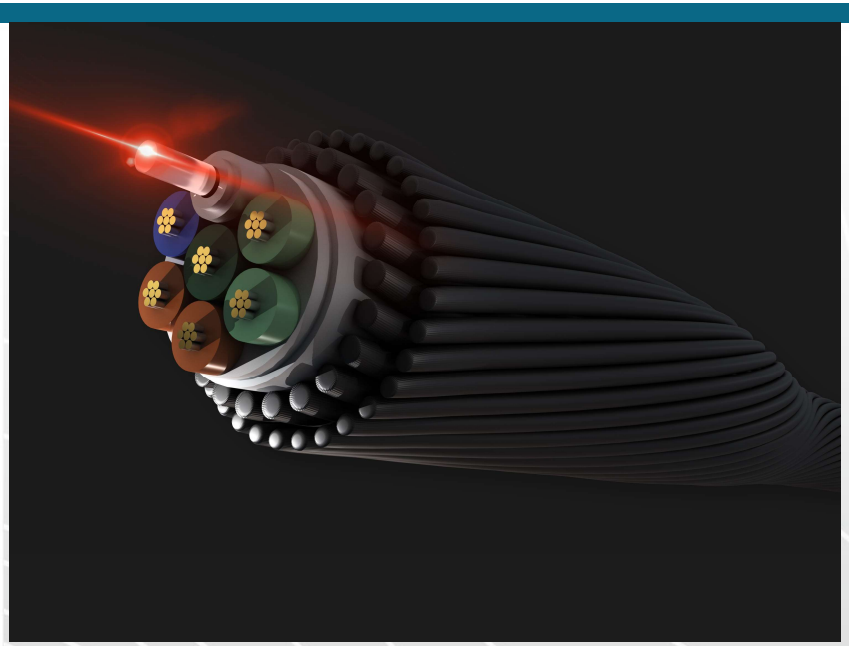
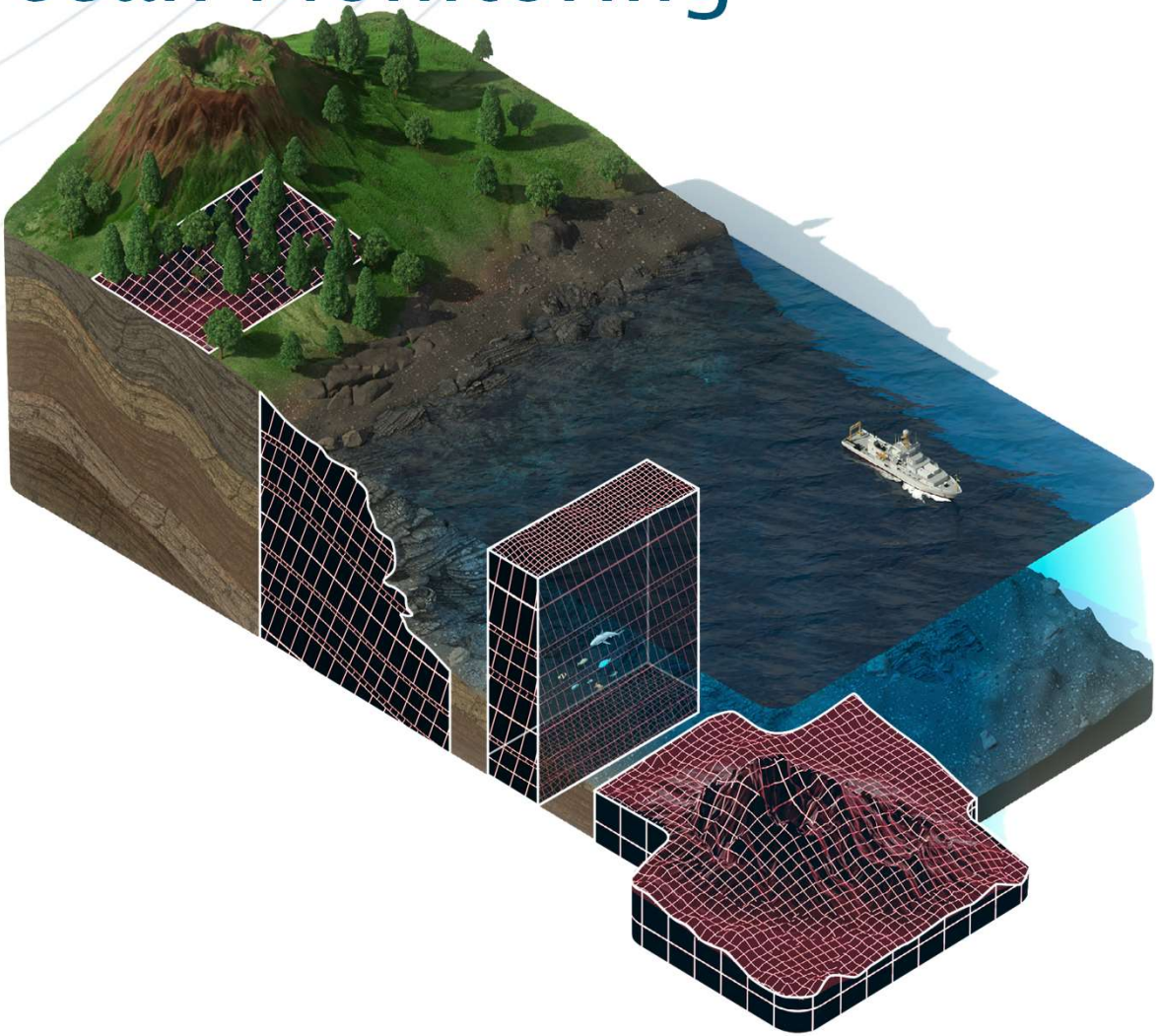


