Fiber Optic Leak Detection and Integrity Monitoring for Pipelines

IPLOCA's Fall Novel Construction Session Geneva

José María Álvarez, 21/10/2020

Company overview

Fibre Optic based Distributed Temperature, Strain and Acoustic/Vibration monitoring with unique capabilities for long distance with highest performance

- Privately-owned Swiss company, established 1999
- Spin-off from Swiss Technology University Lausanne (EPFL)
- Headquarters & Production in Morges, Switzerland
- Second office in Brazil
- Highly qualified and dedicated team
- Worldwide customer base
- ISO9001:2015, ISO140001:2015, OHSAS 18001:2007

Energy Focus

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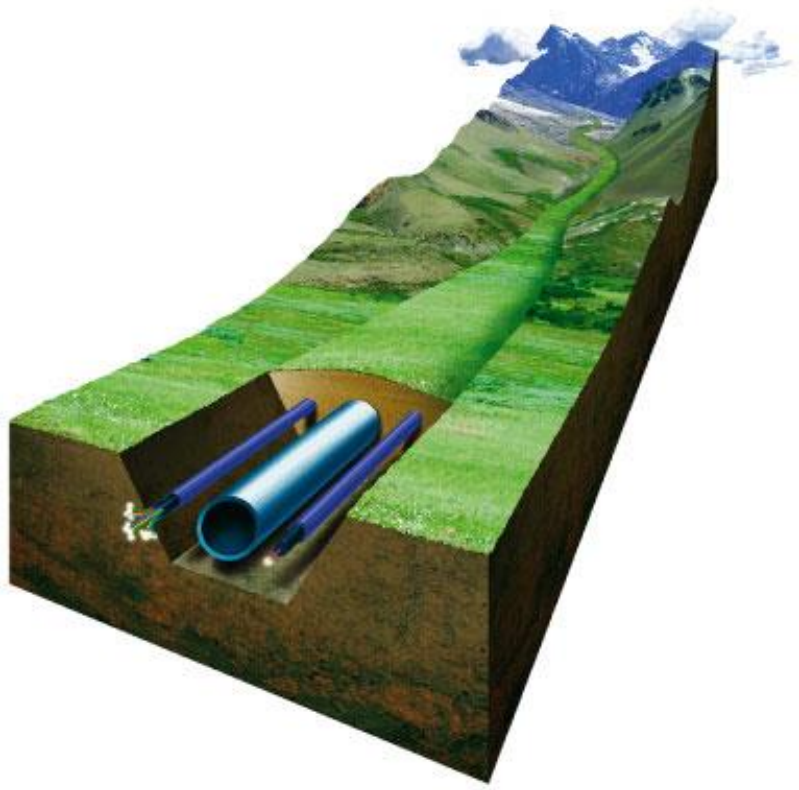
Securing asset integrity

Distributed Fiber Optic Technologies

Working Principles



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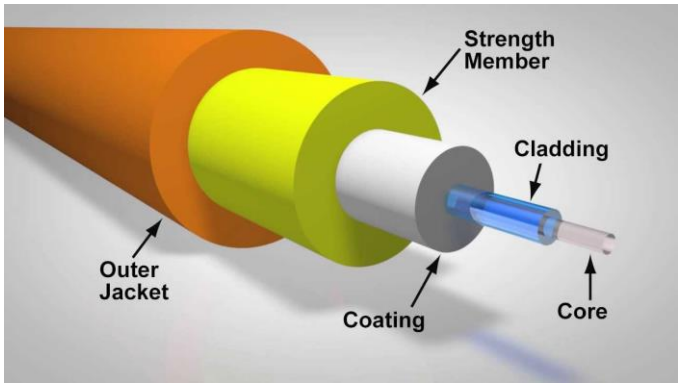
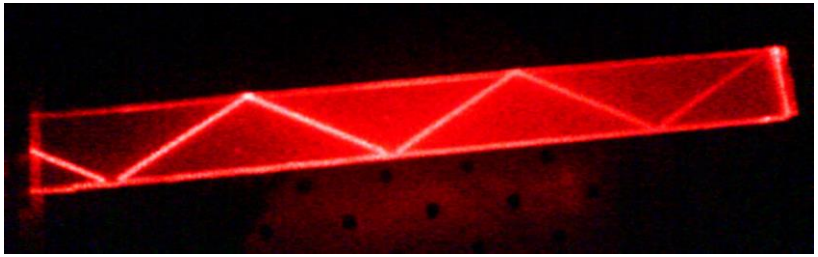
Optical Fiber Guidance

Credit: Harvard University



Credit: Thorlabs Inc.



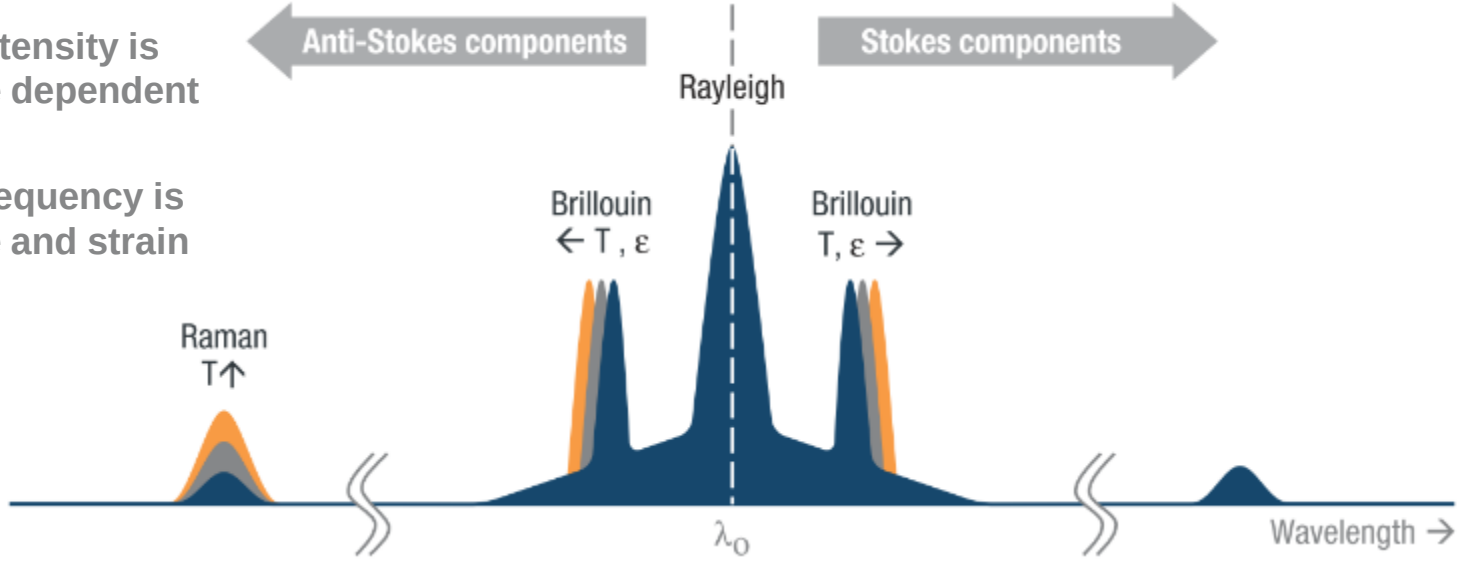
Total internal reflection on PMMA guide using a HeNe laser

Backscattering Mechanisms

Rayleigh
Detection and analysis of scattered intensity

Raman
Scattered intensity is temperature dependent

Brillouin
Scattered frequency is temperature and strain sensitive



Brillouin based DTS/DSS

Time Domain

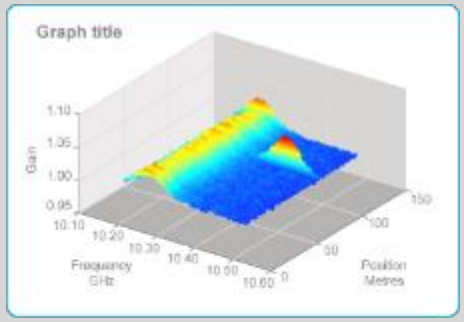
The activating signal is a propagating pulse and the position is given by the time of flight.

