

Report to NSF: Future of Marine Seismics Workshop
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Approximately 40 representatives of the academic community and the private sector met for two and a half days (April 1-3, 2019) at NSF to identify viable options for maintaining U.S. academic marine seismic capabilities comparable to that currently available on R/V *Marcus Langseth*. Another ten individuals joined the meeting remotely. The meeting, facilitated by Knowinnovation Inc., was a response to the NSF decision to divest itself of ownership of the R/V *Marcus Langseth* by mid-2020 and to restrict facility funding for deep crustal and 3-D marine seismic operations after divestment to no more than \$10M/year over an initial period of five years. The workshop included senior and early career scientists, academic administrators, research ship operators, NSF and ONR program staff, and representatives of the commercial sector involved in ship operations and seismic data collection offshore. Both US scientists and foreign scientists participated.

Prior to the meeting, two webinars were held to refine options to be discussed at the meeting. A link to the 'options paper' on which the webinars were based is at the end of this document. In addition, NSF provided a set of criteria to meeting participants that must be met by any successful solution. All options were assessed against these benchmarks.

NSF Goal and Requirements:

Determine if there are viable models for providing marine seismic capabilities to the community and a strategy for implementing these models, with the following criteria:

- There is a cap of (up to) \$10M from NSF/OCE per year for the facility, inclusive of ship, technical requirements, and marine mammal mitigation.
- Science funding is separate from above and is contingent on receipt and award of high quality research proposals.
- NSF will not own the vessel.
- There must be a potential for expanding the ship user base and funding sources beyond NSF.

NSF also provided these additional points to evaluate for each potential model:

- Data acquisition capabilities
- Global access/availability
- Ancillary data collection
- Cruise planning needs
- Opportunities for education, training, and outreach

The pre-meeting document identified three initial options and three variants, which were designated 1, 1A, 2, 2A, 3 and 3A. Links to the workshop reports are included at the end of the document to provide more detail.

- **Options 1 and 1A:** a private entity, institution or consortium of institutions purchases and outfits a general purpose oceanographic vessel with seismic capabilities and operates it as part of the Academic Research Fleet (with the 1A option being purchase of R/V *Langseth* from NSF by a private operator and operated as a general purpose vessel.) It is preferred that these options would allow cross-decking and continued use of existing seismic equipment currently on R/V *Langseth*.
- **Options 2 and 2A:** a private entity, institution or consortium of institutions purchases and outfits a ship for use only in seismic operations, with 2A being R/V *Langseth*.
- **Options 3 and 3A** represent different methods of leasing vessels with seismic capabilities. Option 3 involves a long-term lease (~5 years) with a single commercial operator providing one or more vessel(s) as required to meet NSF-funded science objectives. Option 3A involves setting up a contracting office at a research institution to negotiate individual charters of commercial or foreign academic seismic vessels of opportunity as need arises.
- **"New Option 2"** was developed during the course of the meeting, when a proposal was presented by the JAMSTEC representatives, who offered to provide their ship R/V *Kaimei* to US researchers for collaborative projects at a fixed rate far below its operating cost. This was developed into a broader recommendation encouraging collaboration in both directions and extended to other countries.

Issues addressed by attendees:

Before discussing each option, presentations were made by leaders of the three institutions conducting most of the marine seismic research in the US (LDEO, UTIG and SIO) and by representatives of the commercial sector. Following these presentations, participants engaged in discussion and expressed some general concerns about future directions. There was near-unanimous belief on the part of the participants that in order to maintain US deep crustal and 3-D marine seismic research capacity, all efforts should be made to avoid a hiatus in seismic data acquisition operations after mid-2020. There was also a consensus that to ensure this lack of hiatus, and to clearly demonstrate a long-term commitment to the collection of deep crustal and 3-D marine seismic data, NSF should continue to call for the submission of proposals that involve seismic field data collection. This call should not require a research team to provide full information and cost of the facilities to acquire the data. This would reverse a recommendation in Dear Colleague Letter 18-061, which stated

