Seafloor to Surface to Satellite to Shore

Moored buoys offer potential for continuous, real-time observations anywhere in the ocean

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The next great leap in our understanding of the earth-ocean system will require us to put our "eyes" and "ears" in the ocean to observe the dynamic processes going on there as they are happening, in real time. In the oceans, physical, chemical, biological, and geological processes are continually interacting—over time scales ranging from seconds to millions of years and on space scales ranging from centimeters to the globe.

A key new tool to untangle these complex interactions will be ocean observatories, with sensors taking measurements in the water column, on the seafloor, and in the earth below. These observatories will require two-way communications capabilities to remotely control instruments and to transmit data in real time back to shore. And they will have to provide power to operate instruments unattended for months or years at a time.

The Dynamics of Earth and Ocean Systems (DEOS) program (see article on page 2) is exploring two technologically distinct approaches for seafloor observatories. The first entails using dedicated cables to link observatories to shore (such as the LEO-15, Martha's Vineyard, H2O, and NEPTUNE projects described elsewhere in this issue). The second involves linking observatories to moored buoys on the ocean surface and transmitting data back to shore via a constellation of Earth-orbiting telecommunications satellites.

Moored ocean buoy observatories have certain advantages. They can be located in very remote ocean areas, far from land, where the cost of laying a fiber-optic cable would be prohibitive. They are also portable and potentially could be used for shorter-term (two- to five-year) studies in one area, and then moved to a new location. This provides greater flexibility, as circumstances change, to reconfigure experiments that track processes continuously over long time periods. It also gives scientists the ability to respond in time to observe transient natural events, or even relocate to a new site, as their knowledge of an area increases incrementally over the course of a study.

Moored buoys, however, have certain limitations. They can't supply as much power to instruments as a fiber-optic cable can, and they can't transmit as much data via satellite. They also require more frequent servicing.

The ability of buoyed observatories to make long-term measurements of ongoing processes anywhere in the world's oceans gives them the potential to play an important role in oceanographic and climatic studies.

Moored buoy systems have been deployed in the deep ocean since the 1950s as platforms to acquire meteorological and oceanographic data in the upper ocean (see article on page 20), but they have not been used for seafloor observatory studies. So important design questions remain: What is the optimal buoy shape (spar- or disk-shaped floats)? What is the best mooring design (single-point or three-point)? What is the best way to isolate the electromechanical cable connecting the buoy to the seafloor from wave and current motion? How can maintenance costs be curtailed?

We are currently working with colleagues at the Scripps Institution of Oceanography and the Monterey Bay Aquarium Research Institute, and with a partner from industry, Deep Oil Technology, to design and build a prototype moored ocean buoy seafloor observatory for use in the deep ocean.

One design under study (right) consists of a large (4 to 6 meters in diameter) discus-shaped buoy on a single S-tether mooring, connected to an array of sensors on the seafloor. The S-tether mooring design, developed at WHOI in the early 1990s, combines the advantages of a subsurface mooring (isolation from surface waves and currents, durability and long life, and low cost) with the capabilities of a surface mooring (access to satellite telemetry and a platform for power generation).

It would consist of a surface float, a subsurface float, an "S"-shaped cable connection between the surface and subsurface floats, a standard mooring from the subsurface float to a seafloor anchor, and an on-bottom segment from the mooring to a seafloor junction box.

A variety of sensors (thermistors, flow meters, chemical sensors, seismometers, magnetometers, hydrophones, strain meters) could be plugged into the junction box. The box would transmit power from the surface buoy to these instruments through a double-armored, multi-conductor cable. Data from seafloor sensors would be transmitted up the cable to the surface float for transmission back to shore.

The electromechanical cable would connect to a large subsurface float—a sphere made of buoyant

