Fiber Optic Sensing Association
Connect and Protect

FOSA

Fiber Optic Sensing for Pipeline Leak and Damage Prevention

Overview of Installation and Operation

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What is FOSA?

- The Fiber Optic Sensing Association ("FOSA") is a non-profit industry association formed in 2017 in Washington D.C.
- Provides North American education on the benefits of distributed fiber optic sensing technology, including through:
  - Webinars
  - Videos
  - White papers
  - Developing standardized industry practices
  - Public policy advocacy
- Membership is open to companies globally who make, install, support and use distributed/quasi-distributed fiber optic sensors.

FOSA Members

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Fiber Optic Sensing Applications

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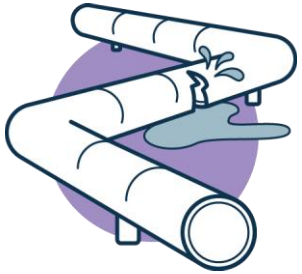
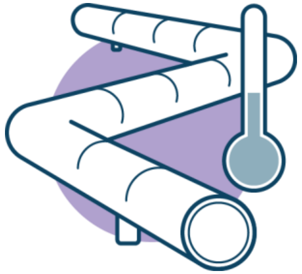
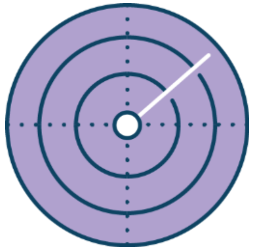


Pipeline Condition Monitoring



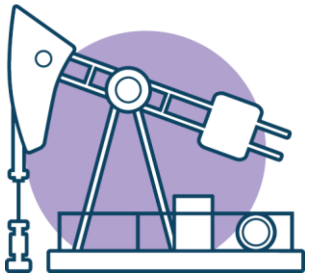
Pipeline Heat Trace Monitoring



Third Party Intrusion/Security

Geo-Technics

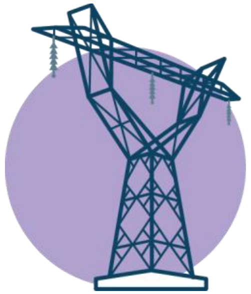
Transport Monitoring



Oil & Gas In-Well Monitoring

Industrial Process Monitoring

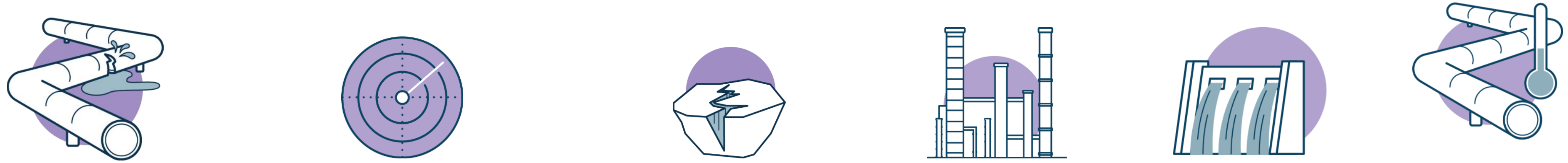
Structural Health Monitoring



Power Cable Monitoring

Key benefits / safety applications

- **Reliable** – Ruggedized interrogator, simple fiber optic sensing cable, little to go wrong
- **Safe** – passive sensor along pipeline, often dielectric, electricity only used at interrogator point / block valves
- **Secure** – buried, affixed, or aerially installed, tampering is immediately evident
- **Economical** – cost per sensing location is lowest on market, single fiber becomes thousands of sensing points
- **Scalable** – multiple technologies or applications on a single cable



Pipeline Condition Monitoring	Pipeline ROW Monitoring	Pipeline Geo-Technics	Pipeline Process Monitoring	Structural Health Monitoring	Pipeline Heat Trace Monitoring
Single Phase Detection Mixed Phase Leak Detection Subsea Leak Detection	Pipeline ROW Intrusion Hot Tap Theft Prevention Valve (Theft) Detection Perimeter security Subsea Pipeline Monitoring	Earthquake Detection Soil Erosion Monitoring Subsidence Monitoring Land Slide Monitoring	Slack line monitoring Slug Profiling Pig tracking	Pipeline Deformation / Hoop Strain	Pipeline Heat Trace Monitoring

Introduction

Distributed Fiber Optic Sensing (DFOS)

Installation Considerations

Use Cases

What is Distributed Fiber Optic Sensing?

