

Observing the Ocean and Earth with SMART Subsea Cables - Application to the Arctic

□

Science Monitoring And Reliable Telecommunications



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



2021 United Nations Decade
2030 of Ocean Science
for Sustainable Development



GORDON AND BETTY
MOORE
FOUNDATION



Arctic Science Summit Week
Tromso, Norway
28 March 2022

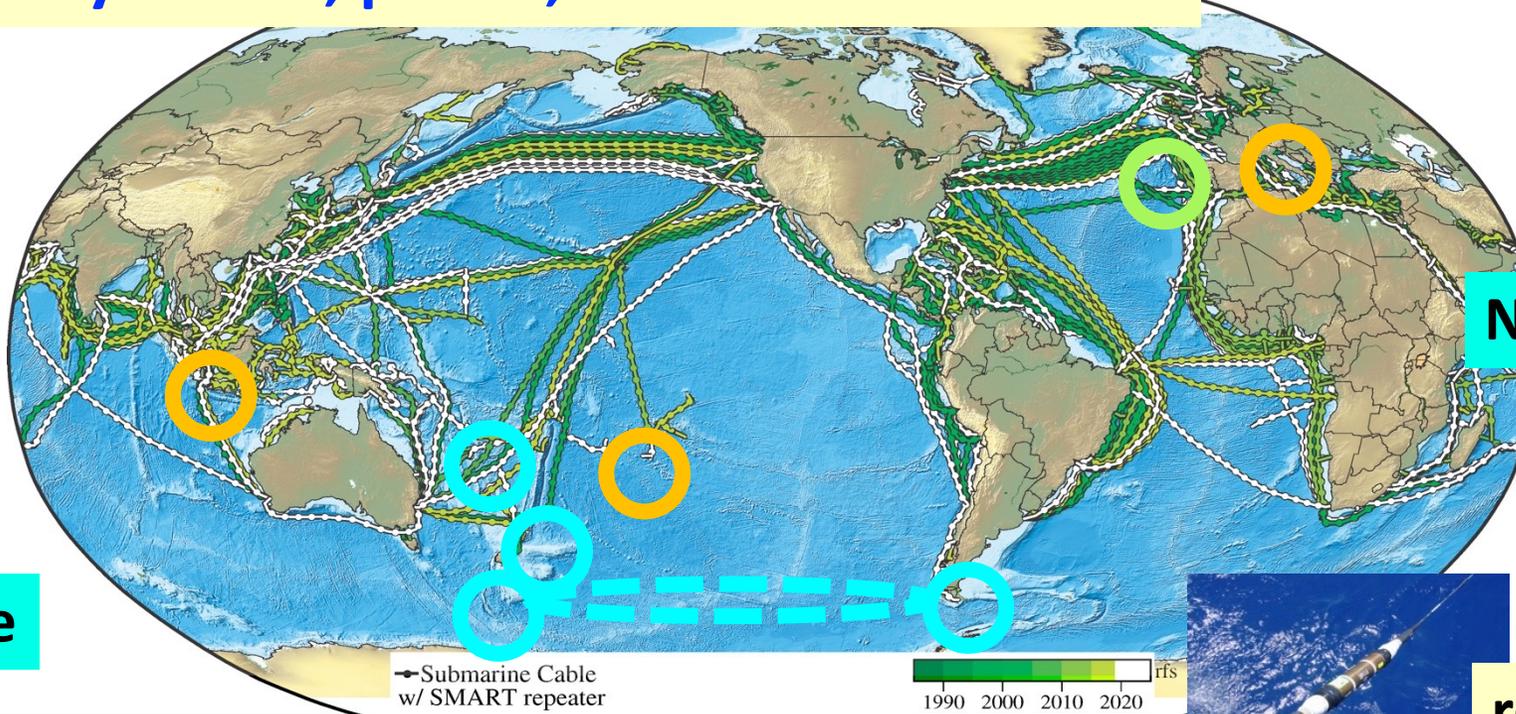


SMART Subsea Cables

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

UN Decade



Know the environment – protect the network

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

Bottom temperature, pressure, seismic acceleration

repeaters ~70 km



Climate change – humanity’s greatest existential threat

Societal and environmental issues

SMART: UN Decade of Ocean Science Project

Climate
SDG 13



– **Climate change** – ocean temperature, circulation
direct impact on societies, short and long term

Ocean
SDG 14



– **Sea level rise** – hazard for coasts, islands, cities

UN
DRR

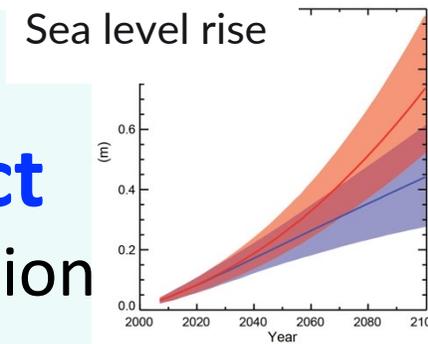


– **Disaster Risk Reduction** – tsunami
and earthquake monitoring
throughout ocean basins and coastal margins

Infrastructure
SDG 9, 11



– **Societal Connectivity** – Enable progress with
resilient and sustainable telecom infrastructure



Tsunami



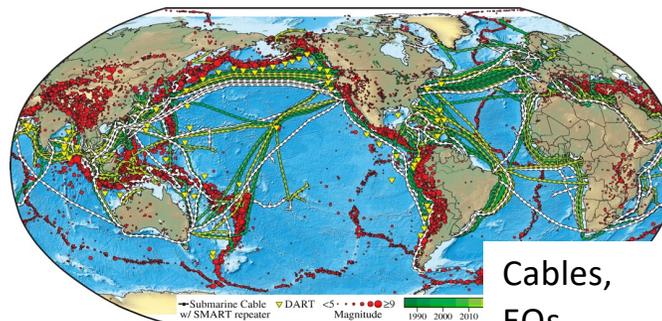
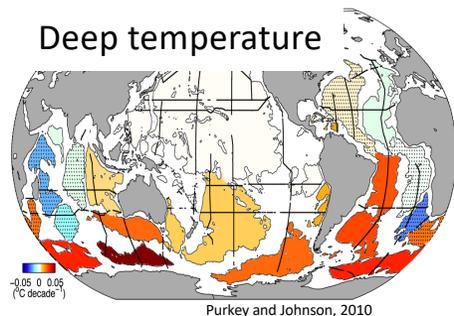
Science and Early Warning - Observables

Climate and Oceans

Hazards

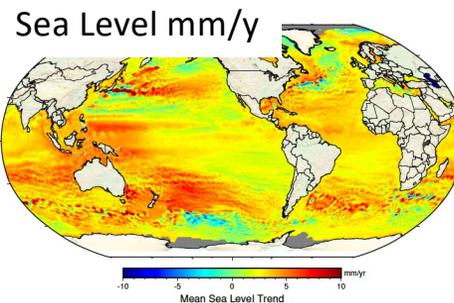
Tsunami, Earthquake Warning

Temperature



- SMART cables - vastly increase existing ocean **pressure/seismic sensors**
- Improve tsunami warning precision, Reduce unnecessary warnings/evacuations.

