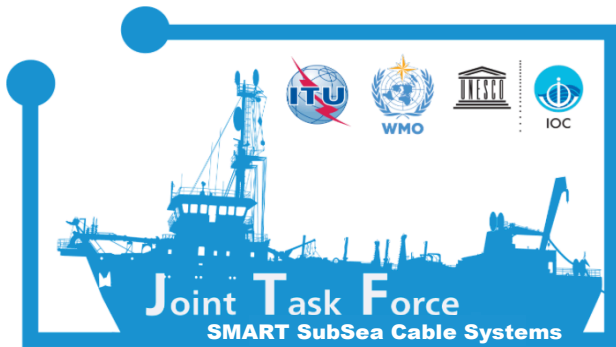


Observing the Ocean and Earth with SMART Subsea Cables: Update

Science Monitoring And Reliable Telecommunications



Bruce M. Howe
Chair, JTF SMART Cables
University of Hawai'i at Mānoa
And many others!



2021
2030 United Nations Decade
of Ocean Science
for Sustainable Development





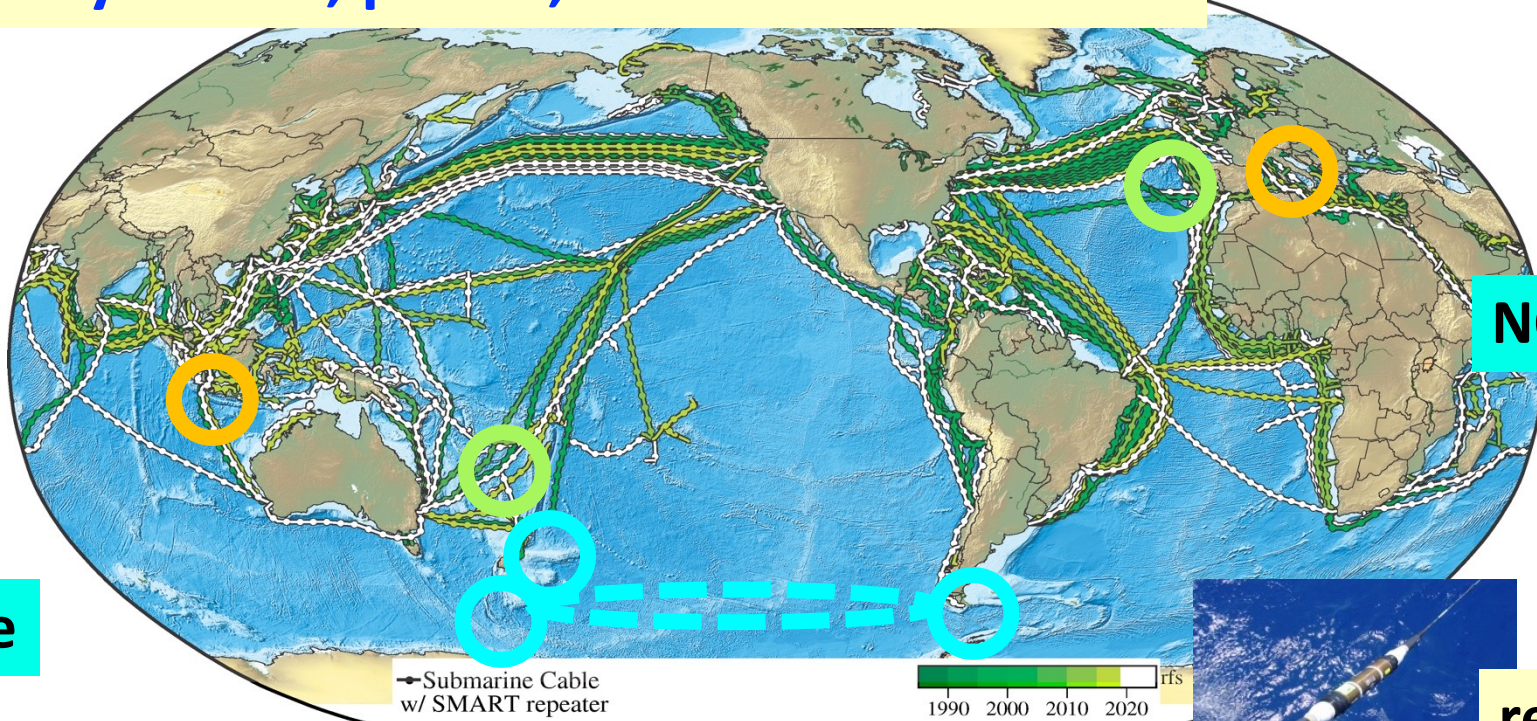
SMART Subsea Cables



Global Array: Climate, Oceans, Sea Level, Earthquakes, Tsunamis

Create a Planetary sensor, power, Internet network

1st order addition to Ocean-Earth observing system



Share submarine cable infrastructure
Telecom + science
NO Interference ↓€\$

1.2+ Gm
~20,000 repeaters
20 year refresh

repeaters ~70 km

Know the environment – protect the network

CAM: 3700 km, Gov't, install 2025 → SMART
Continent/Lisbon-Azores-Madeira ring

Bottom temperature, pressure, seismic acceleration

UN Decade

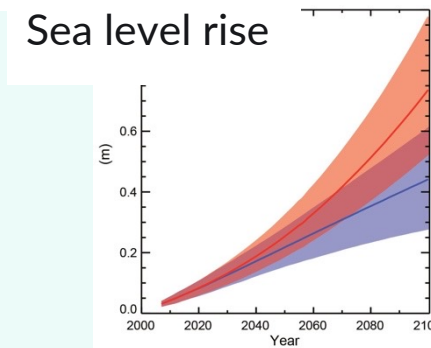


Climate change – humanity’s greatest existential threat

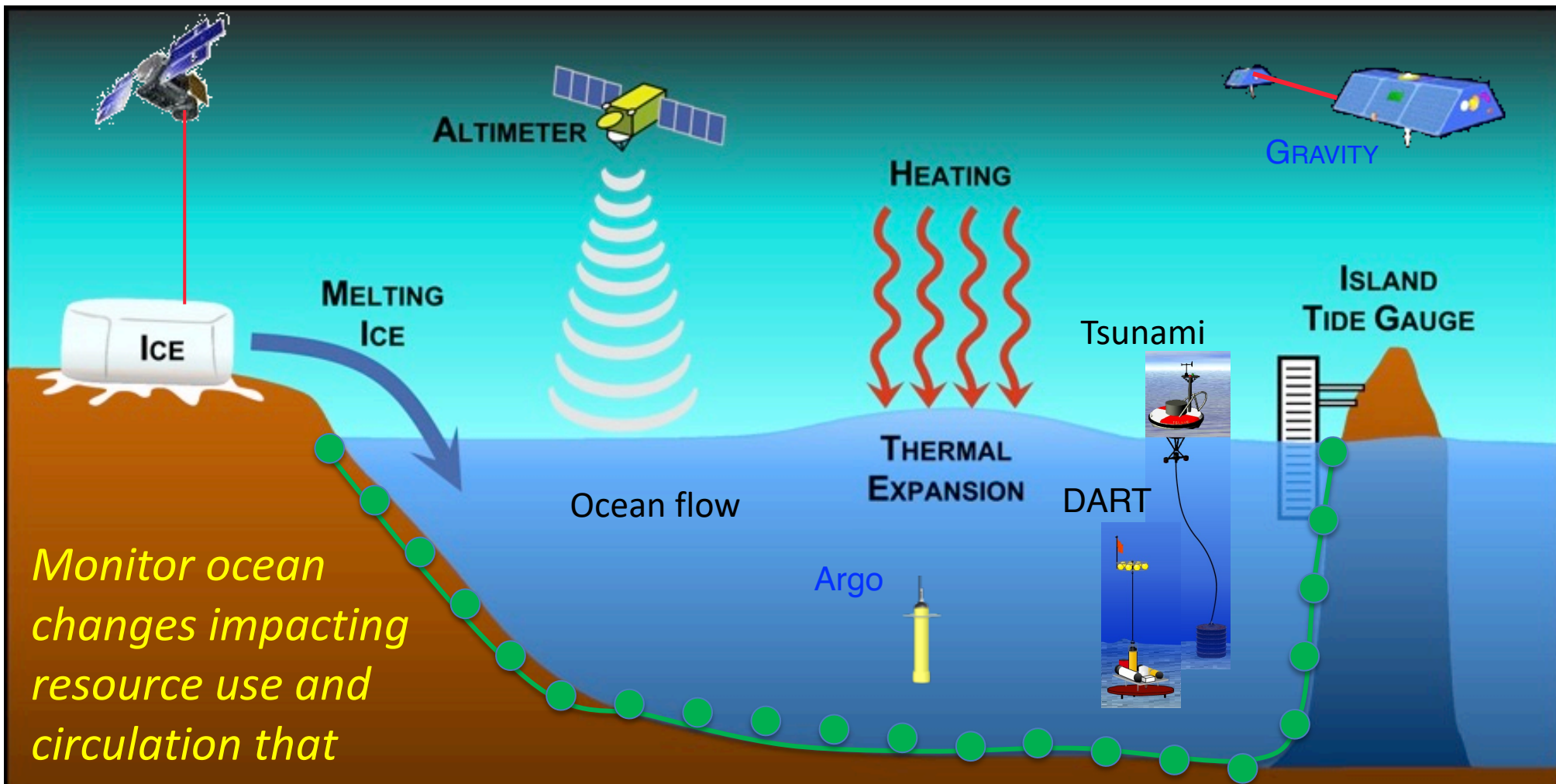
Societal and environmental issues



- **Climate change** – ocean temperature and heat content, circulation
- **Sea level rise** – hazard for coasts, islands, cities
- **Disaster Risk Reduction** – tsunami and earthquake monitoring
