Liquid: 2.8 to 37 gpm
  - Gas: 14.7 to 421 scfm
- Repeat tests conducted for reproducibility
- Monitoring occurred over a 30 day period, unannounced simulated leaks conducted on 8 days

High-Fidelity Dynamic Sensing

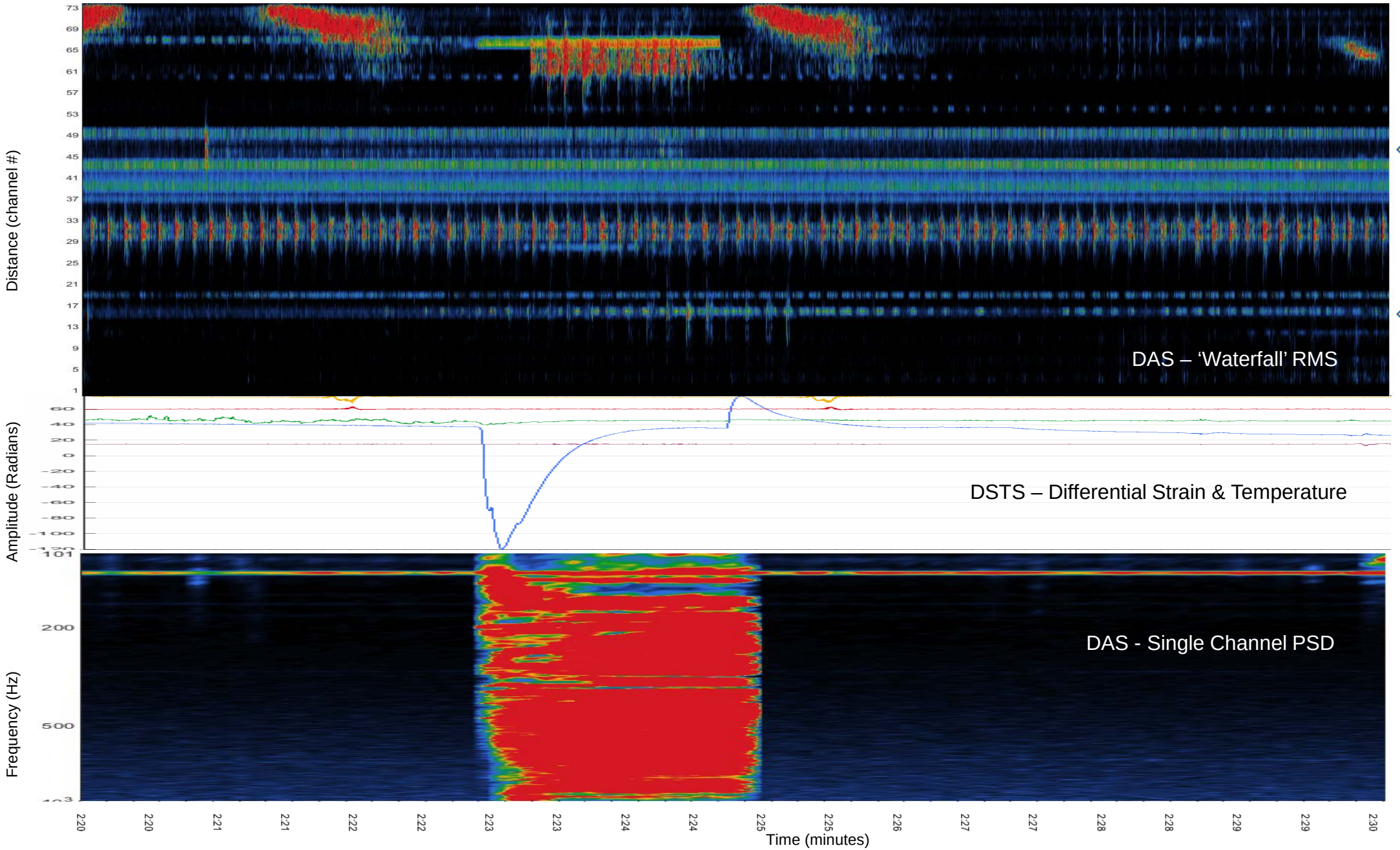
- Fidelity: Ability to accurately sense and understand surroundings, with little or no distortion



- High-Fidelity Dynamic Sensing is a unique DFOS system utilizing wavelength multiplexing to achieve optimal fidelity.
- High-Fidelity Dynamic Sensing is sensitive to multiple forms of ***dynamic*** energy: acoustic (DAS) + strain (DSS) + temperature (DTS), in high fidelity



High-Fidelity Dynamic Sensing Example: Water Leak 1,000 psi @ 1ft, 1/8” orifice
Estimated flow rate (volume): 8.8 gpm (8.8gal)