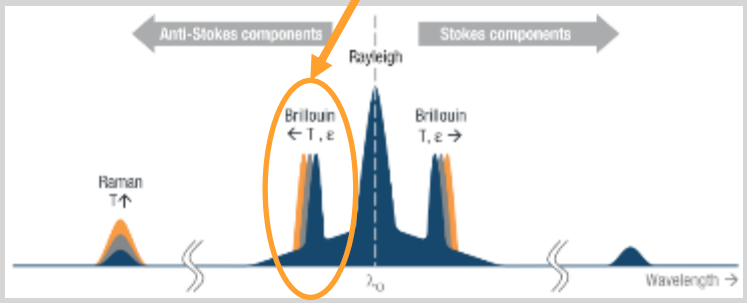
Spatial resolution is given by the pulse width.

+

Frequency Domain

The frequency shift is computed by recording the Brillouin spectrum at different frequencies and extracting the maximum peak location.





BOTDR: spontaneous scattering, single end access

BOTDA: stimulated scattering, loop configuration

Rayleigh based DAS

Time Domain

The activating signal is a propagating pulse and the position is given by the time of flight.

Spatial resolution is given by the pulse width.

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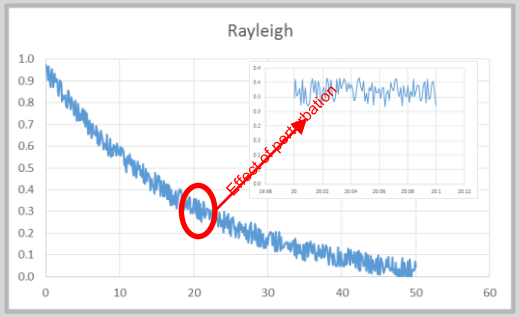
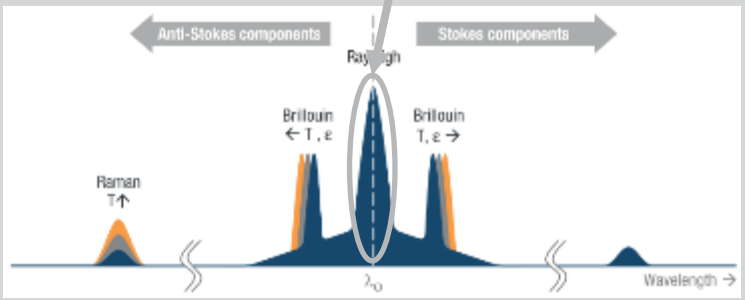
Intensity/phase Domain

The intensity/phase variations of the Rayleigh signal as a function of time provides acoustic signature.





Long Range Distributed Sensing

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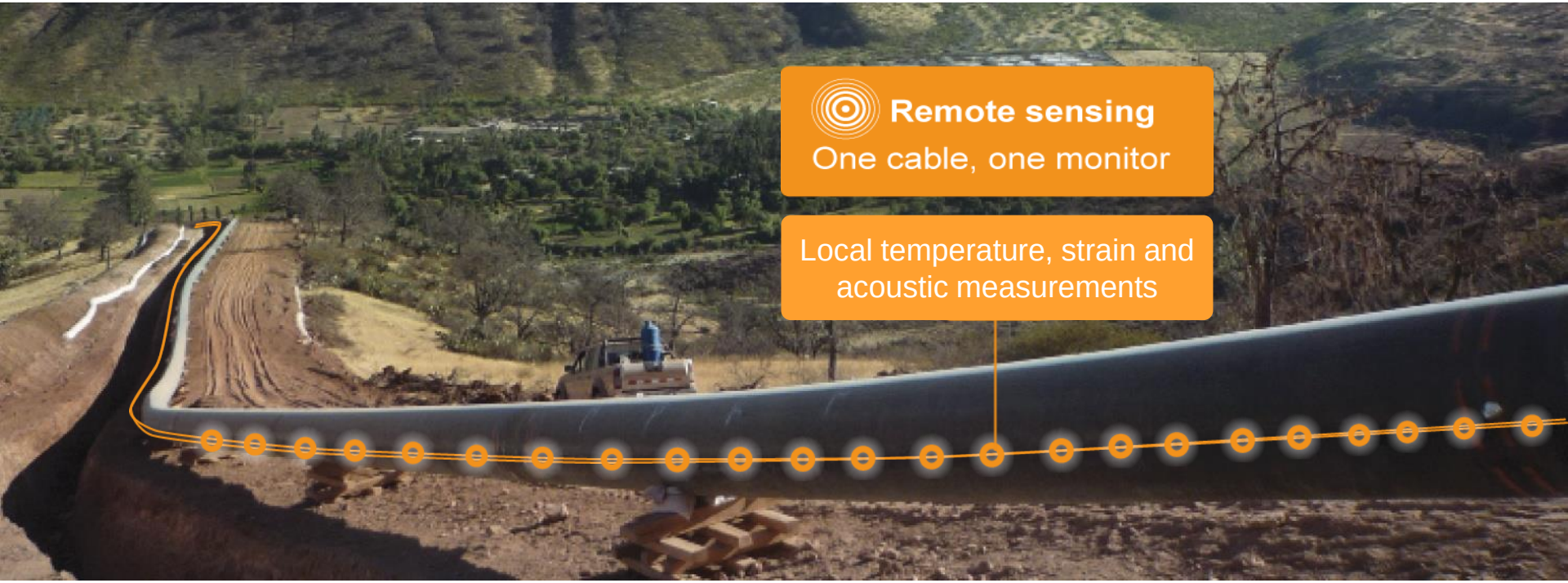
Turning optical fibers into a fully distributed sensor



Lynx Pipeline Monitoring System

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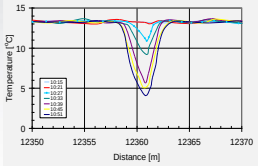
Early detection of leaks, geo-hazards and intrusion threats

Pinpoint location within meters

Minimum false alarm rate

Leak Detection



- DTS/DAS or DTS+DAS
- >100 km range
- Few meters accuracy
- Measurement from seconds to few minutes
- Suitable oil products, crude oil, gas, chemicals or water

Intrusion Threats

- DAS based
- 100 km range
- ±10 m location accuracy
- 5 m human digging
- 10 m machine digging
- Very fast detection

Geo-Hazards

- DSS & DTS based
- Focus high risk areas
- Micro-strain sensitivity
- Few meters accuracy
- Soil erosion
- Terrain subsidence
- Ground movement

How does it work? Leak Detection

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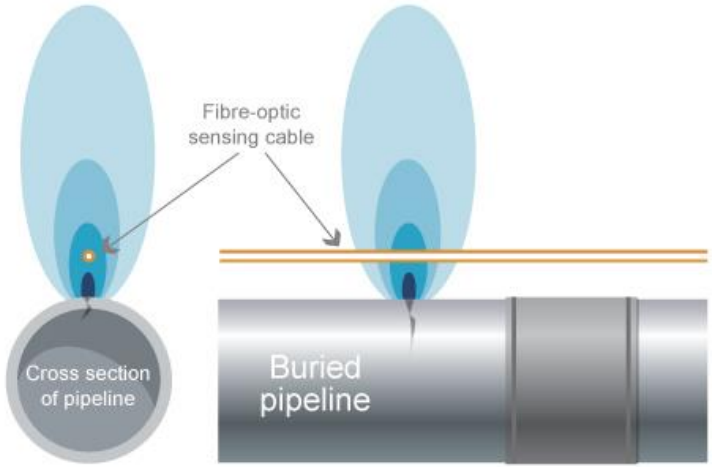
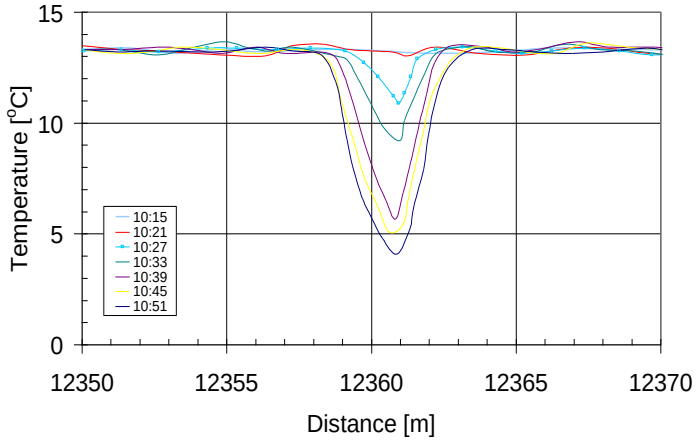
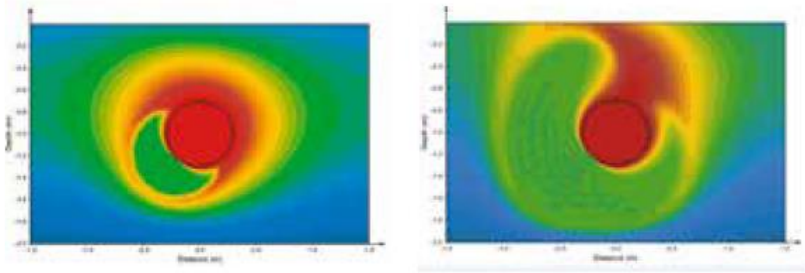
- DTS based – Local temperature difference caused by released fluid
- DAS based – Acoustic signature caused by released fluid
- Crude oil, oil products, gas, chemicals, water pipelines