- **Societal Connectivity** – Resilient and sustainable telecom infrastructure



Ocean Observing Tools



Monitor ocean changes impacting resource use and circulation that drives weather and climate patterns

SMART Cables measure Essential Ocean Variables: Pressure, temperature; seismic acceleration + ...

Now:
Very few bottom obs

Future:
Add SMART Cables Augment and complement present



Science and Early Warning - Observables

Climate and Oceans

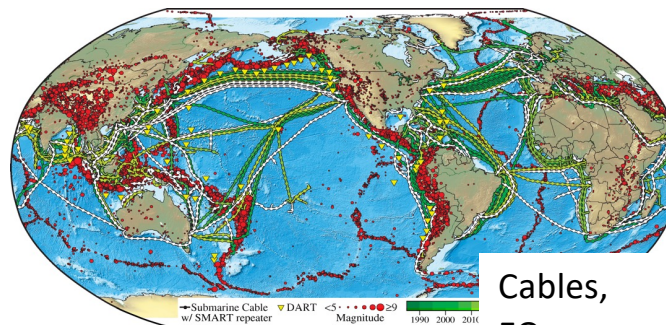
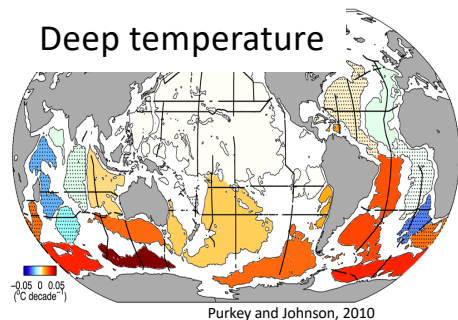
Hazards

Tsunami, Earthquake Warning

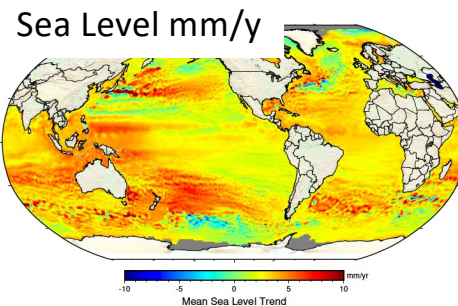
SMART cables - vastly increase existing ocean **pressure/seismic sensors**

- Improve tsunami warning precision, Reduce unnecessary warnings/evacuations.

Temperature

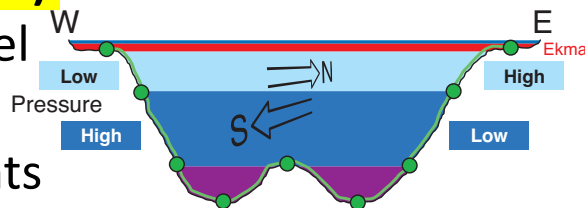


- SMART → **Subsurface temperature, EOV**
- Deep ocean warming → sea level rise.
- Δ deep ocean temperature → Δ circulation, Δ climate.



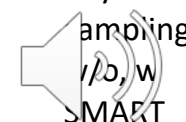
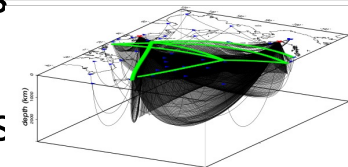
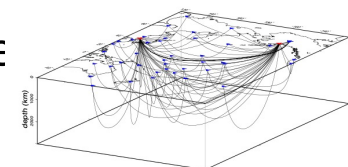
Circulation, sea level rise, mass distribution

- SMART **Ocean bottom pressure (OBP, eEOV)** → expansion due to melting ice → sea level change (x,t).
- Δ_x between OBP → depth-averaged currents and ocean circulation.



