Observing the Ocean and Earth with

SMART CABLES

Observing the oceans and Earth with submarine cables, into the future

Bruce M. Howe
JTF SMART Cables Initiative
International Programme Office
University Hawai‘i at Mānoa

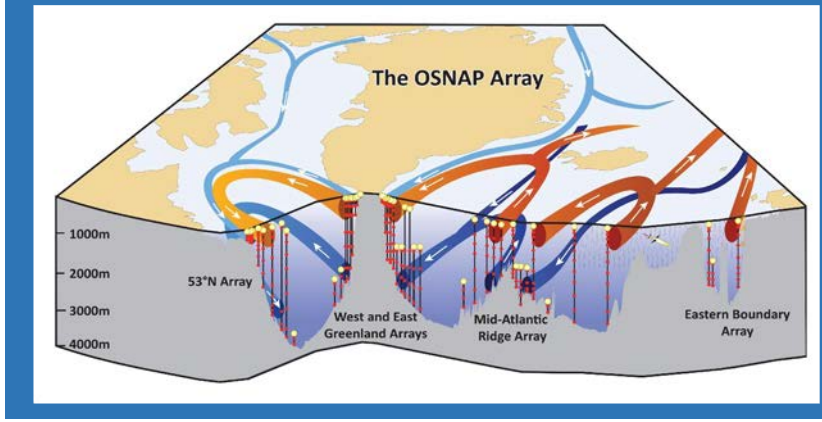
Underwater Technology Symposium
UT 2025
Taipei, Taiwan
2-5 March 2025

Scientific **M**onitoring **A**nd **R**eliable **T**elecommunications

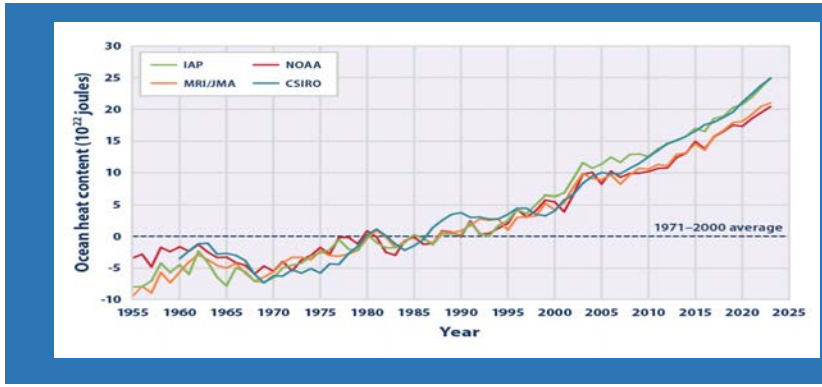
ITU/WMO/UNESCO-IOC JTF SMART Cables

United Nations initiative to bring together science with the telecom industry for Global Observation of the Oceans and Earth

Ocean general circulation – all scales



Ocean heat and circulation

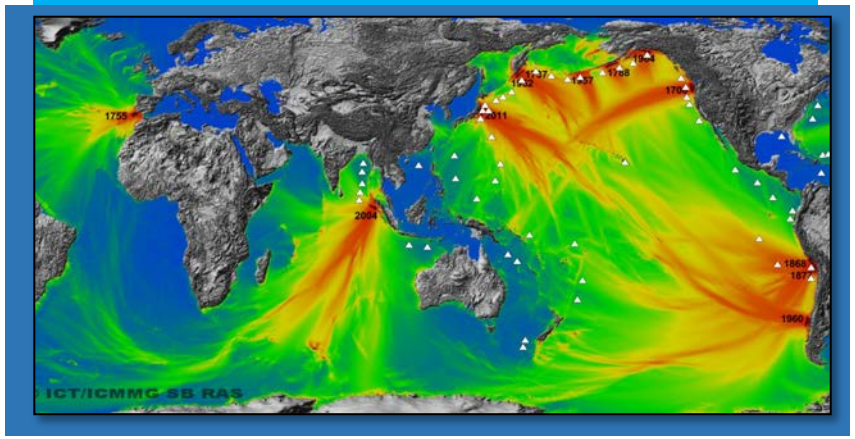


Climate Change

Early Warning

Sea Level Rise

Earthquakes and Tsunamis



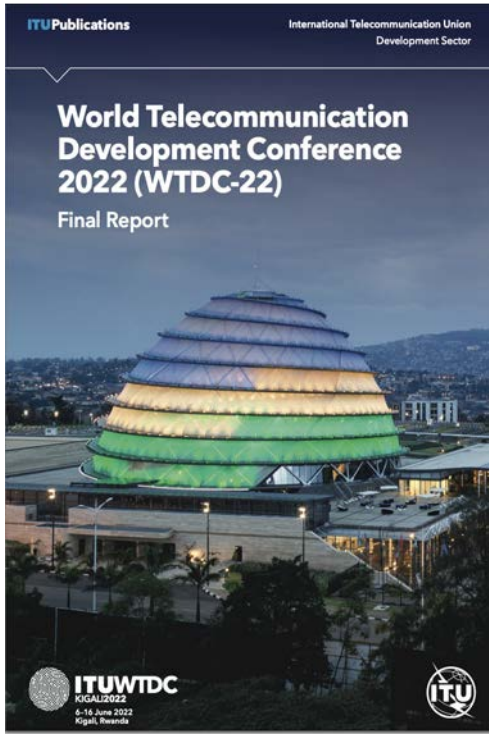
Disaster Mitigation

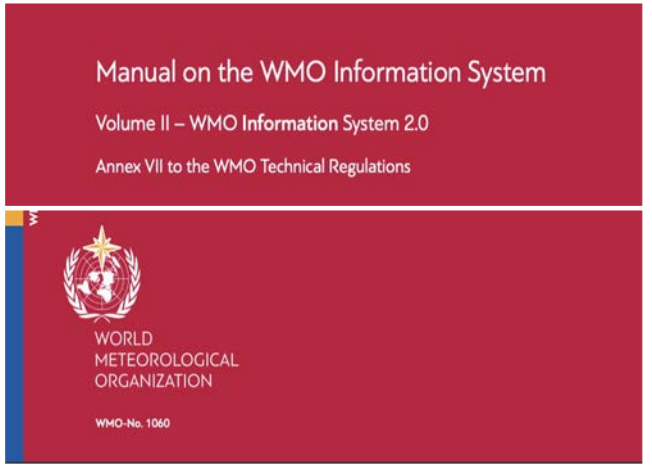
JTF Sponsors

- JTF Secretariat
- Resolutions on climate change Disaster Risk Reduction (DDR) includes SMART
- Recommendations SG15/Q8 G.dsssc/9730.1 and G.SMART/9730.2

- Integrates SMART into WMO Information platform

- Global Ocean Observing System (GOOS)
- Tsunami Programme
- UN Ocean Decade: endorsed Project
- Emerging Observing Network of GOOS