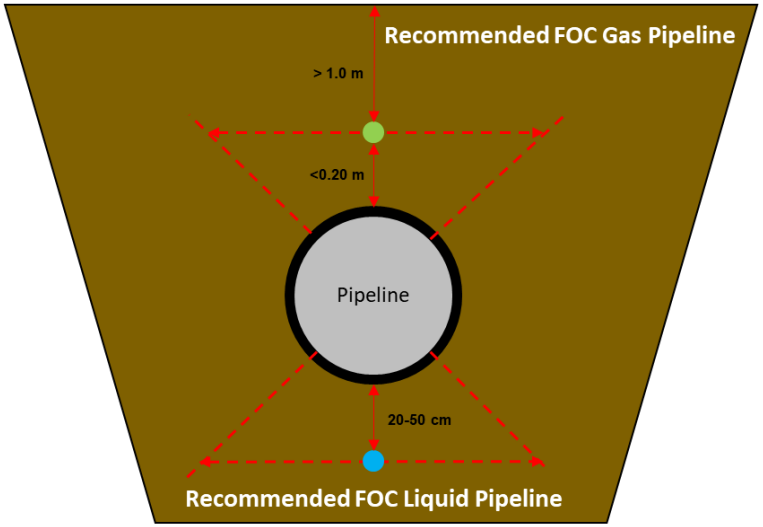






Simulations showing the rapid temperature changes occurring after a leak at 7 o'clock/0700 hour position in a gas pipe.

How does it work? Leak Detection



- DTS based – Standard telecoms FOC with loose tube.
- DAS based – Standard telecoms FOC with either loose tube or tight buffer.
- Optical fibers must be Single Mode (ITU-T G652C/D or G655)
- HDPE deployment possible but direct ground burial recommended

How does it work? Intrusion Threats

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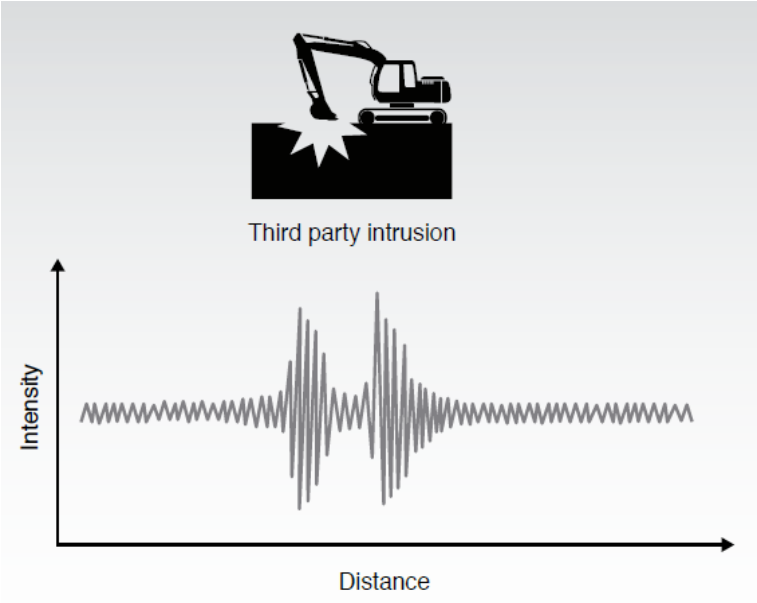
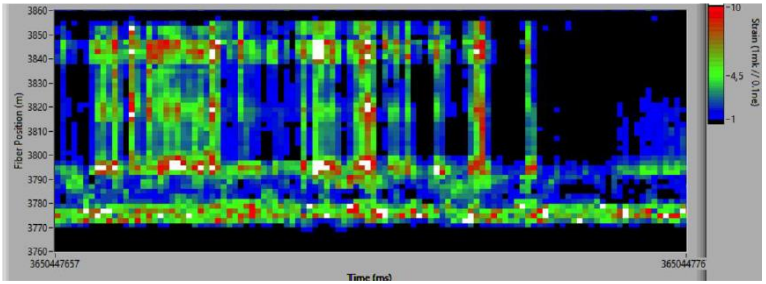
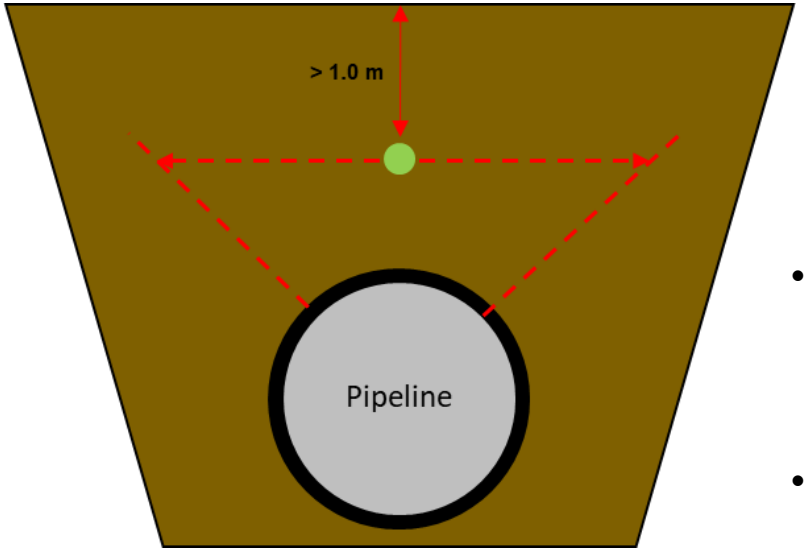
Analysis acoustic signature of potential pipeline threats

- Human activity 5m around FOC
- Machine activity 10m around FOC
- PIG tracking
- Others (i.e. seismic events)





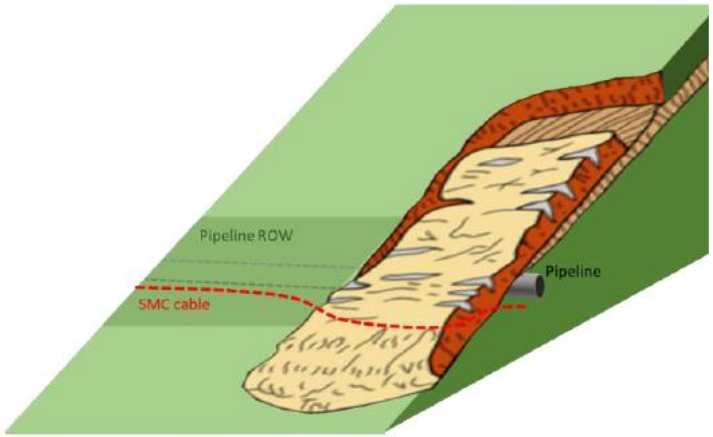
How does it work? Intrusion Threats

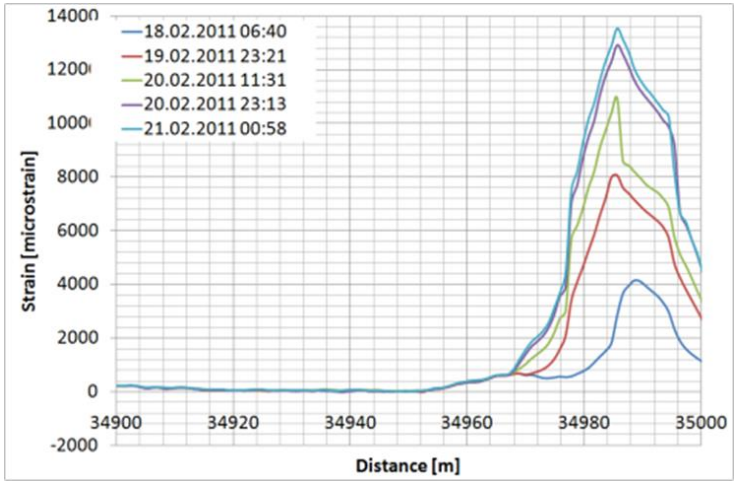


- DAS based – Standard telecoms FOC with either loose tube or tight buffer.
- Optical fibers must be Single Mode (ITU-T G652C/D or G655)
- HDPE deployment possible but direct ground burial recommended