Fiber Optics Sensing

Technologies and Applications

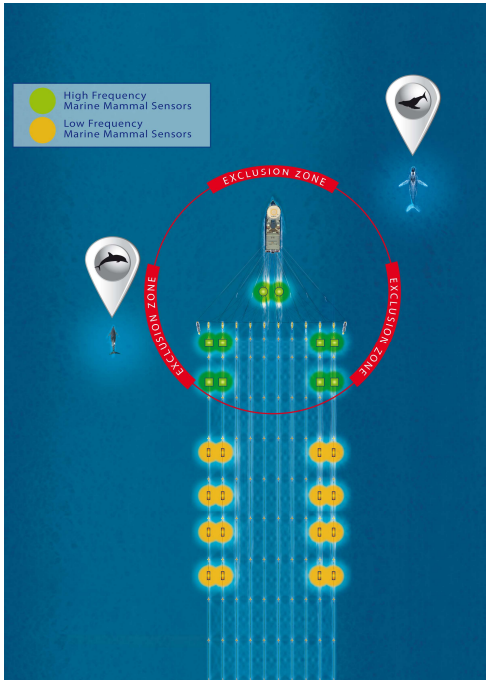
July, 2023

Earth & Ocean Monitoring



Background in Oil & Gas domain

- 25-years of regulation for wildlife protection
- Large investments of Sercel to follow and go beyond
- Marine Mammal Monitoring system
- Automated & Real-time



Seabed monitoring equipment

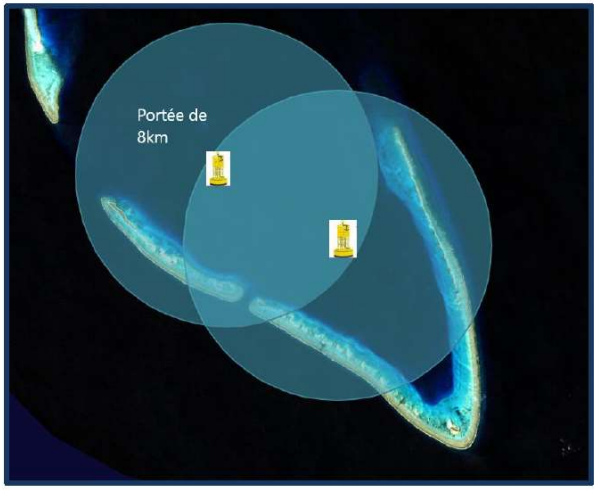
- To study effects of anthropic noises (maritime works, traffic) on benthic life
- 4-channels broadband seismometer
- 60 days of autonomy
- Up to 300-meters water depth

Deep water seabed monitoring equipment

- To monitor marine landslide and prior weak signals
- To image subsurface without seismic source
  - Ambient noise tomography
- 4-channels seismometer
- 180 days of autonomy
- Up to 6000-meters water depth
- Free-fall / self pop-up deployment

Acoustic buoy network

- Automatic ship detection by acoustic monitoring
  - Allow detections without relying on AIS signals
- Low operational cost
  - Few data transmitted by satellite as processing is done in the buoy



Underwater acoustic communications

Long-range solutions

MATS 3G-12

- Solutions for long range in noisy environment
- Up to 15Km
- Only 40mW in reception

High-speed solutions

MATS 3G-34

- Solutions for high-speed in mid-range horizontal transmissions & shallow water environment
- Up to 24,6kbps
- Licence free