The Global Ocean Observing System

UN World Conference on Disaster Risk Reduction
2015 Sendai Japan

Climate Change and Disaster Risk Reduction

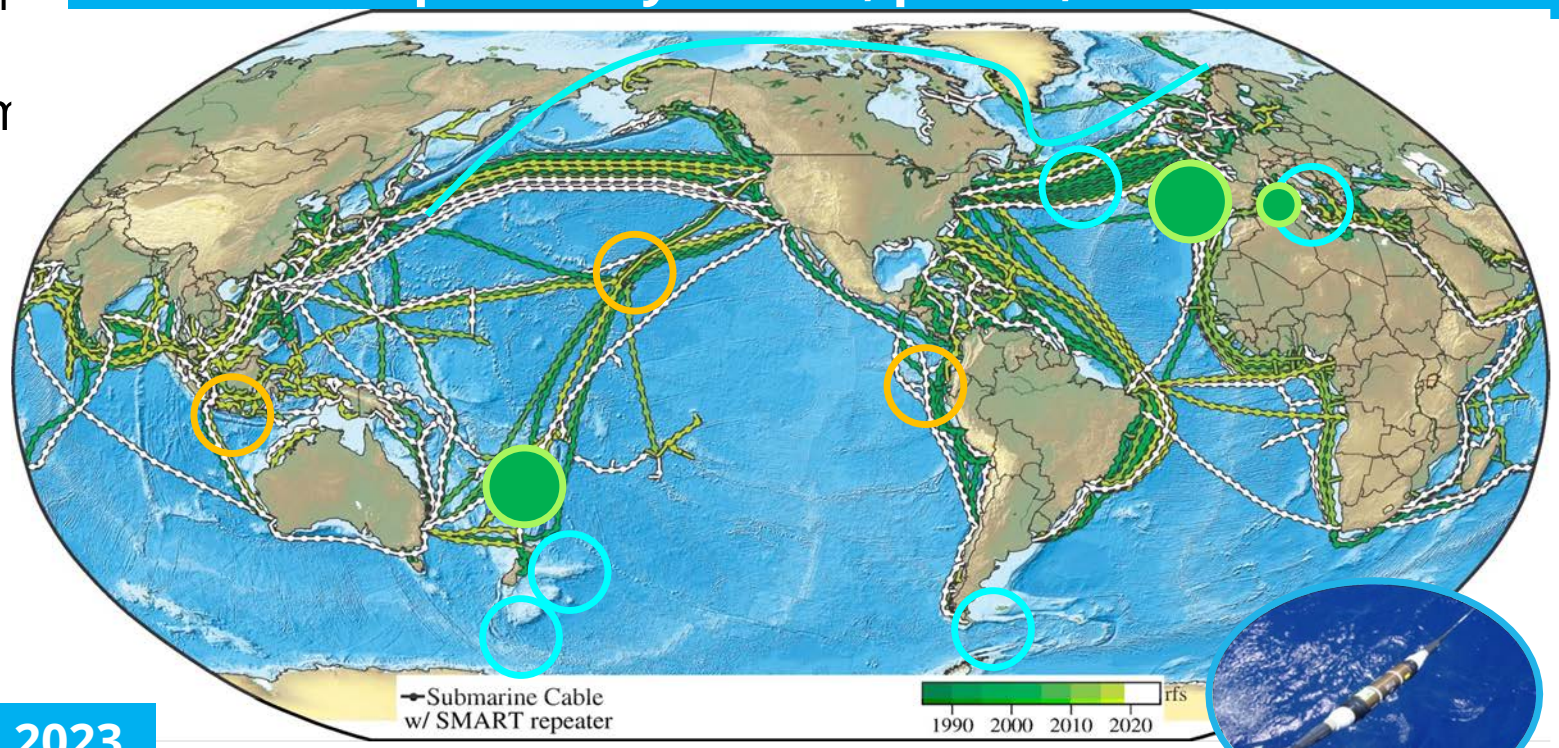
Global Array for Climate, Oceans, Sea Level, Earthquakes, Tsunamis

1st order addition to Ocean-Earth observing system

Emerging Network

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

A sustained planetary sensor, power, Internet network



Share submarine cable infrastructure
Telecom + science
⬇ €$

NO Interference

1.4+ GM
~20,000 repeaters
20 year refresh

Every ~100 km

InSEA Wet Demo 2023

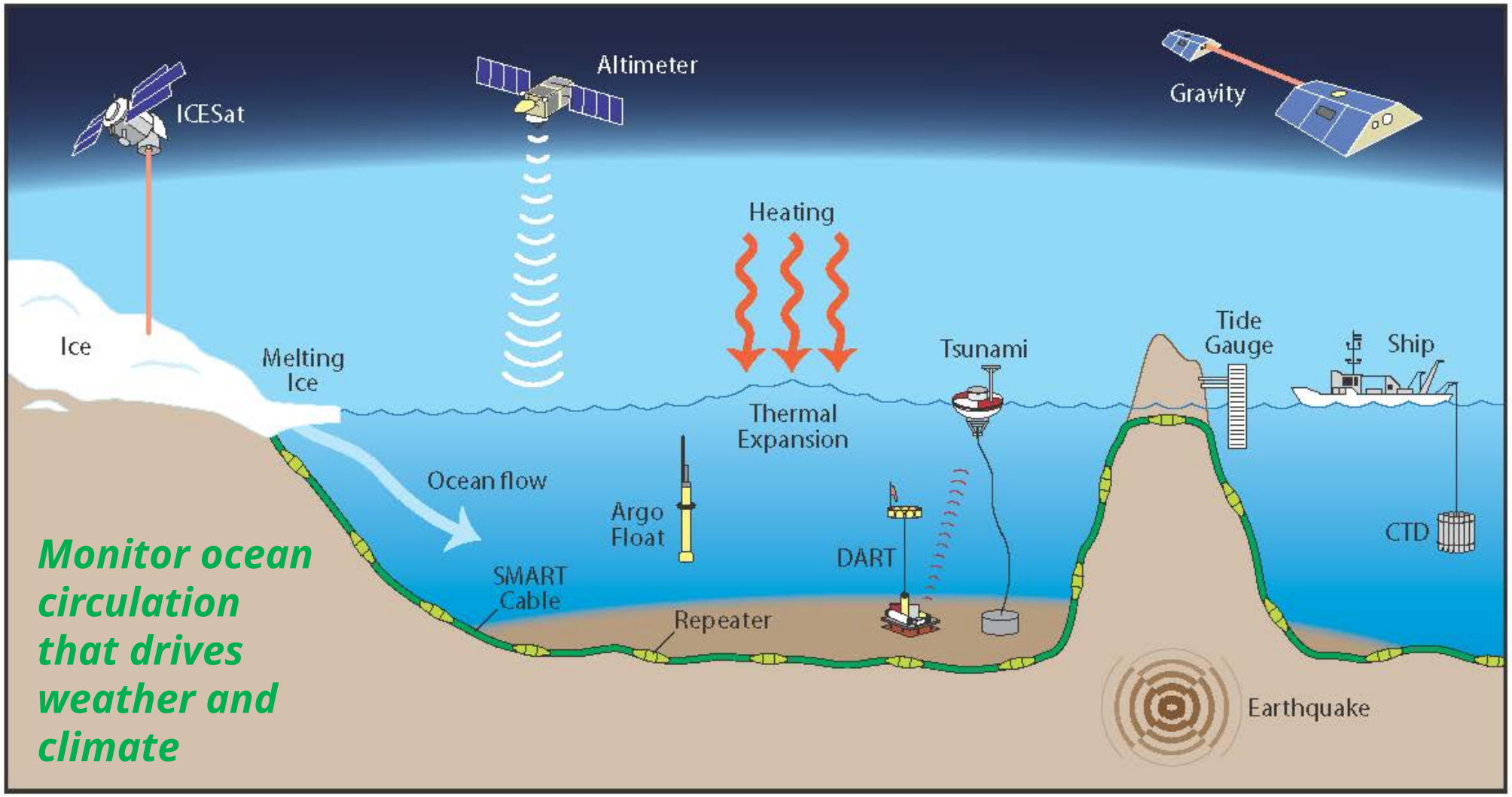
SMART Atlantic CAM and Tamtam V-NC Funded, install 2026

Know the environment protect the network

Bottom temperature, pressure, seismic motion

ITU unesco WMO

Ocean + Climate change – Long term Observation



SMART Cables measure the bottom boundary condition
Essential Ocean Variables: Temperature, Pressure; Seismic motion + …

SMART Technical Solution

Shared Cable Infrastructure: Telecom + Science

S-net

Existing Technology

Sensor module
INGV InSEA SMART Wet Demo

Leverage Existing Technology

Guralp + Global Marine

Sensors:

- Temperature
- Pressure
- Seismic

Key point:

