

Seismic acquisition technologies for CCUS and windfarm surveys

April 2022



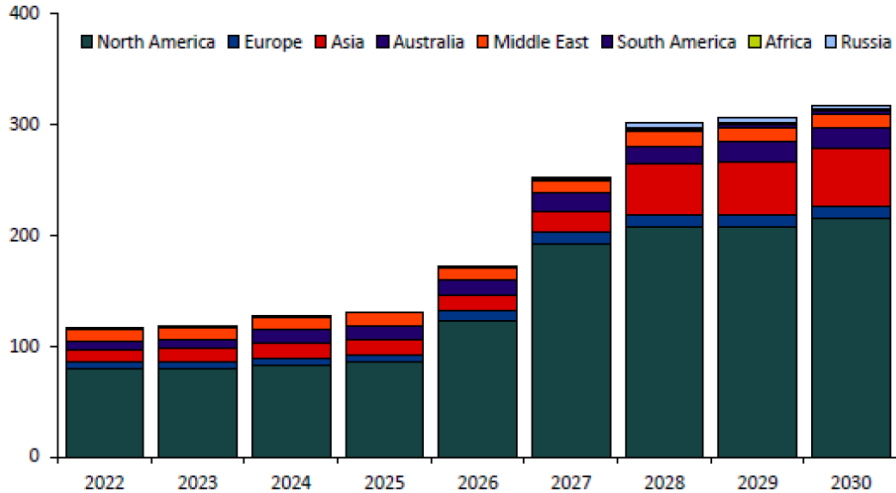
Aberdeen Section

Nicolas Tellier*, Oleg Valishin

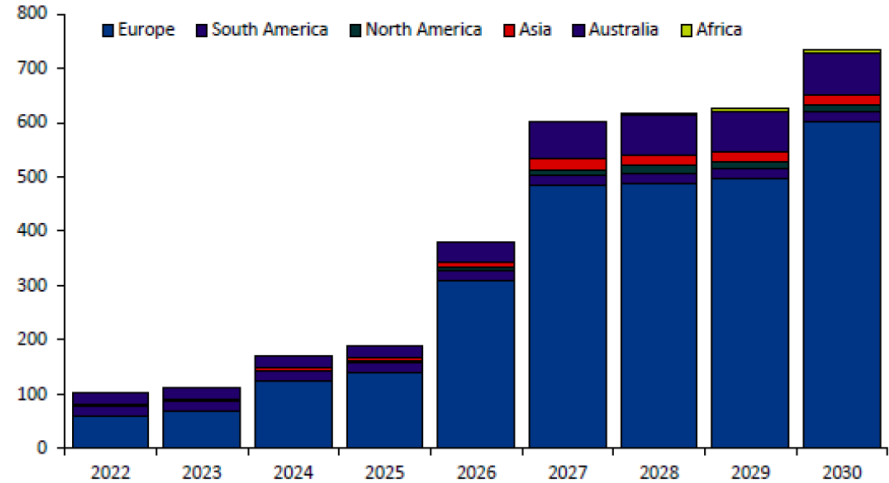


Carbon Capture & Storage market

Onshore seismic expenditures*
USD million



Offshore seismic expenditures
USD million



2017

Clean Growth Strategy
Make UK “a global
technology leader for
CCUS”.

2020

CCUS Cluster
Sequencing
Process starts

2022

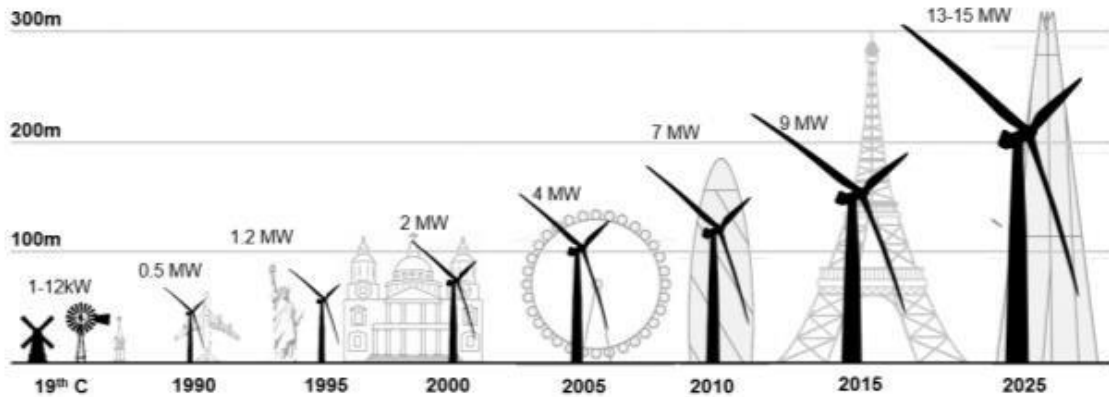
HyNet and East
Coast confirmed as
1st clusters

2022

CCS Infrastructure
Fund
(\$1.2bn funding)

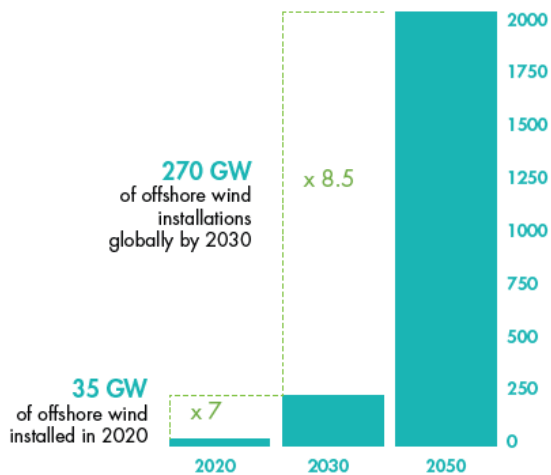
March 2023

£20 billion for CCS
funding



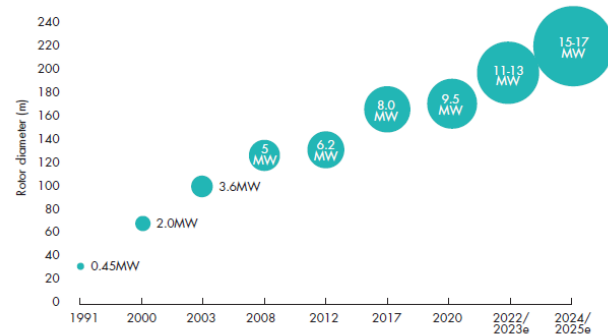
Unit: GW

2,000 GW
of offshore wind by 2050 to
achieve net zero emissions by 2050
and maintain a 1.5°C pathway

