Observing the Ocean and Earth with

SMART CABLES

Observing the oceans and Earth with submarine cables: Looking towards the future

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

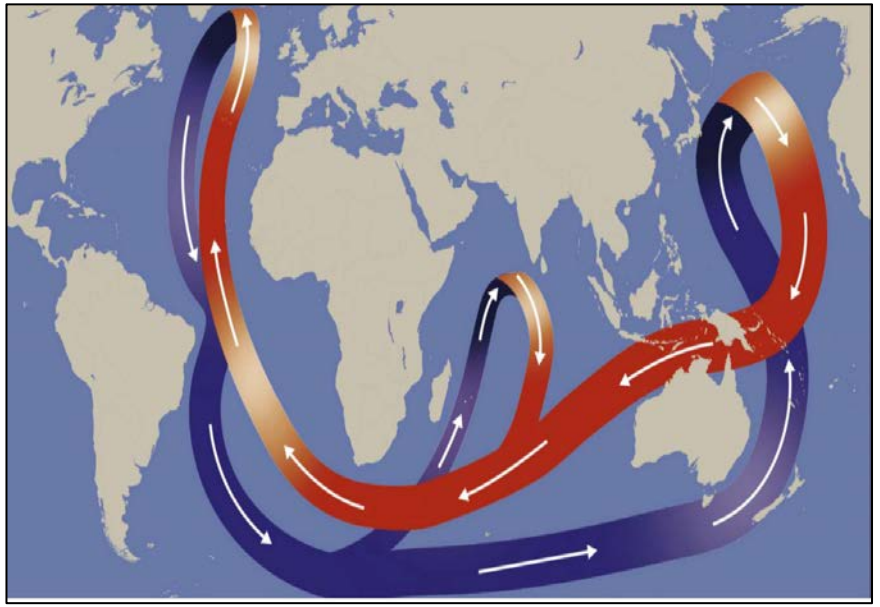
Future prospects for scientific uses of submarine cables and related technologies - 7th session (SSC24)
Tokyo, Japan
5 December 2024

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

Who we are, our mandate

....a global initiative, uniting 300 volunteers and stakeholders from science and society, engineering, data management, business development, and legal and regulatory disciplines...

Earthquakes and Tsunamis



Climate Change, ocean heat, circulation and sea level rise

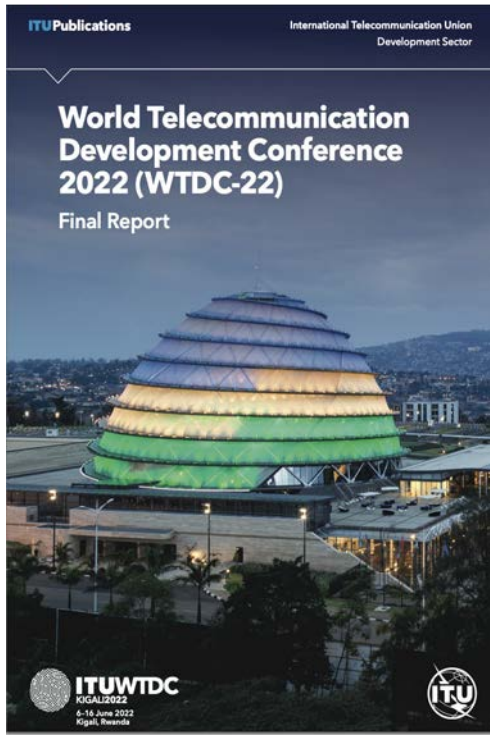
United Nations effort uniting science with the telecom industry to observe the oceans and Earth

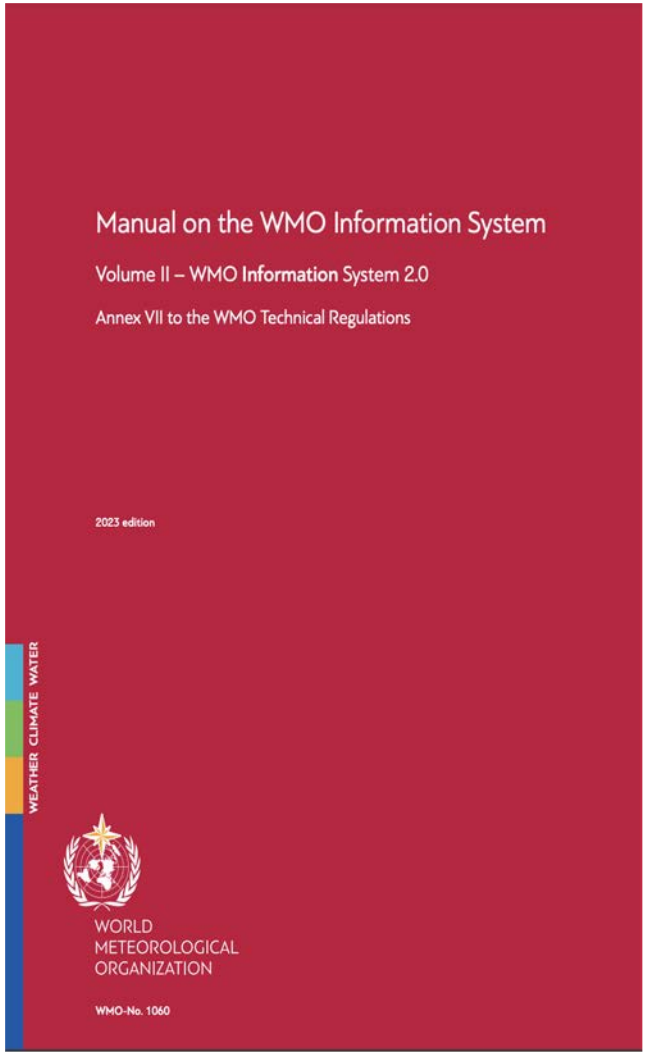
JTF Sponsors

- 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





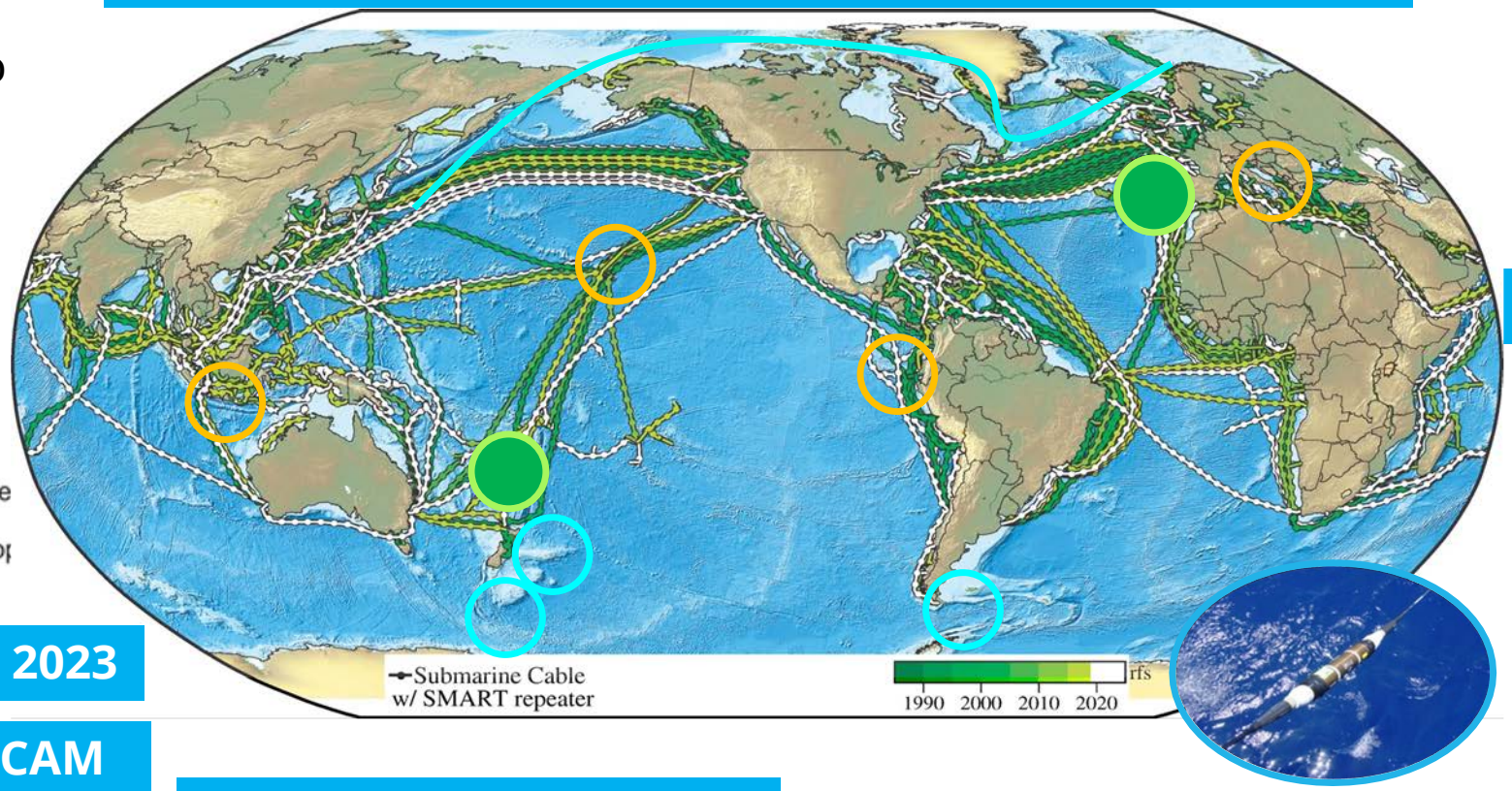
UN World Conference on Disaster Risk Reduction
2015 Sendai Japan