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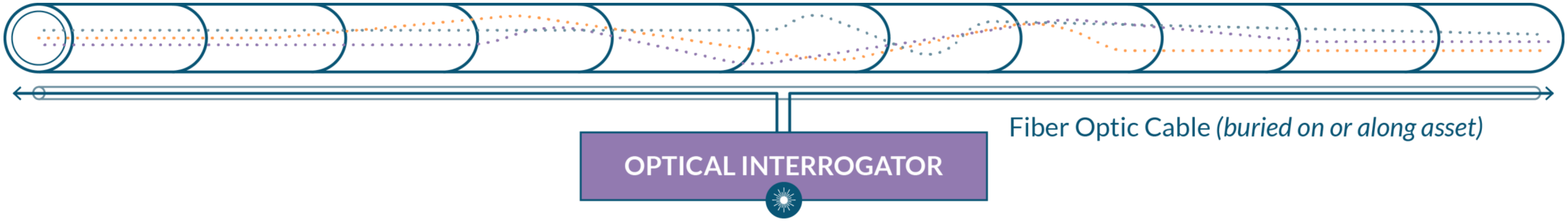
DTS — Temperature

DAS — Vibration

DSS — Strain

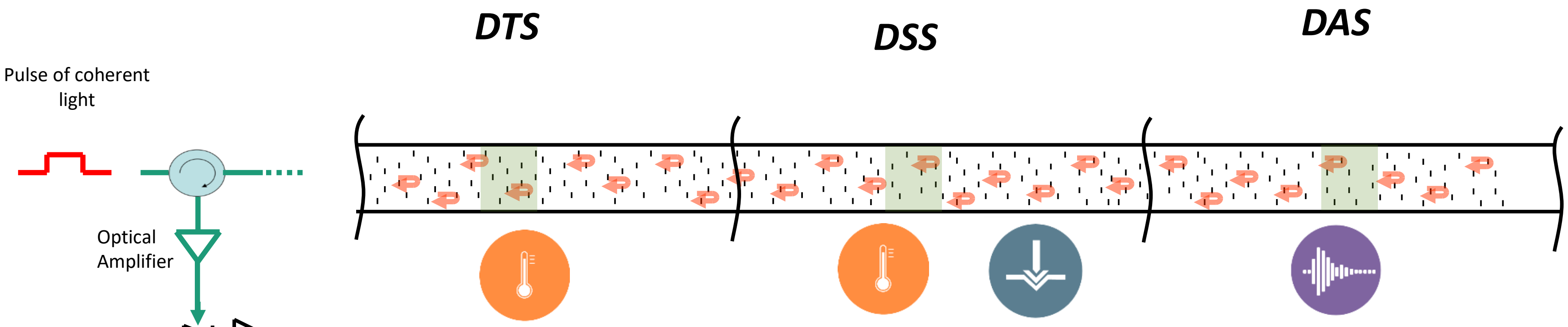
- Monitoring of fiber optic cables from a single location via pulsed laser light
- 24/7 Continuous Monitoring – over long continuous distances
- 1,000’s of sensing points – high resolution with meter size localization potential

- Passive sensor: No power along asset
- Monitors temperature, strain and/or vibration
- Multiple applications possible in a single system
- Upgradeable technology - without replacing sensor

