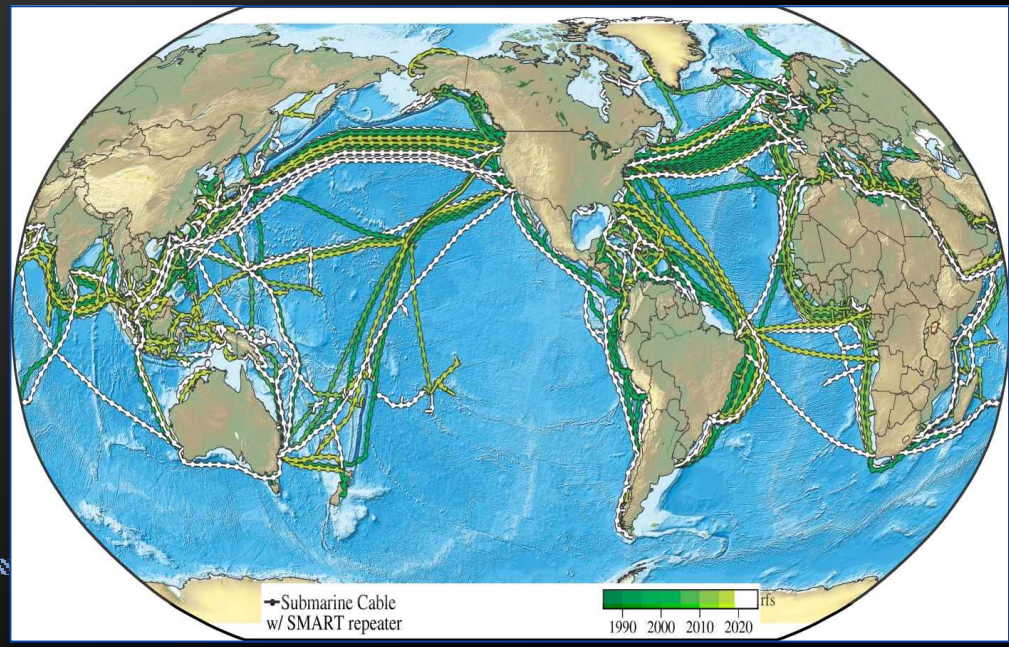
SMART Cables: A New Technology for Monitoring Natural Hazards and Climate Change

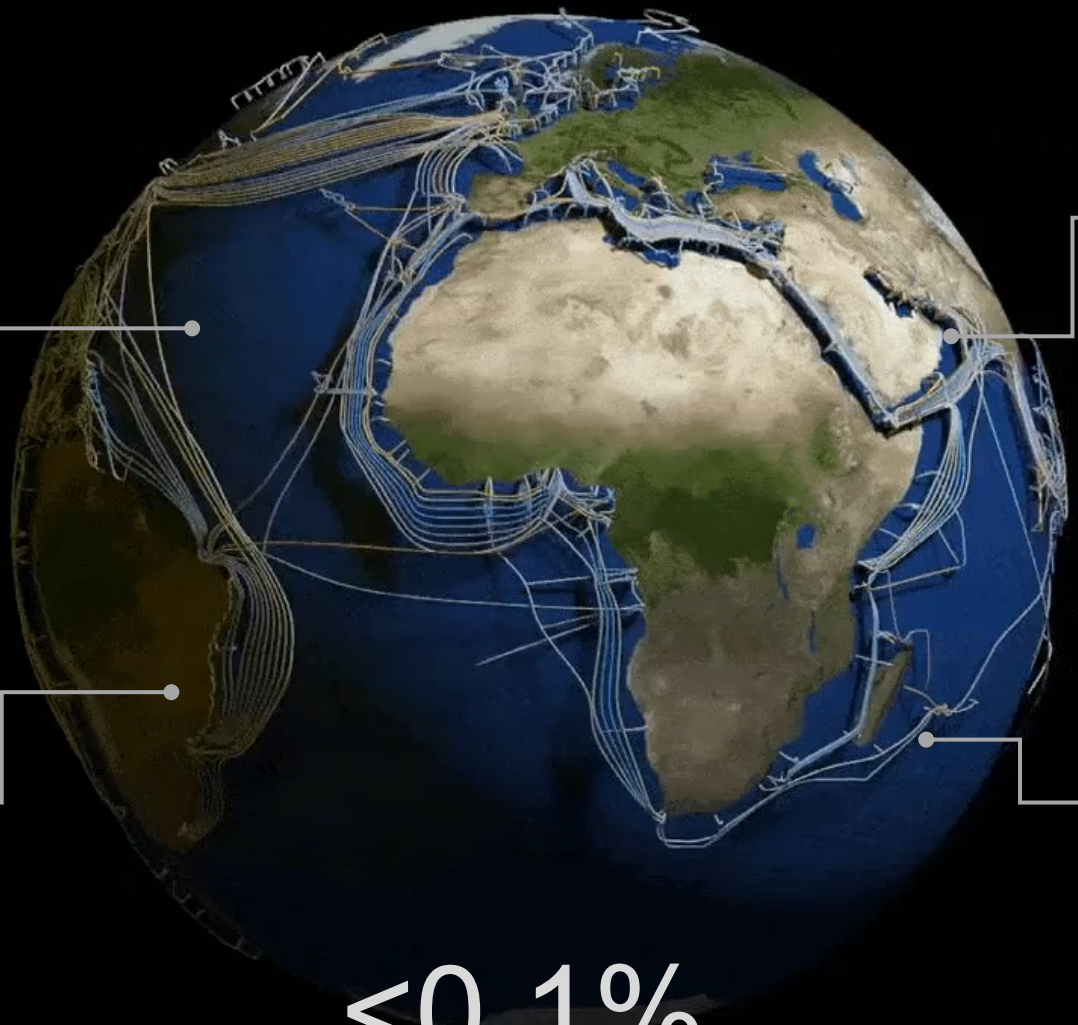
Matt Fouch and Steve Lentz
Subsea Data Systems

Brad Avenson
Silicon Audio Seismic



SUBSEA DATA SYSTEMS

Earth’s Submarine Fiber Cable Network



99.5%
Total Intercontinental Internet Traffic

1.4M km
Total Submarine Fiber Cable In Use

$10B/day
Financial Transactions Transmitted

0.2-0.4M km
New Cable Installed Each Year

<0.1%
Cable Used for Non-Telecom Purposes

What if We Instrumented the Oceans Using Telecom Infrastructure?

