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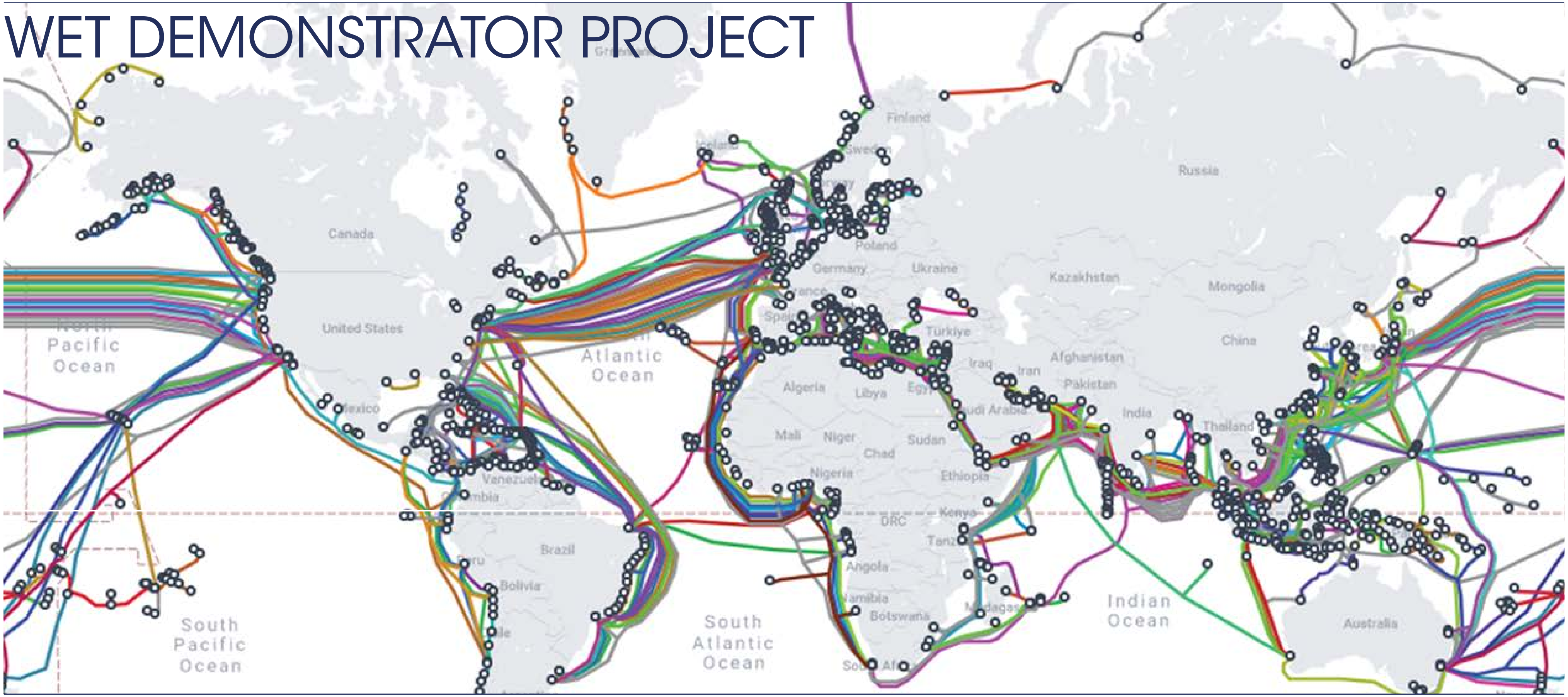
güralp

INSEA SMART CABLE

WET DEMONSTRATOR PROJECT



Submarine cable map courtesy of TeleGeography

Deployment of the InSEA SMART Cable from the Antonio Meucci cable-laying ship, off-coast Catania, Italy

SMART Cables: The Background

World's first SMART cable

In December 2023, Güralp, working with Istituto Nazionale di Geofisica e Vulcanologia (INGV), successfully deployed the Worlds first 'SMART Cable' to monitor seismic activity on the floor of the Ionian Sea.

The 21 km SMART (Science Monitoring and Reliable Telecommunications) cable, is an innovative system developed by Güralp in partnership with INGV for the Italian InSEA SMART Cable Wet Demonstrator project.