- Essential Ocean Variables

SMART Repeaters: Subsea Data Systems

SUBSEA DATA SYSTEMS

SMART Repeater Sensor System

3-Axis Omni-Tilt Seismic Sensor

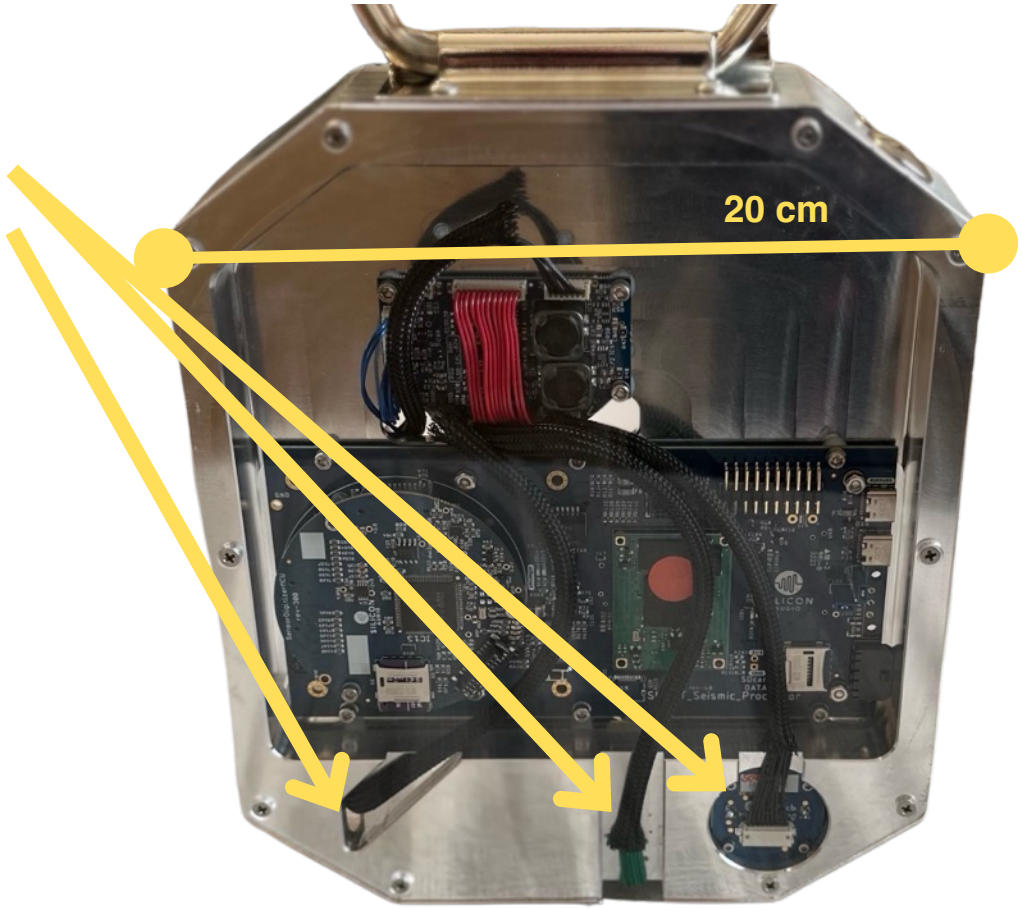
- Low-noise intermediate band switchable seismometer
- Silicon Audio 205 (acceleration); 215 (velocity)
- 0.01 to 500 Hz bandwidth
- Best in class noise performance
- 183 dB dynamic range (high+low gain digitization)
- 30 mm diameter x 35 mm length (each sensing element)

Temperature Sensor (external)

- Glass Coated Thermistor (GCT)
- Sea-Bird SBE 03S
- ±0.002°C accuracy
- Maintains calibration over time
- 49 mm diameter x 256 mm length

Pressure Sensor (external)

- Absolute Pressure Gauge (APG)
- Paroscientific 4*K-101-0
- 1 part in 10^7 resolution
- Few parts in 10^6 accuracy; mainly limited by drift
- Signals of interest between 0.001 and 1 Hz
- 35 mm diameter x 108 mm length



SMART electronics /
seismic sensor in ~20cm / 8in radius cylinder

Climate Change solution (SMART* technology)

ASN, the key partner for
undersea data acquisition
With scientific sensors

Commercially available

Sensors:
- **Nanometrics - OBS + Accel**
- **RBR – A-0-A pressure, temperature**

Separate modules:
- **+ Variable spacing**
- **+ More flexible sensors**
- **– ⬆ $/unit**

Key applications

Risk monitoring
- ⌘ Earthquake detection
- ⌘ Tracking of tsunami wave
- ⌘ Tsunami warning

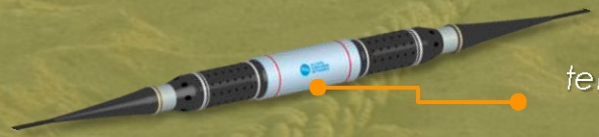
Scientific observation
- ⌘ Sea bottom movements
- ⌘ Sea level rise
- ⌘ Slow drift of sea bottom temperatures
- ⌘ Sea water currents by temperature & pressure combination

ASN solution based on CC-Nodes

New generation of submarine networks integrating sensors for Climate Change observation

dual use (telecom + CC) & dedicated CC systems

CC-NODE



temperature | accelerometer
pressure | specific sensors

ASN, part of the Ocean Decade
"Science we need for the ocean we want"

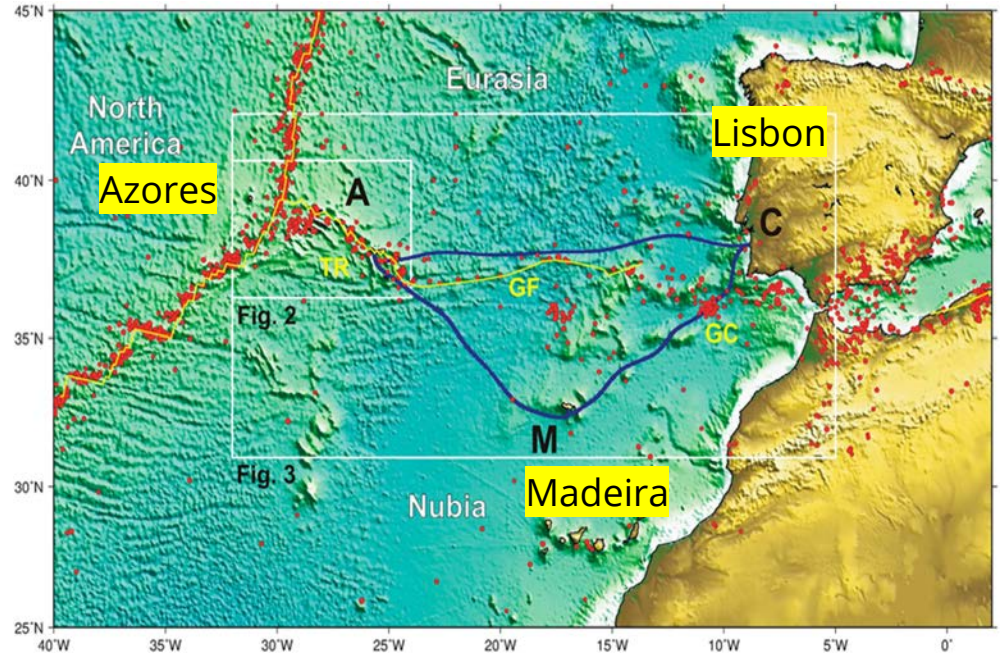
2021 2030 United Nations Decade of Ocean Science for Sustainable Development

First SMART projects planned for 2025 / 2026
- ⌘ South Pacific
- ⌘ Atlantic
- ⌘ Asia

* *Scientific Monitoring And Reliable Telecommunications*

Funded SMART Cable Systems

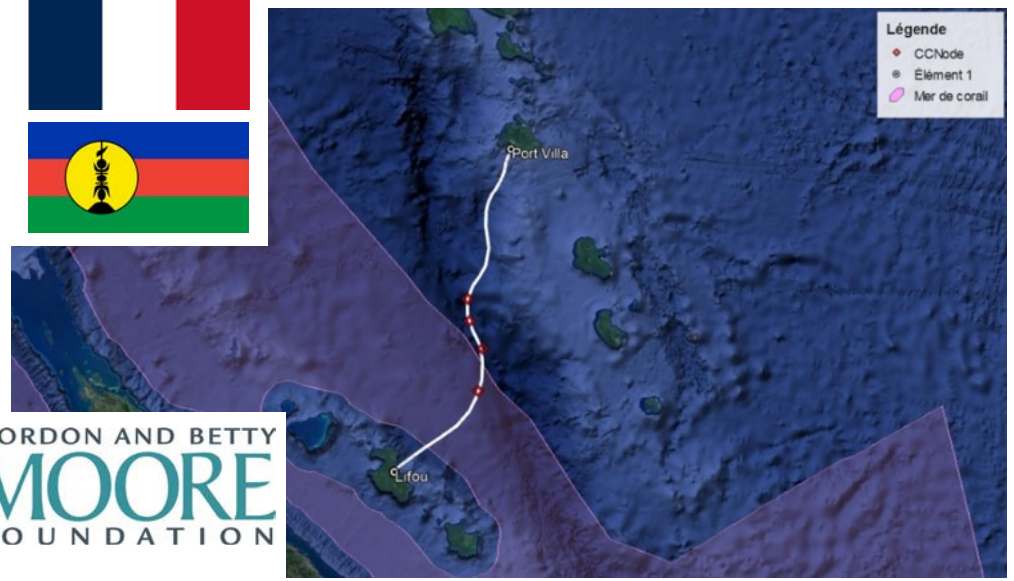
Portugal SMART Atlantic CAM



- 3700 km, ~20 SMART modules
- Gov't €154M. EU support €56M
- SMART 15% ➔ €22M ~ €2/citizen/25 y
- ~= 2 Tsunami buoys, 25 year (unreliable, no seismic, not real time)