An Innovative New Way to Increase Human Resiliency

Listen For Earthquakes

- Improve alert times
- Increase resiliency
- Save lives

ANNUAL

Monitor for Tsunami

- Improve ocean coverage
- Monitor developing nations
- Save lives

DECADAL

Document Climate Change

- Long term observations
- Improve baselines
- Save lives

CENTENNIAL

Tsunami

Innovation Required

Massive Risk for the Most Vulnerable

2.9 Billion

People living in coastal communities

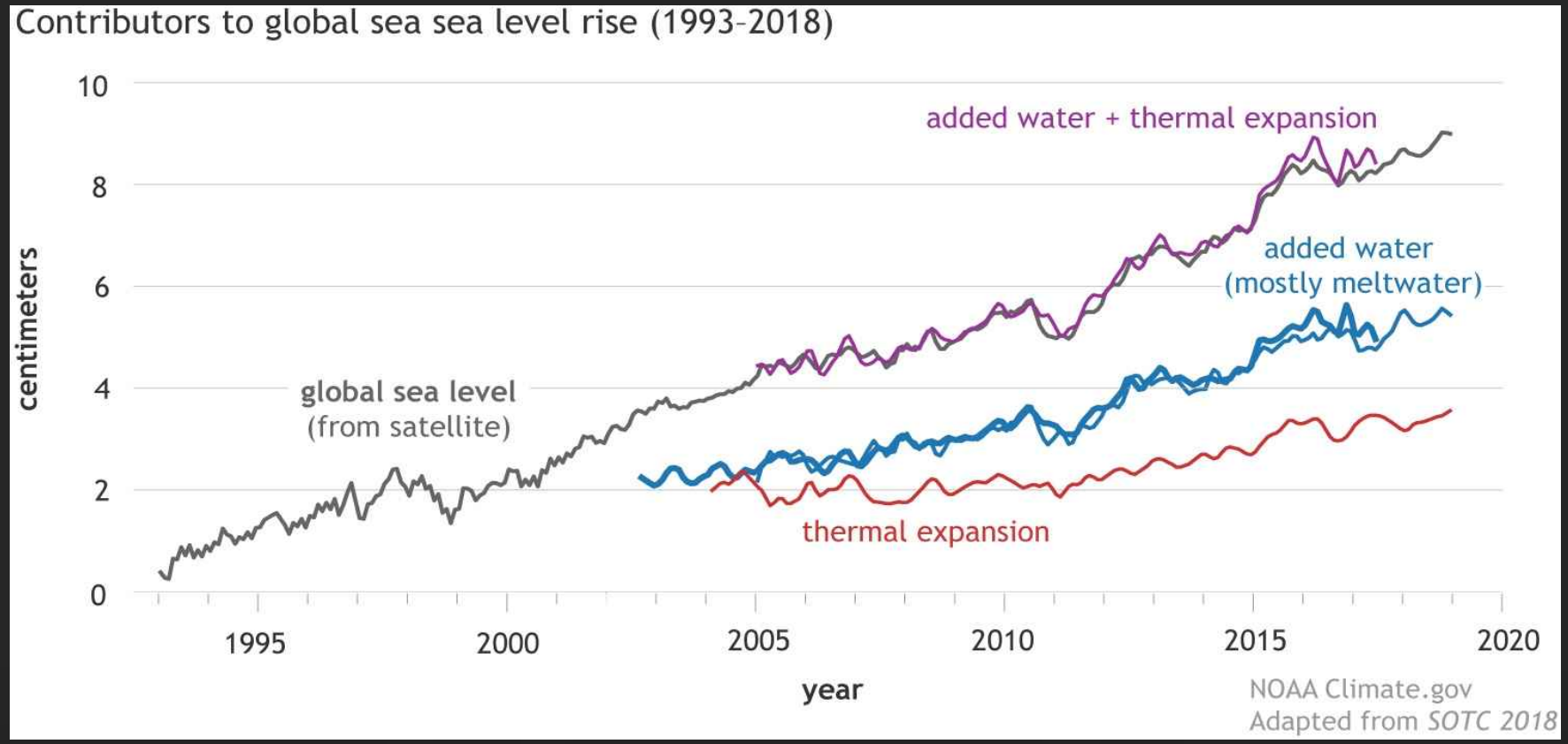
750 Million

People at daily risk of tsunami

$300 Billion

Cost of tsunami damage since 1900

Climate Change and Natural Hazards are Inextricably Linked



Steady Increase Over 150+ Years

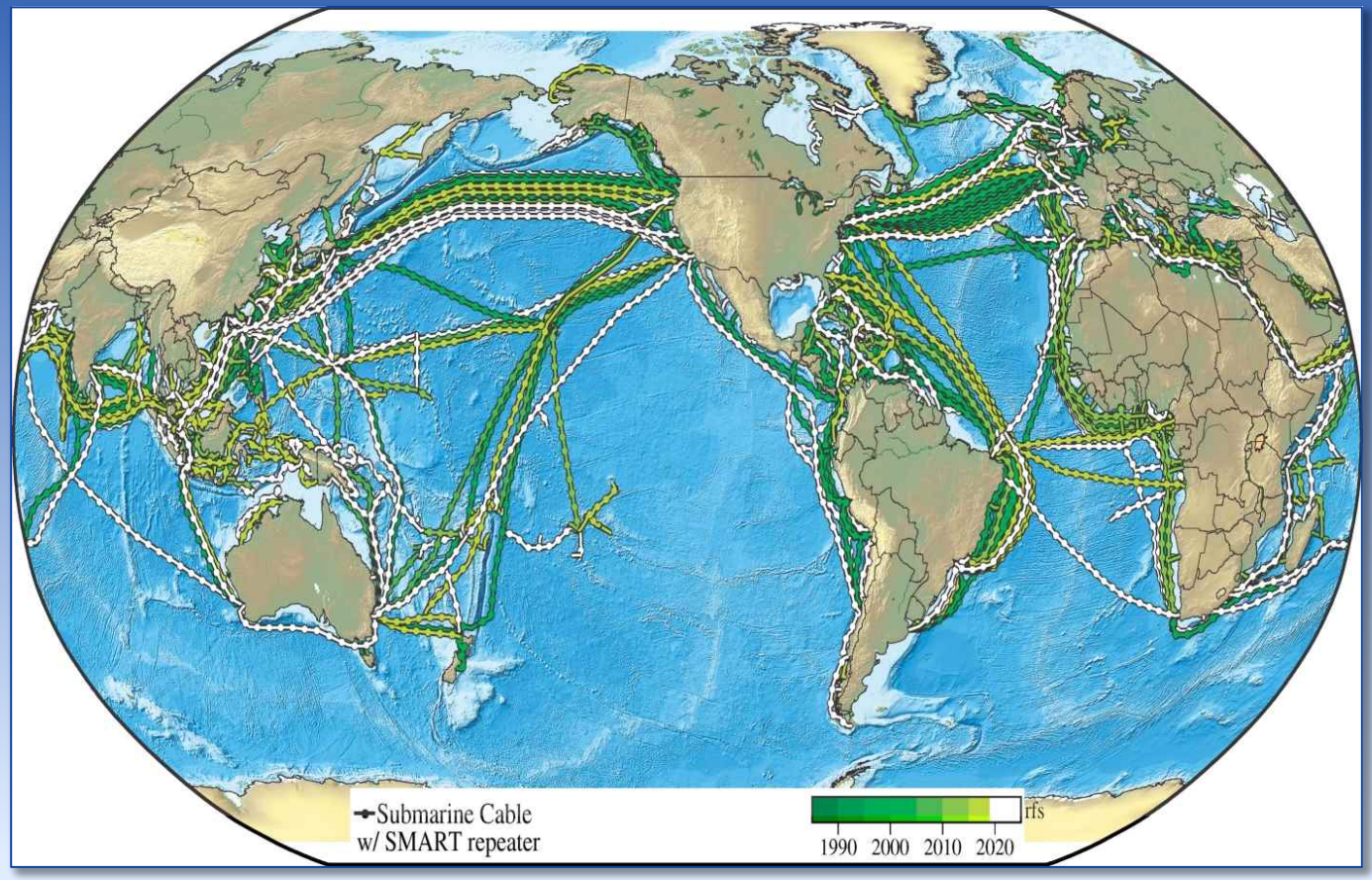
Significant Increase Since 2010

Meltwater + Thermal Expansion

SEA LEVEL RISE INVALIDATES STORM SURGE AND TSUNAMI MODELS

SMART Repeaters on Subsea Cables

SMART = Science Monitoring And Reliable Telecommunications



S Seismic

- Earthquakes
- Underwater landslides

P Pressure

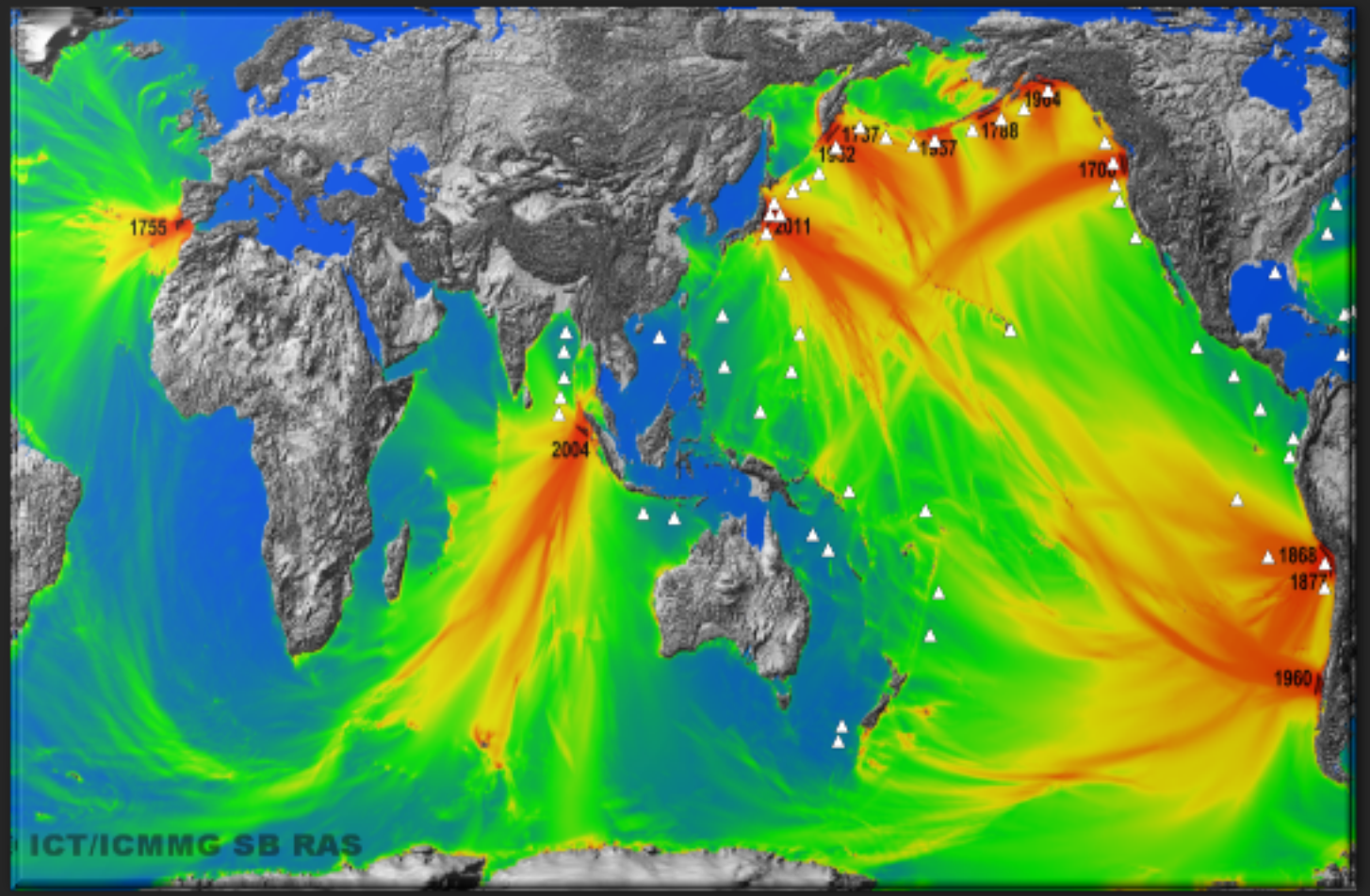
- Tsunami
- Ocean currents

T Temperature

- Sea level change
- Ocean heat + circulation

SMART Cables: Major Societal Benefits

- **Protect life and property**
  - Tsunami / earthquake early warning
  - Mitigate coastal flooding effects
- **Improve societal resilience**
  - Sea level / tsunami inundation
- **Protect / harden telecom infrastructure**
  - Cable system monitoring
  - National security