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

What is a SMART cable?

Historically, the deployment of oceanographic sensors with real-time communications has proven to be demanding in terms of budget, deployment and support requirements.

A global SMART Cable initiative is exploring a number of ways in which these sensors could be integrated into commercially standard telecommunication cables to create SMART cable systems.

The expectation is that if the scientific community can realise the potential for utilising existing industry and deployment methods to deploy ocean bottom sensors, there is potential to deliver real savings. This would pave the way for increasing ocean bottom sensor density, accelerating research and monitoring strategies for climate change and Earthquake/Tsunami warning.

ITU-UNESCO/IOC-WMO Joint Task Force

The advocacy for the SMART cable concept is currently led by the ITU-UNESCO/IOC-WMO Joint Task Force ("JTF"), established in 2012 by the United Nations to investigate the potential of using submarine telecommunications cables for ocean and climate monitoring and disaster warning. This Project is hosted by the Ocean Decade programme, Ocean Observing Co-Design: Evolving ocean observing for a sustainable future.

The JTF, of which Güralp is an active member, collaborates with a number of public and private organisations to assess and develop technologies that have the potential to make SMART cables feasible (Howe et al., 2022).

The InSEA SMART Cable Wet Demonstrator Project

Figure 1:
Map showing submarine cables offshore Sicily (map courtesy of TeleGeography.)

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"The installation of the SMART Cable represents a pilot experiment of international importance that many scientific communities are looking at, in particular the JTF. The success of this experiment opens up new possibilities for collaboration with the telecommunications sector and the blue economy sector."

Massimo Chiappini,
Director of the Environment Department of INGV

The InSEA SMART Cable Wet Demonstrator Project

In 2020, INGV awarded Güralp the contract to design, manufacture, test and deploy a 21km SMART cable system in the Western Ionian Sea. The project forms part of a wider programme known as the InSEA project.

The SMART cable project is funded by the Italian Ministry of Research and aims to investigate the effectiveness of seismometers and environmental monitoring sensors deployed in and around the repeater housings of a traditional telecommunications cable. (Howe et al., 2022).

In particular, the project is investigating if the system can be deployed in a commercially standard manner without compromising the scientific or operational value of the data being transmitted by the sensors.

The Observation Area

The selected observation area for the SMART cable is prone to numerous natural hazards including seismicity caused by the nearby Mount Etna. Past events include a major earthquake and tsunami in 1693 that caused ~60,000 casualties in Catania (Tonini et al., 2011).

The in-situ measurements from the deployed seismic and pressure sensors will be crucial for generating reliable tsunami height forecasts for the region and will also aid with improving tsunami warning times.

Figure 2: Map showing the location of the deployed SMART cable

Additional Ocean Bottom Seismometers

Güralp also supplied three cabled Orcus ocean bottoms seismometers (OBS). The Orcus is an observatory grade station that delivers exceptionally high quality data for research applications. Each Orcus incorporates a 3T broadband seismometer, a 5T broadband accelerometer, a hydrophone and a high resolution Affinity digitiser.

The Orcus were deployed in the same area and at the same time as the SMART cable as part of a related scheme within the InSEA project. They provide a high quality reference for evaluating the effectivenesss of the sensors located inside the repeater housings.

Image 2: View of Mt. Etna from the SMART cable deployment vessel.

Image 1: The observatory grade cabled Orcus OBS is designed to be placed on the seafloor.

About Güralp

Established in 1985, Güralp Systems Ltd. is a leading global provider of seismic instrumentation and seismic monitoring systems.

We manufacture a wide range of broadband seismic instrumentation for surface, downhole and ocean bottom deployment. We also provide related services including:

> Bespoke engineering and system design
> Design and supply of turnkey seismic monitoring systems
> Field services, including integration testing and commissioning
> Project management
> Maintenance and after-sales support
> Summary data analysis
> Quality Control
> Compliance monitoring solutions

Our customers are mainly research institutes, government departments, civil engineering firms and the energy sector.

We have supplied in excess of 50,000 seismic instruments over our nearly forty year history. Our technology is deployed across all continents and includes our ocean bottom systems which have been installed in all major ocean basins.