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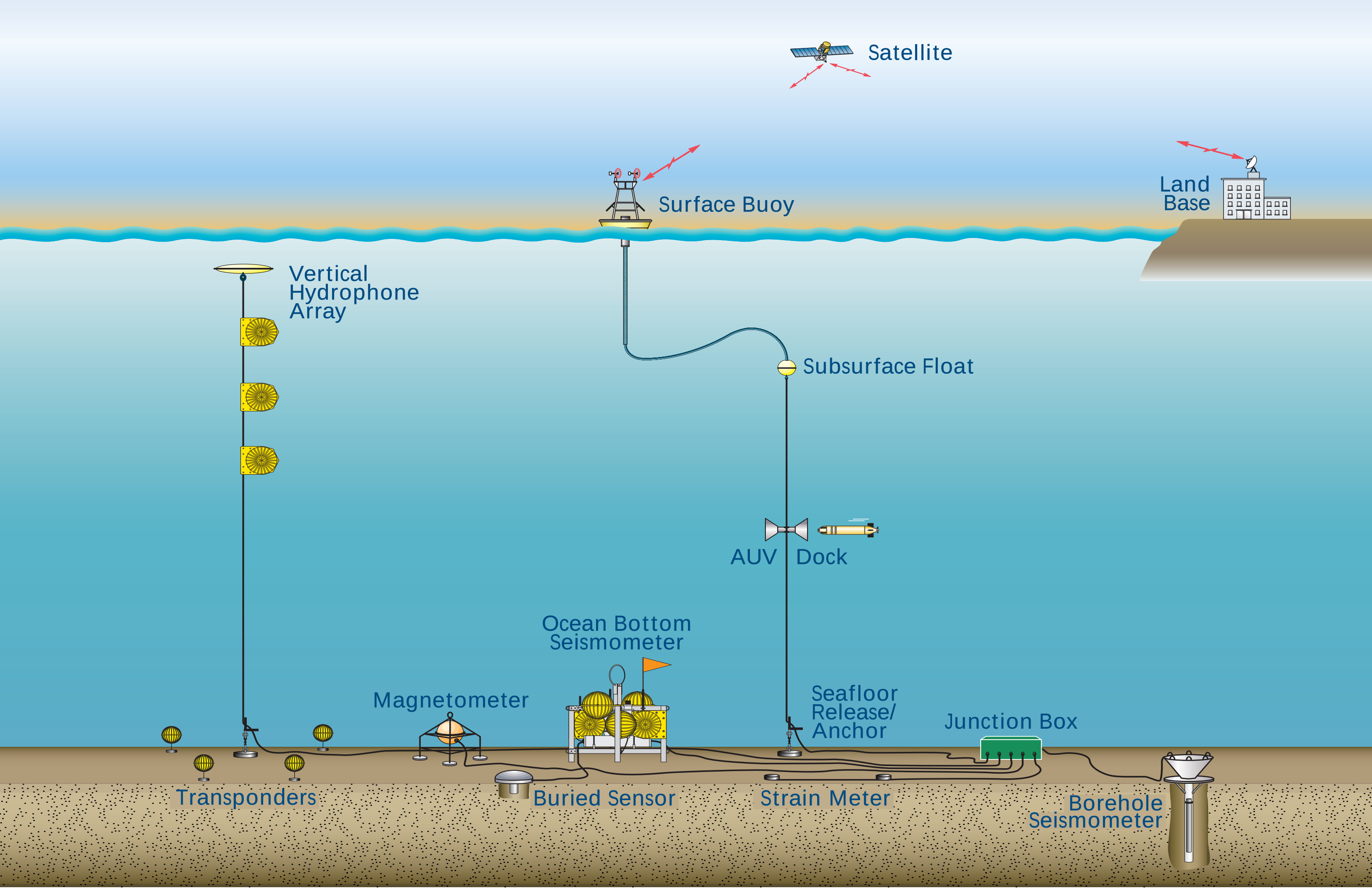

syntactic material to support the weight of 3,000 meters of cable. A fluid-filled, stretchable rubber hose with an integral coil of electrical conductors would connect the subsurface and surface floats. By carefully distributing flotation along the upper cable section, we can maintain an “S”-shaped tether to effectively isolate the subsurface float from the motion of the surface buoy.

The surface float would be made of a Surlyn foam that is frequently used in marker or navigation buoys in shallow waters. It combines durability, light weight, and low cost. Solar panels, diesel generators, and batteries mounted on the buoy could provide up to 500 watts of continuous power to instruments on the seafloor. An omni-directional antenna atop the buoy would provide bi-directional communication via satellite to shore. We anticipate that a system like this would require annual servicing.

A moored ocean buoy observatory of this design could be used in a variety of experiments requiring long-term observations and real-time data telemetry. For example, a buoy observatory moored over a volcanically active section of the East Pacific Rise or Mid-Atlantic Ridge could monitor all the dynamically interacting volcanic, hydrothermal, and biological processes that occur over two or three years.

Autonomous underwater vehicles (AUVs) could be stationed at a mooring. On command from shore, these AUVs could resurvey the surrounding area and upload their observations to the buoy for transmission back to shore.

Other buoys could be permanently deployed at some of the 20 strategic (and remote) ocean sites needed to fill large gaps in the global network of broadband seismic stations, greatly enhancing our ability to use seismic waves to image the earth’s internal structure. To study processes that generate earthquakes, buoy-based observatory systems linked to an array of seismic and geodetic sensors could be placed in earthquake-prone geological locales—along an ocean transform fault or above a subducting plate landward of an oceanic trench, for example.

The ability of buoyed observatories to make long-term measurements of ongoing processes anywhere in the world’s oceans also gives them the potential to play an important role in other oceanographic and climatic studies. They could track the flow of major currents along the oceans’ western boundaries or episodic upwelling of water and nutrients at eastern ocean boundaries. They could also be used for experiments using sound waves to monitor ocean temperature changes related to global climate change.

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In this prototype design for a moored buoy system, a surface buoy connects to an “S”-shaped tether that isolates a subsurface float from surface buoy motions. The surface buoy provides power via a cable to a seafloor junction box, that accommodates a variety of sensors. Data from the sensors travel up the cable to the surface buoy for transmission via satellite to shore.