Contracts signed
ASN
RFS 2026

TAMTAM SMART Cable System



GORDON AND BETTY MOORE FOUNDATION

- 450 km long, 4 SMART modules
- France funding SMART (telecom: AFD, ADB)

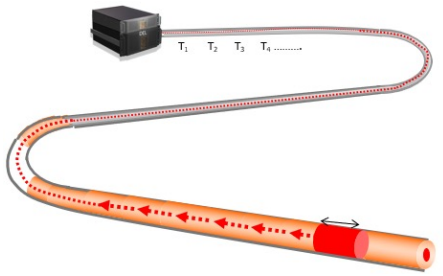
- 25+ year life, reliable, low lifetime cost
- Leverage $5B/y industry, 175 y

Optical Fiber Sensing in both

SMART and Optical Fiber Sensing (OFS)

Complementary not Competition

OFS – fiber strain at various time and space resolutions – 1-D ~acoustics



- SMART sensors and data types operational
- OFS science sensing and data in research state
- Measurement characteristics can differ in complementary ways
- SMART sensors can calibrate fiber sensing observations
- Each can validate unexpected observations
- Expectation that a combination will contribute to the protection of the cable itself as well as other cables in the vicinity

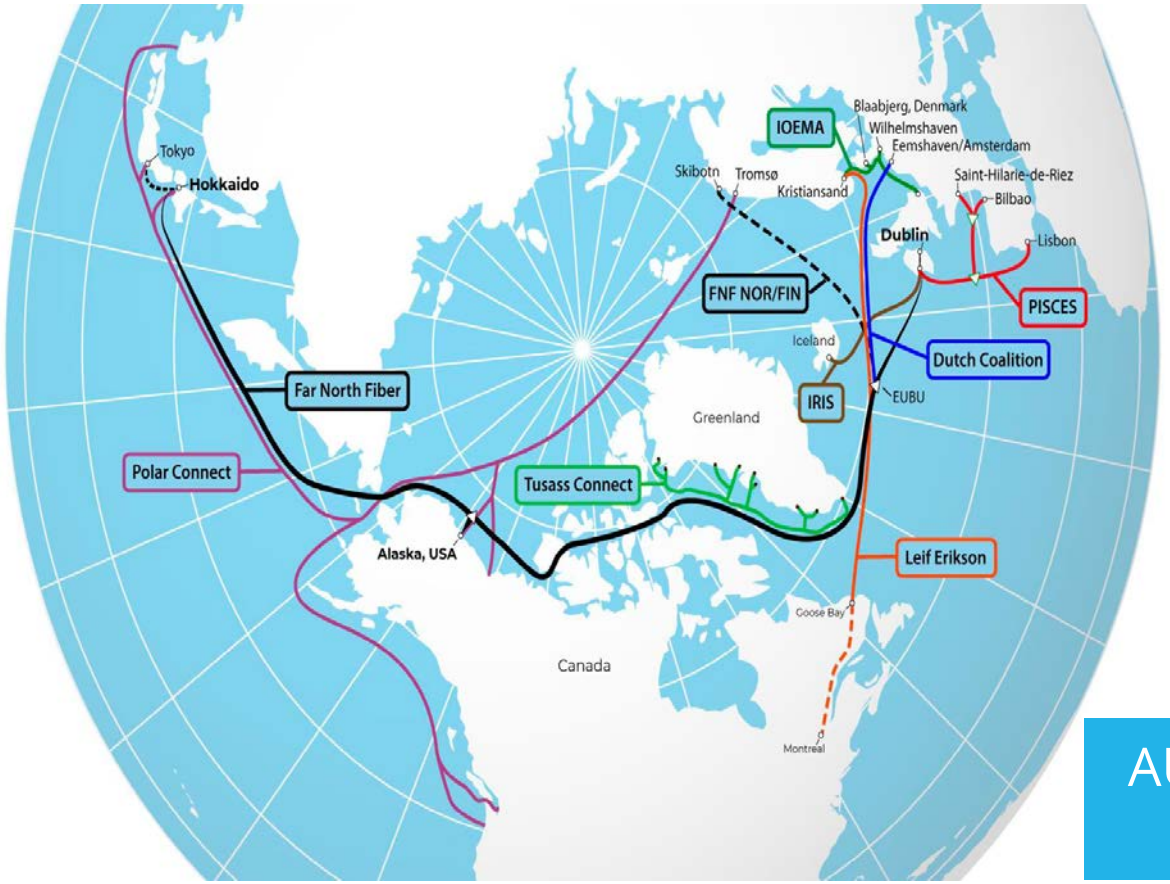
Note: Ocean Sound is a GOOS Essential Ocean Variable

CAM and Tamtam:

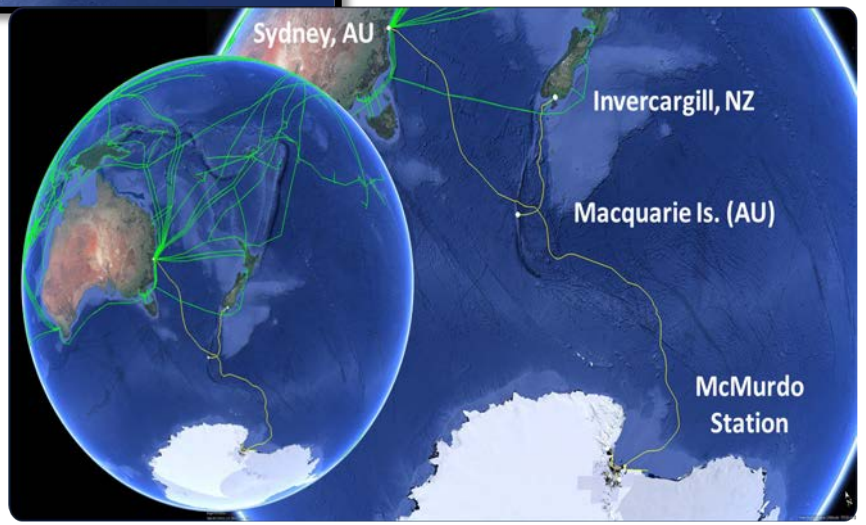
Ideal for investigating capabilities and complementarity