Climate Change and Disaster Risk Reduction

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

Create a Planetary sensor, power, Internet network

1st order addition to Ocean-Earth observing system



Share submarine cable infrastructure
Telecom + science
⬇€$

NO Interference

1.4+ GM
~20,000 repeaters
20 year refresh

repeaters ~100 km

2021 2030 United Nations Decade of Ocean Science for Sustainable Develop

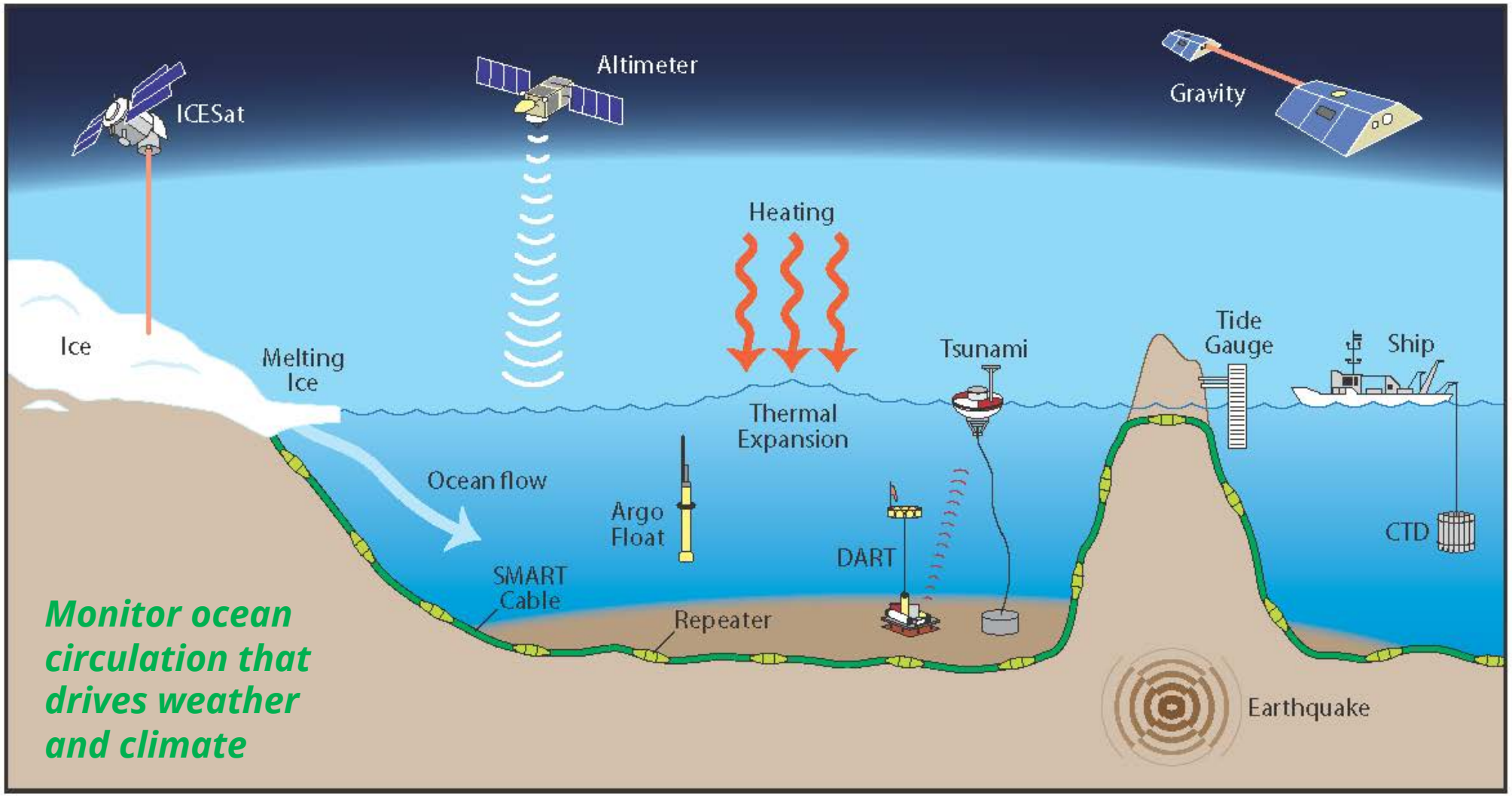
InSea Wet Demo 2023

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

Know the environment protect the network

Bottom temperature, pressure, seismic motion

Ocean + Climate change – Long term Observation



SMART Cables measure Essential Ocean Variables:
Temperature, Pressure; Seismic motion + ...

SMART Technical Solution

S-net

Shared Cable Infrastructure: Telecom + Science

Existing Technology

Sensor module
INGV InSea Wet Demo

Leverage Existing Technology

Sensors:

- Temperature
- Pressure
- Seismic

Key point:

- Essential Ocean Variables

Climate Change solution (SMART* technology)

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

Commercially available

Separate modules:

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

Key applications

Risk monitoring

- Earthquake detection
- Tracking of tsunami wave
- Tsunami warning

Scientific observation

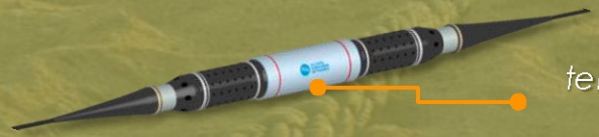
- Sea bottom movements
- Sea level rise
- Slow drift of sea bottom temperatures
- Sea water currents by temperature & pressure combination

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

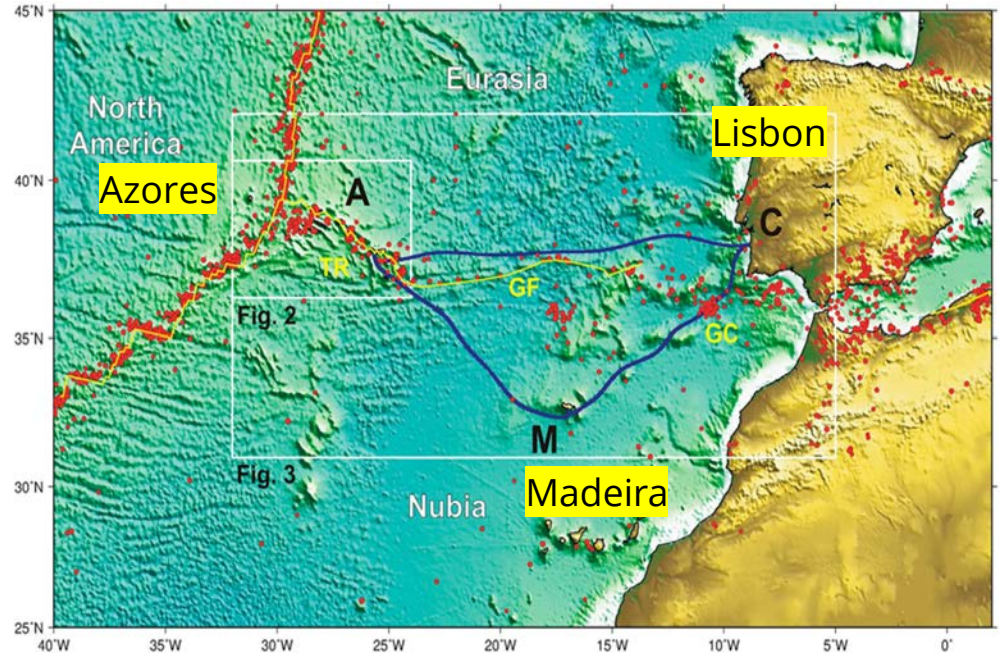
First SMART projects planned for 2025 / 2026