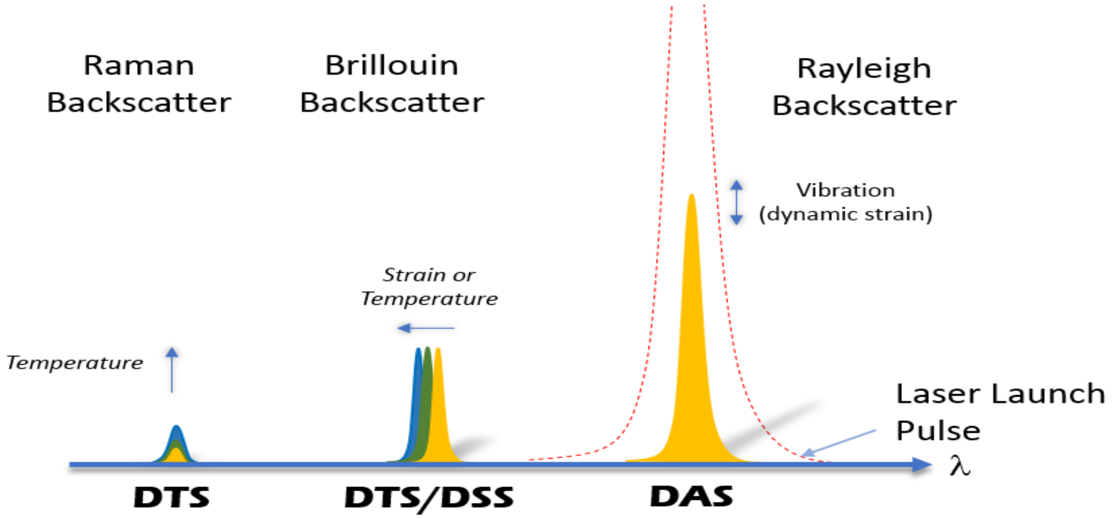


Signals extractable from a fiber

Note: shown figuratively – separate fibers / devices required for each technique



Mechanism: Raman Backscatter	**Mechanism**: Brillouin Backscatter	**Mechanism**: Rayleigh Backscatter
Signal: Thermally Excited Molecules	**Signal:** Thermally Excited Vibrations	**Signal:** Refractive Index changes
Responds to: Heat	**Responds to**: Heat, Strain	**Responds to**: Vibration, Heat, Strain



Brillouin based DTS / DSS is often combined in a single DSTS device

How Does It Work? – general concept

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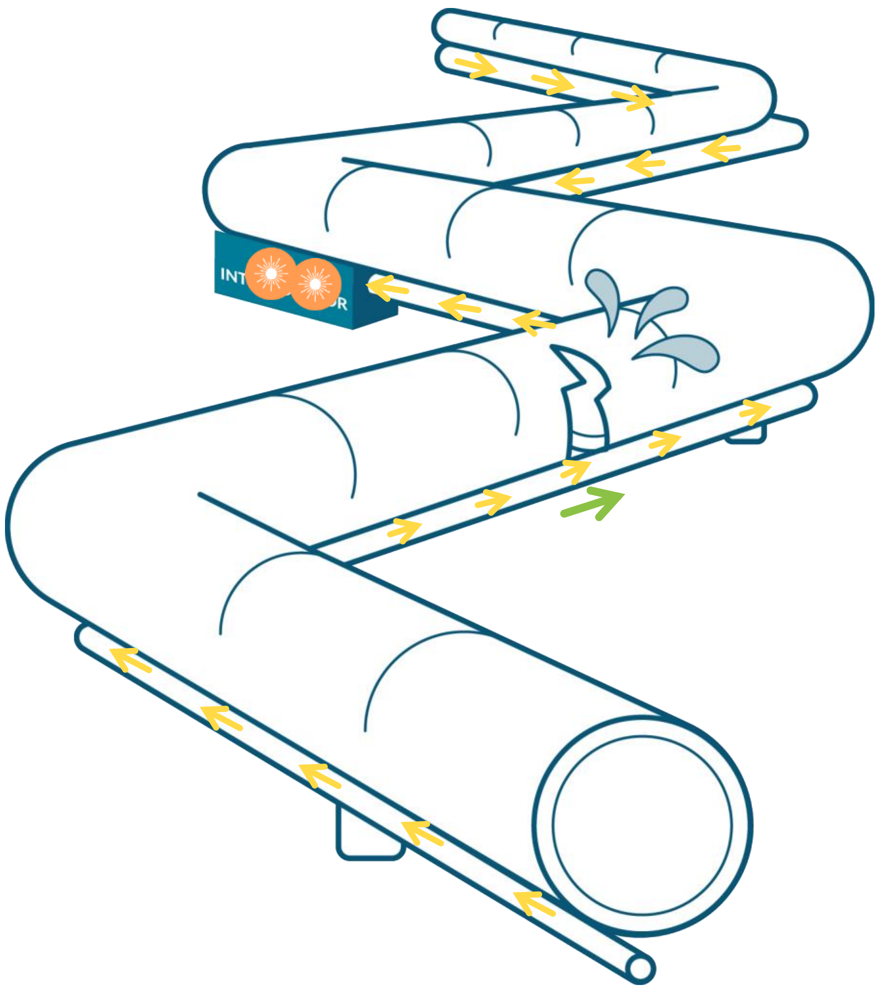
The phenomenon used to measure vibration, temperature or strain in a fiber optic cable relies on the interaction between a laser light and the glass in an optical fiber.

When light travels through a transparent media, the main pulse travels forwards, but a small fraction is back-scattered through interaction with the glass. This changes at every point along the cable in accordance with the local environment.

