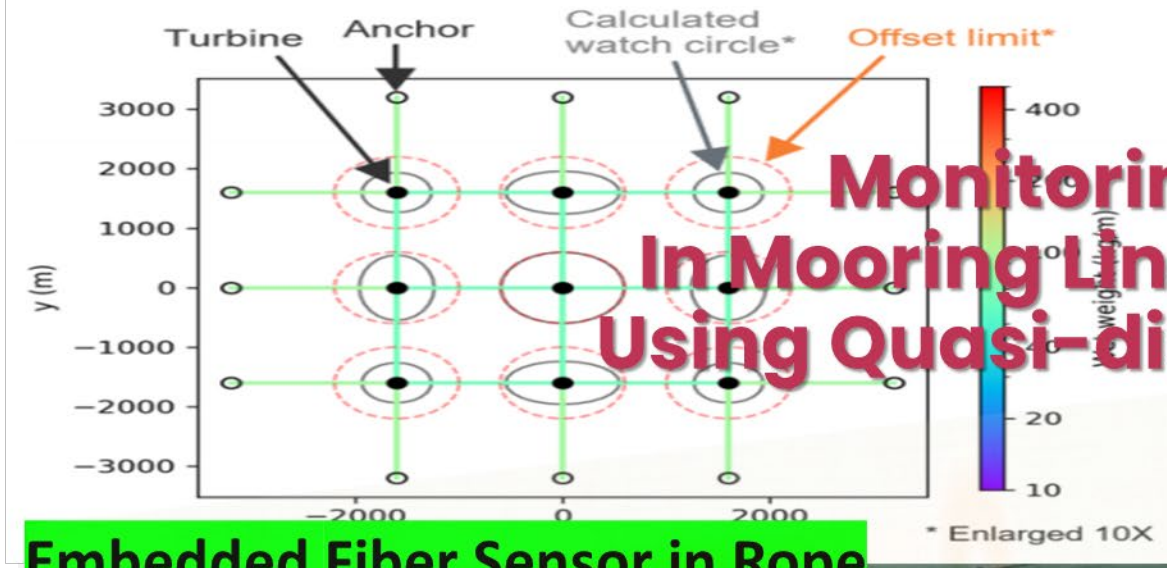
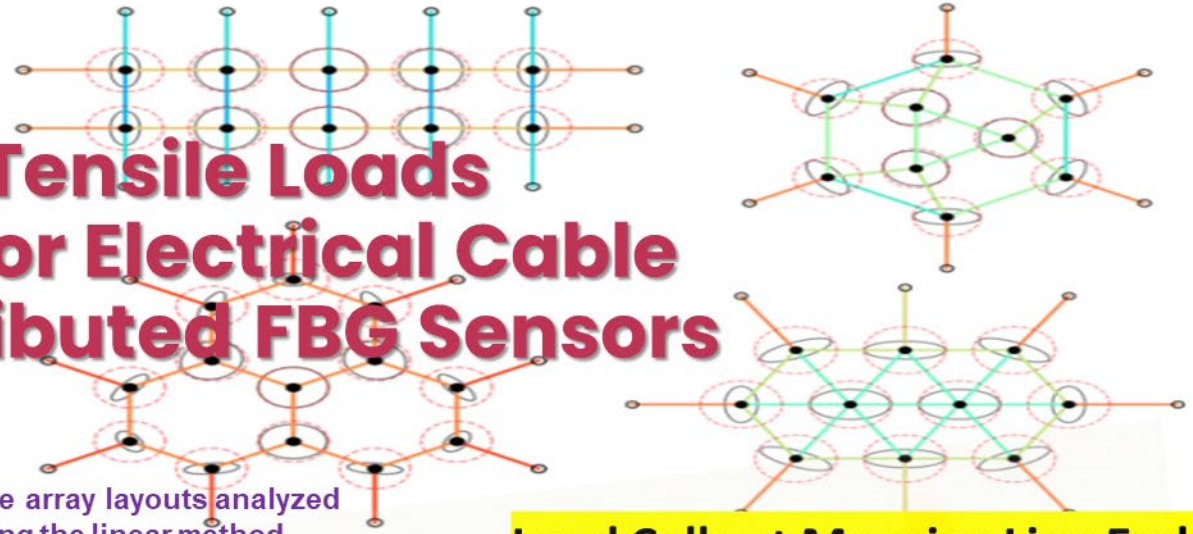