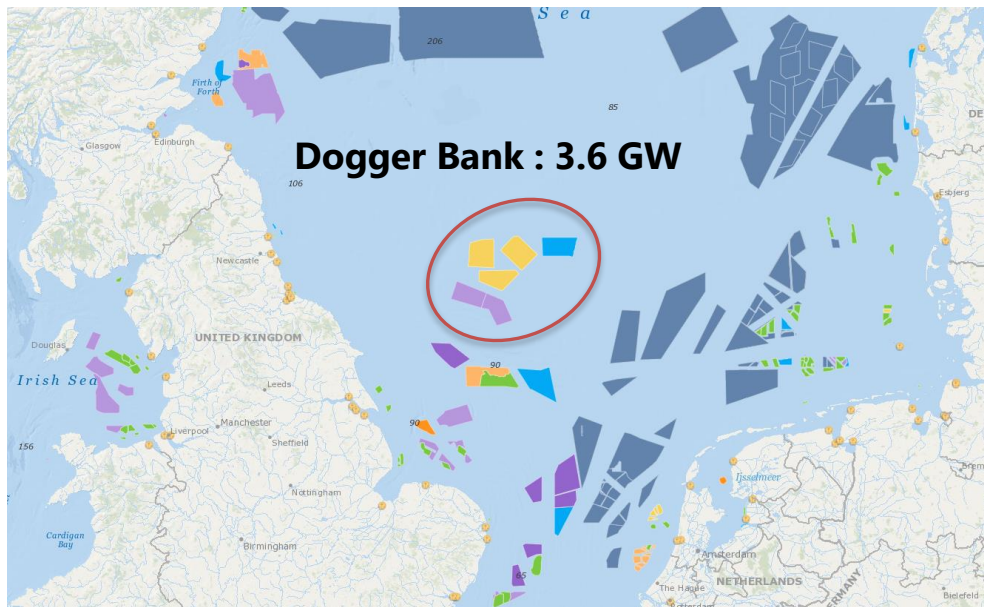


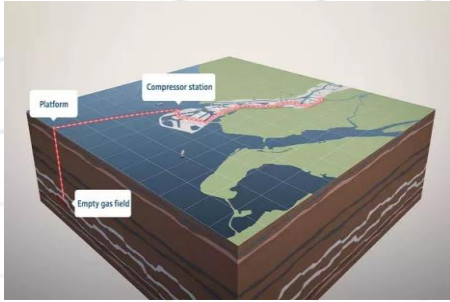
Source: GWEC Market Intelligence; IRENA World Energy Transitions Outlook 2021.

Rotor size and power rating continue to increase
Based on commercial offshore wind turbine installation



Source: GWEC Market Intelligence, July 2021





1. Carbon Capture & Storage

2. Offshore wind site surveying



3. Conclusions / Take-away

The challenges to address



CCS: a monitoring issue...

- MMV commitments:
 - Mainly, detect plume + Check seal integrity
 - Repeatability is paramount (4D)



MMV strategies and tools for carbon storage sites need to address conformance irregularities and containment breaches using a risk-based approach. **A robust suite of surface, marine and downhole tools/methods needs to be tested and deployed to support these strategies, including through trials.** (From NSTA, Aug.22)

- “There is no one-size-fits all MMV solution”
- Currently, restricted to shallow areas
- Simultaneous operations (wind, CCUS, O&G...)
- Environmental monitoring



... under strong cost constraints

- Financing critical – Low budgets (waste management)
- MMV driver: governments’ incentives, tax regime, insurances requirements
- OBN technically preferred (depleted field for CCS + nearby active O&G field), streamers financially preferred, with tailored acquisitions.

MMV: a repeatability issue

Primary goal of surface / borehole seismic monitoring:

- **Remove all variations** in the data that are not related to the changes occurring in the reservoir
- While **preserving meaningful variations** that may be related to injection and production.

These **unwanted variations** can be due to a variety of reasons including:

- 1) changes in surface or near-surface conditions,
- 2) variations in source type, wavelet, size or location,
- 3) variable noise conditions at the receivers,
- 4) variations in receiver locations, orientations, timing, or coupling.

