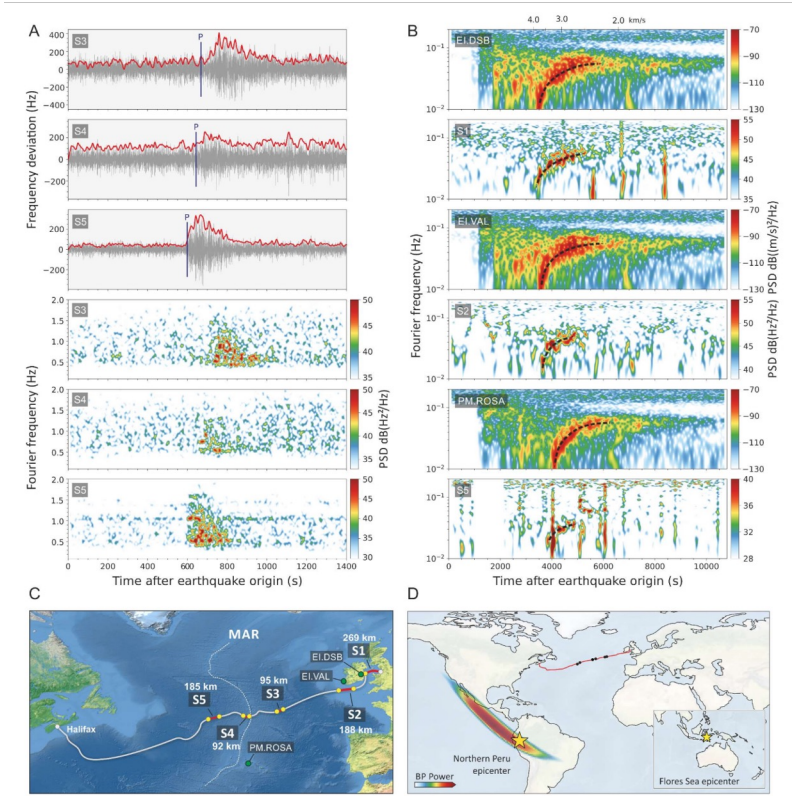
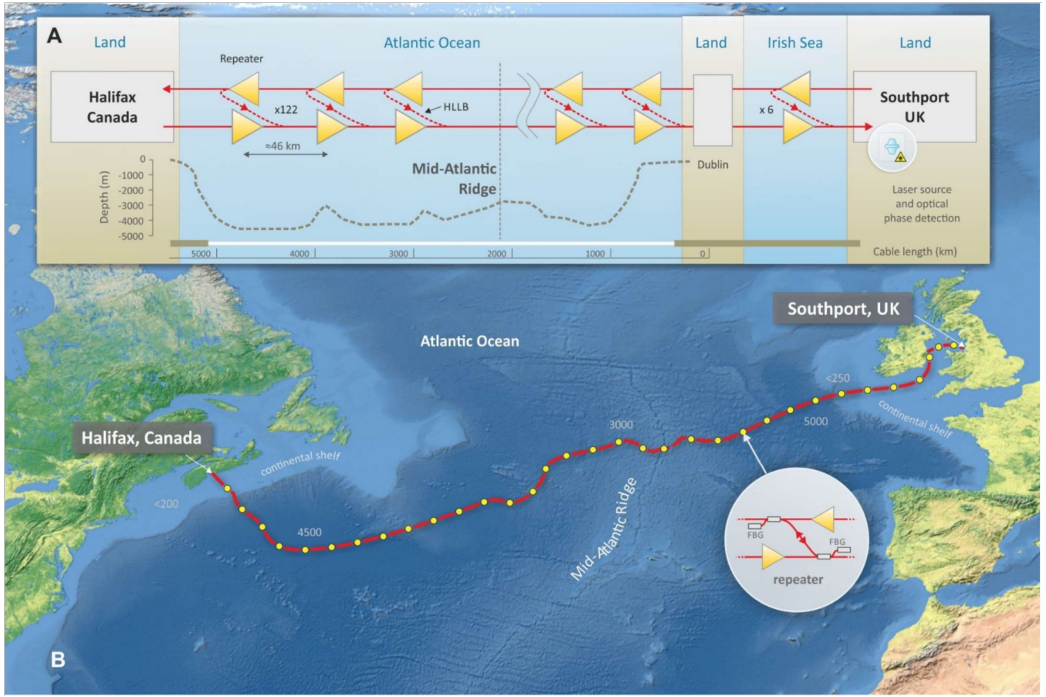
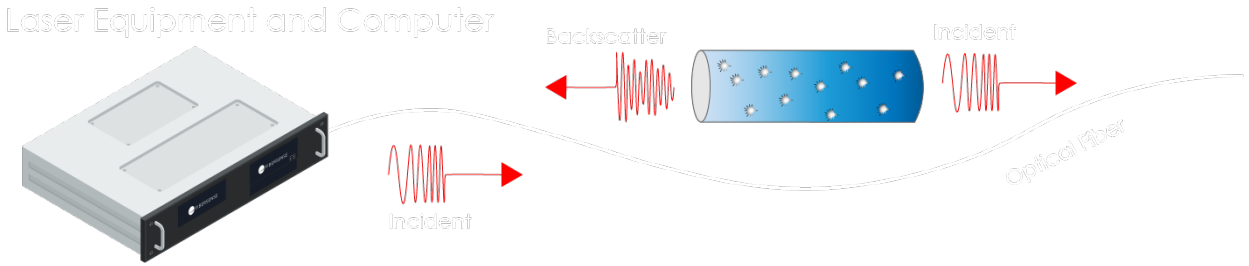
Distributed fiber span array. Phase: G.Marra et al, Science 2022, SubOptic 2023. Polarization: See our latest paper Luis Costa et al, Nature Communication Engineering, 2023; SubOptic 2023 +