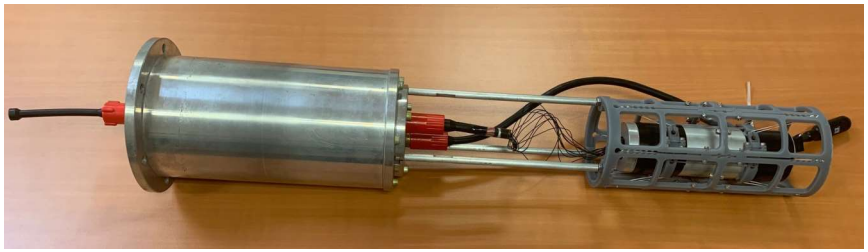
IoT solutions

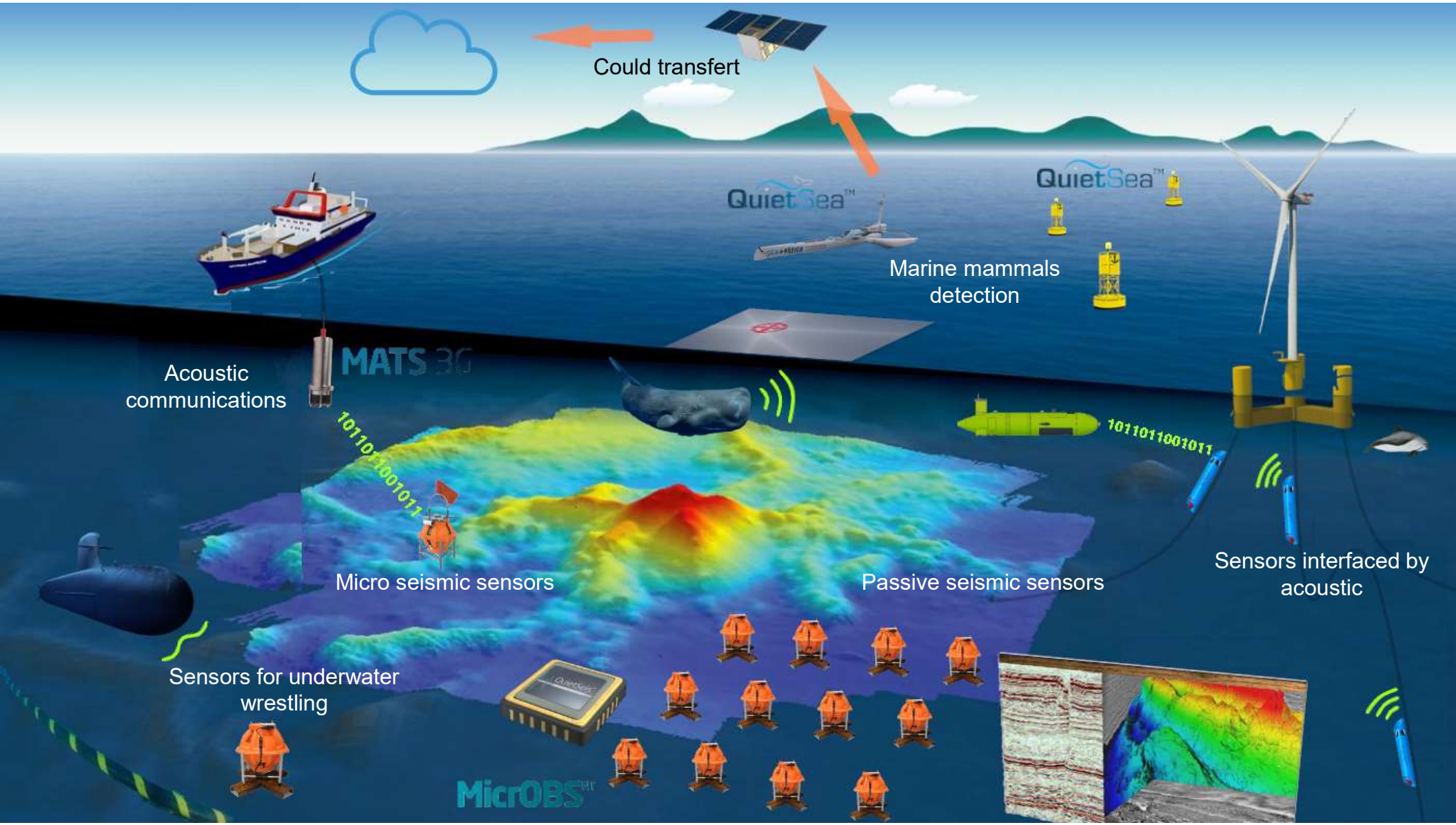
- Solutions for acoustic network applications
- Only 15mW in reception
- Cost effective & Compact design

AVS

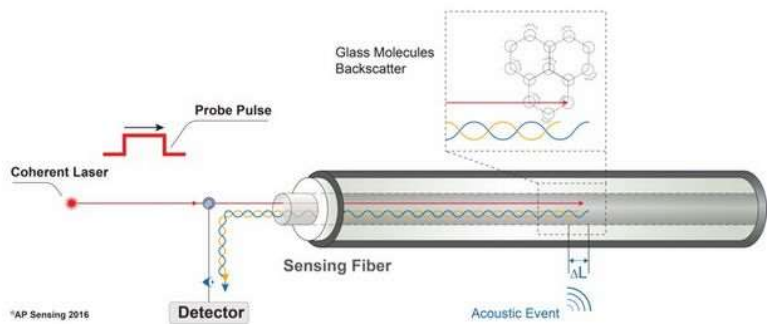
- Water column equipment to record particle motions as they are felt by fishes and invertebrates

- Unique digital solution over the world




Could transfert
QuietSea™
QuietSea™
Marine mammals detection
MATS 3G
Acoustic communications
10110110011011
Micro seismic sensors
Passive seismic sensors
10110110011011
Sensors interfaced by acoustic
Sensors for underwater wrestling
MicrOBS