Achieving fit-for-4D repeatability is a seismic chain issue



Project planning

Source/receiver positions

Source/receiver specifications

Timing accuracy

Geometry & Acq. parameters

Processing

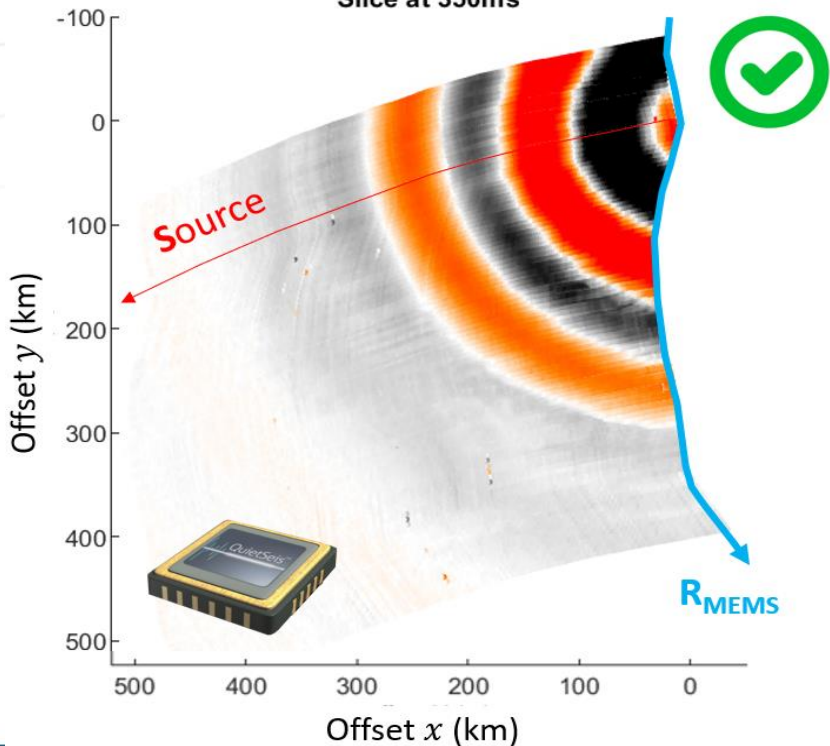


MMV: Sensors & Repeatability



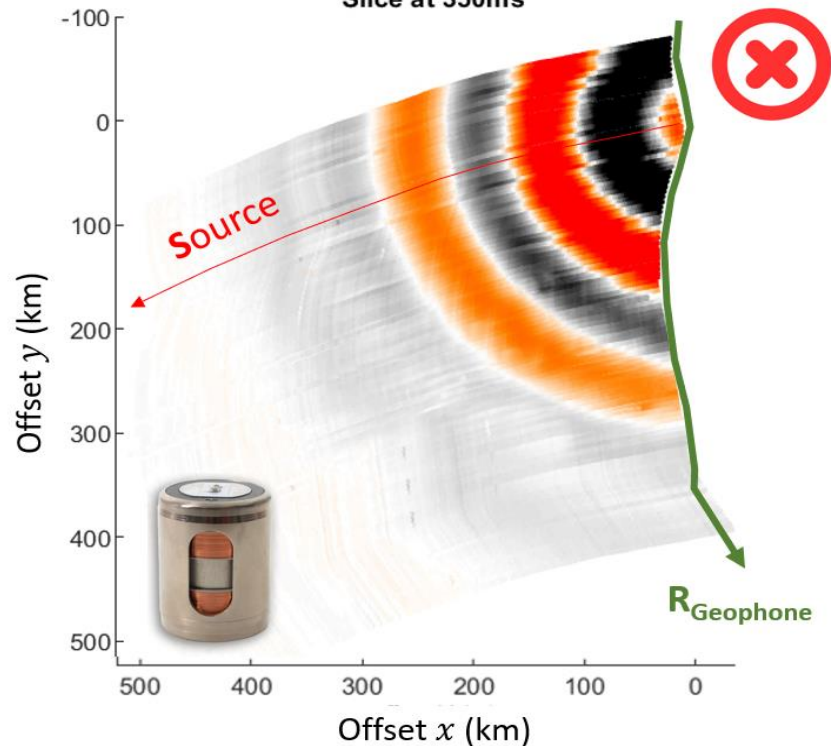
MEMS

Slice at 350ms

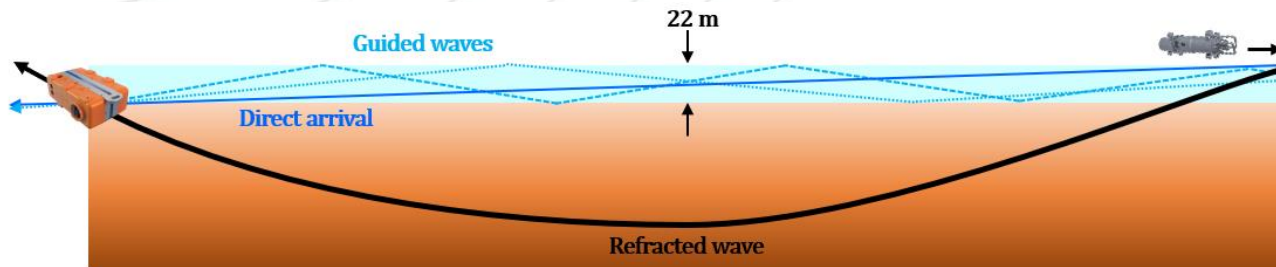


GEOPHONE

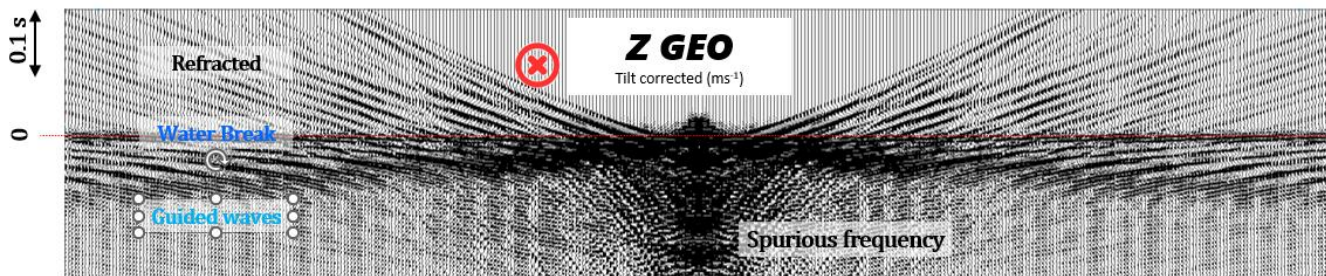
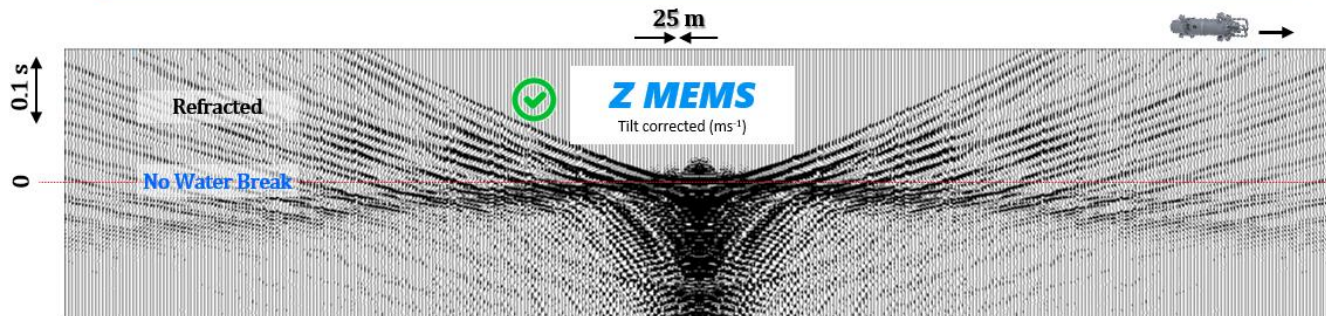
Slice at 350ms



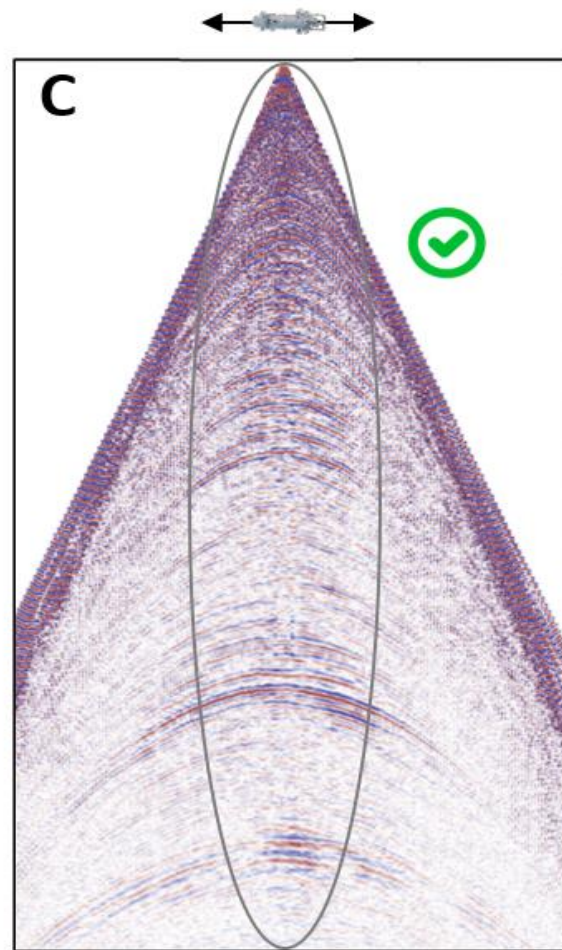
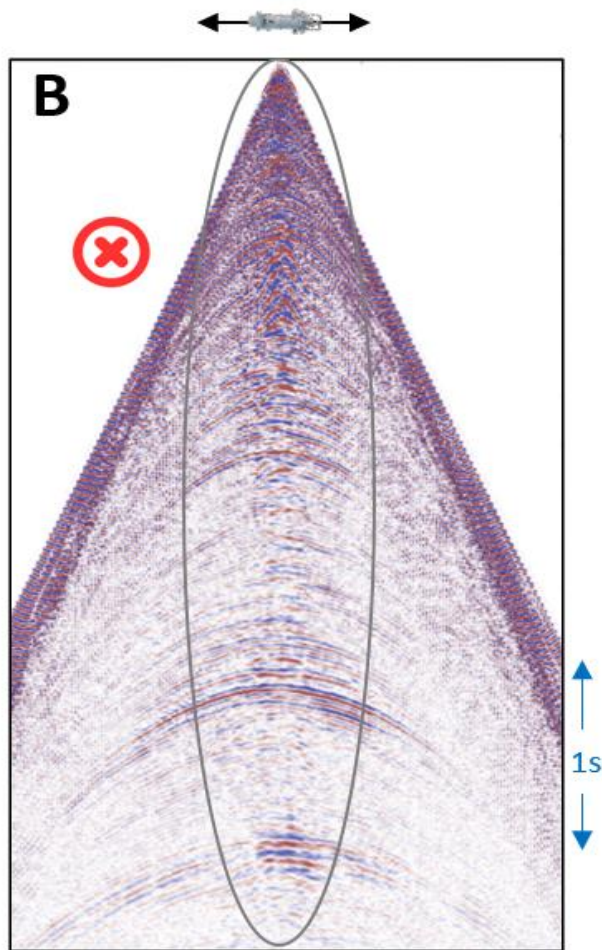
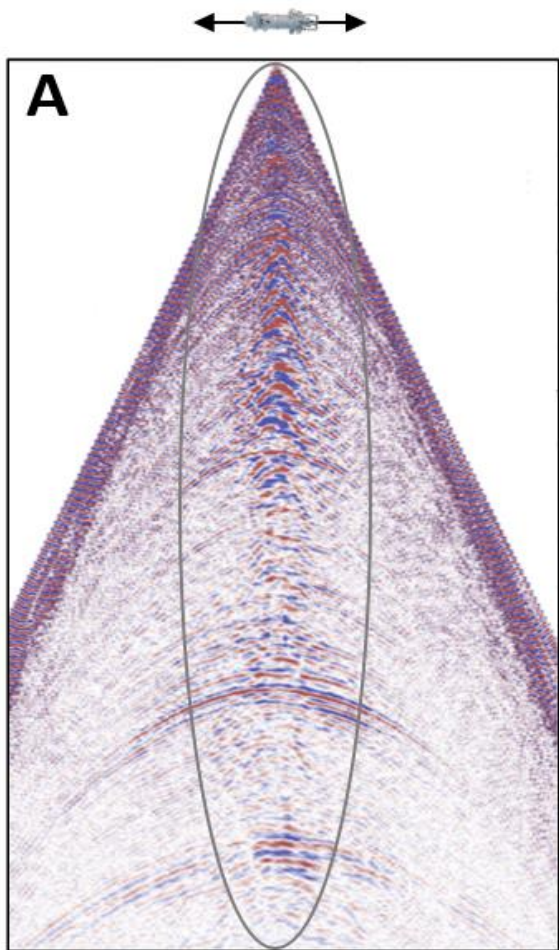
MMV: Sensors & Repeatability