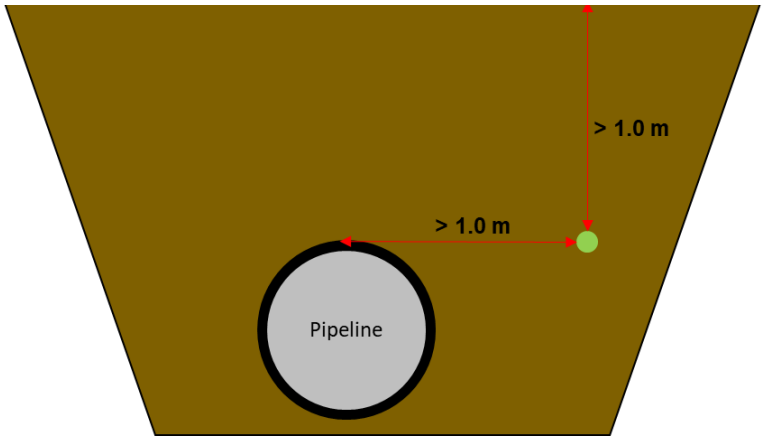
How does it work? Geo-Hazards

- DSS – Landslides, terrain subsidence, pipeline deformation, etc.
- DTS – Soil erosion
  - Water infiltration
  - Wind erosion

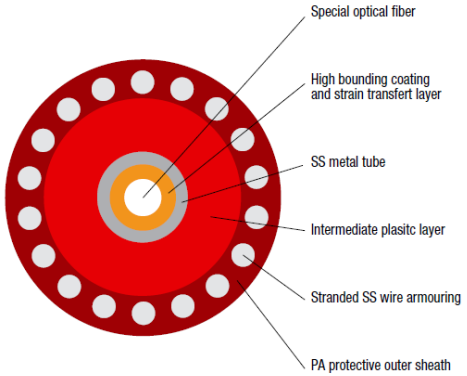




How does it work? Geo-Hazards

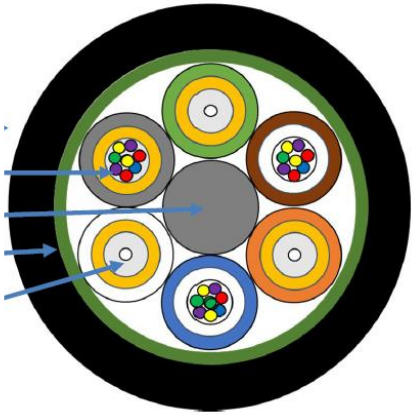


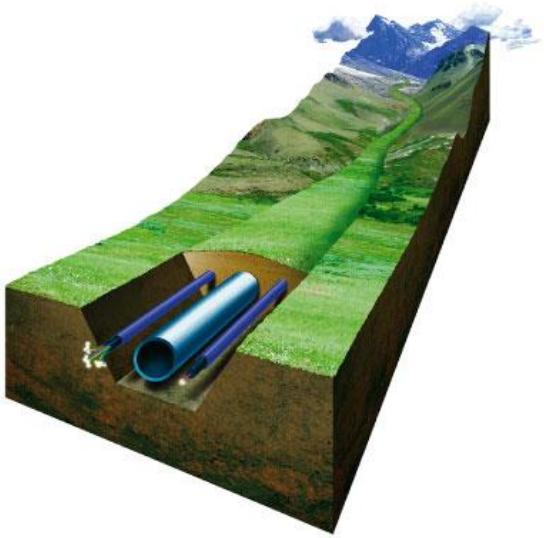
Strain Monitoring Cable (SMC-3)



- Special tight buffer strain sensing FOC required
- Optical fibers must be Single Mode (ITU-T G652C/D or G655)
- HDPE deployment not possible. Must be direct ground burial

