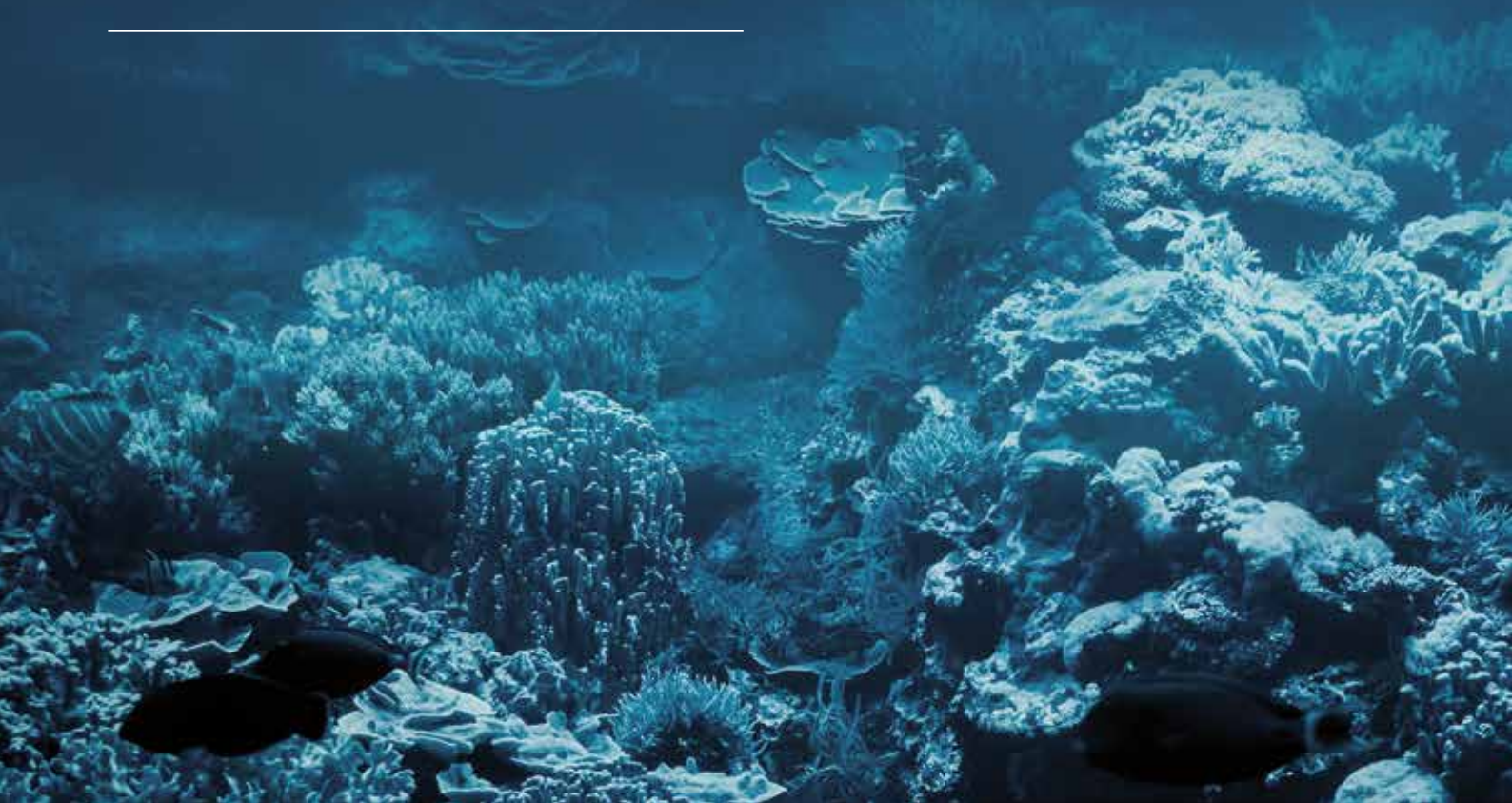


güralp

OCEAN BOTTOM

SEISMOMETERS





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

We have developed our OBS systems over the last twenty five years for projects all over the world. Tried and tested, the Güralp OBS family is the most comprehensive range of cabled and portable ocean bottom instruments available. The true broadband nature of the Güralp seismometers we use means they are capable of capturing the full seismic frequency range, a must for all seismic monitoring applications.