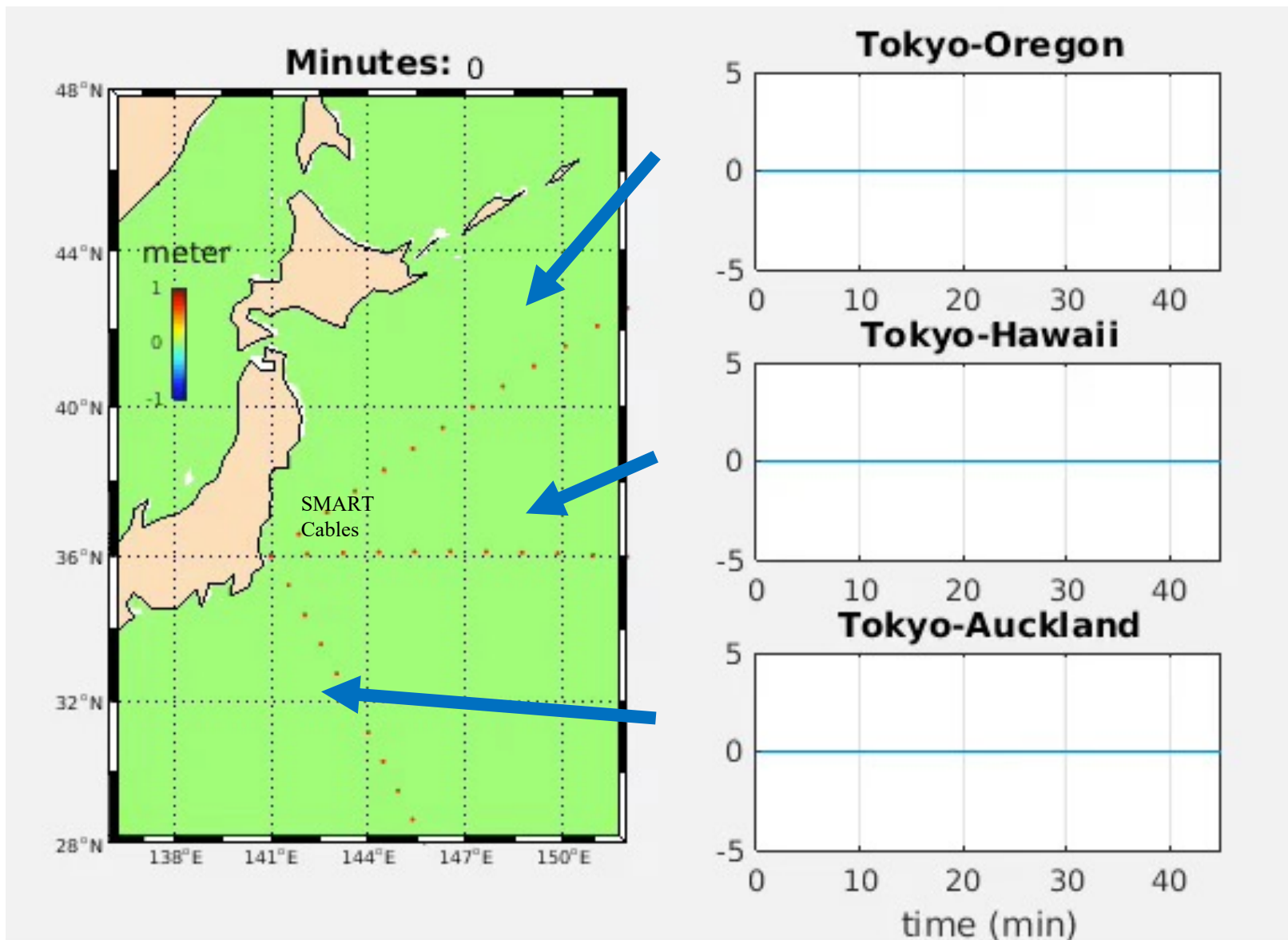
Seismology

- SMART **Seismic accelerometers** → advance seismology:
- Detect, locate small quakes below ocean floor
- Rupture type and dynamics larger offshore earthquakes
- Image Earth's interior





Simulation – Tsunami Detection (bottom pressure)



Each line represents pressure sensor along cable

Realtime!

Reliable!