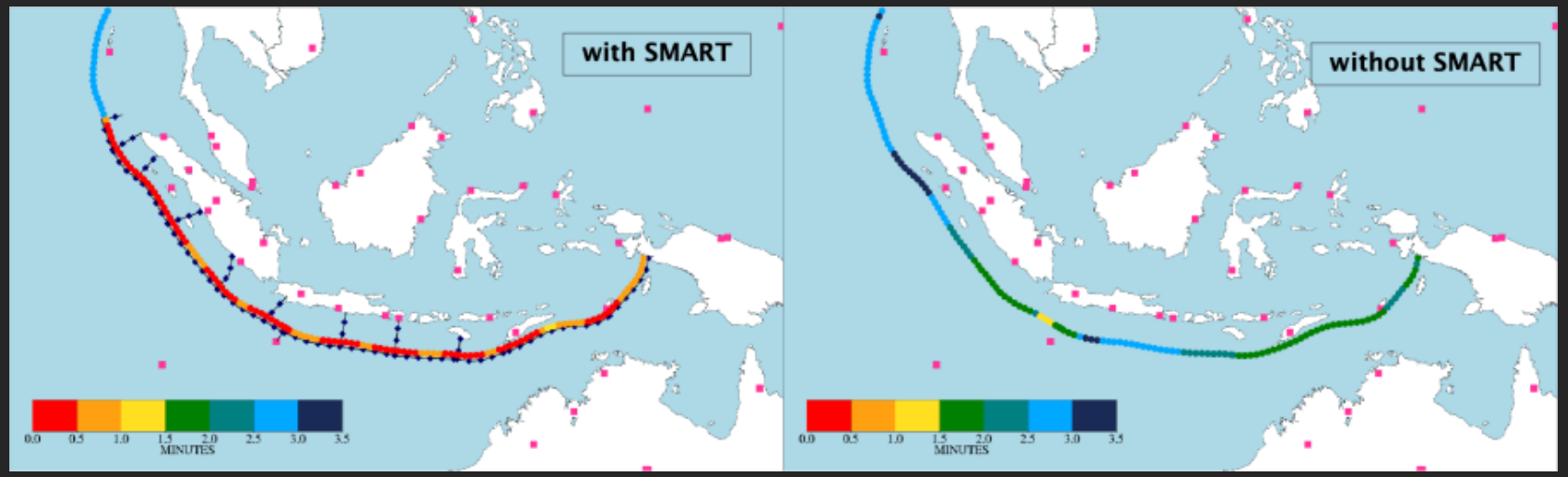


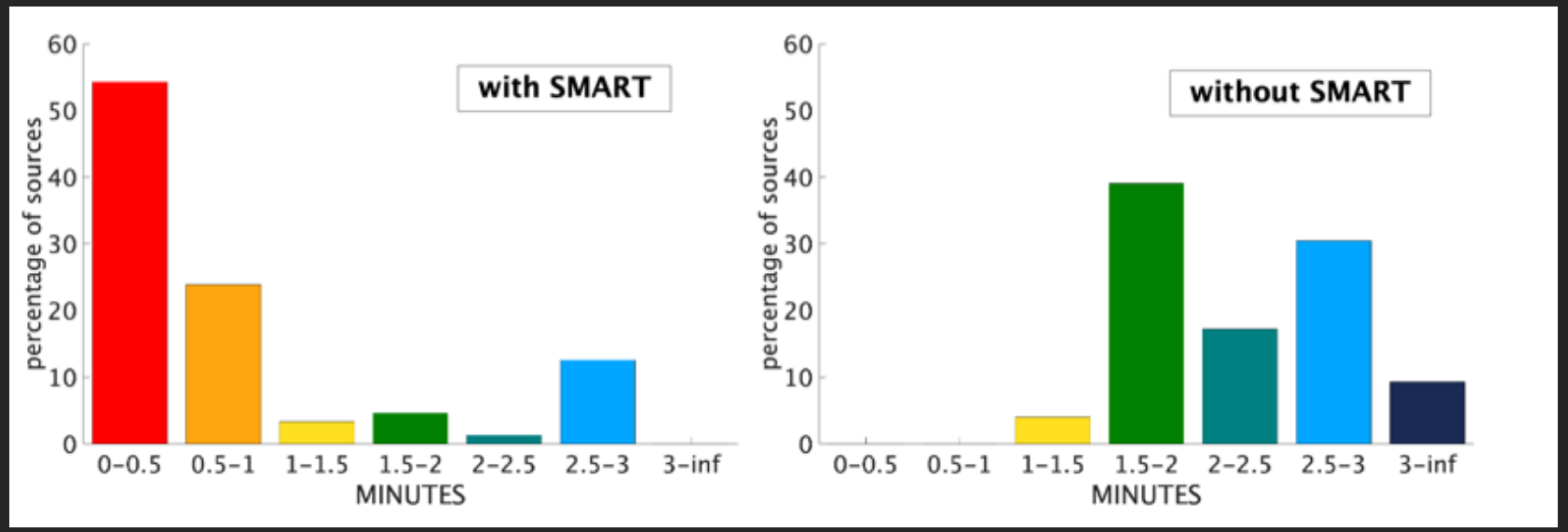
Historical major tsunami events and current DART (deep water) buoy network

SMART Cables: Improving Earthquake Early Warning (EEW)

INDONESIA

- 3X improvement in earthquake alert times with SMART Cables
- Similar results for tsunami wave detection



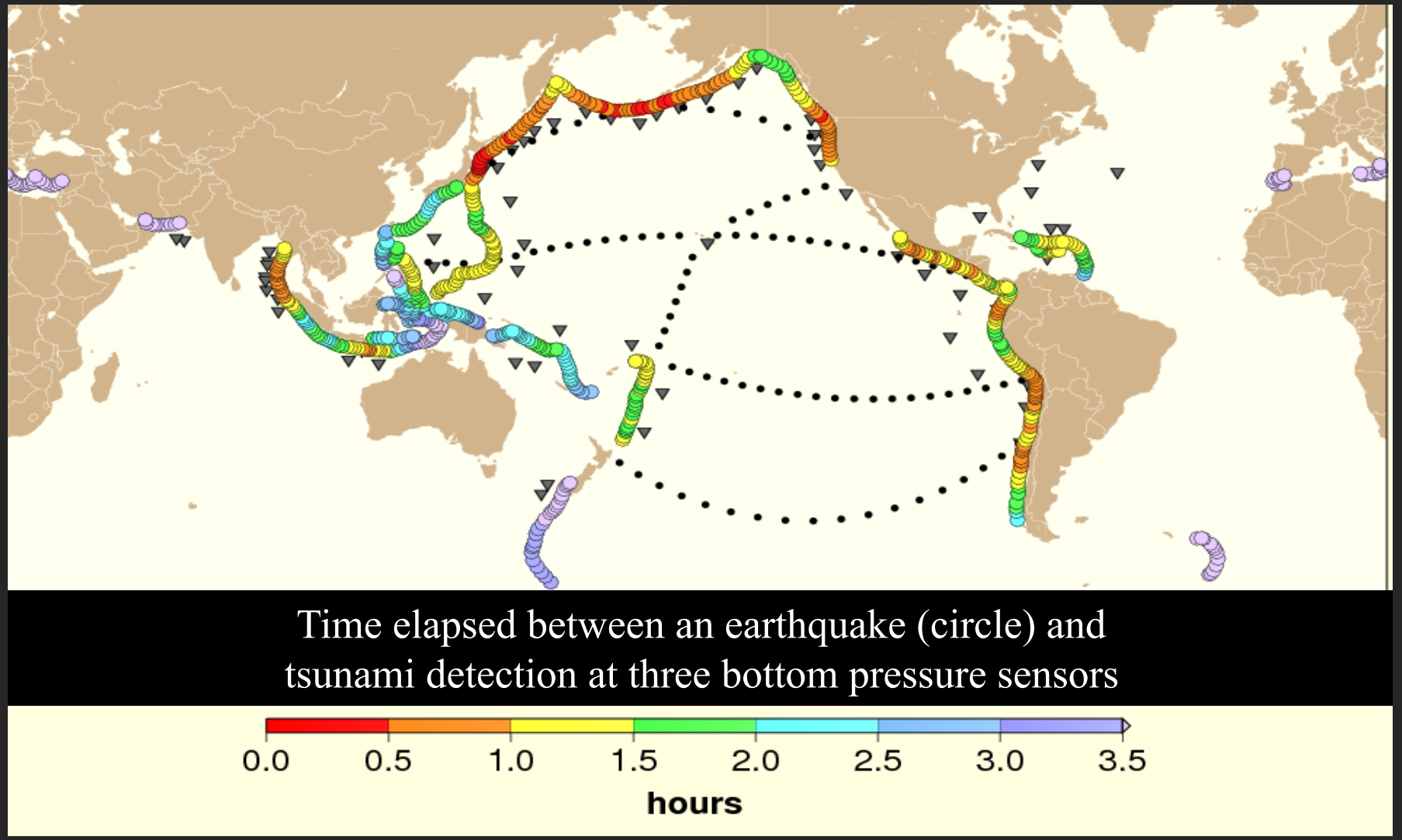


K. Nishizawa, U. Tokyo / NOAA PTWC

SMART Cables: Improving Tsunami Early Warning (TEW)

