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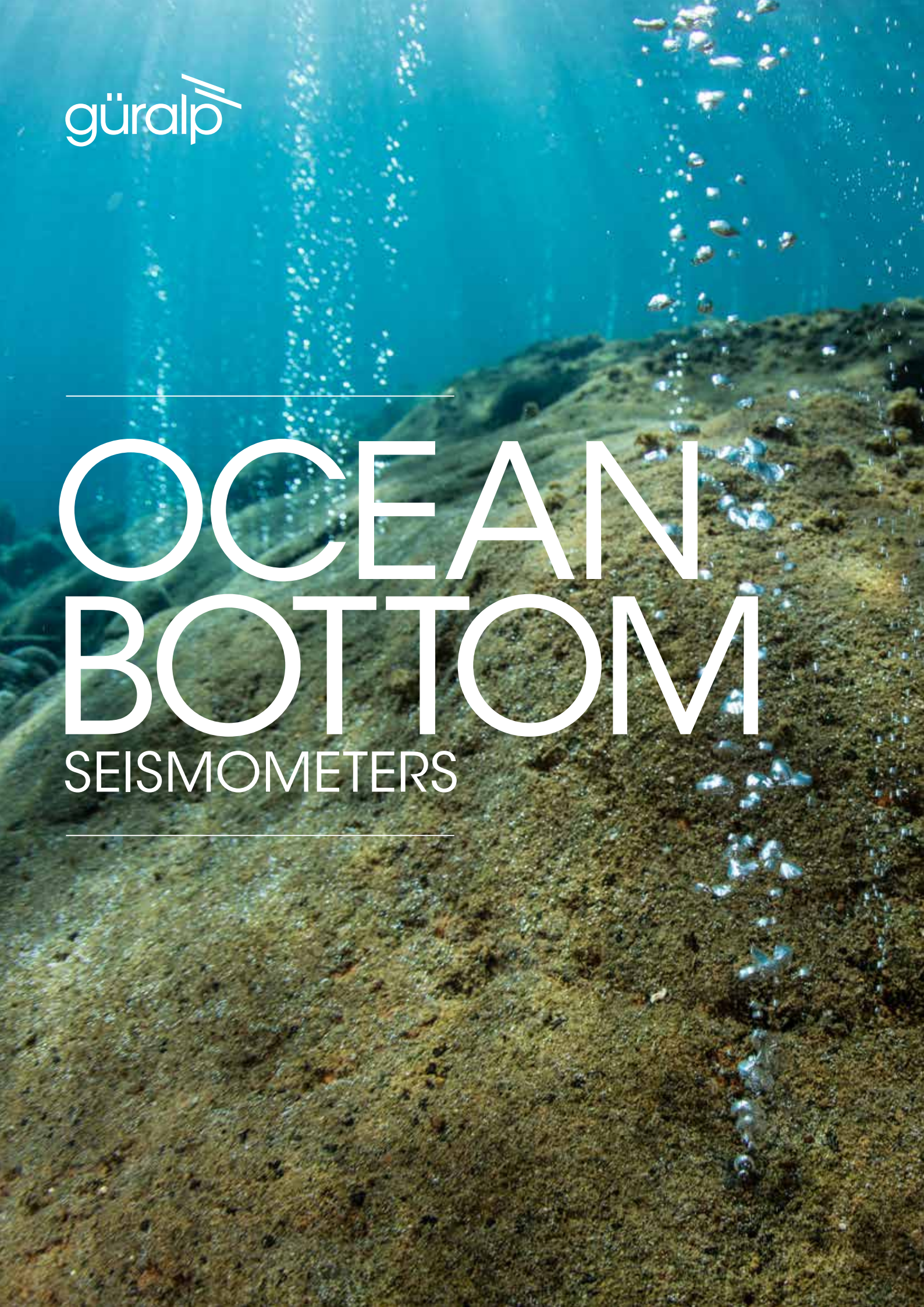
OCEAN BOTTOM SEISMOMETERS



Güralp ocean bottom seismometers (OBS) have been measuring seismic activity from deep on the ocean floor since 1989.

We are specialists in force-feedback, broadband seismic sensors and have been developing ocean bottom systems to house our broadband sensors since 1989. We have created ocean floor systems for virtually every type of deployment scenario you can think of, putting us in a truly unique position.

By combining our state-of-the-art sensor technology with our extensive OBS design capability we have devised a truly comprehensive range of ocean bottom instruments to choose from.

