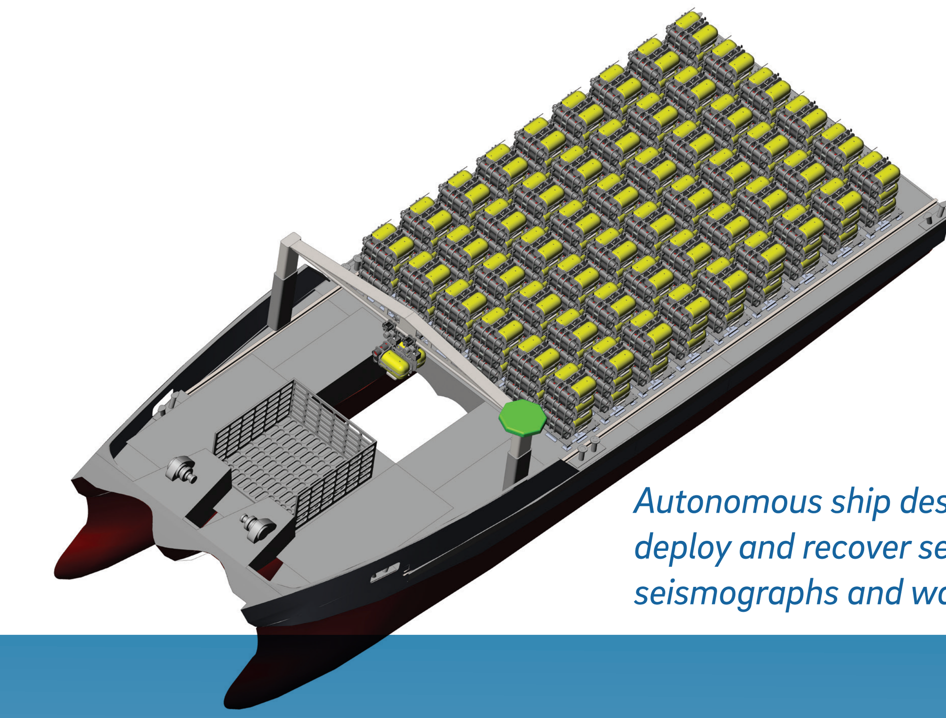
Long-Term, Global Seafloor Seismic, Acoustic and Geodetic Network



Autonomous ship designed to deploy and recover seafloor seismographs and wave gliders

