The JTF SMART Subsea Cable Initiative
***S**cience **M**onitoring **A**nd **R**eliable **T**elecommunications*
Climate Monitoring and Disaster Mitigation

Report
10th Workshop on SMART Cables
23 – 24 January 2025

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Executive Summary: 10th Workshop on SMART Cables

The 10th Workshop on SMART Cables (January 23–24, 2025) brought together representatives from UN agencies, telecommunications industry, and scientific communities to discuss significant progress in integrating environmental sensors into submarine telecommunications cables for climate monitoring and disaster risk reduction.

Key Achievements and Current Projects

- **InSEA Wet Demonstration Project**: Successfully deployed a 21 km SMART cable in the Western Ionian Sea (Italy) in December 2023, featuring accelerometers, seismometers, temperature and pressure sensors; now providing real-time data.
- **Atlantic CAM Project**: Plans for a 4,000 km system connecting mainland Portugal to the Azores and Madeira Islands with ~20 SMART nodes containing four-sensor packages and dedicated Distributed Acoustic Sensing (DAS) fiber. Manufacturing beginning soon with deployment targeted for late 2026/early 2027.
- **Tamtam Project**: A 450 km system between New Caledonia and Vanuatu with four sensor nodes, scheduled for late 2026 deployment, funded by the French Government's France 2030 program (€18 million).

Regional Developments

- **Northern Hemisphere Systems**: Seven major SMART cable systems in development, including Polar Connect (Arctic), Far North Fiber (Northwest Passage), PISCES (Ireland-EU), Tusass (Greenland), IOMEA (Northern Europe), MISTS (Mediterranean), and Azores Interisland system.
- **Southern Hemisphere Systems**: Chilean Antarctic Cable Initiative connecting continental Chile with the Antarctic Peninsula, and the US NSF Antarctic Cable project establishing terabit-scale communications to McMurdo Station.

Scientific Applications and Early Warning Systems

- SMART cables will significantly enhance ocean observation by providing continuous deep ocean measurements for climate monitoring, seismic detection, and tsunami warning systems.
- Implementation will improve earthquake detection capabilities, reduce false tsunami alarms, and enhance scientific understanding of ocean processes, including the Atlantic Meridional Overturning Circulation (AMOC).

Governance, Finance, and Technology

- Data governance frameworks are being developed to address challenges of international data sharing while maintaining open access principles.
- Financing opportunities are expanding through ESG frameworks and EU digital infrastructure programs, with the EU committing substantial funding to SMART cable initiatives.
- Technical developments are focused on balancing innovation with reliability, in particular, the challenge of achieving 25-year operational lifespans for sensor packages.

Roadmap for Implementation

The JTF outlined a three-phase implementation strategy.

1. **Short-term (2025–2026)**: Develop technical standards, metadata schemas, and data exchange protocols; document lessons from the InSEA Wet Demo.
2. **Medium-term (2026–2027)**: Build capacity through training programs, research sensor longevity, and strengthen partnerships with telecommunications industry and early warning centers.
3. **Long-term (2027+)**: Expand network coverage, focusing on the Southern Hemisphere, secure long-term funding, establish maintenance protocols, and develop assessment frameworks.

The workshop demonstrated significant momentum in SMART cable development, with multiple projects moving from concept to implementation. Success will depend on continued collaboration between telecommunications, scientific, and regulatory communities, while maintaining a balance between innovation and reliability.

Day 1 Summary: Panels and Discussions

Opening Remarks

The 10th Workshop on SMART Cables brought together representatives from UN agencies, telecommunications industry, and scientific communities to discuss the integration of sensors into submarine cables for climate monitoring and disaster risk reduction. The two day workshop highlighted significant progress in ongoing telecommunications projects that include SMART capability and addressed challenges in implementation, funding, and governance.

Panel 1: Current SMART Cable Systems Update

Moderated by Juan José Dañobeitia. This panel showcased three major implementations.

The InSEA SMART Wet Demonstration Project, implemented at the EMSO Western Ionian Sea Facility (WIS) in Italy, achieved a significant milestone with a 21 km subsea cable off Catania, Sicily. The system features accelerometers and seismometers within repeater housings, complemented by temperature and pressure sensors positioned 30 m from the main housings. The successful December 2023 deployment is already providing real-time data, validated against existing seafloor observatories.

The deep-sea Atlantic CAM SMART project offshore of Portugal presented plans for a 4,000 km system connecting mainland Portugal to the Azores and Madeira Islands in a ring, featuring ~20 SMART nodes with four sensors (ASN Climate Change [CC] nodes) and dedicated DAS fiber. With site surveys completed, manufacturing is set to begin soon, targeting deployment in late 2026 or early 2027.

The Tamtam SMART project between New Caledonia and Vanuatu, South Pacific, outlined their 450 km system with four CC Nodes, scheduled for late 2026 deployment. With an €18 million budget from the France 2030 program, this project aims to validate the SMART cable concept while serving multiple scientific purposes.

Panel 2: Northern Hemisphere Systems

Moderated by Jose Barros. This panel presented seven SMART cable systems.

- Polar Connect SMART system connecting Northern Europe with Asia through the central Arctic

- Far North Fiber system connecting Northern Europe with Asia through the Canadian Northwest Passage
- Tussas SMART system connecting Greenland with Denmark via the Faroe Islands and Ireland, and to the US and Canada
- PISCES system connecting Ireland with France, Spain, and Portugal
- IOMEA SMART system serving as Northern Europe's west coast backbone
- MISTS SMART system spanning the Mediterranean and Northeast Atlantic
- Azores Interisland SMART domestic system

These projects share a common vision of combining telecommunications infrastructure with scientific monitoring capabilities, targeting completion around 2027–2030. Synergies and collaboration should be promoted.

Panel 3: Southern Hemisphere Systems

Moderated by Nicholas Koopalethes. This panel focused on two major initiatives.

The Chilean Antarctic Cable Initiative aims to connect Southern Chile with the Antarctic Peninsula, addressing critical connectivity needs and monitoring the climatically important Antarctic Circumpolar Current ACC flowing through the Drake Passage. The project faces unique challenges due to rough bathymetry and strong currents in Drake Passage.

The US NSF Antarctic Cable project will establish terabit-scale communications to McMurdo Station, enhancing telecommunications and enabling scientific sensors to provide an ocean observing instrumentation platform for the Southern Ocean and ACC.