As well as housing broadband, triaxial sensors to capture the full seismic frequency range, we can also integrate additional sensors and gauges, vastly extending the application and capability of our OBS systems.

Whether you need a permanent ocean observatory delivering real-time digitised data for earthquake or tsunami early warning; portable instrumentation capable of near-real-time data transmission; a pool instrument with flexibility for a variety of research applications; or a seismic sensor you can integrate with your own system, we have a solution that will meet your requirements.

READ ABOUT OUR WORK ON SMART CABLE SYSTEMS THAT INTEGRATE SEISMIC SENSORS INTO STANDARD COMMERCIAL TELECOMMUNICATION CABLES, PAGES 18-19

Design flexibility for unique project requirements

We will support you through the planning and design phase, fine-tuning our most appropriate instrumentation to the unique demands of your project.

Depending on your requirements, we can incorporate additional multidisciplinary sensors into the OBS system, for example:

- Hydrophone (1 Hz – 30 kHz) - to widen the bandwidth, for example for high frequency airgun shots
- Acoustic Current Meter - for monitoring seafloor currents for scientific research and to correct seismometer signals for current noise, dramatically cleaning waveforms
- Pressure gauges - our OBS systems can incorporate differential pressure gauges (DPGs) or absolute pressure gauges (APGs)

Designed to match the deployment environment

Our instrumentation can be housed in titanium, stainless steel or aluminium. We will select the most appropriate casing material to suit the depth rating you require. We can also supply OBS modules housed in a subsea vessel rated to your depth requirements for integration into your own system.

Once your instrumentation is designed and built, we have experienced engineers who can assist with the system deployment or, if desired, we can provide full on-site or off-site training for your team.

ADDITIONAL SENSORS OR GAUGES CAN BE INCORPORATED INTO THE SYSTEM TO MAXIMISE DATA CAPTURE





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OCEAN BOTTOM INSTRUMENTATION

CABLED SYSTEMS

Real-time data for permanent observatories and Earthquake Early Warning

ORCUS

Winch or ROV deployment

Sits fully or partially buried on the seafloor

Gimballed self-levelling over ±26° tilt range

Acceleration (Fortis): DC to 100 Hz

Velocity (3T): 120 s or 360 s to 50 Hz

MARIS

ROV deployment, pushed or cored into the seafloor

Operational over ±180° tilt range

Select either velocity or acceleration response when ordering

120 s to 200 Hz with user selectable long-period corner

PORTABLE SYSTEM

Customisable system with acoustic telemetry

AQUARIUS

Freefall installation

Up to 18 month deployment with rapid battery recharge on recovery ready for re-use

Operational over ±90° tilt range

120 s to 100 Hz with user selectable long-period corner

OBS MODULES

Integratable modules for third party systems

CERTIS & MINIMUS OBS

Deploy as is, or integrate into your own system

Pressure vessel matched to your requirements

Low power consumption

Flexible configuration options

CABLED SYSTEMS

> Permanent deployments
> Real-time data
> Multidisciplinary systems

Orcus

The Orcus is a seismic observatory that combines a long-period broadband seismometer with a force balance accelerometer for unparalelled dynamic range. Suitable for cable-to-shore or cable-to-buoy systems for real-time data streaming.

The unique spherical shape of the casing protects the instrument at high pressures, and an underlying metal plate ensures optimum ground coupling. An optional concrete dome hood can be employed to reduce noise and protect against trawling in shallower waters.

Select your choice of integrated advanced Güralp digitiser for delivery of real-time data to the cable system. Additional sensors can also be incorporated.

The frequency range of the sensor can be engineered to suit the requirements of the project. If more than one response range is required, additional sensors or hydrophones can be incorporated. Non seismic sensors, such as absolute pressure sensors for tsunami early warning can also be integrated.

Key facts:

- Instrumented with a 3T-120 seismometer, a Fortis accelerometer and your choice of Güralp digitiser
- Dual sensor arrangement allows for simultaneous monitoring of both weak or distant seismic events, and near-field, high intensity shaking, in a single system.
- Cable-to-shore or cable-to-buoy system
- Includes pressure, temperature and current sensors with capacity for two additional environmental sensors
- Optional concrete dome to reduce noise and protect against fishing trawlers
- Data digitised at site with real-time streaming to onshore data centre
- Digitiser timing synchronised with NTP or PTP protocols
- Flexibility to connect with a wide range of cable systems e.g. Ethernet or optic fibre
- Constant power supply plus back-up battery
- Deployment via winch, with ROV support required for deeper installations
- Robust gimballed self-levelling system

THE COMBINATION OF THE HIGHLY-SENSITIVE 3T-120 AND STRONG MOTION FORTIS SENSORS PROVIDES UNPARALLELED DYNAMIC RANGE

Case study: Cabled Earthquake Early Warning System in Turkey

The Northern Anatolian Fault (NAF) is one of the most dangerous continental fault zones in the world.