Based in the UK, our talented team is the global leader in designing, building and deploying specialist broadband seismic equipment.

The importance of broadband.

Technology that meets the brief

Our 'next generation' of smart seismic instruments offer user-friendly features and advanced data communication capabilities that make them ideal for simple, rapid deployments in uncontrolled environments, such as the ocean floor.

Designed and built in the UK

All of our instruments are manufactured by our dedicated team at our specialist facilities based fifty miles from London in the United Kingdom.

Our business is certified to ISO9001:2015 recognising our quality management system covering the design and manufacture of low noise broadband seismometers, accelerometers, digitisers and networking equipment for science and engineering. Software design and development.

Image 3: The remotely configurable Certimus seismometer, selected for the SMART cable project, utilises advanced sensor technology allowing it to operate at any angle whilst providing true broadband data, critical for accurate event assessment.

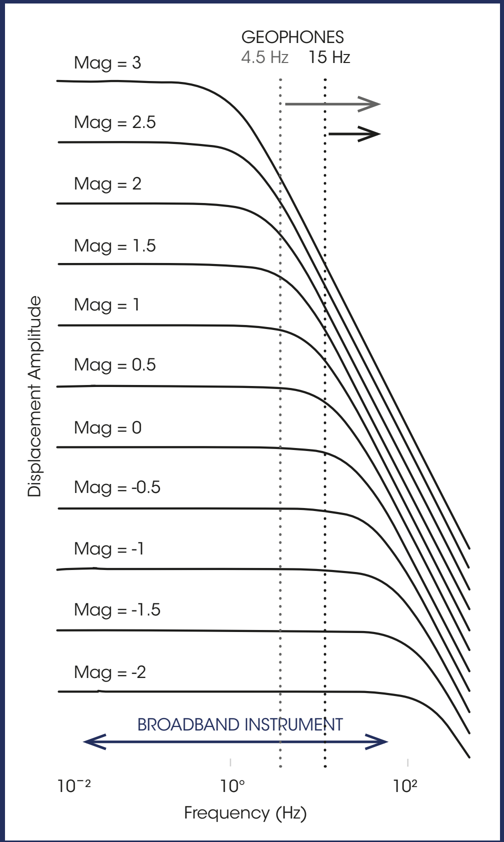


Figure 3: Comparison showing Güralp broadband instrument and geophone responses

The Full Energy Spectrum

In order to accurately locate seismic events, clear arrival times need to be observed in the data. Thanks to the superior sensitivity of Güralp's broadband instruments, these arrivals are clearly recorded, even for events on the other side of the world!

Broadband instruments are the key to recording the full spectrum of seismic events in an area (shallow vs. deep; small vs. large), allowing for the most complete catalogue of events.

Accurate cataloguing of event locations and magnitudes is mission critical for warning systems that rely on this data. For example, Earthquake Early Warning requires accurate location information to determine how much time there is before damaging ground motion arrives at a certain location. This is the reason our broadband instrumentation is integral to leading early warning systems around the world.

Determine Complex Faulting Behaviour

Earthquakes have complicated rupture mechanics. Our broadband seismometers offer the optimum solution for accurate determination of source mechanisms across a wide range of natural and induced events. This information feeds into global seismic hazard models, used to advise government and hazard management groups to reduce risk to vulnerable populations around the world.

System Design

Image 4: One of the three decommissioned repeater housings prior to being reconditioned and retrofitted with the seismic instrumentation.

The Repeater

The InSEA system totals 21km in length and incorporates three instrumented repeater housings and three inline instrumentation pods.

The repeater housings are reclaimed from a decommissioned system that has been modified internally by Güralp to incorporate the necessary instrumentation. This allows the system to be tested using industry standard cable-laying techniques.

The Instrumentation

The instrumentation in the repeater housings consists of a Force Balance Accelerometer ("FBA") and a Broadband Seismometer ("BBS") mounted within the frame. These instruments are high performance sensors, utilised for local and teleseismic monitoring.