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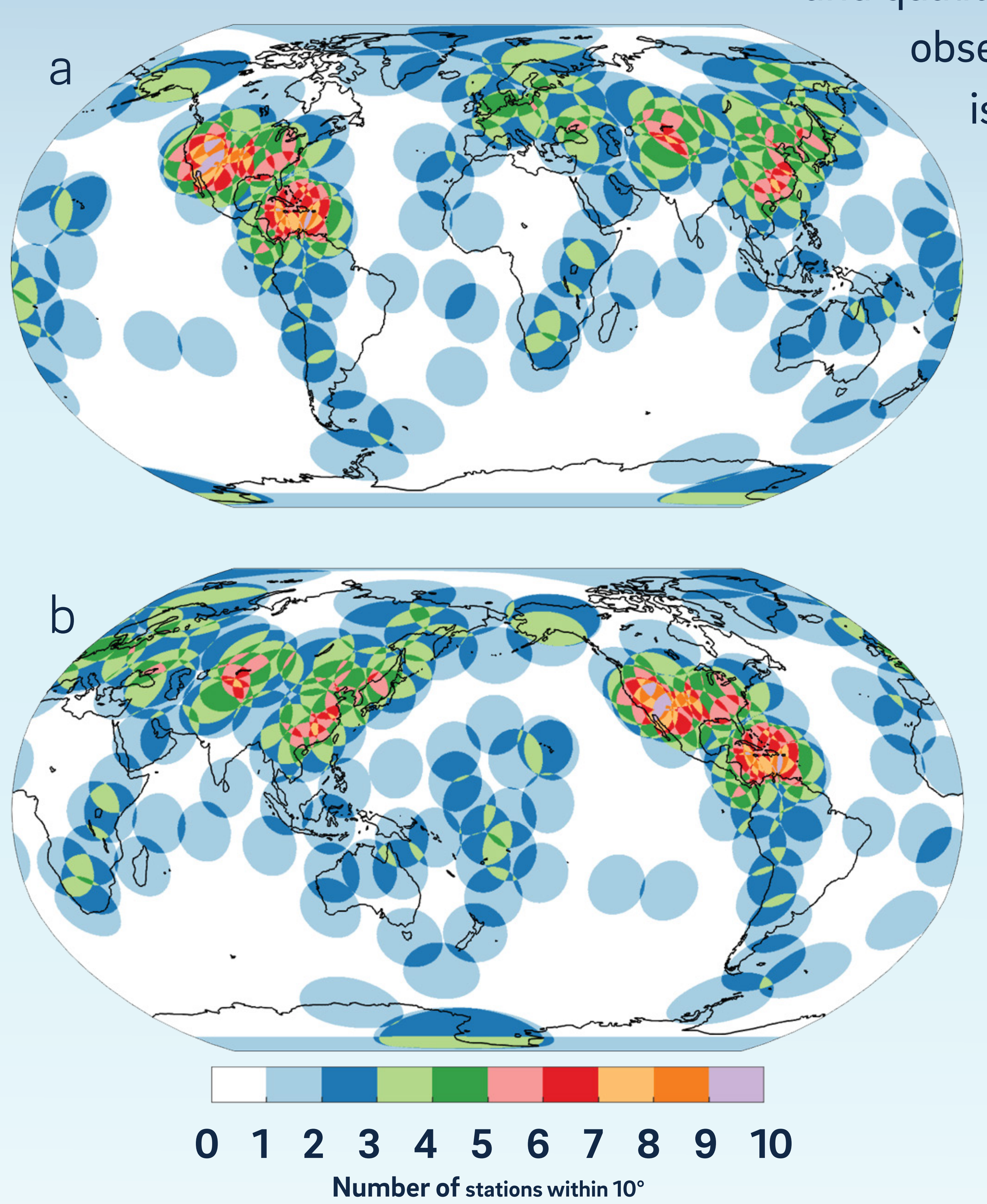
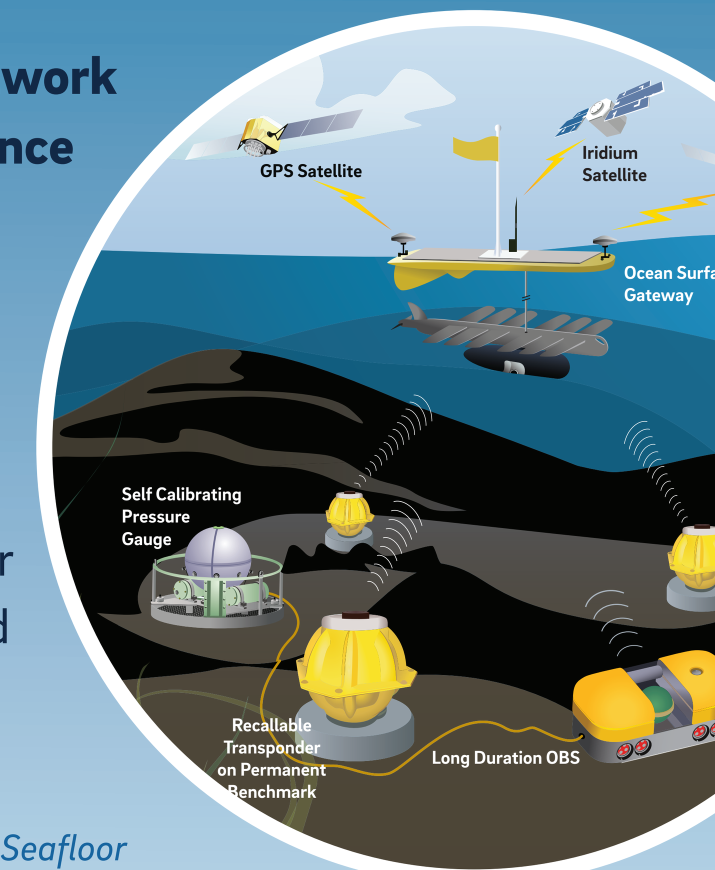
Hundreds of broadband seismic and geodetic stations have been deployed on continents and islands over the past 50 years. Most of these stations now provide near-real-time data to locate and quantify potentially damaging events, which may include tsunamis, large earthquakes or indications of nuclear tests on land or in the oceans. From the scientific point of view, the continental and island stations have provided data necessary for inferring the elastic and inelastic structure of Earth. However, the continents comprise less than a third of Earth's surface. The fidelity of the inferences of three-dimensional structure is poor, given the geographic limitations of current observatories. Ocean thermometry using low-power acoustics has been applied to make measurements of ocean temperatures over great distances. International collaboration in extending the number and quality of geophysical observations is essential. Participation of many countries and universities will be required to develop new technologies, artificial intelligence related to autonomy, and educate students with skills related to vehicle autonomy.