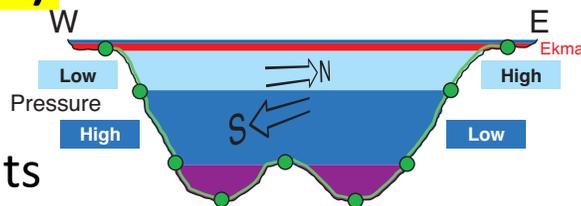
- SMART → **Subsurface temperature, EOV**
- Deep ocean warming → sea level rise.
- Δ deep ocean temperature → Δ circulation, Δ climate.



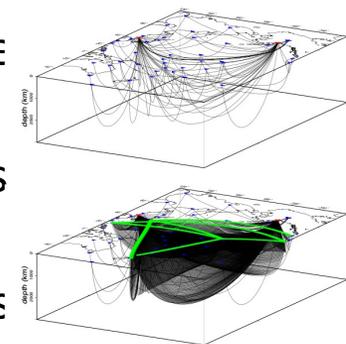
Circulation, sea level rise, mass distribution

Seismology

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

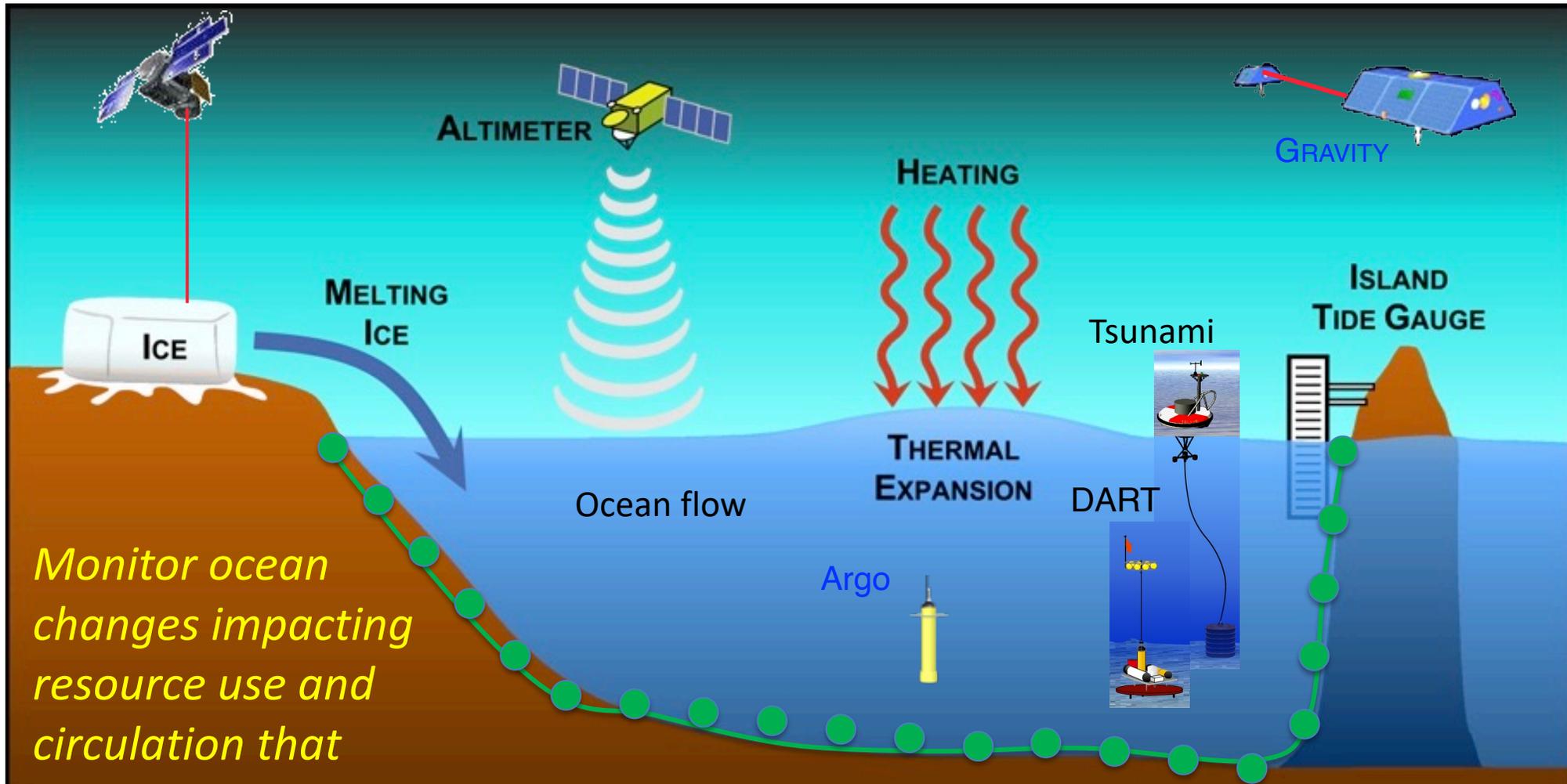


- SMART **Seismic accelerometers** → advance seismology:
- Detect, locate small quakes below ocean floor
- Rupture type and dynamics larger offshore earthquakes
- Image Earth's interior



sampling with and without SMART

Ocean Observing Tools



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

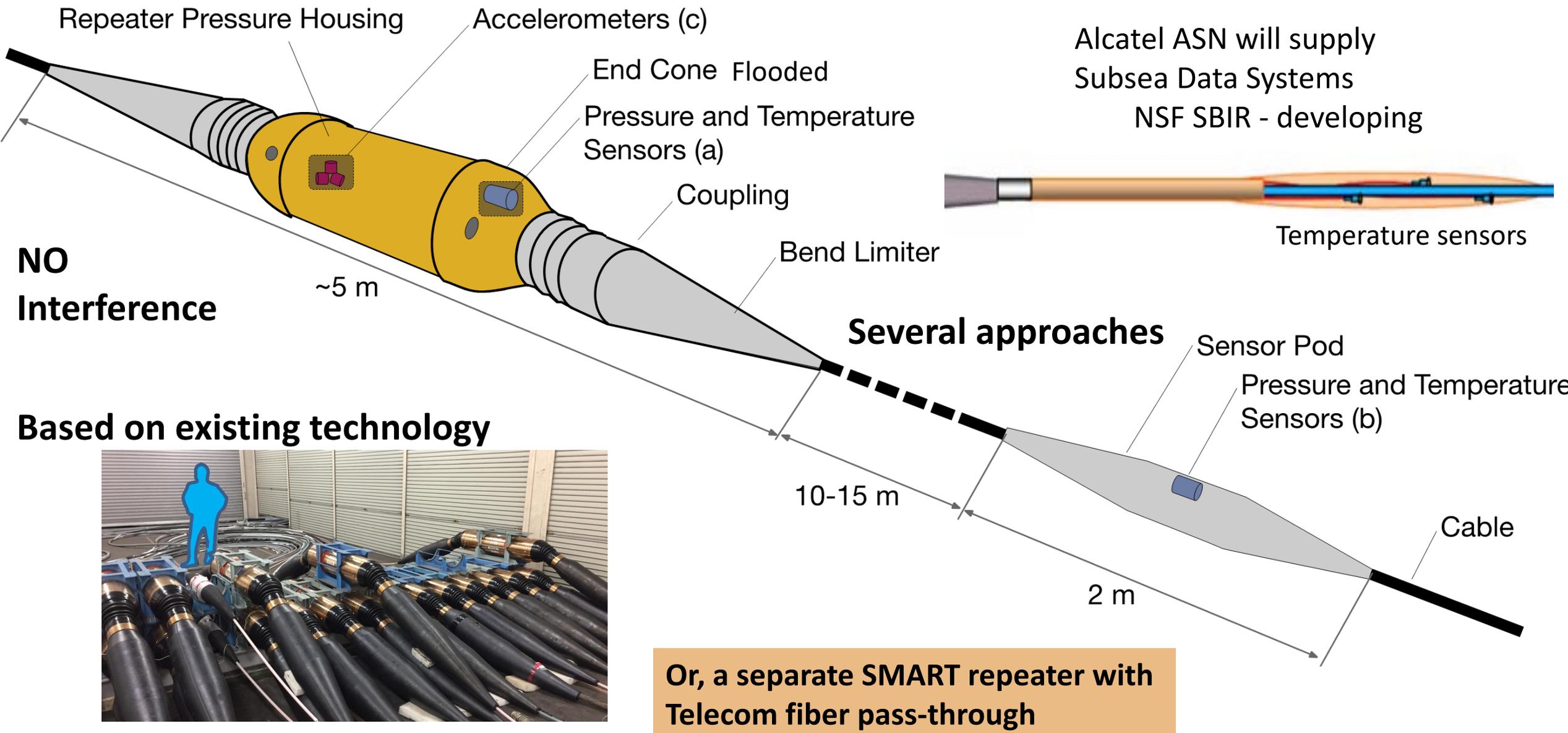
SMART Cables measure Essential Ocean Variables: Pressure, temperature; seismic acceleration + ...