The instrumentation pods house an Absolute Pressure Gauge ("APG") and a premium temperature sensor favoured by the global ocean science community. The pod is external from the main repeater and set some distance away to provide the sensors with exposure to the seafloor environment without the risk of heat transfer from the instrumentation in the repeater.

The Cable System

At one end of the cable there is a Cable Termination Assembly (CTA). The CTA connects to an existing underwater junction box via a wet-mateable connector and jumper cable. It was deployed and connected using an ROV. The CTA houses the constant current power supply, fibre optic systems and facilitates connection to the sea cathode. The power system uses a single conductor in the telecoms cable and utilises a sea-return via the sea anode.

The repeaters housing the seismic sensors are connected by standard telecoms cable.

The final part of the power system is the sea anode which is housed on the final length of cable in the Loop Fibre End Seal.

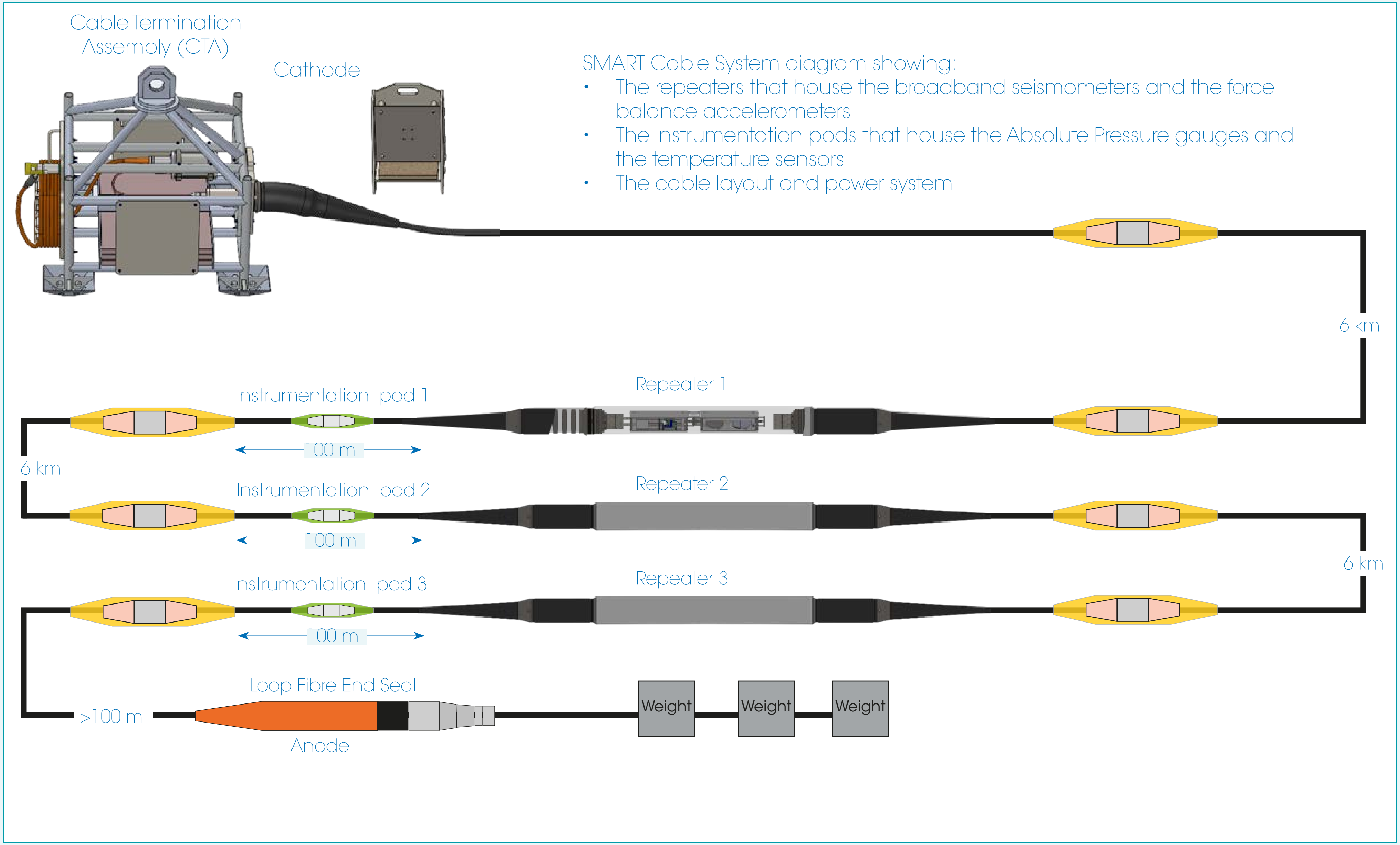


Figure 4: InSEA SMART cable system diagram

Instrument Selection and Performance

Within each repeater housing is a Fortimus force-balance accelerometer and a Certimus broadband seismometer. Both instruments are installed within their standard instrument housings for additional pressure and temperature stability to maintain performance.

Both sensors can automatically adjust for tilt, without the use of a gimbal, enabling them to dynamically adapt to the deployment conditions and so ideally suited for SMART cable applications. Time synchronisation is critical for both seismic sensors and is achieved through a PTP timing source making use of a land-based grandmaster GNSS receiver.

Image 5: Frame that fits inside the repeater housing and holds the seismometer and accelerometer

INSTRUMENT POD:

Seabird SBE 39Plus

The SBE 39Plus temperature sensor has an operating range between -5°C and 45°C with an accuracy of ±0.002°C. The temperature sensor is favoured within the ocean science community and will help to facilitate the monitoring of sea floor oceanographic conditions with data fed into existing oceanographic models.

Paroscientific 8000 Series

The Paroscientific 8000 Series APG has a depth rating of 3,000m and a precision of <0.01% full scale range. Selected for it's proven performance and robustness, the Paroscientific 8000 has been successfully used in other Güralp ocean bottom sensing systems. It is frequently selected globally for tsunami warning systems.

REPEATER:

Certimus

The Certimus is a triaxial broadband seismometer with a flat adjustable frequency response between 120 s and 100 Hz.

