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MANAGEMENT MODELS FOR FUTURE SEISMOLOGICAL AND GEODETIC FACILITIES AND CAPABILITIES

PROCEEDINGS OF A WORKSHOP

Sammantha Magsino, *Rapporteur*

Board on Earth Sciences and Resources

Division on Earth and Life Studies

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Although the reviewers listed above provided many constructive comments and suggestions, they were not asked to endorse the content of the proceedings nor did they see the final draft before its release. The review of this proceedings was overseen by **George Hornberger**, Vanderbilt University. He was responsible for making certain that an independent examination of this proceedings was carried out in accordance with the standards of the National Academies and that all review comments were carefully considered. Responsibility for the final content rests entirely with the rapporteur and the National Academies.

Contents

1

Introduction

Technologies that support the fields of seismology and geodesy have advanced greatly in the past few decades and many scientific advances in these and other Earth science fields have resulted from the contributions of geodetic and seismological facilities. The National Science Foundation's (NSF's) Division of Earth Sciences (EAR) currently supports two community-governed geophysical facilities: (1) Seismological Facility for the Advancement of Geoscience (SAGE), currently managed by the Incorporated Research Institutions for Seismology (IRIS), and (2) Geodetic Facility for the Advancement of Geoscience (GAGE), currently managed by UNAVCO.[1] These facilities prioritize their capabilities based on the scientific needs of their stakeholder communities, and allow their capabilities to evolve as scientific and technological needs evolve.

The National Academies of Sciences, Engineering, and Medicine (the National Academies) were asked by EAR to conduct a study that would provide input on priorities and strategies for NSF investments in Earth science research, infrastructure, and training for the coming decade (see the Statement of Task in Box 1.1). That 2-year effort, which began in 2018, is titled Catalyzing Opportunities for Research in the Earth Sciences (CORES).[2] To fulfill that request, the National Academies convened an ad hoc committee of volunteer experts to prepare a consensus study report that will include a set of high-priority scientific questions central to the advancement of Earth sciences; an analysis of the EAR research infrastructure investment portfolio; and a discussion of how EAR can leverage and complement the capabilities, expertise, and strategic plans of other NSF units, federal agencies, and other domestic and international partners.

As an additional, integrated part of the study, EAR requested that the National Academies organize a workshop to address different management models for future seismological and geodetic facility capabilities—specifically (1) instrumentation, (2) user support services, (3) data management, (4) education and outreach, and (5) workforce development. A separate planning committee was convened, which included expertise in seismology, geodesy, and research administration drawn from the CORES consensus study

[1] UNAVCO was first organized as the University Navstar Consortium in 1984, but incorporated as an independent entity under the name "UNAVCO" in 2001. See Chapter 3 for more detail.

[2] Information about the CORES consensus study committee may be found at http://nas-sites.org/dels/studies/cores.

committee, as well as additional expertise in management of scientific infrastructure and facilities and geophysics-related disciplines drawn from the broader scientific community. Appendix A includes biographies of the planning committee members. Organization of the workshop by the planning committee was independent of the activities of the CORES consensus study committee. Members of the consensus study committee who also served on the planning committee acted as liaisons between the two groups. The workshop took place on May 13-14, 2019, in Chicago, Illinois. It included participation by the workshop planning committee, members of the consensus study committee, managers of UNAVCO and IRIS and their respective boards of directors, members of the facility user communities, management from other NSF-sponsored scientific facilities, personnel from other U.S. and international scientific facilities, and EAR and National Academies staff.

BOX 1.1
Catalyzing Opportunities for Research in the Earth Sciences
Statement of Task

This National Academies of Sciences, Engineering, and Medicine study will help provide advice that the National Science Foundation's Division of Earth Sciences can use to set priorities and strategies for its investments on research, infrastructure, and training in the coming decade. An ad hoc committee will prepare a report that includes the following elements:

1. A concise set of high-priority scientific questions that will be central to the advancement of Earth sciences over the coming decade and could help to transform our scientific understanding of the Earth. Identification of these questions may derive from consideration of relevance to societal benefits, new technological breakthroughs, potential for fruitful interaction and collaboration with other disciplines, emerging subjects poised for rapid development, or other drivers.
2. A) Identification of the infrastructure (e.g., physical infrastructure, cyberinfrastructure, and data management systems) needed to advance the high-priority Earth science research questions from task #1;

   B) discussion of the current inventory of research infrastructure supported by EAR and other relevant areas of NSF; and

   C) analysis of capability gaps that would need to be addressed in order to align B with A.
3. A discussion of how EAR can leverage and complement the capabilities, expertise, and strategic plans of its partners (including other NSF units, federal agencies, domestic and international partners), encourage greater collaboration, and maximize shared use of research assets and data.

The ad hoc committee will consider these tasks within the context of the present EAR budget. It also will consider potential adjustments in priorities identified in task #1 or approaches to implementing those priorities that could be applied if future budgets were to increase or decrease.

In addition, the National Academies will convene a workshop (as an additional, integrated part of the CORES study) to address different management models for future seismological and geodetic facility capabilities such as instrumentation, user support services, data management, education/outreach, and workforce development for the Division of Earth Sciences. This workshop will provide additional information for Task 2 of the CORES study.

INTERPRETING THE STATEMENT OF TASK

To determine an effective workshop organization, the workshop planning committee and National Academies staff discussed with EAR program managers what NSF hoped to learn from the workshop. EAR program managers desired to better understand how NSF might sustainably support the diverse needs of the seismological and geodetic communities as technologies and the research landscape evolve. The Statement of Task (see the last paragraph of Box 1.1) required the workshop to address "different management models for future seismological and geodetic facility capabilities." Because the management of facility capabilities is directly related to facility management and decision making processes, the workshop was organized to explore options for facility management and governance to determine if any of those options warrant consideration for future seismological and geodetic facilities. The workshop was not designed to evaluate current seismological or geodetic facilities, their management structures, or their processes, but input from those facilities was included for the purpose of comparison. Furthermore, topics related to funding and resource allocations were not to be addressed at the workshop. The workshop planning committee organized the workshop to learn about different management and decision-making approaches that could accommodate the defined services, resources, and capacities of seismological and geodetic facilities (i.e., the capabilities) to scientific advantage.

The CORES consensus study committee was asked by EAR to identify future science priorities and infrastructure needs for the Earth science research community over the next decade. The workshop planning committee, on the other hand, was asked to plan an agenda to consider management models that could accommodate instrumentation, user support services, data management, education and outreach, and workforce development capabilities of future seismological and geodetic facilities. While the consensus study committee's tasks could encompass the priority capabilities of future seismological and geodetic facilities, committee deliberations were still confidential at the time of the workshop. Therefore, EAR suggested that the workshop planning committee rely on seismological and geodetic facility capabilities as defined in the 2015 community workshop report,[3] although EAR recognized that scientific priorities may have evolved since those capabilities were defined. However, because this workshop was focused on management rather than science priorities, the 2015 capabilities definitions were considered adequate for workshop discussions.

The planning committee focused workshop discussions first on existing scientific facility management and governance models, and then on how those might be applicable to future seismological and geodetic facilities. The breadth and diversity among existing models and facilities were explicitly chosen to provide ample discussion material and to give workshop participants examples of methodologies that have proven successful or that have presented challenges under specific circumstances. The planning committee made no plans to discuss alternative or new models that might be developed other than those presented.

SPONSOR EXPECTATIONS

Lina Patino, EAR division director, gave brief remarks at the beginning of the workshop. She and other NSF staff attended the workshop as observers, providing only clarifying comments. She described NSF's interest in supporting the seismological and geodetic capabilities of instrumentation, user support, data management, education and

[3] See https://www.iris.edu/hq/files/publications/other_workshops/docs/futures_report.pdf.

outreach, and workforce development. The goal of sponsoring the workshop was to learn from the scientific community about how various management models might deliver those capabilities in future facilities, she said. Because funding of geophysical facilities comprises approximately 20 percent of the EAR budget, a workshop held within the context of the CORES consensus study was considered appropriate. Patino emphasized that the workshop was not central to the CORES Statement of Task, but was rather included within it. Given that both IRIS and UNAVCO are in the first year of 5-year awards for SAGE and GAGE, she indicated that this workshop would afford EAR time to consider future options for the facilities.