- Simulation: add SMART repeaters @ 500 km spacing for 5 trans-Pacific cables
- Pressure sensors improve warning time from 2.1 to 1.6 hours (~25%)
- Additional improvement denser SMART spacing

N. Becker, NOAA PTWC (2016)



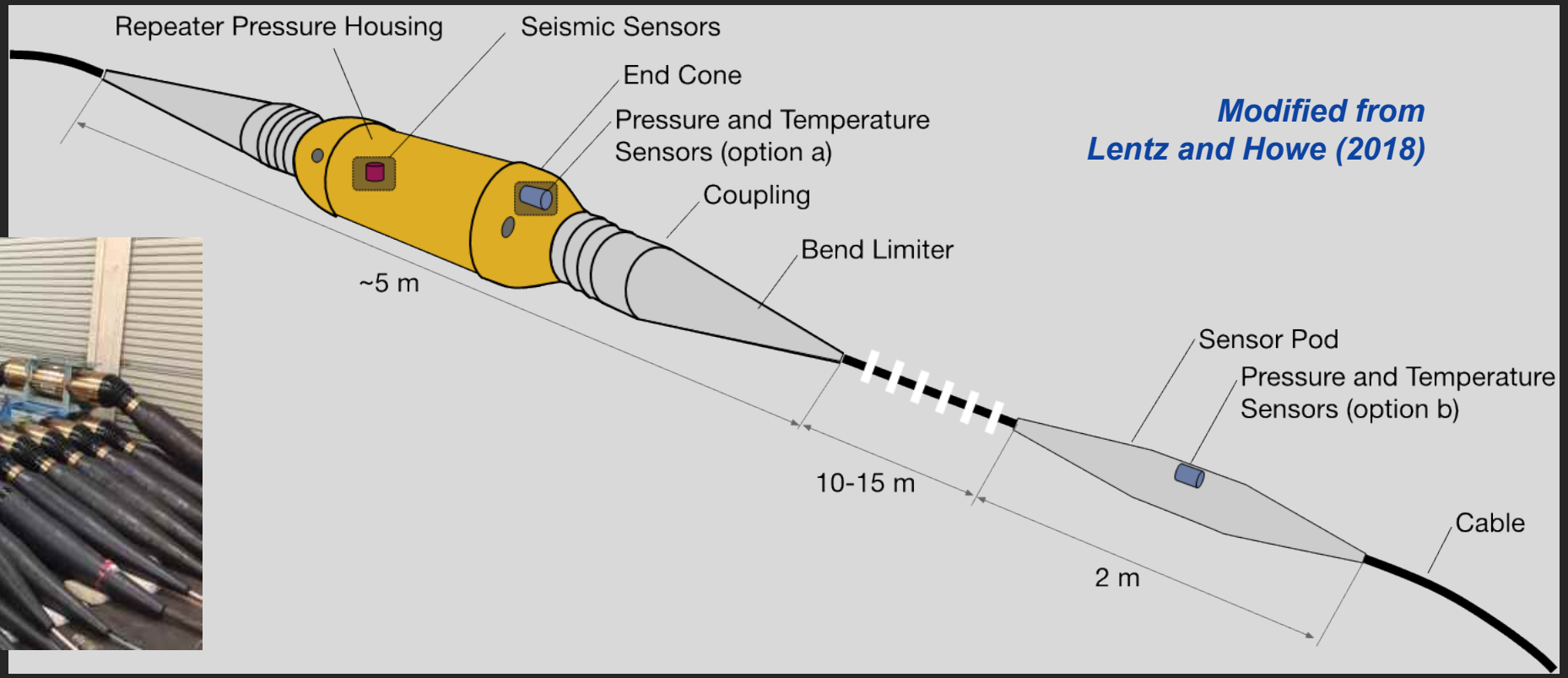
SMART Cables: Potential Customer / User Base

- Government research / monitoring agencies
- Research community
- International agencies / governments

- Commercial submarine fiber cable suppliers
- Commercial submarine fiber cable owners
- Media, Over-The-Tops (OTTs)
  - E.g., Google, Meta, Amazon, Netflix, Hulu

SMART Repeaters: Design Concept

“Keep It Simple…”
(U.S. Navy, 1960)



- Commercial-Off-The-Shelf (COTS) sensors
- Solve basic engineering challenges first
- Start with short-haul, regional systems
- Extend to longer-haul systems once proven

SMART Cables: Technical Challenges

Dependability

- Most repeater systems are several generations along in development

Minimal impact on telecom functions

- Required for adoption by commercial cable vendors

NEC

Sensor accuracy and stability

- No opportunity to calibrate easily or precisely

Compatibility of deployment methods

- Variations in ships, mechanisms, etc.

SubCom

SDS SMART Repeater Prototype

3-Axis Seismic Sensor

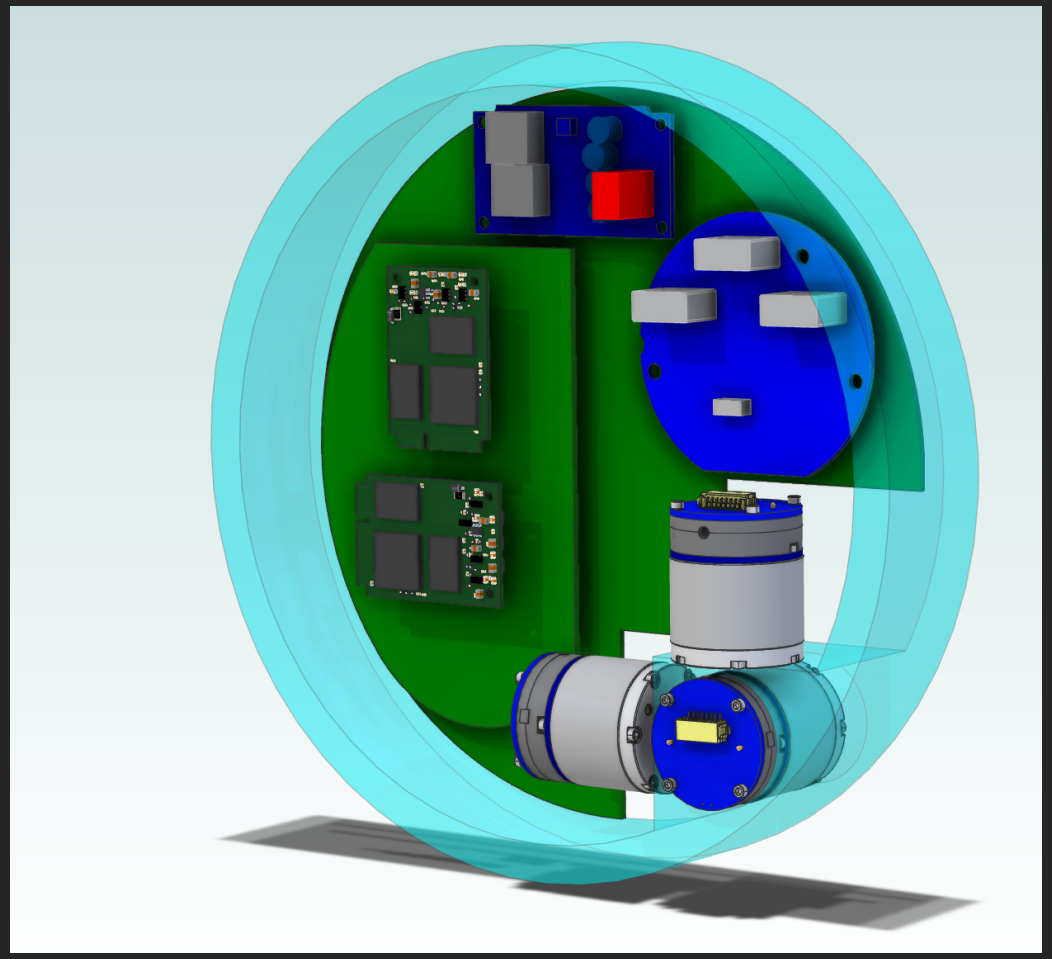
- High performance switchable accelerometer / seismometer
- **Silicon Audio 2X3**
- 0.02 to 500 Hz bandwidth
- 183 dB dynamic range
- Best in class noise performance
- 30 mm diameter x 35 mm length (each sensing element)