AIMCOM Monitoring Cable





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Lynx System Overview

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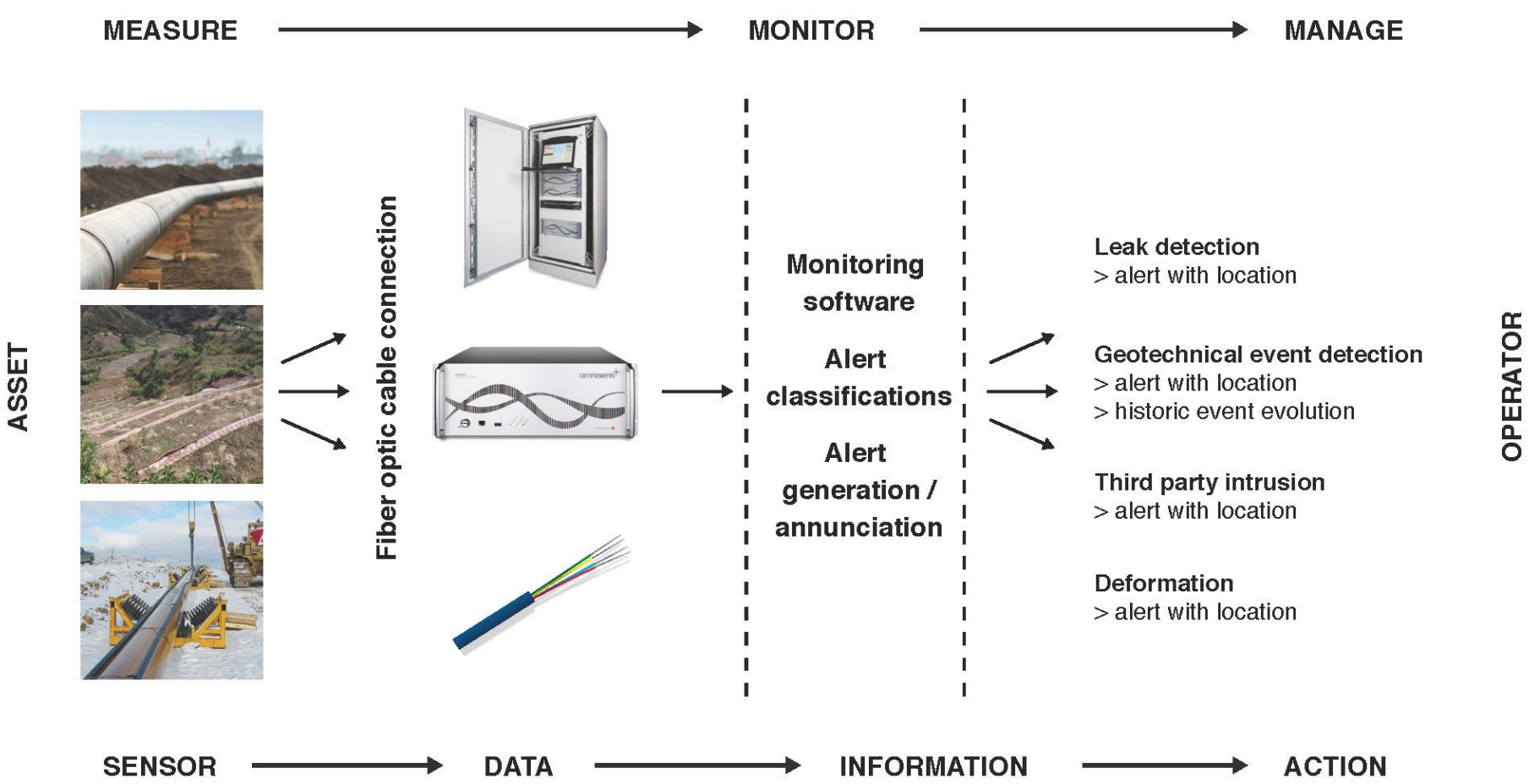
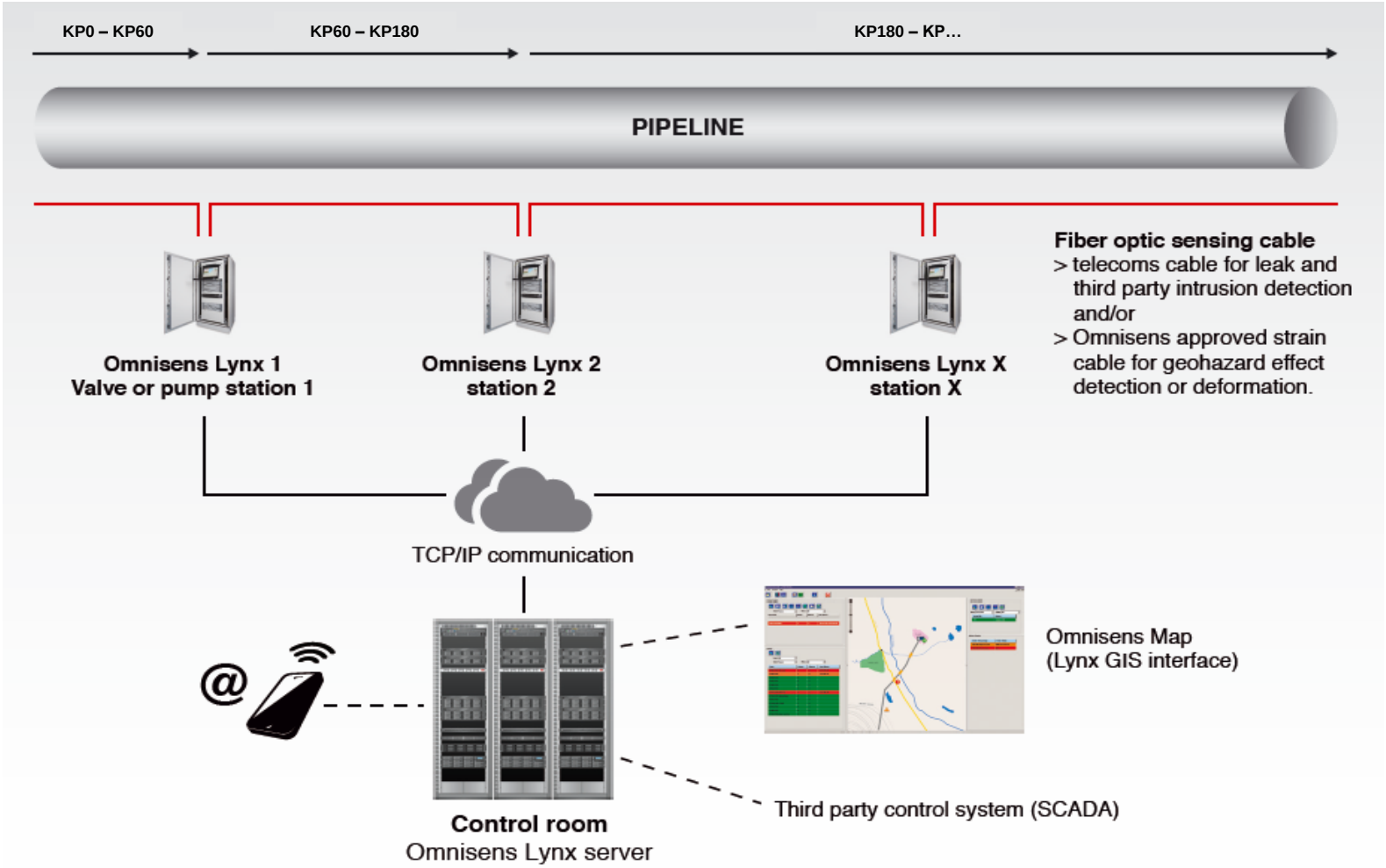
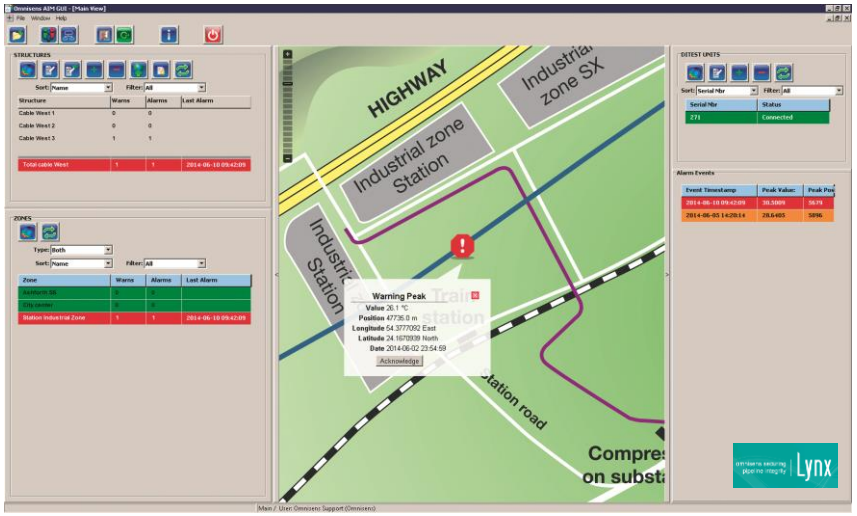
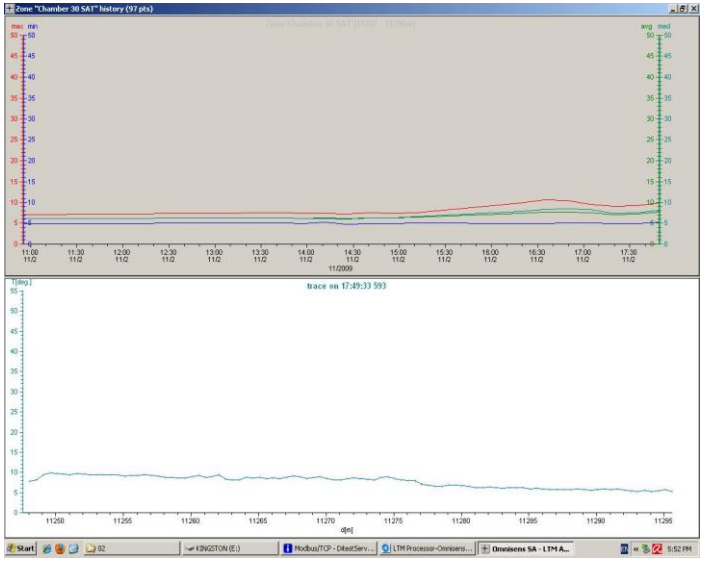


Lynx System Architecture



Lynx Software





- Alarm/warnings:
  - GPS coordinates
  - KP
  - Time & date
  - Alarm Info
- Alarms/warnings on:
  - GIS map
  - SCADA
  - Email
  - Relays