Polar and North Atlantic

Polar Connect, Far North Fiber, Tussas, PISCES, IRIS, IOMEA, +



Antarctica Chile
Drake Passage

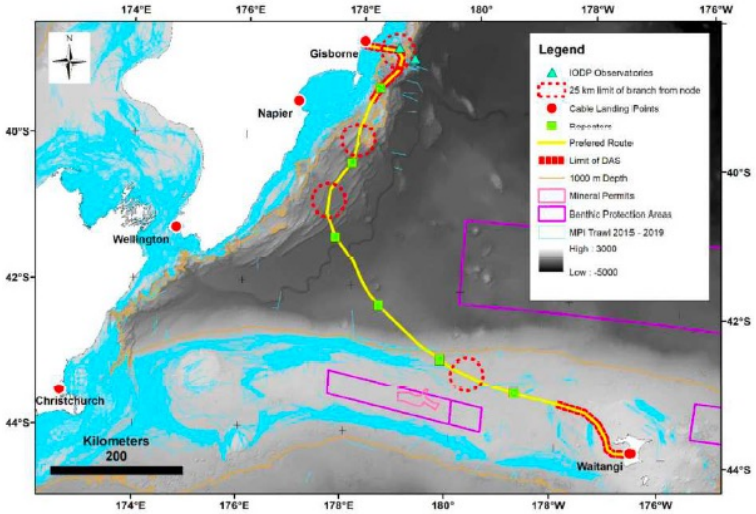


AUS/NZ Antarctica
NSF McMurdo

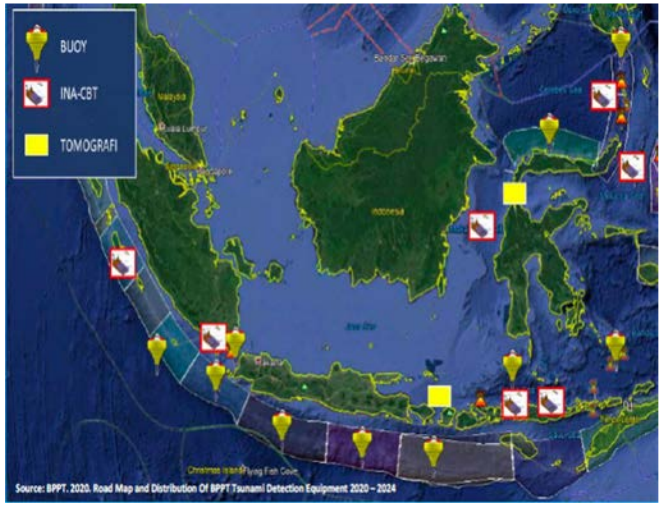
Pacific, Mediterranean, Indian Oceans

Galapagos

NZ - Chathams



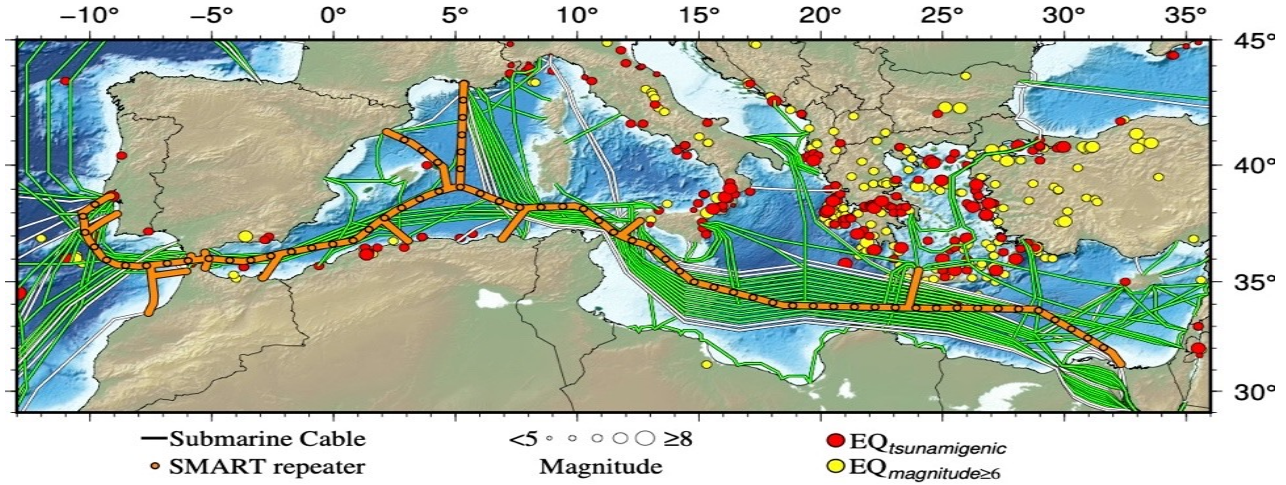
Indonesia



50 km, 2 module test system installed off Labuan Bajo

Medusa

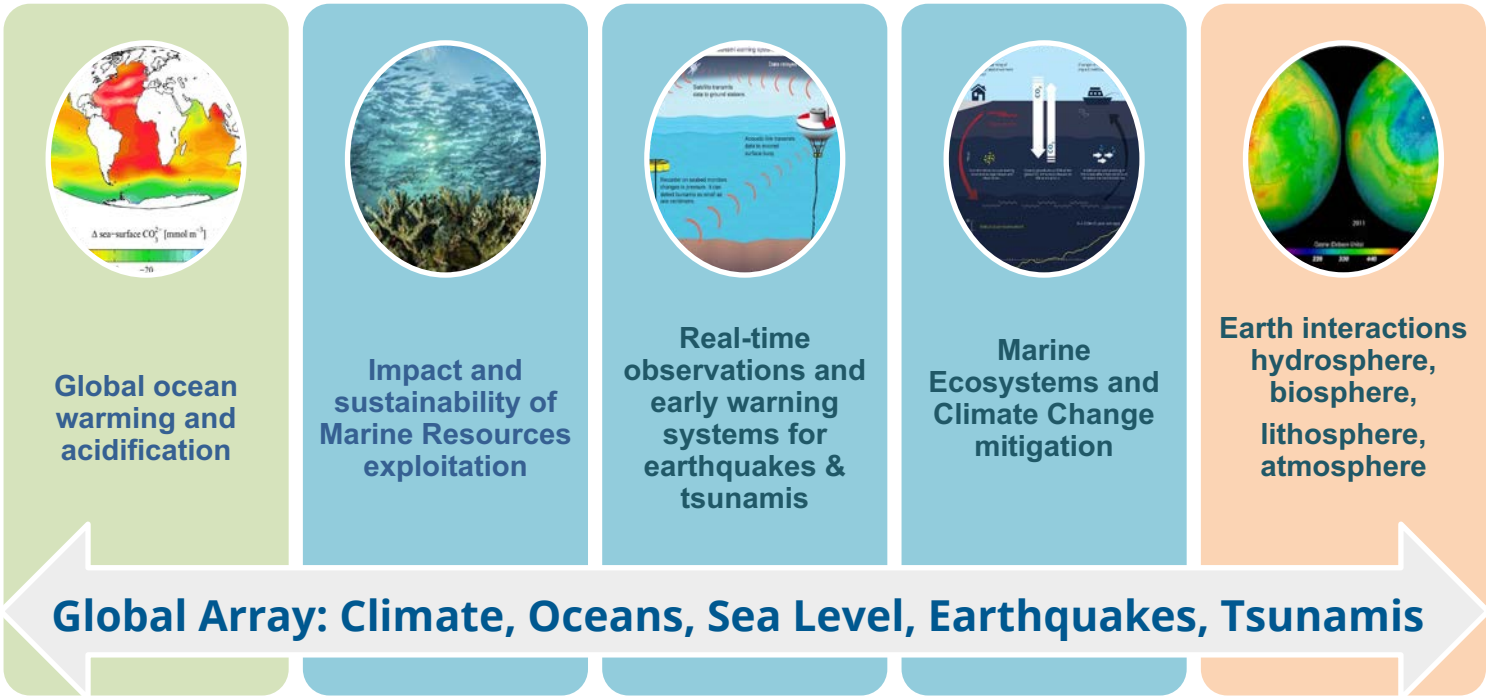
BARRACUDA



MISTS

Scientific benefits

- Enhance **Ocean Global monitoring –** integrate sensors into submarine telecommunications cables
- Establish a robust **SMART Cable network – full integration into GOOS**
- **Connect complex processes – sub-seafloor – seafloor – water column**
- Improve **Tsunami and Earthquake** detection and **early warning systems**
- **Catalyze technology innovation and development – science + telecom + industry**
- Contribute to **Earth dynamic systems – global change, ocean acidification, geological hazards, +**



SMART – Summary

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

- Marriage of science with telecom
- One part of the global environmental monitoring system
- Greater understanding of our planet - undeniable humanitarian benefits
- Leverage annual investment of ~ $ 5 B/y, and ~1.4 M km cable investment by 2037
- Challenges remain – first systems setting positive precedents

Change gears

Into the future

SMART → SMART+

Essential Deep Ocean Infrastructure

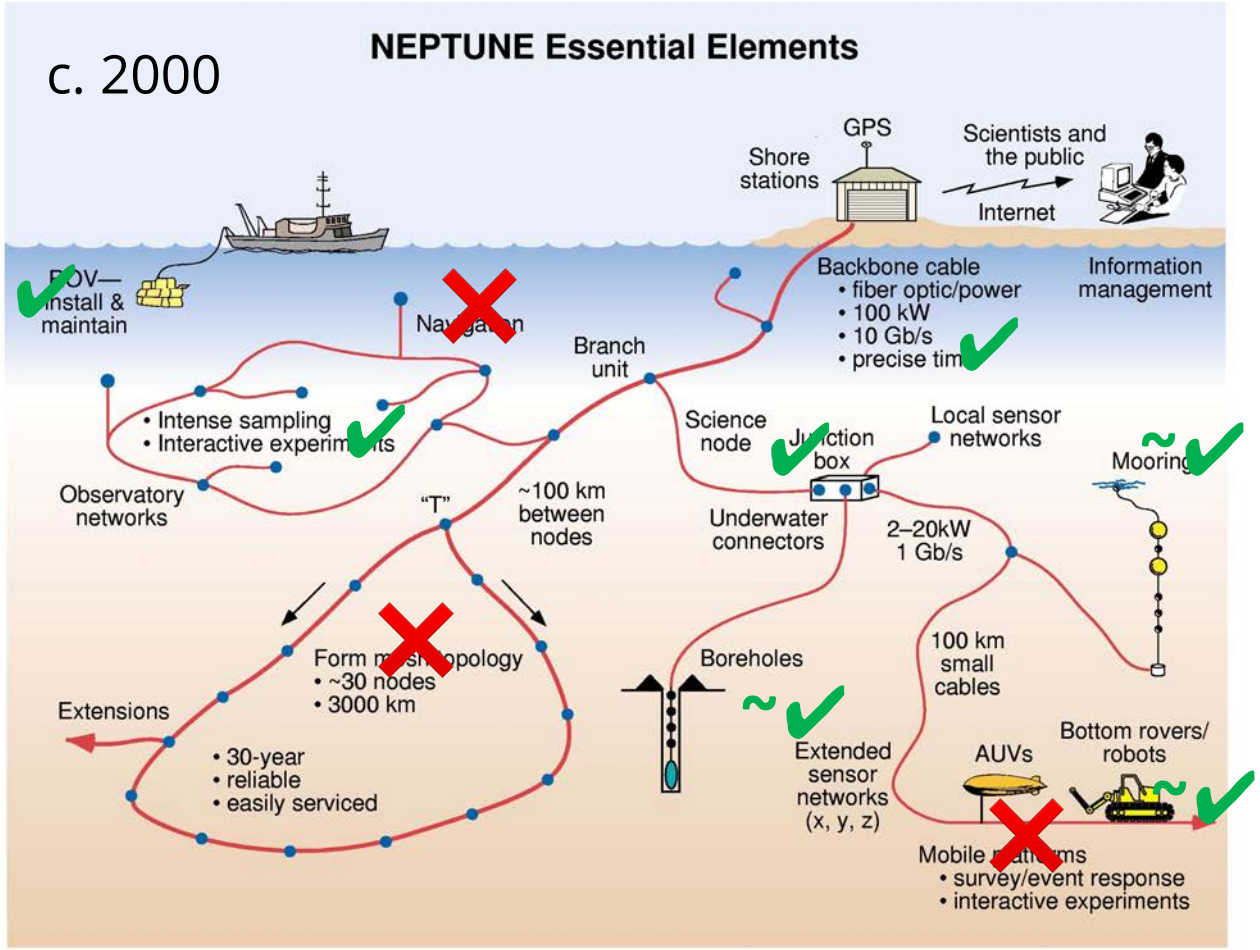
?90% ocean observing cost is infrastructure