WORKSHOP ORGANIZATION

The workshop agenda (see Appendix B) allowed 1.5 days for discussion of management models of theoretical seismological and geodetic facilities of the future. Each session of the workshop was designed to inform the next. The first session introduced workshop participants to the current and future capabilities of seismological and geodetic facilities as defined in a 2015 community workshop report.[4] The second session introduced management models of multiple scientific facilities, including SAGE and GAGE, through presentations and discussions with facility managers. The third session focused on how management and decision-making models might be applied to seismological and geodetic facilities. The fourth session (and final session of Day 1) was a general comment period during which participants could provide comments on any topic. The fifth session (morning of Day 2) invited workshop participants to consider the scientific advantages of distributing seismological and geodetic capabilities among multiple facilities, or the scientific advantages of centralizing some or all of the capabilities. The final session invited workshop planning members to provide observations made throughout the workshop regarding management of facility capabilities (instrumentation, user support services, data management, education and outreach, and workforce development capabilities).

ORGANIZATION OF THIS PROCEEDINGS

This Proceedings of a Workshop was prepared by a rapporteur as a factual summary of what occurred at the workshop. The planning committee's role was limited to planning and convening the workshop. The views contained in this Proceedings of a Workshop are those of the individual workshop participants and do not necessarily represent the views of all workshop participants, the planning committee, or the National Academies.

Chapters 2-8 are organized as the workshop was organized, with each chapter providing summaries of the presentations and discussions held within each session. Supporting material is provided in the appendixes. Appendix A presents biographies of the workshop planning committee; Appendix B contains the workshop agenda; Appendix C offers biographical information of the workshop presenters and panelists; Appendix D is the list of workshop participants; and Appendix E is a transcript of the comments provided during the workshop public comment period at the end of the first day of the workshop.

[4] See https://www.iris.edu/hq/files/publications/other_workshops/docs/futures_report.pdf.

2

Current, Emerging, and Frontier Capabilities of Seismological and Geodetic Facilities

Lucy Flesch (Purdue University), co-chair of the 2015 community workshop organizing committee, and Rick Aster (Colorado State University), co-editor of the 2015 community workshop report writing committee, were invited to provide background about that workshop. This was to familiarize workshop participants with the emerging and frontier seismological and geodetic facility capabilities that were defined at the 2015 workshop, and to summarize relevant report sections. Their presentations were followed by a moderated question and answer period between speakers and audience.

DESCRIPTION OF THE 2015 COMMUNITY WORKSHOP

Lucy Flesch, Purdue University

Lucy Flesch was co-leader of a 2015 workshop organizing committee charged by the National Science Foundation (NSF) with gathering community input to identify the most important geophysical scientific questions, research opportunities, and broader impacts to be pursued in 2018 and beyond. She described how the charge to the organizing committee also included gathering input on the seismic, geodetic, and magnetotelluric facility capabilities required to support research and associated education, outreach, training, and workforce development. Two types of seismological and geodetic capabilities were to be defined: those necessary for geoscience research to occur as practiced today (foundational capabilities), and new capabilities required to allow for rapid progress in addressing scientific grand challenges (frontier capabilities).

The organization of the workshop was informed by community input obtained through 4 webinars and 91 white papers solicited prior to the workshop, according to Flesch. There were 120 workshop attendees. The workshop was divided into four science-based plenary sessions with breakout discussions as part of each plenary: (a) Earth structure, rheology, and geodynamics; (b) time-variant behavior of faults and magmatic systems; (c) evolving landscapes and global environmental change; and (d) links to industry and discovery-mode science from new technologies. She said that participants were asked to define the scientific questions to be pursued through geoscience research, as well as the foundational and frontier geodetic and seismic facility capabilities required to advance geoscience research and education beyond 2018. A final plenary discussion synthesized workshop findings.

According to Flesch, development of community seismological and geodetic facility Centers of Excellence that are available to the scientific and broader community has been key to the scientific and cultural transformation of geophysical disciplines over the past several decades. Flesch concluded with two key points derived from the workshop: (1) future facilities need to be dynamic, responsive, integrative, and agile; and (2) facilities are more than their physical infrastructure; they are centers that catalyze integrative education, diversity and inclusion, and broader public outreach.

DESCRIPTION OF CURRENT, EMERGENT, AND FRONTIER CAPABILITIES

Rick Aster, Colorado State University

Rick Aster described historic advances in geophysics and related disciplines catalyzed by NSF-supported facility Centers of Excellence. Those centers are focal points for community collaboration and professional and leadership growth for researchers at all career levels. They are sources for experiment technology support and of professionally curated and openly available data and metadata. Aster also described the importance of facilities remaining responsive to scientific and community needs. Continued and expanded intra- and interagency leveraging is necessary, he explained, for continued success of future seismological and geodetic facilities.

According to Aster, access to the facilities is democratized so that principal investigators and students from diverse institutions may take advantage of research opportunities, training, and professional staff. The facilities are optimally used and directed as a result of the strong user community support and engagement.

He then described how the 2015 workshop report further split capabilities into three categories:

- Existing foundational capabilities: those that are fundamental to current and near-term science directions, including the continuation of currently supported NSF projects;
- Emergent foundational capabilities: those incorporating current technologies to drive significant progress on major high-priority science challenges for 2018 to 2023; and
- Frontier capabilities: presently nascent capabilities considered important for transformative science.

Table 2.1 summarizes those capabilities in each category as defined in the 2015 workshop report and described by Aster. Aster then summarized capabilities envisioned for the future (noting that progress toward some of these have been made since 2015). Those capabilities include:

- Near real-time daily maps of deformation derived from Global Navigation Satellite System (GNSS) instrumentation and orbiting radar satellites;
- Globally distributed seafloor and surface-drifting geophysical instrumentation;
- Arrays of distributed acoustic sensing fiber optic cables providing continuous high sample rate surface strain;
- Customizable drones that can host or deploy a range of instrumentation;
- Larger instrumentation pools to routinely deploy in diverse environments and across a range of scales to record the full frequency-wavenumber spectrum and range of transient and ambient seismic wavefields;
- Global telemetry providing high-rate and low-latency sampling from remote seismic, geodetic, and other multidisciplinary instruments; and
- Routine access to high performance computing and associated capabilities for data reduction and model inference on an unprecedented scale.

Table 2.1 Capabilities of Seismological and Geodetic Centers of Excellence Defined in 2015[a]

Existing Foundational	Emergent Foundational[b]	Frontier
• Maintained permanent seismic, strainmeter, and geodetic networks (SAGE and partners/GAGE) • Deployable seismograph observation systems (SAGE) • Deployable geodetic observation systems (GAGE/University) • Land and marine magnetotelluric systems (SAGE/University) • Data archiving, quality control and distribution (GAGE/SAGE/WInSAR) • Serving of higher level data products (GAGE/SAGE/InSARf) • Computational modeling tools (Computational Infrastructure for Geodynamics/University) • Professional staff support (SAGE/GAGE) • Workforce development (SAGE/GAGE/University) • Professionally facilitated education and outreach activity (SAGE/GAGE)	• Large-N intermediate-period to high-frequency seismic arrays • Rapid response instrumentation (and ability to optimally respond) • Access to large volumes of InSAR data and products • NISAR December 2021 launch • Operational Global Navigation Satellite System (GNSS) processing • Enhanced capabilities to explore, develop, and apply next generation and emerging instrumentation • Geophysical instrumentation for geomorphological, glaciological, surface, near-surface, and critical zone geophysics	• Seafloor and free-floating geophysical networks • Next-generation magnetotelluric and controlled-source electromagnetic capabilities • Deep borehole access and instrumentation • Instrumentation for high-risk/high-benefit experiments (e.g., volcanos, glaciers, novel wavefields of whole Earth to urban environment) • Programs to communicate broad understanding of Earth system science • Workforce diversity

[a] Parentheticals indicate the facility/ies where specific capabilities are housed.
[b] Significant progress made on some of these capabilities since the 2015 workshop.
NOTE: GAGE = Geodetic Facility for the Advancement of Geoscience; InSAR = Interferometric Synthetic Aperture Radar; NISAR = National Aeronautics and Space Administration—Indian Space Research Organization Synthetic Aperture Radar Mission; SAGE = Seismological Facility for the Advancement of Geoscience; WinSAR = Western North America Interferometric Synthetic Aperture Radar consortium.