- 3C **MEMS** + Hydrophone
- 300 / 1500 m
- 50-day autonomy
- ROV/NOAR compliant



- 3C **MEMS** + Hydrophone
- Free-fall, self pop up
- 6000 m
- 50/180 day autonomy



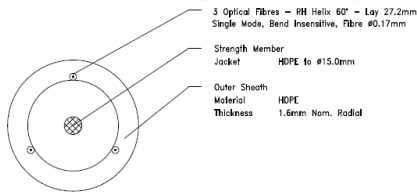
DAS – In wells, on surface, on seabed



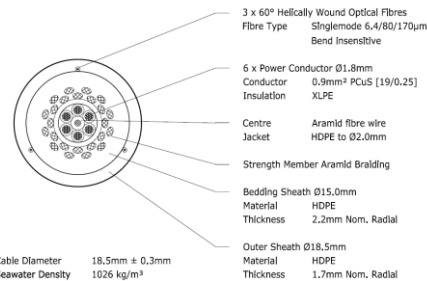
> Helically wound cables

- for any DAS application land streamer and surface/ocean bottom/buried DAS applications

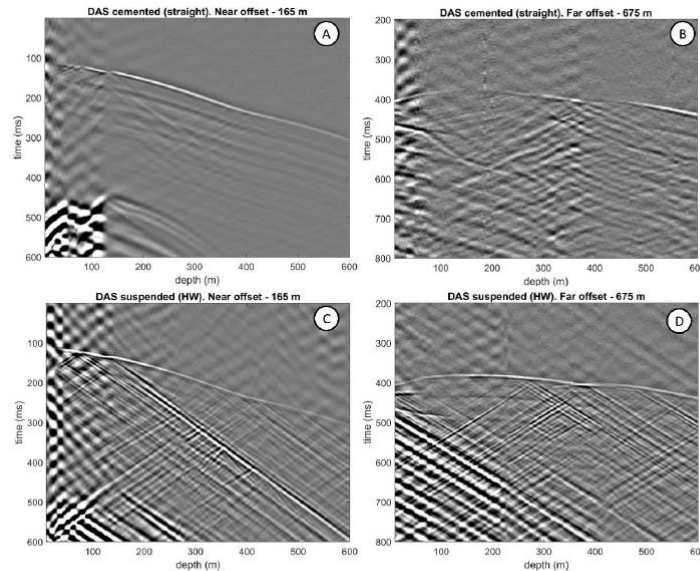
> High-sensitivity fibers and armored options for well deployment



Cable Diameter Ø18.5mm ±0.25



Cable Diameter 18.5mm ± 0.3mm
Seawater Density 1026 kg/m³



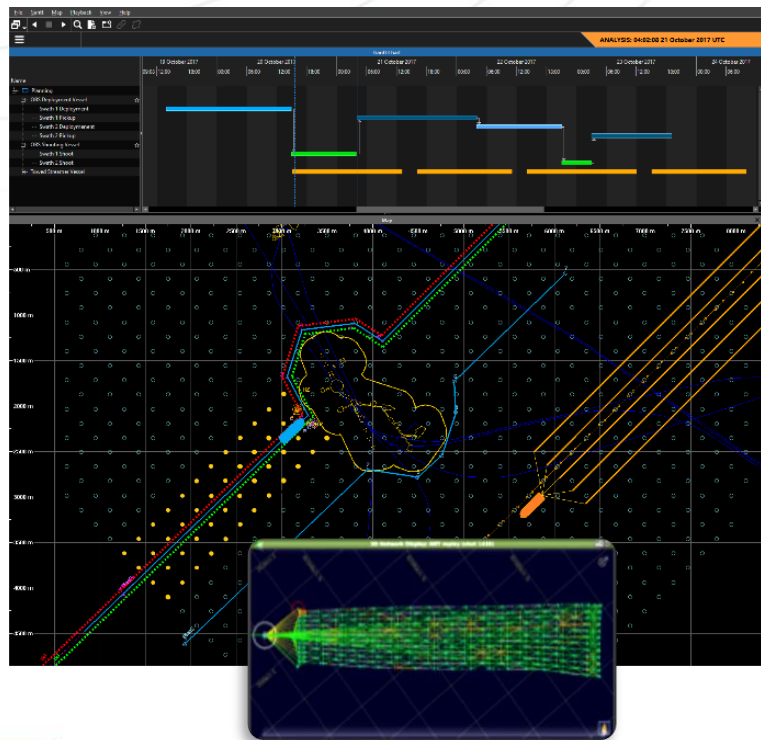
Courtesy Shell

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).

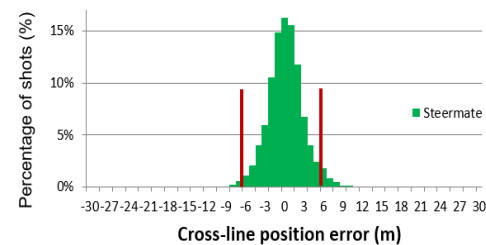
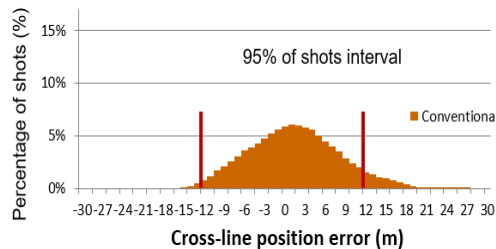
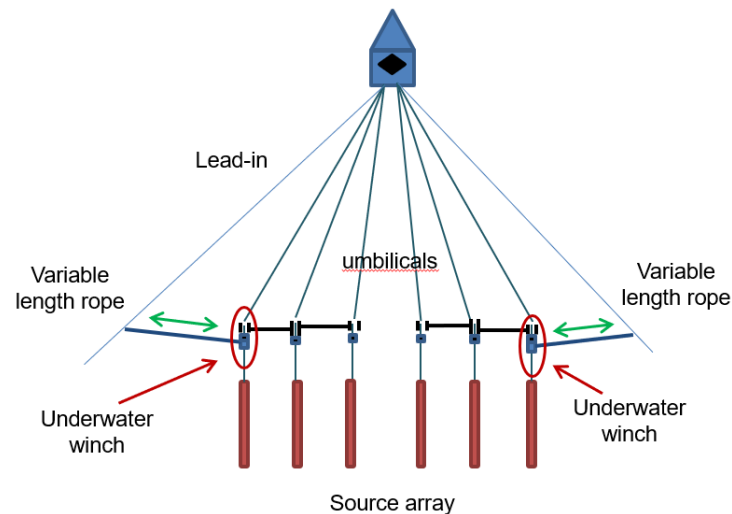
MMV: Positioning Repeatability