Infrastructure Services

- POWER
- EVERYTHING depends on POWER –
- POWER enables all:
  - Communications
  - PNT – position, navigation, timing
  - + Sensing, mobility, …

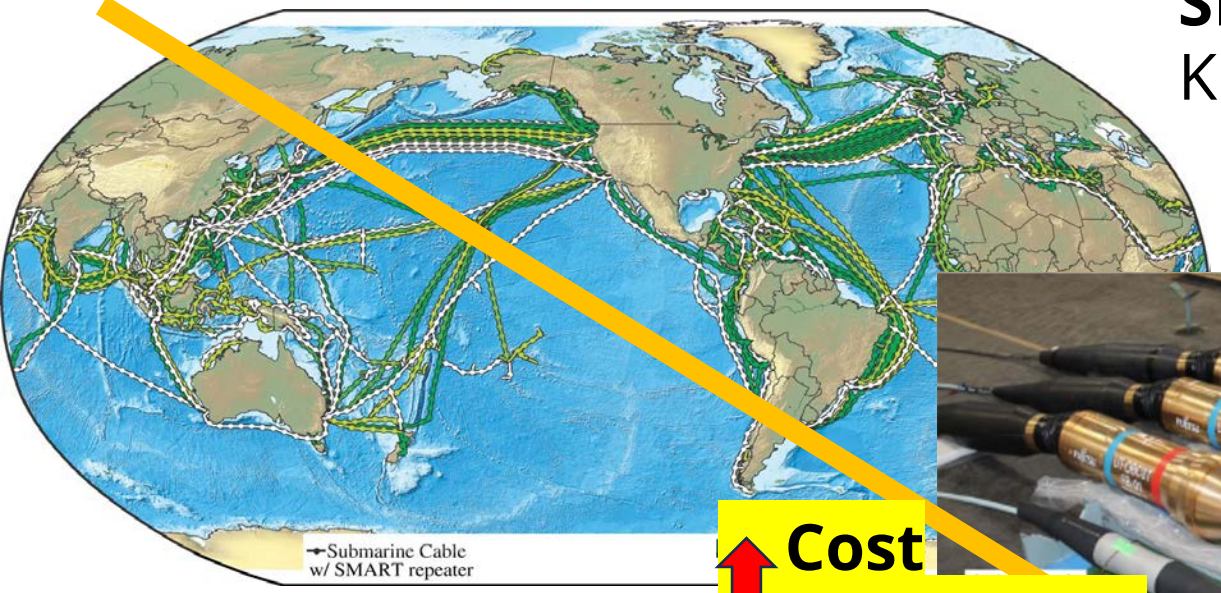
Infrastructure elements

- Cables
- Fixed platforms
  - bottom packages, moorings
- Mobile platforms – + spatial footprint
  - AUVs, crawlers, …



Cable sine qua non for everything else – share with telecom - affordable

Deep ocean essential infrastructure elements - cables



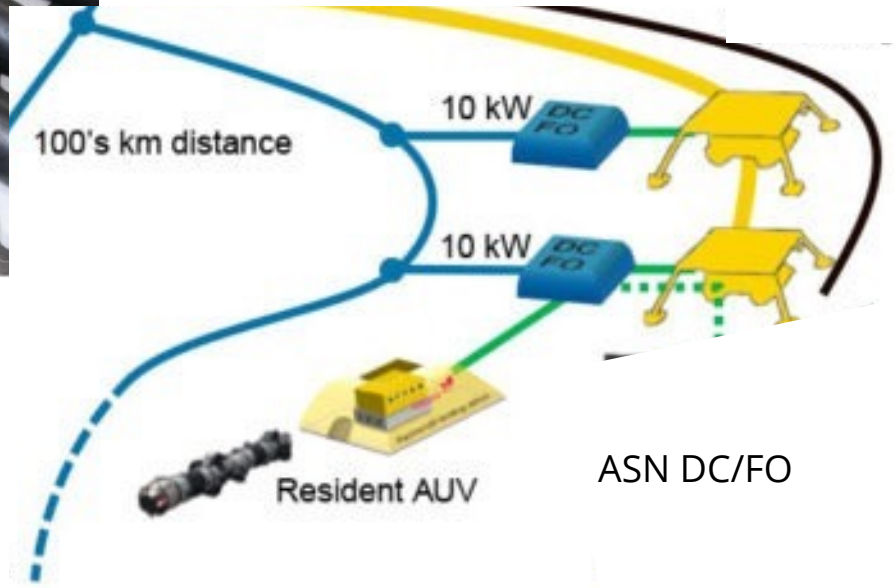
SMART Cables
KISS, a few sensors, global coverage
now with optical fiber sensing