- South Pacific
- Atlantic
- Asia

* *Scientific Monitoring And Reliable Telecommunications*

Funded SMART Cable Systems

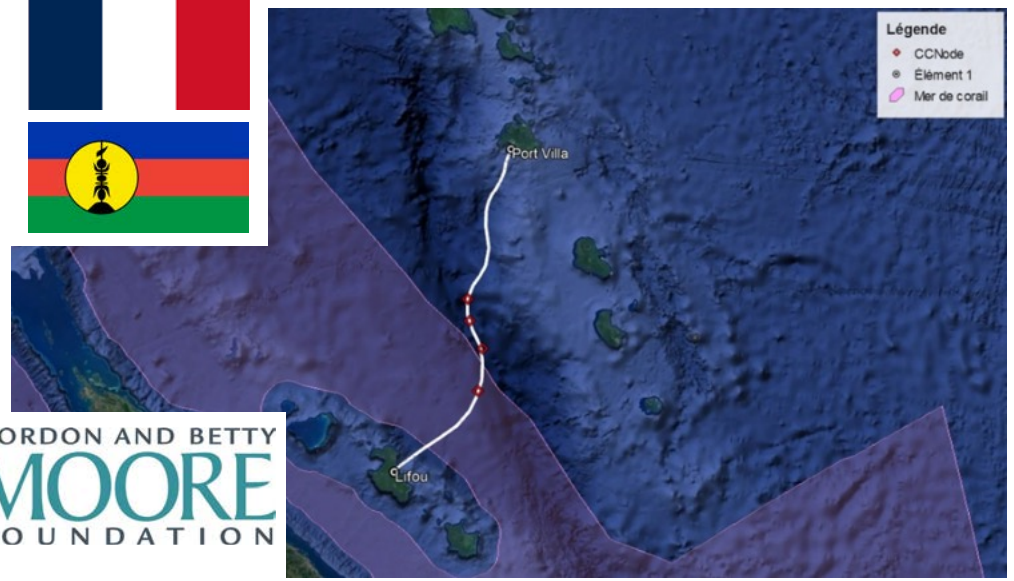
Portugal SMART Atlantic CAM



- 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, 170 y

Optical Fiber Sensing in both

SMART and Optical Fiber Sensing

Complementary not Competition

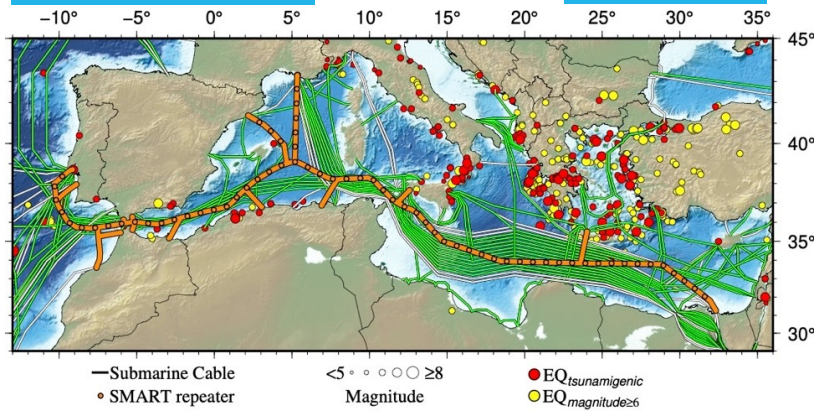
1. Measurement characteristics can differ in complementary ways
2. SMART sensors can calibrate fibre sensing observations
3. Validate unexpected observation

CAM and Tamtam:

Ideal for investigating capabilities and complementarity

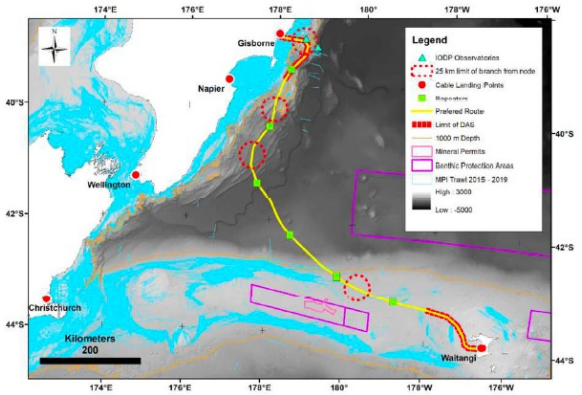
Systems in Play

Medusa



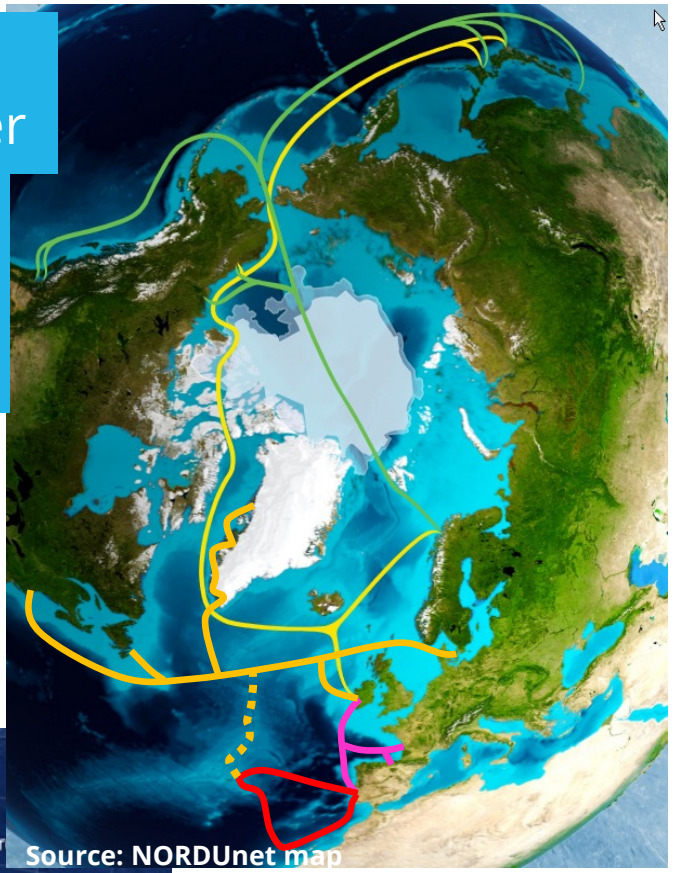
MISTS

NZ - Chathams

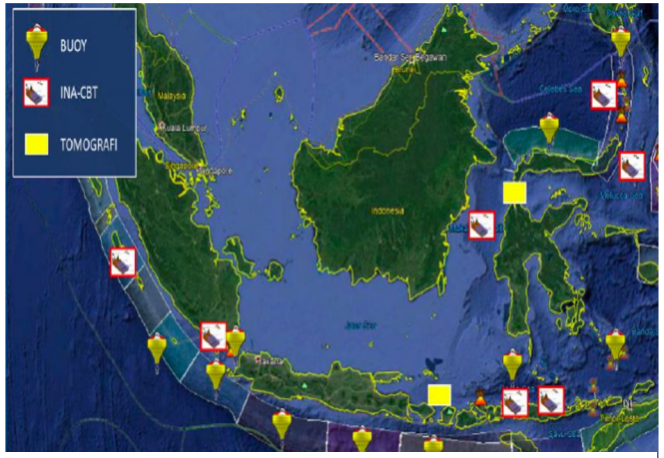


Polar Connect
Far North Fiber

Tusass
Pisces
CAM



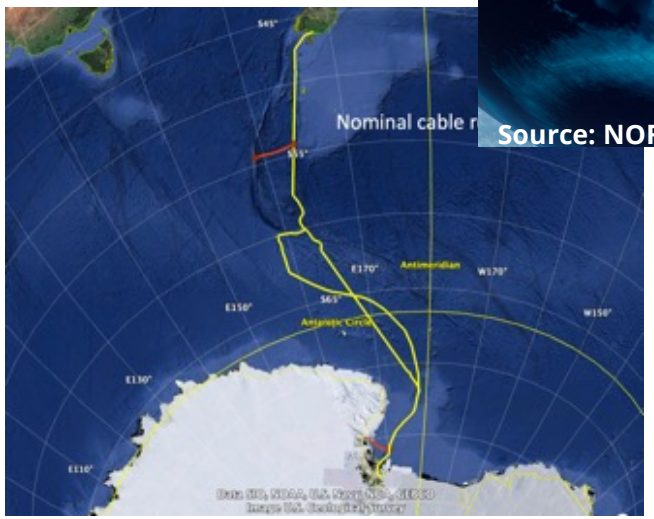
Indonesia



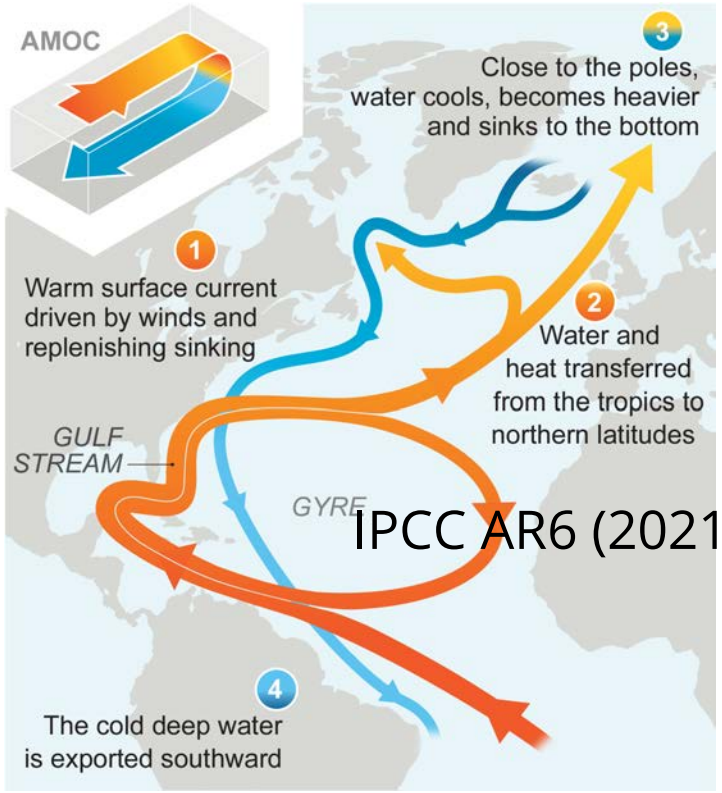
2 module test system Labuan Bajo

Antarctica Chile

Antarctica US



Atlantic Meridional Overturning Circulation (AMOC)

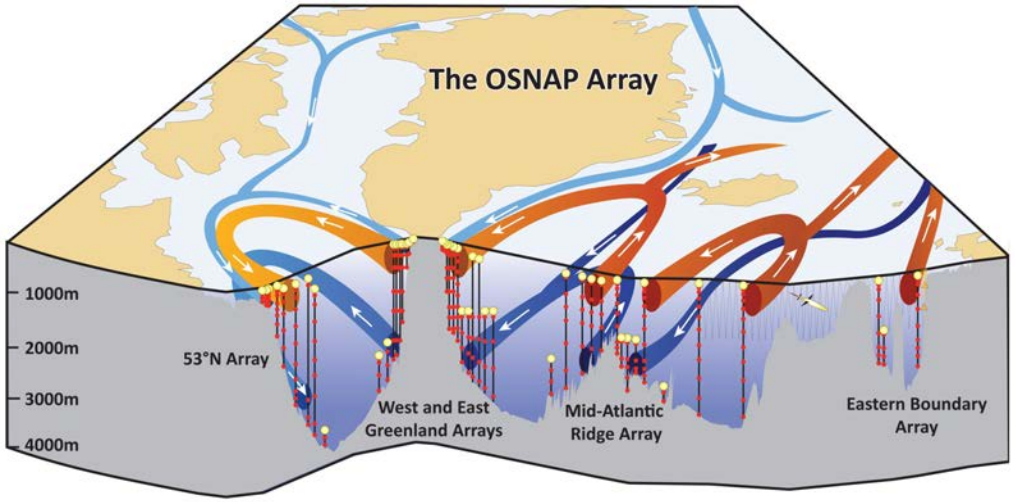


IPCC AR6 (2021)