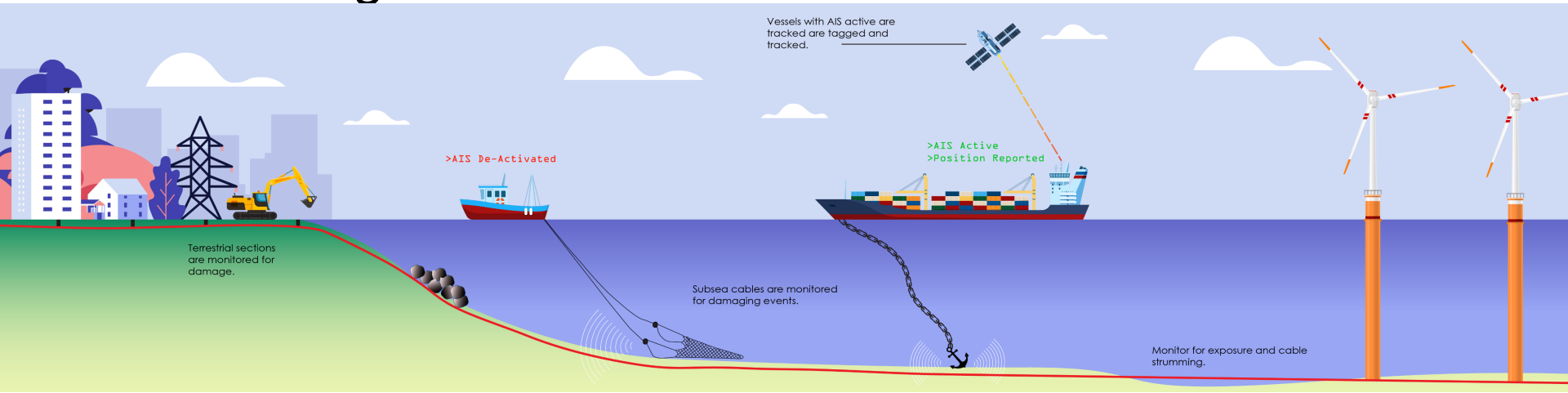


Distributed Fiber Sensing – How does it work?