Now:
Very few bottom obs

Future:
Add SMART Cables Augment and complement present

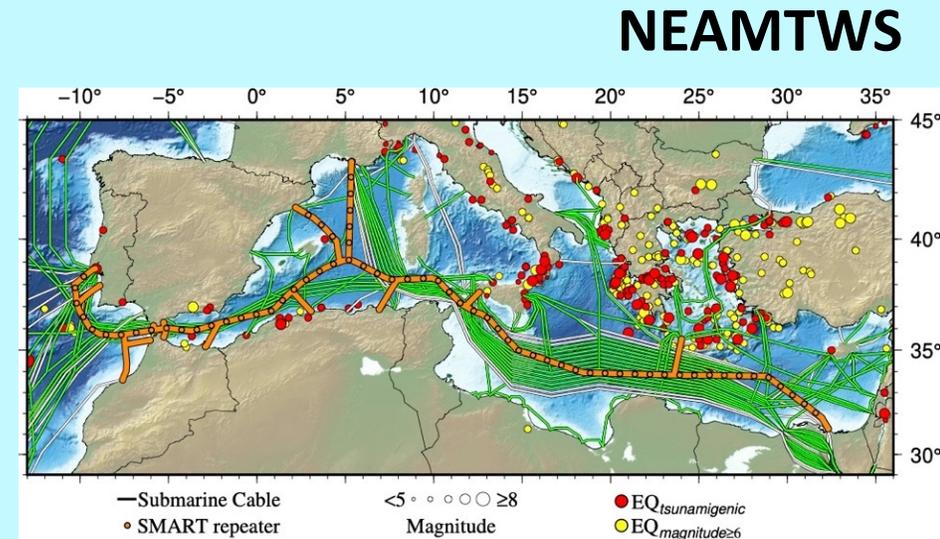
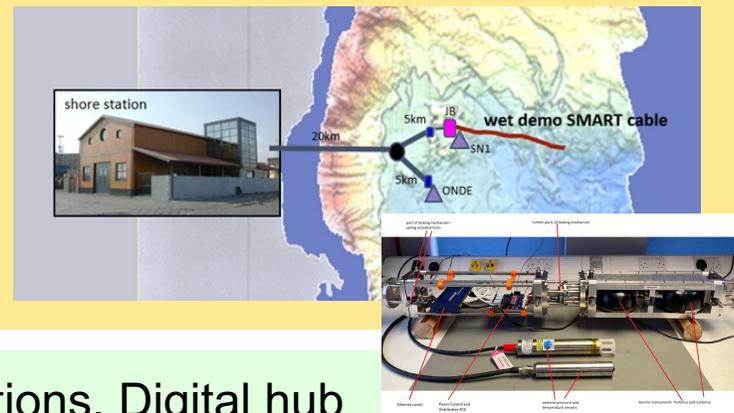


SMART Repeaters

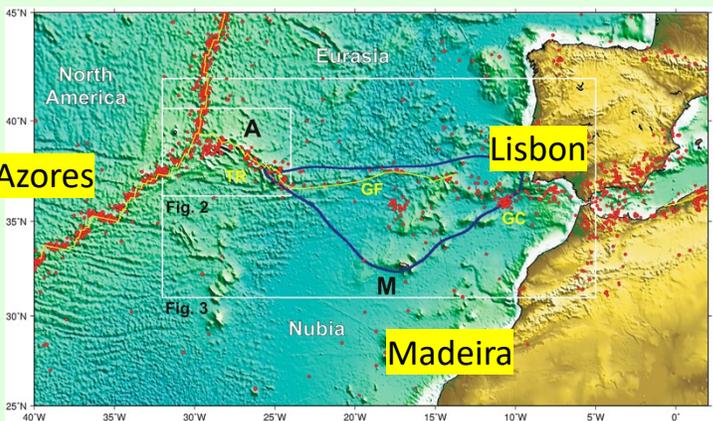


SMART Cables - Europe

- **Wet Demo, Install 2022**
- Three test SMART repeaters (sans telecom)



- **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**



- **CAM2**
- Domestic, international connections, Digital hub
- 1755 earthquake tsunami
- Seismic, tsunami, ocean, environment
- 3700 km, 50 SMART repeaters, €120M
- RFP 2022, **Ready For Service 2025**
- ANACOM connection to telecom

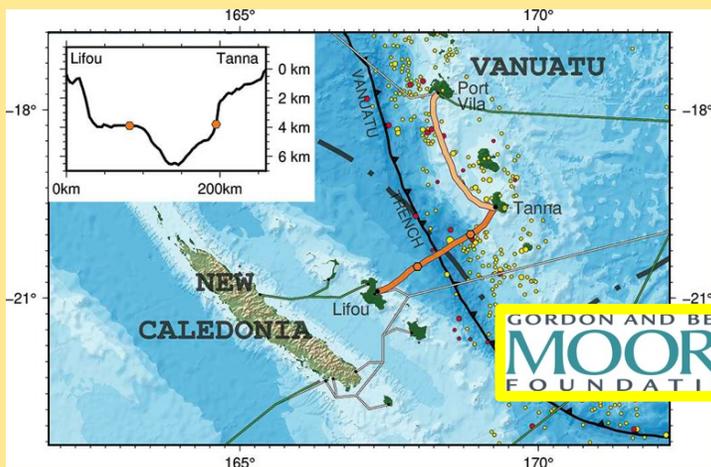
LEA – Listening to the Earth under the Atlantic