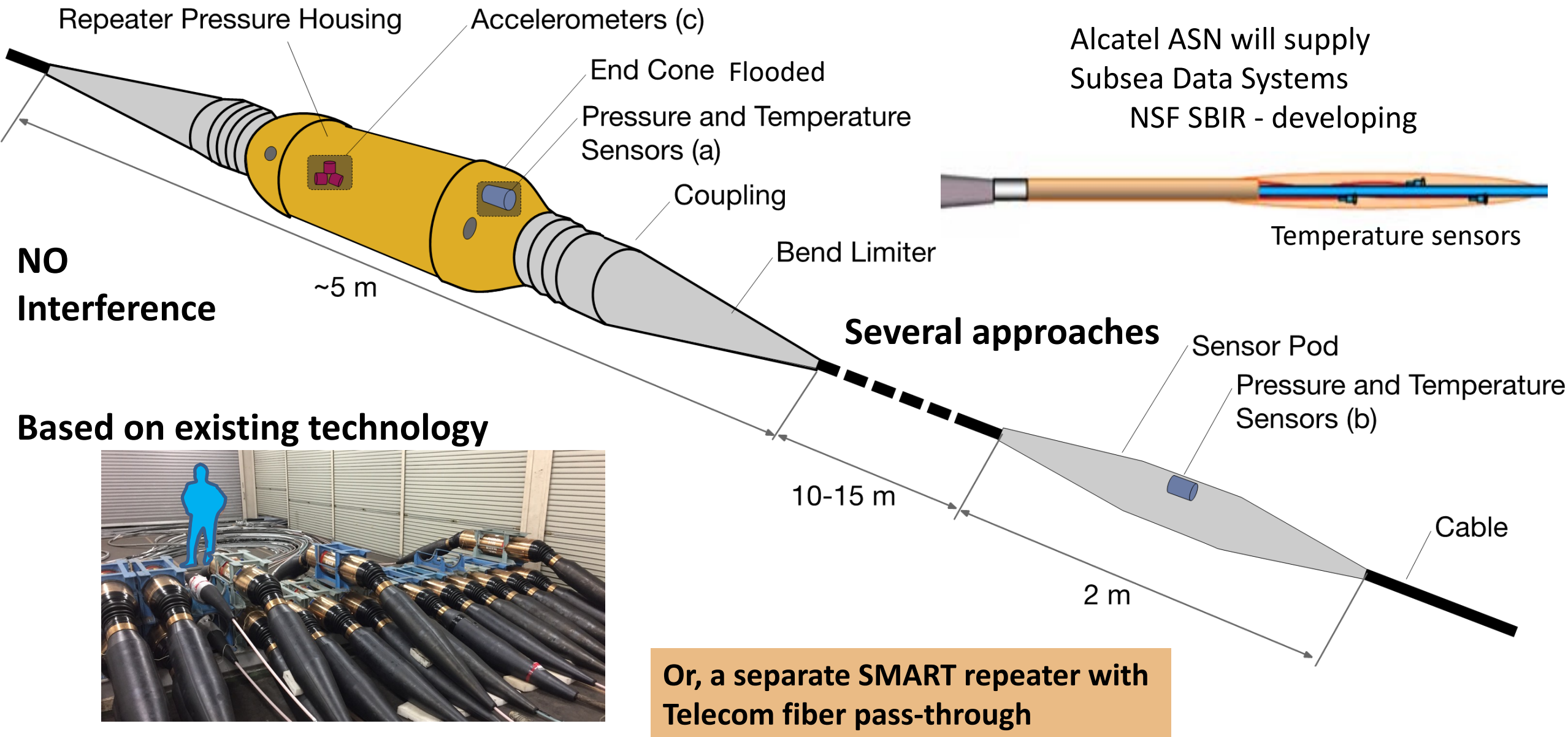
In situ

Tony Song,
JPL/CalTech

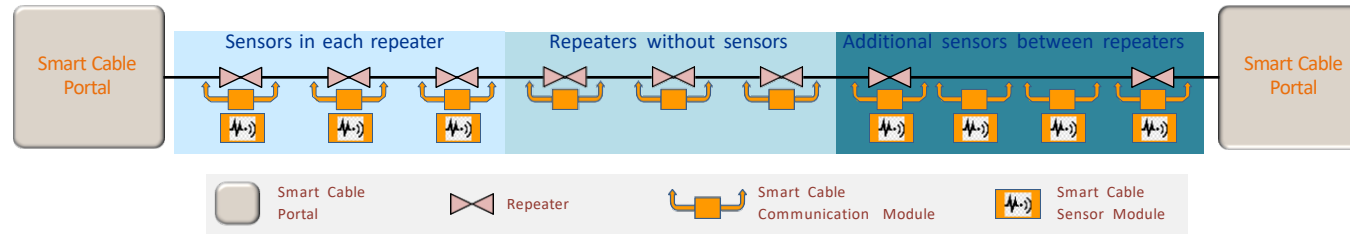
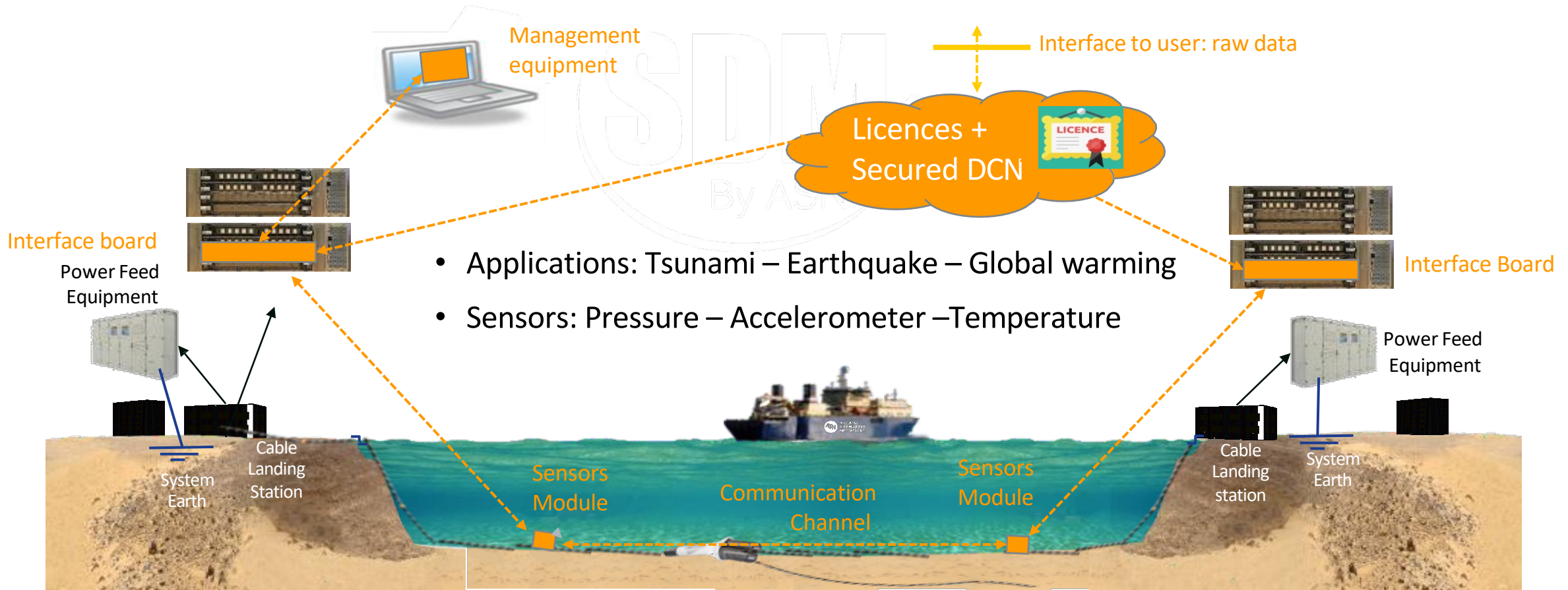




SMART Repeaters



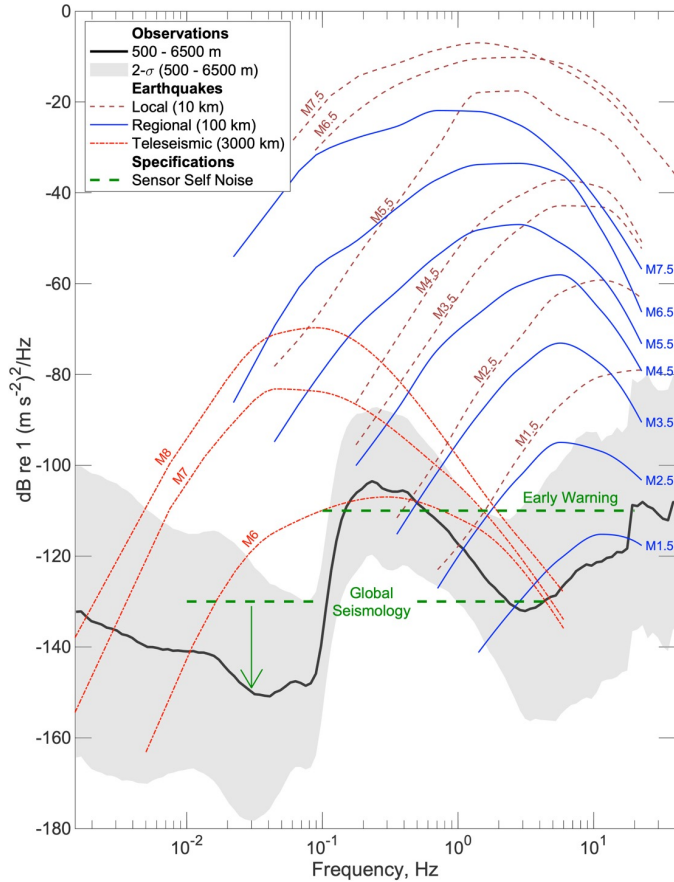
The SMART option – Alcatel Submarine Networks – RFS 2025