Temperature Sensor

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

Pressure Sensor

- 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



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

SDS SMART Hardware

Data Processing Unit

- Subsea Data Systems SMART system

Temperature Sensor

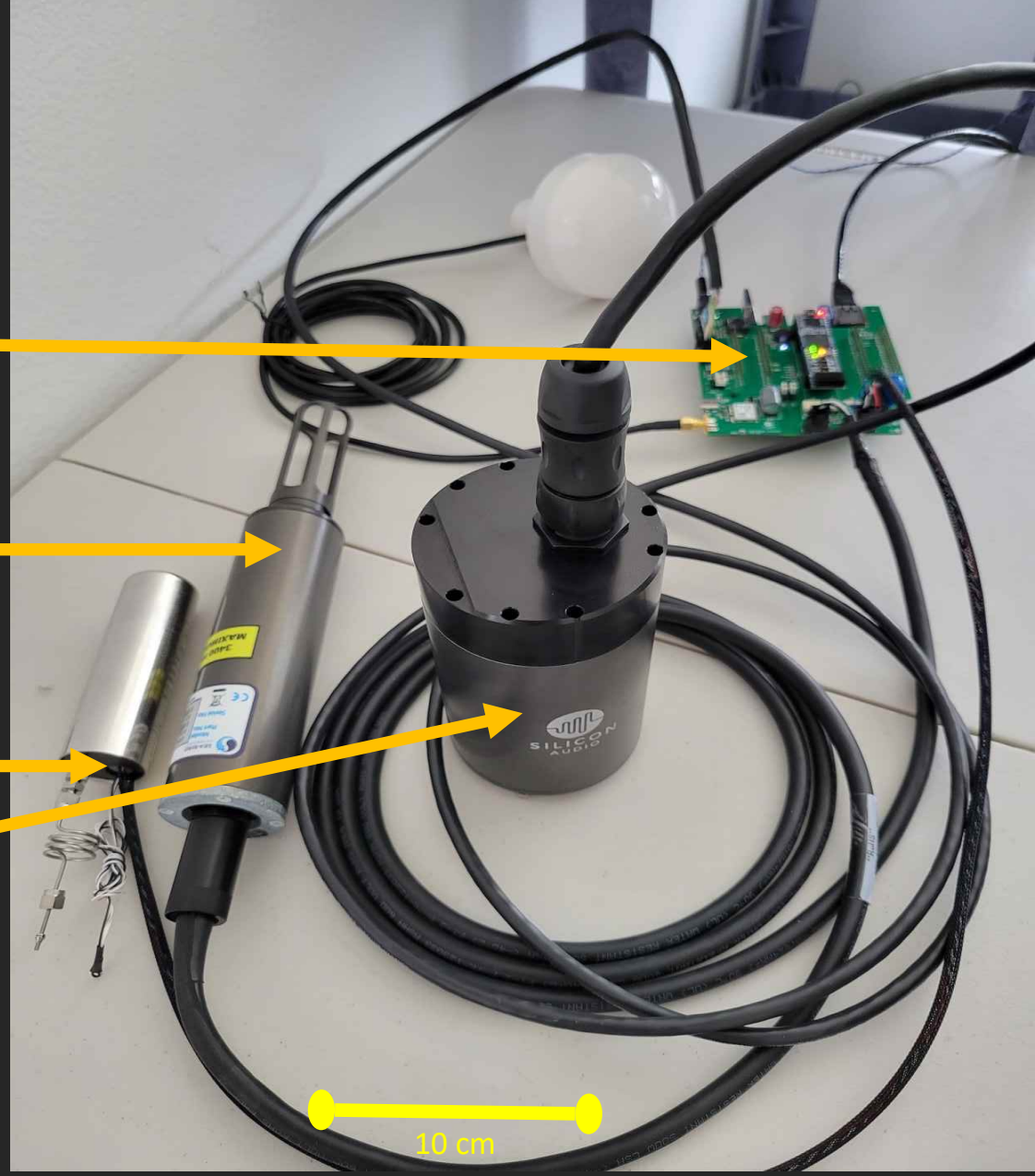
- Seabird Glass Coated Thermistor (GCT)

Pressure Sensor

- Paroscientific Absolute Pressure Gauge (APG)