4D Navigation Systems



Vessel & Source Steering for 4D



Commissioning / Construction



Numerous vessels in activity when commissioning requires due traffic management and optimization

Concept's Marlin: "Air Traffic Control" for marine environment



Integrates environmental data with operational plans to make complex decisions in real-time

- Conflict avoidance
- Time sliding (replay of past events, potential future conflicts identified)
- Remote access through web browser

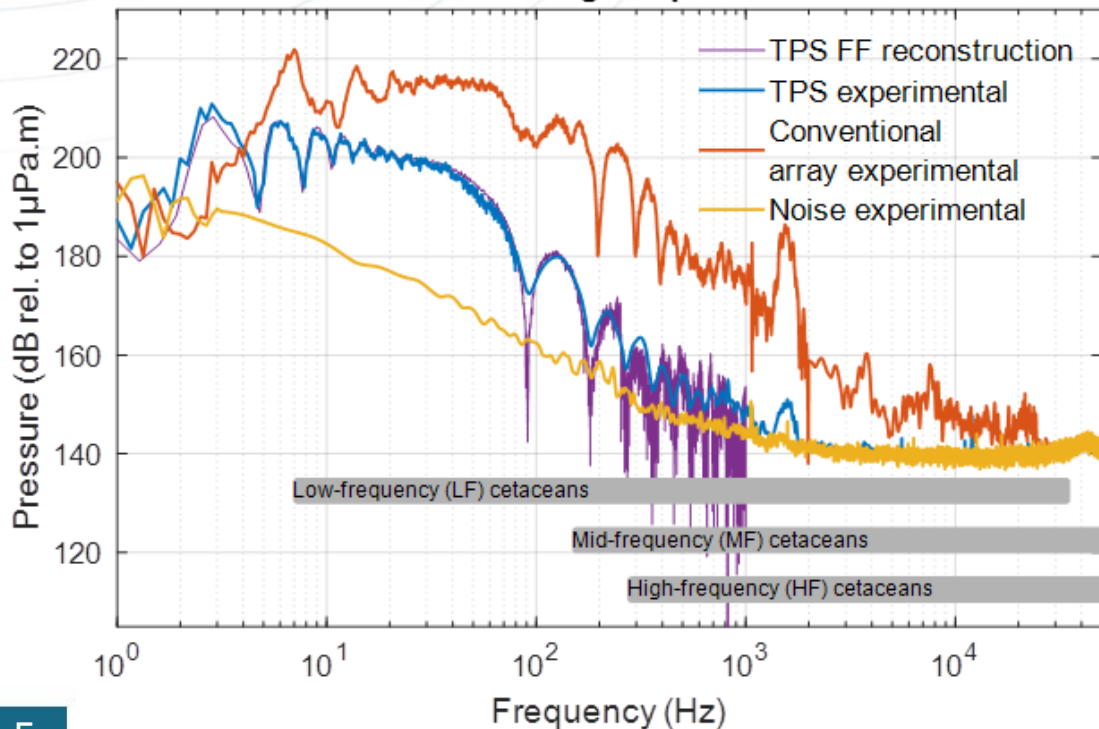


Environmental monitoring

Low-impact marine sources



TPS vs Airgun spectrum



Ambient noise:

- **TPS:** @ 1.5 kHz
- **Airguns:** @ 30 kHz

TPS spectrum:

20 dB+ lower than airguns on most frequencies hazardous for wildlife

@2830m

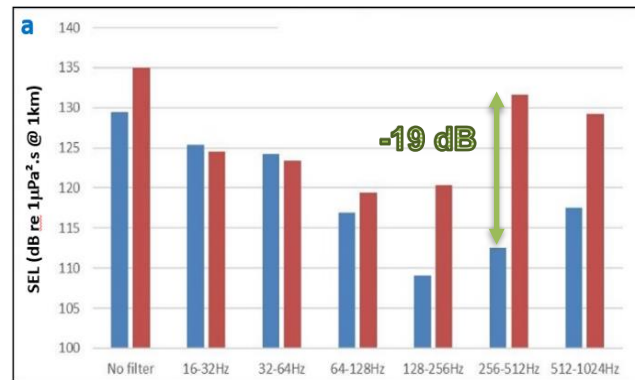
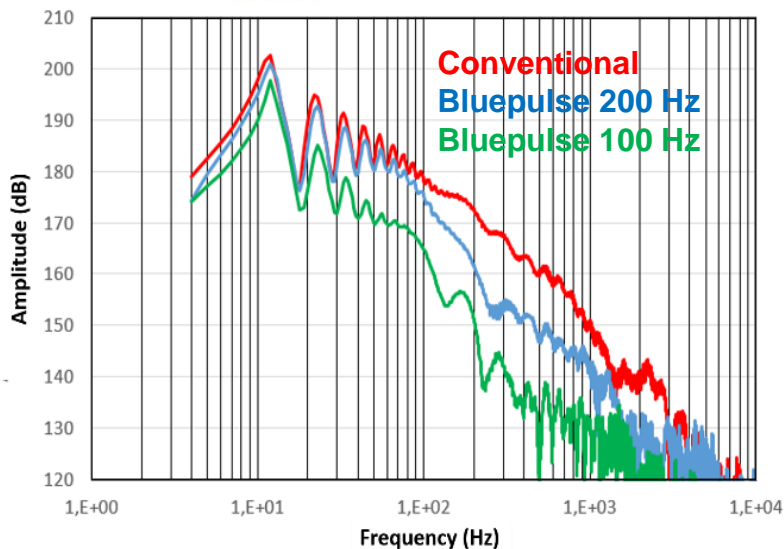
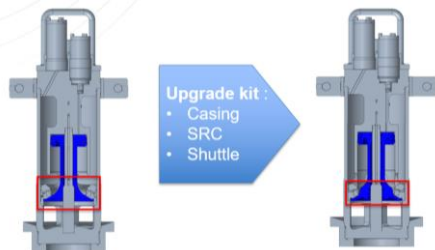
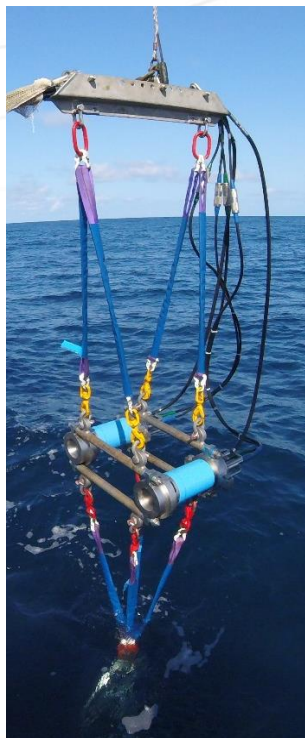
Source type	SPL	SEL	L_{p90}
Conv. array (5.02 kcu)	192	168	175
TPS (26.5 kcu)	169	152	155

(dB re 1 μPa)