- Measure coherent OTDR phase (Raleigh Backscatter)
- Sensing channels effectively every metre
- Axial strain over gauge length 1-10m
- Range ~150 km
- External equipment can be added to existing cable systems
- Operates on live and dark fiber out to first repeater



DFS: Making the invisible world of subsea cables visible



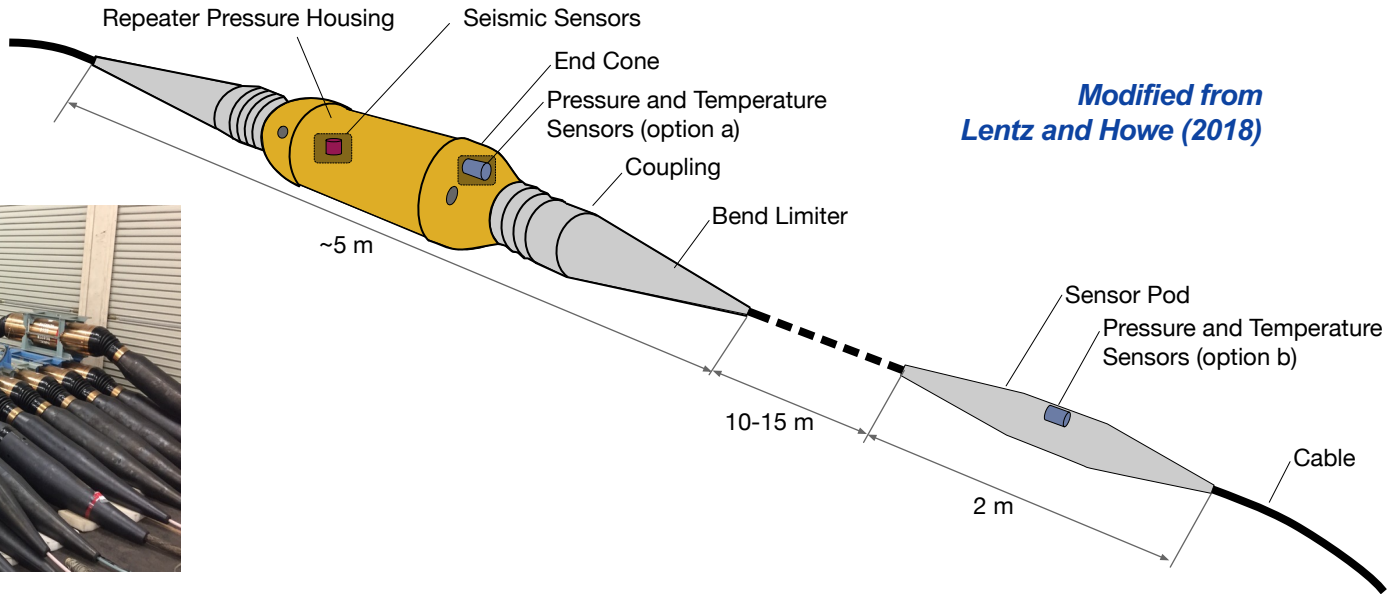
DFS innovations as applied to subsea telecom cables are rapidly evolving

Capabilities

- Can be inserted on fully loaded existing marine telecom cables – all subsea telecom cables can now be covered by DFS out to first repeater
- Fishing nets and anchors in proximity of the subsea cable
- Detect and locate vessels acoustically (when vessels turn off AIS)
- Detect and locate cable unearthing
- Detect and locate cable tampering
- Estimate residual strain changes on cables that lead to electrical, mechanical and temperature induced fault

SMART Repeaters: Design Approach

“Keep It Simple…”
(U.S. Navy, 1960)



Modified from Lentz and Howe (2018)

- Leverage existing technologies
- Utilize Commercial-Off-The-Shelf (COTS) sensors
- Seismic sensor located inside pressure housing
- Pressure and temperature sensors located in coupling OR in pod outside repeater unit

- Start with short-haul, regional systems
- Extend to longer-haul systems once proven
- Solve basic engineering challenges
- Communication on dedicated fiber pair or OOB wavelengths

SMART Cables: Technical Challenges

- **Dependability**
  - Most repeater systems are several generations along in development
- **Minimal impact on telecom functions**
  - Required for adoption by commercial cable vendors

- **Sensor accuracy and stability**
  - No opportunity to calibrate easily or precisely
- **Compatibility of cable deployment methods**
  - Variations in ships, mechanisms, etc.