Cost
Complexity
fewer

Shinohara, 2021

Test system, Japan
Single port, PoE

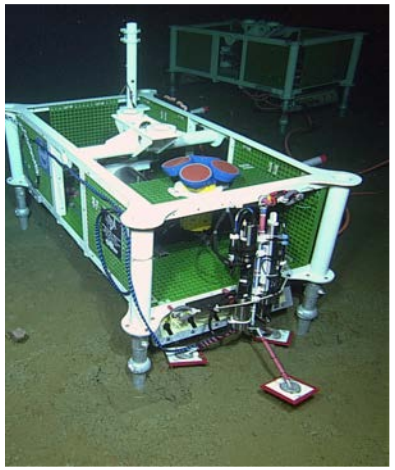
+ fixed and mobile platforms

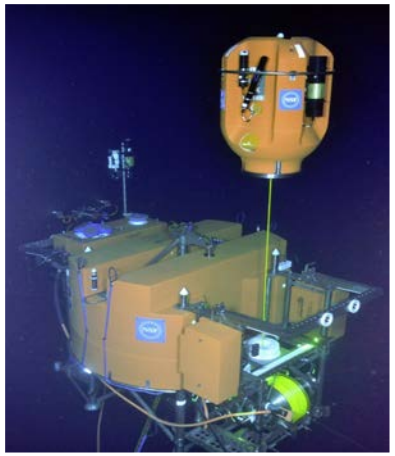


ASN DC/FO

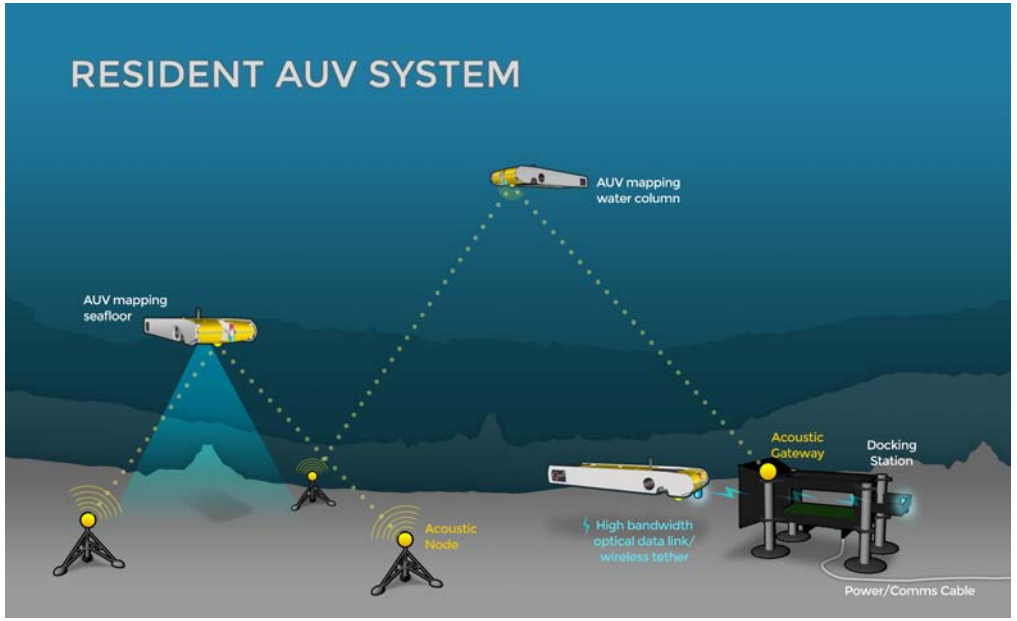
Multi-port node with power comms
Telecom rated
Support AUV docks, Moorings, other

Cabled Instrumentation and Resident AUVs



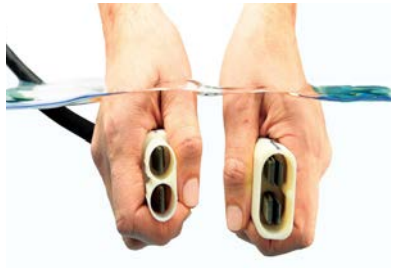


NSF OOI Regional Cabled Array



Courtesy D. Manalang, APL-UW

Bottom packages, upper ocean profilers, deep moored profilers, Resident AUVs ➜
All one-offs – bespoke, NEED STANDARDS



Cost, reliability, ease of use

New UW connector will help
Niobium, Nb, Passivates, 80 V max , 10 A now
niobiConn™ Wet-Mate Electrical Connector

Pressure tolerant electronics?

Persistent Mobile Ocean Observing: Marine Vehicle Highways

Dana Manalang[1], William Wilcock[1], Kendra Daly[2]
[1]University of Washington, [2]University of South Florida

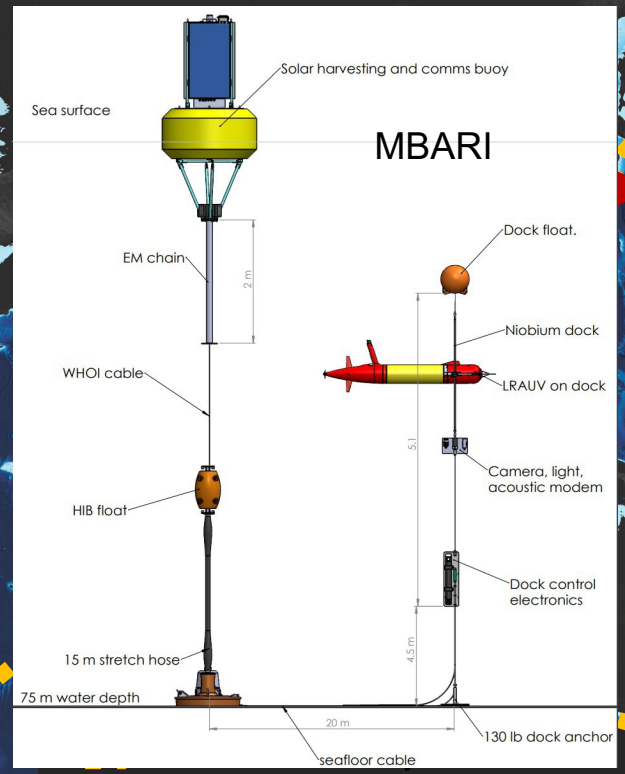
The National Academies of SCIENCES ENGINEERING MEDICINE

Marine Vehicle Highways (MVH):

- Global infrastructure for Ocean and Planetary Health Monitoring
- fleet of marine vehicles with standard interface
- Expand the spatial footrprint

✓ Exponential decrease in cost per measurement
✓ Exponential increase in AUV operations
✓ Testable on smaller scales

Docking still in infancy
Needs standards
Include mid-ocean a la EV charging stations
On telecom cables



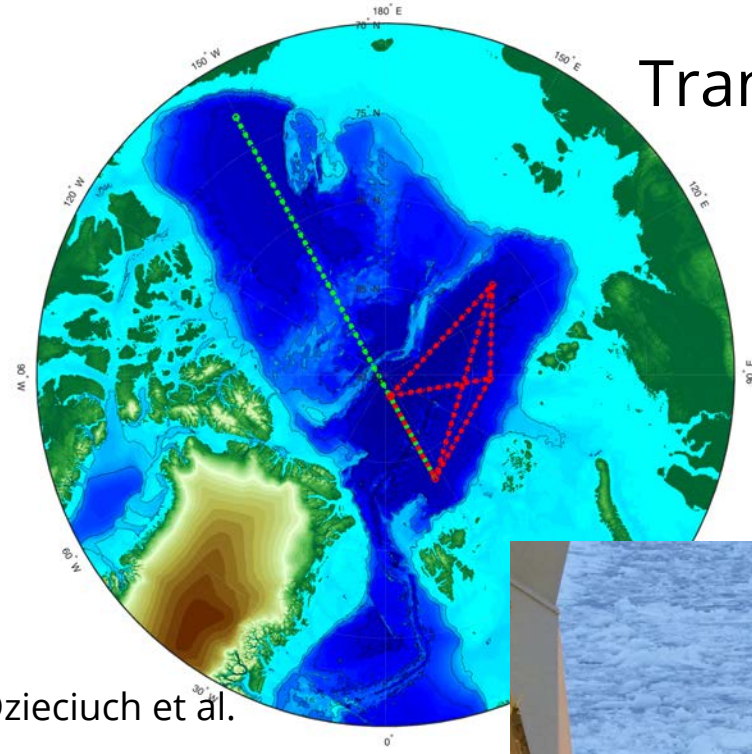
stations

Vehicle maintenance site

25 docking developments around the world – all different

A review of underwater docking and charging technology for autonomous vehicles, Jixin Liu et al., 2024