Panel 4: Science and Early Warning Systems

Moderated by Bruce Howe. This panel covered multiple scientific applications.

- Ocean state estimation and data assimilation
- AMOC monitoring through the OSNAP program
- Seismology applications demonstrating improved detection capabilities
- Regional early warning systems for the Iberian Peninsula, Vanuatu, and Southern Ocean.

The panel emphasized how SMART cables could revolutionize ocean observation and early warning systems by filling critical monitoring gaps.

Panel 5: Governance and Data Policy

Moderated by Benoit Pirenne. This panel addressed data management challenges across international networks. Key presentations included the following.

- Comprehensive data governance framework
- European perspective on multinational data management
- GOOS network overview
- Station ALOHA case study

The discussion emphasized the importance of standardized metadata schemas and clear data governance frameworks.

Panel 6: Finance, Legal, Regulatory, and Security

Moderated by Jose Barros. This panel explored critical implementation aspects.

- Legal framework and its evolution
- ESG financing opportunities within financial institutions
- EU's digital infrastructure program (DG-Connect CEF-2)

The panel highlighted the growing recognition of SMART cables as vital infrastructure and the increasing alignment with ESG goals.

Panel 7: Technology and Sensors

Moderated by Mikael Mazur. This panel focused on technological advances and implementation challenges.

- ASN's Climate Change Node approach
- Subsea Data Systems technology and sensors
- Guralp's seismometer implementation experiences
- Nanometrics' seismic instrumentation package details
- JTF Sensor Review Working Group findings

The discussion emphasized the balance between innovation and reliability, particularly regarding the 25-year service life requirement.

Day 1 Concluding Remarks

The JTF SMART Cables must adopt a structured approach across three key phases: immediate, medium, and long term.

In the short term (2025–2026), the priority is to lay the groundwork by developing technical standards for sensor integration, performance metrics, and metadata standardization schemas for uniform data collection. This period is crucial to obtain quality-tested information from the InSEA Wet Demo and provide guidance to other ongoing projects like Tamtam in the South Pacific and Atlantic CAM. The JTF must also focus on establishing homogenized data exchange protocols and standard operating procedures for multinational projects.

In the medium term (2026–2027), the focus shifts to capacity building and expanding capabilities. This includes: creating training programs for cable operators; researching sensor longevity and reliability; and addressing technical challenges such as reducing ocean current noise in seismic measurements. The Task Force should also strengthen collaborations with the telecommunications industry, early warning centers, and marine science and technology researchers, while exploring the development of new sensor technologies and energy optimization strategies.

In the long term (2027 and beyond), the Task Force should focus on expanding the user network and ensuring its sustainability. This involves identifying priority regions for future deployments, with special attention to the Southern Hemisphere, and developing a global SMART cable network roadmap. Securing long-term funding, establishing maintenance protocols, and implementing technology upgrades cycles will be essential. Assessment frameworks will be crucial for monitoring system performance, safety, assessing climate science contributions, oceanographic, geophysics and other emerging disciplines, and measuring socio-economic benefits.

Throughout all phases, strong coordination among stakeholders and effective communication will be key to success. By balancing innovation with reliability, and ensuring governance and communication frameworks are in place, the JTF can drive the continued development of SMART cable systems globally.

Day 1 Detail

Opening Remarks

Welcoming comments and charge to the participants were provided by Seizo Onoe, Director of the Telecommunication Standardization Bureau of the ITU; Bilel Jamoussi, Chief of the Study Groups Department, TSB; Bernardo Aliaga, Lead, UNESCO-IOC Tsunami

Programme; and Bruce Howe and Mike Constable, Chair and Vice Chair of JTF SMART Cables.

Speakers emphasized the transformative potential of SMART cables, highlighting their cost-effectiveness and complementary environmental benefits compared to traditional observing systems. The focus was on their role in climate monitoring, disaster risk reduction, and advancing Sustainable Development Goals.

Panel 1: Current SMART Cable Systems Update

Panel moderated by Juanjo Danobeitia.

The InSEA (Initiatives in Supporting the consolidation and enhancement of the EMSO research infrastructure consortium (ERIC) and related Activities) Wet Demonstration Project in the Western Ionian Sea, Italy was presented by Dr. Giuditta Marinaro from INGV. In December 2023, a 21 km SMART cable was successfully deployed, featuring a sensor arrangement with accelerometers and seismometers from Guralp installed inside repeater housings along with power, communication, and timing boards, while temperature and pressure sensors were positioned 30 m away from the housings. The deployment process was documented through vessel photography. Particular attention was paid to the precise positioning of the sensor modules by means of a ROV (Remotely Operated Vehicle) and their subsequent operation, which provided real-time data. The project team validated the experimental setup from nearby seafloor observatories. Notably, all collected data is freely available on their website*(http://www.moist.it/sites/western_ionian_sea/2/INSEASC)*, with the only requirement being proper citation using the provided DOI when the data is used.

The Atlantic CAM project represents a major advancement in SMART cable technology, with plans to deploy the 4,000-km cable system connecting Mainland Portugal to the Azores and Madeira Islands in a ring. Alberto Passos of IP Telecom, the implementing organization, presented the project. The project features ~20 SMART ASN CC nodes equipped with an enhanced four-sensor package (accelerometer, seismometer, A-0-A pressure sensor, and temperature sensor) and dedicated DAS fiber, with a strategic concentration of six nodes near the seismically active Gorringe Seamount. Starting from Carcavelos near Lisbon and extending to the Azores archipelago, the cable system will provide crucial monitoring capabilities, particularly in the southeast region of Portugal where the historic 1755 earthquake and tsunami occurred. With site surveys completed and manufacturing set to begin in six months, the project is on track for deployment in late 2026 or early 2027. The initiative also encompasses plans for a complementary 1,000-km system connecting seven of the islands in the Azores archipelago, potentially incorporating similar SMART technology (see below), while developing comprehensive regulations for data flow and security measures in response to recent concerns about cable vulnerabilities.