Whether you need a permanent ocean observatory delivering real-time digitised data for earthquake or tsunami early warning; or portable instrumentation for research applications such as oil and gas exploration, we have a system that will meet your requirements.

Flexible design

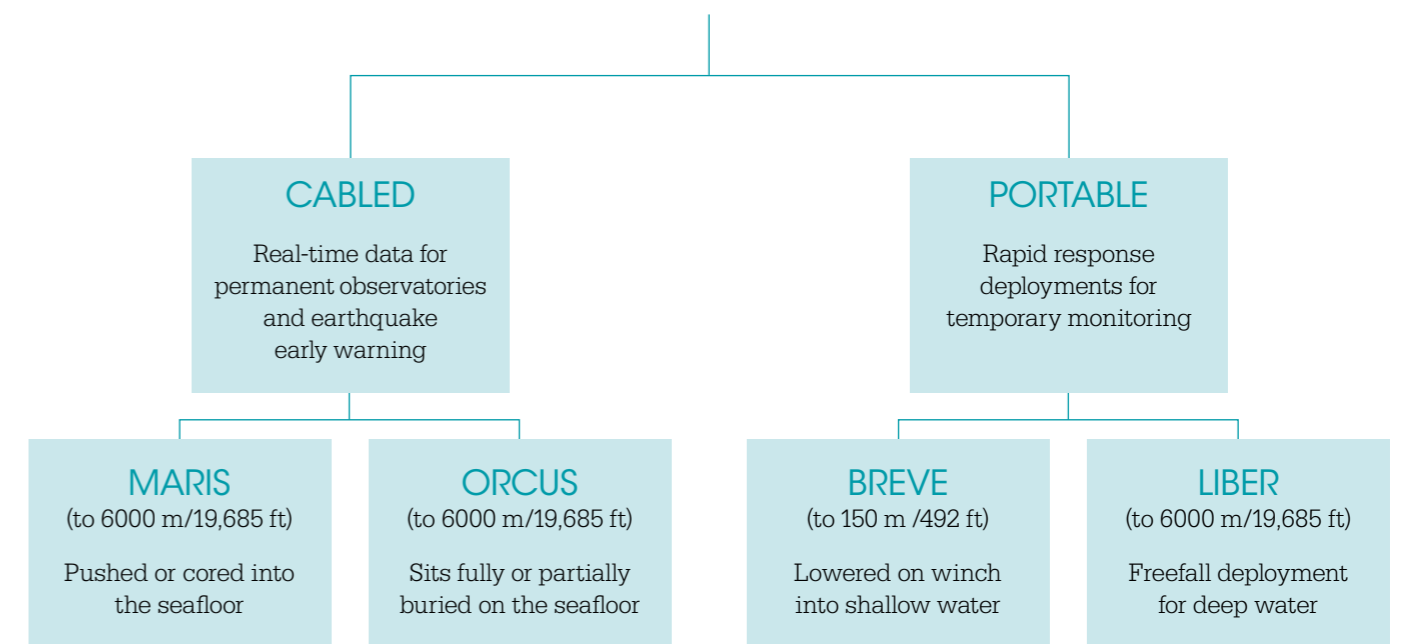
Design flexibility for unique project requirements

Our range of OBS housings have been designed to perform at different depths via the most appropriate deployment method. Each can be combined with the sensor or sensors that will give you the dynamic range you require.