Continuous sensing : using backscattering

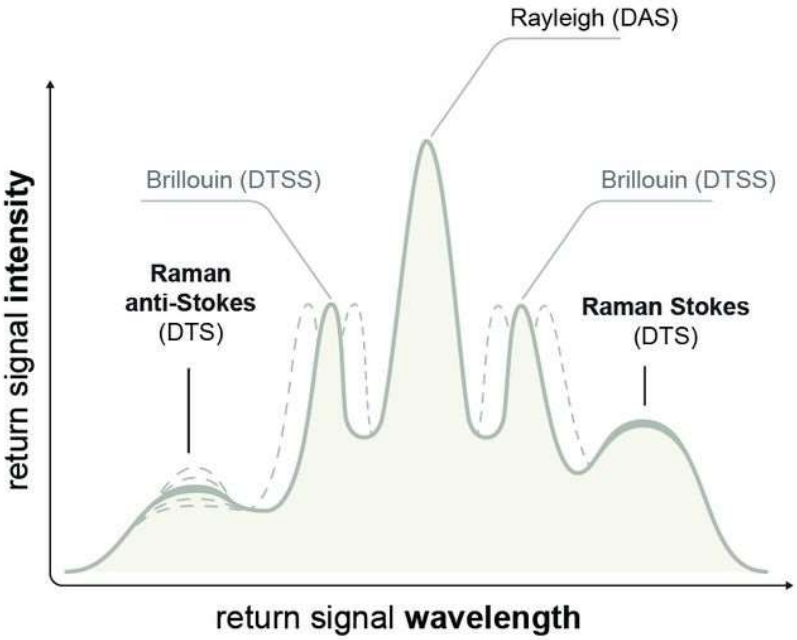


Principle: using the natural backscattering of the glass to measure differences in the state of the fiber.

Sensor : the fiber is the sensor, over a significant length (up to 50km), or pitches down to a few mm

Advantage : works on any standard fiber, long distances

Applications : Depending on the back-scattering used, allows continuous measurement of Temperature (DTS), Temperature and Strain (DTSS), Vibrations/acoustics (DAS).



Key Takeways

DAS – Distributed Acoustic Sensing

- Up to 120 km (typical range 40 km)
- Minimum sampling ~1 m
- Outputs : acoustics (from strain or strain rate). Derived: Temperature Gradient

DTS - Distributed Temperature Sensing

- Up to 100 km (typical range 40 km)
- Minimum sampling ~ 10 cm
- Output : temperature measurement
- Repeatability ~ 0,2 degC (depending on conditions)

DSS - Distributed Strain Sensing

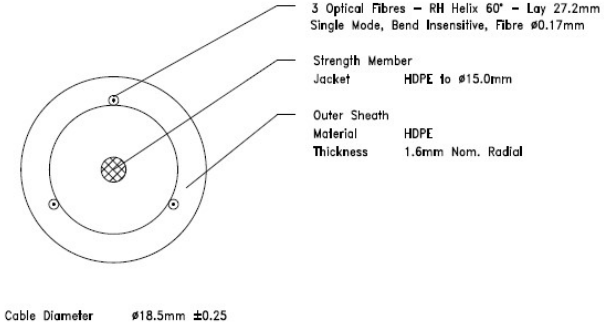
- Up to 100 km
- Minimum sampling ~ 10 cm
- Output : deformation / strain
- Repeatability : ~ 4-10 microns/m

Specifications and Limitations

- Typical max distances – up to 40-100 km
- Optical budget is important (connectors, rotating head) – typical max 17dB for DTS/DSS, and up to 10dB for DAS
- Type of fiber : Single Mode / Multi Mode
- Type of fiber encapsulation : FIMT (Dry/Gel), Tight Buffered
- Fiber positioning in the cable
- Simulation and PoC required
- Need access to fiber onshore
- The success depends on the choice of right technology(ies) depending on your needs

Sercel DeRegt – Surface Seismic

- Helically wound cables for land steamer and buried DAS applications
- Possibility to integrate specialty fiber (higher DAS sensitvity)



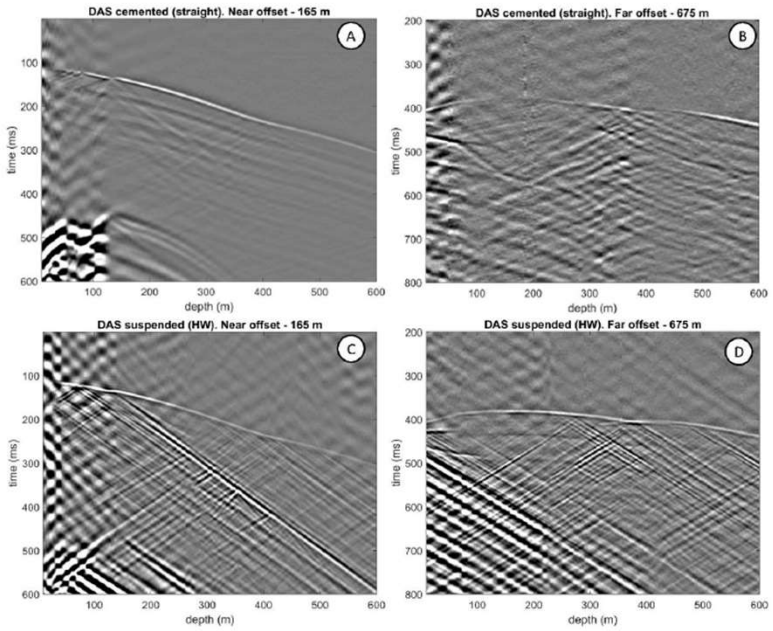
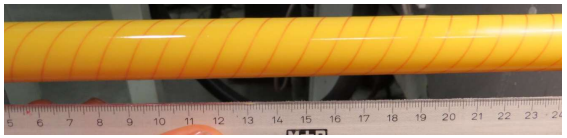


Figure 2 Raw (after source signature deconvolution) single shot VSP DAS data acquired with two different DAS cables from two source points. A/B – cemented straight DAS, near/far offsets (parameters set 1). C/D - suspended HW DAS, near/far offsets (parameters set 2).