In terms of organizational structures, and the ability to be nimble and to partner with other organizations, Aster offered that the current seismological and geodetic facilities are "extraordinarily efficient" in realizing data collection and utilization when compared to individual projects that are distributed by funding agencies to standalone researchers, even at well-supported universities. He noted that there is still potential for partnering with, for example, ocean science facilities, or for improving diversity in the Earth sciences. Aster summarized his presentation by stating that community engagement in facility management has resulted in sustained transparency, consensus vision, optimal facilities and resource use, mentorship of leadership within the community itself, and overall agility in the service of research, teaching, and broader impact goals.

MODERATED QUESTIONS AND ANSWERS

Multiple themes were raised during a question and answer session with Flesch and Aster. The sections below synthesize the major themes raised. Some of the discussion fell slightly outside the bounds of the workshop planning committee's Statement of Task, but are included here to present a complete record of discussion themes.

2015 Community Workshop Topics

Flesch and Aster were asked how topics for the 2015 community workshop were chosen. Flesch responded that the organizing committee for that workshop received a skeleton outline of science topics from NSF. The organizing committee then solicited white papers from the technical community, which identified scientific community needs, revealed key questions to be asked, shaped the focus of workshop topics, and informed the workshop organization. The agenda of that workshop diverged from the charge given to the organizing committee so that the workshop could be optimally responsive to scientific community needs.

Data and Computing Challenges

When asked if data access and data management were becoming a bigger barrier and whether issues related to data were getting solved, Aster responded that there were multiple issues at various scales. Examples he provided include:

- deciding how much computational power would be needed for a particular investigation and how to make that computational power available to the investigators and their students;
- managing community software of varying quality that has been heavily customized;
- grassroots development efforts that are changing the way people do workflows;
- university issues (e.g., related to tapping into regional supercomputers); and
- professional support (e.g., specialized groups that can handle data structures and programming of calculations for full-waveform seismic inversion).

Aster indicated that a lot of work remains to democratize access to computing capabilities.

Another workshop participant added that some investigations generate or compute terabytes of data per day, and that the common model in which data are distributed to users will not scale to need in the near future. It might be appropriate in the next 5 to 10 years to think beyond democratizing computing, and to move analysis closer to where the data are, the participant continued. Aster agreed and stated that the community is considering how to manage massive data sets such as those from distributed acoustic sensing technology and large experiments involving thousands of seismographs. Flesch added that data from the GNSS and from interferometric synthetic aperture radar (InSAR) can be large and provide management challenges.

Partnerships

In response to a question about the Incorporated Research Institutions for Seismology (IRIS) and UNAVCO aspirations to form partnerships with agencies other than NSF, Aster stated that both facilities have a record of working adaptively and collaboratively with other agencies, such as the U.S. Geological Survey (USGS) and the National Aeronautics and Space Administration. The partnerships are often driven by opportunities that arise—for example, IRIS promoting seismology on Mars—but they might also arise synergistically. Aster gave the example of the longstanding Central and Eastern U.S. Seismographic Network established by IRIS. That network has been transferred completely to the USGS for long-term seismic studies in the Eastern United States.

Unanticipated Science Emerging from Facilities

When asked if there are examples of revolutionary science that are the result of capabilities offered by current seismological and geodetic facilities, Flesch provided the example of how a Global Positioning System (GPS) campaign at the Cascadia Subduction Zone resulted in the discovery of phenomena at multiple temporal scales that ultimately informed science in unexpected ways. Initially, it was thought that GPS data in Cascadia would allow researchers to measure plates moving at a constant velocity, but instead the campaign revealed slow slip events[1] on the Cascadia Subduction Zone. As a result of that discovery, permanent stations were established to monitor the phenomena.

Integrating Earth and Ocean Science Capabilities

Multiple workshop participants questioned why IRIS and UNAVCO did not support marine seismic research. Aster agreed that there is less understanding of the tectonic and process significance of oceanic plates and earthquakes versus terrestrial plates and earthquakes, and that there is a strong scientific motivation to think about seismology from a global perspective. He stated that less instrumentation in the oceans corresponds

[1] Slow slip events, also called episodic tremor and slip, are ground motions that occur along subduction zone boundaries over a period of time (weeks/months/years). The movement occurs at slower rates than traditional earthquakes, and can propagate over the length of the subduction zone. It is believed that slow slip events may increase stress on sections of the subduction and trigger a larger earthquake event. Slow slip events have been occurring approximately every 14 months along the Cascadia Subduction Zone in Washington State. See https://www.iris.edu/hq/inclass/fact-sheet/episodic_tremor_and_slip.

to missed opportunities. A workshop participant stated that a global seismic network was a worthy goal, and other participants described the potential for scientific and technical synergies between the land and marine seismic communities. A workshop participant observed that a better understanding about the fundamental tectonic structure of Earth and its crustal plates would only be possible with a greatly expanded ability to make seismic measurements in the ocean. Aster indicated that there were organizational boundaries within NSF that would need to be addressed before such collaborative work could be undertaken. Patino acknowledged this statement and stated that similar organizational boundaries exist elsewhere. As an example, she mentioned the management boundaries that prevent those working on earthquake scientific issues, earthquake early warning efforts, and earthquake mitigation efforts to collaborate formally. Maggie Benoit, the NSF program director for the Seismological Facility for the Advancement of Geoscience (SAGE) and the Geodetic Facility for the Advancement of Geoscience (GAGE), indicated her appreciation of the comments, and that efforts for greater cooperation were being made at NSF.

3

Management of Current Division of Earth Sciences–Sponsored Seismological and Geodetic Facilities

During the next workshop session, workshop participants learned about and discussed with leadership from the Incorporated Research Institutions for Seismology (IRIS) and UNAVCO the management and governance structures of their respective organizations. The session began with presentations by the presidents of IRIS and UNAVCO. The workshop planning committee provided the presidents prompting questions prior to the workshop to guide their presentations (see Box 3.1). A panel discussion with representatives of the facilities' management and boards of directors followed. This session was designed to provide a basis for comparison of these facilities' management structures with those of other facilities to be discussed in a later session.

BOX 3.1
Prompting Questions Provided to Scientific Facility Leadership

To allow comparison of management and governance models among scientific facilities, the workshop planning committee provided the following questions to facility managers making presentations at the workshop:

- What are the mission and capabilities/services offered by your facility?
- What management and governance or decision-making models does your facility employ?
- How does your facility management structure incorporate interactions with stakeholders to set priorities?
- How has the management model changed over time?
- Which elements of your management structure best accommodate instrumentation, user support services, data management, education and outreach, and workforce development capabilities?
- Are there weaknesses or gaps?
- What elements of the management model are designed to allow responsiveness to technological advances and emerging science? Have these been tested?

MANAGEMENT OF INCORPORATED RESEARCH INSTITUTIONS FOR SEISMOLOGY (IRIS)

Robert Detrick, IRIS

Robert Detrick described IRIS, created in 1984, as a facility operator. It has managed facilities for the National Science Foundation (NSF), and has served the seismological community in the United States and internationally. According to Detrick, IRIS is a nonprofit 501(c)(3) corporation with a budget of about $30 million per year. It employs the equivalent of 56 full-time employees, is headquartered in Washington, DC, and has offices in Seattle, Washington, and Anchorage, Alaska. A small headquarters staff includes a chief financial officer and four to five people providing financial services for IRIS, a business/human resources manager, and a grants and contract administrator overseeing the NSF award and 12 sub-awards granted to other institutions. Detrick, as president of IRIS, reports to the IRIS Board of Directors.