3-Axis Seismic Sensor

- Silicon Audio high performance switchable accelerometer / seismometer



2.7 Watts total power consumption

SDS SMART
Data Processing Unit

Ethernet Interface

FPGA

- COTS Daughter board
- Pressure and Temperature sensor frequency counts

Seismic Sensor Input

- Digitizers are in sensor housing

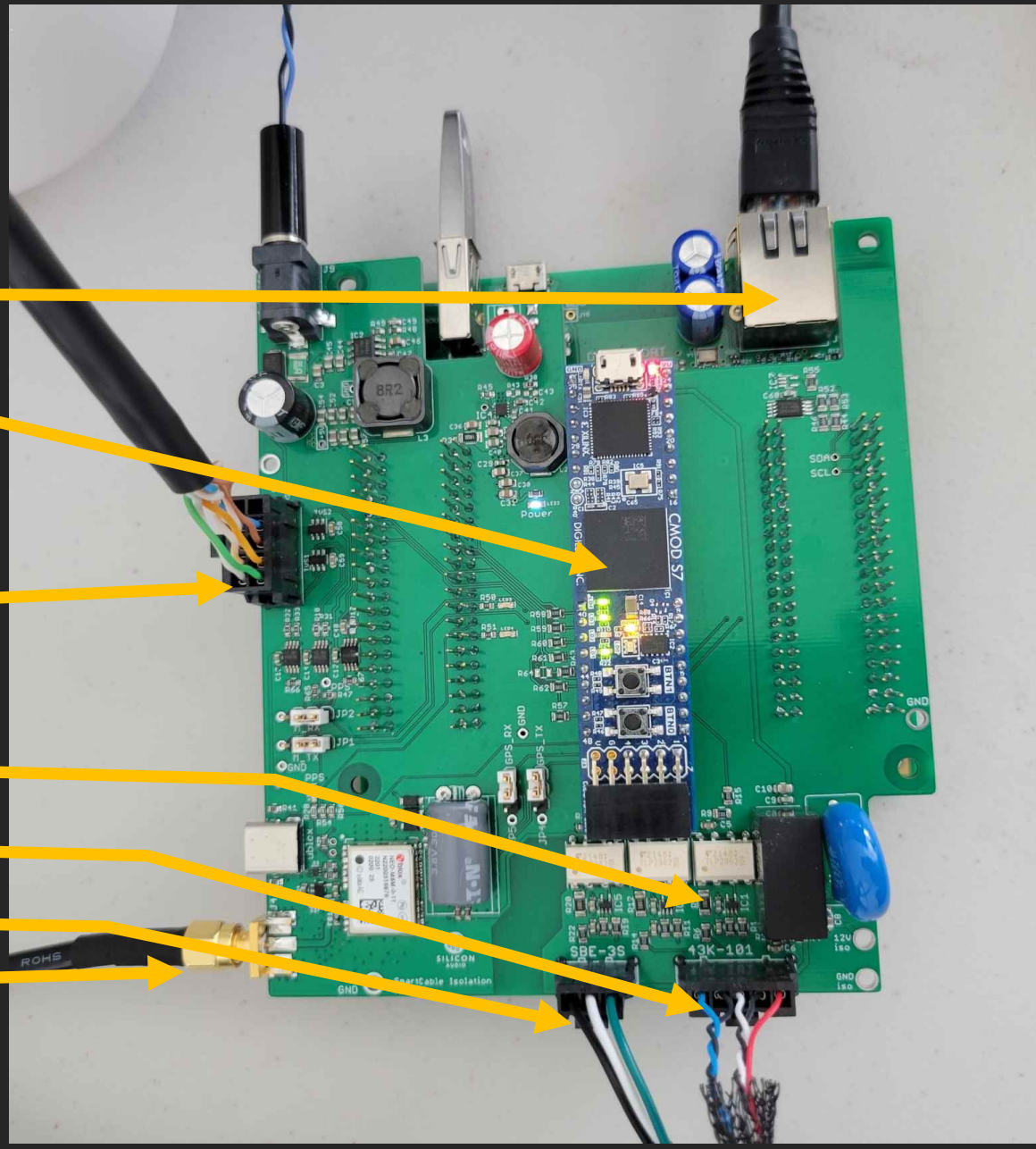
External Sensor Electrical Isolation

Pressure Sensor Input

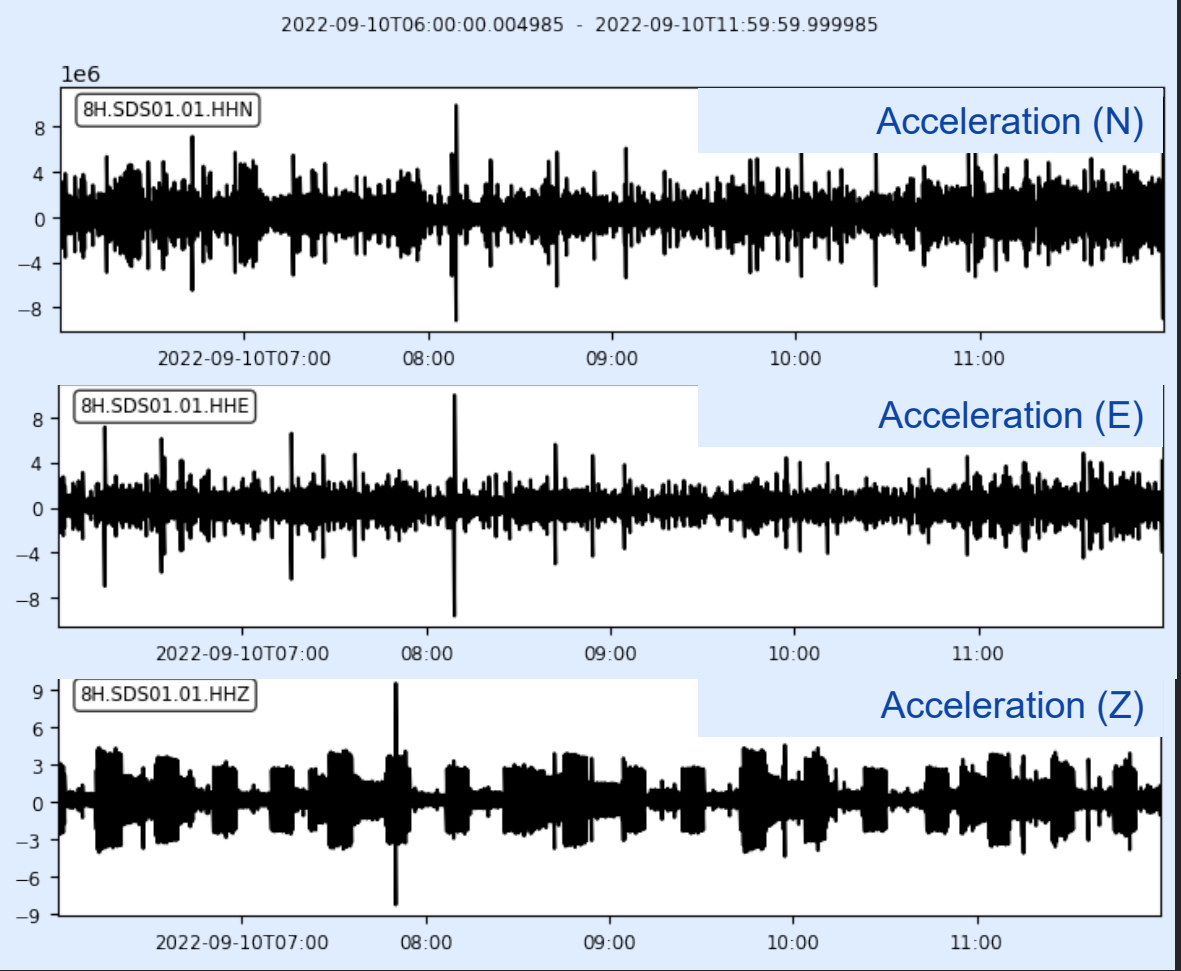
Temperature Sensor Input

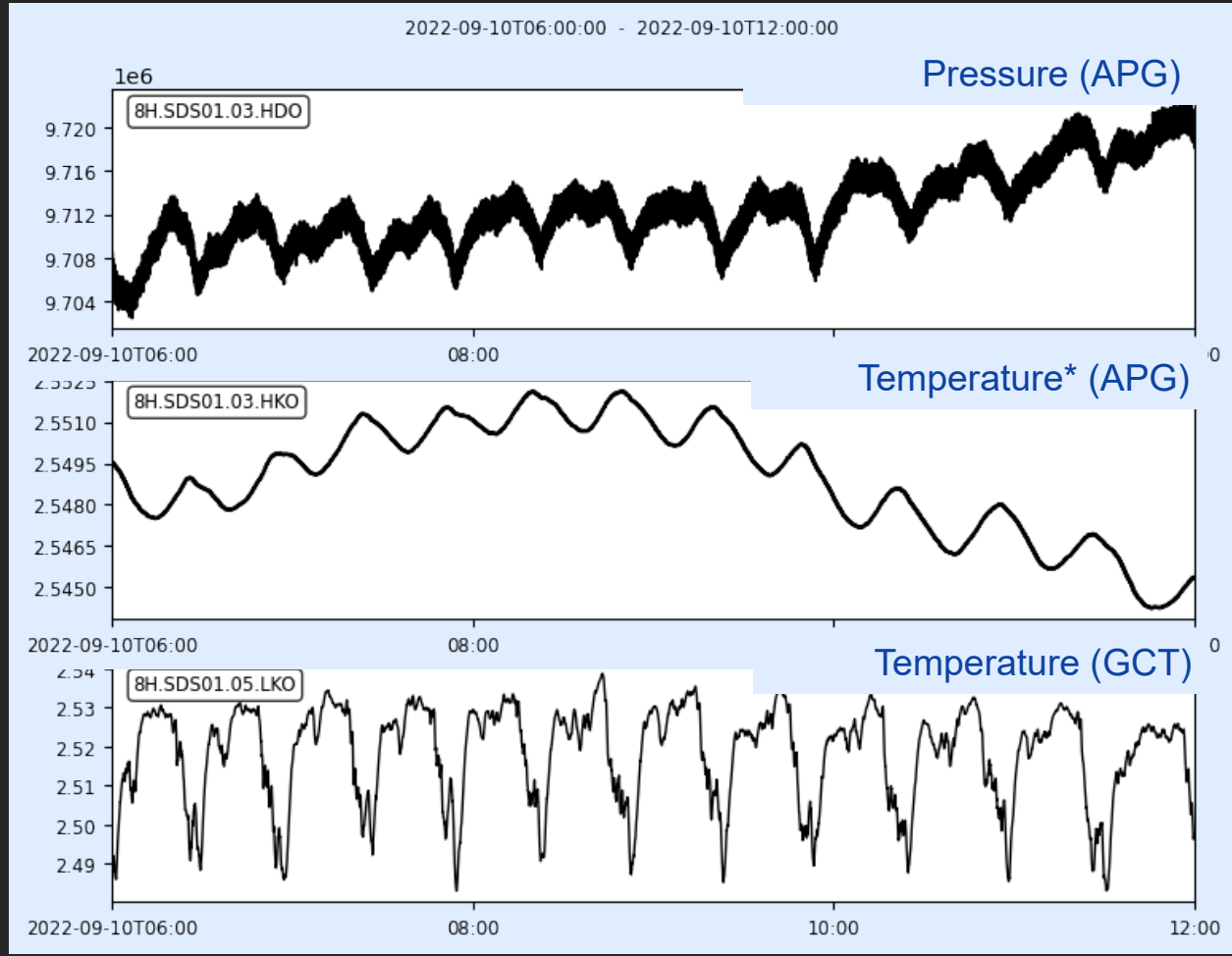
Timing (PPS) Input

- Using GPS for now;
  will migrate to PTP in Phase II



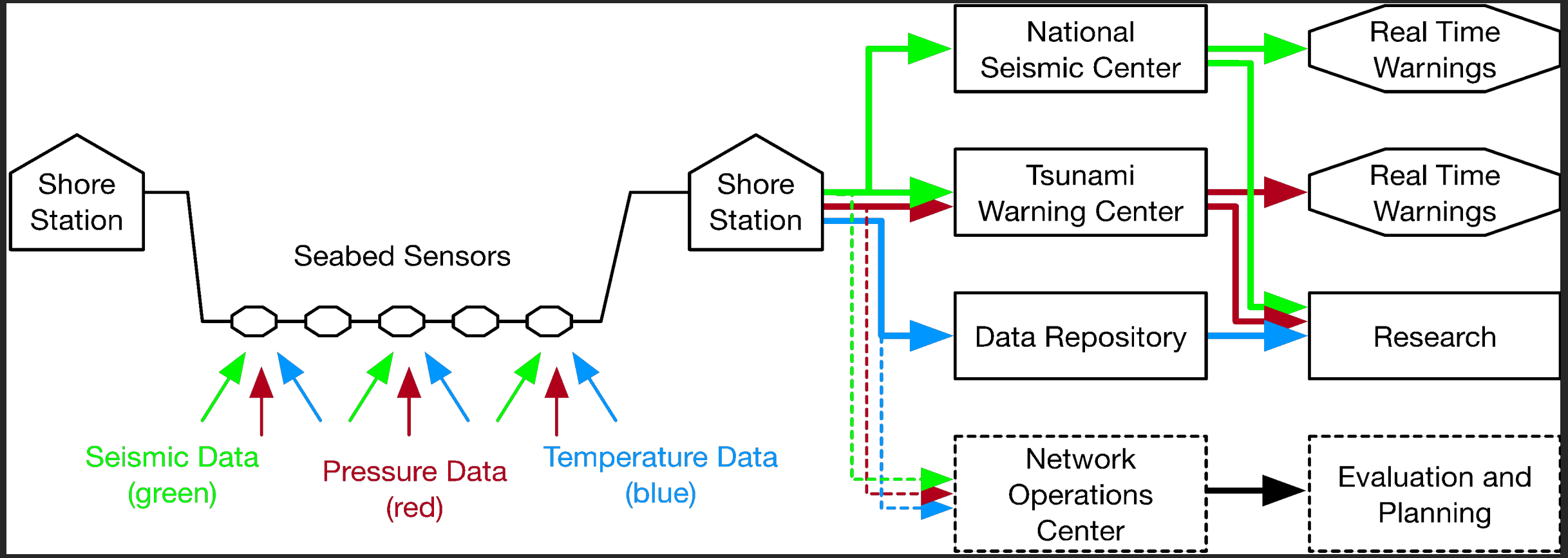
Sample SMART Prototype Data





APG = Absolute Pressure Gauge (Paros Scientific)
GCT = Glass Coated Thermistor (Sea-Bird)
* APG temperature used to correct raw APG pressure signal