Different backscatter processes can be used to extract relevant information.

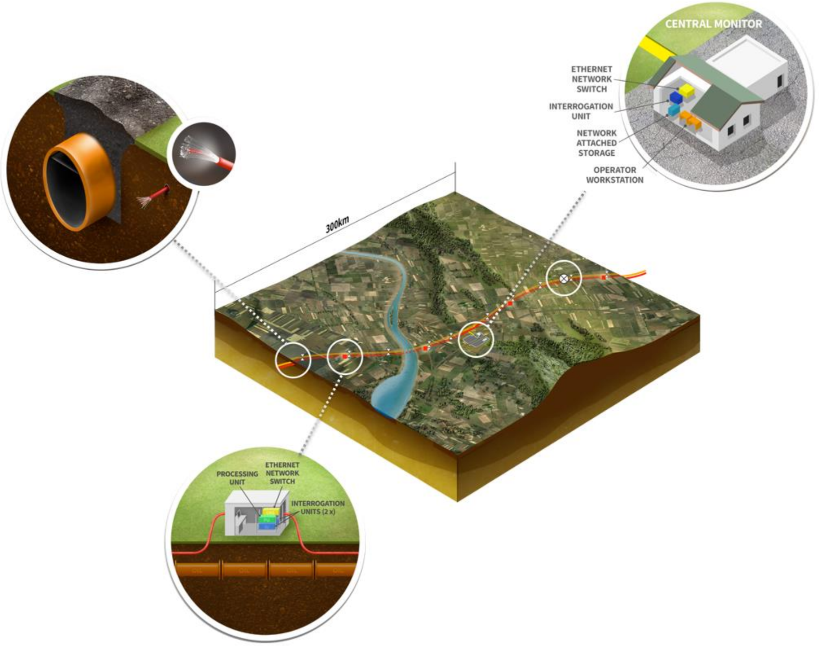
That backscatter signal can be exploited by different technologies to understand the external environment– strain, temperature, vibration, etc.

The end data can be used to understand the environment at every point along the fiber and act on the information.



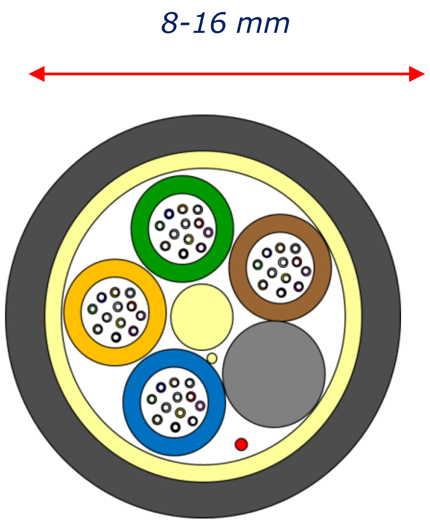
What are the Benefits?

- Long reach – spans greater than 50 miles (80 km) possible
- Quick scan – entire length scanned in seconds – real time reporting
- High spatial resolution – thousands of sensing points, detect every few feet
- Precise event location detection – know quickly and accurately when problems occur
- All dielectric – centrally powered, no risk of sparking
- Almost zero maintenance
- Add additional fiber to the sensor cable – built-in communications capability along rights-of-way / broadband delivery



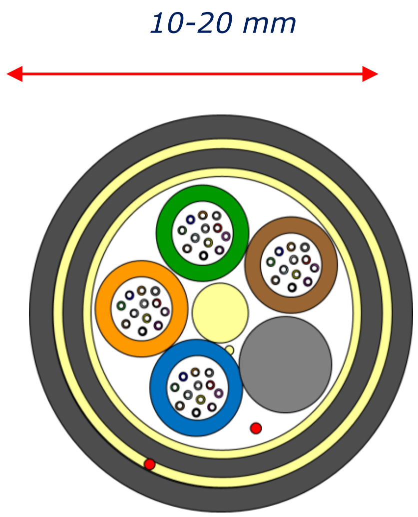
Per sensing point, there is no more economical way to monitor lengthy, critical assets

Selection of an appropriate cable



Single Jacket (All-dielectric)