True broadband performance combined with low self-noise makes it well suited for regional seismic monitoring. Certimus utilises an advanced sensor technology enabling it to work at any angle, making it particularly suited to atypical deployment methods like the SMART cable.

The Certimus is used globally for applications ranging from volcano monitoring to regional and national networks with more than 1000 components delivered globally.

Fortimus

The Fortimus is a modern force balanace accelerometer with integrated digitiser. It has a flat acceleration response between DC-315 Hz.

The instruments' low self-noise, makes the data useful for local and regional seismic monitoring, so far more than 1500 instruments within the range have been sold worldwide.

Ultra-wide dynamic range

Certimus benefits from an adjustable frequency response and Fortimus from an adjustable clip levels both of which can be configured, post deployment, using Güralp Discovery software. By combining the Fortimus and Certimus, each repeater becomes a monitoring station with ultra-wide dynamic range.

System Integration

Design approach

We undertook extensive work to integrate our existing Fortimus and Certimus instruments into the repeater housings. For the purpose of the Wet Demonstration project, the power circuits and optical amplifiers normally found within the repeater were removed and replaced with a power supply, media converter and the seismic sensors.

The repeater

The repeater cylinder is sealed by two bulkheads within which is a penetrator that carries the optical fibres and the conductor from the cable into the housing. A mechanical bend limiter at each end allows the repeater to pass through the handling machines of the cable laying ship.

Integrating the sensors

The seismic sensors, power supply electronics and media converter were preassembled into metal frames that allowed for system testing before they were mounted inside the repeaters.

The frames are designed to ensure sufficient protection of the sensor and electronics as well as maximising coupling of the sensor components to the frame to improve performance of the sensors during the deployment.

The instrument pod

To ensure that the APG and the temperature sensore are exposed to the seafloor environment, they are enclosed in an instrument pod that attaches inline with the telecoms cable. The pods are mounted far enough away from the repeaters to minimise any thermal effects on sensor performance.

Image 6: The three instrument pods on laid out on the cable-laying deck awaiting deployment

Deployment

Main image 7: Panoramic photo of the ship's cable-laying deck where the system was laid out and the repeaters were spliced into the cable prior to deployment.