Pumpjack

Intersecting pipelines

Pumpjack

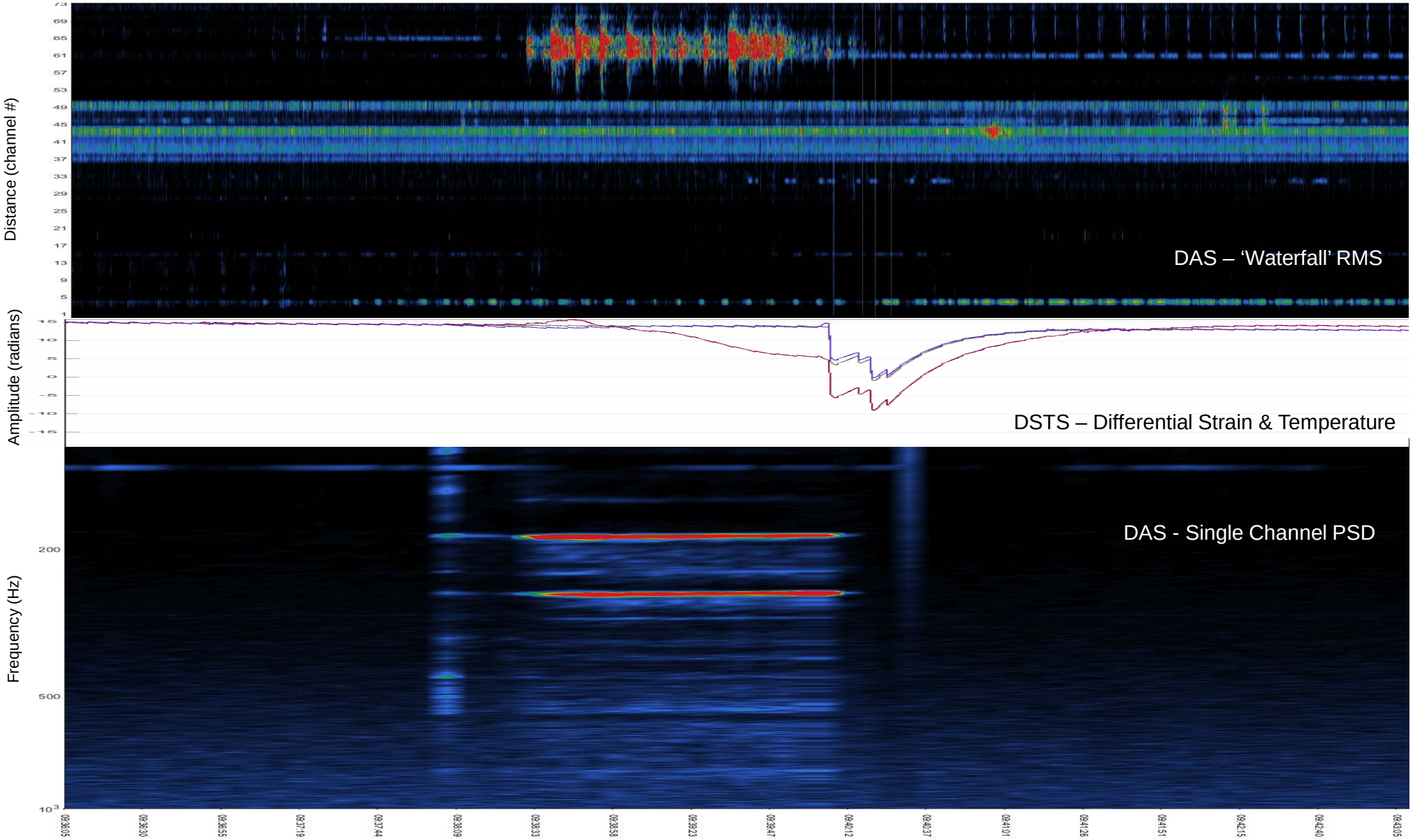
Intersecting pipelines

DSTS shows fluid being released

PSD confirms fluid flow

Very high confidence leak

High-Fidelity Dynamic Sensing Example: Water Leak 500 psi @ 2ft, 1/8” orifice
Estimated released rate (volume): 6.2 gpm (6.2 gal)