- Warm upper-ocean water flowing northward
- Cold deep water flowing southward
- Redistributes heat, freshwater, oxygen, carbon, and nutrients on a global scale
- Very important for the global climate and marine ecosystem

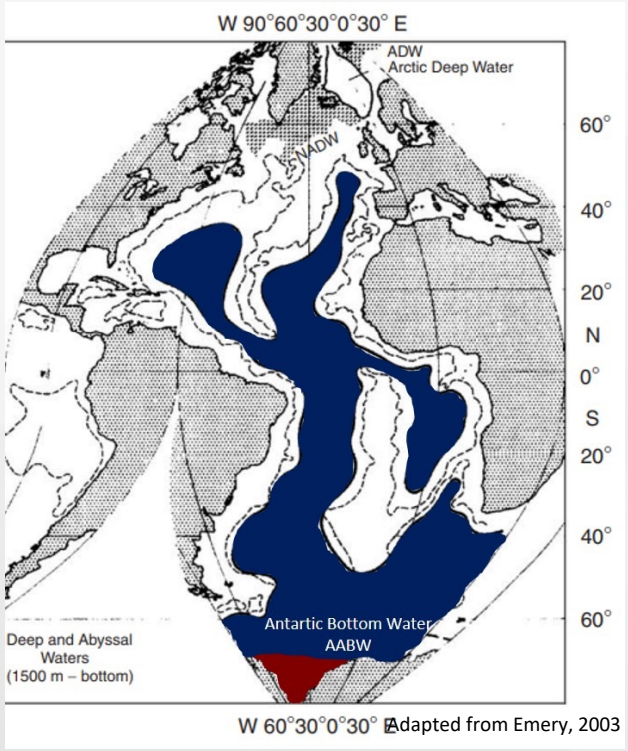
OSNAP: Overturning in the Subpolar North Atlantic Program

Cf. Tusass

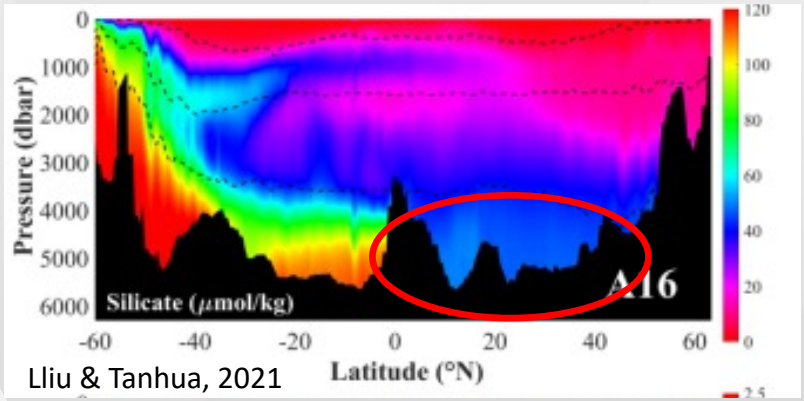


Courtesy Y. Fu, Georgia Tech

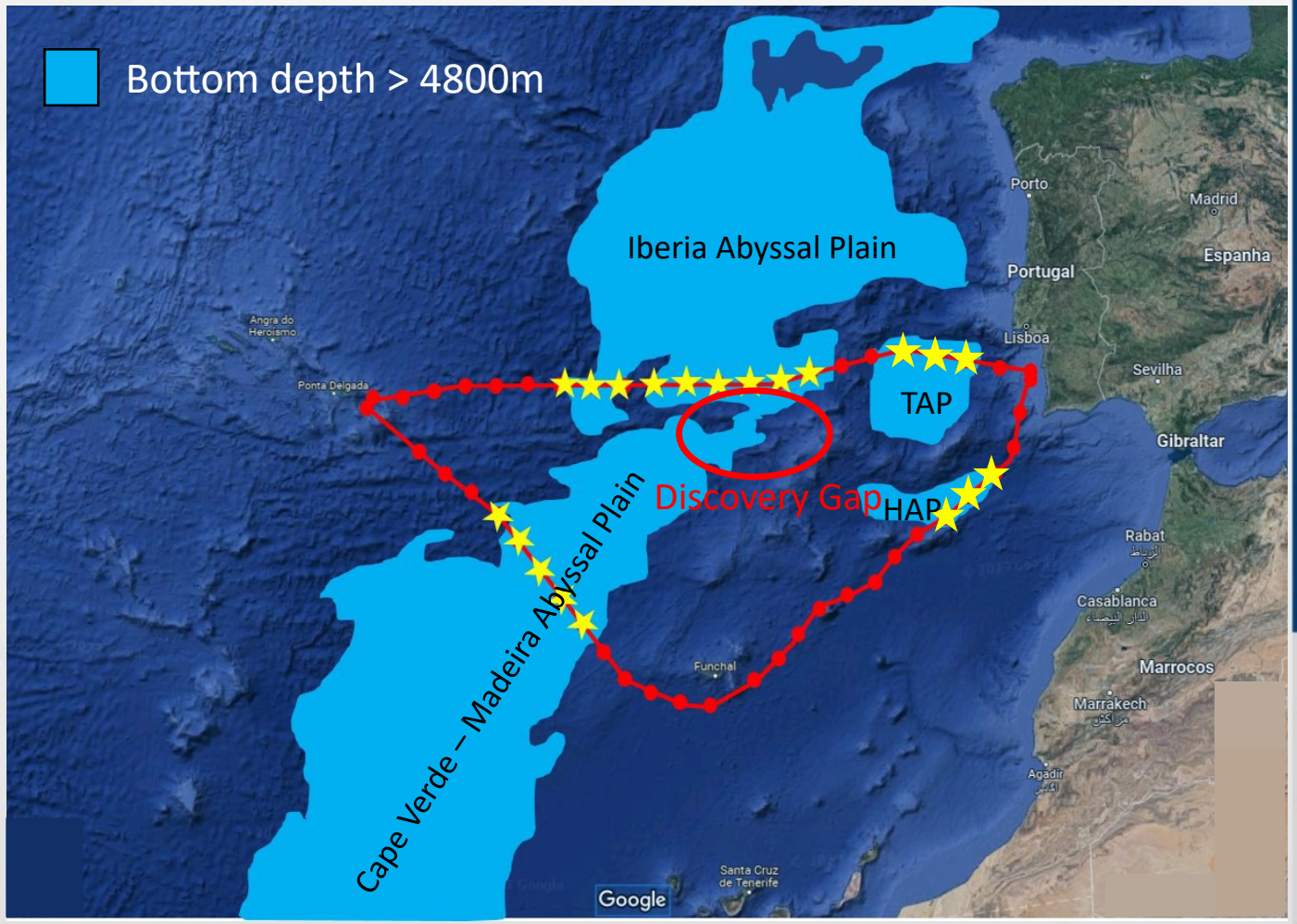
Monitoring the deep ocean - Antarctic Bottom Water



Adapted from Emery, 2003



Lliu & Tanhua, 2021



Temperature Range: 0.9 –1.71 ºC

Salinity Range: 34.64 – 34.72

Courtesy J. Vitorino, Instituto Hidrográfico

Marinha

hidrográfico marinha·portugal

www.hidrografico.pt

SMART Cables

JTF SMART Cables – positive attributes:

- Improve Global Ocean Observing System with new EOV long-term, deep data
- Improve the understanding of ocean currents, heat content and sea level rise for climate change
- Improve earthquake and tsunami early warning
- Improve cable protection and integrity – no longer “deaf, dumb and blind”
- SMART is multi-disciplinary, multi-purpose, at modest cost
- Catalyse research and development, long-life infrastructure for ocean obs
- Address Science, Technical, Finance, Data, Legal and Regulatory, Security

SMART – Concluding Remarks

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

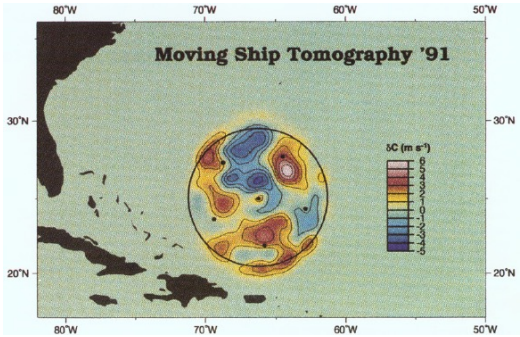
Biased by my Background

Change gears

SMART → SMART+

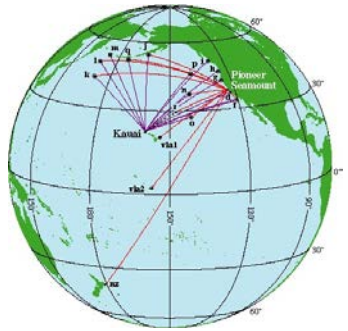
Howe - Personal perspectives

Moving Ship Tomography



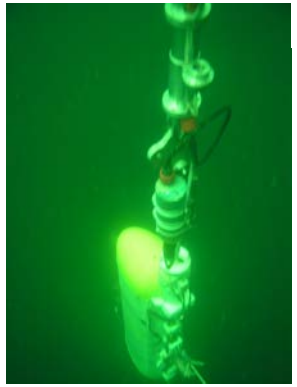
Acoustics

Acoustic Thermometry of Ocean Climate (ATOC)