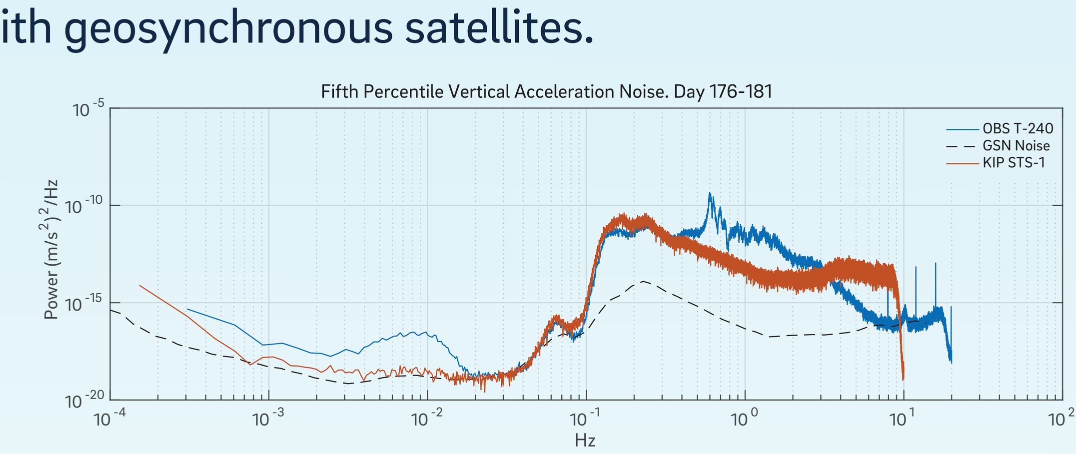
Global Seismographic Network (GSN) station coverage as represented through geographical density of stations. (a) Africa centered; (b) Pacific centered. Color contours show the number of GSN stations within 10°of each point on the maps (Figure: Andy Frassetto).

The establishment and maintenance of the proposed network will depend upon the design, construction and maintenance of a small number of autonomous ships capable of operating in the world ocean without a dedicated crew. Currently, with support from the Office of Naval Research and NSF as well as industry, industry has developed small, autonomous vehicles that are capable of operating autonomously using wave power to propel the vehicle and solar cells to provide electrical power (in particular, the Boeing/Liquid Robotics wave gliders). In addition, these gliders have exploited small antennae for internet connections to laboratories ashore. The Navy's Sea Hunter autonomous ship has successfully traveled from San Diego to Pearl Harbor and back with no personnel on the ship. The Sea Hunter has recently been joined by the Seahawk. Both were designed and built by Leidos with support from DARPA and the Office of Naval Research (ONR).