Smart Repeater

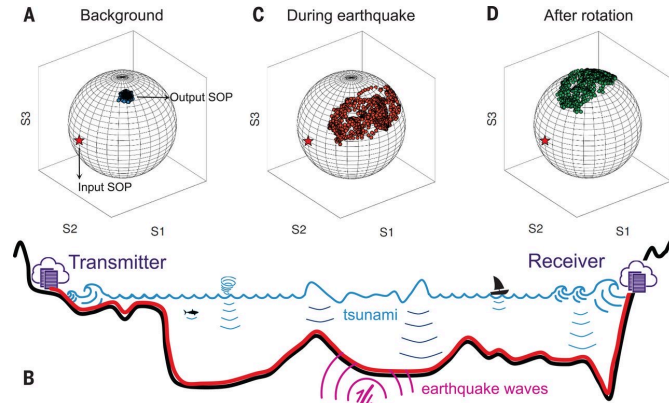


Practical Capability and Other Sensing Methods for Seismic and Tsunami detection

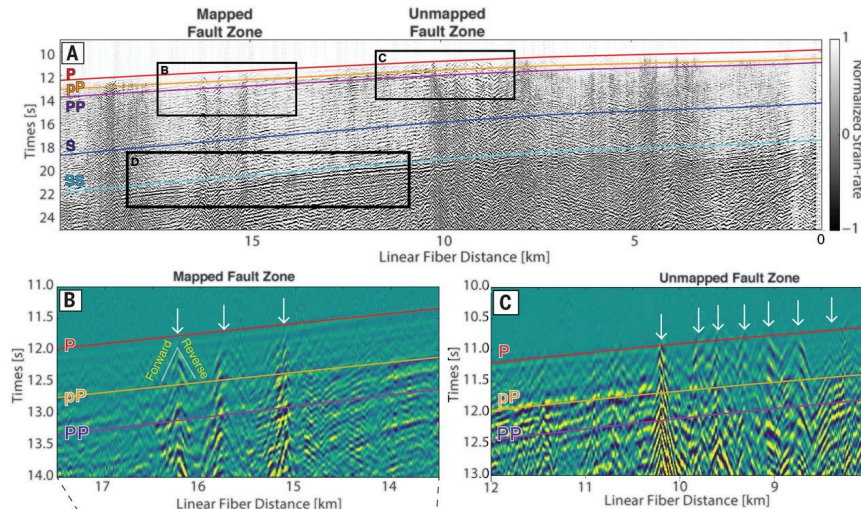


Other sensing beyond SMART sensors: The cables themselves can serve as sensors using such methods as Distributed Acoustic Sensing, Optical Polarization and Ultrastable Laser Interferometry.

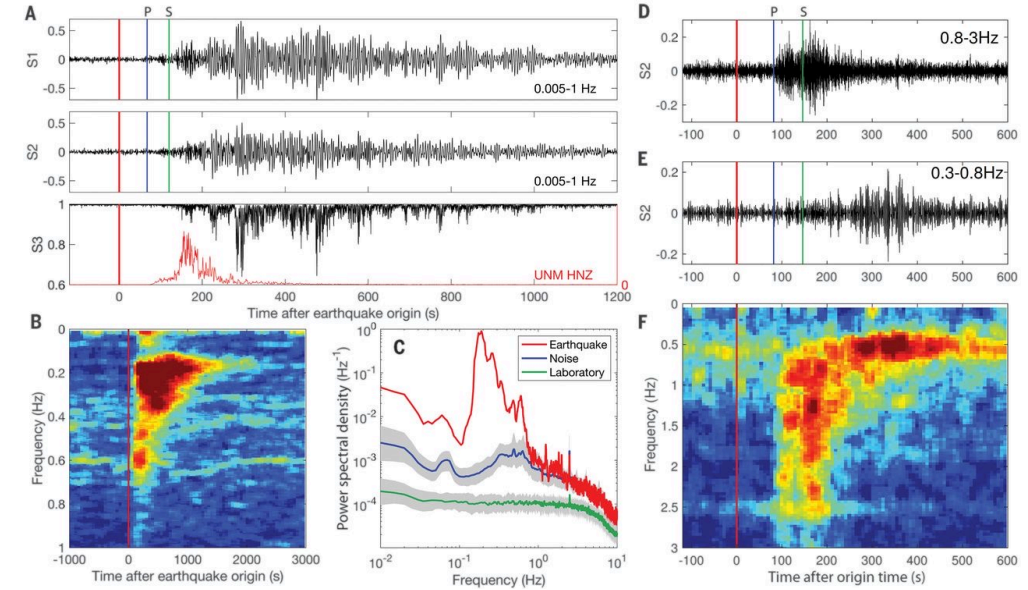
Zhan et al. (*Science*, 2021)



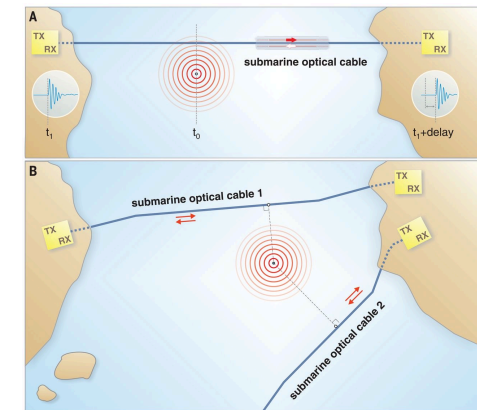
Above: Optical Polarization schematic
 Below: Example seafloor DAS



Lindsey et al. (*Science*, 2019)



Below: Ultrastable Laser Interferometry can identify closest cable segment to source, can estimate source location with multiple cables.

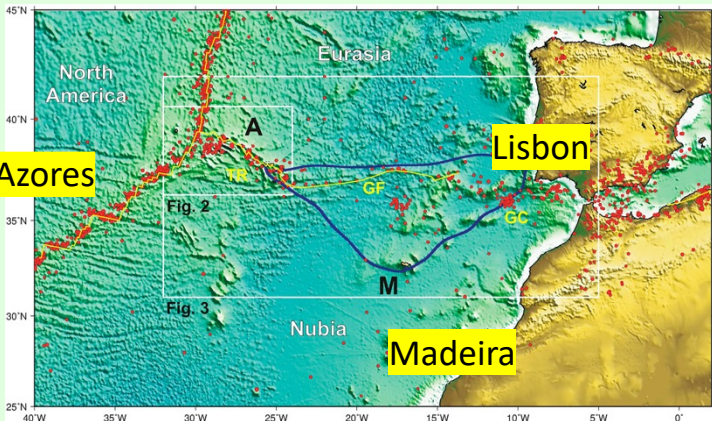


Marra et al. (*Science*, 2019)