Monitoring Tensile Loads In Mooring Lines or Electrical Cable Using Quasi-distributed FBG Sensors

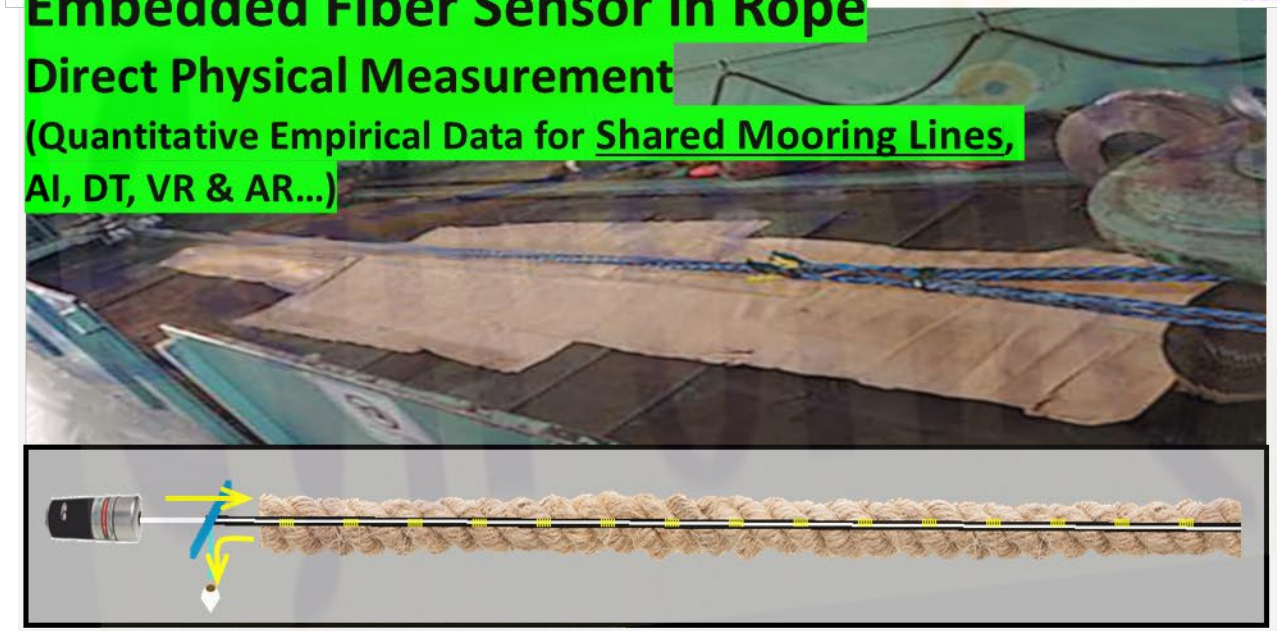


Example array layouts analyzed using the linear method

Embedded Fiber Sensor in Rope

Direct Physical Measurement

(Quantitative Empirical Data for Shared Mooring Lines, AI, DT, VR & AR…)



Versus

Load Cells at Mooring Line Ends

Indirect Physical Measurement

(Qualitative Downtrend to a Cartoon)

Mooring Load Monitoring, MSL Oilfield Services Ltd Hampshire, United Kingdom https://msluk.net/mooring/