SMART Cable Data Flow: Overview



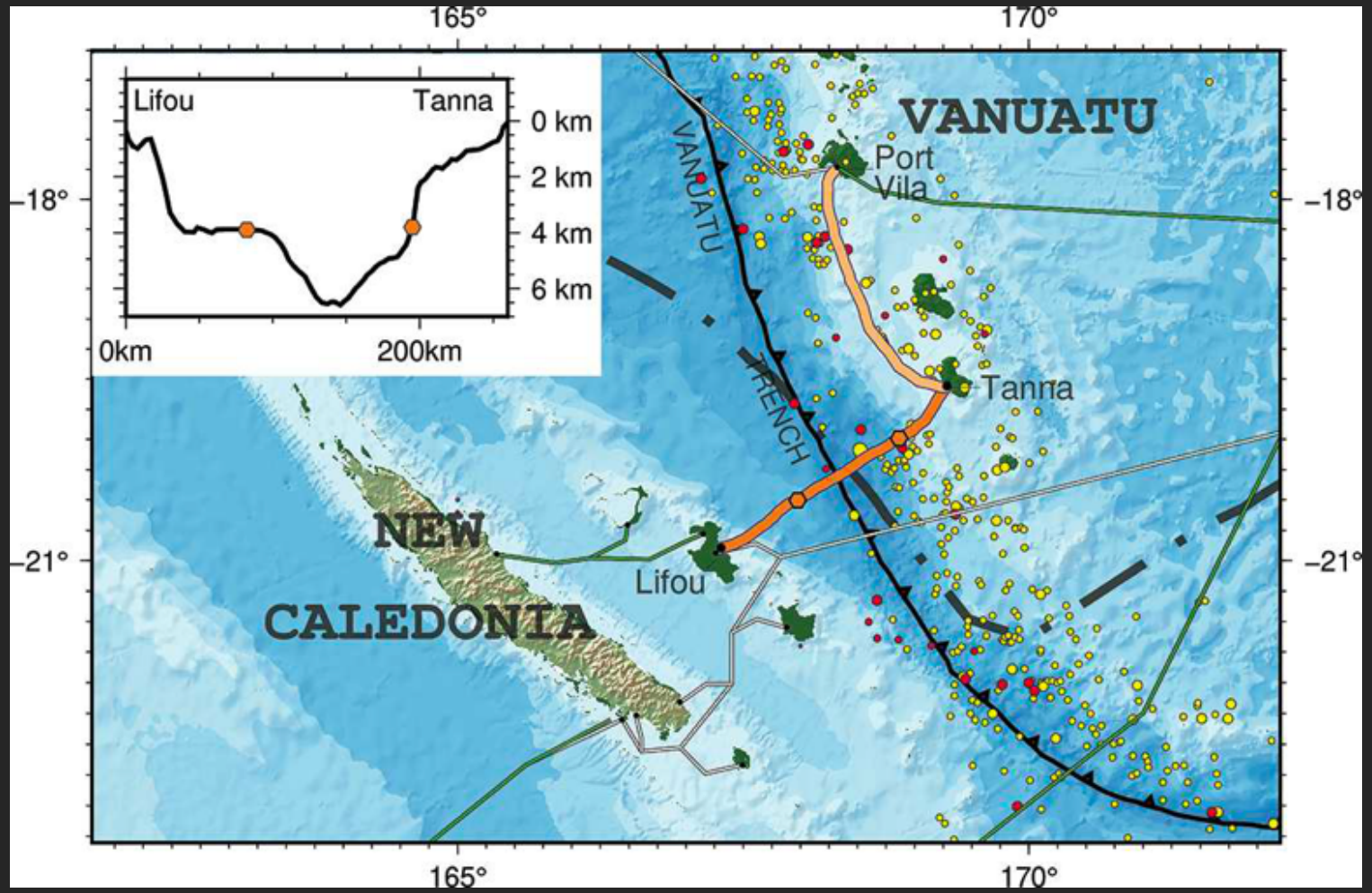
Example United States Government Customers/Agencies

- USGS National Earthquake Center https://earthquake.usgs.gov (earthquake monitoring)
- NOAA NWS Tsunami Warning Centers https://www.tsunami.gov (tsunami monitoring)
- NSF SAGE Repository https://www.earthscope.edu (scientific research)
- NOAA Pacific Marine Environmental Lab https://www.pmel.noaa.gov (scientific research)

SMART Cable System: New Caledonia-Vanuatu

- **Connects New Caledonia and Vanuatu**
- Essential improvements in earthquake and tsunami monitoring/warning
- 4 SMART repeaters

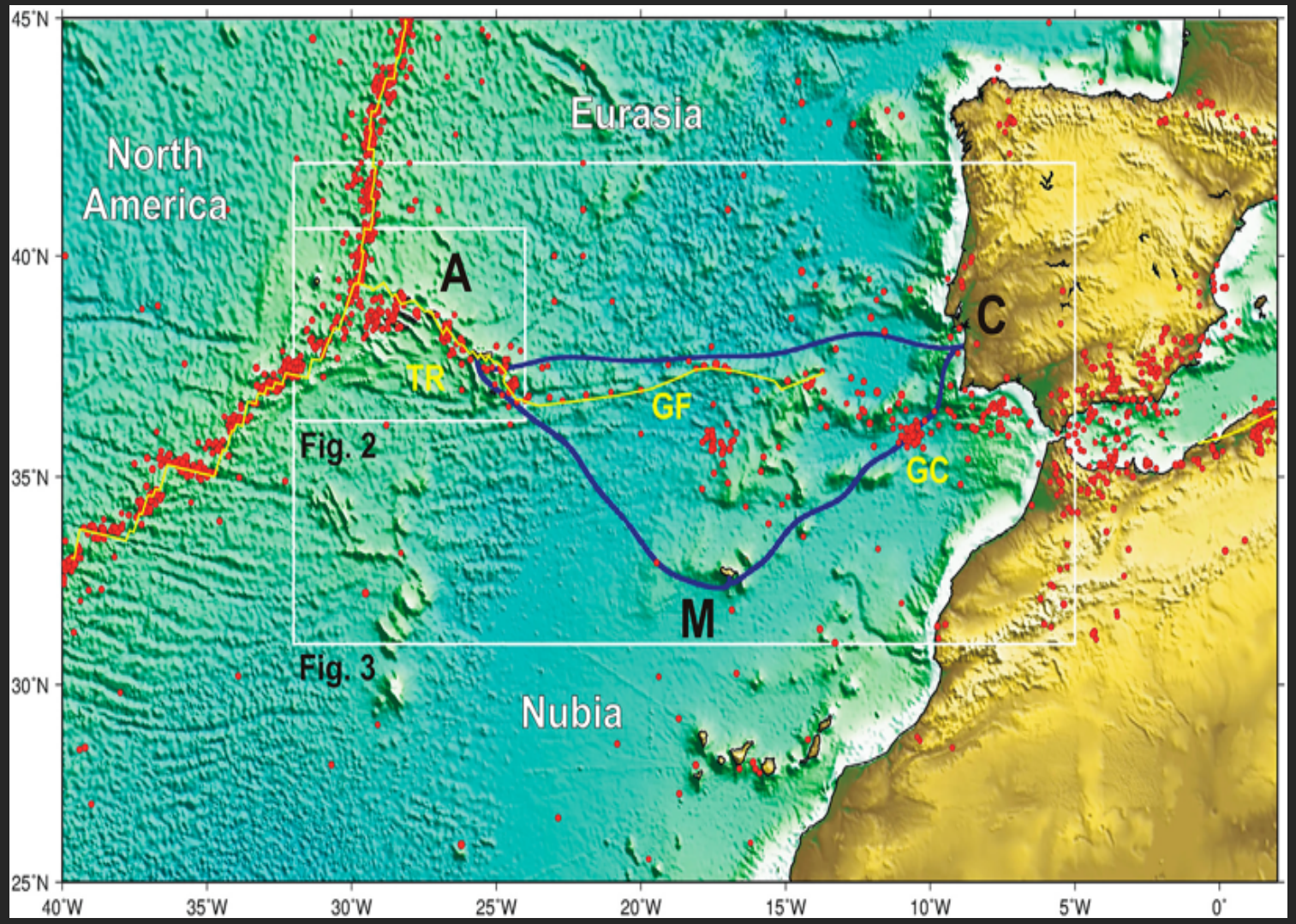
- **Bilateral MOU: 2021**
- **Funding: 2023**
- **Ready for Service: 2025**



SMART Cable System: CAM-2 (Portugal)

- **Portugal – Azores – Madeira**
- Domestic system with international connections
- 1755 Lisbon earthquake, tsunami, fires (30,000 - 50,000 deaths)
- 3,700 km, €154M
- ~50 SMART repeaters