As experts in the design and manufacture of OBS systems, we will support you through the planning and installation process, providing full deployment training if desired. All of our OBS systems are fitted with a magnetometer to determine instrument orientation at depth to maximise data quality and your investment.



OCEAN BOTTOM SYSTEMS





CABLED SYSTEMS

Applications

- > Permanent ocean observatories
- > Earthquake and tsunami early warning systems
- > Long term reservoir monitoring

Maris

The Maris, suitable for depths of up to 6000 m or 19,685 ft, has a slim-line silhouette designed to be pushed or cored into the seafloor.



Housed in titanium or stainless steel, the 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.

An internal magnetometer and MEMS accelerometer work together to automatically compensate for tilt and horizontal orientation to deliver high-quality waveforms.

Key facts:

- > Suitable for depths of up to 6000 m (19,685 ft)
- > Subsurface burial for improved data quality and trawl resistance
- > Easily strung together for daisy chain arrays
- > Titanium or stainless steel casings
- > The system Minimus digitises data at site with real-time streaming over Ethernet to the onshore data centre
- > Optional low-latency mode running causal filters
- > Power and Ethernet stream via wet-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 ROV

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

The Maris system, can be a single instrument or a string of up to eight instruments and includes the Minimus digitiser, housed in a separate 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.

The frequency range of the broadband sensor can be engineered to suit the requirements of the project.

Case study: Ocean Observatories Initiative, North America

The Ocean Observatories Initiative (OOI) is an ambitious 25 year project to develop the world's largest interactive portal to study the oceans.

The University of Washington in Seattle have been installing seismometers, amongst other geophysical equipment, as part of an ocean cable observatory.

The aim of the network is to monitor geological processes in the Juan de Fuca tectonic plate, from its formation at the mid-ocean ridge to its eventual demise in the Cascadia subduction zone. As well as yielding new scientific research, the subsea network also monitors regional subsea geological hazards, such as large megathrust earthquake ruptures and underwater volcanic eruptions.

Güralp Solution

In 2013, Güralp supplied 10 Maris horizontal ocean-bottom seismometers, fitted with 3-component 6T broadband sensors to the University of Washington.

The University of Washington deployed the instruments in summer 2014 across the northeast Pacific Ocean in water depths ranging from 800 to 1500 m. A remotely operated underwater vehicle (ROV) buried the instruments into sediment on the seafloor.

The network of five Maris OBS stations deployed in and around the summit caldera made unprecedented high quality recordings of the submarine eruption of Axial Seamount volcano in April 2015.

On average, 100-200 micro-earthquakes were detected by the monitoring network each day. However, on 24 April 2015, the daily earthquake count reached nearly 8,000 events.

The OOI continues to deliver real-time data, providing new insights into the geological processes inside ocean plates and their associated hazards.

Orcus

The Orcus is suitable for depths of up to 6000 m or 19,685 ft and is suitable for cable-to-shore or cable-to-buoy systems for real-time data streaming.



Depending on the deployment depth, housing is either duplex stainless steel or titanium to protect against corrosion. 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.

An integrated state of the art Güralp Affinity digitizer delivers data in real-time to the cable system. Other sensors can 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 (see page 18).

Key facts:

- > Suitable for depths of up to 6000 m (19,685 ft)
- > Cable-to-shore or cable-to-buoy system
- > Optional add-on sensors include absolute pressure sensor, hydrophone, current meter and thermometer
- > Aluminium or titanium housing for corrosion resistance and waterproofing
- > Optional concrete dome to reduce noise and protect against fishing trawlers
- > Data digitised at site with real-time streaming to onshore data centre
- > Digitizer timing synchronised with NTP or PTP protocols.
- > External sensors with Ethernet can use the same timing 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 self-levelling system

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 COMBINATION OF HIGHLY-SENSITIVE 3T AND STRONG MOTION 5T SENSORS PROVIDES UNPARALLELED DYNAMIC RANGE.