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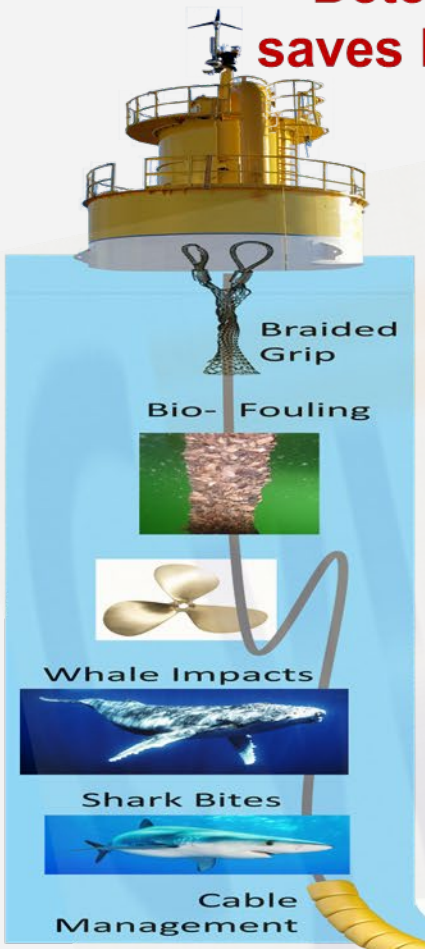
Detecting Mooring Line or Electrical Cable degradation before fails, saves Emergency Maintenance Costs and Avoids Service Interruptions.



The Problem…

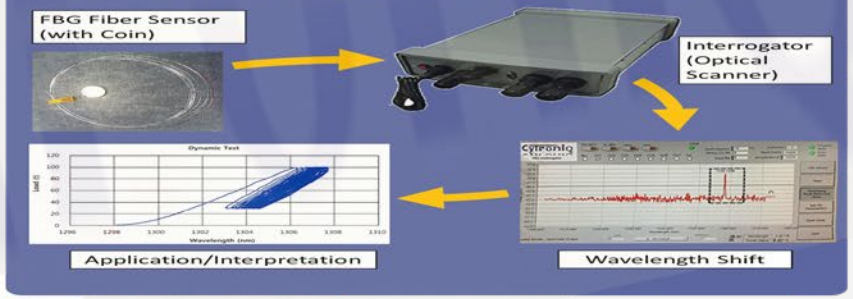
Mooring Line or Electric Cables are Fragile.

- Mooring Line or Electrical cables subject to catastrophic failure
  - May snap under load or be cut
  - Easy to detect
  - Prevent with armor and cable management equipment
- Mooring Line or Electrical cables subject to slow degradation
  - Abrasion, biofouling, corrosion, multiple impacts
  - Same preventative measures
- Slow degradation is difficult to detect before catastrophic failure

Applications of Distributed Sensors

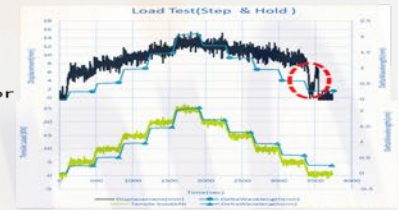
- Directly Monitor:
  - Localized strain
  - Creep in Lines
  - Sound/Noise
  - Mammal Impacts
  - Ship Collisions
  - Temperature
- Indirect Measurements
  - Localized stress
  - Remaining fatigue life
  - Progress of chemical processes
  - Biofouling (weight change)
  - Fishing Gear Entanglement