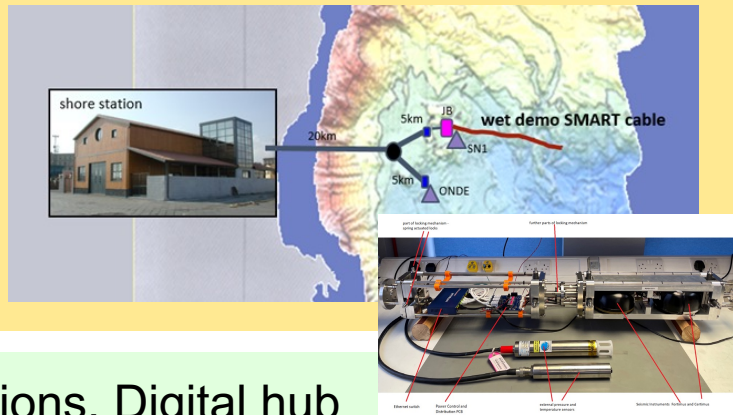
Seafloor seismic sensing capability: Typical amplitude ranges for local, regional and teleseismic sources as a function of frequency, compared to seafloor seismic noise average PSD and two sigma range. This does not address sensor coupling.

SMART Cables - Europe

Approved – underway!



- Wet Demo, **Install 2023**
- Three test SMART repeaters (sans telecom)



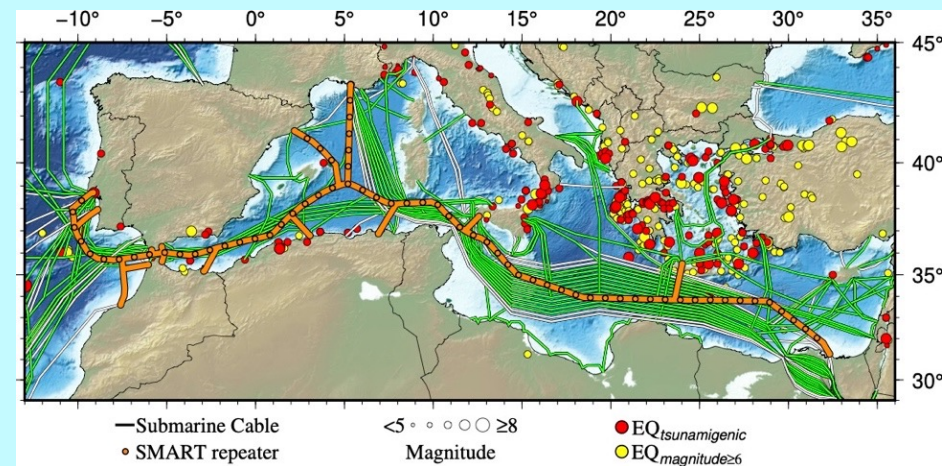
- **SMART CAM**
- Domestic, international connections, Digital hub
- 1755 earthquake tsunami
- Seismic, tsunami, ocean, environment
- 3700 km, 50 SMART repeaters, €120M
- RFP 2023Q1, **Ready For Service 2025**
- ANACOM connection to telecom

LEA – Listening to the Earth under the Atlantic

Risk analysis (V. Silva, pers. comm.)

- Improved EEW (~10 s) with less loss of life will more than pay for the system
- Next: include infrastructure and tsunami inundation

NEAMTWS

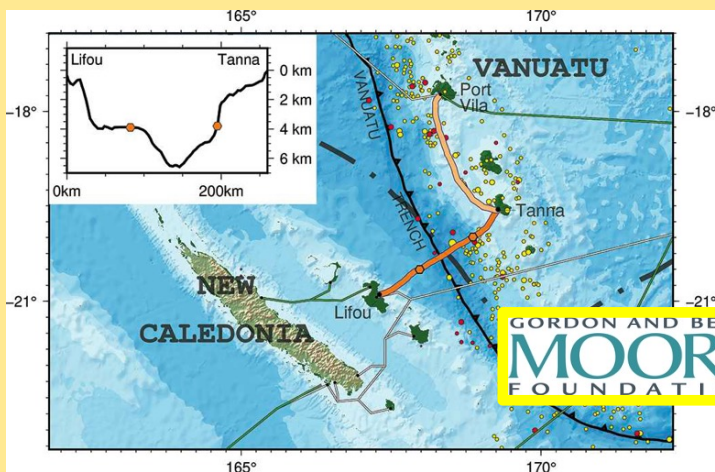


- **MEDUSA**
- Install 2024/25
- Possibly up to ~60 SMART repeaters on main cables
- Improve coverage for large regional area
- **Raising funds for SMART capability now**



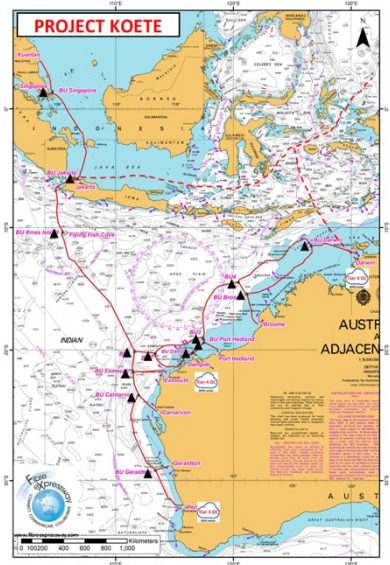


SMART Cables - Pacific

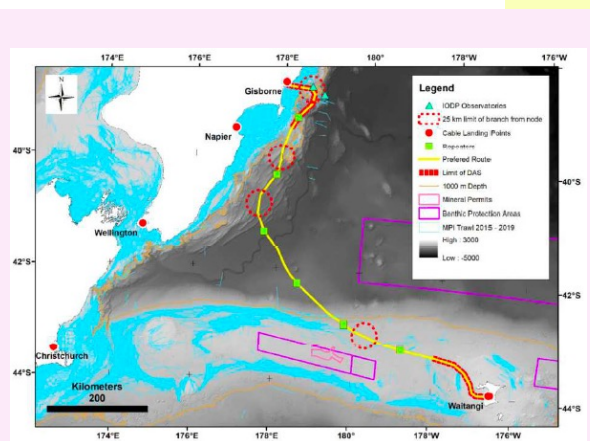


Vanuatu – New Caledonia
SMART, DAS

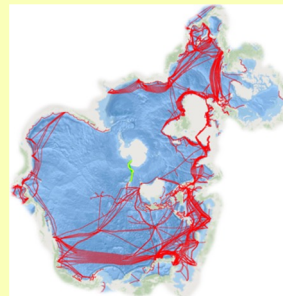
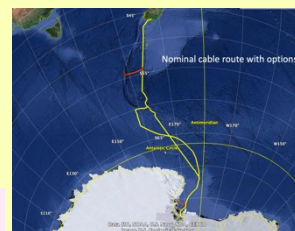
Intergovernmental MOU