Deployment method

The system was installed adhering to a standard method for telecommunication cable deployment using a commercial cable-laying vessel, the Elettra Tlc ship 'Antonio Meucci'. The ship has a full suite of fibre optic termination equipment and utilises dynamic positioning to ensure accurate placement of the subsea cable.

Dockside preparations

A dockside test was undertaken before the system components were loaded onto the vessel to ensure all instrumentation and hardware was working as expected.

Image 8 : Top - Winching equipment from dockside onto the Antonio Meucci
Image 9 : Bottom - The third repeater being placed onto the deck of the Antonio Meucci

Pre-deployment preparation

Once onboard the repeaters and instrument pods were spliced into the main cable, and the loop fibre end seal fitted.

Image 10 (Top): Two of the repeaters on the deck of the Antonio Meucci
Image 11 (Bottom):The instrument pods on the cable-laying deck of the Antonio Meucci

Unversal joints

The cable connections required seven universal joints to be made in the 21 km cable, which was contracted by Güralp to specialist contractors, Global Marine.

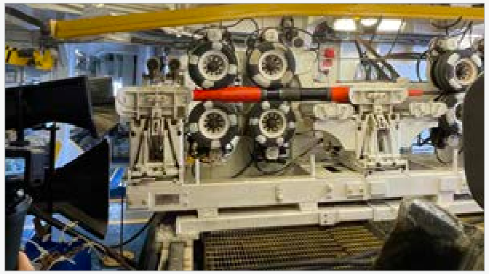


Image 12 (Top): The seven universal joints required to splice the repeaters into the cable.
Image 13 (Bottom):A universal joint passing through the cable engine on the cable deck.

Deploying the CTA

The CTA was deployed via winch and connected to an existing junction box on the seafloor using a remotely operated vehicle (ROV).

Image 14 (Top): CTA being deployed
Image 15 (Bottom): ROV positioning CTA on seabed

Deploying the system

With the CTA in place, the 21 km cable system could be installed following the predefined route.

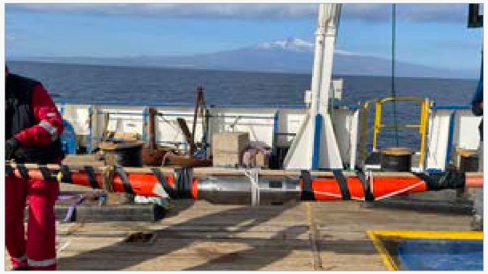
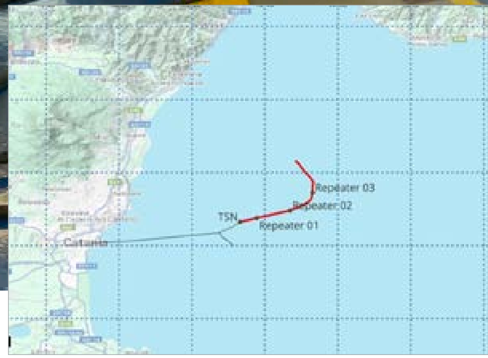


Image 16 (Top): Repeater being deployed
Image 17 (Bottom): Instrument pod being deployed



The route

The SMART cable was installed approximately 30 km off the coast of Catania with full deployment taking 36 hours.

A bathymetry map was utilised to ensure the planned cable path achieved an installation depth in the region of 2,000 m and avoided sharp deformation areas or assets already located on the seabed.

Image 18: Map of cable deployment route

Power and data acquisition

Data is streamed via cable to a shore station in Catania Harbour run by the National Institute for Nuclear Physics (INFN) which also supplies power to the system. Timing is provided using GNSS with Precision Time Protocol (PTP) synchronisation.

Güralp Discovery software provides an instant view of seismic and temperature data alongside instrument state-of-health data and control over data recording on the instruments.

Image 19: INFN Shore station in Catania Harbour

Initial monitoring data

The InSEA Wet Demonstrator SMART cable instruments have provided high quality seismic data for teleseismic, regional and local events.