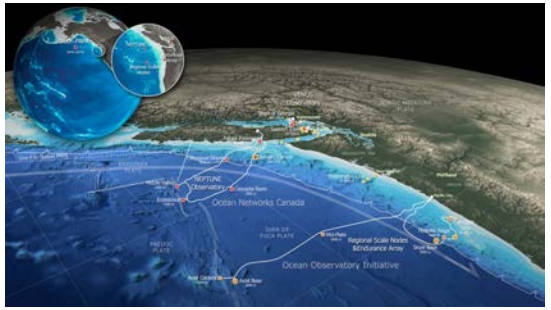
Mobile

Moored profiler
Inductive power dock
Cable connected



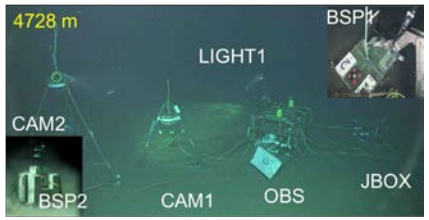
SeaGliders – acoustic comms and nav

Fixed - cable



NEPTUNE, OOI

ALOHA Cabled Observatory
Deepest plug and play power, Internet node on planet



SMART → SMART+

- Submarine cables have always been critical subsea infrastructure
- Telecom connecting society and empires
- Now understand must protect this critical subsea infrastructure
- Leverage industry, here beyond SMART
- New Capabilities (foundation commercial telecom):
  - dedicated science systems, flexible, high power, bandwidth, reach
  - SMART, acoustic modems, oil and gas, …
  - AUVs, long range acoustics, …
  - “Future Proof” – flexible to accommodate new tech

Essential Deep Ocean Infrastructure

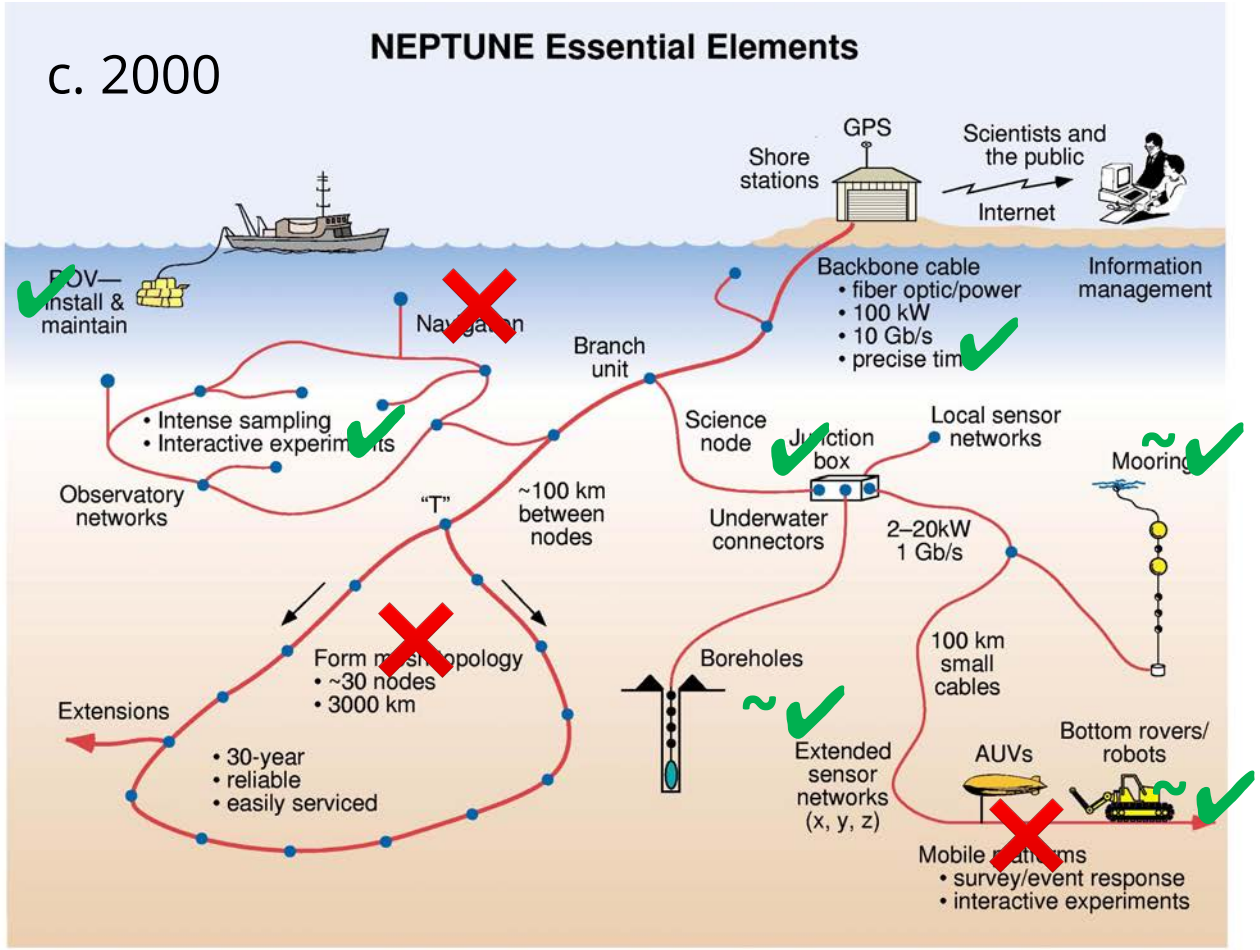
?90% ocean observing cost is infrastructure

Infrastructure Services

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

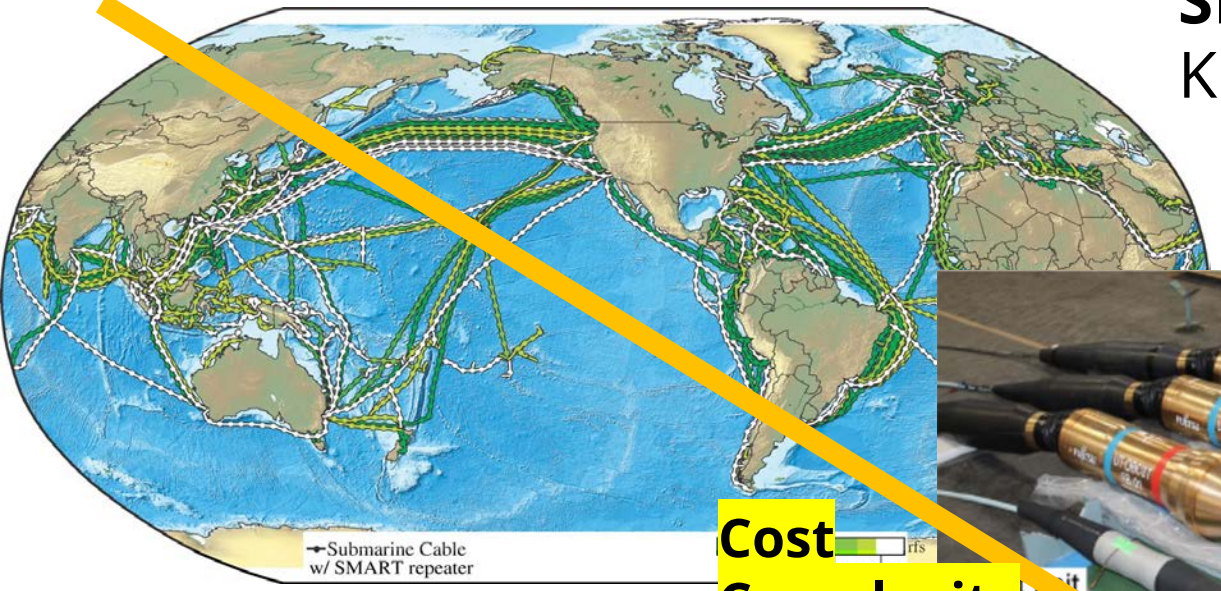
Infrastructure elements

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



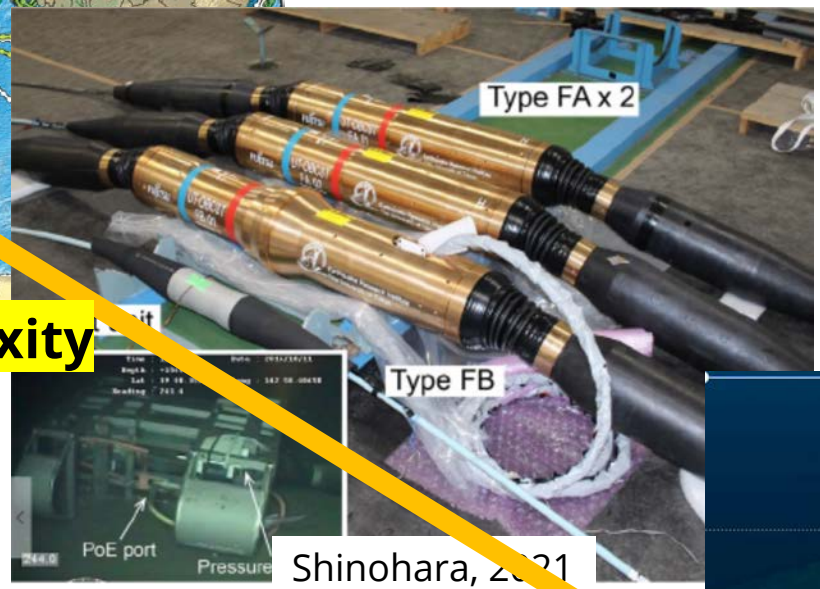
Cable sine qua non for everything else – share with telecom - affordable