Project Koete
Perth-Darwin-Malaysia
Communities
SMART integral
Raising funds



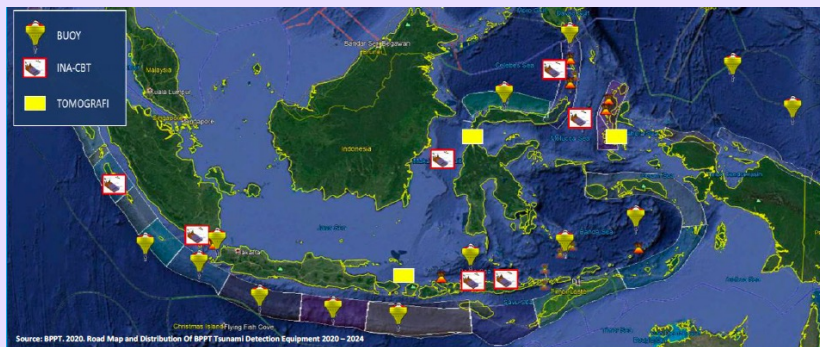
NZ–Chatham Islands
SMART + DAS + BUs/nodes
Under gov't review (MBIE)



Antarctica – NZ

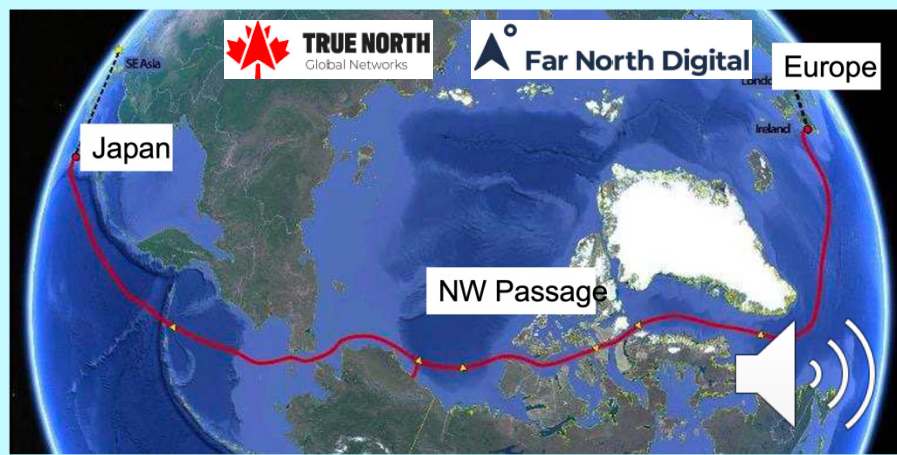
Improve connectivity
SMART Cable

Workshops, NSF, NAS, Chile



Indonesia
In country development Ina-CBT
Single ended, 50 km, 2 module test
system working off Labuan Bajo

Far North Fiber
14,000 km
Low latency
Communities
Contract 2023
RFS Q4 2026
SMART integral





SMART Cables – Moore Foundation Project

GOAL:

SMART cables become the world standard, ... global network for sustained ocean observation, ... study of earthquakes, and earthquake and tsunami warning in a world with rising sea levels.

Objectives:

- **Science and early warning simulations of observing systems, data analysis, and sustained scientific operation.**
- **Vanuatu-New Caledonia, active subduction zone, dynamic ocean region, earthquake and tsunami early warning.**
- **International Project Office for Joint Task Force Scientific Monitoring And Reliable Telecommunications cables**

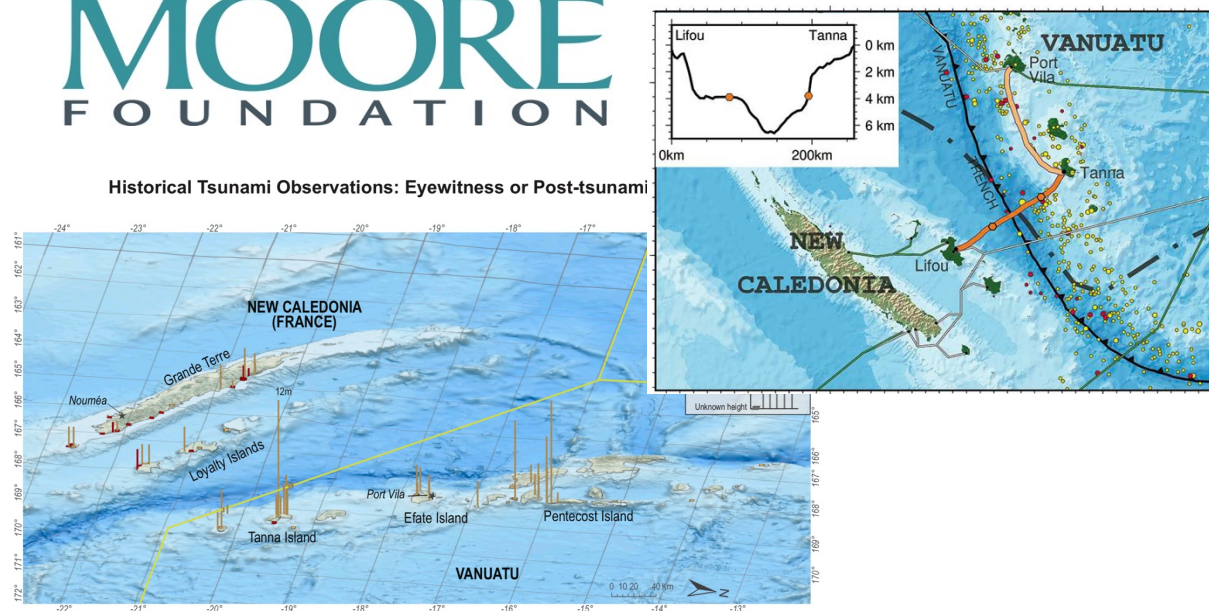


\$7M
5y

Team, 2022-2026

- | | |
|---|--------------------------------------|
| University of Hawai'i at Mānoa | National University of Vanuatu (NUV) |
| Univ Texas-Austin | Pacific Community (SPC) |
| Louisiana State University (LSU) | California Institute of Technology |
| University of Otago, NZ | Subsea Data Systems |
| Los Alamos National Laboratory (LANL) | |
| French Institute for Research and Sustainable Development (IRD) | |
| Vanuatu Meteorology and Geohazards Department (VMGD) | |
| GNS New Zealand | |
| International Tsunami information Center (ITIC) | |

GORDON AND BETTY
MOORE
FOUNDATION





EC DG CONNECT CEF-2 Funding – NEW!