*“Until such time as a new approach for provision of seismic capabilities is in place, NSF will continue to accept proposals that include large tuned-source, long-offset data acquisition, **but access to these capabilities will need to be coordinated by Principal Investigators as part of their proposals, through industry providers or international/institutional partners.** Should a sustainable new approach not be in place by the end of R/V Langseth operations, this practice will continue until a new approach can be identified and implemented.”*

Workshop participants felt that DCL 18-061 had a chilling effect on young investigators, and they were particularly concerned that early career researchers need firm assurance of NSF’s commitment to maintain access to marine seismic capabilities, as requested in the FY 2018 House and Senate Appropriations Act, which stated

The agreement reiterates the importance of ensuring that NSF-funded marine research vessels with unique seismic capabilities remain available to the academic marine geology and geophysics community to support a variety of important undersea research efforts.” (FY 2018 Omnibus Appropriations Act)

There was broad agreement at the meeting that student training in field operations is an essential component of marine seismic education. Careful attention needs to be paid to how student training will be carried out in any option that is adopted in order to maintain a healthy user community through the sustainable production of investigators with deep knowledge of, and interests in, marine seismic approaches, as noted in the MSROC white paper on the Broad Characteristics of an Academic Active-Source Seismic Capability (see link to background material at end of this report). Importantly, it was made clear that the immersive experience of participating in seismic-based geophysical cruises is both 1) essential to providing students and young investigators with a deep understanding of the data collected at sea and, by virtue of the engaging nature of the experience, and 2) a critical factor in transforming student participants into active investigators at a sufficient rate to maintain a sustainable number of researchers in marine seismology and marine geophysics broadly.

Finally, there was also broad agreement about the critical importance of seismic data to support IODP drilling. The crucial importance of the link between scientific ocean drilling and marine seismic imaging (at various scales of resolution) was often highlighted during the workshop. The group was also made aware of recent NSB support for continued NSF support of *JOIDES Resolution* IODP operations for the period 2019-2023; it was emphasized that IODP’s future success would in part depend on robust access to high quality seismic imaging capabilities by US investigators. The apparent lack of financial participation by the NSF programs that support IODP drilling in the support of related seismic research (including facility operations) was viewed as an area in need of internal NSF correction. Specifically, the workshop recommended that a portion of the NSF/OCE budget should be specifically dedicated to support ship time for IODP-related geophysical surveys. Information further addressing this issue was provided by NSF post-meeting as is noted in the final section of this document.

In addition to the IODP connection, some workshop participants felt that improvement of communication between the GEO Divisions of EAR and OCE might provide additional support for deep crustal marine seismic activities. In past decades EAR funded onshore-offshore experiments using MCS technology and the cross-disciplinary research benefited both divisions and their affiliated scientists. Additionally, EAR, in conjunction with OCE, made excellent use of MCS reflection and OBS refraction data in developing physical models of the

transition from oceanic to continental crust, lithosphere and underlying asthenosphere. A goal of the new chair of the UNOLS MSROC will be to improve communication between UNOLS and the NSF programs that can take advantage of deep crustal and 3-D MCS technology, and ensure that scientists and program staff in both OCE and EAR at NSF are aware of the capabilities and proposal guidelines to access these techniques.

There was a general concern about the rationale for the specific \$10M limit of funds from NSF/OCE imposed on spending, as well as some confusion about what specifically is included in this cap. This cap seems to include two parts. The first part is a cap on NSF funds paid from the Ship Operations Program for R/V *Langseth* ship days. This cap on support for any single award applies to all UNOLS vessels, and it is currently about \$9 million annually. Awards from one program cannot be higher unless specifically approved by the National Science Board (as is the case for funding for ocean drilling, for example). This level changes annually as a percentage of the NSF/OCE budget. The second limit on funds is described in the 2017 NSF proposal solicitation NSF 17-563 and this is a more general cap on NSF funds to be used for '*Langseth* type' seismic acquisition (\$10 million annually). It does not have a specific underlying regulation, nor was it entirely clear in the workshop what specific costs are included. In some instances it seems that these two types of NSF expenditures could be summed together to reach the \$10M limit imposed on seismic spending by NSF/OCE. An example described during the workshop noted that the 'cap' could be reached if NSF/OCE funds were used for \$5M of non-seismic work on R/V *Langseth* and another \$5M of NSF funds was used for crustal-scale seismic work on some other vessel. It remains unclear how this particular model for calculating 'capped' funds translates to the various options under consideration. It was learned after the workshop that the cost to operate R/V *Langseth* in 2019 will be approximately \$8.5 million for ship operations and \$2.7 million for technical support including environmental permitting, for a total of about \$11.2 million, all from NSF/OCE.