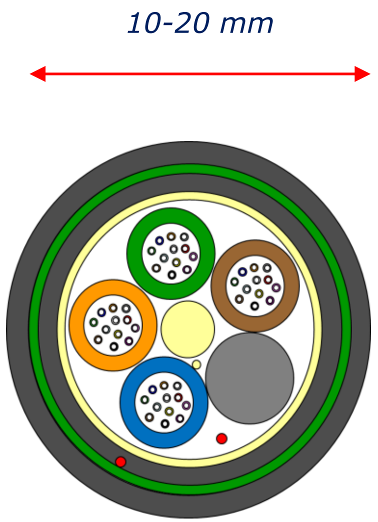
In Conduit



Double Jacket (All-dielectric)

In Conduit
(or Direct Buried)

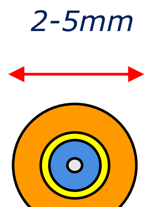
General Backbone Cable - Conduit

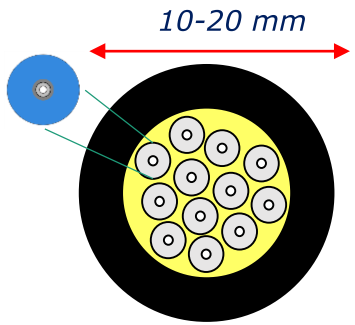


Single Steel Tape Armor
With one or two PE jackets

Direct Buried

General Backbone Cable - Buried



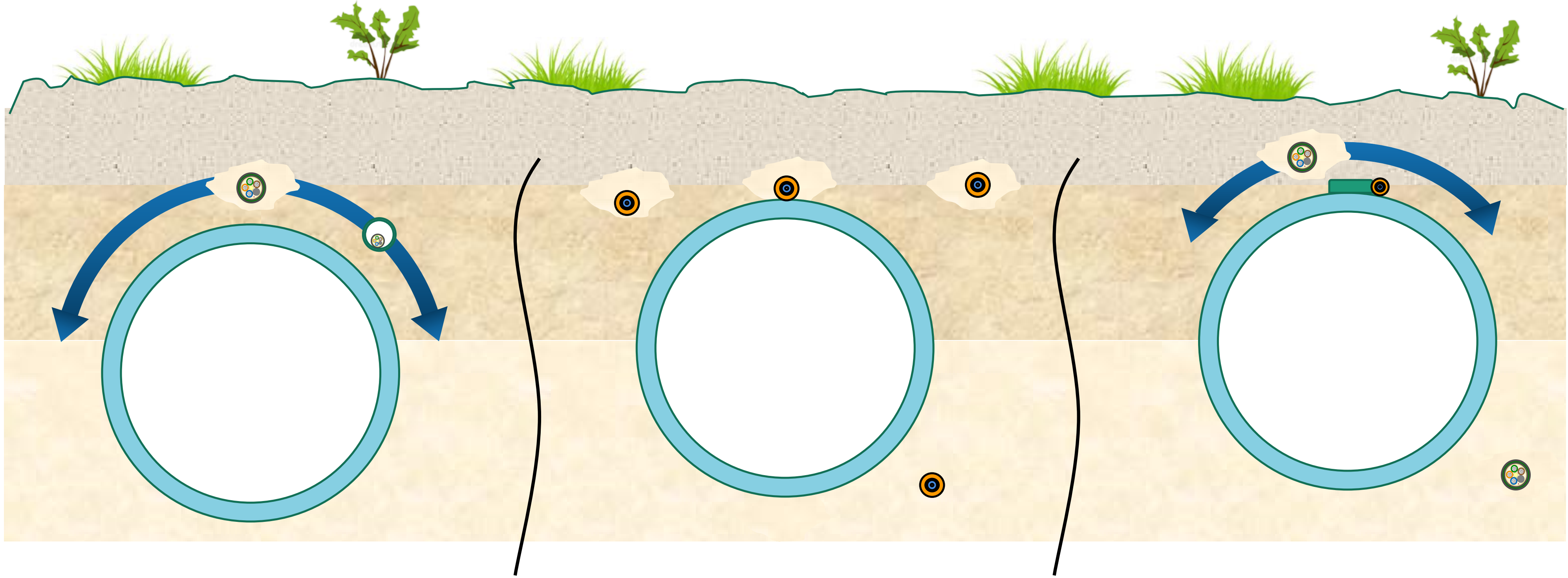


Tight Buffer Cable, shown as tactical cable (top) and Distribution unit (below)

Special Application (direct buried / conduit)

Fiber types also influence the application but are largely choices of varieties of Single Mode (in long haul and general formats) or short haul Multi Mode.
Raman DTS devices ONLY work on Multi Mode fibers