CALIPSO reference data

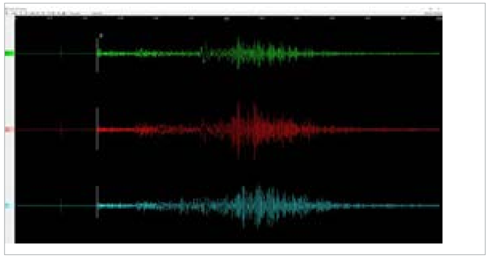
A Güralp Orcus OBS was deployed at the same time as the SMART cable, as part of a broader InSEA project, in close proximity to the three repeaters.

Data from the Orcus OBS (CALIPSO station) is given as reference for each event. It is not a direct comparison as the Orcus is an observatory grade instrument, however it does provide a comparison for the SMART cable data.

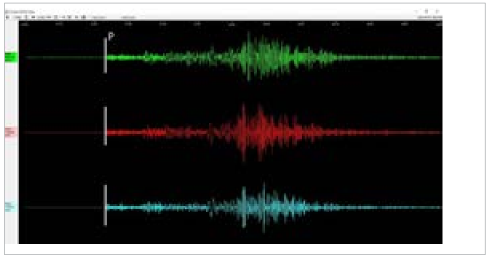
The SMART cable waveform data is very closely correlated to CALIPSO waveform data demonstrating successful operation of the instruments housed in the three repeaters.

TELESEISMIC EVENT

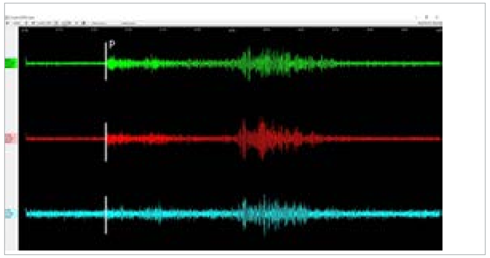
WEST COAST, EASTERN HONSHU, JAPAN
01/01/2024 07:10:13 M_{wpd} 7.4



Waveform data: CALIPSO Station



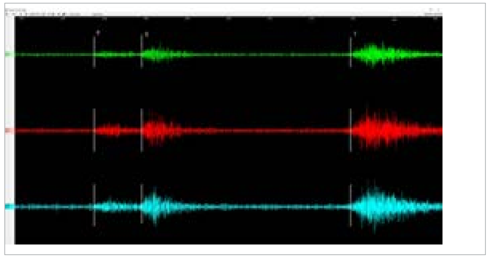
Waveform data: Repeater 1, (Certimus seismometer)



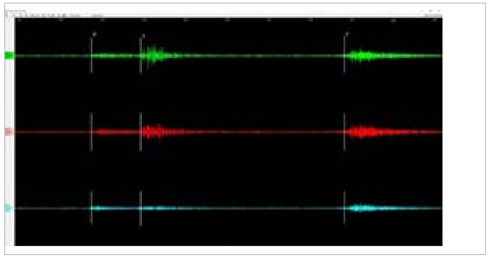
Waveform data: Repeater 1, (Fortimus accelerometer)

REGIONAL EVENT

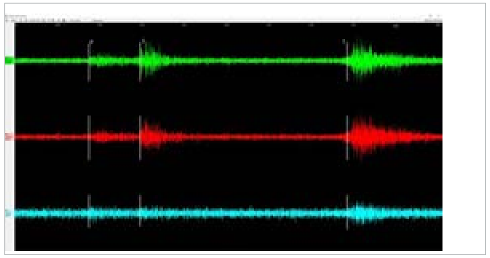
WEST COAST CRETE, GREECE
12/01/2024 03:51:07 M_b 4.7



Waveform data: CALIPSO Station



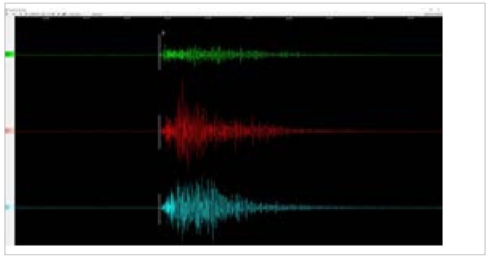
Waveform data: Repeater 2, (Certimus seismometer)