Deep ocean essential infrastructure elements - cables



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

Cost
Complexity

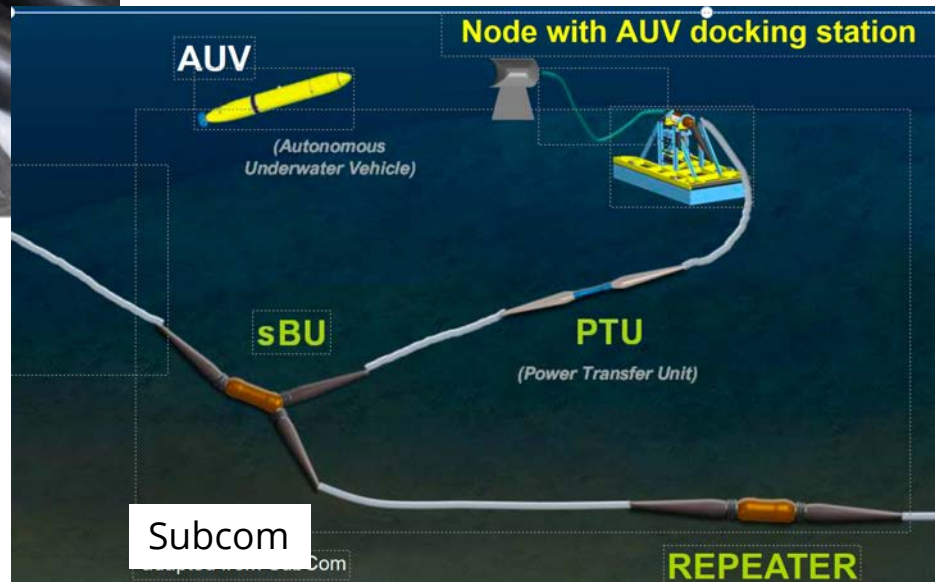


Shinohara, 2021

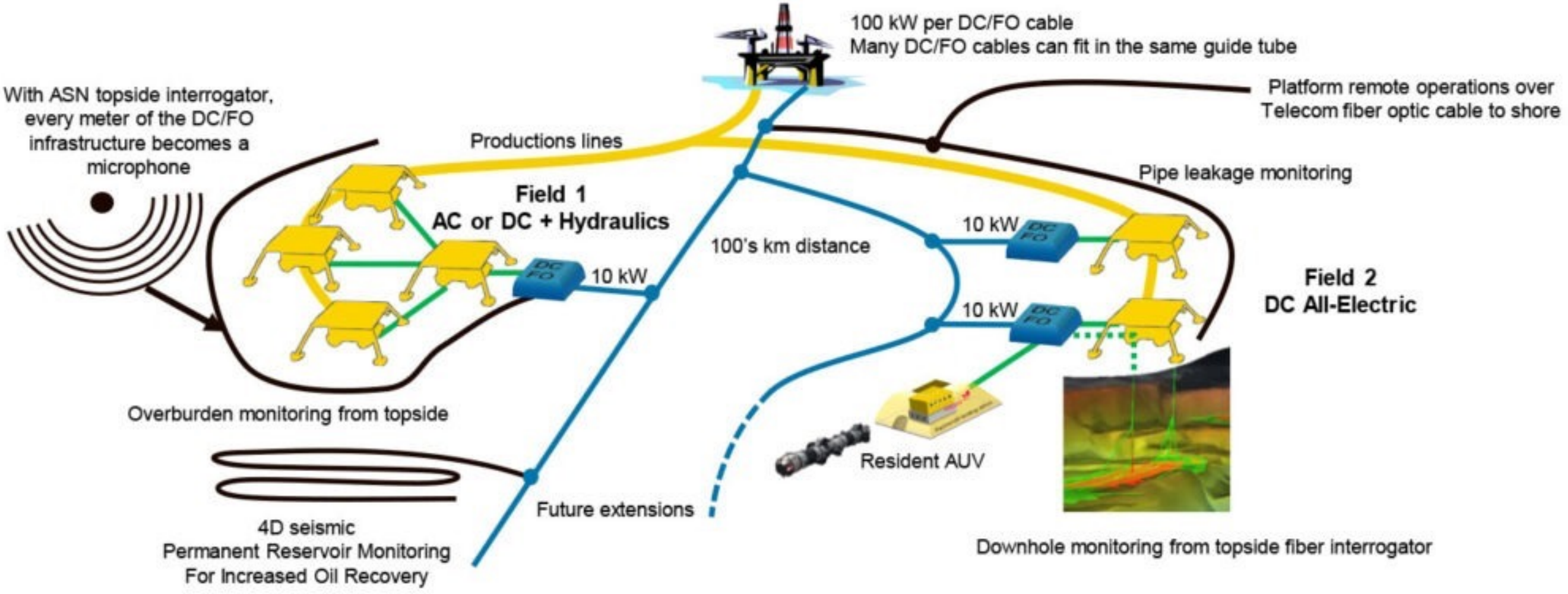
Test system, Japan
Single port, PoE

+ fixed and mobile platforms

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



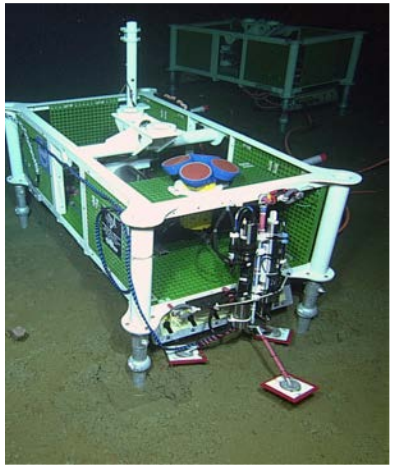
ASN DC/FO Network – “Nodes” – main application Oil and Gas
Need to integrate with commercial telecom

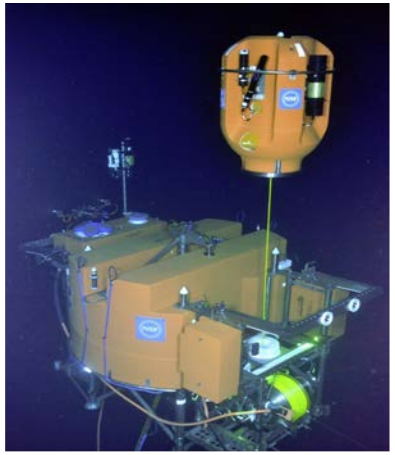


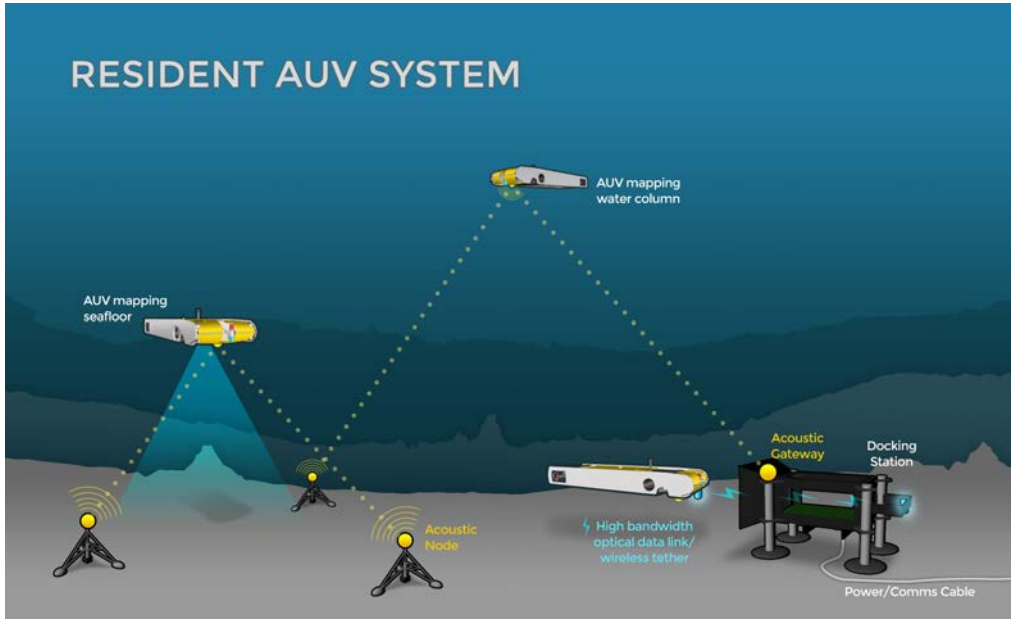
https://www.asn.com/energy-solutions/

Evolved from NEPTUNE Canada

Cabled Instrumentation and Resident AUVs

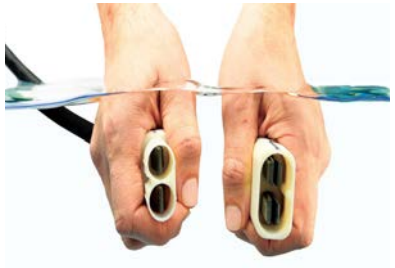






Courtesy D. Manalang, APL-UW

Bottom packages, upper ocean profilers, deep moored profilers – exist, but bespoke
Resident AUVs – one-offs (Saab …) – no standards
New UW connector