In 2010, Güralp installed a cabled, five instrument ocean bottom observatory to increase the capacity of the regional seismic network beyond the land mass and into the sea. Each OBS houses a broadband sensor, strong motion sensor and digitizer as well as a current sensor, differential pressure gauge and thermometer to ensure accurate time-keeping.

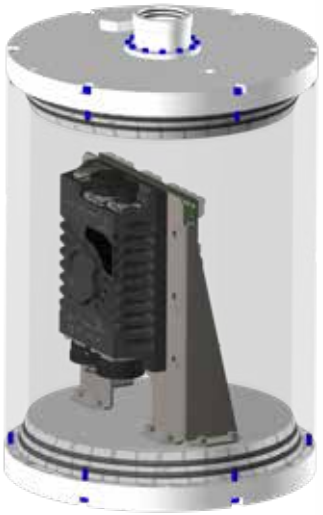
To overcome trawling issues in a busy inland sea, each OBS was covered with a 1 m diameter concrete cone to minimize current fluctuations, maximize coupling with the sea floor and protect against fishing trawlers.

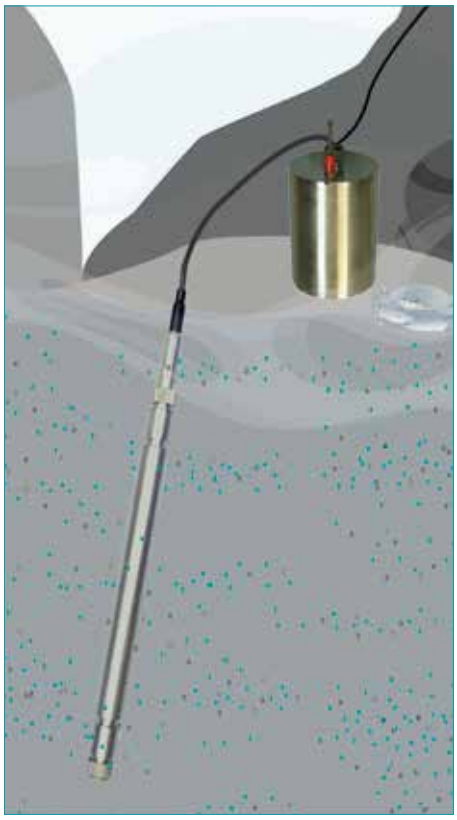
The OBS observatory has significantly improved the determination of earthquake hypocentres and the ability to detect small earthquakes not identified by onshore stations alone.

The optional concrete dome reduces noise and protects against fishing trawlers

Maris

The Maris has a slim-line silhouette designed to be pushed or cored into the seafloor and delivers real-time data streaming. The Maris system can be a single instrument or a string of up to eight instruments connected together to form an array on the seafloor.





Maris houses a broadband sensor that is fully operational at any angle to support versatile installations. Insertion into the seafloor minimises ambient noise to produce exceptional data quality and increase trawl resistance in shallower deployments.

The Maris system, can be a single instrument or a string of up to eight instruments and includes the Minimus digitiser, housed in a seperate vessel, to deliver data over Ethernet direct to the cabling system. The Minimus also offers a low-latency mode running causal filters alongside traditional acausal filters for earthquake early warning applications.

Key facts:

- 120 s to 200 Hz response with user-selectable long-period corner within this range
- State-of-the-art seismic sensor allows operation over a full tilt range of ±180° by automatically centring the mass
- At just 60 mm diameter, the Maris is designed to be pushed or cored into the seafloor to minimise ambient noise for exceptional data quality
- Subsurface burial for improved data quality and trawl resistance
- Easily strung together for daisy chain arrays
- If desired, the Minimus can digitise the data at site with real-time streaming over Ethernet to the onshore data centre
- Optional low-latency outputs available (~0.04 s delay)
- Power and Ethernet stream via dry-mateable connector
- Synchronised absolute time with onshore GPS
- Flexibility to connect with a wide range of cable systems e.g. optic fibre
- Deployment and cable installation via diver or remotely operated vehicle (ROV)
- ROV operable connectors make it possible to string multiple units together for daisy chain arrays or to extend an existing string without recovery.