The Tamtam project between New Caledonia and Vanuatu, Southwest Pacific Ocean, was presented by Martin Patriat, project manager at IFREMER. This significant SMART cable project is being developed to cross one of the world's most active subduction zones, the Vanuatu Trench, representing one of the first operational deployments of this technology. The 450-km cable system, scheduled for deployment in late 2026, will feature four CC Nodes equipped with accelerometers, seismometers, pressure sensors (with in situ A-0-A calibration), and temperature sensors, along with dedicated optical fibers for DAS. It will be implemented by ASN with a budget of €18 million from the France 2030 program. The project aims to validate the SMART cable concept while serving multiple purposes: tsunami and earthquake monitoring; early warning system integration; and scientific research in subduction zone dynamics, physical oceanography, and climate change. The infrastructure includes a land-based data center and research funding for system validation, with the telecommunication cable agreement pending but scientific funding already secured.

Panel 2: Northern Hemisphere Systems

This panel was moderated by Jose Barros and describe seven groundbreaking SMART cable systems, which represent the next generation of submarine telecommunications infrastructure. Polar Connect SMART system crosses the central Arctic with the shortest path between Europe (Norway) and Asia (Japan). It is complemented by Far North Fiber, which also connects Europe to Asia but via the Canadian Northwest Passage. PISCES connects Ireland with EU partners through a diverse route along Europe's western seaboard with plans for DAS units and scientific monitoring capabilities. Tusass SMART system connects Greenland with multiple international points. The IOMEA SMART system serves as Northwest Europe's high-capacity backbone. The MISTS SMART system spans the Mediterranean from the Canary Islands to Cyprus and the Azores Interisland SMART system will modernize regional connectivity. While each system addresses unique regional needs and challenges—from ice-breaking requirements in the Arctic to seismic monitoring in the Mediterranean—they all share a common vision of combining telecommunications infrastructure with scientific monitoring capabilities. Most projects estimate completion around 2027–2028 and all emphasize the integration of various sensors and monitoring technologies for environmental—climate and ocean, and seismic—data collection. This new approach to submarine cable development highlights an important shift in the industry. Traditional telecommunications infrastructure is being reimagined to serve both connectivity and scientific research needs, supported through various funding models and international collaborations, with support from European Union CEF-Digital programs calls (1-2) funding €278 million for public benefit research aspects.

The Polar Connect System is an ambitious project, led by NORDUnet. The project is focused on the central Arctic, with CEF funding contribution of €5.3 million, representing a crucial component of pan-Arctic connectivity. Unique challenges include the need for specialized ice-breaking capabilities, with project timelines heavily dependent on the completion of a new Swedish icebreaker scheduled for 2028. The system's route planning benefited from existing survey data and will be further refined through an UN-driven seabed mapping project conducted by Canada and Sweden over the next three summers. After analyzing four possible routes, the project identified an optimal path that addresses the challenging crossing of the ridges (Lomonosov Ridge , Alpha Ridge, and Gakkel Ridge) between European and American tectonic plates. The system's particular significance lies in its achievement of the shortest possible route, and telecommunication latency, to Japan. The system's development timeline extends into 2027–2028, incorporating extensive scientific workshops to determine sensor deployment priorities, and involves comprehensive planning for commercial viability, financing, and technical implementation.

The Far North Fiber system, developed by Far North Fiber, a partnership between Far North Digital, Cinia, Arteria Networks, and ASN, represents an ambitious 14,000-km cable project stretching from Japan to Europe through the Northwest Passage/Canadian Archipelago. The system will incorporate approximately 150 repeaters and about 60 ASN Climate Change (CC) nodes. The project takes a unique route through the Northwest Pacific: Bering, Chukchi, and Beaufort basins; Northwest Passage, Baffin Bay, and the Labrador Sea; and around to Norway. It offers significant opportunities for climate and ocean observations and seismic sensing and tsunami warning, particularly along the Japanese and Aleutian trenches. The marine survey is planned for 2025–2026, with cable installation scheduled for late 2026 through 2028. The project received substantial support from the European Union, with an EU CEF-Digital contribution of €38.3 million, particularly for its public benefit research aspects.

The PISCES system is a joint venture between McMahon Design and Management (MDM, Ireland) and Orange Marine (France). It focuses on providing new and diverse connectivity between Ireland and its EU partners. The system shares a landfall with the Far North Fiber cable system in Galway, Ireland, and extends along the western seaboard of Europe to connect France, Spain and Portugal. While primarily a commercial system, PISCES is incorporating SMART capabilities, complemented by DAS, and is exploring opportunities to expand its scientific monitoring capabilities. The project received three separate grants from the CEF-2 Fund of €48.4 million and is targeting installation in 2027–2028.

The Tusass SMART System represents a pioneering connectivity initiative in Greenland, establishing a comprehensive network that extends beyond domestic connections to link with the US, Canada (Newfoundland), Ireland, Faroe Islands, and Denmark. Together with the Far North Fiber and Polar Connect projects (and perhaps being integrated), this system's strategic positioning promises to deliver exceptionally low latency connections between Northern Europe, North America, and Japan. Tusass aims to develop strong synergies with parallel projects, positioning itself as a key player in Arctic telecommunications infrastructure. Through CEF Digital actions, the EU contributed €20.6 million to the project.

The IOMEA SMART System stands as a high-capacity data backbone project for Northern Europe, spanning 1,620 km from Dumpton Gap in the UK to Christiansand in Norway, with branches along the way. The system features 24 fiber pairs capable of delivering up to one Petabyte of capacity. Its extensive network includes strategic branches to Rotterdam, Leiston, Emshafen, Willemshafen, and Blabburg, with each cable landing station equipped with Power Feeding Equipment (PFE) to ensure network reliability. The project incorporates robust protective measures, including single armor cable with double armored sections and complete burial at depths of 1.5–3 m. In contrast to most other SMART cables in mostly deep water, this system runs along the nearshore in shallow (20 m) water. The system plans to integrate subsea sensors for scientific research, potentially dedicating an entire fiber pair for this purpose, with a targeted completion date between early 2027 and 2028.

The MISTS SMART System is a Mediterranean telecommunications initiative, stretching from the Canary Islands to Cyprus. It is currently in a high-level study phase supported by EU funding of € 0.55 million under the CEF-2 program. This system will enhance Mediterranean basin connectivity while incorporating advanced monitoring technologies. The system design integrates four key technologies: CC nodes for multiple environmental parameters; DAS; hydrophones; and wireless sensors. What sets MIST apart is its pioneering approach to system design, giving equal priority to both telecommunications and scientific monitoring capabilities from the project's inception, rather than treating scientific capabilities as an afterthought.