Environmental monitoring

Low-impact marine sources



Environmental monitoring

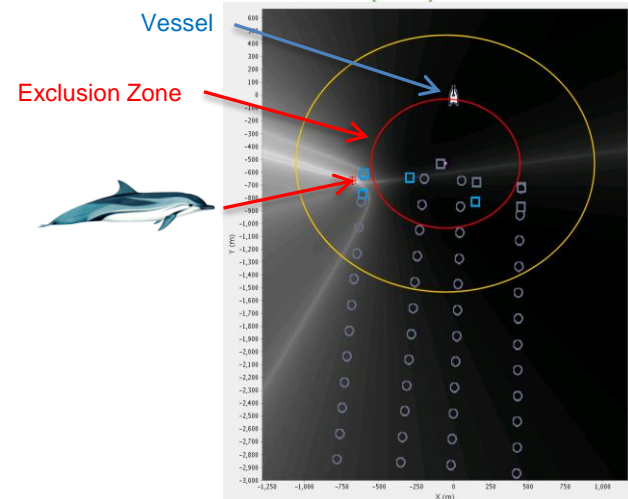
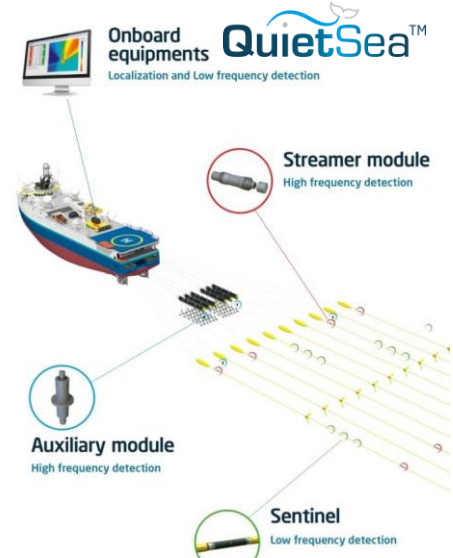
Automated mammal monitoring

Advanced marine mammal detection

- Automated, with objectivity of results & decisions
- Integrated in streamers / source vessels, or autonomous
- High precision of marine mammal localization, very low false alarm rate
- Good coverage of the exclusion zone

Designed for Oil companies and contractors

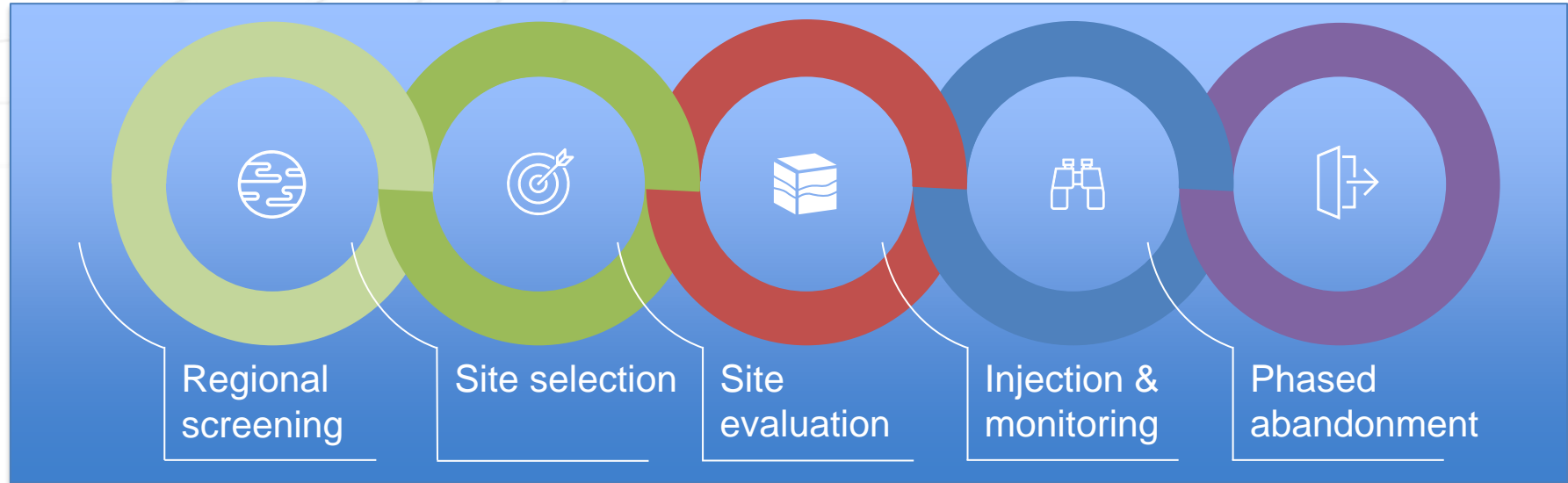
- ✓ Supports complying with regulations
- ✓ With sustainable commitments
- ✓ While ensuring cost-effective operations (downtime reduction)



Tailored solutions



Fit-for-purpose solutions combining imaging & equipment expertise



Rapid well integrity screening

Modular customised screening

Cost to purchase seismic

Regulatory uncertainty

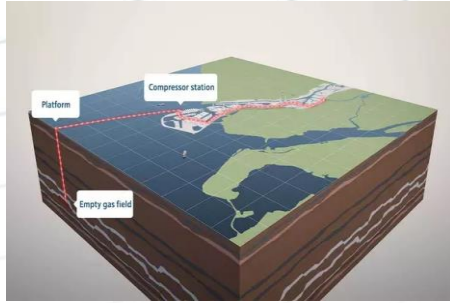
Fast & direct seismic to
reservoir model

Robust monitoring planning

Non-seismic plume tracking
away from wells

Seismic-integrated
continuous monitoring

Contractor
management



1. Carbon Capture & Storage

2. Offshore wind site surveying



3. Conclusions / Take-away

The challenges to address



Geoscience challenges

Optimal implementation of foundations / piles

- Detailed ground model of the near-surface (~100 m below seabed), with fit-for-purpose resolution (e.g., for boulder detection)
- Geophysics to geotechnics

Other seismic technology related challenges

- Management of construction work
 - Fleet management
 - Simultaneous operations (Wind + CCUS + ...)
- Environmental monitoring (e.g., when driving piles)
- Life of field (monitoring)



All within strong cost constraints



Seismic is the key geophysical monitoring technology providing best resolution. Surveying activities for carbon storage sites in and **around offshore windfarms** can be extremely challenging, and **unacceptable collision risk if deploying long towed seismic streamers (receivers)**. There are some potential mitigating seismic solutions (e.g. Ocean Bottom Nodes OBN) although with higher cost and more limited coverage.

(From "MMV of CCS projects with co-location considerations, NSTA, Aug.2022)

Offshore wind - Site surveying



- A shallow topic
- 2D are cheap, but 3D are better
- Fit-for-purpose resolution @ local drivers
 - 1m or less resolution.
 - SR < 0.5m, if not 0.25.
 - Geohazards, e.g., North Sea boulders.
- Frequent accidents reported owing to poor prior studies.



HR/UHR 3D: towards sub-meter resolution



Applications



High Resolution (HR)

(to ~1000m):

- ✓ Reservoirs,
- ✓ CCUS,
- ✓ 4D seismic



Ultra-High Resolution (UHR)

(to ~100m):

- ✓ Geotechnical site surveys,
- ✓ offshore construction,
- ✓ UXO, geohazards assessment

An industry collaboration



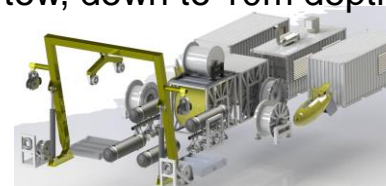
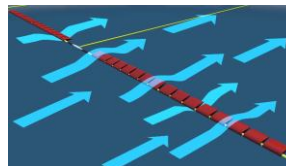
Widespread & proven seismic technologies

- Seal428 Recording system
- SeaPro Navigation system
- QuietSea PAM system compatible
- Any Sentinel streamer



Offshore seismic experts

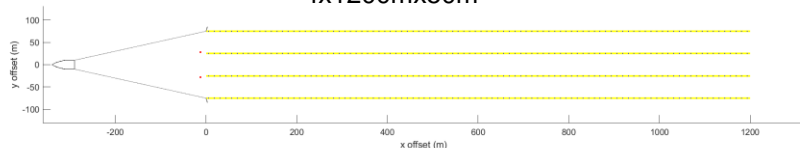
- Containerized and modular solution, for vessels of opportunity
- Dedicated rigging system (5 knots tow, side deployment)
- Hydrodynamic tow, down to 10m depth