Cost savings and reducing NSF's exposure to environmental risk were described to the workshop as primary drivers for divestment. Based on information presented at the workshop, transfer of title to a University or contractor to continue operating R/V *Langseth* as a research vessel will not save NSF much money, if any. In the present market, the consensus is that R/V *Langseth* has a market value of essentially zero - the market is flooded with newer seismic vessels, and thus there is no significant market at the moment for either the ship or the seismic equipment (only part of which is owned by NSF, and much of which was acquired at deep discount or donation from companies with commercial ships that have been laid up). The workshop was also advised by NSF's Environmental Protection Specialist that most of the environmental rules (under NEPA, ESA, and MMPA) that apply to operations on NSF-owned R/V *Langseth* will also apply to NSF-supported research on any vessel, independent of ownership, since it is the source of the funding of the research (i.e. NSF) that guides whether NEPA applies and how the ESA and MMPA regulations affect a project. Notably, most of the industry representatives at the workshop were unfamiliar with the NEPA and MMPA regulatory framework that impacts NSF-funded operations outside of territorial waters, as these rules do not apply in the same way to commercial projects. Additionally, from the presentation by the LDEO Director, there appears to be no interest by the current R/V *Langseth* operator in offering the ship for commercial seismic operations, and thus tapping industry revenues to help support full year operations, unless it could be done in a manner allowing data to become public (i.e. rules similar to those imposed on federally-owned ships).

Part of the rationale offered for the \$10M cap was the goal of the Sea Change report to bring NSF/OCE's spending to a 50/50 split between research and infrastructure. At the workshop we learned from NSF staff that this goal has been reached. This led some workshop participants to question the need to continue to hold costs below \$10M, suggesting that this element of infrastructure support be allowed to grow again as the overall NSF/OCE budget increases.

Recommendations:

After carefully evaluating the range of options, including discussion of current commercial vessel costs and availability, the workshop concluded that except for original options 2 and 2A (a private entity, institution or consortium purchasing and refitting a ship for use only in seismic operations, with 2A being R/V *Langseth*), all other options were viable, but each has associated compromises and/or risks. With respect to option 2, the group concluded that despite the "buyers' market" for offshore survey vessels at the present time, the purchase,

conversion and operation of a dedicated seismic vessel would not be a viable option, given the limited funds available to support this type of research by NSF, and the stated opinion from Columbia University that their institution would not be interested in leasing a Columbia-owned ship for non-academic commercial work without an agreement that data would be freely shared (essentially the same concern expressed by NSF about federal ownership). This understanding led the participants to the conclusion that a general-purpose vessel (which provides the possibility of support for non-seismic operations) with seismic capabilities is more appropriate than a dedicated seismic ship, and thus the original Options 2 and 2A were eliminated from further discussion. Information about current availability of ships for sale or charter is provided through a link at the end of this document.

The workshop proposed short-term (transitional) plans and long-term solutions:

