Modernization and enhancement of active-source Ocean-Bottom Seismic (OBS) capabilities

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NSF's Marine Geology and Geophysics program operates the Ocean-Bottom Seismology Instrumentation Center (OBSIC) to support individual PI-driven science projects and community experiments using ocean-bottom seismic (OBS) sensors. Originally formed in 2001 as the OBS Instrument Pool (OBSIP), over its lifetime the NSF OBS program has supported over 60 individual experiments involving dozens of unique PIs and co-PIs, enabled at-sea training for early career scientists, and produced OBS data downloaded by nearly 4000 unique users (OBSIP Final Report, 2019). Demand for the instruments remains high, and for some instrument types the facility is fully subscribed through 2024.

In this document, the OBSIC Operations Subcommittee (OBSIC-OS[1]) provides a community perspective on the urgent need to address the lack of modern, high-quality instruments available to support active-source imaging experiments by US scientists. The current OBSIC facility[2] operates approximately 30 short-period (SP) instruments for active-source experiments, with approximately 60 additional SP instruments often available through a subcontract relationship with an external provider. SP instruments are critical for imaging Earth's crust and upper mantle at high spatial resolution at a lower cost than broadband seismic sensors. The currently available instruments use over 20-year-old technology, which limits their scientific potential, and makes them expensive to operate and maintain.

The current facility hampers scientific advancement and innovation:

- The small number of SP instruments prohibits US scientists from conducting frontier, state-of-the-art experiments with close instrument spacing for high-resolution active-source imaging. Limited instrument availability leads to inefficient active-source experiments that require complex deployment – shoot – recovery – redeployment – shoot – recovery sequences using heterogeneous instruments from multiple providers. Such strategies limit the scientific return (reducing on-bottom time and 3D recording opportunities) and are expensive in terms of personnel and ship time.
- Existing instruments are large and cumbersome compared to modern designs, and their complexity requires expert personnel for deployment, operation, and maintenance. These factors significantly drive up experiment costs (specifically shipping, travel, and salaries), further increasing the base cost of scientific return.
- Performance of aging SP sensor components is increasingly unreliable, which restricts their usage in deep water, raises the cost per useful datum, and further reduces the effective number of instruments and science output overall.

The scientific rationale for improved active-source imaging capability is clear, with significant benefits to programs in multiple divisions within NSF's Geosciences Directorate. Two of the decadal OCE research priorities (ocean-basin evolution and forecasting geohazards) outlined in the National Academies' "SeaChange" report require improved seismic imaging from the oceans. The 2015 report on "Future

Geophysical Facilities Required to Address Grand Challenges in the Earth Sciences" considers 100 active-source OBS as a foundational facility, deemed critical for achieving several EAR priorities described in the National Academies' "Catalyzing Opportunities for Research in the Earth Sciences (CORES)" report. Improved active-source imaging is also a prerequisite for the Implementation Plan for the SZ4D Initiative, as well as the USGS subduction zone science plan. Common to these programs is the need to efficiently conduct active-source imaging of the crust and uppermost mantle with sufficiently high resolution and large spatial scale, with a focus on critical properties such as temperature, composition, fracturing, and the presence of fluids such as magmas. These properties have significant variations at all length scales, and increasingly higher-resolution analyses are required to constrain the associated dynamic processes. In groundbreaking, iconic examples exploiting more expansive OBS facilities, Japanese scientists have demonstrated that volcano crustal thickness and internal structure vary over length scales of <20 km for over 1000 km of arc, and captured spatial variations in crust and mantle hydration in subducting plates with length scales of 10's of km over 500-km distance. Imaging such structures, even in 2D, required 200 short-period OBS deployments, far beyond the currently available OBSIC instruments. Equivalent imaging in 3D is presently impossible. Addressing the aforementioned decadal priorities identified by the US earth and ocean science communities requires a significant improvement in imaging capabilities. Without this necessary improvement, the US community risks falling behind those elsewhere including China and the European Union.

Recent changes in seafloor technology provide an opportunity to develop and build a new generation of SP OBS instrumentation that would elevate the scientific capabilities of the OBSIC program to a new level. Several seismic instrument vendors now offer products specifically for the seafloor environment. These instruments offer low-power sensors, data loggers, clocks, rechargeable battery systems, and procedures for faster and easier deployment and recovery that will reduce technician costs and ship time. Vendors serving the energy industry have developed highly specialized systems that are compact and easy to operate in numbers well above current OBSIC capabilities. These systems allow for refurbishment and recharging at sea, enabling them to potentially remain on board as part of a seismic research vessel's standard equipment. These instruments present an opportunity to form the nucleus of a new, and substantially enlarged, OBSIC SP fleet. This fleet will enable 2D active-source experiments at unprecedented spatial scales and density, allow for 3D experiments that are currently impossible, and do so with a significantly lower cost per deployment.

As representatives of the US science community engaged in OBS-based research, we encourage the OBSIC facility to pursue new funding that will enable it to take advantage of technological advancements that provide new opportunities for science. At this time, we specifically encourage development and procurement of a new SP fleet. Most recent advances in SP OBS have been driven by the energy industry, so direct adaptation of these instruments is not feasible due to their limited maximum depth and expensive (generally remotely-operated vehicle) deployment methods. New OBSIC SP designs should incorporate key components of the latest industry models: rechargeable power systems; small, easy-to-handle designs that streamline deployment, recovery, and data download; an on-board system that could be housed on the Langseth and any future UNOLS marine seismic facility vessel; and reduced reliance on dedicated OBSIC staff at sea. Other detailed specifications should follow the "Technical Specifications" guidance of previous OBSIP/OBSIC committees[3] wherever possible.

The role of the OBSIC-OS is to provide operational guidance and assistance to the OBSIC facility in serving the NSF community. While we do not have a specific role in instrument development, it has become clear from our interactions with the OBSIC facility, as well as from experiences in the user community, that an infusion of new SP instrumentation would greatly enhance the effectiveness of the facility for supporting science. We encourage the OBSIC facility operator to pursue funding opportunities to support these developments.

Submitted by the current and recent membership of the OBSIC Operations Subcommittee:

James Gaherty, Northern Arizona University (Chair)
Kasey Aderhold, IRIS
Emilie Hooft, Univ. of Oregon
Helen Janiszewski, Univ. of Hawai'i at Mānoa
Ross Parnell-Turner, Univ. of California, San Diego
Susan Schwartz, Univ. of California, Santa Cruz
Lindsay Worthington, Univ. of New Mexico

[1]For details on OBSIC-OS see https://www.unols.org/committee/ocean-bottom-seismometer-instrument-center-operations-sub-committee-obsic-os

[2]For details of the OBSIC facility and available instrumentation, see https://obsic.whoi.edu

[3]http://www.obsip.org/instruments/functional-specifications/