IRIS is a university consortium of 126 member colleges and universities in the United States, 21 educational affiliates, and 128 foreign affiliates. It is funded by NSF to operate the Seismological Facility for the Advancement of Geoscience (SAGE), but also has partnerships with the U.S. Geological Survey (USGS), the U.S. Department of Energy, the U.S. Department of State, the U.S. Air Force, and various state geological surveys, he continued. IRIS has more than 100 memoranda of understanding with organizations around the world to help facilitate the operation of temporary and permanent seismic networks and experiments, and to exchange seismic and other geophysical data.

The IRIS mission, according to Detrick, is to

- Facilitate investigations of earthquakes and Earth structure using seismic and other geophysical methods;
- Promote exchange of seismic and other geophysical data and knowledge through use of network operations standards and data formats, as well as through pursuing policies of free and unrestricted data access; and to
- Foster cooperation among IRIS members, affiliates, and other organizations to advance geophysical research and education, expand the diversity of the geoscience workforce, and improve Earth science literacy in the general public.

SAGE is operated as a Center of Excellence around instrumentation services, data services, and education and outreach. Detrick described a "dirt-to-desktop" approach that includes all aspects of instrument preparation, deployment, data collection, and quality control through data archiving and distribution. This approach allows for close communication among those collecting, distributing, and using data, and allows problems to be caught early to avoid cascading errors with the data. He indicated that the dirt-to-desktop approach, combined with the deep technical domain knowledge of IRIS program managers, has contributed to the long-term success of IRIS in meeting community needs.

Figure 3.1, shared by Detrick, shows the organization of IRIS and the relationship between its three directorates (instrumentation services, data services, and education and outreach). Each directorate includes program managers and project leads. Approximately two-thirds of the SAGE budget is allocated to instrumentation services. SAGE operates the Global Seismographic Network (GSN) in collaboration with the USGS and the Portable

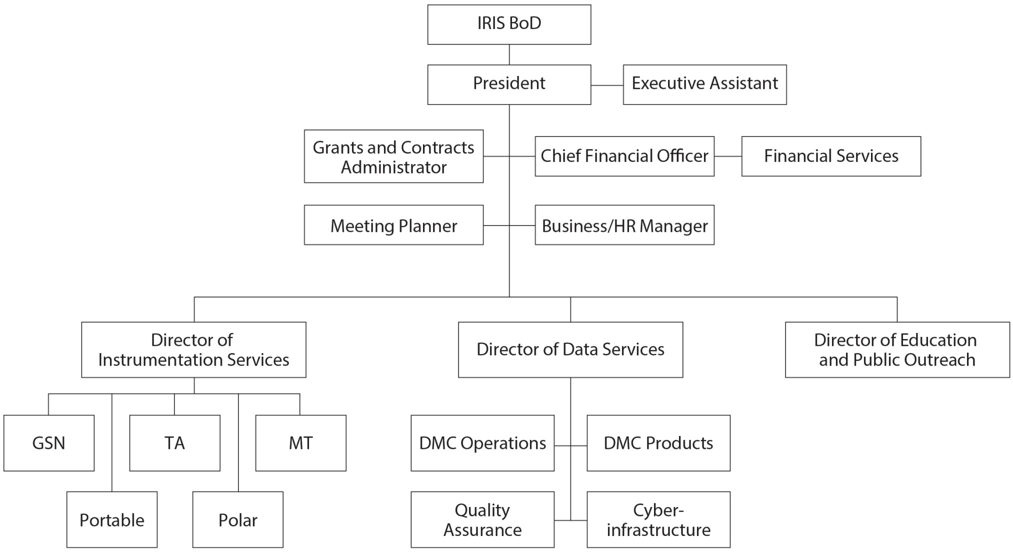

Figure 3.1. Organization chart showing the IRIS Management structure and the three directorates of instrumentation services, data services, and education and outreach. NOTE: BoD = Board of Directors; DMC = Data Management Center; GSN = Global Seismic Network; HR = Human Resources; IRIS = Incorporated Research Institutions for Seismology; MT = Magnetotelluric Array; TA = Transportable Array. SOURCE: Detrick presentation, slide 10.

Array Seismic Studies of the Continental Lithosphere (PASSCAL; the world's largest open access portable geophysical instrumentation center) in collaboration with the New Mexico Institute of Mining and Technology. IRIS also supports polar instrumentation for experiments in Antarctica and the arctic regions. The IRIS data services directorate supports the world's largest broadband waveform seismic data center.

IRIS utilizes a university consortium governance model with a flat organizational structure devoted to facility operations (see Figure 3.1). IRIS program managers, directors, and staff do not engage in research, but program managers and directors have deep technical domain knowledge and program management experience. Detrick described IRIS as a cost-effective organization due to its leveraging of scientific and technical expertise in the academic community through sub-awards for some IRIS facilities. Approximately half of the IRIS annual budget goes to 12 major sub-awards. Additionally, IRIS remains lean by sharing facilities where feasible. For example, IRIS shares some office and warehouse space with UNAVCO and houses its data management center servers and storage devices at the University of Washington (with backup at the Lawrence Livermore National Laboratory). By outsourcing administrative functions such as human resources, payroll, information technology, and its retirement plan, IRIS maintains an overhead rate of 25 percent.

Detrick described IRIS's community governance structure and interaction with facility users (see Figure 3.2 presented by Detrick). The 9-member Board of Directors is elected by the 126 member institutions. Members typically serve 3-year terms. Through service on standing or advisory committees established by the IRIS Board of Directors, community members provide oversight of facility operations, guidance on annual budget priorities, and strategic planning. The committees meet twice per year and may have

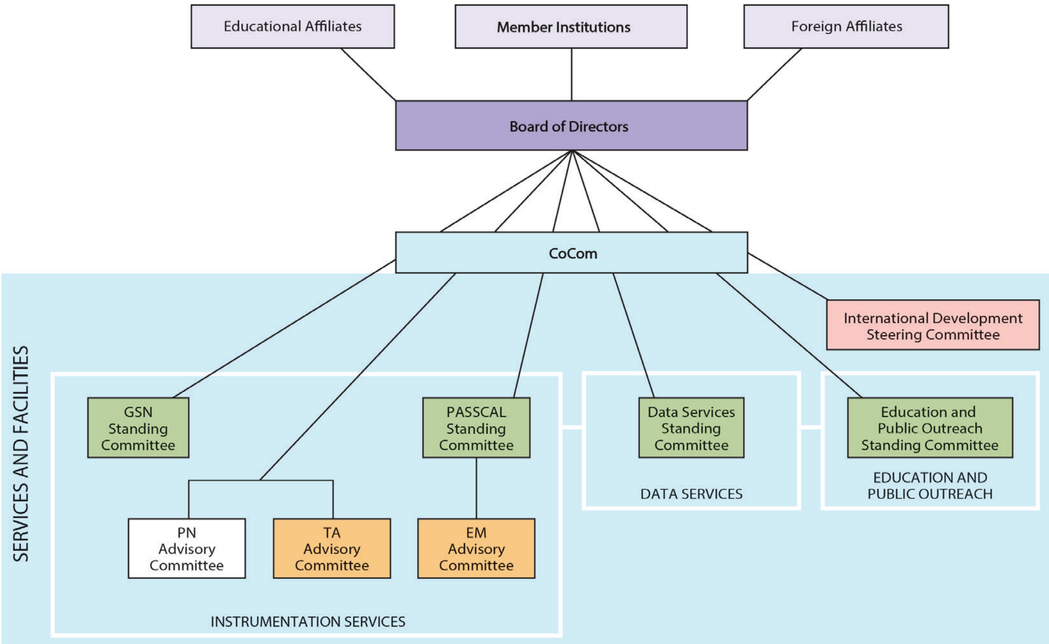

Figure 3.2. The organizational structure of IRIS. Consortium members (at the top) elect a Board of Directors, which then establishes standing committees for each of the major facility programs (green boxes). The coordinating committee is comprised of project managers and standing committee chairs. NOTE: CoCOM = Program Coordinating Committee; EM = Electromagnetic; GSN = Global Seismic Network; PASSCAL = Portable Array Seismic Studies of the Continental Lithosphere; PN = Polar Network; TA = Transportable Array. SOURCE: Detrick presentation, slide 13.

working groups or advisory committees to help them. Governance issues that crosscut different facilities are addressed by a coordinating committee comprised of project managers and standing committee chairs. The IRIS Board of Directors and its standing committees identify longer-term goals and priorities for the facilities that IRIS operates, and IRIS staff implement those plans and priorities.