- **For the period between 2020 and ~2025, the workshop endorsed either Option 1A or Options 3/3A, with a preference for Option 1A – continuation of operation of R/V *Langseth* for up to 5 more years.** The workshop noted that operation could continue with NSF ownership, or it could go forward via sale (or donation) of the ship to a new owner, as title transfer away from NSF is a stated criterion of NSF. Should major maintenance or repair costs be needed to keep *Langseth* operating before a long-term solution has been implemented, then NSF can shift to a lease model, either from a single provider (Option 3) or from multiple providers via an institutional coordinator (Option 3A). The rationale for the preference of Option 1A over 3/3A is presented below.
- **For the longer term, beyond 2025, the workshop endorsed either Option 1 or Options 3/3A, with a preference for Option 1 – acquisition by a private institution, conversion and operation of a general purpose vessel with seismic capabilities as part of the Academic Research Fleet.** Should there not be a private institution able or willing to raise funds to acquire and convert such a ship in this time frame, then the workshop endorsed moving forward with a lease option, either from a single provider or from multiple providers via an institutional coordinator. The workshop participants are aware that Columbia University is actively pursuing funding for the purchase of a general purpose/seismic vessel, and endorses that activity. The rationale for the preference of Option 1 over 3/3A is presented below.

Rationale for recommending ownership (option 1/1A) over lease (option 3/3A):

Long-term leasing arrangements with an industrial partner for several months per year of seismic operations will allow some seismic work to continue, either immediately or long-term. Such an arrangement can be scalable – one can likely do one, two or three projects annually with \$10M, depending on scheduling, operations area, lease terms and market rates. However, it is expected that over time, the cost per unit of science completed will be higher if a lease is used, since it is necessary to pay for the vessel capitalization as well as the operations in the day rate. That said, there may be times, possibly like the present, when low demand for seismic vessel operations, and a need to retain staff and equipment through a downturn, results in costs even lower than a university could charge on a vessel that is fully paid for. The details of these trade-offs need a more detailed evaluation than could be accomplished in a two-day workshop.

Of the lease options, long-term lease from a single company, and not necessarily a single ship, may be the most cost-effective approach, allowing access to fleets of vessels from large operator(s). Given the NSF budget constraints, long-term leases with a single company will still only allow a few months a year of NSF-funded operations, and not full year use, given the NSF/OCE annual limit of \$10M. Though not directly comparable, we received some information at the meeting about the cost of R/V *Nathaniel Palmer*, an icebreaker owned by Edison Chouest Offshore (ECO) and operated via lease in support of NSF activities in the Antarctic. The information provided suggests that about 20-30% of the \$15-17 million annual cost of ship operations paid by NSF goes toward recovery of the purchase price and interest, amortized over 20 years, indicating some of the additional costs associated with lease options.

Under a long-term lease option, there will frequently be elements that require special contract arrangements to address the differences between normal commercial seismic vessel operations and the requirements of the academic research projects. These would need to be incorporated into the operational requirements, and would limit the suitability of some vessels. Examples are the support of large numbers (50-200 in some cases) of Ocean Bottom Seismometers (OBS), which have been an important part of many recent academic active source seismology projects. This requires sufficient open deck space and handling equipment that will likely entail additional costs. Most seismic vessels available for lease are also not outfitted with multibeam bathymetric sonars, gravimeters or magnetometers, as these are not standard tools for commercial seismic survey operations, though again, these capabilities can mostly be provided if specified, and funds (or equipment) are available through the contracting office. Other issues that would require planning, and could limit some operations if not negotiated up front, will include operations in remote areas (and the costs for long transits), and inclusion of large numbers of scientific participants, especially students, in seismic operations. With regard to the latter, the safety training and physical tests (firefighting, swimming, abandon ship) that are normally required to sail on commercial seismic ships will likely prevent more scientists and students from being able to participate than on academic research vessels, although the ARF requires some safety drills at sea, and also has limited ability to support severely disabled scientists.

Short-term leasing of vessels of opportunity may provide a bit more flexibility, but suffers from the same concerns about ability to handle OBS, student space, multibeam mapping and ancillary geophysical data acquisition, and an even greater susceptibility to uncertainties of market pressures on availability, cost and operations areas. On the positive side, it was recognized that the seismic industry generally offers state of the art technology, e.g. as many as ten-twelve 10-km long streamers for a 3D seismic experiment, with a well-trained acquisition team, and hence can provide high-quality data that can lead to transformative science that in some cases exceeds the capabilities of an academic research vessel. **Therefore, despite some concerns about cost and potential compromises about capabilities, both the long- and short-term lease options do provide a suitable mechanism to continue seismic work by the U.S. academic community if an Academic Research Fleet vessel is not available.**