NEC

SubCom

ICPC Sensing Working Group

Terms of Reference (summarised)

To **provide information** to governments and other stakeholders, cable owners and ICPC Members on … cable-based sensing technologies, specifically as they relate to the protection of submarine fibre-optic and power cables.

To **minimise jurisdictional creep and regulatory burdens** resulting from the use of cable-based sensing technologies.

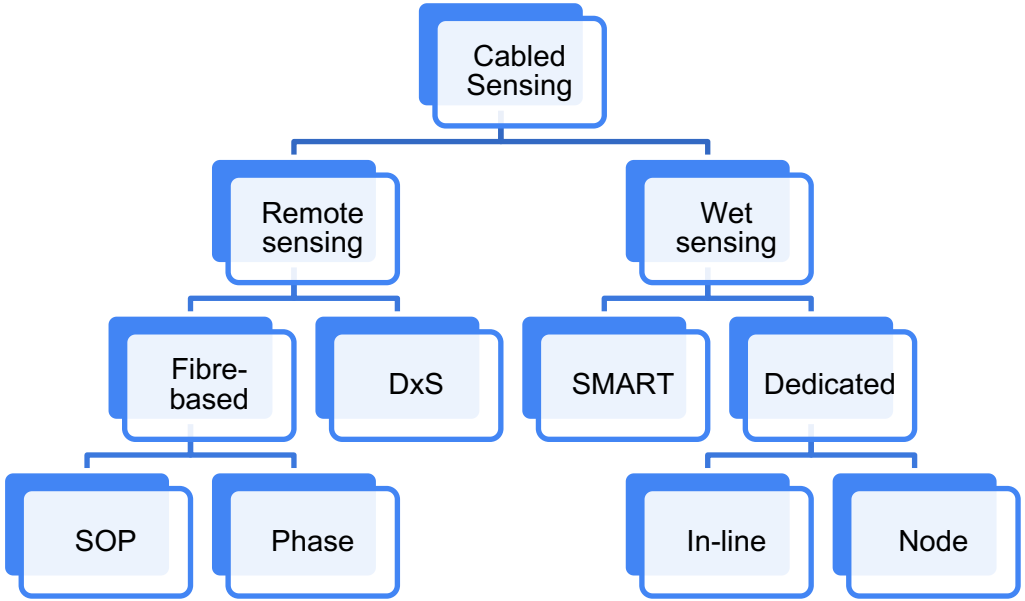
31 members from 28 organisations

Simon Webster, NEC
ICPC Executive Committee Member and Chair, Sensing WG

simon.webster@emea.nec.com

White Paper (under development)

- Strong focus on legal and policy implications (not today's topic)
- Comparison of technologies and their attributes



Primary function
Constitutes MSR?
Ownership of sensing assets
Delineation of sensor data from telecom
Raw data requires processing?
Range
Range resolution
Sensitivity
Calibration
Reliability
Cable data capacity needs
Capital cost
Wet Plant Maintenance implications

Submarine Sensing Community is a single body with mutually dependent parts. Goals - i) reduce cable cuts; ii) bring new revenue streams to cable owners

Technology	Parameters	Spatial resolution	Maximum range	Sensitivity	Key applications / remarks
Fiber sensing in transoceanic cables	Science, 2018 (Marra); Science, 2021 (Zhan) demonstrated fiber as excellent sensor without localization				
Existing Distributed span array	Power based line monitoring	per span	10,000 km	high	optical loops in repeaters - equipment monitoring
Existing Distributed fiber sensing span array	polarization	per span	10,000 km	low	**Not capable to see boats, whales** due to low repetition rate (long cable length)
Existing Distributed fiber sensing span array	T, x.., P through phase	per span	10,000 km	high	Tsunami warning • Geophysics • Global warming (**Not capable to see boats, whales** due to low repetition rate (long cable length))
DAS	T, x.., P through phase	1-50 m	150 km	high	Subsea asset protection • Geophysics • Mammals monitoring
SMART	T, x.., P	point sensor	not relevant	high	Tsunami warning • Geophysics • Global warming

L-band DAS - Noninvasive to telecom traffic DAS (see me at my Poster today)

Submarine Sensing Community is a single body with mutually dependent parts. Goals - i) reduce cable cuts; ii) bring new revenue streams to cable owners

Technology	Parameters	Spatial resolution	Maximum range	Sensitivity	**Purpose and Need?**
Fiber sensing in transoceanic cables	Science, 2018 (Marra); Science, 2021 (Zhan) demonstrated fiber as excellent sensor without localization				
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Why would someone deploy or implement each technology?