Pumpjack

Intersecting pipelines

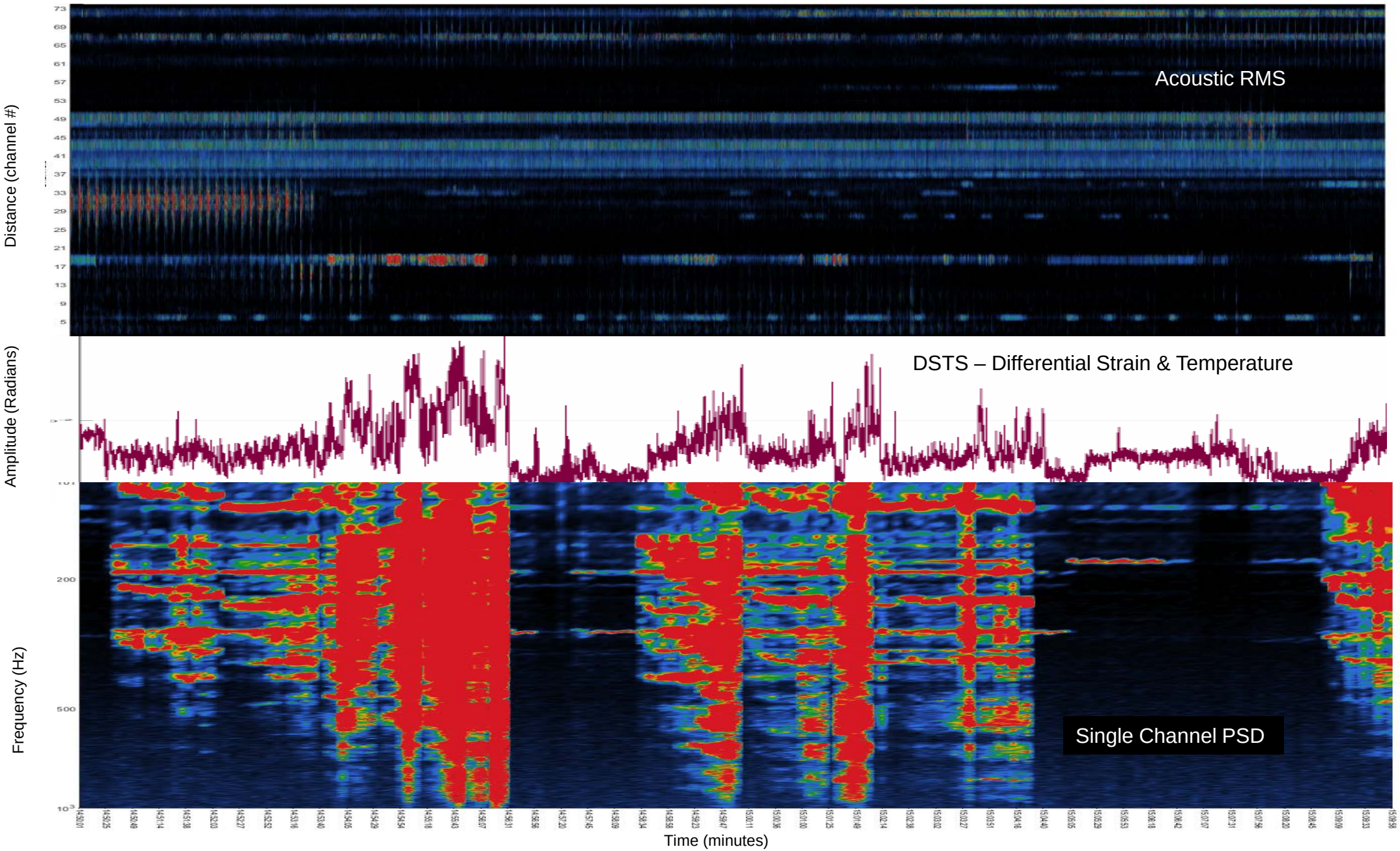
No sign of leak

DSTS suggests fluid being released

PSD shows very faint fluid flow

High Fidelity DAS and DSTS used together provides confidence to declare a leak

Other Example - HydroVac Operations on Pipeline ROW



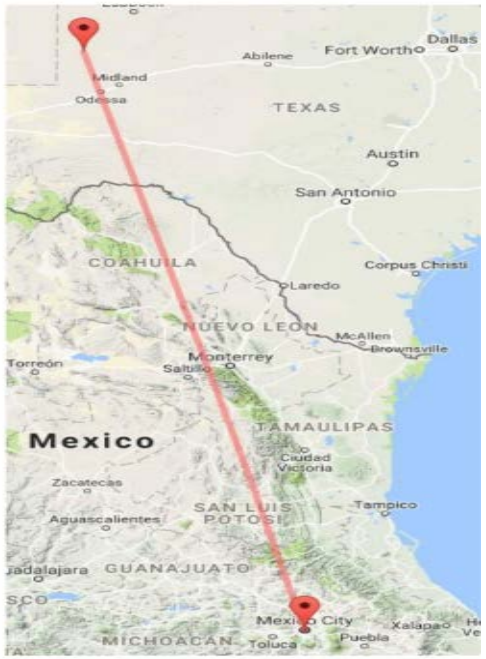
Acoustic activity

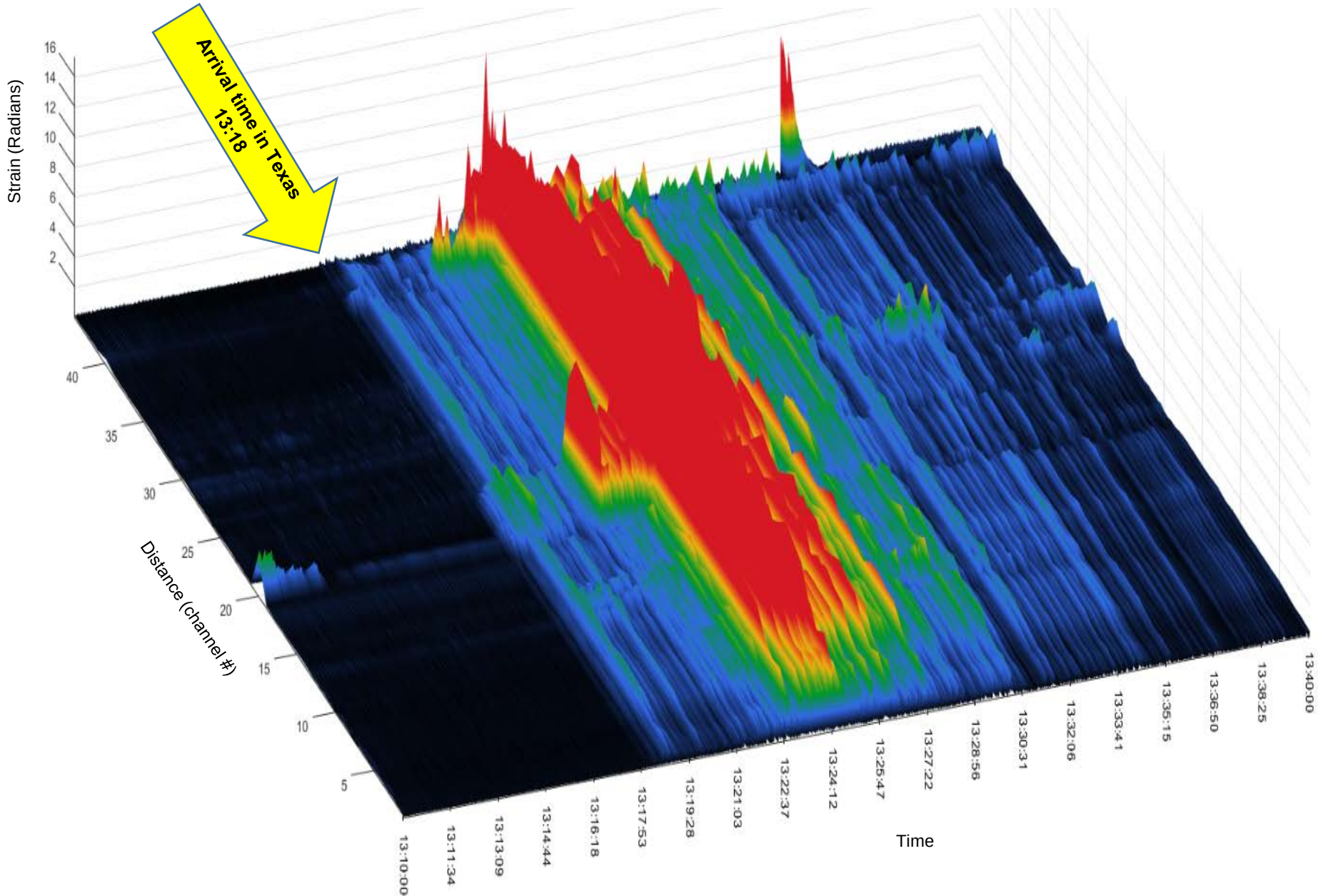
PDS shows flow and intrusion

High Fidelity DAS and DSTS used together confirm hydrovac activity

Other Example - Earthquake

Epicenter in Mexico 1,500 km away, September 19 local time 13:14





Test Results

- 118 / 134 (88%) simulated leaks successfully detected
  - Consistently detected down to ~200 psi with a 1/8” orifice, corresponds to 4.0 gpm water and 27.5 scfm nitrogen
  - Typically alarmed within minutes
  - Detected simulated leaks up to 8 feet away
- 16/134 (12%) simulated leaks not detected
  - Simulated leaks below ~200 psi become a challenge to consistently detect and characterize
  - Other contributing factors include high ambient activity, sensor proximity, and short leak duration
  - Detection accuracy can be improved with further algorithm development
- Zero false positives

Field Trial Conclusions

1. Field trial demonstrated technical readiness of High-Fidelity Dynamic Sensing DFOS system for pipeline leak detection with good accuracy and zero false positive rate

2. High-Fidelity Dynamic Sensing system sensitive down to ~200 psi, at low flow rates

3. Ongoing algorithm improvements will help further improve leak detection accuracy

Thank you

Questions?