Optimizing the position for various techniques



<u>*DAS / Acoustic / Vibration Sensing*</u>

- *Optimum location for ROW Monitoring – upper half of pipeline, 0.5-1.0m below surface*
- *Optimum location for leak – minimum offset from pipe 0.3-0.5m*
- *Similar for armored / ducted cable*
- *Sand screening to protect cable*

<u>*DSS / Strain Sensing*</u>

- *Strain measurement delivered WHERE the fiber is:*
- *n soil close to pipe (~1m) – picks up soil strain*
- *at pipe bottom picks up soil sagging / lift*
- *strapped to pipe picks up strain coupled to pipe*

<u>*DTS / Temperature Sensing*</u>

- *Liquid leak applications – at pipe bottom (gravity spill) – 15-30cm*
- *Gas leak applications – above pipe (Joule Thompson cooling) – 15-30cm*
- *Trace Heat Monitoring – strapped to pipe / heating element*

Getting the fiber in the same trench

FERC

Utility Products Magazine

– Direct Buried Cable
  - Armored cable placed directly into the pipe trench, e.g. partially backfill, place cable – complete backfill
  - Good coupling and position orientation
  - Pauses to pipeline operation for splicing operation – cable in ~5-10km reels

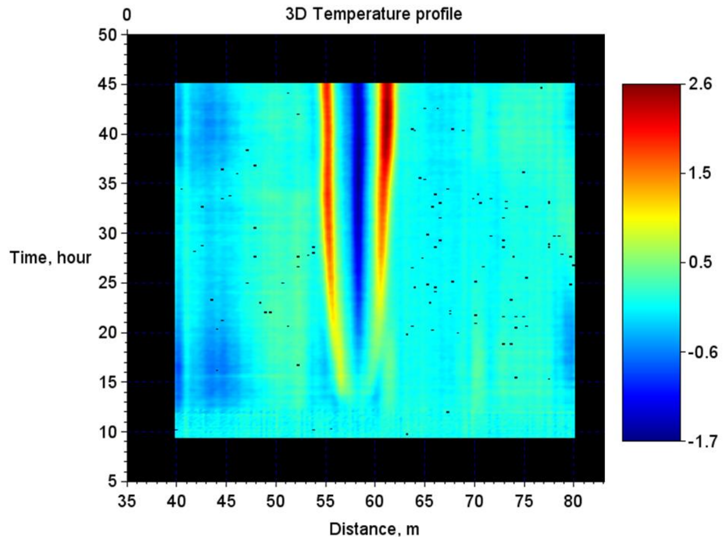
– Cable In Conduit
  - HDPE Conduit placed directly into the pipe trench, e.g. partially backfill, place conduit – complete backfill
  - Unarmored Cable blown through conduit once backfill complete
  - Less disturbance to pipeline lay
  - Less well coupled but compensated for by lack of armor
  - Not suited to all measurement types (retards temperature measurement)

– Retrofit
  - Currently in R&D with industry and government funding
  - Being addressed by both Government and Industrial R&D funding

Leak Detection

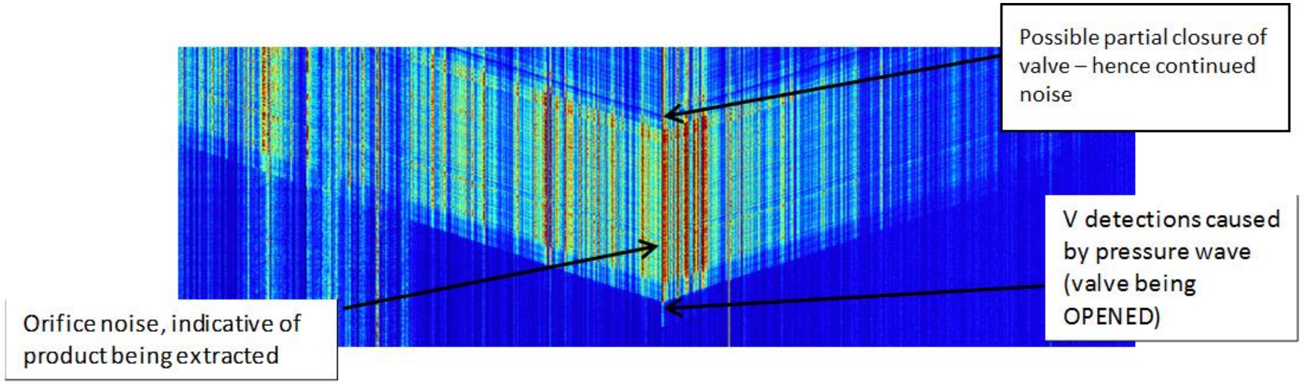
- Some/insipient leaks are associated with abnormal local temperature changes
  - Detection limit < 0.1% of flow – order of magnitude better than conventional CPM or Mass/Volume balance systems)
  - Thermal leak shows “signature pattern” that can be distinguished from surrounding conditions
  - Independent from leak size
- Dedicated alarming algorithm provides efficient leak detection