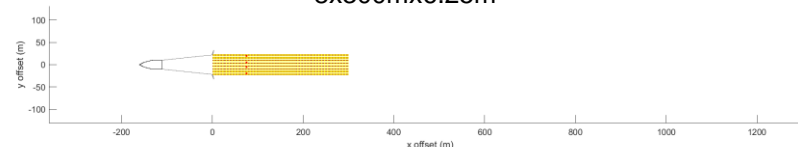
Examples of configurations



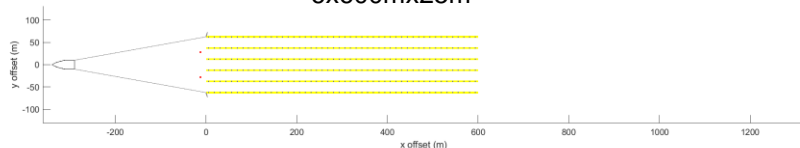
4x1200mx50m



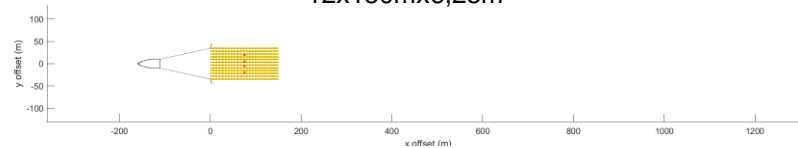
8x300mx6.25m



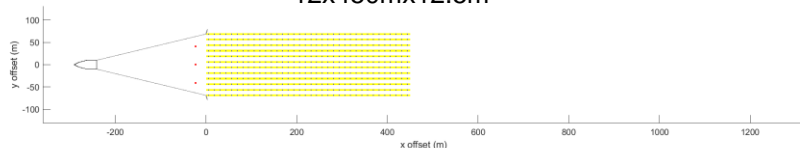
6x600mx25m



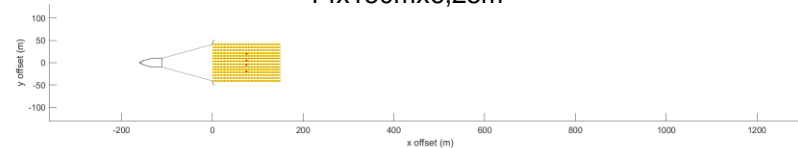
12x150mx6,25m



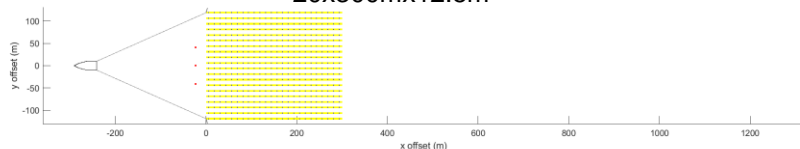
12x450mx12.5m



14x150mx6,25m



20x300mx12.5m



16x150mx6,25m



From geophysics to geotechnics



Seismic supports due soil characterization, to

- Support optimal location
 - Design piles & foundations (type / size).
- How to make the link between seismic and geotechnics?



Resting ground: the monopile was lost in the Taiwan Strait Photo: NORTHLAND ENERGY

Setback: Yunlin offshore wind farm monopile slips into Taiwan Strait

French giant TotalEnergies is a key stakeholder in the offshore project



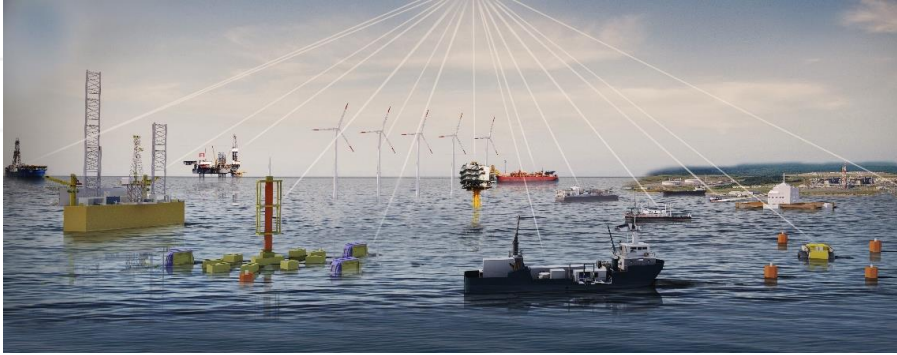
US leader in the geotechnical and structural risk management

- Testing : largest lab in the US for offshore wind, with fully automatized, and certified sophisticated soil testing
- Consulting : geostructural design and engineering, geohazards identification and mitigation, sites investigations
- Structural Monitoring : design, installation and monitoring
- Industry recognition: numerous references in wind offshore

Construction work management



Management of maritime operations



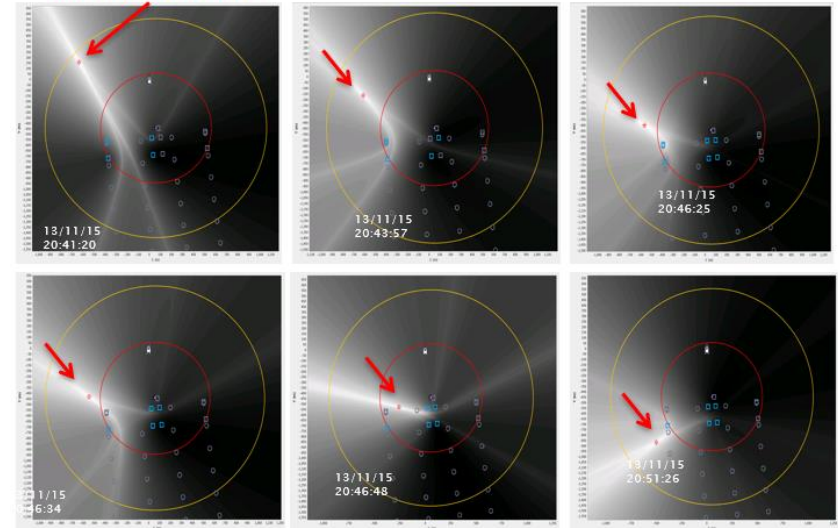
- Where are vessels on their schedule ?
- Did they manage to deliver as per plan?
- Has the schedule changed?
- Did/will conflicts or incidents occur?
- Are 3rd parties acting as planned?
- Planning, reporting, automated alerts

Mammal Monitoring

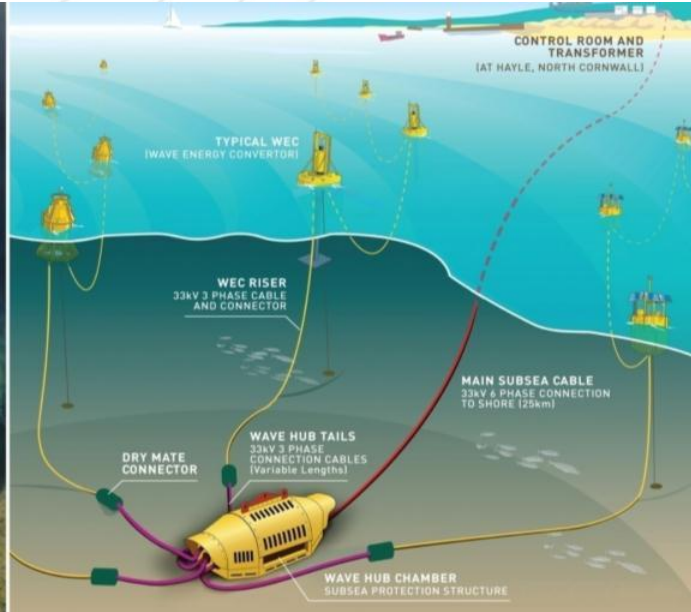
- When driving piles
- Throughout operations
- For traffic evaluation