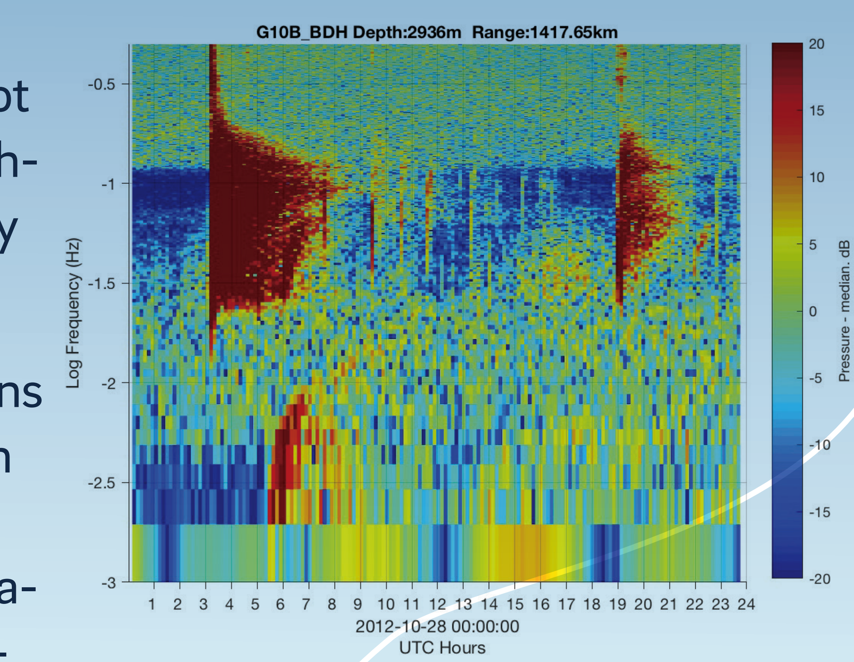
Seafloor Gateway network enables real-time data and command/control, minimization of ship costs, and acoustic modem efficiency. The use of small satellite date telemetry increase bandwidths to Gbps levels. Telemetry costs are minimized through the use of platform agent software.

Pioneering work has been done by the US Navy as well as large companies that transport goods and autonomous ships and smaller platforms that are used to collect ocean and seafloor data including mapping. In Norway, experiments are underway to develop autonomous ferries at fjords. While digital communications with research vessels at sea are now common when coupled with geosynchronous satellites, the hardware is too large for small, autonomous vehicles. The exploitation of Low Earth Orbit (LEO) satellites for communications is becoming more common. Small antennae on autonomous vehicles can operate at speeds many times those available with geosynchronous satellites.