Submarine Sensing Community is a single body with mutually dependent parts. Goals - i) reduce cable cuts; ii) bring new revenue streams to cable owners

Technology	Parameters	Spatial resolution	**Where?**	Sensitivity	Key applications / remarks
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Where is each technology applicable?

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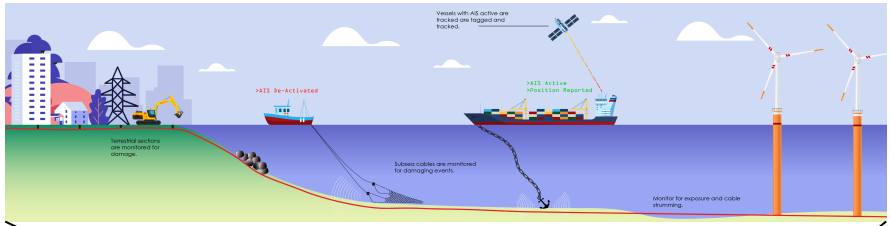
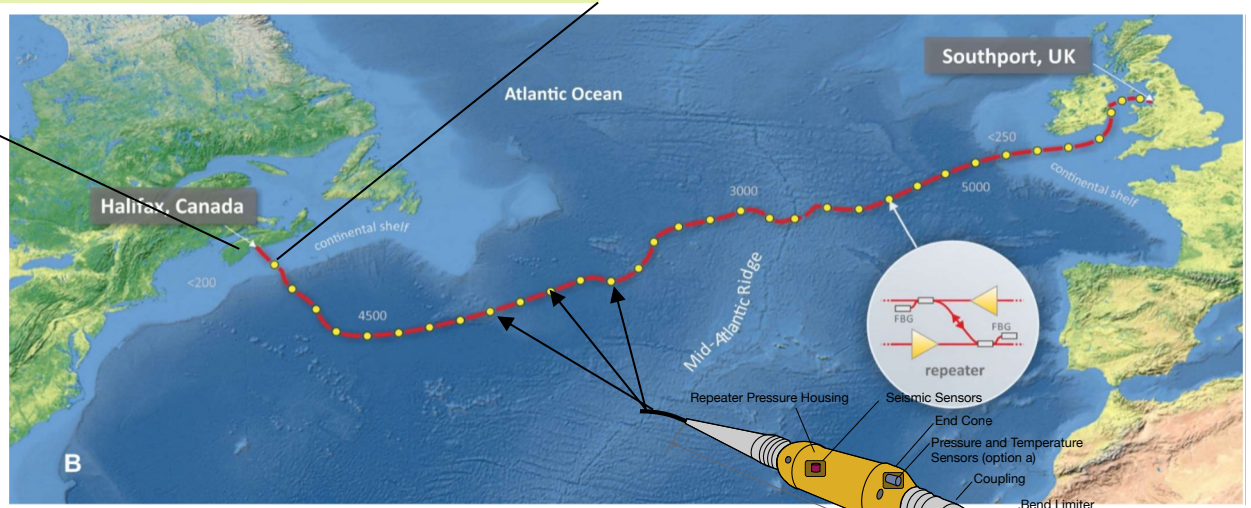
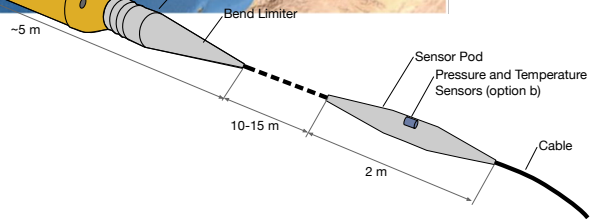
Expanding “Parameters” – what other factors are relevant, i.e. cost, operational logistics, risk vs. benefit, etc?



Coordinated Sensing or Mutually Exclusive?





Where will cabled sensing be in 10 years?