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



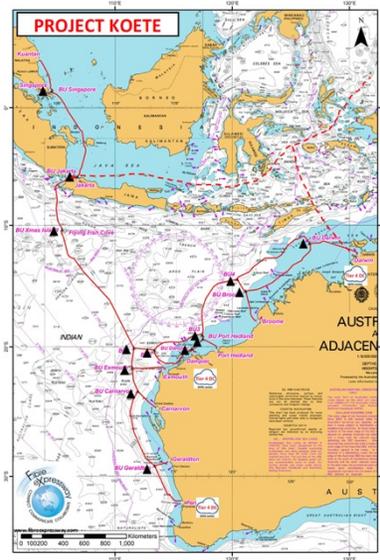
SMART Cables - Pacific



Vanuatu – New Caledonia

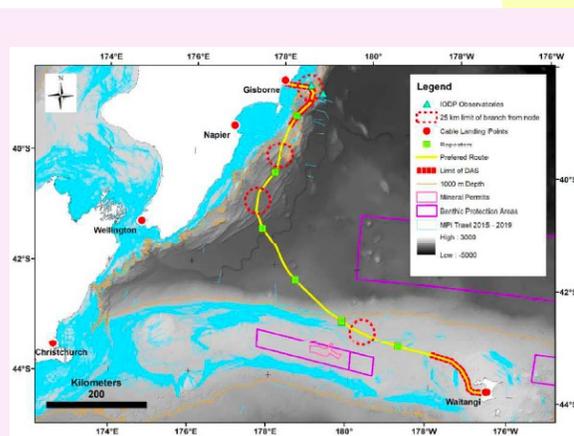
SMART, DAS

Partial funding; under gov't review



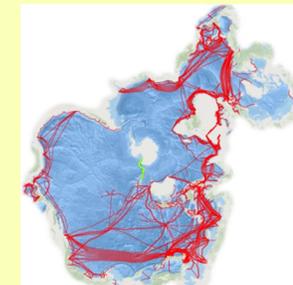
Project Koete

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

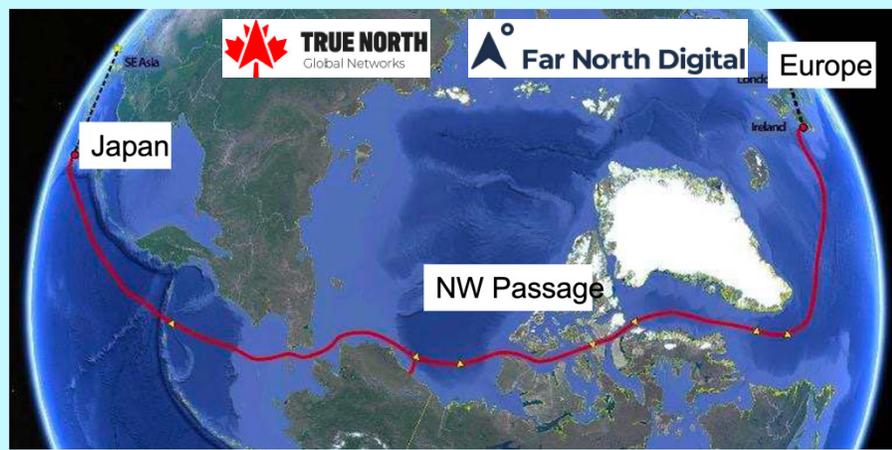


Indonesia

In country development Ina-CBT
Single ended test systems underway
Follow with Makassar Strait, with telecom

Arctic Express

14,000 km
Low latency
Communities
Contract Q1 2022
RFS Q4 2025
SMART integral





SMART Cables – Moore Foundation Project

LEAD

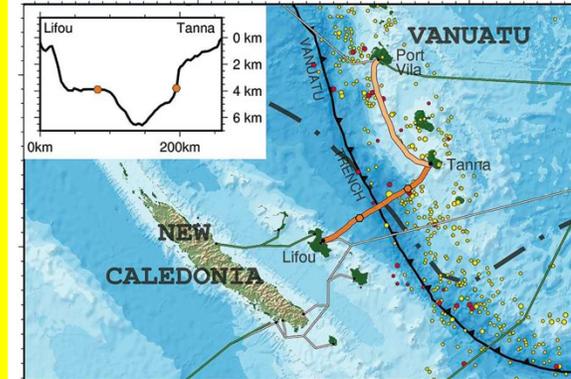
PI Bruce Howe
University of Hawai'i at Mānoa

FUNDING: 2022 – 2026, \$7M

GORDON AND BETTY
MOORE
FOUNDATION

COLLABORATORS

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)	



GOAL:

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

Objectives:

- Lay groundwork for science and early warning use by **simulations** of the observing system before deployment, **data analysis** after deployment, and **sustained scientific operation**.
- Apply results to the modest-scale 300 km **Vanuatu-New Caledonia** system and extract scientific results from this active tectonic subduction zone and dynamic ocean region. Demonstrate SMART earthquake and tsunami early warning.
- Establish the international project office for **Joint Task Force Scientific Monitoring And Reliable Telecommunications** cables to facilitate adoption of scientific sensors in all new telecommunications cables to reach a global scale.



Arctic and SMART, Cables

- Goal here – infrastructure for ocean observing, climate – support fixed and mobile platforms – including under-ice
- Emphasis here on physics – heat/temperature, etc. but consider other
- Need sustained, reliable, low maintenance infrastructure – Cables, acoustic (followed by AUVs)
- Follow parallel simultaneous paths
- Portions battery operated – transition to cable, fill gaps
- Trans-Arctic cables
 - Arctic Express – Canadian Northwest Passage (Phase 1)
 - Borealis (or descendants) Central Arctic (Phase 2)
 - Support SMART + nodes

Essential Deep Ocean Infrastructure

Infrastructure *Services*

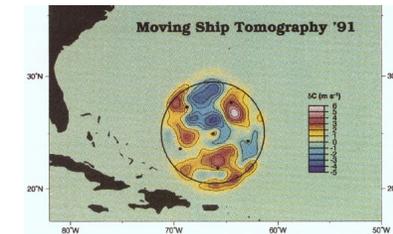
- POWER
- EVERYTHING depends on POWER –
- POWER enables all:
 - Communications
 - PNT – positioning, navigation, timing

Infrastructure *Elements*

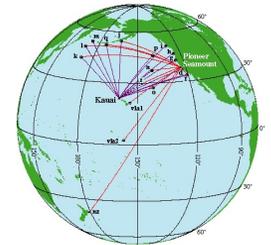
- Cables
- Fixed platforms
 - bottom packages, moorings
- Mobile platforms
 - AUVs, crawlers, ...