The Azores Interisland SMART System represents a crucial public infrastructure project aimed at modernizing the archipelago's connectivity. This system will replace the existing central-east network that currently connects the seven islands, with the distinction of being fully funded through public investment due to limited commercial viability (i.e., small populations). The new infrastructure will incorporate SMART capabilities throughout its network and feature a combination of repeated and non-repeated segments equipped with copper conductors to support sensor deployment. Scheduled for completion in 2028, this system exemplifies the growing trend of incorporating comprehensive ocean monitoring capabilities into essential telecommunications infrastructure, promising to deliver both improved connectivity and valuable scientific data collection capabilities across the Azores region.

Panel 3: Southern Hemisphere Systems

The panel was moderated by Nicholas Koopalethes. The presentations underscore the unique challenges and opportunities in developing submarine cable infrastructure in the Southern Ocean region, with a strong emphasis on combining telecommunications needs with scientific research capabilities. These initiatives represent significant steps toward filling a major gap in global submarine cable coverage while advancing our understanding of this crucial oceanic region.

The Chilean Antarctic Cable Initiative, presented by Captain Zuñiga from the Chilean Navy Hydrographic and Oceanographic Service, highlights the critical need for improved connectivity and monitoring in the Southern Ocean, for climate and ocean monitoring as well as tsunami threat detection. The project aims to connect continental Chile with the Antarctic Peninsula at King George Island. Currently, there are significant challenges with data delays and gaps in monitoring coverage. A consortium led by Salient was awarded the contract to study the technical, legal, and economic feasibility of the project, with completion expected in the first semester of 2026. The project faces unique challenges due to the Drake Passage's varying depths (from 600–4,000 m), rough bottom, and strong currents. The study includes "design criteria, installation and operation of sensors or devices that make it possible to use the submarine cable system for monitoring the weather, disaster alarms or any other physical variable of scientific interest (SMART Cables)".

The US Antarctic Cable Concept, presented by Patrick Smith from the US National Science Foundation's Office of Polar Programs, outlines an ambitious plan to establish terabit-scale communications to McMurdo Station, connecting either to Australia or New Zealand. The project serves dual purposes: enhancing telecommunications for NSF McMurdo Station (which currently operates on minimal bandwidth despite supporting 900–1,000 people during peak season); and enabling scientific research across the Southern Ocean, in particular, studying the Antarctic Circumpolar Current. The project is in its concept definition phase, having completed a comprehensive desktop study and hosted a major science workshop in 2021. The initiative is currently seeking public input through a Request for Information (RFI, https://new.nsf.gov/geo/opp/ant/antarctic-subsea-cable) covering various aspects including sensor specifications, data management, and operational considerations. The project emphasizes the importance of scientific collaboration and the potential to enhance Antarctic research capabilities through improved connectivity.

Panel 4: Science and Early Warning Systems

The panel was moderated by Bruce Howe. It highlighted how SMART cables could revolutionize continuous ocean observation and early warning systems by: filling critical gaps in current monitoring networks; providing real-time deep ocean observations; improving warning times and accuracy; reducing false alarms; enhancing scientific understanding of ocean processes; and supporting multiple applications from a single multi-purpose infrastructure. This integration of telecommunications and monitoring capabilities represents a significant and complementary advancement in both scientific research and public safety applications.

Patrick Heimbach focused on how SMART cables could enhance global ocean state estimation, addressing current challenges with sparse ocean sampling. He explained that data assimilation combines heterogeneous observations with numerical models, referencing NASA's ECCO Project (Estimating the Circulation and Climate of the Ocean). The presentation demonstrated potential applications for the North Atlantic, particularly the OSNAP array, emphasizing how boundary waves carry information through ocean basins (reflected in the ocean bottom pressure measurements). The potential for using temperature, pressure, and acoustic data for improved constraints was noted.

Yao Fu addressed the Atlantic Meridional Overturning Circulation (AMOC) as being observed by OSNAP (Overturning in the Subpolar North Atlantic Program), detailing current monitoring methods including moorings, satellite altimetry, shipboard measurements, Argo floats, and gliders. The program measures temperature, salinity, velocity, oxygen, and carbon pCO_2. Eight years of data revealed strong variability but no clear trend. Fu proposed using SMART cables along the OSNAP path for real-time monitoring.

For seismology applications, Charlotte Rowe showed how SMART cables could fill ocean data gaps in ocean observing systems, as evidenced by the current global distribution of earthquakes and lack of oceanic seismic stations. Her presentation showed tomographic modeling improvements with SMART cable integration and illustrated enhanced ray path coverage for hypothetical events. A notable example from Cascadia showed how one offshore sensor increased detected earthquakes from 1,100 to 5,000. The presentation included data from the InSEA Wet Demo recording seismic waves and T-phases in the West Ionian Sea, off Catania.

For Regional Early Warning Systems, Portugal's Fernando Carrilho focused on the Northeast Atlantic region, highlighting historical large earthquakes (M8+) and tsunamis (e.g., 1755 Lisbon). He discussed current limitations with land-based monitoring and projected a 10–15 second improvement in earthquake/tsunami warning times with the

Atlantic CAM SMART system, emphasizing the reduction in location uncertainty and thus reducing false alerts.

Also focusing on Regional Early Warning Systems, Vanuatu's John Junior Niroa described their current system of 23 seismic land-stations and six tide gauges, highlighting their recent devastating earthquake experience (M=7.3, 17 December 2024). The current monitoring system does not reach the trench/subduction zone. They use software systems such as Seiscomp5 and collaborate with the Oceania Regional System Network (ORSNET), emphasizing the need for better subduction zone monitoring.

Amy Williamson detailed the challenges with short tsunami travel times to coastlines and current DART tsunami gauge network limitations for the Regional Early Warning Systems-South America trench scenario. She demonstrated how coast-parallel SMART cables could provide positive lead times and showed improvement in azimuthal gap coverage (i.e., epicenter location accuracy) for earthquake location. Her presentation emphasized benefits for both earthquake and tsunami early warning systems, explaining how improved location estimates lead to better magnitude calculations.