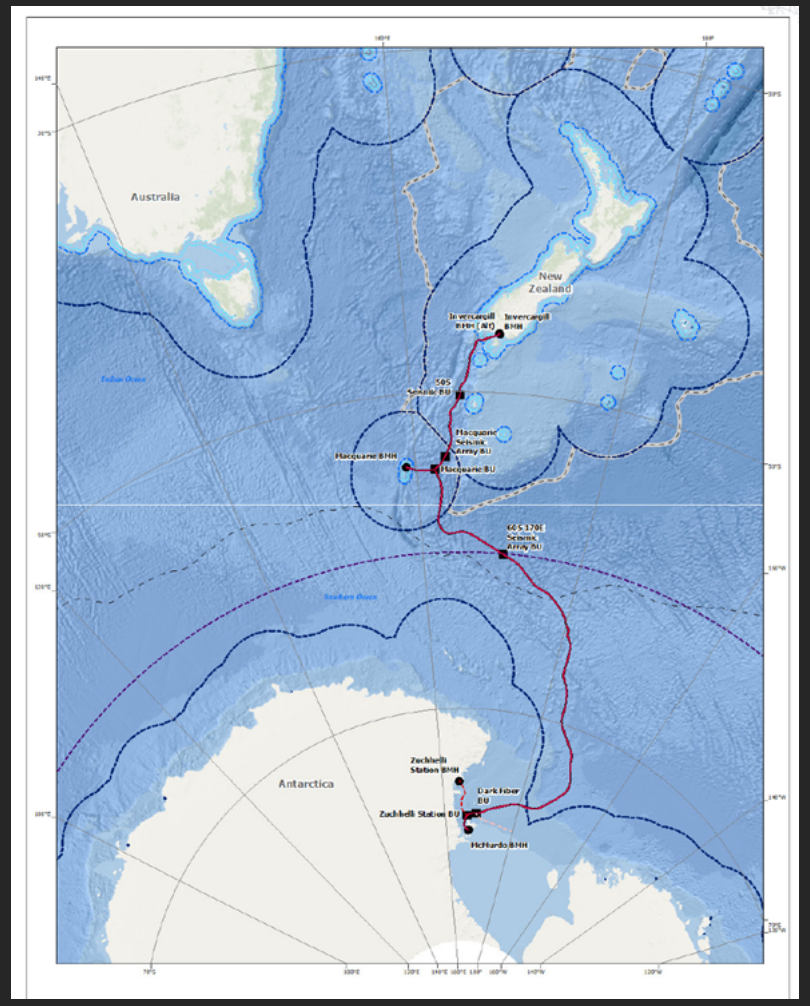
- **Request for Proposals: 2023**
- **Ready for Service: 2026**



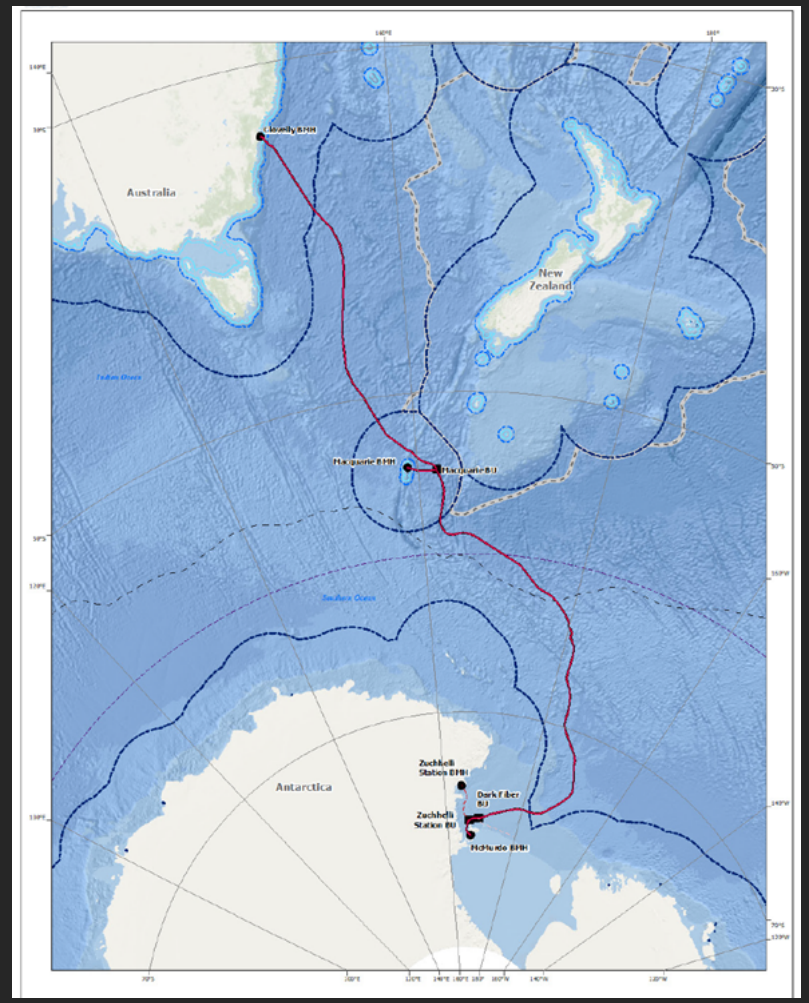
SMART Cable System: McMurdo (Antarctica)

- **McMurdo Station – Australia / New Zealand**
- Entities leading:
  - US National Science Foundation
  - US National Academy of Science
  - Chile
- Hybrid science-telecom cable
- Increase bandwidth to McMurdo Station staff
- Enable more types of real-time science monitoring
- ~50-65 SMART repeaters
- ~4-6 Powered Branch Units (PBUs)

- **Science Workshop: 2021**
- **Desktop Study (DTS): 2022**
- **Report / next steps pending**



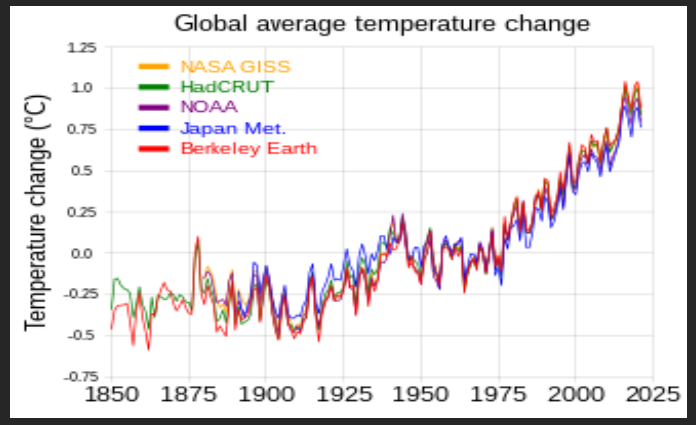
Antarctica – New Zealand Route



Antarctica – Australia Route

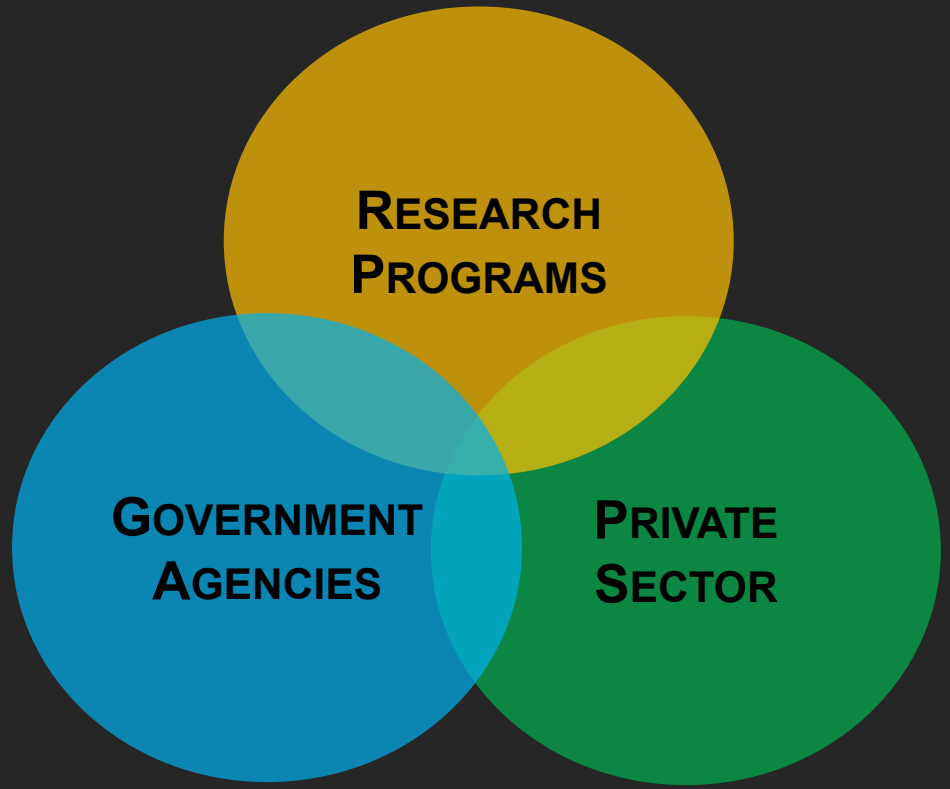
Innovative Technologies Should Benefit Science AND Society

Reduce Vulnerability ⟷ **Improve Utility** ⟷ **Increase Resiliency**



Global Climate Change Monitoring

Earthquake Early Warning



Submarine Fiber Cable Security

Tsunami Early Warning

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