Influenced by my Experience

Moving Ship Tomography



Acoustics



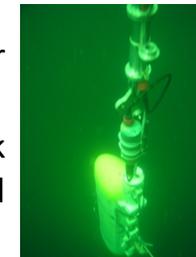
Acoustic Thermometry of Ocean Climate

SeaGliders

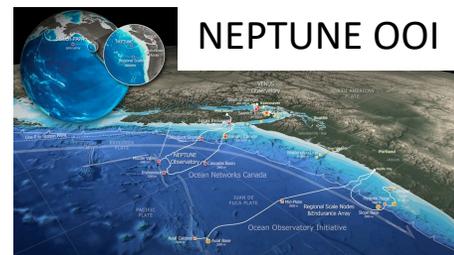
acoustic comms and nav

Mobile

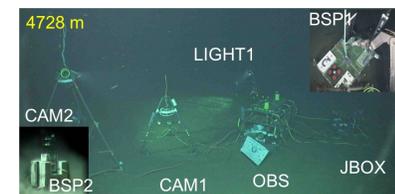
Moored profiler
Inductive
power dock
Cable connected



Fixed - cable



ALOHA Cabled Observatory
Deepest plug and play
power, Internet node





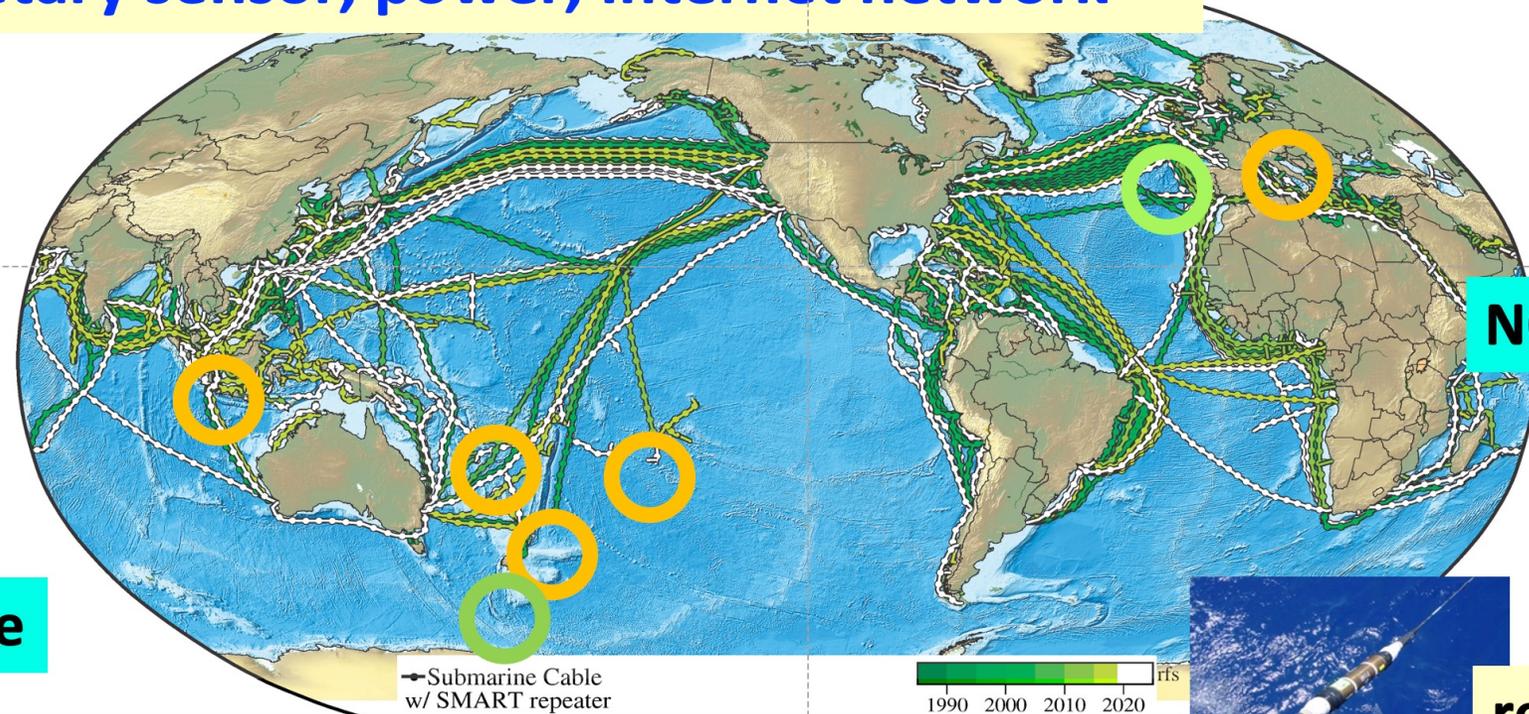
SMART Subsea Cables



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Share submarine cable infrastructure Telecom + science

NO Interference ↓ € \$

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Bottom pressure, temperature, seismic acceleration



Dual-end Feed from shore stations

sBU – Standard Branch Unit - Power and Optical fiber switching

Dual conductor cable to PTU

PTU – Power Transfer Unit - kW DC Power, 10G channels

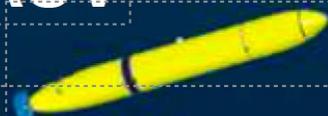
PTUs:

Enabler

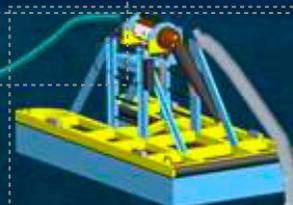
At Select locations

Node with AUV docking station

AUV



(Autonomous Underwater Vehicle)



sBU

PTU

(Power Transfer Unit)

adapted from SubCom

REPEATER

Telcom qualified
36 kV

1st unit 2022

“Several” \$M
Every 1000-2000 km
along cable

Many kWs (minus
repeater power)

