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## Utilising ocean bottom seismometer platforms for tsunami early warning and hazard assessment

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Seismic instrumentation is critical for instantaneous tsunami early warning systems as well as assessing long-term risk of tsunami activity in areas with high seismic hazard. Ocean Bottom Seismometer (OBS) systems provide real-time data in areas with appropriate infrastructure or batch data from offline temporary autonomous stations.

OBS systems detect ground motion from seismic waves significantly before detecting any pressure change in the water column from an associated tsunami due to the order of magnitude difference in wave velocity. Guralp's OBS systems combine seismic and pressure detection in both permanent cabled networks and temporary non-cabled systems utilising near-real-time acoustic transmission. All seismic sensors used in Guralp systems are sensitive to both earthquakes as well as other tsunami-triggering events such as landslides (e.g. Anak Krakatau, 2018) or volcanic eruptions (e.g. Hunga Tonga–Hunga Haʻapai, 2022).

Cabled systems provide obvious benefits of real-time data, confidence of installation and flexibility to add additional instrumentation without power consideration. For example, Guralp Orcus and Maris cabled OBS systems are both deployed off the western coast of North America monitoring volcanic and tectonically induced earthquakes that have potential to cause tsunamis. Seismometers at these stations coupled with pressure gauges allow for immediate notification of a threat and subsequent refinement of hazard estimates using surrounding assets such as dedicated DART buoys.

Both Orcus and Maris allow for multiple auxiliary systems to be incorporated into the system while maintaining as well as providing additional installation flexibility for operators. Orcus has facility for both strong & weak motion seismometers in addition to auxiliary sensors while Maris has the unique feature of operating at any angle without the need for a gimbal mechanism, simplifying installation and network design considerations.

The Guralp Aquarius is the latest generation autonomous OBS for short-to-medium term or rapid response campaigns to monitor areas with increased seismic and tsunami hazard. Aquarius also uses omnidirectional capabilities as well as acoustic communication of seismic data to the surface to improve operator confidence of installation. Acoustic communication also allows for near-real-time communication with land-based warning systems after a significant seismic event in anticipation of a tsunami. This can be verified and communicated after the initial seismic wave

using onboard pressure gauges. In areas where surface communication is not required, intelligent battery systems optimise deployment lengths beyond 18 months for maximum data/cost benefit.

Güralp is also pioneering the use of seismic sensors and auxiliary equipment within Science Monitoring And Reliable Telecommunications ("SMART") cables which have already been shown to be useful in incorporating pressure gauges to detect tsunami events. These cables utilise regular telecommunication cables making uses of their natural communication and power source qualities to improve sensor network coverage. Güralp is currently manufacturing a demonstration system to be deployed in the Ionian Sea, monitoring seismic and volcanic activity with the aim of indicating practicality and data quality using this installation method.