Detrick described that IRIS and UNAVCO are experimenting with a coordinated program governance and management structure as part of the new awards for SAGE and Geodetic Facility for the Advancement of Geoscience (GAGE). Under the joint management structure, IRIS and UNAVCO operate independently under separate cooperative agreements with NSF, but a newly established Joint Executive Committee considers issues that affect both facilities (e.g., planning the annual SAGE/GAGE workshop, or reviewing SAGE and GAGE data services). Figure 3.3, presented by Detrick, shows the organization of the joint governance model and its committees. The joint governance model includes six standing committees, one for each major SAGE or GAGE program. Some of the standing committees include members from a single facility when there is little or no overlap of interests across facilities. Other standing committees include members from both when there is overlap (e.g., data services, education, workforce and outreach). The joint structures are still too new, according to Detrick, to determine the effectiveness of the approach.

Detrick stated that he believes the success of IRIS is due to its model of community governance. The model ascribes a sense of ownership to the research community, and

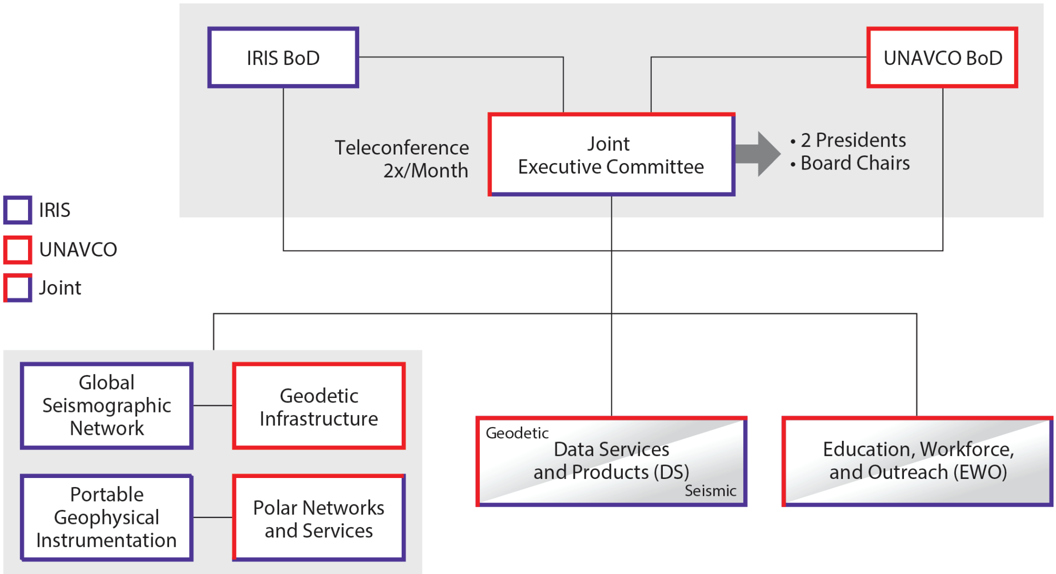

Figure 3.3. GAGE-SAGE governance model comprised of six standing committees, one for each GAGE or SAGE program. Committees comprised of SAGE-only members are outlined in blue, committees with GAGE-only members are outlined in red, and committees with members from both are outlined in blue and red. NOTE: BoD = Board of Directors; GAGE = Geodetic Facility for the Advancement of Science; IRIS = Incorporated Research Institutions for Seismology; SAGE = Seismological Facility for the Advancement of Geoscience. SOURCE: Detrick presentation, slide 14.

the sense that community needs and priorities are met. According to Detrick, community governance avoids the perception of conflict of interest that some may sense in facilities housed at a single university (i.e., because facility managers at IRIS are not competing for use of the facility for their own research). Detrick also stated that the governance structure includes early-career investigators in facility governance, integrating them into the seismic community and, according to Detrick, grooming them to be future leaders in the field. Consortium activities such as workshops, internships, and online training and networking helps to build a large and vibrant seismic community. He cited 35 years of NSF facility operation, an international reputation as a model facility operator, the on-time and on-budget construction and operation of EarthScope's U.S. Array facility, the construction of the world's largest repository for waveform, broadband seismic data, and the wide use of IRIS educational and public outreach products and activities as examples of IRIS's good track record.

Figure 3.4, presented by Detrick, shows the breadth of science topics that the SAGE and GAGE facilities support. Detrick noted that while there are some research areas of common interest to the IRIS and UNAVCO communities, there are also many research areas only of interest to one community or the other. As a result, according to Detrick, the seismic and geodetic communities remain relatively distinct, and the broadly different research approaches used by these communities need to be considered when contemplating the future management of seismological and geodetic facilities. He stated that it would be challenging for any single facility, regardless of the management structure employed, to continue to provide the domain expertise typical of IRIS and UNAVCO.

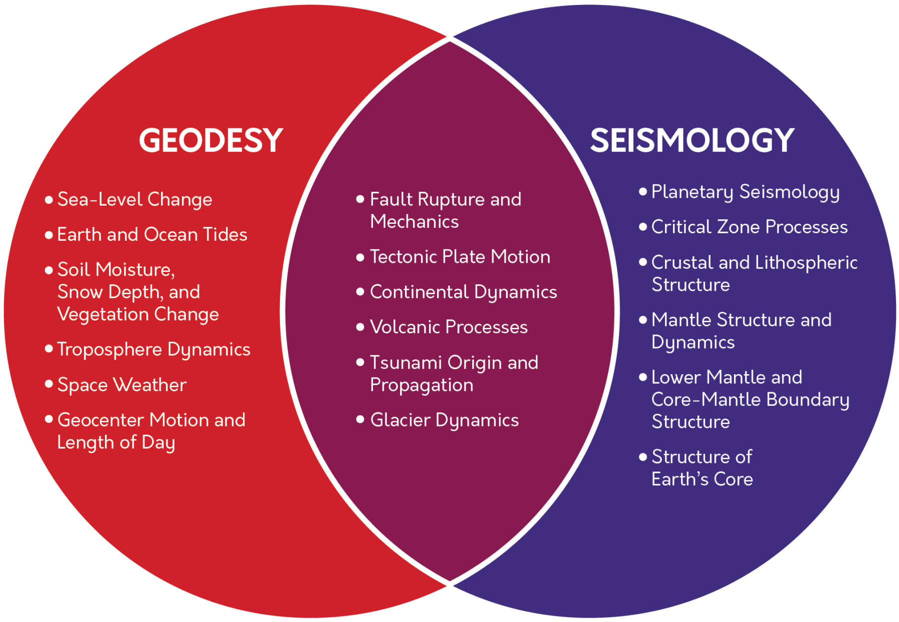

Figure 3.4. Research topics of interest in the seismology community (blue circle), the geodetic community (red circle), and where interests overlap and require the expertise of both. SOURCE: Modified from Detrick presentation, slide 17.

UNAVCO MANAGEMENT OF THE GEODETIC FACILITY FOR THE ADVANCEMENT OF GEOSCIENCE (GAGE)

M. Meghan Miller, UNAVCO

Meghan Miller, president of UNAVCO, described the UNAVCO management of NSF's GAGE facility. Support for GAGE is received primarily from the Division of Earth Sciences (EAR) at NSF, but the program also receives support from the NSF Office of Polar Programs and the National Aeronautics and Space Administration. The UNAVCO mission, according to Miller, is to facilitate geoscience research and education using geodesy. UNAVCO is a university consortium community with 120 U.S. member institutions, 111 international member institutions, and other associate member institutions. The consortium also includes a research and education community of diverse investigators reliant on technology and innovation in geodesy. She described a mission-driven organization that is an active partner in dozens of national and international projects that augment UNAVCO core funding. UNAVCO is a federally compliant 501(c)(3) nonprofit corporation incorporated in the state of Colorado.