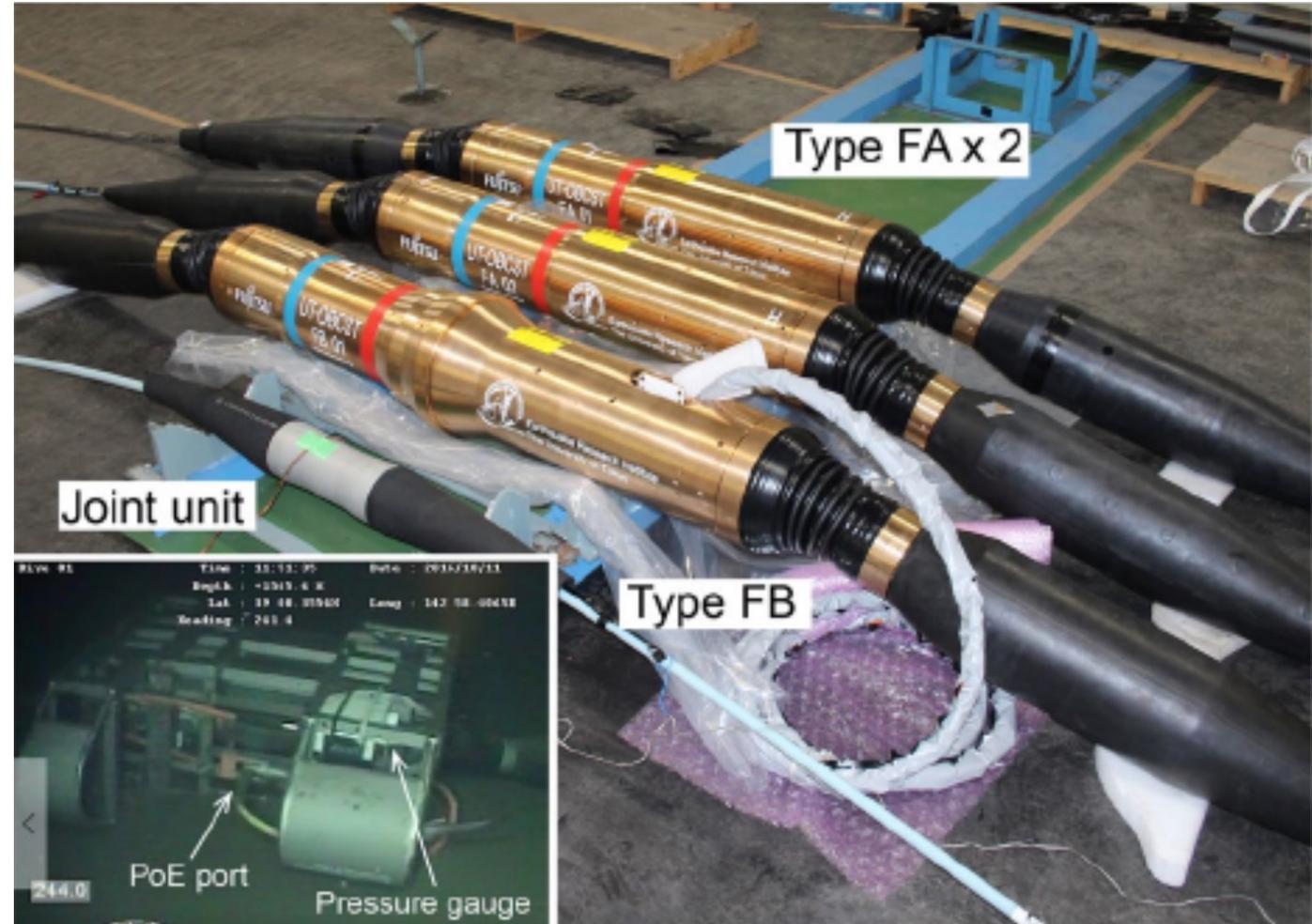
AUV docking –
essential, but nascent

An in-between hybrid alternative: Sanriku system

Early SMART prototype (sans telecom)

Demonstrated single port plug-and-play interface, standard ROV UW-mateable connector, PoE

In between a SMART repeater and a full “Powered Branch Node”



Multi-purpose Acoustic Systems for Observing the Oceans Acoustically

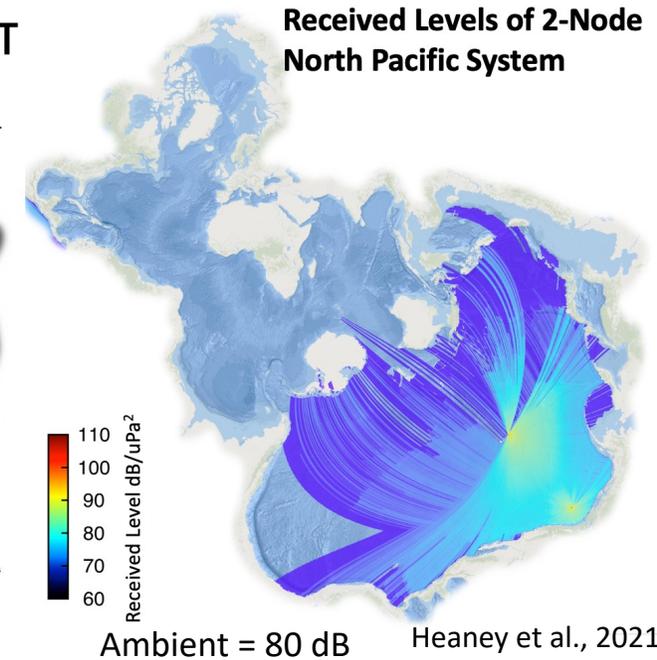
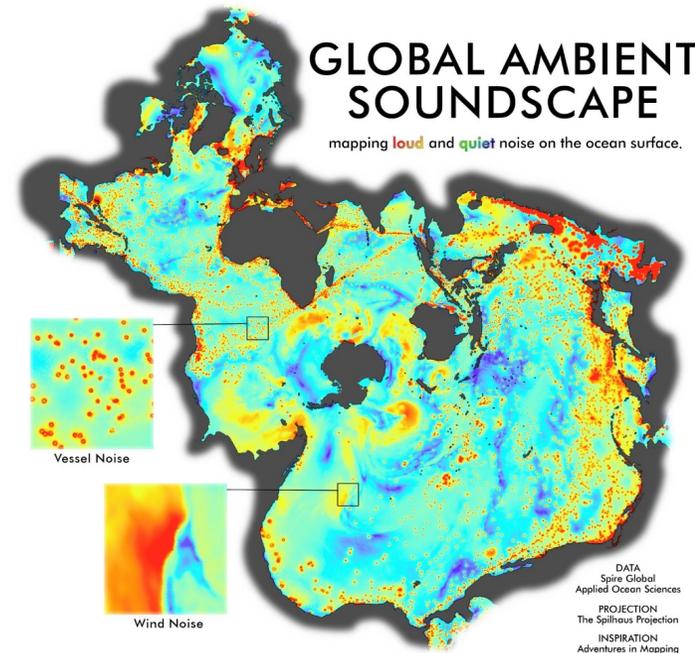
Cable power enables long range acoustic PNT

- U-GPS
- Acoustic source moorings
- Long range A-Comms
- Tomography – heat content, daily, basin (PAM hydrophones in SMART repeaters – N^2)

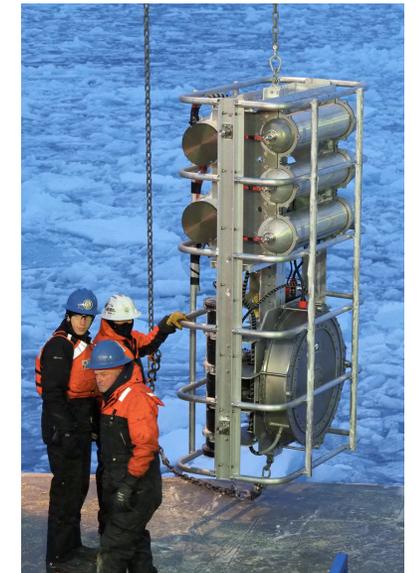
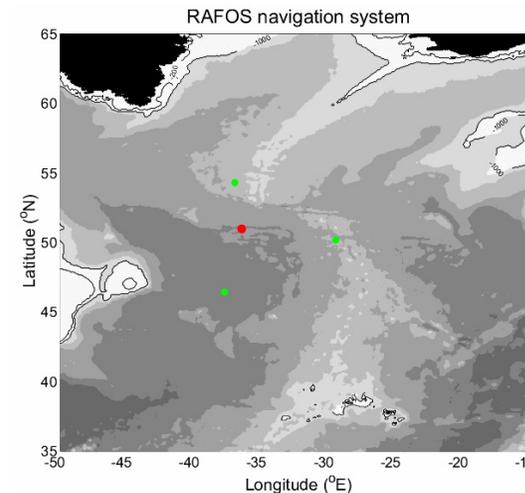
- Every float tracked = hi-res position and velocity
- Resident AUVs, continuous patrolling, repeat surveys, explore (e.g., mid-ocean ridges), from node to node, independent of surface
- AUVs carry sensors – cross calibrate fixed ones, easy to change out surface/shore

Climate - Acoustic tomography

– ocean temperature and heat content, using fixed and mobile platforms (data $\sim N^2$)