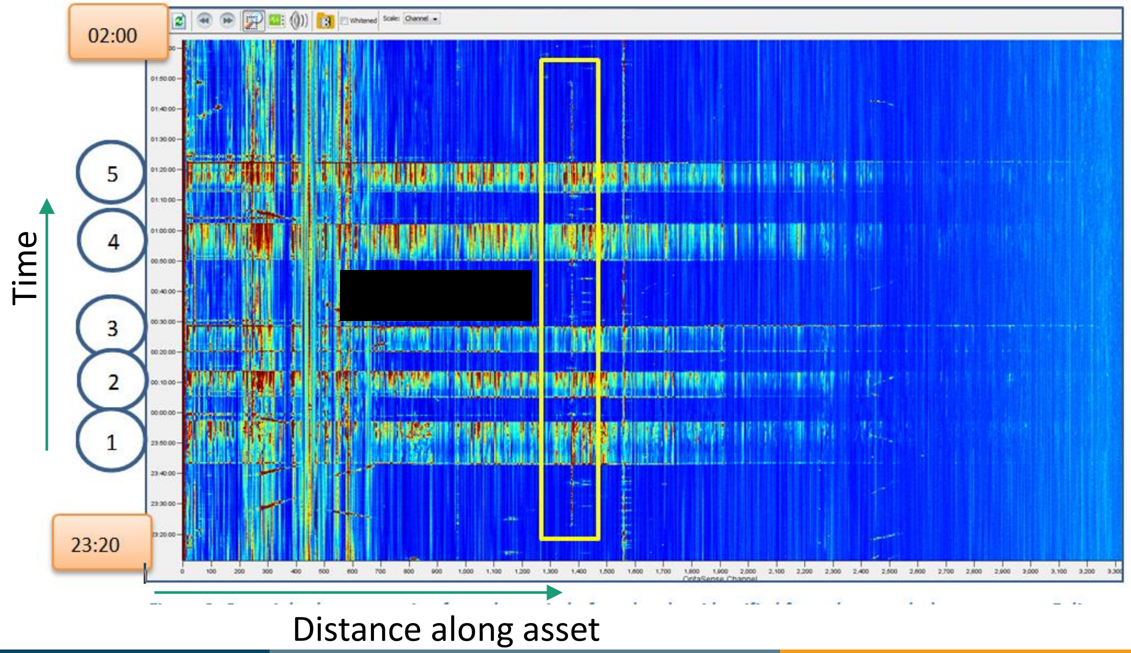
- Example: Controlled Methane leak
  - 800 µm pinhole size
  - 2.5bar gas pressure
- Alarming
  - ~15h after leak
  - <1.7°C measured DT



Pipeline and facility security

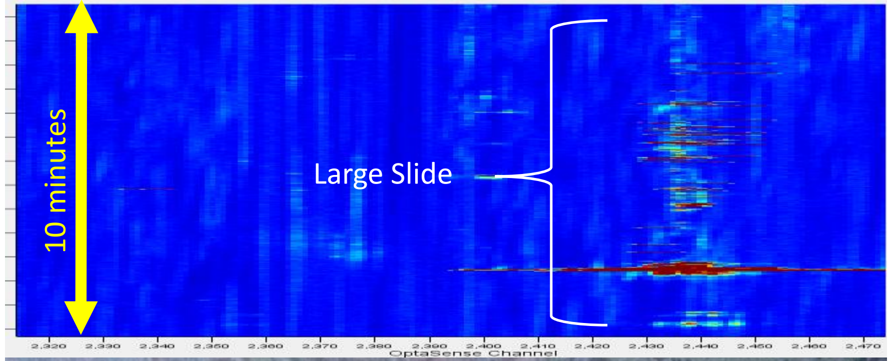
- Whether through theft or accidental damage, fiber optic sensing monitors 24/7 and protects in real time.
- In this example, illegal valve activity was observed – the data shows the sudden pressure pulse caused by the valve being opened
- 1st night – system alerts to operation of illegal valve (not one known to client) and identifies approximate position – activity repeated 5 times – each corresponding to ~1 tanker load
- Client heads to approximate location and is guided in by system to location with 10m accuracy