Courtesy Shell

Surface Installation - Onshore

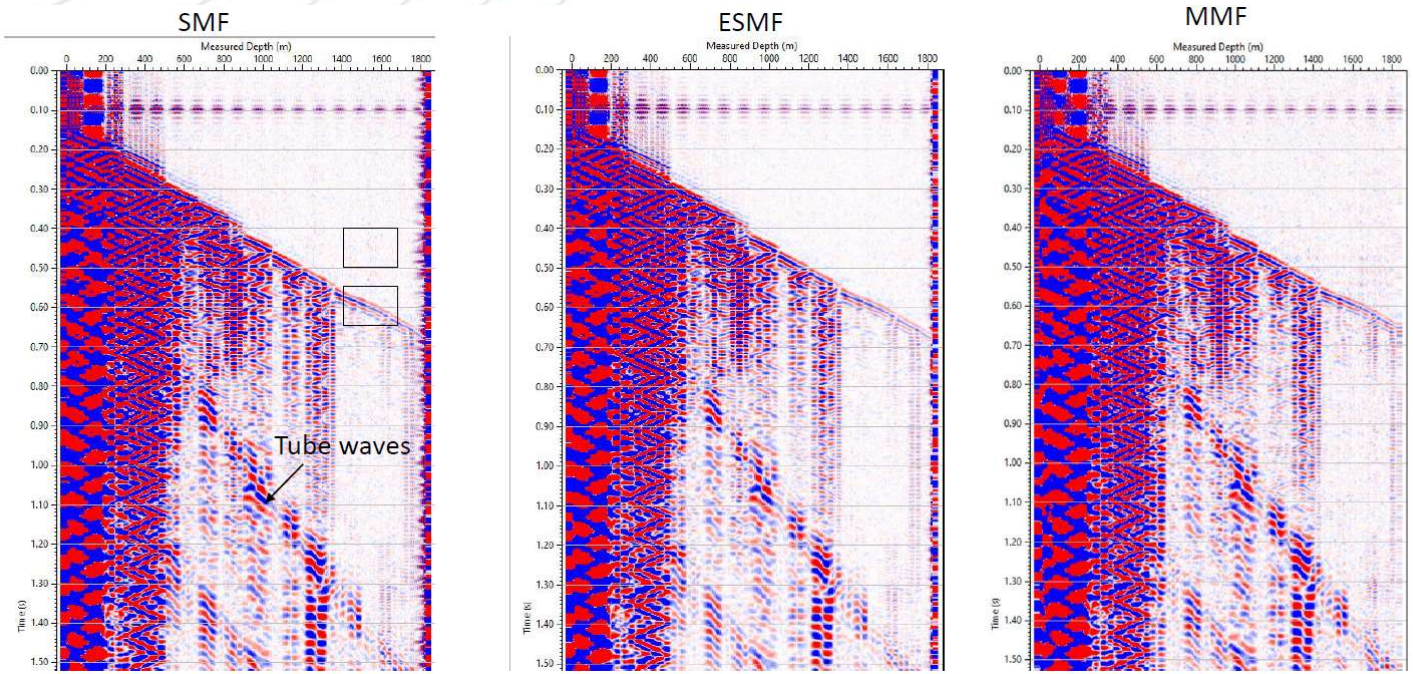
Acquisition solutions

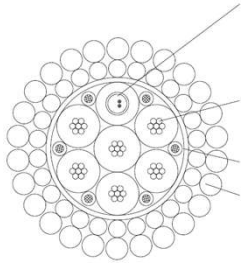
- Choice and design of specialty cables – DeRegt helically wound DAS cables
- Interrogators, servers, data preparation, data streaming

Sercel Scope

- Design of array
- Supply of cables, junction boxes, data storage, remote QC, data streaming
- Interrogators and maintenance
- Field Service Engineers for installation, georeferencing and commissioning