Positioning fixed source to mobile platform



Matt Dzieciuch

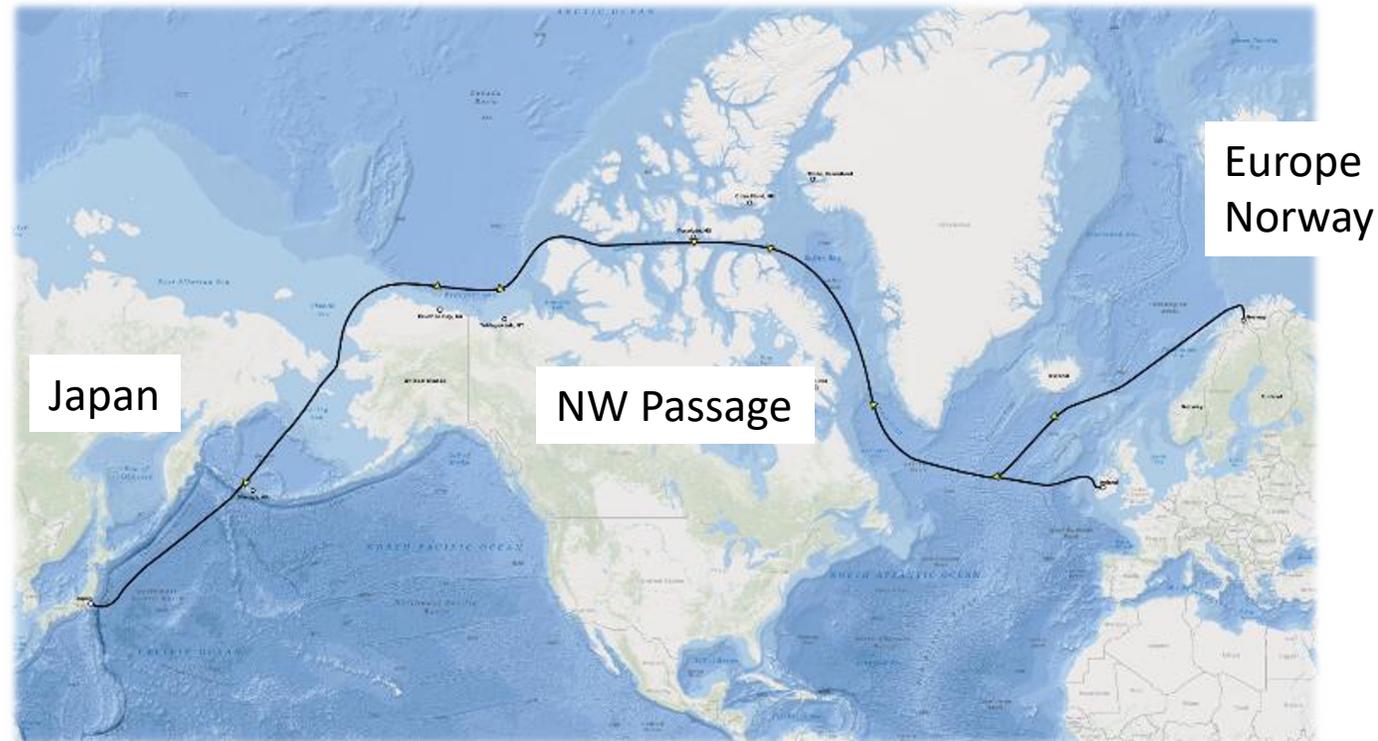


Phase 1 - Arctic Express – SMART +



- 14,000 km
- Low latency
- Communities
- Contract Q1 2022
- RFS Q4 2025

Ik Icard –
next speaker!



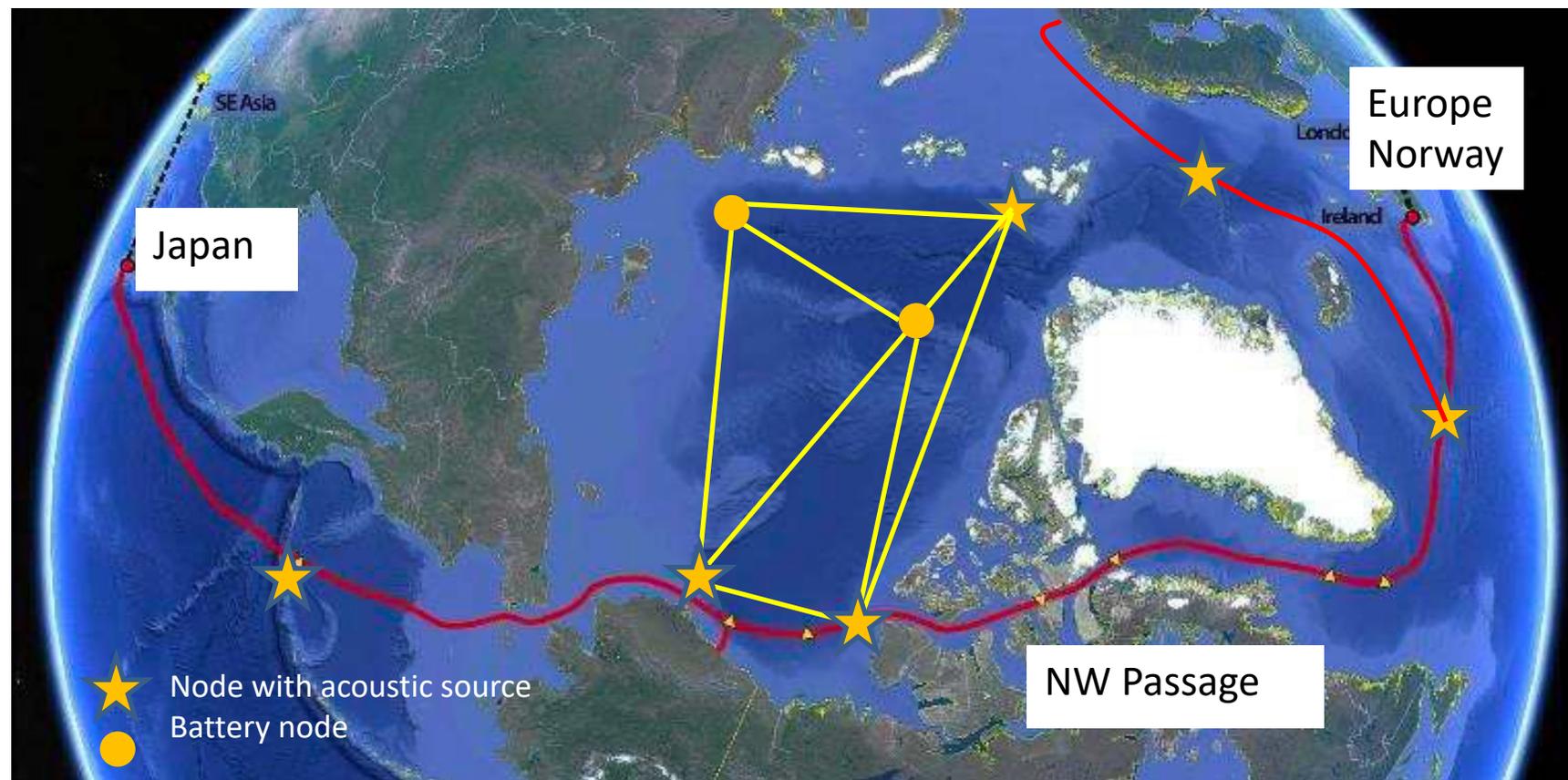
‘The Arctic Express system, with integrated SMART cable technologies, will give Indigenous peoples, academic institutions, and science agencies across the Arctic advanced new tools to study the oceanography of the most rapidly changing ocean and region of earth.’