A photograph of a portable system unit, likely a generator or power source, with a control panel on top. A hard hat and a document are placed on the unit. The document has text that is partially legible: "AGSIS DISC 02", "PROPERTY OF THE AUSTRALIAN GOVERNMENT", "PLEASE RETURN TO RESIDENCE AUSTRALIA", "PHONE: +61 2 8249 8111", "EMAIL: DISC@DA.gov.au". The background is a light blue gradient.

PORTABLE SYSTEMS

Applications

- > Temporary installations for up to one year
- > Research projects
- > Rental fleet
- > Oil and gas exploration and monitoring

Breve

The Breve is suitable for temporary installations on the shallow continental slope to a maximum depth of 150 m or 492 ft.



The system is lowered to the seafloor using a winched cable which allows for accuracy of deployment location, whilst avoiding the requirement for specialist deployment vessels. The instrumentation is housed in a protective, waterproof, aluminium casing to protect the instrument from corrosion. On project completion, the system is recovered via an acoustic activated release buoy.

The frequency range of the sensor can be engineered to suit the requirements of the project. A hydrophone is incorporated, alternatively this channel can be used for another analogue sensor like a differential pressure gauge or an absolute pressure gauge (see page 19).

Key facts:

- > Maximum depth of 150 m (492 ft)
- > Sensor is operational at any angle
- > Simple deployment process via winched cable
- > Non specialist deployment vessels can be used
- > Minimal Linear clock drift: < 1 ms per day
- > Low-power electronics maximises battery power for continuous running durations of up to six months
- > Is equipped with a hydrophone
- > Aluminium housing material to protect instrument from water and corrosion
- > Acoustic mechanical release system

Case study: Gas reservoir monitoring, North Sea, UK (ongoing)

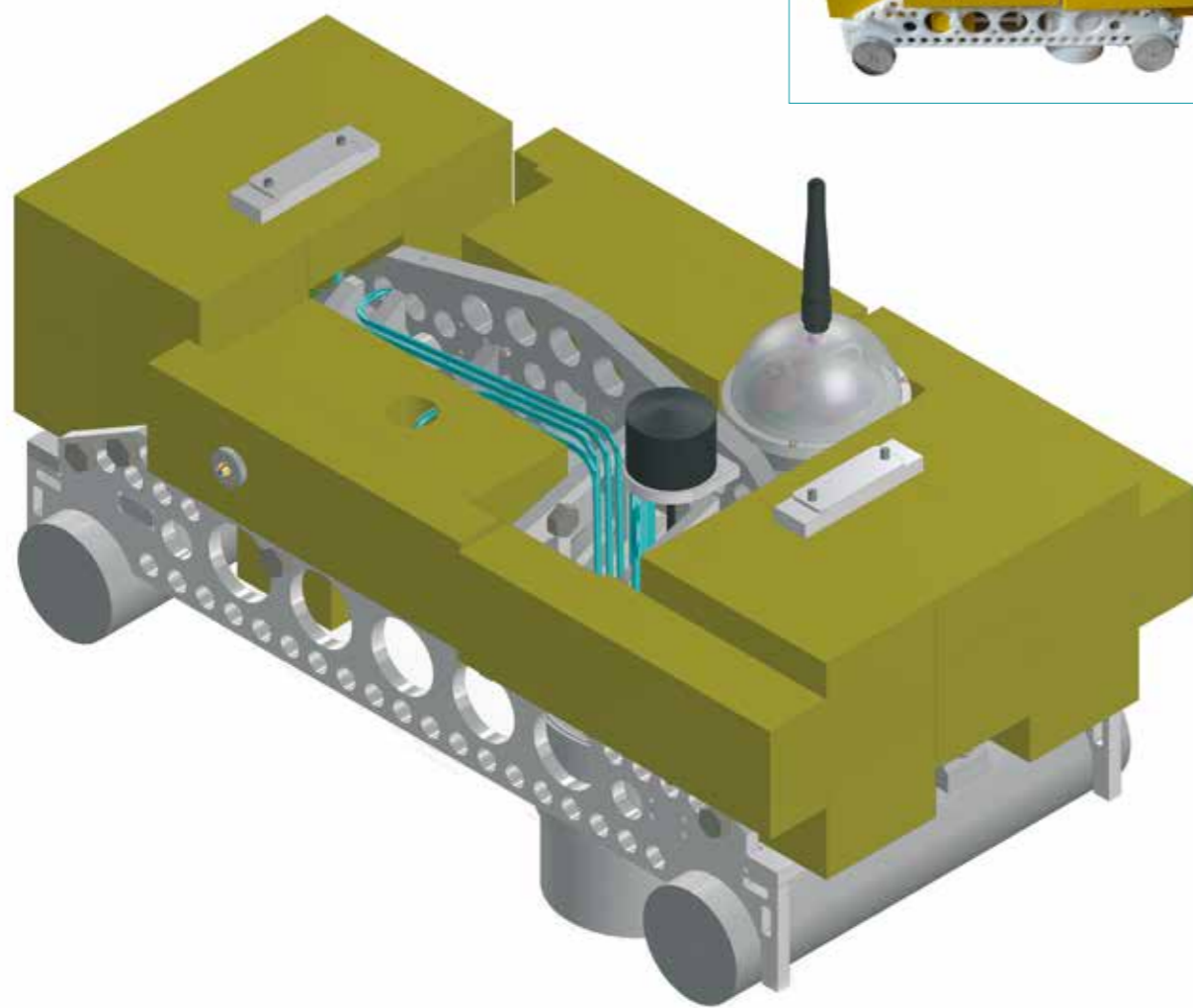
A large multinational oil and gas operator wanted to improve their understanding of rock mechanics and potential future well sites in the North Sea. Guralp developed 55 long period OBS Nodes for a passive seismic monitoring system covering 6 km² of the seabed at approximately 90 m depth.