Panel 5: Governance and Data Policy

This panel moderated by Benoit Pirenne brought together leading experts in oceanographic data management to address the growing challenges of handling data from SMART cable systems across international networks. The panel explored crucial aspects of data governance frameworks, international collaboration, and strategies for technical implementation. The discussion highlighted both existing solutions and emerging challenges in managing complex, multinational oceanic data systems, with a focus on maintaining accessibility while respecting varying national jurisdictions and security requirements.

Benoit Pirenne opened the discussion by presenting a comprehensive data governance framework for SMART cable systems. He outlined three distinct sensing capabilities: branched nodes with instrument platforms (NEPTUNE-style); SMART sensor packages placed approximately every 100 km; and distributed fiber sensing (DAS and other techniques). Pirenne emphasized that while data should be open and freely available, the complexities of data ownership and sovereignty across different countries necessitate careful consideration of varying data access policies. He proposed technical solutions, including VLANs and encryption, to enable data and sensor segregation, noting that proven solutions exist for managing data distribution between military and academic sectors.

Ingrid Puillat from EMSO ERIC provided valuable insights from the European perspective on managing multinational data systems. Drawing from EMSO ERIC's experience coordinating data across eight countries and 27 institutions, Puillat described their successful implementation of a federated data system. This system integrates regional and national data centers using a central ERDDAP (Environmental Research Division Data Access Program—a web application and data server that lets users access scientific datasets) while following FAIR principles (Findable, Accessible, Interoperable, Reusable). Her presentation highlighted ongoing challenges in data tagging and ownership tracking through multiple organizational levels, offering practical lessons for similar international collaborations.

Kevin O'Brien presented an impressive overview of the GOOS network, which spans 84+ countries and encompasses over 8,400 platforms. His presentation outlined a data implementation strategy firmly rooted in principles of free and open data availability, clear licensing requirements, and proper archiving with identifiers. O'Brien emphasized the importance of supporting federated data endpoints while maintaining a clear distinction between oceanographic and seismic data streams, providing a blueprint for managing large-scale, distributed data networks.

Jim Potemra from the University of Hawaiʻi concluded the presentations with a compelling case study of Station ALOHA monitoring. His presentation demonstrated the critical importance of accurate deep ocean measurements and highlighted significant discrepancies between operational models and in-situ measurements. Potemra made a strong case for standardized data services such as OpenDAP and ERDDAP, emphasizing their role in facilitating scientific integration and data accessibility. His practical examples underscored the real-world implications of data management decisions and the importance of maintaining high data quality standards.

The panel discussions that followed touched on several critical themes, including: the need for standardized metadata schemas for SMART cables; the challenges of integrating data into global telecommunications systems; and regulatory perspectives on data management. Particular attention was paid to the development of DAS data standards and ongoing efforts to establish marine seismology data standards. Throughout the session, participants emphasized the importance of establishing clear data governance frameworks while maintaining accessibility and interoperability across different user communities and national jurisdictions.

Panel 6: Finance, Legal, Regulatory, and Security

Panel 6 was moderated by Jose Barros. It explored critical aspects of implementing SMART cable systems, focusing on legal frameworks, financing opportunities, and regulatory considerations across international jurisdictions. Presentations highlighted both challenges and opportunities in advancing SMART cable development while ensuring proper governance and security measures.

Esteban Rastrepo presented a comprehensive overview of the evolving legal landscape for SMART cables. He emphasized that the current legal regime extends significantly beyond traditional frameworks like the UN Convention on the Law of the Sea (UNCLOS, 1982) and the Convention for Telegraphic Cables (1884), incorporating complex domestic regulations and new international laws. Rastrepo highlighted the growing recognition of cables as vital infrastructure and discussed the implications of recent developments such as the BBNJ treaty (Biodiversity Beyond National Jurisdiction) and the commitment to protect 30% of maritime areas. He noted that while these developments present certain challenges, they also offer opportunities for SMART cables to play a crucial role in environmental monitoring and protection.

Tiago Prado presented an innovative perspective on financing SMART cables through ESG (Environmental, Social, and Governance) frameworks. He outlined how SMART sensors align perfectly with ESG priorities by enabling real-time environmental monitoring and contributing to disaster preparedness. Prado emphasized that private sector banks and multilateral development institutions (e.g., World Bank, ADB, IDB) are increasingly prioritizing green infrastructure projects, creating new funding opportunities for SMART cable initiatives. He identified key challenges, including the need for greater awareness about SMART cable capabilities and importance of mobilizing private sector integration, while stressing the potential for unlocking additional financing through green infrastructure classification.

Georgios Tselentis from the European Commission detailed the EU's substantial commitment to digital infrastructure development through its €2 billion program. He outlined the current funding framework, which includes €500 million allocated for 2021–2023 and a current call for €128 million closing in February. Tselentis highlighted the program's co-funding structure and explained how SMART technology costs are explicitly eligible for European funding. He emphasized recent security recommendations in response to incidents in the Baltic region and outlined the EU's plans to enhance infrastructure protection and repair capacity.

The panel discussions underscored several key conclusions. First, the legal and regulatory landscape for SMART cables continues to evolve, requiring adaptable approaches to compliance and governance. Second, the alignment of SMART cable capabilities with ESG goals presents significant opportunities for funding and development. Third, institutional support, particularly from entities like the EU, demonstrates growing recognition of SMART cables' importance in digital infrastructure. Finally, recent security incidents highlight the need for enhanced protection measures and international cooperation for the maintenance and security of critical submarine infrastructure.

Looking ahead, the sector faces both challenges and opportunities. The need for greater awareness about SMART cables capabilities, improved stakeholder collaboration, and enhanced security measures continues to drive development. Financial institutions increasingly recognize the value of SMART cable projects, particularly when aligned with ESG goals and environmental monitoring capabilities. As political attention to submarine cable infrastructure grows, support mechanisms and regulatory frameworks are likely to expand, emphasizing the importance of coordinated approaches across jurisdictions and stakeholders.

Panel 7: Technology and Sensors

Panel 7, moderated by Mikael Mazur, addressed the future of SMART cable technology with a particular focus on how to incorporate technological advances within the expected 25-year cable system lifetime. The discussion brought together leading manufacturers, sensor developers, and researchers to explore the challenges and opportunities in SMART cable sensor integration.