Downhole Wireline SMF/MMF/Enhanced

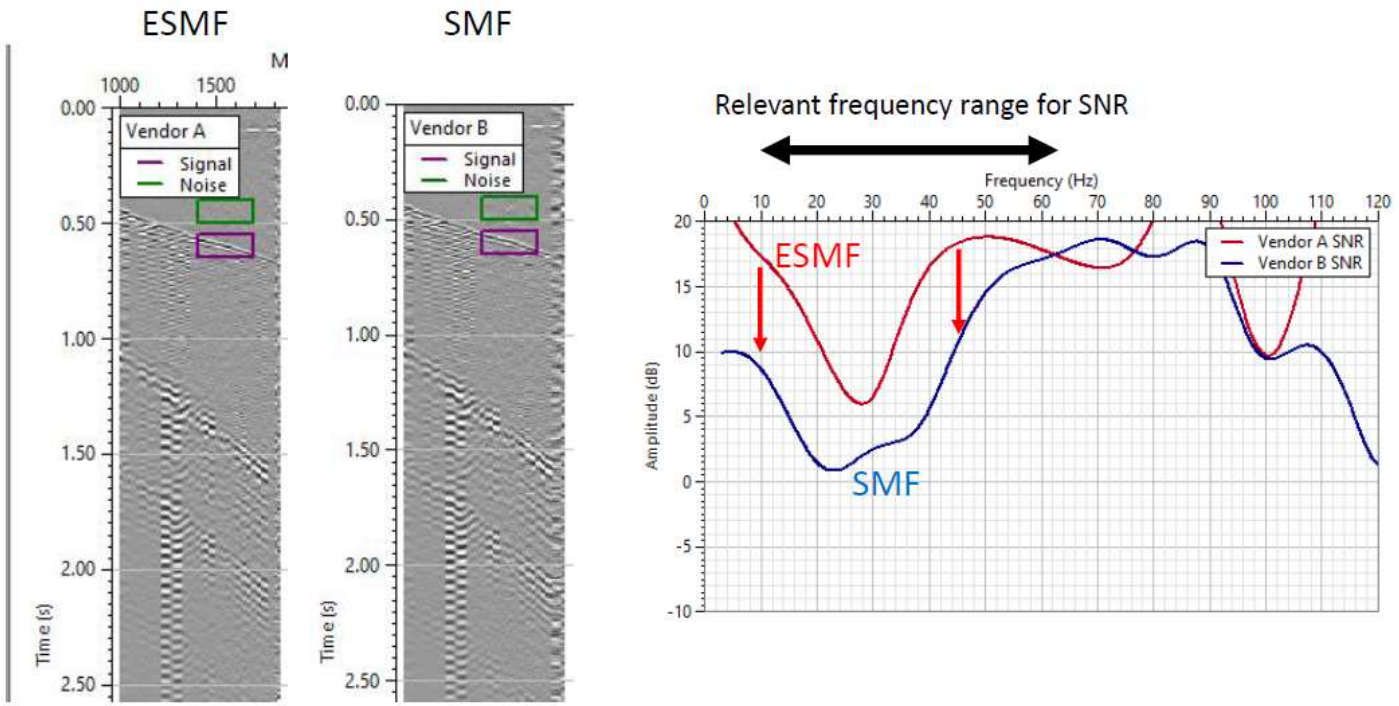




Cable Diameter	12.3mm ±0.3mm
Filling Compound	Petro-Jelly
Seawater Density	1026 kg/m³

Good Quality DAS data on all fiber types (Single Mode; Multi-Mode; Enhanced Backscatter)

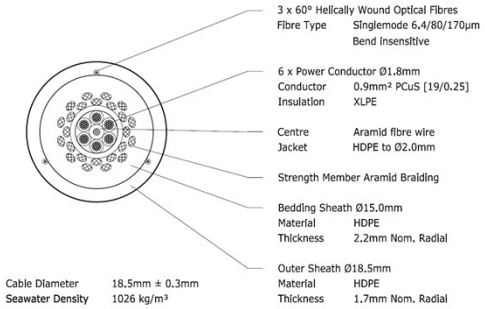
Comparison SMF and Engineered Fiber

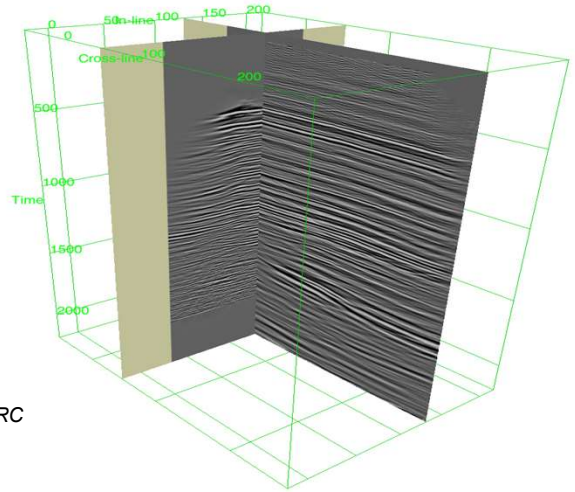


Enhanced Backscatter Fiber improvement over SMF ~ 8 dB

Downhole - 4DVSP, Microseismic, P&T, Deformation

- Downhole GeoWave II or SlimWave array. On tubing, on casing or wireline. Combinable with DAS/DTS
- Reference real time P&T gauge
- Reference real time Quartz Gauges – single drop or multi drop
- Tiltmeter with < 5 nanoradians resolution for casing deformation measurement
- Helically Wound (armored). On tubing, on casing or wireline