UNAVCO capabilities, according to Miller, include construction and operation of new geodetic networks (e.g., Global Positioning System [GPS] and Global Navigation Satellite System [GNSS] networks); engineering, instrumentation, development and testing, and data services for NSF-funded investigators; operations to support NSF-funded community GNSS networks and the National Aeronautics and Space Administration's (NASA's) Global GNSS network; and planning support for principal investigators (e.g., to advance geoscience education, geodesy community engagement, and investigator proposals). She noted that priorities at UNAVCO are set based on collaboration with stakeholders.

Figure 3.5 is a schematic provided by Miller showing the various stakeholder pathways for input, which begin as early as strategic planning. To set priorities, UNAVCO works within the GAGE governance structure, with GAGE advisory committees, UNAVCO sponsors and other federal stakeholders, participants in UNAVCO workshops, and with partners in community projects and programs, among others.

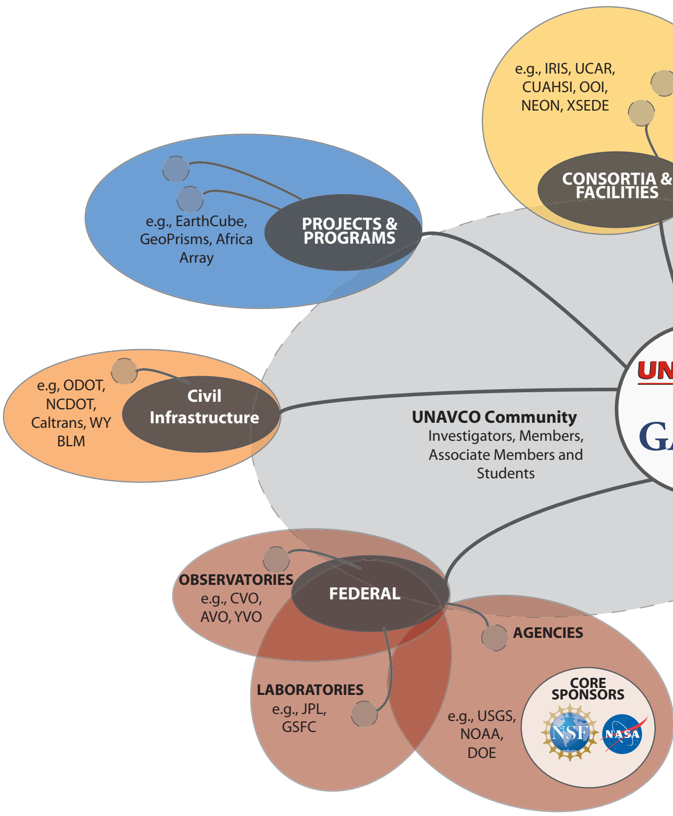

Figure 3.5. Schematic showing UNAVCO routes for stakeholder engagement and priority setting. NOTE: AGI = American Geosciences Institute; AGU = American Geophysical Union; AOGS = Asia Oceania Geosciences Society; AVO = Alaska Volcano Observatory; Caltrans = California Department of Transportation; COCONet = Continuously Operated Caribbean GPS Observational Network; CUAHSI = Consortium of Universities for the Advancement of Hydrologic Science, Inc.; CVO = Cascades Volcano Observatory; DOE = Department of Energy; EPOS = European Plate Observing System; GGN = Global Geoparks Network; GSA = Geological Society of America; GSFC = Goddard Space Flight Center; IGS = International Global Navigation Satellite System (GNSS) Service; IRIS = Incorporated Research Institutions for Seismology; IUGG = International Union of Geodesy and Geophysics; JPL = Jet Propulsion Laboratory; NCDOT = North Carolina Department of Transportation; NEON = National Ecological Observatory Network; NOAA = National Oceanic and Atmospheric Administration; ODOT = Oregon Department of Transportation; OOI = Ocean Observatory Initiative; PBO = Plate Boundary Observatory; SCEC = Southern California Earthquake Center; TLALOCNet = Trans-boundary Land and Atmosphere Long-term Observational and Collaborative Network; UCAR = University Corporation for Atmospheric Research; USGS = U.S. Geological Survey; WY BLM = Wyoming Bureau of Land Management; XSEDE = Extreme Science and Engineering Discovery Environment; YVO = Yellowstone Volcano Observatory. SOURCE: Modified from Miller presentation, slide 5.

In response to the prompting question related to accountability in management, Miller presented a high-level organization chart that demonstrates UNAVCO's up-line management (see Figure 3.6). The three programs within UNAVCO—the Geodetic Infrastructure Program, the Geodetic Data Services Program, and the Education and Community Engagement Program—report directly to Miller as the UNAVCO president. The president reports to the community member-elected Board of Directors. Historically, according to Miller, the governance structure has mirrored the management structure. There are advisory committees to each of the three UNAVCO programs that report to the Board of Directors and provide advice to the programs through the president. An Audit and Finance Committee and a Membership Committee also report directly to the Board of Directors, with the Finance committee providing oversight for fiscal compliance. The Western North America Interferometric Synthetic Aperture Radar Consortium (WInSAR) executive committee acts as an advisory committee, reporting directly to the UNAVCO Board of Directors.[1]

Miller also referred to the new joint governance structure with IRIS that Detrick described in his presentation. She added that IRIS and UNAVCO were also transitioning to joint management of some functions common to both facilities. UNAVCO and IRIS are exploring ways to increase interaction between the two facilities without losing the deep domain expertise necessary to each.

According to Miller, UNAVCO has changed organizational homes twice and has a history of adapting its management to suit community needs. In 1984, the geodesy community first organized as the University Navstar Consortium (UNAVCO) under the Cooperative Institute for Research in Environmental Sciences (CIRES) at the University of Colorado Boulder. The organization then operated under the Office of Programs at the University Corporation for Atmospheric Research (UCAR) from 1991-2003. UNAVCO incorporated as an independent 501(c)(3) nonprofit in 2001 and UCAR/UNAVCO and

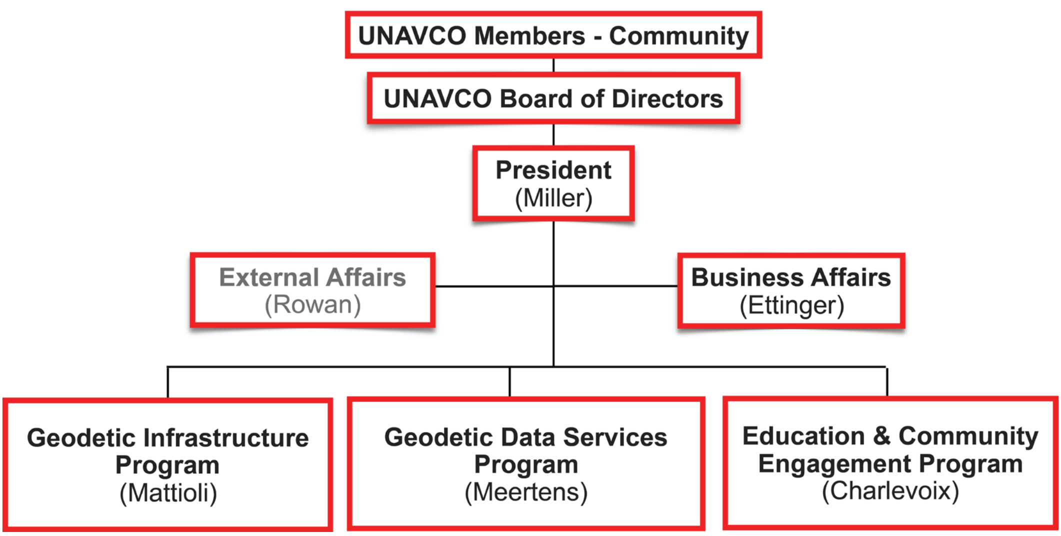

Figure 3.6. High-level UNAVCO organization chart showing up-line management structure.
SOURCE: Miller presentation, slide 6.