As part of phase one, we undertook a noise survey to enable us to optimize the instrument response. Following the survey we gave the 6T sensor a customised sensitivity in the frequency range 60 s-100 Hz. This minimised the effects of ocean noise and amplified the sensitivity to high frequency seismic waves from microseismic events. We also found we could get very good signals at shallow depths of just 20 m in a tidal area if we buried the sensor 1 m (3 ft) into the seabed.

WE ARE EXPERIENCED IN DEPLOYING OUR BREVE OBS TO MAXIMISE THE QUALITY OF THE DATA, EVEN IN NOISY ENVIRONMENTS AT VERY SHALLOW DEPTHS.

Liber

The Liber system is designed for temporary installations on continental slopes or abyssal plains at depths of up to 6000 m or 19,685 ft. The instrumentation is housed in titanium to protect the components at high pressure.



The portable system is designed to be deployed freefall to the ocean floor, although ROV deployment is also an option. Recovery is via an acoustic mechanical release system, with the OBS emitting an automatic identification system (AIS) radio signal upon reaching the surface for easy location and collection.

The frequency range of the sensor can be engineered to suit the requirements of the project. A hydrophone is incorporated, alternatively this channel can be used for another analogue sensor like a differential pressure gauge or an absolute pressure gauge (see page 19).