NiobiCon™ Wet-Mate Electrical Connector
Niobium, Passivates in ms, 80 V max , 10 A now

Docking – One example

Courtesy Brett Hobson, MBARI

Monterey Bay Aquarium Research Institute

For Persistent Operations

Omni-directional, compliant vertical line dock

Niobicon sliding contact power transfer: Patent pending with Northrop Grumman; 500 Watts (48v @ 11 amps)

1+ Mbps data transfer, plus acoustic modem backup

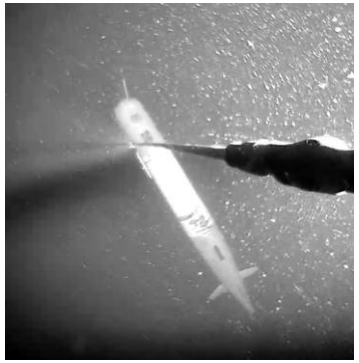
Web-based dock control interface with live video Input

power: Solar, wind, wave, cable, battery

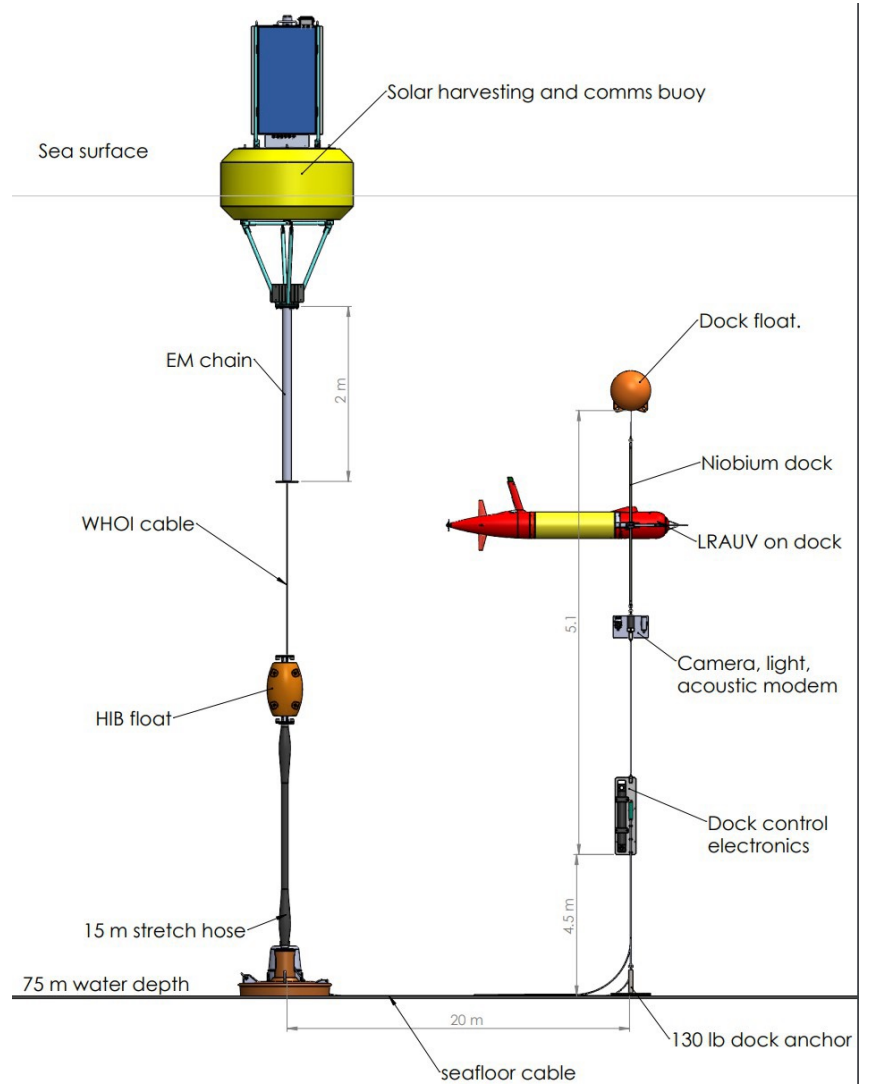
Solar for 1 LRAUV

Homing to Dock

MBARI



AUV Parked on Dock

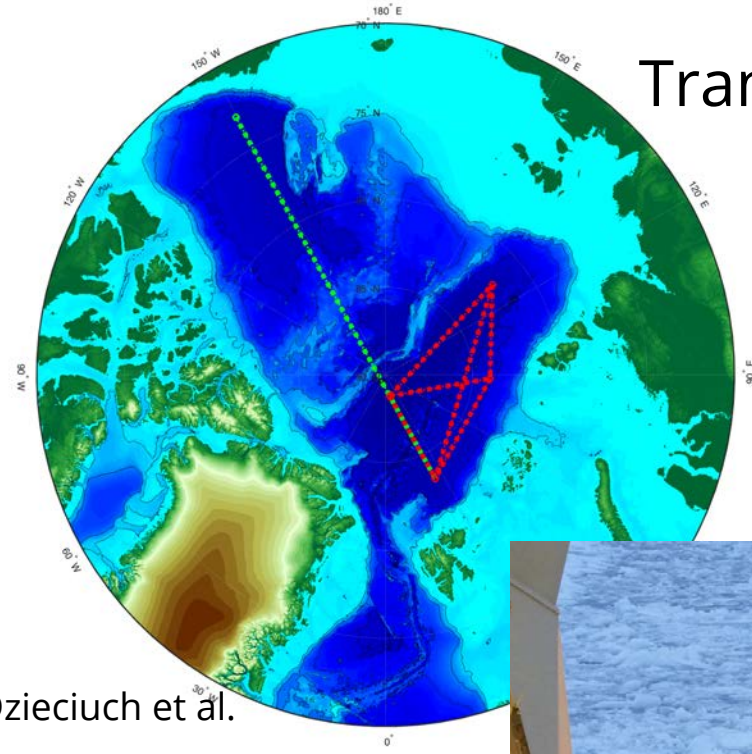


Note: A review of underwater docking and charging technology for autonomous vehicles, Jixin Liu et al., 2024

Acoustic tomography and navigation

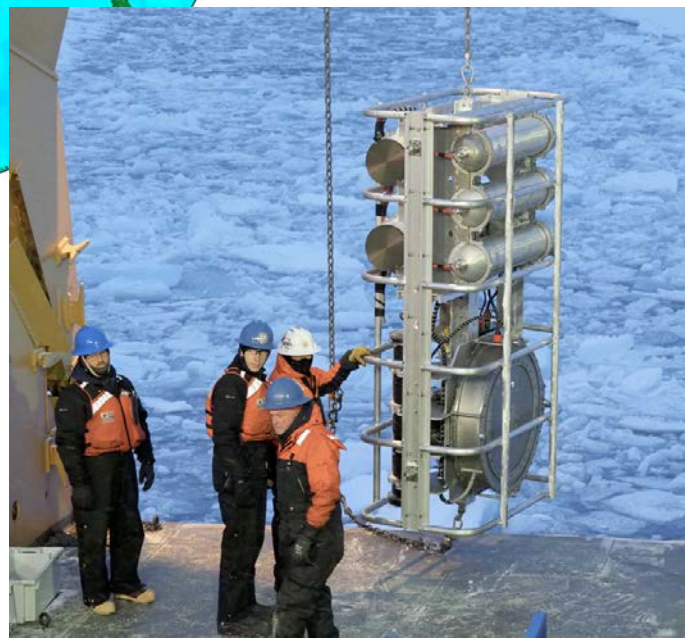
Hydrophones on Mermaids/EarthScope Oceans and Seatrec infiniTE™ Float
ASN – integrating acoustic modems

Trans-Arctic



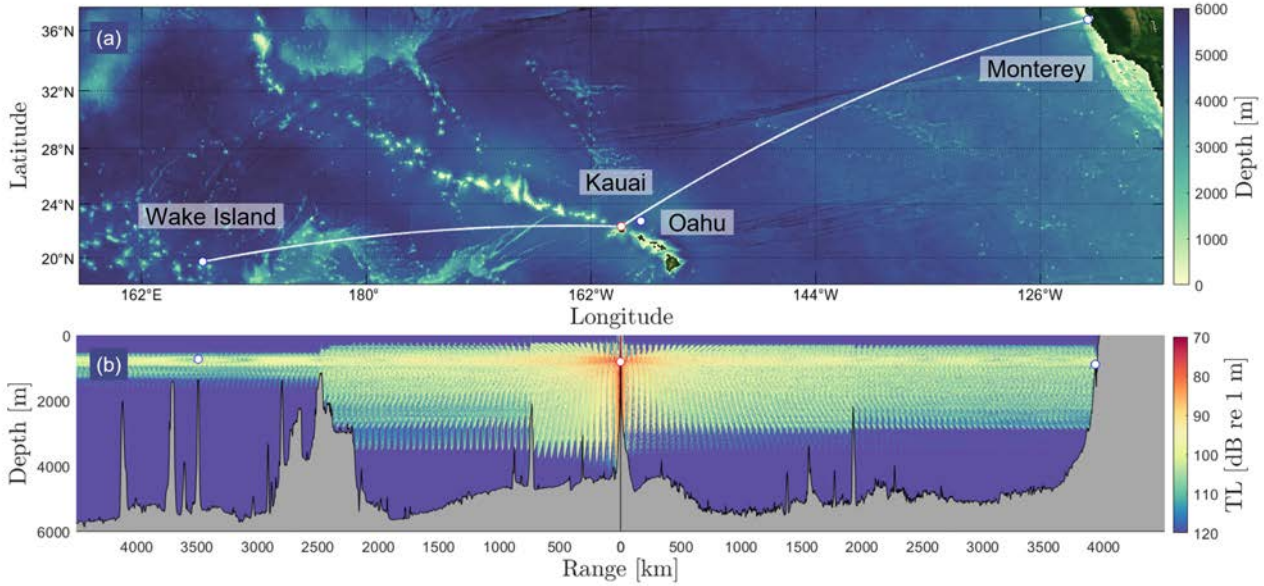
Dzieciuch et al.