Emmanuel Danjou from ASN presented their CC Node approach, emphasizing the importance of leveraging proven subsea telecom technology. ASN's solution focuses on measuring climate change parameters and earthquakes, and providing tsunami warnings. Danjou acknowledged that while the current lifetime expectation is around 10 years for sensors, they are working toward the 25-year goal. He highlighted ASN's collaboration with sensor suppliers Nanometrics and RBR, noting that different sensing technologies serve different use cases. Particularly interesting was his discussion of future expansion possibilities through WiFi connectivity (e.g., acoustic modems), potentially enabling sensor placement up to 30–40 km from the cable.

Neil Watkiss brought Guralp's extensive 35-year experience in ocean bottom systems to the discussion. His presentation focused on the practical challenges and achievements in implementing seismometers within repeater housings. Guralp's recent successful demonstration, i.e., InSea Wet Demo, of seismometer functionality in these housings marked a significant milestone. Watkiss emphasized the importance of modular, serviceable components while maintaining proven reliability. He also discussed their work on DAS integration, acknowledging current limitations while highlighting the technology's potential for specific applications like Tamtam projects.

Nanometrics' representative Marián Jusko provided detailed insights into their seismic instrumentation package designed for ASN's CC node. Their system combines strong and weak ground motion detection capabilities, featuring a class A force balance accelerometer with DC to 430 Hz response and a 3-D broadband instrument with kinematic gimbal. This dual-capability approach enables both earthquake early warning and global seismology applications, with demonstrated performance across various ocean depths. The presentation highlighted how their instrumentation package augments the range of detectable events, providing comprehensive seismic monitoring capabilities.

Steve Lentz, Subsea Data Systems, discussed the "Twenty-Five Year Conundrum: Ocean observatory systems allow adding and replacing sensors during the operating life of the infrastructure." This flexibility comes with a significant capital cost and with uncertainty in reliability. They also introduce a new set of operational activities that are very unlike telecoms, which may include periods where the entire system is powered down. Lentz also noted that connectors are not a panacea. Currently, ROVs are needed to support cable ships and plug things in. The original vision for SMART is to have a basic set of sensors in every repeater. As new cables are continually deployed, the technology on the seabed will evolve, just as telecommunications does.

Lastly, while remote sensing of optical fiber strain has potential for mainly seismic purposes, it does not directly measure ground motion, water pressure, or temperature (with milli-Kelvin resolution).

For now, a "plug-and-play" platform deployed on a global scale (albeit very coarsely) could be engineered, but would take time and effort to define, develop, and test—and finance.

Helen Janiszewski from the University of Hawaiʻi presented findings from the JTF Sensor Review Working Group, providing a crucial academic perspective on sensor performance and requirements. She identified three key factors affecting seismic instrumentation performance: water depth (i.e., pressure); instrument design; and coupling to the seafloor. Janiszewski emphasized the importance of thorough metadata documentation for any customizations, as subtle changes can significantly impact data quality. Her presentation also covered pressure sensor considerations for tsunami detection and ocean mass change measurements.

The panel's discussion revealed several key themes about the future of SMART cable technology. A central challenge emerged around the balance between innovation and reliability, considering the target 25-years operational lifetime. Power constraints within the SMART portion of the system were identified as a limitation, as current designs typically dedicate one fiber pair to sensing and operating within a 5–6-watt power envelope per module. The possibility of adding new sensor types, such as pH and nutrient monitors, sparked discussion about future expansion capabilities.

Looking ahead, the panel emphasized the critical importance of maintaining deployment simplicity while accommodating technological advances. The potential for transformative science through integrated measurements was highlighted. A key conclusion was the need to balance innovation with the primary function of telecommunications, ensuring that sensor integration does not compromise cable reliability or performance.

The discussion concluded with a forward-looking perspective on the industry's readiness to advance SMART subsea cable technology while maintaining critical telecommunications functionality. Participants agreed that while significant challenges exist in achieving long-term reliability and future-proofing, the industry has developed robust approaches to sensor integration and is well-positioned for continued innovation. The success of these developments will depend heavily on continued collaboration between industry players, careful attention to power and volume constraints, and maintaining the delicate balance between adding capabilities and ensuring reliable operation.

Day 1: Workshop Conclusions

The JTF SMART Cables must proceed with a carefully structured approach across multiple time horizons. In the immediate term (2025–2026), priorities should focus on establishing foundational elements: developing comprehensive technical standards for sensor integration and performance metrics; creating detailed guidelines for future-proofing sensor systems for 25-years of lifetime; and finalizing metadata schemas for uniform data collection and sharing. It is critical to document lessons learned from the InSEA Wet Demo and provide technical guidance for ongoing implementations like Tamtam and Atlantic CAM, and the systems in planning stages (e.g., the seven in the Northern Hemisphere). Urgent attention must also be given to establishing data sharing protocols across jurisdictions and developing standard best practices and operating procedures for multinational projects.

In the medium term (2026–2027), the focus should be building capacity and expanding capabilities, including: creating robust training programs for cable operators and scientific users; coordinating research on sensor longevity and reliability; and developing solutions for persistent technical challenges such as ocean current noise reduction in seismic measurements. During this phase, the JTF should strengthen partnerships with the telecommunications industry, enhance coordination with early warning centers, and expand academic research partnerships. Particular emphasis should be placed on research of new sensor technologies for future integration and studying energy optimization strategies for expanded sensor capabilities, all while maintaining the delicate balance between innovation and reliable operation.

Looking toward the long term (2027 and beyond), the JTF should focus on network expansion and sustainability. This involves identifying priority regions for future deployments, encouraging increased Southern Hemisphere coverage, completing the trans-Arctic connections, and creating a comprehensive roadmap for a global SMART subsea cable network. Securing long-term funding mechanisms, establishing maintenance and upgrade protocols, and developing strategies for technology refresh cycles will be crucial for sustained operation. The JTF must also implement robust assessment frameworks to monitor system performance, evaluate contributions to climate science, measure the effectiveness of early warning capabilities, and document socio-economic benefits (e.g., key performance indicators, KPIs). Throughout all phases, maintaining strong coordination between stakeholders and ensuring clear communication channels will be essential to successfully advancing SMART cable systems globally.

This multifaceted approach ensures systematic progress while maintaining flexibility to adapt to technological advances and emerging opportunities in the rapidly evolving field of submarine cable systems. The success of these initiatives will depend heavily on the JTF's ability to coordinate effectively across international boundaries and organizational stove pipes while maintaining focus on both technical excellence and practical implementation.