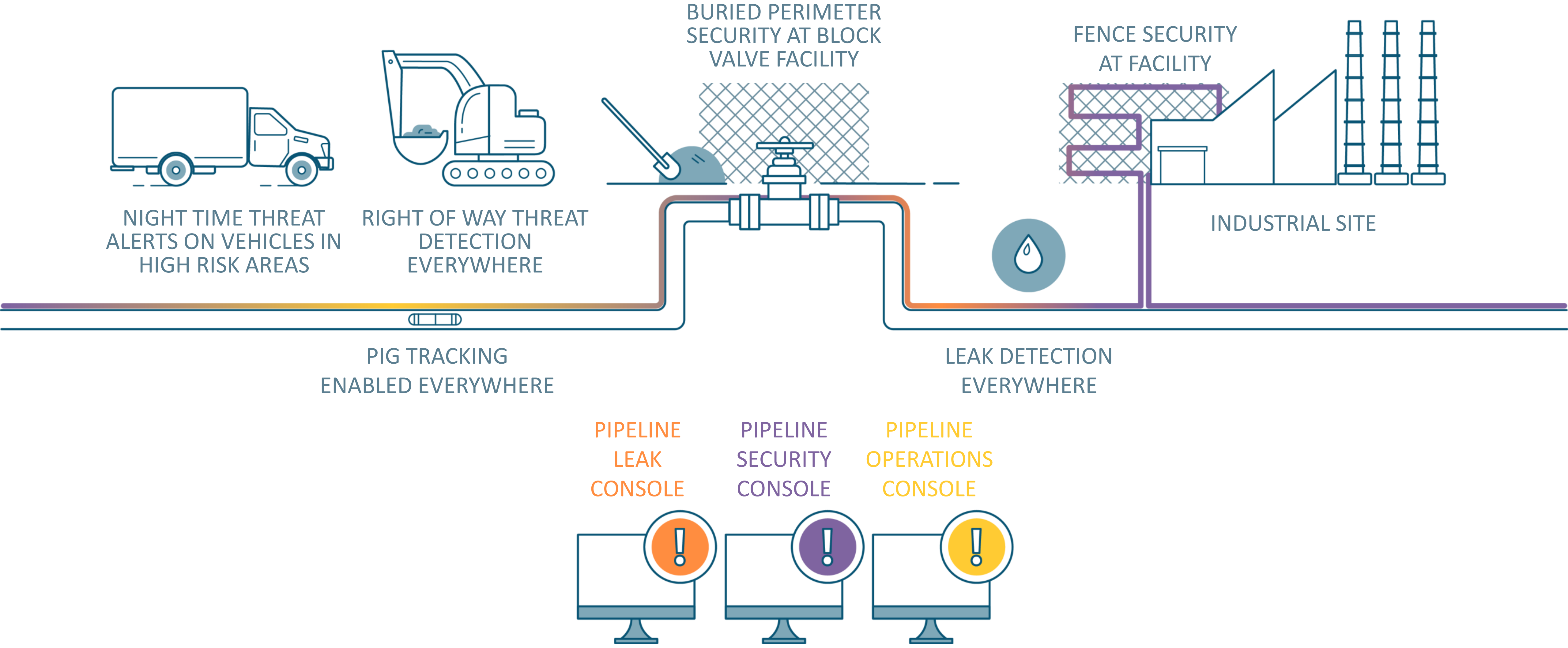


Rockfall and landslide detection

- Persisten rain within a canyon initiated a land slide that caused the track to be damaged
- Multiple landslide alarms were raised from the DAS system to the dispatcher and were announced over the voice radio



Individually Configured Zones



Take-aways

- Sense strain, temperature and/or vibration (acoustics) over spans exceeding 80 km (~50 miles) for each interrogator
  - DSS, DTS, DAS, DSTS
- Non-invasive – install alongside or on pipe – method dependent
- Distributed detection – spatial resolutions of 10 meters (~33 feet)
  - Less than 1 meter (~ 3 feet) is also common
- Detect gas leaks, liquid leaks, third-party intrusion (vehicles, footsteps, hand-digging, excavation, hot-tapping)
- Complements aspirations to create “zero incident” pipelines
- Proven technologies - worldwide

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