[1] WInSAR operates as a consortium within a consortium (UNAVCO). UNAVCO provides operational support to WInSAR, including membership administration, financial management, data management and archiving, and software tools.

the private UNAVCO both existed until 2003. At that time, staff transitioned fully to UNAVCO, Inc. UNAVCO support of the Plate Boundary Observatory (PBO) construction for EarthScope[2] occurred under its own leadership. Miller mentioned that in 2011, the UNAVCO and PBO structures were realigned into a single facility organized around geodetic infrastructure, geodetic data services, and community engagement programs. This decision was made by Miller as president of UNAVCO because she felt that multiple data and instrumentation sites were not necessary, there was greater potential for synergies with this realignment, and the structure was better suited to serve the community in the long-term.

Miller described how the work of UNAVCO is prioritized through the UNAVCO governance and management structures, and that those structures are, in turn, aligned to support existing observing capabilities as well as new observational and cyberinfrastructure innovation. Priorities are also established based on GAGE facility requirements to enable stakeholder discovery through observations, data services, and education, workforce, and outreach activities. However, budgets do not keep up with needs, and compromises are necessary in the interest of science, she stated. Miller described other feedback loops, such as those between the evolving geodetic capabilities and the science questions that result from new observations, development and testing of new instruments, deployment of new technologies, support for innovative observations and data services, and cultivation of the science community. New tools, according to Miller, have led to unexpected observations and important discoveries. Miller noted that given the rapidly evolving nature of geodesy, an important aspect of UNAVCO priority setting is proactively managing emerging technologies in the best interest of science and stakeholder needs. Governance-developed priorities are informed by UNAVCO staff and other domain experts, but constrained by budgets.

Miller mentioned that UNAVCO functions through a passionate and expert staff. However, UNAVCO does experience high staff turnover because of competition for human capital. Limited resources make it challenging to retain talent, to accommodate the increasingly varied demands of stakeholders, to maintain aging instrument systems, and to reduce technical debt. Miller did describe a landscape that is broad and active based on the large number of active awards, sub-awards, memorandums of understanding, or other former relationships. The mission of UNAVCO compels UNAVCO management, partners, and stakeholders to develop strategies to identify new opportunities in geodetic observing and cyberinfrastructure capabilities for science, for mission-oriented federal agencies, and beyond.

MODERATED DISCUSSION WITH IRIS AND UNAVCO MANAGEMENT AND BOARDS OF DIRECTORS

The workshop planning committee asked IRIS and UNAVCO staff and Boards of Directors to join Miller and Detrick for a panel discussion. Table 3.1 is a list of those on the panel, and their biographies are presented in Appendix C. Workshop participants were invited to ask the panel questions and engage in discussion. The sections below summarize the major themes discussed during this session.

[2] See https://www.unavco.org/projects/past-projects/pbo/pbo.html.

Table 3.1 IRIS and UNAVCO Panelists

IRIS	UNAVCO
Robert Detrick, President	Meghan Miller, President
Doug Wiens, Chair, Board of Directors	Glen Mattioli, Director of Geodetic Information
Bob Woodward, Director, Instrumentation Services	Chuck Meertens, Director of Geodetic Data Services

Balancing Organizational Vision Within NSF Contractual Requirements

In response to a question about how to balance organizational visions developed independently of contractual agreements with sponsors, Detrick responded that the vision of the IRIS community far exceeds available resources, especially those from core awards. Detrick opined that IRIS needs to look beyond the basic 5-year NSF award to manage and operate the facility, and pursue new initiatives that are not funded through their core award. This might be, for example, through other NSF divisions and beyond NSF.

Managing Sub-Awards

IRIS sub-awards, according to Detrick, are monitored and annually assessed for performance. If performance is determined insufficient, IRIS may terminate a sub-award agreement and choose another awardee, generally through open solicitation. The three largest sub-awards are periodically re-competed, although these might require specific technical capabilities and expertise that few organizations could provide. Miller described a different process at UNAVCO. UNAVCO sub-awards are mostly for data processing and instrumentation, but UNAVCO uses sub-awards to bring in new capabilities that could be used broadly by the investigator base under the umbrella of a single geodetic capability. Detrick reminded the workshop participants of the benefits of leveraging funds through sub-awards and academic partnerships—sub-awardees often have other sources of funding so staff are not necessarily 100 percent supported by IRIS or UNAVCO funds. Sub-awardees bring additional expertise to the IRIS and UNAVCO facilities, and often bring resources from their parent institutions with them at no cost to the sub-awardees or to IRIS or UNAVCO. Detrick cited the construction of a major warehouse at the New Mexico Institute of Mining and Technology, and facilities made available for instrument testing at the University of California, San Diego, as an example of such a resource.

Governance of Innovation

The committee structure established as part of IRIS governance has been an effective innovation driver, according to Woodward. The committees review budgets and work directly with facility staff to identify which capabilities and technologies to prioritize. IRIS staff, as domain experts, also interact broadly with the research community and contribute to prioritization discussions. Innovations may then be incorporated into facility capabilities, and often quickly. Detrick described how until 3 years ago, IRIS had no nodal ("coffee can") sensors,[3] but in response to community need identified through the governance structure, IRIS now has around 500 of those sensors, which are in great demand, and expects IRIS to obtain 1,500 sensors total. Mattioli described that governance is pushing innovation at UNAVCO in two new directions: (1) moving from a GPS-only sensor platform toward a multi-constellation GNSS platform; and (2) using unmanned aerial vehicles for high-precision geodetic imaging. UNAVCO is looking for support for these initiatives. Wiens added that the community governance model helps avoid expenditures on engineering improvements that may not represent the optimal use of funds from a scientific standpoint. Wiens also suggested that IRIS responsiveness to community demands for innovation is greater than that of other facilities under different governance structures because IRIS managers answer to the IRIS Board of Directors.

Maintaining Technical Expertise

In response to a question about how IRIS and UNAVCO maintain their unique expertise required to excel, Meertens said that UNAVCO provides a rich experience that long-time employees appreciate. He admitted that retaining younger people is a bigger challenge. UNAVCO has been strategizing ways to manage the environment with greater agility, allow for more collaborative research, and use innovative approaches to help attract and retain younger staff. Both UNAVCO and IRIS, according to Meertens, are working with the NSF Extreme Science and Engineering Discovery Environment (XSEDE)[4] resource on several projects to enhance cyberinfrastructure, and UNAVCO is working with XSEDE for system administration support and to move more to the Cloud. IRIS and UNAVCO have a joint project funded by EarthCube.[5] Detrick noted that in Seattle, Washington, IRIS has been able to hire people away from large technical corporations because of a preference for the IRIS work environment, in spite of the lower pay.

Availability of Resources to Principal Investigators

In response to a question about availability of instrumentation to principal investigators, Woodward stated that investigators first make an instrument request to the SAGE facility and SAGE provides a letter indicating whether the requested instrumentation is available at the facility. Once funded, the investigator is put on the facility's schedule, which is based on instrument availability, mostly on a first-come-first-served basis. NSF-funded investigators are given priority over other agencies wanting to use the equipment. No distinction is made on experiments funded by EAR versus other parts of NSF, according to Woodward. New equipment is sometimes purchased if, for example, NSF's Office of Polar Programs needs equipment in Antarctica during a given field season, but it is in use elsewhere. Under such conditions, funding will be given to purchase new instruments. Mattioli described UNAVCO's process as similar. UNAVCO has a web-based interface for

[3] These are compact, three-channel, all-in-one sensor and data loggers that IRIS uses for active and short-term passive deployments. See https://www.passcal.nmt.edu/content/instrumentation/sensors/high-frequency-sensors/nodes.
[4] XSEDE, housed at Indiana University, is a virtual system that can be used to interactively share computing resources, data, and expertise. See https://www.xsede.org.
[5] See https://www.earthcube.org.

investigators to request support. UNAVCO will provide a letter of support, if required, that will also describe the additional funds necessary to procure additional instrumentation. During scheduling, EAR-funded investigators are prioritized first, then NASA, and then other projects. Mattioli says resources are limited for new procurements.

Recapitalization of Equipment

When asked about long-term management challenges for IRIS, Woodward responded that recapitalization of the $80-$100 million instrument fleet maintained on behalf of the research community was a major challenge. Many of the instruments have been in operation for 12-14 years and the base award for SAGE does not include significant funds for recapitalization. IRIS has had some success obtaining recapitalization funds from other U.S. agencies that recognize the value of collaboration with the NSF-funded facility. Mattioli described UNAVCO as critically underfunded to recapitalize existing networks and pools of instruments available to principal investigators. The current UNAVCO award, according to Mattioli, allows for a limited amount of equipment replacement.