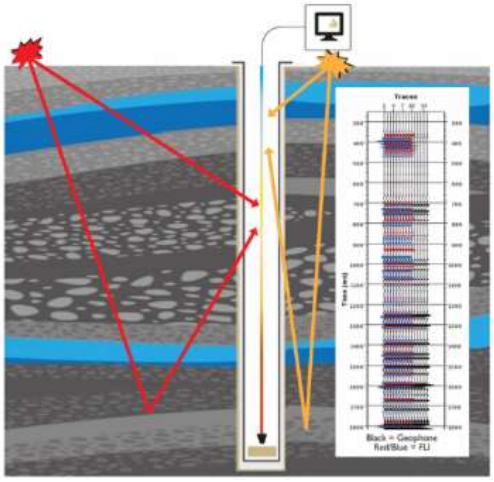




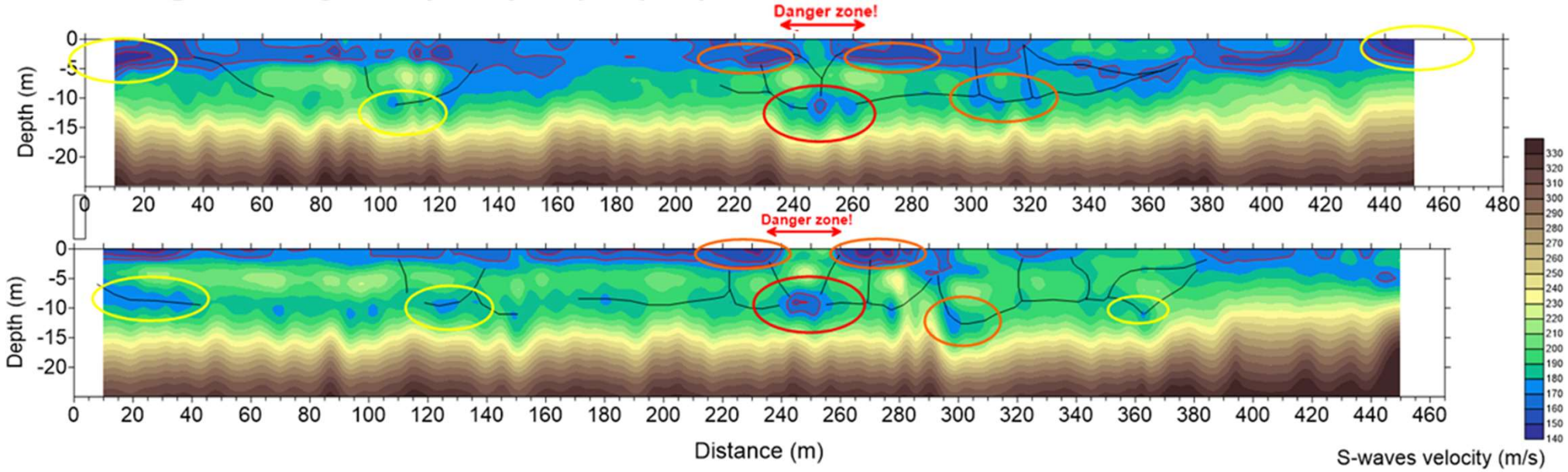
Courtesy of CO2CRC and Curtin U (R.PEVZNER)

Mining Exploration

- MINEX project : surface and borehole DAS. BHP, Anglo and Gov't sponsored
- Straight and helically wound DAS cables
- *Surface*: shallow buried and land streamer
- *Downhole* : disposable (drop), low cost and helically wound cables

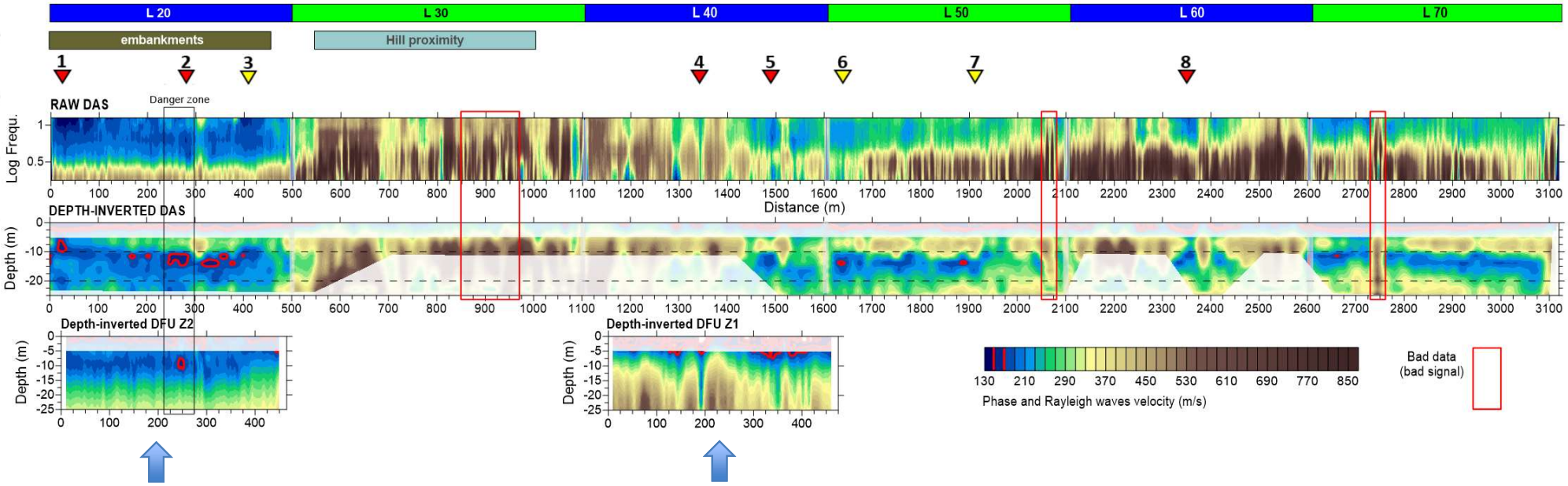


Railway – Nodal Sensors



- 2 railroad tracks, intensive rail traffic
- 2 lines of nodal sensors 3 feet apart
- 16 hours of monitoring. 3 hours to deploy, 2 hours to pick up sensors
- No interruption to rail operations