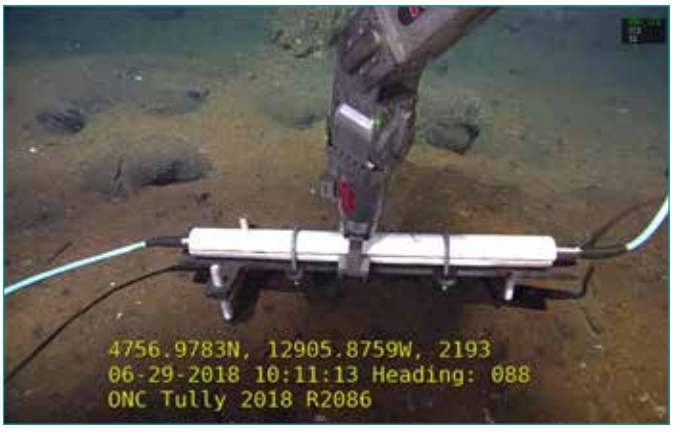
DATA IS DIGITIZED AT SITE WITH REAL-TIME STREAMING TO THE ONSHORE DATA CENTRE

Case study: Wiring the abyss with Ocean Networks Canada

In 2018, Ocean Networks Canada (ONC), a University of Victoria initiative, successfully deployed a string of three cabled Güralp Maris ocean bottom seismometers (OBS) as part of their 'Wiring the Abyss' expedition aboard the Canadian Coast Guard Ship 'John P. Tully'.

The Güralp OBS were deployed on the Juan de Fuca Ridge, a divergent boundary between the Pacific and Juan de Fuca tectonic plates. The instruments were positioned at a depth of approximately 2200 m adjacent to hydrothermal vents that have formed along the ridge, and were lifted into place using the Canadian Scientific Submersible Facility's remotely operated vehicle for ocean science—ROPOS.

The string has acceleration response and is sampled at 500 samples per second. The aim of the array is to detect very small, very local events that are related to the hydrothermal activity of the Main Endeavour Vent Field. The instrument spacing is 70-100m.



Güralp Maris Seismometer being placed in position at 2200m depth (Image courtesy of Ocean Networks Canada)

PORTABLE SYSTEMS

> Free-fall autonomous system
> 4th Generation evolution
  – Real-time deployment verification
  – Acoustic telemetry
  – Any angle operation
  – Additional environmental sensors
  – Compact and robust form factor
  – Intelligent recovery system

Aquarius

The Aquarius is a free-fall system that is fully operational at +/- 90°. Aquarius features acoustic telemetry capability that delivers seismic data from the ocean floor to the surface without cables.

The low profile and compact design is optimised to minimise the noise generated by the current flow whilst reducing transportation and deployments costs.

The seismometer, which is fully operational at +/- 90 degrees, has a flat response between 120 s and 100 Hz and benefits from a user-selectable long-period corner from 120 s to 1 s, so the response can be tailered to the environment.

For real-time deployment verification, state-of-health parameters and noise performance plots can be transferred from the seabed to the deck unit using acoustic telemetry to assess deployment integrity. The same acoustic system can be used to select the desired response of the sensor and measure the time offset of the digitiser housed in the OBS pressure vessel.

Once on the seabed, the Aquarius can be accurately located using integrated location and ranging software. The recovery system is initialised via acoustic link, via a pre-programmed time-out, or with an optional critical level battery trigger.

Aquarius key facts:

- Freefall deployment from a non specialist vessel for up to 18 months deployment
- Compact, low profile design minimises noise generated by the current flow on the seafloor
- Operational at ±90 °
- 120 s to 100 Hz reponse with a user-selectable long-period corner from 120 s to 1 s
- Transfer state-of-health parameters and noise performance plots from the seabed and configure sensor response
- Near-real-time transmission of seismic waveforms and STA/LTA triggered event data from the seafloor to a receiver located at the surface
- Up to 9000 bps transmission of data between seabed and surface
- Single cable connection to the Güralp deck unit for Gigabit Ethernet data, download, system configuration and external power
- Rapid recharge of lithium-ion batteries for easy re-deployments (1 hr re-charge / 1 month deployment)
- Choose from on-demand, pre-programmed or critical battery level activated acoustic burn-wire release
- Discovery software platform provides a suite of powerful tools that dramatically simplify instrument and data management as well as aiding in the system recovery
- The intelligent recovery system incorporates:
  - Satellite tracking system that issues location alerts visible on Discovery and/or sent via email and SMS
  - Acoustic localisation function on Discovery
  - LED strobe light simplify navigating to the precise location of the surfaced OBS system