Omnisens' Lynx

Case Studies

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The Peru LNG Pipeline

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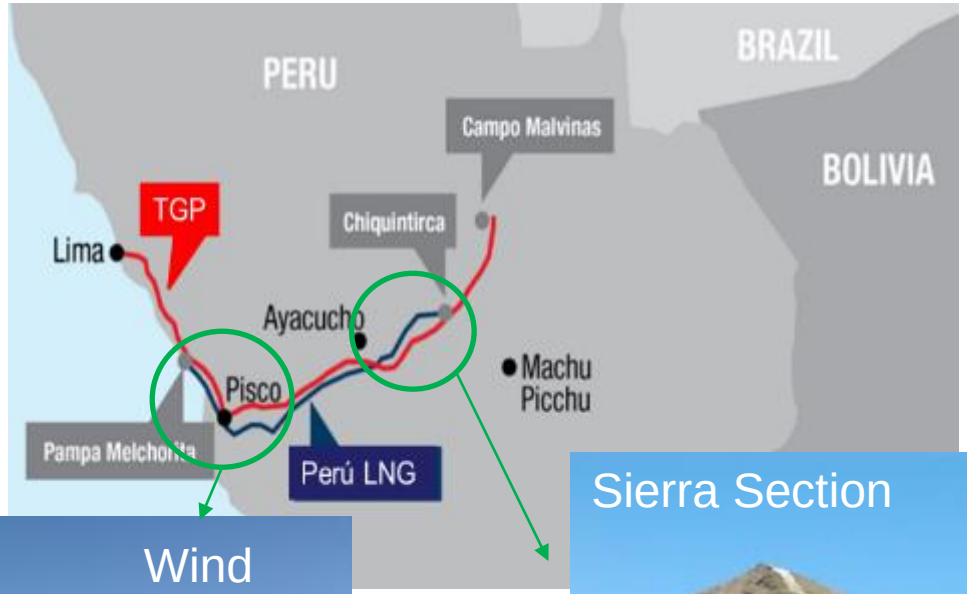
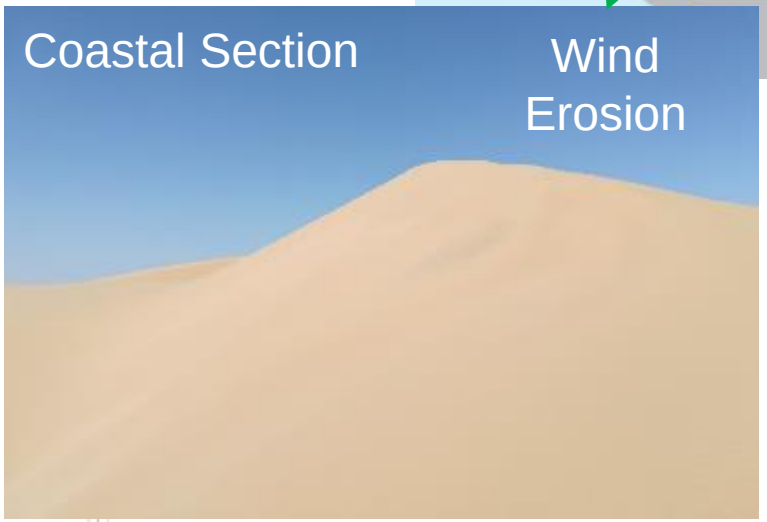
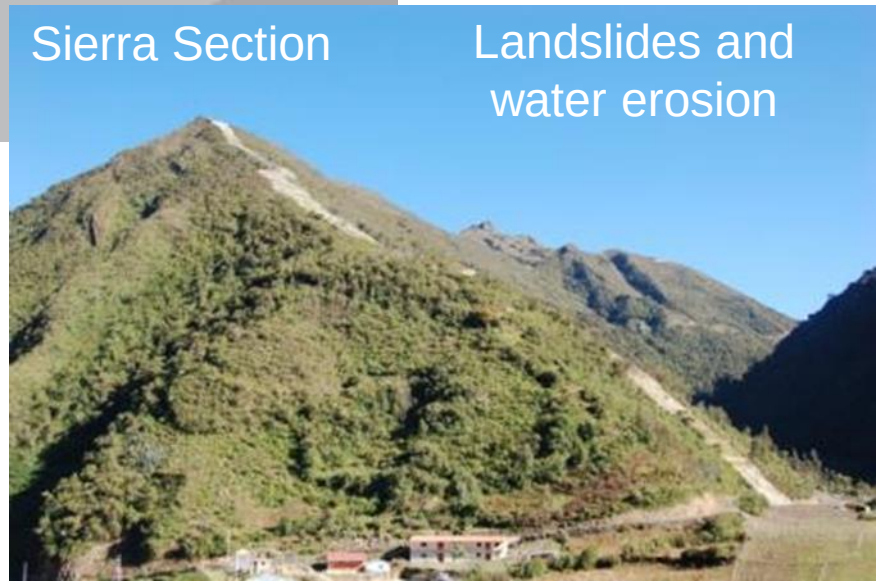
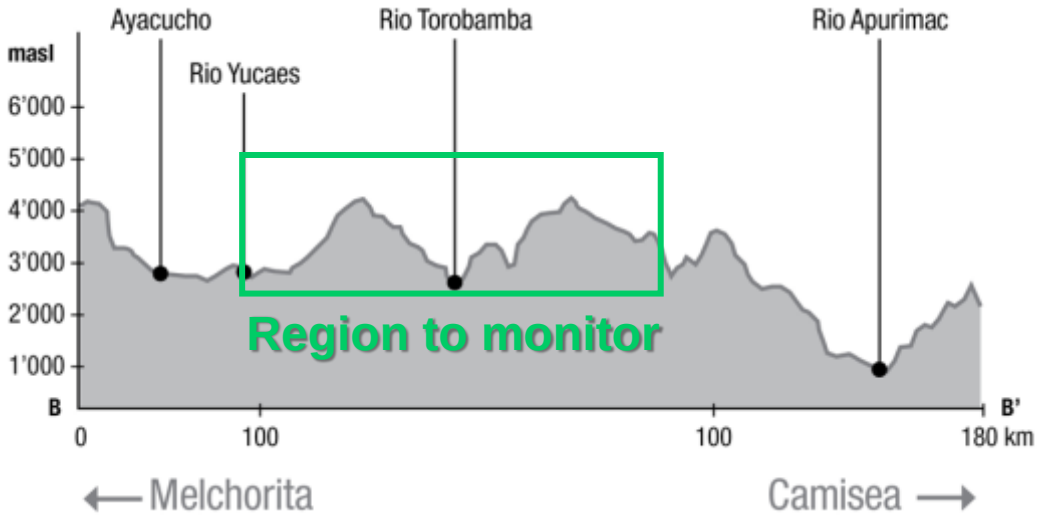