‘For the first time, technology, market conditions and climate change have aligned to make this project technically possible, economically viable and a national priority.’



Phase 1 - Arctic Express – SMART +

- Bottom water temperature, pressure, seismic acceleration entire length (SMART base)
- Add Hydrophones in SMART the entire length – marine mammals, geophysics, acoustic thermometry
- Add nodes/acoustic sources (and VLAs and AUVs) –
 - Norway, Svalbard
 - Mid Atlantic Ridge
 - N Alaska
 - Shemya
- Atlantic Meridional Overturning Circulation, thermometry – N Atlantic
- Tsunami, earthquakes, thermometry, western Pacific
- Trans Arctic - climate

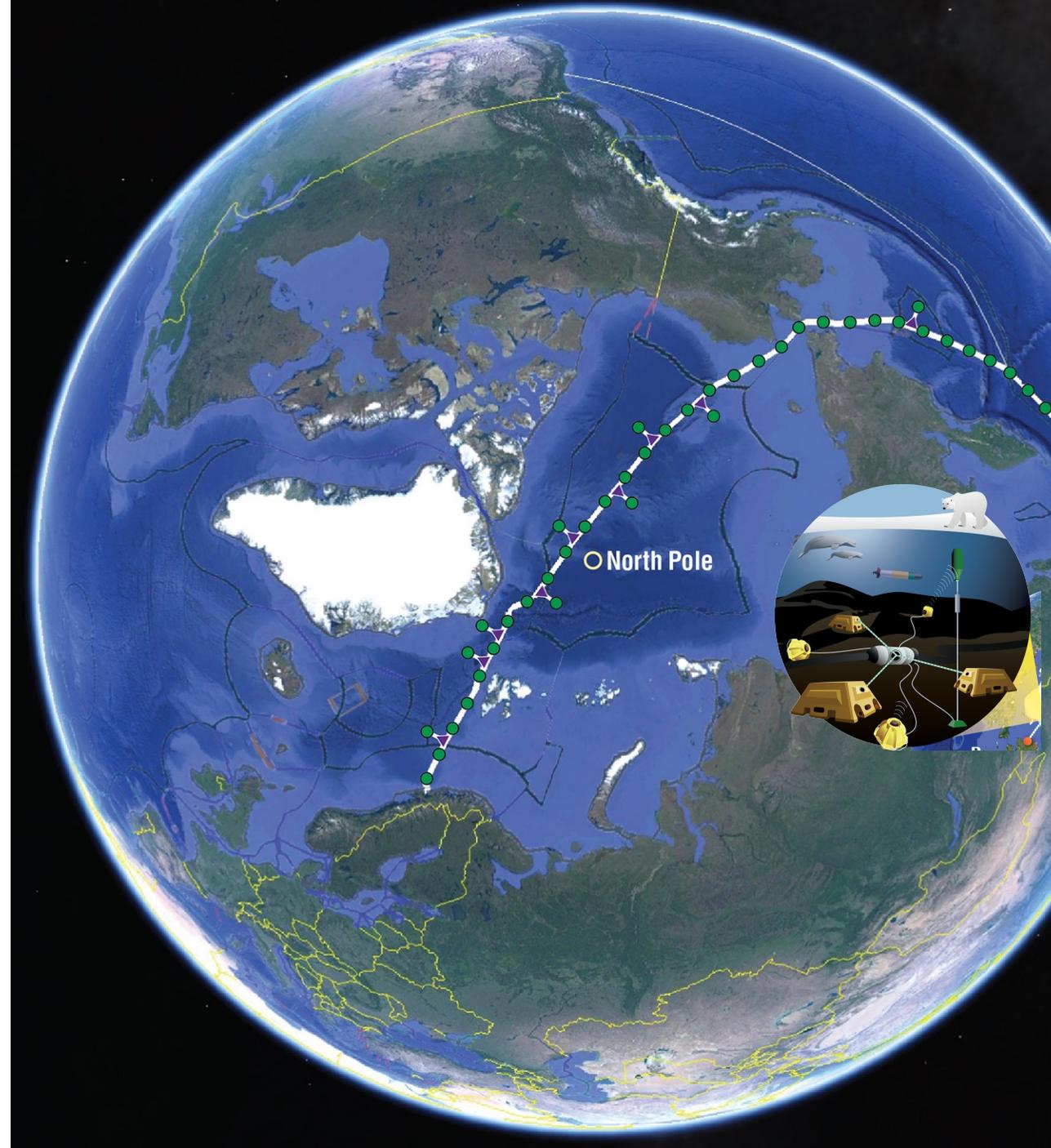


Nodes – compare with DONET, ONC, OOI cabled arrays

SMART – 10-15% incremental cost over telecom

Phase 2 – Central Arctic

- In addition to Phase 1
- Adds dense bottom sensing across central Arctic – SMART (with PAM)
- Includes nodes, spacing TBD
- Nodes – TX/RX, profiler moorings, AUV, etc



Phasing

- Battery operated TX/RX in eastern Arctic
- Svalbard cable – SMART + node(s) – dedicated (Norway)
- Arctic Fiber – SMART + (few) nodes (can get BU stubs to start)
- Borealis – SMART + (more) nodes Need planning and implementing entities

- Parallel and independent developments
 - SMART Cables – Portugal 2025 in service
 - Operationalize acoustic tx/rx moorings, cable connected
 - Demo long range nav + tomography (beyond CAATEX)
 - BU/Power transfer unit – complete (2022-2024, telecom rated)
 - Nodes, cabled connected moorings, AUV docking and long term ops



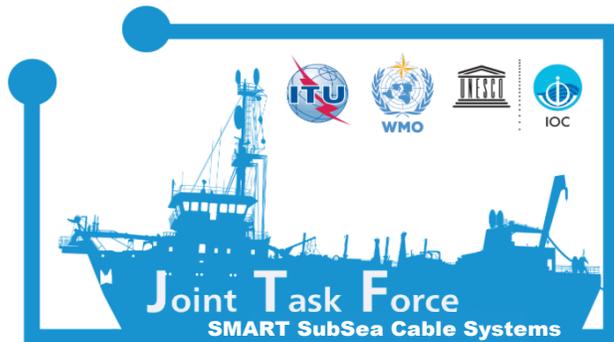
Concluding Remarks

- 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: CAM2, MEDUSA, V-NC, Antarctica, Arctic, ... will set valuable precedents
- SMART integrated in UN organizations (ITU, WMO, IOC, Decade); Arctic
- Arctic – Cable infrastructure – SMART+:
 - + = Add hydrophones, Add nodes
 - Enable long range nav and AUVs (with docking), tomography, and **more**
 - Doable in 5-10 years, at affordable cost, leverage industry, access new funding

Observing the Ocean and Earth with SMART Subsea Cables - Application to the Arctic

□

Science Monitoring And Reliable Telecommunications



Thank you



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2030 of Ocean Science
for Sustainable Development



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Arctic Science Summit Week
Tromso, Norway
28 March 2022