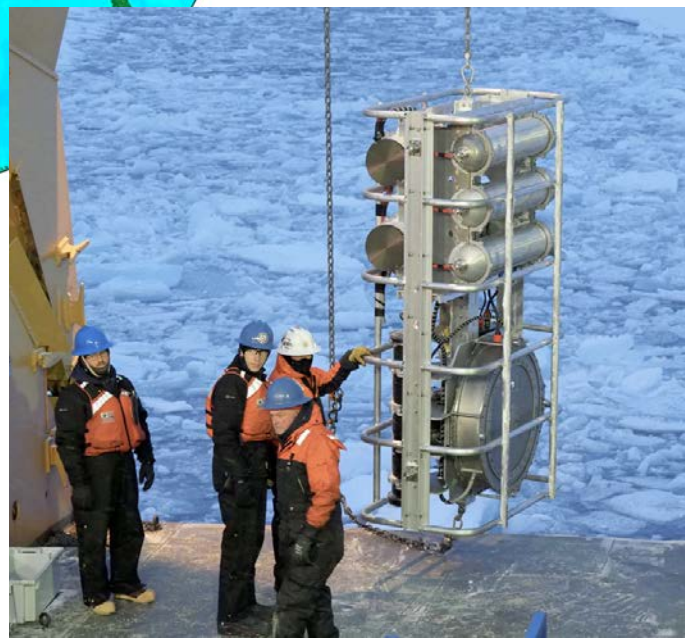
Acoustic tomography and navigation



Trans-Arctic

Ocean Temperature at the speed of sound

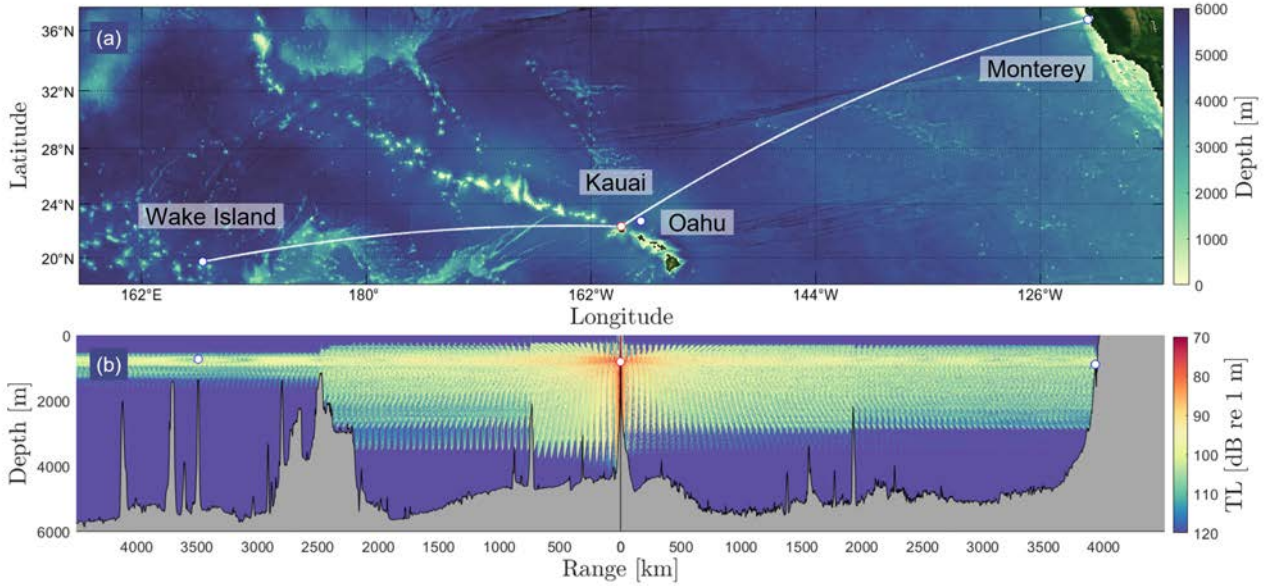
Dzieciuch et al.



Need deep cabled ocean mooring

Hydrophones on Mermaids/EarthScope Oceans and Seatrec infiniTE™ Float
ASN – integrating acoustic modems

North Pacific



- Kauai Beacon, ONR
- Transmitting regular 2% duty cycle
- RX on OOI, MARS, CTBT/Wake, ACO
- Gemba et al. NPS, UW, UH, …

1. Start with telecom network – 1.5 Gm, 20,000 repeaters, every ~70 km

2. In existing and new systems, SMART optical fiber sensing (DAS, SoP, phase)

3. In new systems, SMART nodes: temperature, pressure, seismic motion

4. Include hydrophones – Passive Acoustic Monitoring, soundscapes

5. Single ports at select nodes – acoustic modem, more basic sensors

6. Branch nodes: AUV docking, acoustic moorings, instrument arrays

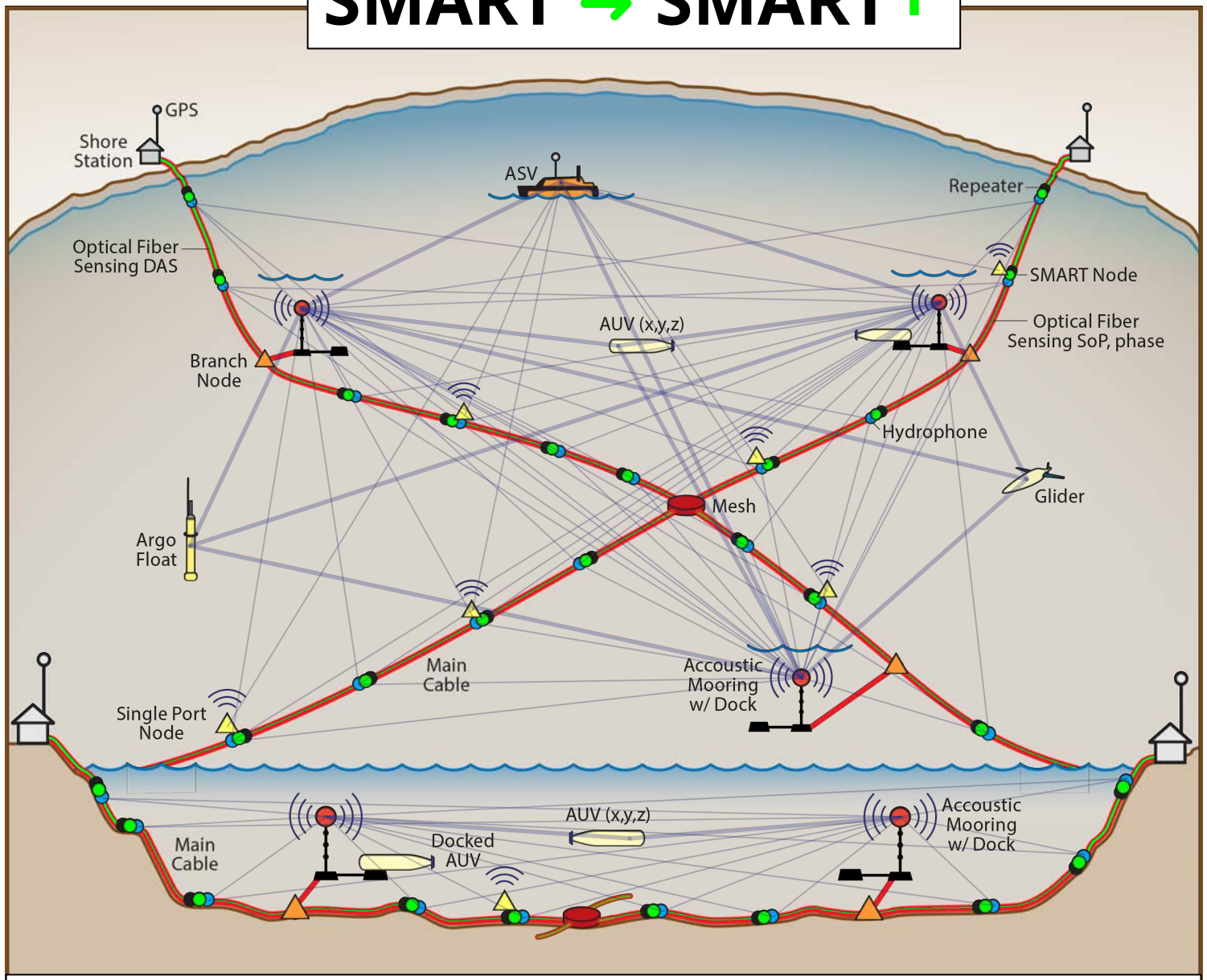
7. Mesh SMART subsea power grid

8. Add mobile platforms with sensors

9. Acoustics – tomography, sound speed, temperature, heat content

10. Acoustics – long range nav + comms for autonomous platforms

SMART → SMART+



SMART: telecom + environmental sensing

Cable network protection and resilience

- Much in the news of late – cable breaks and cuts
- Submarine telecom cables are critical infrastructure
- Require protection and network resilience
- **European Commission Joint Communication:**
  - *Stepping up security requirements and risk assessments on submarine cables,* ***while prioritising funding for the deployment of new and smart cables*** *…* *21 Feb 2025*
- **ITU + IPCP - International Advisory Body for Submarine Cable Resilience**
  - *… innovative technologies and solutions that can mitigate the risks of damage to and enhance the resilience …* *27 Feb 2025*

- **Cables can no longer be "deaf, dumb, and blind"**
- **Need sensing – cable and environment – SMART and SMART+**

SMART and SMART+

- SMART – early systems underway setting valuable precedents
- Prepare for Antarctica cables, Trans-Arctic, N Atlantic, Med, SAm, …
- Deep ocean – unknown, essential for science
- Need network services: power, comms, PNT, …, “future proof”
- Need network elements: AUVs, cable connected docking, moorings, acoustics
- DONET, Snet, Nnet, NEPTUNE, OOI led to many developments, follow through
- Incentivize industry, capacity building, sustainable Blue Economy
- Many challenges to address: finance, legal, regulatory, security
- Much to do!

SMART CABLES

ITU unesco WMO

GORDON AND BETTY MOORE FOUNDATION

Schmidt Marine TECHNOLOGY PARTNERS

SMARTCables.org

ITU/WMO/UNESCO-IOC Joint Task Force

Scan to Join!

Danke Gracias ありがとう 谢谢 **Xièxiè** Arigatō Thank you Dhanyavaad
Merci Tankyu tumas Terima kasih Takk Grazie Mālō 'aupito Kop koon
Salamat po S' efharistó