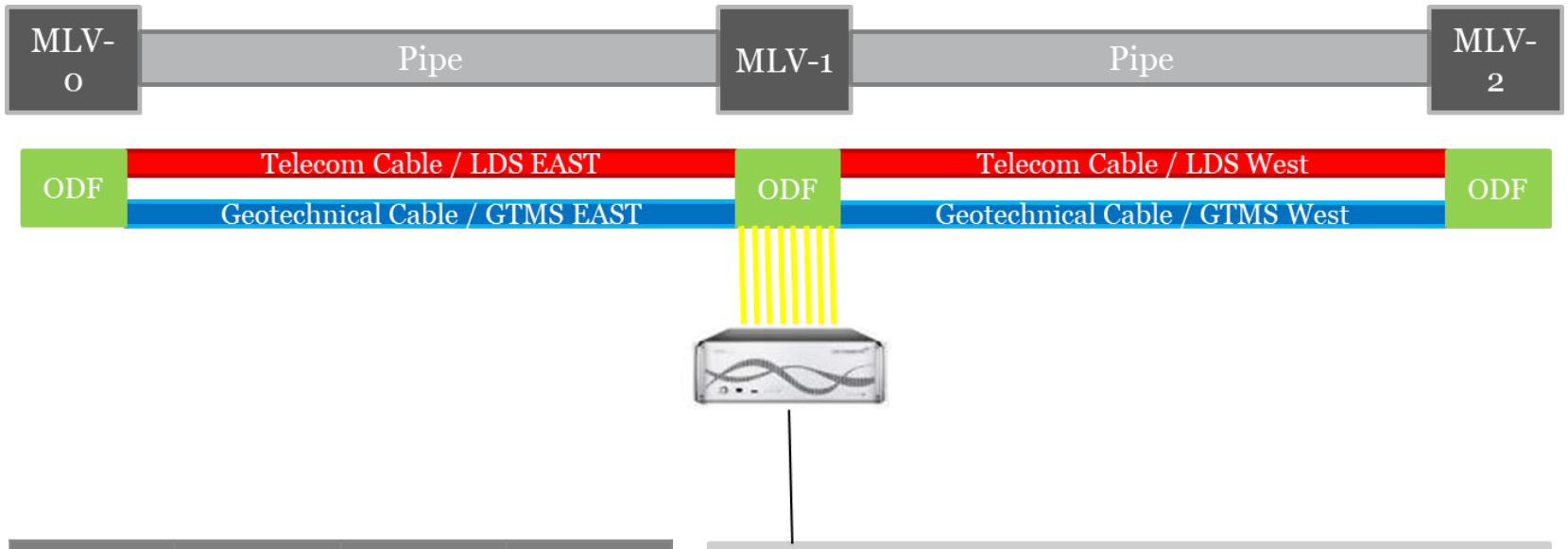


Perú LNG: the challenge



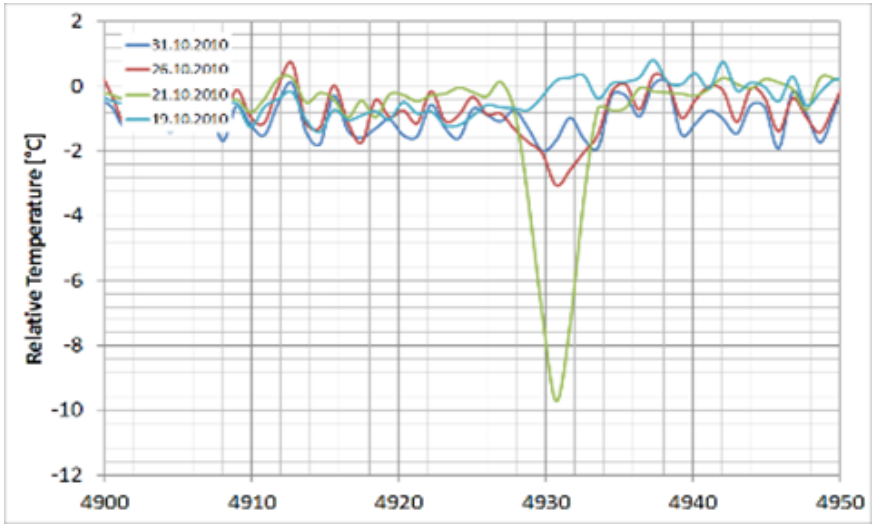
- **Pipeline crosses region with following profile:**
  - Steep slopes, high peaks, deep valleys, canyons
  - Climate from warm humid to cold temperate with heavy precipitations at rainy season
- **Several sections over 60km classified as high geohazard risk zone**
- **Need for geotechnical monitoring system**

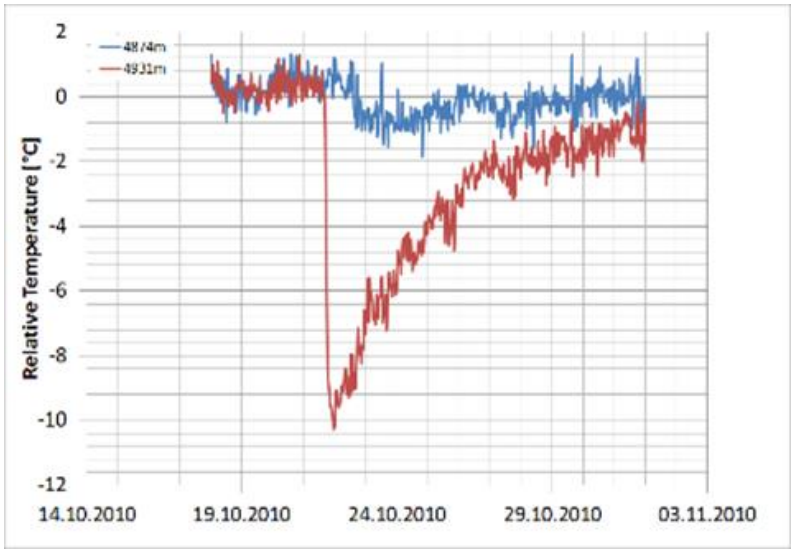
System architecture



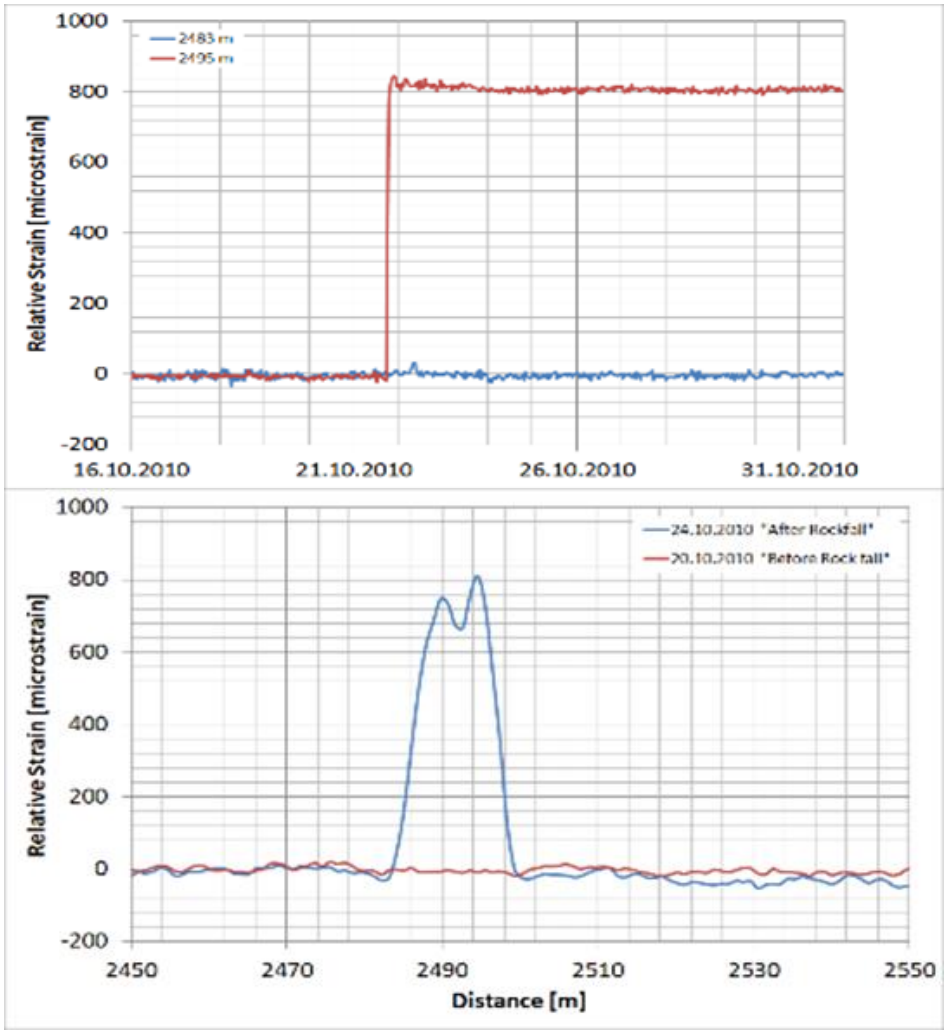
Span	FO Cable	Sensor	Measured Parameter
MLV-0 to MLV-1	Telecom	LDS East	Temperature
	Geotechnical	GTMS East	Strain
MLV-1 to MLV-2	Telecom	LDS West	Temperature
	Geotechnical	GTMS West	Strain