In summary, the JTF should focus on translating the workshop's insights into actionable initiatives while maintaining strong coordination between stakeholders. Success will require careful attention to balancing innovation with reliability, ensuring proper governance frameworks, and maintaining clear communication channels between all parties involved. The JTF's role in coordinating these efforts will be crucial for the continued advancement of SMART cable systems globally.

10th Workshop on SMART Cables
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Day 2 Summary: SMART Cables Workshop Parallel Sessions Science, and SMART Cables Integration into GOOS

Introduction to Parallel Sessions

Bruce Howe introduced two parallel breakout sessions designed to address different aspects of SMART cables implementation. The first session focused on science applications and research opportunities, while the second addressed the integration of SMART cables into the GOOS. The parallel structure was designed to allow focused discussion on both the scientific potential and practical implementation challenges.

The GOOS integration session was structured to address fundamental questions about forming a federation of individual systems, including the Wet Demo, Atlantic CAM, and Tamtam projects, into a cohesive GOOS SMART Cables Network. The session aimed to explore data governance, policy frameworks, and integration with existing UN systems via OceanOPDS, while also addressing crucial aspects of documentation requirements, metadata management, and technical considerations for data flow implementation.

Science Session Details

Session Overview

Moderated by Matthew Goldberg, the science session brought together researchers, industry representatives, and technical experts to explore the scientific applications and potential of SMART cable systems. The discussion emphasized the complementary nature of SMART cables with existing observation systems and the importance of demonstrating their value across multiple scientific disciplines.

Scientific Applications and Opportunities

The session began with a detailed exploration of how SMART cables complement existing observation systems. In the context of oceanography, compared to current technologies like GRACE satellite gravimetry, SMART cables offer distinct advantages in providing high-frequency sampling capabilities, though with different spatial coverage. The increased frequency will improve estimates of essential ocean processes of which the Atlantic Meridional Overturning Circulation (AMOC) is a prime example. The continuous, real-time deep ocean measurements provided by these systems represent a significant advancement, particularly in remote and polar regions where data collection has traditionally been challenging. Moreover, SMART observations will refine representation of the bottom boundary layer, a feature ocean models often struggle to capture accurately.

The discussion then turned to specific scientific applications, examining the potential for ocean bottom pressure monitoring and comprehensive Arctic data collection. Participants explored the capabilities for seismic monitoring and detection thresholds, as well as the systems potential for tsunami detection and early warning. Particular attention was paid to acoustic propagation studies and the role of SMART cables in temperature and climate monitoring.

Technical validation emerged as a crucial topic, with participants examining the analysis of wet demonstrator data and its comparison with traditional ocean bottom seismometer deployments. The discussion included detailed consideration of different sensor types' performance and the importance of noise characterization studies. This technical evaluation provides essential groundwork for understanding the systems' capabilities and limitations.

Collaboration and Future Directions

The session emphasized the importance of engaging with diverse scientific communities. Participants discussed strategies for integrating SMART cable data with existing monitoring networks and fostering connections with academic and research institutions. The relationship between scientific research and hazard monitoring communities was identified as particularly important for maximizing the systems' societal impact.

Industry collaboration emerged as a critical factor for success. Discussions focused on finding the right balance between scientific ambition and commercial practicality, with an emphasis on maintaining deployment simplicity while incorporating proven technologies. Participants acknowledged the importance of considering future sensor integration while ensuring current system reliability.

Publication strategies were discussed at length, with participants identifying various venues for disseminating results. Traditional scientific journals such as JGR, GRL, and BSSA were noted as primary targets, while the importance of industry-focused publications was also emphasized. Additionally, SMART should be advertised at scientific conferences such as AGU, OSM, EGU, and SSA. The group discussed the need for cross-disciplinary outreach to maximize the impact of research findings.

Implementation and Future Considerations

Short-term priorities were established, focusing on the analysis of existing wet demonstrator data and preparation for upcoming Atlantic CAM and Tamtam system data. Participants discussed the development of research proposals and the establishment of robust analysis frameworks. These immediate goals are designed to build a strong foundation for future development.

Long-term goals were outlined, including the integration of new sensor types and the extension of monitoring capabilities. The group emphasized the importance of developing standardized analysis methods and enhancing early warning systems. These objectives are balanced against practical challenges, including the need to maintain data quality and ensure long-term system sustainability.

Conclusions

The science session demonstrated the broad potential of SMART cable data across multiple scientific disciplines while maintaining focus on practical implementation considerations. The discussions revealed strong interest in the complementary nature of these systems to existing observation networks and potential to enable transformative science through integrated measurements.

Moving forward, the success of SMART cable scientific applications will depend on careful documentation and analysis of initial deployments, development of robust data analysis frameworks, and strong collaboration between scientific and industry partners. The session concluded with a clear emphasis on maintaining deployment simplicity while working toward expanded capabilities through careful, systematic development of the technology and its applications.

SMART Cables Integration into GOOS Session Details

Session Overview

The JTF SMART Cables initiative aims to integrate telecommunications cables with environmental sensors into the Global Ocean Observing System (GOOS). This report outlines the dialogue between attendees about key areas of development and integration required to successfully implement the SMART Cables Network of GOOS.

Presentations

The presentations began with Ann Christine Zinkann providing context about GOOS and OCG (Observation Coordination Group), focusing on the integration of SMART Cables. She explained that OCG coordinates a total of 16 networks, including 13 established networks and three emerging networks, with SMART Cables being one of the emerging networks. A significant development occurred in 2024 when SMART Cables was officially adopted as a GOOS OCG emerging network. To progress toward becoming a mature network, several key requirements were outlined, including global-scale deployments, FAIR data implementation, metadata alignment, development of best practices, and a network specification sheet.

The second presentation by Mathieu Belbeoch focused on OceanOPS, which serves as the technical backbone of GOOS. OceanOPS is a sophisticated real-time monitoring system, which provides operators with comprehensive tools for planning and overseeing their operations. Based in Brest, France, at IFREMER, it functions as a WIGOS (WMO Integrated Global Observing System) specialized center for the ocean, as a joint initiative of WMO and UNESCO-IOC. The WIGOS 2021-2025 strategic plan encompasses five major goals, ranging from monitoring GOOS performance to strengthening infrastructure. Notably, OceanOPS is establishing a baseline Service Level Agreement (SLA) with SMART Cables, with full integration pending the commencement of data and metadata flows.