Case study: National Facility for Seismological Investigations, Canada

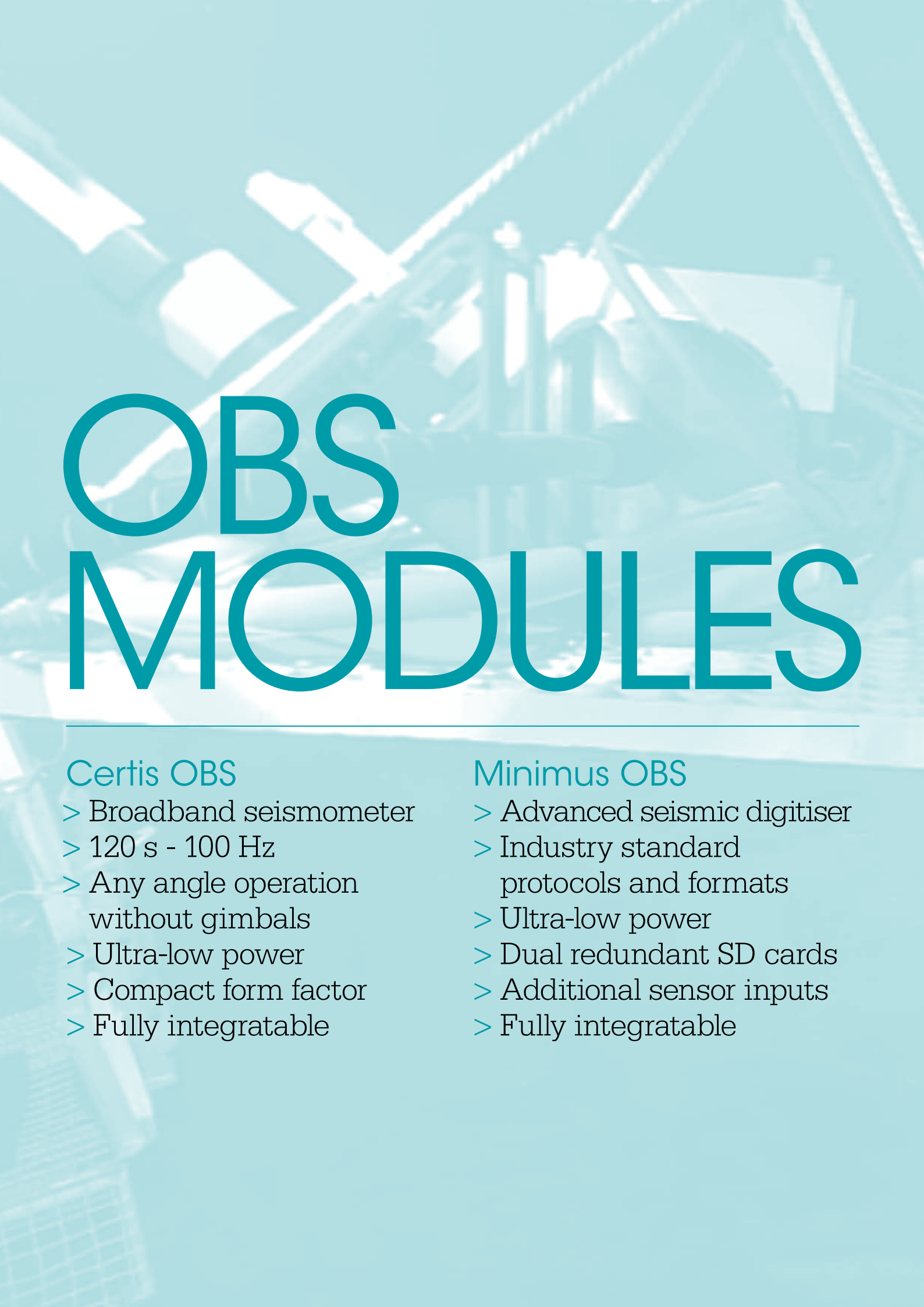
Based on the industry leading technical specifications of the Aquarius, the National Facility for Seismological Investigations (NFSI) chose Güralp for the supply of 120 Aquarius units to form Canada's national broadband OBS pool.