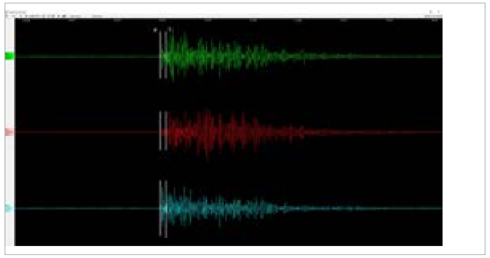
Waveform data: Repeater 2, (Fortimus accelerometer)

LOCAL EVENT - 24 KM DEPTH

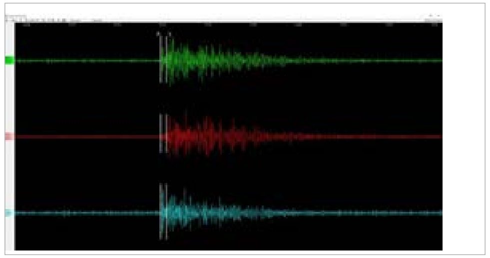
CATANIA COAST, ITALY
14/01/2024 19:53:23 M_L 2.0



Waveform data: CALIPSO Station



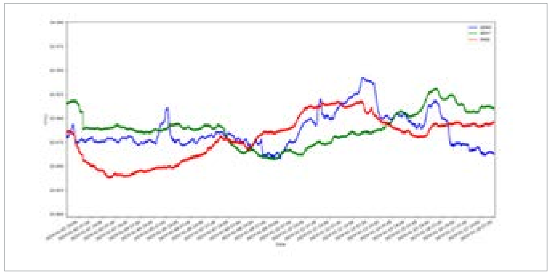
Waveform data: Repeater 3, (Certimus seismometer)



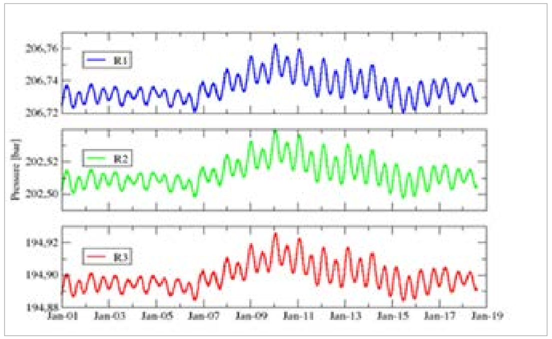
Waveform data: Repeater 3, (Fortimus accelerometer)

Data from the instrument pod

The SBE 39Plus temperature sensor and Paroscientific 8000 Series Absolute Pressure Gauge housed in each of the three instrument pods have been providing continuous data since the system deployment.



Temperature data from the three SBE 39Plus temperature sensors.



Pressure data from the three Paroscientific 8000 Series Absolute Pressure Gauges.

Looking to the future

The InSEA wet demonstrator project is a critical step towards wider acceptance and implementation of SMART cable systems globally.

The project has demonstrated that high performance seismic and ocean observing sensors can be deployed using standard commercial telecommunication cable-laying procedures.

The broadband sensor's ability to work at any angle combined with the engineering effort to ensure that the instruments were coupled effectively with the repeater housing has resulted in good coupling with the seismic sensor.

Initial data would appear to be of a high quality and although not directly comparative to observatory grade OBS data such as provided by the Orcus, we can see with the reference data that it is certainly to be of significant scientific value.

There has already been an increasing level of interest in projects seeking to utilise the SMART cable concept so we are developing our relationships with industry specialists further to ensure that we can respond effectively to any opportunities that arise.

We are committed to further developing this technology and have already identified strategies to explore further improvements to our design.

Vital to our success has been our collaboration with other key parties involved on the project.

"The use of innovative underwater telecommunications cables, i.e. equipped with geophysical and environmental instrumentation, represents a solution to extend observations to marine areas never reached, to have real-time access to observations and to support studies on the climate, oceans, on the structure of the Earth and on natural disasters.

INGV has been very satisfied with the level of project management, engineering support and collaboration that Güralp have demonstrated on this project. I wouldn't hesitate to recommend Guralp as a supplier for future SMART cable projects globally."

Giudditta Marinaro
Head of Multidisciplinary Research on Geoshpere-Ocean-Atmosphere Interactions of the Rome 2 Section of INGV

Image 20: Deployed SMART cable repeater on the seabed

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