Mammal detected

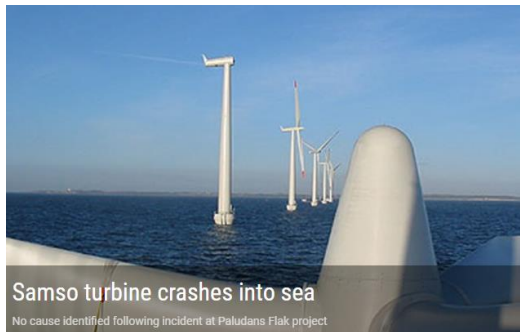


Construction work management



Ocean Power Technologies PB3 PowerBuoy: an Uninterruptable Power Supply (UPS) which constantly recharges itself by harvesting energy from the waves (20 – 3000 m)

Life of field



Wind Turbine Collapses are Supposedly Rare, but Several Have Occurred

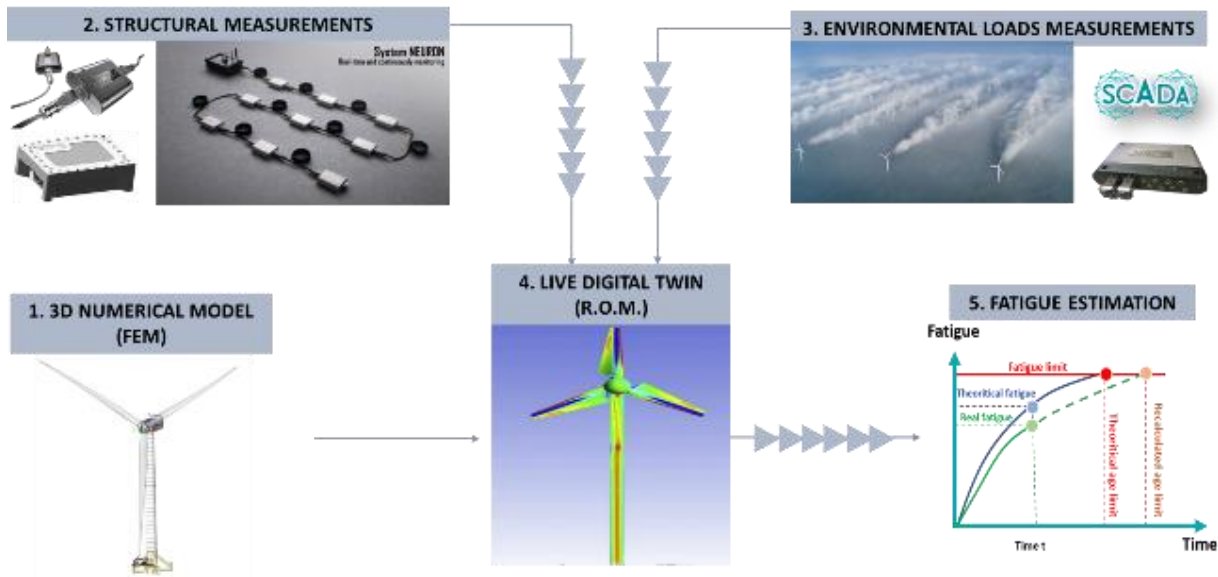
BY IER

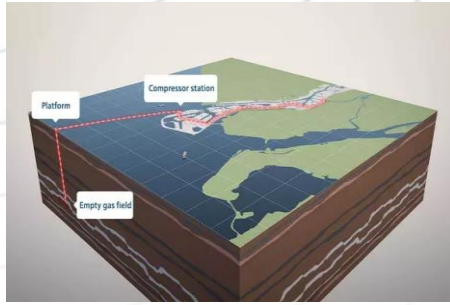
JANUARY 30, 2023

<https://www.instituteforenergyresearch.org/renewable/wind-turbine-collapses-are-supposedly-rare-but-several-have-occurred/>

Structural Health Monitoring (SHM)

- For foundations and mast
- At construction / operation / decommissioning





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3. Conclusions / Take-away

TAKE AWAY MESSAGES



Seismic for CCUS and Wind site surveys:

A “fresh” industry, with requirements and standards still being defined

- *DAS on seabed: an option?*
- *What sources for CCUS?*
- *Additional measurements?*

Numerous synergies with seismic technologies

- Seismic (data acquisition) or support technologies
- Upgrades to be expected as technical requirements get clearer
- On-demand tailored monitoring solutions





Artificial lift Monitoring



Downhole Monitoring



Smarter Management of Offshore Operations



Ultra-High Resolution 3D Offshore windfarm exploration



Marine Mammal Monitoring Solution



Geotechnical testing for Offshore engineering



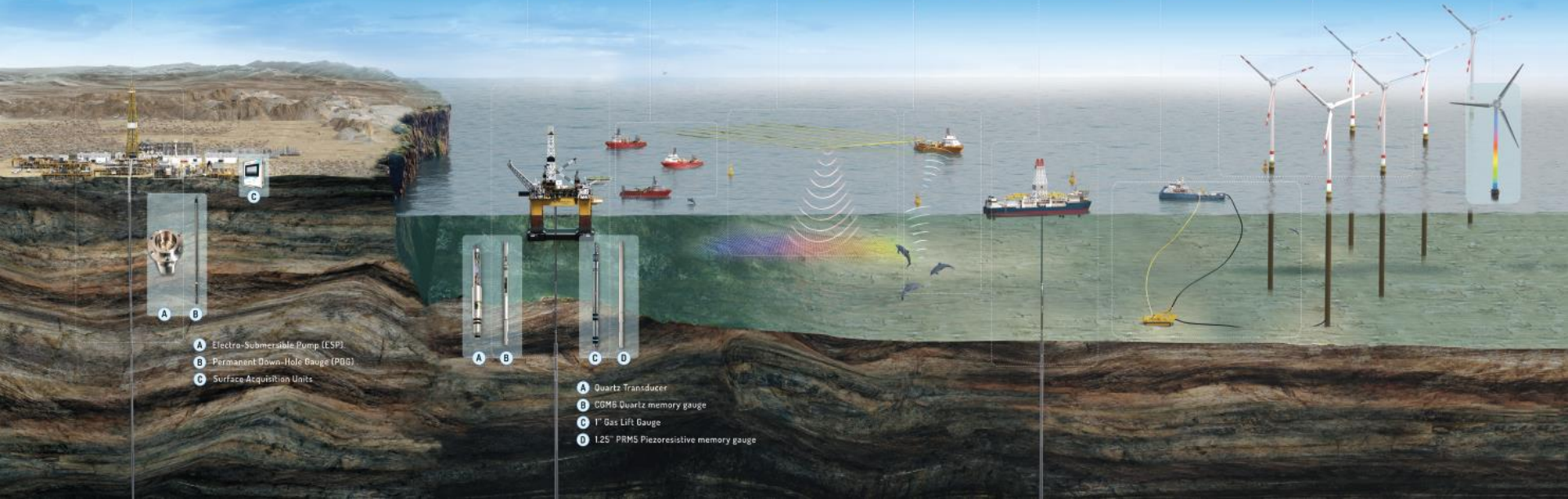
ROV Umbilical Cables



Wind Turbine Structural Health Monitoring



Fatigue and residual lifetime estimation



- A Electro-Submersible Pump (ESP)
- B Permanent Down-Hole Gauge (PDG)
- C Surface Acquisition Units



- A Quartz Transducer
- B COMS Quartz memory gauge
- C 1" Gas Lift Gauge
- D 1.25" PRMS Piezoresistive memory gauge