Railway DAS

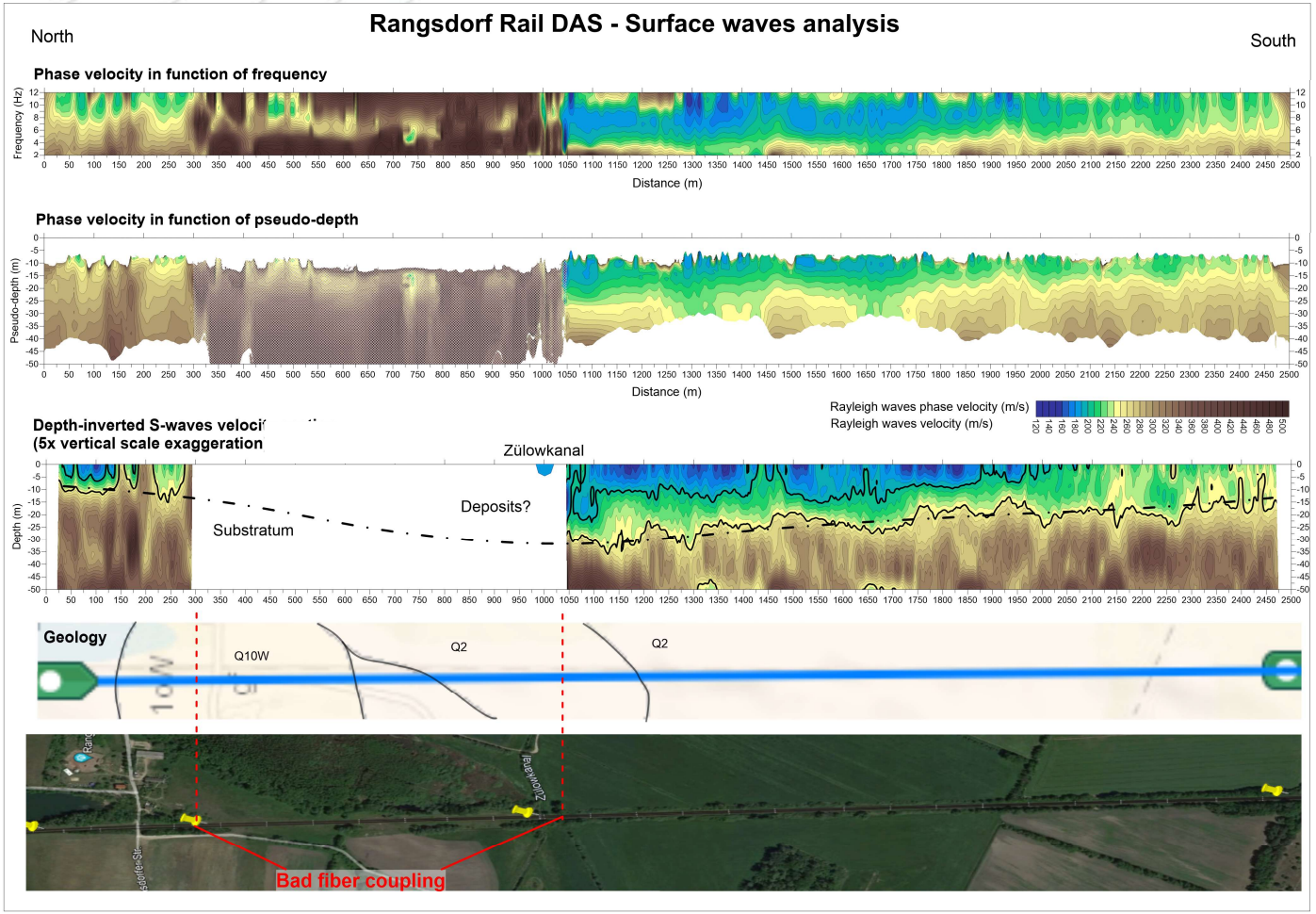


Nodal Survey

Nodal Survey

- 3000 m (10000 feet) of Distributed Acoustic Sensing monitoring during 4 hours
- Objectives : identify risk zones for confirmation and remediation works

Railway DAS on existing fiber



Courtesy of Deutsche Bahn and AP Sensing

Mine Tailings and Sea Dykes

DTS – Distributed Temperature

- Basic : hot spot detection
- Calculation of conductor temperature profiles along power cables from Distributed Temperature Sensing (DTS) and load data
- Dynamic temperature variation in a power cable due to the applied load current
- The calculation of steady-state ampacity, i.e. maximum permissible load
- Emergency ratings, i.e. real-time prediction of maximum conductor temperature, emergency time or emergency current for up to one week
- Detection of change of depth of cable by temperature change monitoring (buried)

DSS – Distributed Strain Sensing

- Cable elongation
- Cable bending
- Cable fatigue monitoring (complemented by DAS)

DAS – Distributed Acoustic Sensing

- Detection of vortex-induced vibrations
- Detection of isolation fault
- Cable fatigue monitoring
- Proximity of boats
- Detection of marine mammals

Summary – Shopping List

- Hot spot detection
- Calculation of conductor temperature profiles along power cables
- Dynamic temperature variation in a power cable due to the applied load current
- The calculation of steady-state ampacity, i.e. maximum permissible load
- Emergency ratings, i.e. real-time prediction of maximum conductor temperature, emergency time or emergency current for up to one week
- Detection of change of depth of cable by temperature change monitoring (buried)
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Sercel