- Provide international digital connectivity for the EU, support territorial cohesion
- All EU Submarine cable connectivity
- 100s M euros
- 1st call complete
- 2 more in next year – October!
- 30-70% support for approved projects
- OuterMost Regions and Overseas Countries and Territories: e.g., Greenland, Caribbean, Azores, Madeira, Canaries, New Caledonia, French Polynesia – Global scope
- **Precedent for other organizations**
- **Two for the price of one**

Backbone connectivity for Digital Global Gateways

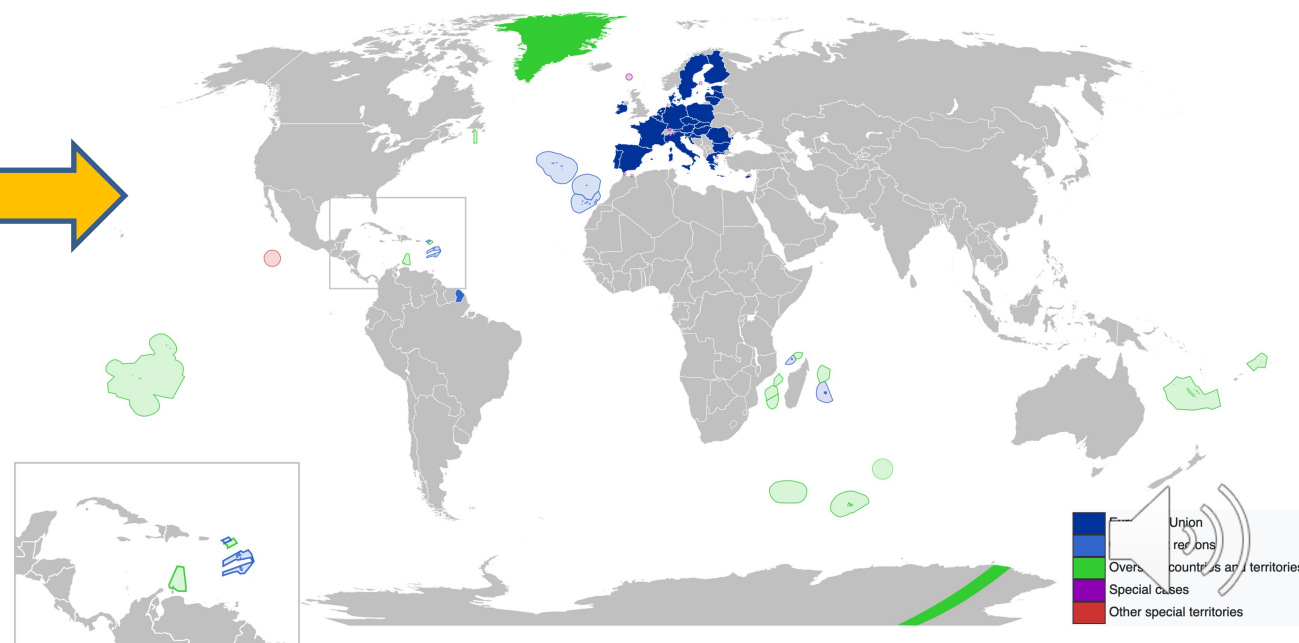
Future Planning Call 2

20.9.2022

Thomas Kuepper

- **Smart Cables included.**
- **Current draft call text proposal (not final!)**

"Costs related to integrating sensors into a submarine cable system are in the scope of this call."





Concluding Remarks

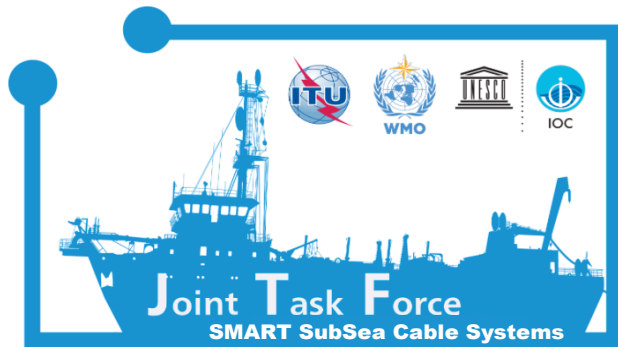
Earthquake, volcano, tsunami

- SMART – essential ocean variables and disaster risk reduction
- Global scale, power+internet on seafloor, sustained, realtime, 25+ year life, highly reliable, leverage \$5B/y industry, 170 y experience, low lifetime cost
- SMART available (ASN, Subsea Data Systems), 2025+
- SMART systems: CAM, MEDUSA, V-NC, Antarctica, Arctic, ... will set valuable precedents
- SMART integrated in UN organizations (ITU, WMO, IOC, Decade)
- Work towards global scale, coverage – KISS
- Many opportunities in many regions, toward (near) global scale



Observing the Ocean and Earth with SMART Subsea Cables: Update

Science Monitoring And Reliable Telecommunications



Thank you!



2021 United Nations Decade
2030 of Ocean Science
for Sustainable Development





SMART Progress and References

- Joint Task Force (JTF), ITU/WMO/IOC SMART Cables for Observing the Ocean Science Monitoring And Reliable Telecommunications, Climate Monitoring and Disaster Mitigation
- SMART Cables for Observing the Global Ocean: Science and Implementation, 2019. Frontiers of Marine Science
- Wet Demo off Sicily to be installed 2023, INGV, Funded
- Alcatel Submarine Networks (ASN) 2020.09.29 Press release - climate change an integral part of business strategy, will supply SMART capability 2025.
- SMART Subsea Cables for Observing the Earth and Ocean, Mitigating Environmental Hazards, and Supporting the Blue Economy, 2022, Frontiers of Earth Science
- Portugal SMART CAM system Continent-Azores-Madeira ring, 3700 km, 50 SMART repeaters, ready for service 2025, ~\$120M. Authorized by Gov't 2022.04.13; 2022.10.20; Science paper. Early Warning Paper.
- Vanuatu-New Caledonia - Leaders signed MOU for 2nd international cable 2022.07.29, SMART
- NZ-Antarctica/McMurdo Base SMART Cable, US National Science Foundation and workshop report - desk top study just complete (awaiting public report)
- NZ-Chatham Islands - MBIE report under consideration, w/ SMART, and Science workshop report
- Norway-Japan via Arctic - Far North Fiber - under consideration, welcome SMART. NORDUNet PolarConnect Video.
- MEDUSA - Lisbon-Egypt - raising funds for SMART portion
- Moore Foundation has awarded Joint Task Force/UHawaii \$7M to facilitate SMART, globally, regionally, as well as Vanuatu-New Caledonia, proposal
- ITU - Circ. Letter Member States, Assemblies (WTSA-20, WTDC-22, PP-22); Study Group 15/Q8 G.SMART. Forwards - Submarine Telecom, 2019/20, 2021/22
- SMART endorsed as Project of the UN Decade of Ocean Science for Sustainable Development 2021-2030, Supporting Docs, Web page, with GOOS, Tsunami
- European Union Funding: CEF-2 Digital Global Gateways, Submarine Cables, Call 2 2022.10.12, w/ SMART, outlying territories, 100M euro, 30-70% of project cost; (see DG Connect ppt); Call 3 summer 2023
- JTF SMART Cable Workshop 19-20 January after PTC23 in Honolulu, followed by Moore SMART Cable project meeting 21-23 January.