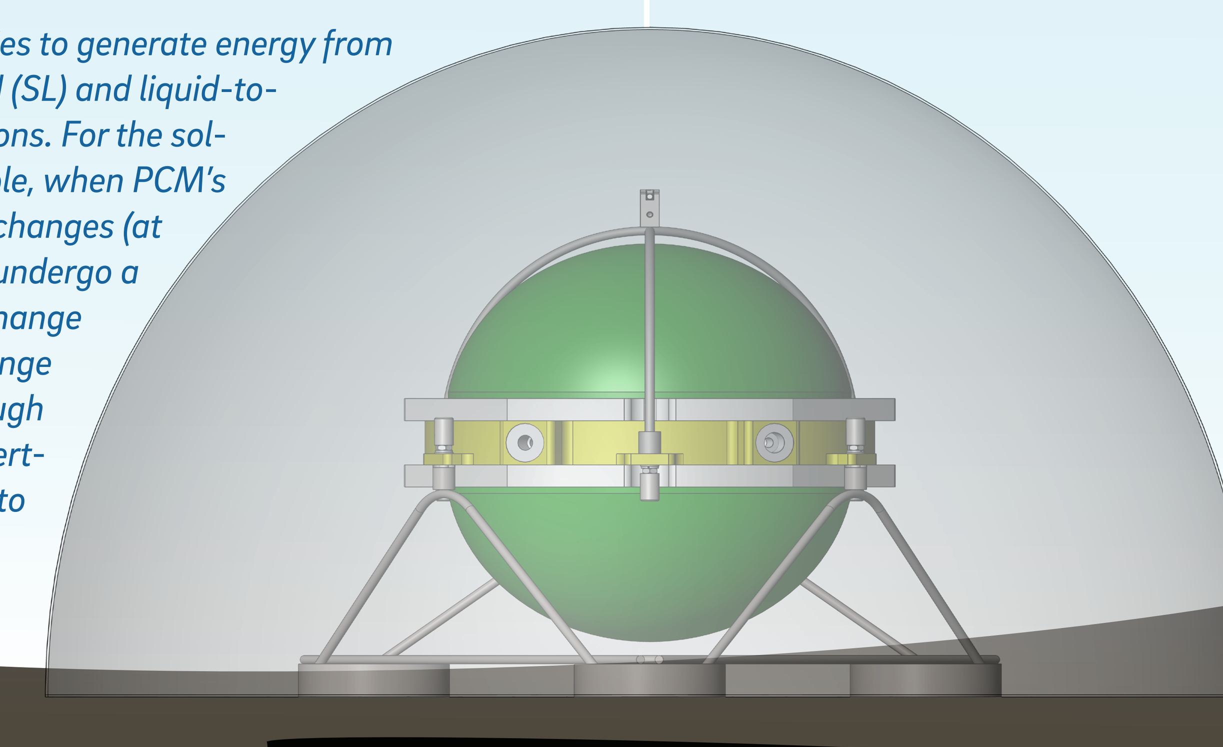
Power spectrum showing the noise levels on an OBS during a four-day period when wave action was at a minimum. The dashed line is an estimate of broadband noise on continental seismic stations. The red line is taken from the IRIS GSN station on Oahu (KIP) – a particularly low noise level for islands. The blue line represents the OBS noise at a site in the eastern North Pacific. At low frequencies the noise levels at KIP and the OBS are close. At high frequencies above 7Hz, the OBS record lies on the low levels of land observations.

The autonomous systems for scientific seafloor mapping, ocean sampling, and seafloor system maintenance depends upon a global distribution of autonomous ships and qualified technicians and scientists. Data essential for hazards observations and warnings (e.g. tsunamis or nuclear test detection) require international involvement. For example, the Global Seismic Network is an international undertaking that involves many countries, universities and government organizations. A coherent global network of seafloor instruments cannot be built and operated without the involvement of many governments worldwide.



This is a spectrogram of data from a differential pressure gauge (DPG), which depicts the frequency content of seismic waves from the Haida Gwaii earthquake on 27/10/2012 about 1100km north of the OBS. The higher frequencies (0.1 Hz) show the earthquake body and surface waves including a later aftershock. The lower frequencies (0.0018-0.001Hz) show a chirp, which depicts the tsunami which was excited by the earthquake.

Presently, Seismologists, acousticians and geodesists working in the ocean depend upon regular access to the deployed instrumentation on the seafloor to collect data and replace batteries. In the case of seismology, the instruments are brought back to labs for data access, maintenance and preparation for the next deployment. Long term measurements are largely impossible. In the case of continents, small government and university groups maintain stations on land with visits every 1-5 years for maintenance and upgrades. Nearly universal access to telemetry with instruments on land has led to essentially 100% data return of well-timed data.



Seatrec has technologies to generate energy from both the solid-to-liquid (SL) and liquid-to-gas (LG) phase transitions. For the solid-to-liquid (SL) example, when PCM's experience temperate changes (at the thermocline), they undergo a phase transition and change volume. This value change will drive a motor through pressurized fluid, converting hydraulic energy into electricity.

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