Ocean Temperature at the speed of sound



Need deep ocean mooring

North Pacific

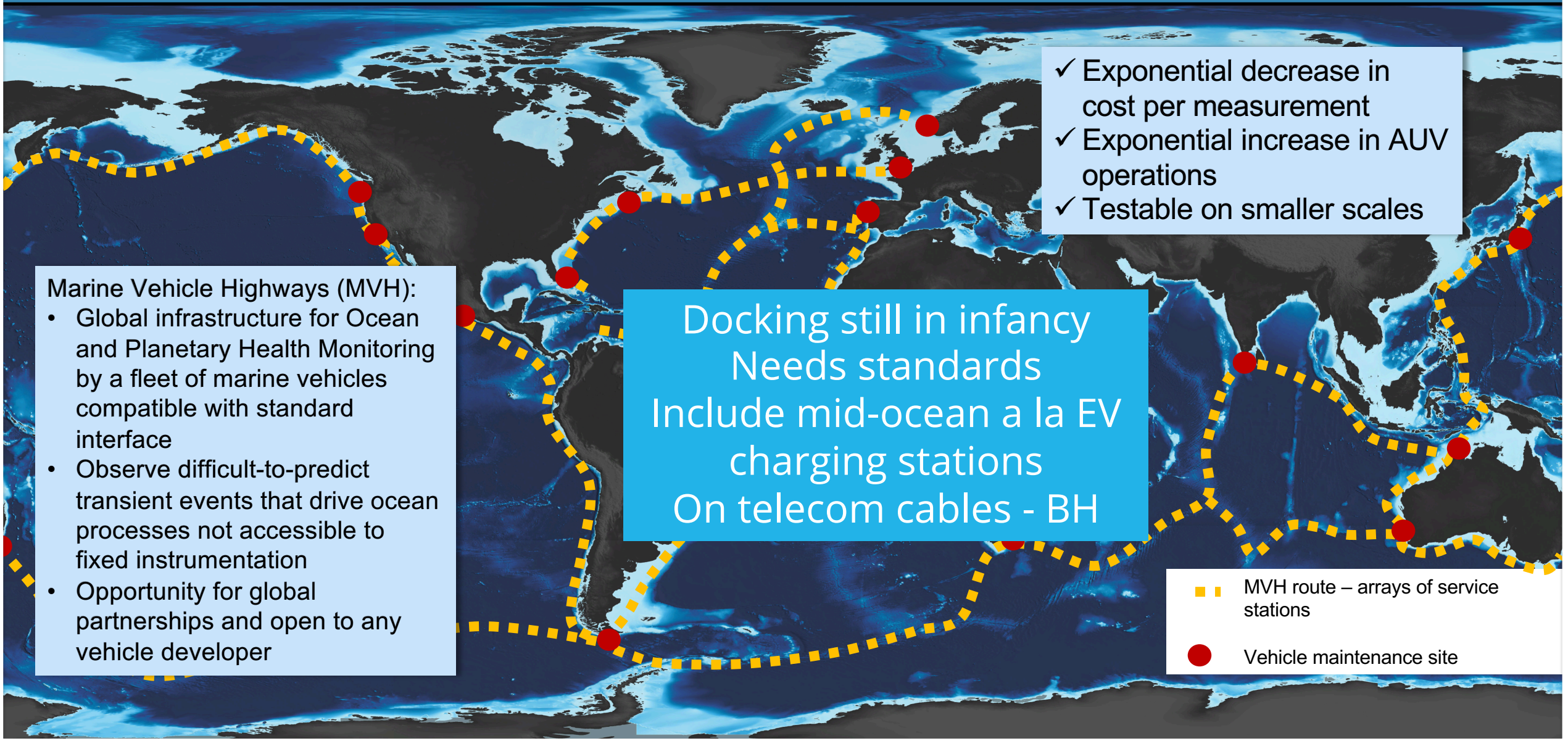


- Kauai Beacon, ONR
- Transmitting regular 2% duty cycle
- RX on OOI, MARS, CTBT/Wake, ACO
- Gemba et al. NPS, UW, UH, …

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



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

Marine Vehicle Highways (MVH):

- Global infrastructure for Ocean and Planetary Health Monitoring by a fleet of marine vehicles compatible with standard interface
- Observe difficult-to-predict transient events that drive ocean processes not accessible to fixed instrumentation
- Opportunity for global partnerships and open to any vehicle developer

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

MVH route – arrays of service stations

Vehicle maintenance site

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

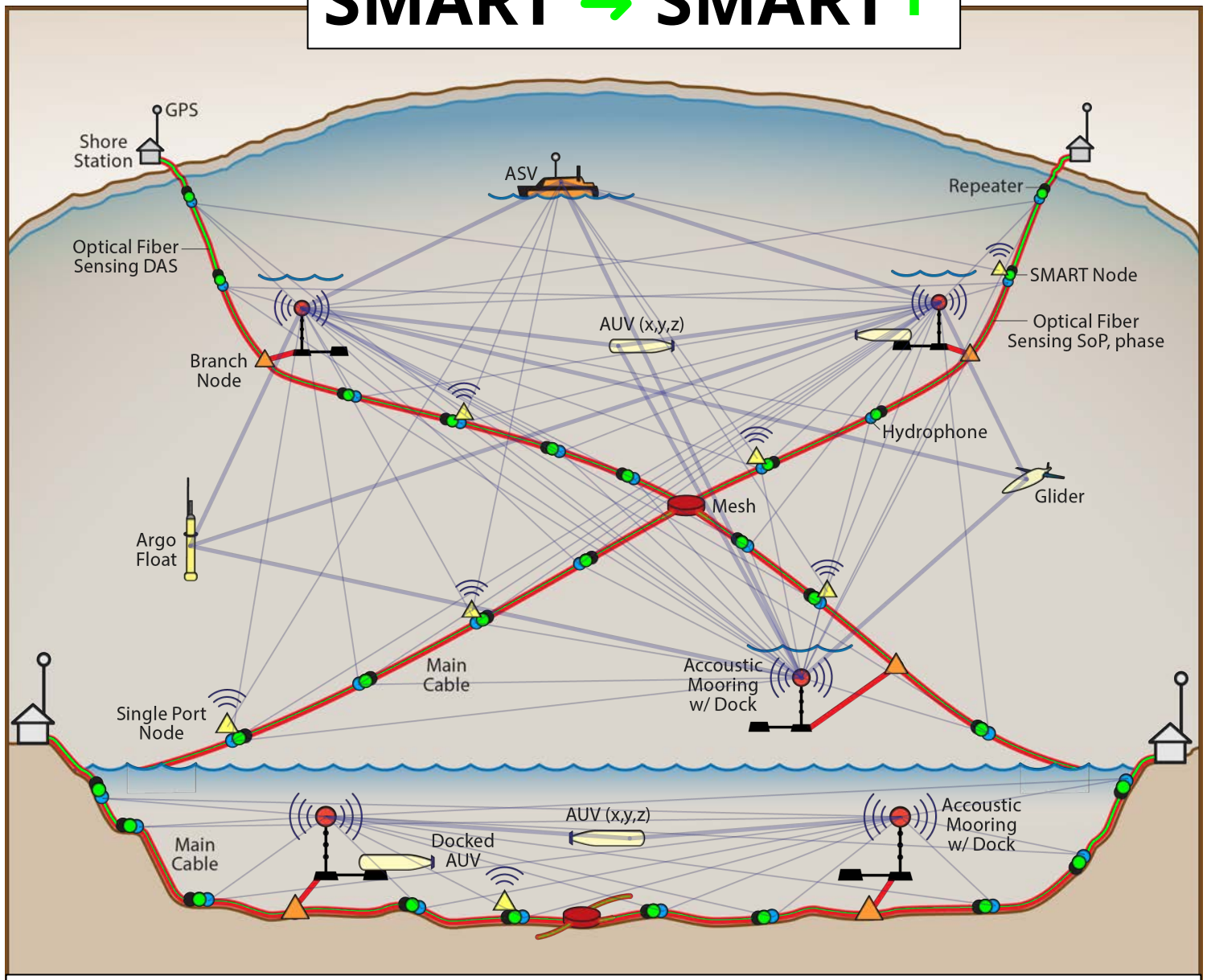
7. Mesh SMART subsea power grid

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

SMART and SMART+

SMART and SMART+ are within reach in the coming Decade, …

- SMART – early systems now underway will set valuable precedents
- Deep ocean – largely unknown, essential for science, need protection
- Needed elements
  - Test beds and long duration demos
  - AUVs multi-purpose, with docking (all sizes); Cabled Connected Moorings
  - Acoustic moorings (TX, RX), PNT Smart Subsea Power Grid
  - Model/data assimilation – ALL data, bottom boundary layer, fluxes – C(**x**,t)
  - Sensors – 25-year life, low drift, …
- Incentivize industry, capacity building, sustainable Blue Economy
- Prepare, implement SMART, SMART+ projects …
- Achievable with international collaboration

A long way since SSC1990 in Honolulu!

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 — Arigato** Thank you Dhanyavaad
Merci Tankyu tumas Arigatō Xièxiè Terima kasih Takk Grazie
Mālō 'aupito Kop koon Salamat po S' efharistó