Workshop Conclusions and Guidance to NSF

The workshop concluded that of the options presented, the most cost-effective and suitable short-term option is the continuation of R/V *Langseth* operation for an additional 3-5 years beyond 2020. Under reasonable assumptions, and barring major repair costs, this option will provide the most science for \$10M of NSF funds, and address most of the concerns expressed above. This statement is true despite the need to keep the ship idle about half the year and/or find additional sponsors to keep the NSF/OCE cost below \$10M. If NSF insists that it divest ownership of the vessel, as stated in NSF 17-563, this will require a proposal solicitation and an entity or consortium willing to accept ownership. If NSF can reconsider the need to divest for up to five years, it would not appear to require a solicitation to implement.

Continued operation of R/V *Langseth* will not necessarily generate more ship days of science, but in these 3-5 years, efforts can be made to engage in more general purpose operations, and additional ship days can also be generated from student training cruises supported by a consortium of interested institutions. Strong support for student training came from both Columbia University and the University of Texas at Austin, along with commitments to seek external support to implement training cruises through a broader consortium of research institutions. Scripps now offers a Masters degree program in seismic data collection and processing and is incorporating an at-sea program using a small research vessel and a sparker source – such training might be moved to R/V *Langseth* and a successor vessel as well. The best part of these options is that they would buy time (with minimal disturbance) for a longer-term option that Columbia University is pursuing for the purchase/lease of a relatively new vessel with both seismic and general-purpose capabilities. Columbia is pursuing fundraising towards this goal as an important component of their ongoing capital campaign, and they should be encouraged to continue to do so.

If R/V *Langseth* can be continued for at least three years with a commitment of \$10M annually from NSF, it will provide sufficient time to determine whether private acquisition of a general-purpose ship to support seismic operations is feasible, and what its secondary focus should be. Advances in long coring (30 m) with synthetic line provides one possible additional capability, and adding a high resolution subbottom profiler and an excellent multibeam would provide a superb capability to address topics in climate research, and to expand site survey support for future ocean drilling.

If, over this period of extended R/V *Langseth* operations it becomes clear that the private acquisition of a general-purpose ship to support seismic operations is not feasible, then the industrial lease options identified by the workshop can and should be quickly invoked.

Finally, the JAMSTEC participants offered to enter into an agreement (“New Option 2”) with NSF to support US scientist participation in seismic research on R/V *Kaimei* in the western Pacific and Indian Oceans. The workshop endorsed this idea, with the caveat that the cost associated with this option should not directly compete with a US vessel solution. Participants felt that cooperation of this sort would be an added benefit, and per guidance from the NSF ship operations program, can be implemented without a specific MOU. It was the sense of the workshop that such agreements could be made with several countries, and would be broadly beneficial in both expanding capabilities and exchanging scientific ideas. The details would need to be worked out, and costs addressed, but the offer by JAMSTEC was well received and appreciated.

Link to the background material used in preparation for the workshop:

<https://hub.ki/groups/marineseismic/collections/background-reading>

Link to the ‘options paper’ discussed in the pre-meeting webinars:

[Final 03-13-19 - second webinar options.pdf](#)

Links to the workshop reports prepared for each option are listed to provide more detail:

Option 1: <https://docs.google.com/document/d/1RdbqEjJEtGgbSpoOJJlbsctXQtq1MmZRWgkHCLUhdg/edit>

Option 1A: <https://docs.google.com/document/d/1yWJAKHsXyF-ofAzzMPCqwY8NuP1jLqIna-8s-QOdsjw/edit>

New Option 2: <https://docs.google.com/document/d/1BrkT2hyYsn5t1MIYD55mC7dBI89YnBEHnE-xuZO238k/edit>

Option 3: https://docs.google.com/document/d/12Ovqtyj9Yn1tin746rroC_nR_hhW9PGt9AKa9KIdIH4/edit

Option 3A: <https://docs.google.com/document/d/1oiZQgczsrn5bR1VKvxKmYnGyOoadrGNHAnmHnunuY0/edit>

Updated information on availability and cost of commercial seismic vessels (April 2019):

[Seismic market background material 190401 unbranded.pdf](#)

POSTSCRIPT: UPDATES RECEIVED FROM NSF PROGRAM STAFF AFTER THE WORKSHOP

During preparation of the workshop report, we received communications from NSF that updated and clarified information available to participants at the workshop. In the interest of full transparency, we are including those updates here, noting that they were not available to the Workshop participants as they evaluated the options and made their recommendations.