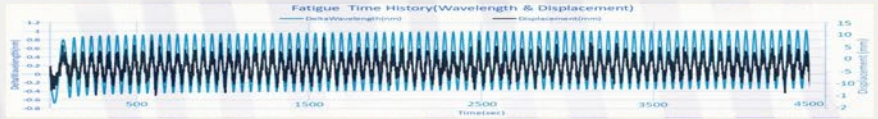
CyTro-X Distributed Sensor System



Prior Calibration and Validation

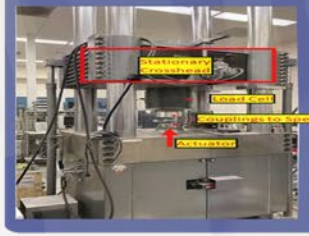
- JIP CALM – Jan. 2022
- Fiber embedded in 2m samples
  - 1 kV cable tested to 25 kN static load and to 14 kN stepped dynamic load
  - 10 kV cable tested to 25 kN stepped dynamic load
  - Fatigue test: 0.05 hz, 700 cycles, 25 kN peak load
- Conclusions and Observations:
  - Change in sensor wavelength tracks displacement (and tension)
  - Cable construction is important
    - ✓Some slip observed
    - ✓Cable failure near potted end connector





Test and Validation Program

- Funded by a TEAMER grant, Pacific Northwest National Laboratory, (PNNL) will perform static and dynamic load tests on cables with embedded CyTro-X sensors.
  - Samples will be representative of marine export cables and ROV cables
  - Procedure: Tensile tests on electrical cable segments, followed by 3 to 5 month soak in seawater to study degradation and excess biofouling on cables, followed by 2nd set of tensile tests
  - Cable will be wrapped on block-and-tackle to scale loads and max displacement to MTI tensile tester
  - Second tensile tests will include fatigue and test-to-destruction



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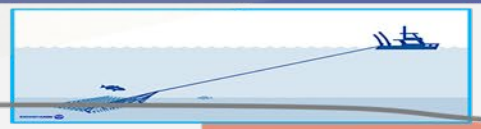
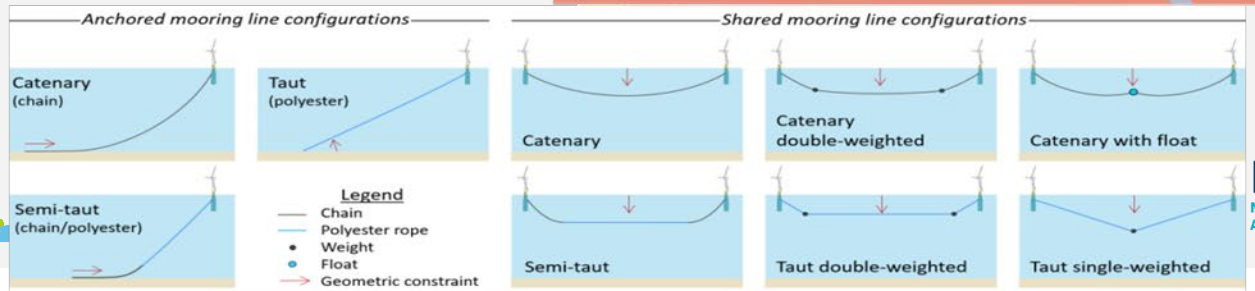
Fishing Gear



Earthquake/Landslide



Do you need Optimal O&M with Prognostic Artificial Intelligence based Scheduling the Preventive Maintenance that CyTroniQ can empower Lowering LCoE?

- **Health O&M System**
  Measure residual fatigue life, extend life of components.
  ① **Mooring System** that consists with Mooring Rope, Anchors/Foundation, and related accessories (Chain, ..)
  ② **Electrical Power Line** for Dynamic and Export Cable, including coupled Structures, Tower, Blade,
- **Marine Environmental O&M System**
  ① Marine Foul growth tendency
  ② Marine Mammal monitoring
- **Motion O&M System**
  ① Floater System that consists with IMU, GPS, Ballast Tank, Tension, and related accessories (Winch,..)
  ② Wind Turbine System that consists with IPC, YAW,
- **Metocean Monitoring O&M System**
- **Electrical O&M System**
  ① Electrical ESS with BMS,
  ② Power Management,
  ③ Wired or Wireless Communication on Air or Underwater,