The presentation by Kevin O'Brien, GOOS OCG vice-chair for data and information, delved into the technical aspects of data management. He introduced the OCG Cross Network Data Implementation Strategy, which aims to enhance FAIR (Findable, Accessible, Interoperable, and Reusable) compliance across the network. This strategy focuses on improving metadata discovery, exchange, and accessibility while developing federated, uniform data services for all stakeholders.

Benoit Pirenne gave an overview of specific data governance issues associated with SMART cables, focusing on different sections of a cable in different EEZs as well as in international waters, with consequences for data sovereignty, ownership, and data policy.

Dialogue

Real-Time Systems Integration
The integration of SMART Cables into the global observing system requires sophisticated real-time data analysis capabilities. This involves developing robust methodologies for processing data from the new SMART systems and extracting meaningful signals for various parameters. A critical aspect is the seamless integration with existing search and

rescue and warning agency systems, ensuring that data can be effectively utilized for early warning and monitoring purposes.

Data Management Framework
A comprehensive data management strategy is essential for handling the anticipated volume of data generated by SMART Cables now and in the future, particularly from DAS. The framework must address real-time data handling, standardized format definitions, and compliance with various organizational requirements. Priority must be given to ensuring data accessibility while maintaining appropriate security and quality control measures.

Seismological Integration
The validation and integration of seismological data from SMART Cables requires careful comparison with existing ocean bottom seismometer (OBS) networks. The JTF proposes a one-year parallel deployment program to validate sensor performance and establish calibration standards. This will enable the integration of SMART Cable data into existing seismic monitoring networks and enhance global earthquake detection and tsunami prediction capabilities.

Oceanographic Monitoring
The integration of SMART Cables will significantly enhance oceanographic monitoring capabilities. The system will provide continuous data on oceanic circulation, heat content, sea level, and tsunami waves. Development work is needed to establish modeling frameworks that can effectively utilize these new data streams, particularly in understanding higher-frequency turbulence and bottom boundary layer dynamics with interaction with layers above.

Tsunami Warning Enhancement
SMART Cables offer unprecedented opportunities for improving tsunami warning systems. Integration efforts focus on developing seabed geodesy applications and enhancing earthquake detection capabilities. This includes creating new methodologies for probabilistic tsunami forecasting incorporating both SMART sensors and future DAS data.

Acoustic Monitoring Integration
The acoustic monitoring capabilities of SMART Cables (e.g., low-frequency capability via seismic sensors) offer new opportunities for marine environmental observation. Integration plans must address marine mammal, acoustic traffic monitoring and noise characterization, contributing to overall marine environmental monitoring efforts.

Collaboration Framework

Success requires strong collaboration between various stakeholders. The JTF is actively developing partnerships with organizations like NSF and regional research institutions. Technical innovations, such as the integration of low-frequency hydrophones (present proxy is the ocean bottom seismometers that will be used) and advanced earthquake location algorithms, are being incorporated through collaborative development efforts.

Regional Implementation

Regional implementation, exemplified by the Vanuatu-New Caledonia case, demonstrates both opportunities and challenges. The formalization of collaboration between VMGD and IFREMER through MOUs shows progress in institutional integration. However, political and organizational challenges must be carefully managed to ensure successful implementation.

Operational Integration

The operational framework must accommodate multiple sensors and shore stations while ensuring efficient data distribution. Priority is given to maintaining low latency for early warning and monitoring applications while supporting research needs. This requires careful coordination between multiple data centers and standardization of data formats.

Suggestions to move forward:

1. Work on the GOOS SMART Cable Network specification sheet;
2. Establish clear integration protocols for each technical area;
3. Develop standardized validation procedures;
4. Create comprehensive data sharing frameworks;
5. Strengthen international collaboration mechanisms;
6. Address regional capacity building needs;
7. Implement robust quality control measures; and
8. Use the InSEA SMART Wet Demo and similar to pilot data procedures (e.g., metadata exchange with OceanOPS and data exchange with WIS2.0).

Conclusion

The integration of SMART Cables into the GOOS represents a significant advancement in ocean monitoring capabilities. Success requires careful attention to technical, operational, and institutional integration challenges. The JTF's comprehensive approach, addressing both scientific excellence and practical implementation requirements, provides a strong foundation for this important initiative.

Additional information

Summary of the GOOS OCG Cross-Network Data Implementation

The Global Ocean Observing System (GOOS) has embarked on an ambitious journey to transform how we manage and share ocean data. At its core, this strategy responds to an urgent need: the ocean science community requires better access to data for addressing climate change, protecting ocean health, and supporting sustainable marine activities.

Every day, observing networks across the world's oceans collect hundreds of thousands of measurements. These networks use different platforms and methods, from ship-based observations to autonomous buoys, creating a complex web of data streams. However, this diversity, while valuable, has created challenges in how data is shared and used.

To address this, GOOS developed a comprehensive strategy built around the FAIR principles—making data Findable, Accessible, Interoperable, and Reusable. At the heart of this approach is ERDDAP, a powerful data platform that acts like a universal translator for ocean data. It acts as a bridge to connect different data formats and communities, allowing scientists using different systems to access the same information seamlessly.

The strategy sets out clear requirements for how data should be handled. Real-time observations need to be shared quickly through global communication systems, while more detailed, quality-controlled data should be stored in accessible repositories. Perhaps most importantly, all this data needs to be well-documented with standardized metadata, ensuring that future users can understand and trust the information they're working with.

To make this vision a reality, GOOS is working closely with international partners, including the World Meteorological Organization (WMO) and the UN Ocean Decade initiative. They created a roadmap for tracking progress, using annual report cards to measure how well different networks are implementing these practices. This is not just about meeting technical standards—it's about creating a truly integrated global ocean observing system that can help us better understand and protect our oceans.

Looking ahead, the strategy acknowledges that this is just the beginning of a longer journey. The ocean data landscape continues to evolve with new technologies, e.g., AI and cloud computing, and the strategy is designed to adapt to these changes. Success will require ongoing support for observing networks, regular assessment of progress, and continuous refinement of approaches as new challenges and opportunities emerge.

Through this coordinated effort, GOOS aims to transform ocean data from a complex maze of different systems into a more unified, accessible resource that can better serve the growing needs of the global community working to understand and protect our oceans.