1. While there was some information available about the cost of operating R/V *Langseth*, the specific cost of operating the vessel was not presented to the Workshop. The 2019 provisional costs are as follows: 2019, 144 operating days, all NSF/OCE-funded, \$8.5 million ship operations (\$59K/d), plus \$2.7 million for technical support plus environmental permitting for four projects, total cost \$11.2 million. The four projects include a 48-day Honolulu to Alaska trip (2-D long streamer in Emperor Seamounts), a 23-day 3-D reflection and OBS/land seismometer refraction study (Alaska margin), a 37-day 3-D and 2-D study of structure of Axial Seamount, and a 21-day OBS recovery cruise (instruments used on the 23-day Alaska project, with no seismics on this leg; a second OBS recovery trip is scheduled on R/V *Sikuliaq*). There are

an additional 15 *Langseth* operating days for three short transits to reposition between Kodiak and Astoria between projects. Despite a 31-day planned shipyard maintenance period in October, the ship schedule shows 167 days before and after the April to September operating period as “Available for Service”.

2. We received the following information about what support has been provided for field work in support of IODP in the past four years. Three of these, in 2016 and 2018, used R/V *Langseth*; the other four, in 2017, 2018 and 2019, all used smaller portable systems on other ships:
 - 2016 Bobby Reece: Collaborative Research: Evolution of South Atlantic Oceanic Crust: A Seismic Transect, *Langseth long streamer*.
 - 2017 Susan Humphris: Collaborative Research: Hydrothermal and Microbiological Investigations of the Active Brothers Volcano in the Kermadec Arc, *mapping and sampling*.
 - 2018 Nathan Bangs: Collaborative Research: A community 3D seismic investigation of fault property controls on slow-slip along the Hikurangi megathrust, *Langseth*.
 - 2018 Mitch Lyle: COLLABORATIVE RESEARCH: Tracing Greenhouse to Icehouse Climate Evolution Along the Western North Atlantic Meridional and Paleodepth Transect, *portable system*.
 - 2018 Michael Gurnis, Sean Gulick, Harm van Avendonk: SISIE – South Island Subduction Initiation Experiment (GeoPRISMS), *Langseth*.
 - 2019 Niall Slowey: Collaborative Research: Understanding the Southern Ocean's Contribution to Cenozoic Deep-Water Circulation, *portable system*.
 - 2019 Will Sager: Collaborative Research: Rio Grande Rise: New Questions on Plume Dynamics, Atlantic Tectonic Evolution and an Important Window to the African LLSVP, *portable system*.
3. We received information during the review of the initial report draft suggesting misunderstandings about the funding sources and procedures for seismic field programs in support of ocean drilling. We have attempted to clarify sections of the report related to how NSF/OCE supports ocean drilling to reflect these comments. However, the consensus recommendation of workshop participants that specific funding for seismic surveys in support of future ocean drilling should be identified and dedicated to this purpose is retained.

Report Authorship and Participant List

The workshop report was prepared by Alexander Shor with extensive input from the workshop chair, Larry Mayer. It was circulated to the workshop attendees during late April 2019 for comment, correction and additions, and went through several drafts addressing those comments. The final version thus reflects input from many individuals, but the specific recommendations and presentation are the sole responsibility of the primary author (Shor), who received salary and travel support from NSF to prepare the background material and the final report, and who managed the contract with Knowinnovation to facilitate the workshop.

Participants were selected by NSF/OCE program personnel in consultation with Shor, Mayer and Knowinnovation. Participant travel costs were paid by NSF. The list of participants, including those that attended online, is attached below.

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