Water Infiltration

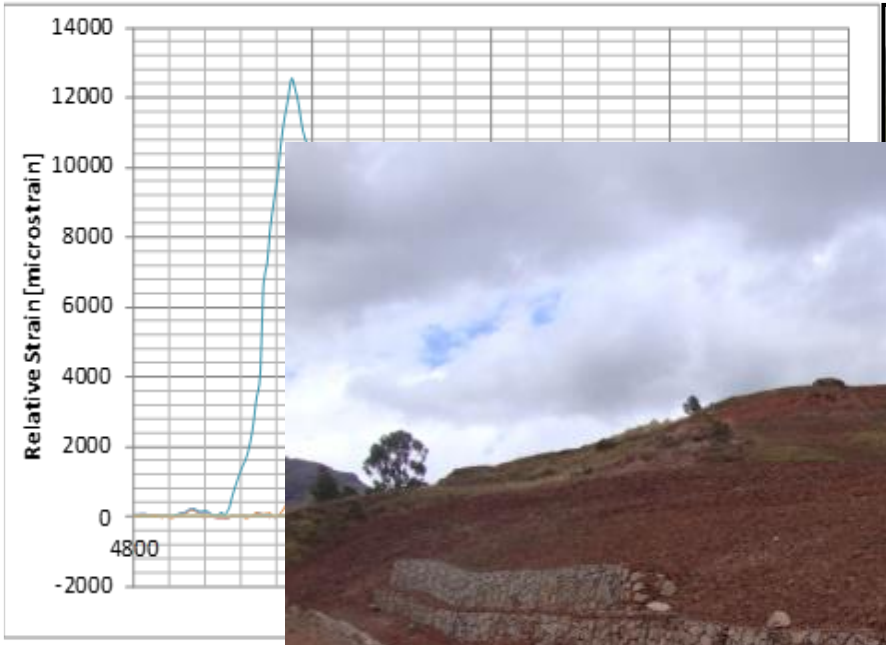




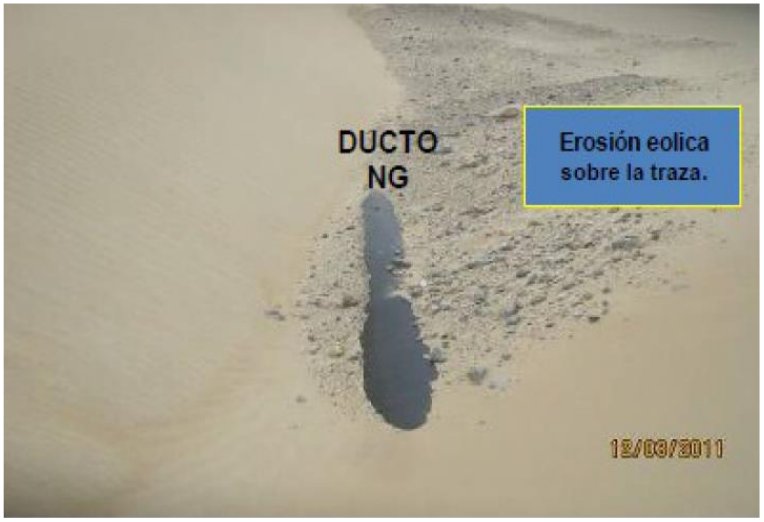
Rock Falls



Landslide

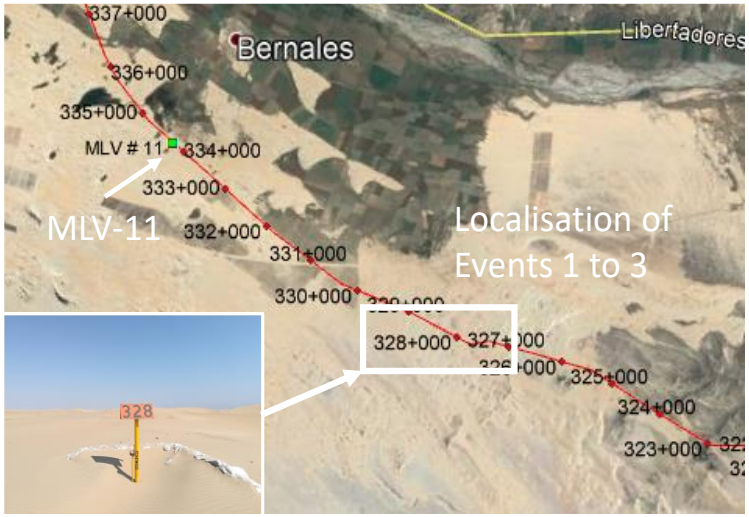


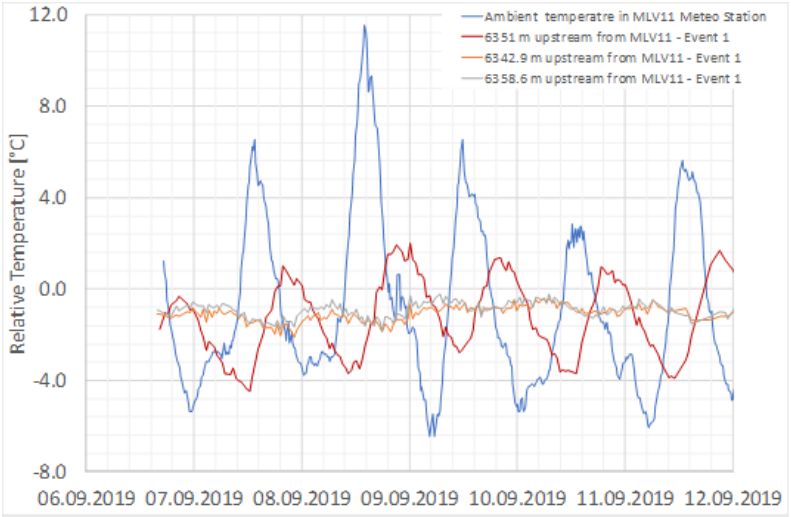
Sand Dune Migration & Wind Erosion

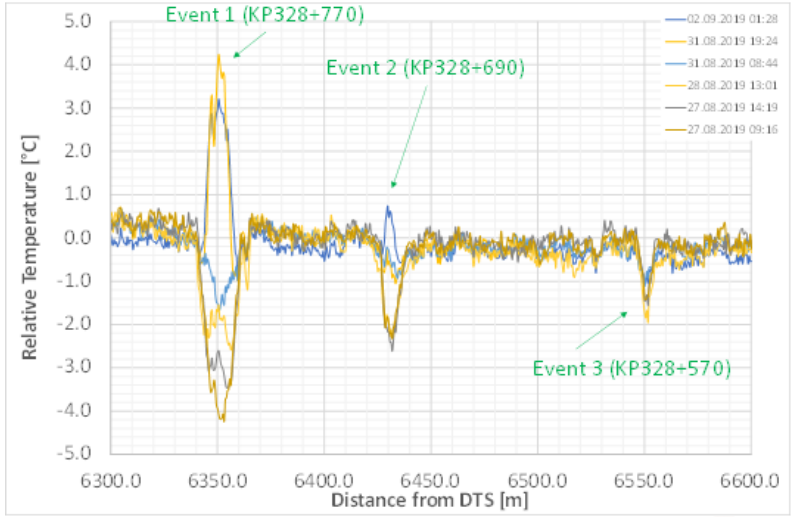


Route MLV10 to MLV11 – Dune Area

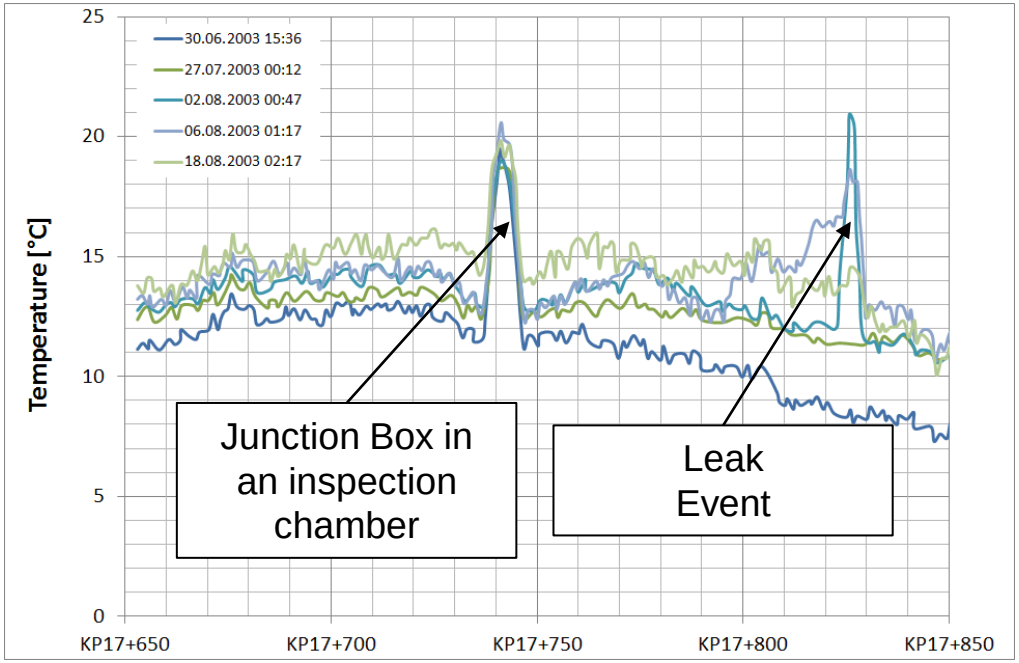
Events near KP328







Berlin Brine Pipeline



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Pipeline