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Son-O-Mermaid: A Green Instrument Platform for the Blue Ocean

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Exploration of the Earth's uncharted interior through global seismic tomography depends on increasing the number of seismic stations where they are scarcest: in the oceans. The high costs and technical challenges of deploying and recovering ocean-bottom devices make them unlikely to contribute to sufficiently dense sustained instrument coverage in the near term. Low-cost, freely-floating autonomous hydrophone arrays are the solution, at least for *P* wave tomography.

Despite proven potential, the MERMAID ("Mobile Earthquake Recording in Marine Areas by Independent Divers") concept has shortcomings that we address through a complete redesign. Long time series of acoustic pressure collected at depth drive this design process, which focuses on the solution that will deliver the most accurate, reliable, and lowest-cost tomographically useful teleseismic travel times. The hurdles that need to be overcome and the problems solved to make this instrument of use for seismology set a very high bar in terms of energy efficiency, measurement accuracy, and longevity, and as a result, future generations of it should be easily adapted to less demanding data collection exercises, be they physical, chemical, or biological.

Son-O-Mermaid is a new, fully autonomous, and long-lived instrument. Unlike MERMAID it is a freely drifting buoy that (1) derives energy from wave action, enough to power (2) a vertical array of three hydrophones suspended from a compliant cable connected to a damping plate below the waves (3) a full-ocean depth echo sounder, (4) GPS for location and timing accuracy, (5) an IRIDIUM satellite communication unit for near real-time data transfer, and an (6) on-board digitizing and processing unit that uses wavelet detection and discrimination algorithms.

The Son-O-Mermaid consists of a floating sphere with a combined GPS-IRIDIUM antenna and data logging equipment, which forms the top part of an environmentally friendly system of "heave response electrical power generation". Wave buoy electrical generators, whose development was sponsored by the Defense Advanced Research Projects Agency (DARPA) and the Office of Naval Research (ONR) have been around for a few years now, and commonly operate as one of three types differing mainly in the nature of the response to ocean wave periods. [1] They could be anchored, [2] they might be simple spar buoys, or [3] they may have a damping plate such that the differential motion of the buoy and the plate can be used for energy harvesting. The first option is impractical due the large cost of deployment and the potential flow and cable noise induced that will most certainly compromise seismic event detection, and we favor the third option because the damping plate will do double duty in lessening the coupling of the wave motion to the hydrophone cable.

The fathometer eliminates the ocean bottom depth as a variable in determining the travel time of teleseismic waves, which can thus be measured with maximal accuracy. As an additional benefit it will also deliver useful data for the high-resolution study of Earth's global bathymetry, and because Son-O-Mermaid is a drifting instrument, surface currents will be another byproduct. The hydrophone array configuration eliminates non-propagating noise and suppresses surface multiples. Materials and manufacturing costs of Son-O-Mermaid are targeted to be less than a third of those of MERMAID, themselves about a third those of conventional ocean-bottom seismometry equipment. The Son-O-Mermaid is to be deployed by untrained personnel from ships of opportunity, which gives it an extra advantage over conventional approaches.

The current state of mantle tomography is limited by data availability; sampling is poorest in the southern hemisphere, which is marked by a number of mantle plumes, which drive the heat engine that cools the deep Earth. Son-O-Mermaid (1) finalizes the design of a new oceanic instrument with a history of promise, (2) will collect long time series of underwater acoustic data for training purposes, and (3) is expected to be a front-runner for the regional and global oceanic arrays of the future. These will contribute to physical, chemical and biological oceanography as well as seismology. The Son-O-Mermaid is an instrument *platform*; seismology its first and most demanding measurement application.