The Aquarius units are configured to operate at up to 6000m depth for deployment periods in excess of 12 months. The instruments are used for innovative research investigations across the world's oceans, inland seas, and lakes in both passive and active source seismology.

The first of the NFSI Aquarius systems were deployed in October 2021.

Güralp Aquarius being deployed by NFSI, October, 2021

THE MOST SOPHISTICATED COMPACT OBS AVAILABLE ON THE MARKET



OBS MODULES

Certis OBS

> Broadband seismometer
> 120 s - 100 Hz
> Any angle operation without gimbals
> Ultra-low power
> Compact form factor
> Fully integratable

Minimus OBS

> Advanced seismic digitiser
> Industry standard protocols and formats
> Ultra-low power
> Dual redundant SD cards
> Additional sensor inputs
> Fully integratable

Certis OBS

The Certis OBS is a compact and portable medium-motion ocean bottom seismometer with advanced sensor technology offering analogue output with state-of-health parameters and fully operational at any angle.

Key facts:

- Triaxial orthogonal (ZNE) instrument with high cross-axis rejection (> 65 dB)
- Compact subsea vessel designed to meet project depth requirements
- Serial output streams instrument serial number, response and calibration parameters
- Analogue output includes sensor mass positions
- The state-of-the-art sensor can operate at any angle without the use of a gimbal for streamlined deployments
- The wide frequency response of 120 s to 100 Hz also benefits from eight adjustable long-period corner settings including 1, 30, 60 and 100 seconds
- When paired with a Minimus digitiser, the long-period corner settings can be adjusted post-deployment to significantly reduce the settling time of the sensor
- Measures 130 mm diameter by 200 mm height

Minimus OBS

Minimus provides 24-bit ADC conversion combined with state-of-the-art communication capabilities and access to the Discovery suite of instrument and data management tools.

Key facts:

- 24-bit, four or eight channel ADC
- Wide dynamic range
- Compact subsea vessel designed to meet project depth requirements
- If desired, the Minimus can digitise the data at site with real-time streaming over Ethernet to an onshore data centre
- Optional low-latency outputs available (~0.04 s delay) e.g. for Earthquake Early Warning
- Industry standard triggering algorithms for Earthquake Early Warning (STA/LTA)
- Power and Ethernet stream via dry-mateable connector
- Synchronised absolute time with onshore GPS
- Flexibility to connect with a wide range of cable systems

USER-FRIENDLY FEATURES FOR SEAMLESS INTEGRATION

SMART Cables

ISTITUTO NAZIONALE
DI GEOFISICA E VULCANOLOGIA

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.

Top: SMART cable repeater being deployed
Bottom: SMART cable instrument pod being deployed

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.

Map of cable deployment route

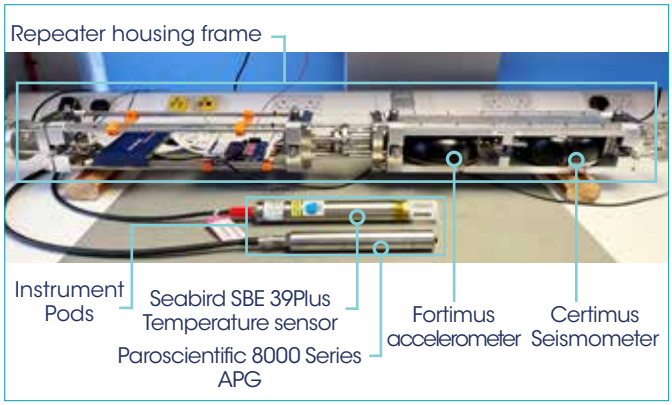
2021 2030 United Nations Decade of Ocean Science for Sustainable Development

System Design and Deployment

The InSEA system designed by Güralp incorporates three instrumented repeater housings and three inline instrumentation pods. The repeater housings used for the project were reclaimed from a decommissioned system and modified internally by Güralp to incorporate the necessary instrumentation. This enabled the system to be tested using industry standard cable-laying techniques.

The instrumentation consists of a Güralp Fortimus accelerometer and a Güralp Certimus seismometer mounted within the repeater frame. These instruments are high performance sensors, utilised for local and teleseismic monitoring.

The instrumentation pods, which are external from the repeater and set some distance away, house an Absolute Pressure Gauge ("APG") and a premium temperature sensor favoured by the global ocean science community.



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 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).

Future Work

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.

International interest in the SMART cable concept is increasing and as we continue to develop this technology, we are exploring improvements and modifications to our design.

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