Key facts:

- > Suitable for depths of up to 6000 m (19,685 ft)
- > Freefall, fully autonomous system for quick and simple deployment
- > Easy recovery via acoustic mechanical release, allowing the instrument to float back to the surface
- > Additional back-up burn-wire release system via acoustic signal or pre-programmed before deployment
- > Incorporates a magnetometer to confirm instrument orientation
- > Non specialist deployment vessels can be used
- > Minimal Linear clock drift: < 1 ms per day
- > Can remain on the seafloor for up to 12 months*
- > Is equipped with a hydrophone
- > Robust housing material to protect instrument from water and corrosion
- > Self levelling gimbal

*We are developing a system that can be deployed for up to 15 months

Case study: Active-Source Survey for Oil/ Gas Exploration, Australia

Australian Geophysical Observing System (AGOS) wanted to research the benefits of using ocean bottom seismometers (OBS) in addition to hydrophone streamer based surveys. Güralp supplied 20 OBS instruments, engineered to withstand ocean depths to 6000 m. Each titanium OBS incorporated a Güralp 6T-OBS 3-component broadband (0.0167 Hz–100 Hz) seismometer with a hydrophone (1 Hz–30 kHz) attached to the fourth channel. AGOS found that the Güralp OBS allowed for recovery of information from much deeper crustal features which would not typically be recovered via streamer based surveys during marine seismic acquisition. In addition they found that the hydrophone records had considerably less information and appeared to be more sensitive to water-born multiples than the seismometer.

AGOS identified a number of findings from their recent surveys for the future of OBS technology development which include:

- > The possibility to image whole crust and upper mantle velocity distributions and unequivocally define the Moho boundary from analysis of both reflected and refracted phases, generated by an industry standard airgun array with certain specifications.
- > Extension of 3D imaging capability, utilising OBS-recorded signal from 3D surveys at larger offsets than achievable with streamer survey configurations.
- > Analysis of background noise and understanding the interaction of broadband airgun generated signal and the ocean/Earth system.

**THE FREQUENCY RANGE CAN
BE ENGINEERED TO SUIT
THE PROJECT REQUIREMENTS.**

Sensors

Our OBS range is designed for flexibility.

Depending on your objectives, the ambient noise level in the deployment environment and your target depth we can incorporate the sensor or sensors that will give you the dynamic range you require. We can also undertake preliminary noise surveys prior to full deployment in order to optimize the exact sensor choice.

Multiple sensors/Hybrid response

If desired, we can incorporate multiple sensors into a single OBS node, for example a 3T and a 5T, likewise hybrid responses can be engineered for medium and strong motion applications for example with induced seismicity applications.

	SENSOR MODELS	FREQUENCY RESPONSE	APPLICATIONS / ENVIRONMENT
Weak motion	Güralp -3T	120 s – 50 Hz	High sensitivity (low clip level) suitable for a low noise environment for applications such as global earthquake monitoring.
Medium motion	Güralp -6T	60 s – 100 Hz	Medium sensitivity, suitable for a high noise environment (e.g. shallow water) for monitoring of local seismicity, induced seismicity, airgun sources.
Strong motion	Güralp -5T	DC – 100 Hz	Low sensitivity (high clip level) suitable for monitoring strong ground shaking such as for earthquake early warning and structural health monitoring.

We can incorporate the following multidisciplinary sensors into our instruments depending on your requirements:

- > Compass and Magnetometer
To determine instrument orientation, improving data analysis.
- > Hydrophone (1 Hz – 30 kHz)
To widen the bandwidth of the OBS system, for example for high frequency airgun shots.
- > Acoustic Current Meter
Used to monitor seafloor currents for scientific purposes, and to correct the seismometer signals for current noise, dramatically cleaning waveforms.

- > Pressure gauges
Our OBS systems can incorporate differential pressure gauges (DPGs) or absolute pressure gauges (APGs).

APGs can monitor permanent vertical deformation over very long timescales (uplift/subsidence) – seafloor geodesy e.g. determination of fault movement, or permanent oil/gas reservoir monitoring.

During large earthquakes APGs can be used to map fault movement, making them valuable for seismic hazard assessment.

DPGs and APGs are both sensitive to sea surface motion, making them a key tool in tsunami warning systems.

Pressure gauges can be used to correct for ocean noise due to tidal forcing and ocean currents and allows seismometer signals to be corrected for this noise, leading to improved seismometer waveform clarity.

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



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