4

Other Facility Management Models

The workshop session continued with presentations from facility managers of the International Ocean Discovery Program (IODP), the National Ecological Observatory Network (NEON), and the National Aeronautics and Space Administration's (NASA's) Earth Observing System Data and Information System (EOSDIS). These speakers had been asked to describe their management and governance structures based on the same prompting questions provided to Detrick and Miller prior to the workshop (see Box 3.1). These presentations were followed by a panel of all of the facility managers that gave presentations. Moderated discussion prompted identification of commonalities and differences among the various management, governance, and decision models. The intent of the session was to provide workshop participants with a suite of management and decision models to consider when thinking about future seismological and geodetic facilities (to be discussed in a later session).

This chapter includes summaries of each of the three presentations given by facility managers, followed by a section describing the major themes discussed during the panel discussion.

MANAGEMENT OF THE INTERNATIONAL OCEAN DISCOVERY PROGRAM (IODP)

Bradford Clement, Texas A&M University

Bradford Clement is the director of Science Services for IODP located at Texas A&M University. The IODP is a multi-national program with about 26 countries that participate, fund, and coordinate program activities. The current program provides the science community with the only means to access sediments and rocks deep within the seafloor. It also installs deep seafloor observatories. IODP has evolved several times since its inception (see Box 4.1, presented by Clement) and has operated under multiple management structures. Clement described his involvement with the program under three different management models (under a contract, a multi-tiered contract as a subcontractor, and then later under a cooperative agreement).

BOX 4.1
Evolution of Scientific Ocean Drilling Programs

Multiple iterations of programs have provided scientists access to the ocean floor since 1956. The programs are listed below.

- Project Mohole: 1958-1966
- Deep Sea Drilling Project: 1968-1983
- Ocean Drilling Program: 1985-2003
- Integrated Ocean Drilling Program (IODP): 2003-2013
- International Ocean Discovery Program (IODP): 2013-2023

Clement noted that today, IODP is a federation of affiliated drilling operations with three platforms supported by different agencies: (1) the National Science Foundation (NSF) supports a non-riser drilling platform (the *JOIDES Resolution*, which Clement manages); (2) a consortium of European countries supports mission-specific platforms; (3) and Japan provides riser operations using the drillship Chikyu. The *JOIDES Resolution* has undertaken the majority of the expeditions for much of the program's history. Because the three platforms can be reformatted to a great extent, they are fairly responsive to changes in science community needs, he said.

The Integrated Ocean Drilling Program—a prior incarnation of the current IODP—had the same capabilities, but operated under a different structure. According to Clement, concerns of the three programs becoming independent and drifting apart resulted in the creation of a nonprofit central management organization (IODP Management International [IODP-MI]) charged with creating similar processes and procedures across all three platforms. Under that management system, he indicated, the IODP-MI gave a contract for a portion of operations to the Consortium for Ocean Leadership,[1] which in turn awarded a subcontract to Texas A&M University, which houses the *JOIDES Resolution*, and to Lamont-Doherty Earth Observatory (LDEO) to provide oversight of wireline logging service subcontractors. He noted that this was a cumbersome model for U.S. facilities, and it proved difficult for IODP-MI to force a single pattern of operations onto all aspects of operations and onto organizations from multiple countries. Each of the three platforms had different technical capabilities, foci, and decision-making processes to implement science, he said. Money from multiple sources had to be tracked separately, making accounting more difficult.

At present, according to Clement, the *JOIDES Resolution* works under a cooperative agreement rather than a contract. Clement provided the following example as an advantage of this arrangement over that of the IODP-MI: a 2-day delay in refueling a vessel—a $2 million event—would have pushed the expenditure across a fiscal year boundary. Accommodating the event would have been difficult under a contract agreement, but the flexibility of the cooperative agreement made this a "non-event." The former system was top-heavy and administratively difficult for those platforms at that time, he said. Operations were streamlined when funding became more constrained, resulting in the current drilling program management scheme. Most of the present funding for the *JOIDES Resolution* is from

[1] See https://oceanleadership.org.

NSF, but international partners also provide funding directly to NSF as unrestricted donations to *JOIDES Resolution* operations, making management of those funds simpler.

The *JOIDES Resolution* and other IODP platforms are overseen by a facility board that sets the schedule and priorities for operations. In the current program, the facility boards for each platform operate fairly autonomously, although all take advice from a similar set of advisory panels. Clement described the program as being a "bottom-up driven program written from the top-down," indicating that the science community drives IODP. The *JOIDES Resolution*, he indicated, undergoes a multi-tiered assessment process including cruise evaluations and feedback to everyone who participated on a cruise, an annual 2-day co-chief review of expedition implementations, and an annual review by an NSF panel. The NSF panel includes members of the ocean science and related communities and directors of other large NSF facilities. Based on that review, NSF provides guidance to the *JOIDES Resolution* facility and board. The program reprioritizes its resources in response, as appropriate.

Clement described how scheduling priorities are set. The program is nominally funded to operate four or five expeditions per year. At the time of the workshop, he said that more than 100 unsolicited drilling proposals had been submitted, of which four will be funded. International panels of scientists from member countries review the proposals. They review for science quality and whether the proposed science can be achieved at a given site. Highly ranked proposals are forwarded to the appropriate facility board and evaluated by a safety panel of industry experts to evaluate the safety of the proposed operations. Each platform's facility board will then prioritize scheduling and operations, decide on the ship track, and consider efficiencies, Clement continued. The platform then invites the shipboard scientists to participate in expeditions to assure quality data collection.

Clement explained that IODP operates under a 10-year science plan that outlines the priorities for the international program. Each proposal must be responsive to those priorities. Proposal review and feedback processes are more streamlined and nimble than in earlier years. Investigators provide a letter of intent and quickly receive feedback regarding whether a full proposal is warranted, he noted. The program has also improved its processes so that experiments generally are implemented within 2.5 years of being proposed.

Clement observed that the Sea Change: 2015-2025 Decadal Survey of Ocean Sciences[2] report directed NSF's Division of Ocean Sciences to better balance IODP facility and science costs. In response, there was an effort to separate facility and science operations, and NSF began funding the *JOIDES Resolution* through one NSF channel and associated science-related costs (e.g., support of U.S. scientists on an expedition and their post-cruise research) through another. This resulted in more efficient science reviews by panels.

Clement described that, overall, the current structure works well, and the three heavily involved universities benefit from such a large program. He noted the unintended consequences of splitting funds so narrowly, particularly in the United States where functions are distributed among multiple universities. (Texas A&M University has the contract for the *JOIDES Resolution*, LDEO runs the U.S. Science Support Program, and the Scripps Institution of Oceanography runs the Science Support Office.) For example, the *JOIDES Resolution* receives no funding for education and outreach, but demand can arise for use of the ship for these purposes (e.g., when arriving at a port of call and several hundred people want to tour the ship). He said that managers do try to facilitate such activities in spite of these barriers.

[2] See https://www.nap.edu/catalog/21655/sea-change-2015-2025-decadal-survey-of-ocean-sciences.

MANAGEMENT OF THE NATIONAL ECOLOGICAL OBSERVATORY NETWORK (NEON)

Michael Kuhlman, Battelle

Michael Kuhlman is the chief scientist of Contract Research at Battelle. Battelle is a nonprofit 501(c)(3) organization with one part that manages six Department of Energy National Laboratories and one Department of Homeland Security National Laboratory, while another part is the contract research organization that performs approximately $800 million per year in contract research for government, commercial firms, and others. Kuhlman works for this latter part of Battelle, which competed for management of NSF's NEON in 2015.

Battelle entered into a cooperative agreement with NSF in 2016 to manage NEON—an ecological observatory network with 81 sites in 20 eco-climate zones in multiple states and Puerto Rico. These produce 177 different terrestrial, aquatic, and aerial data products that support regional-, continental-, and global-scale ecological research, Kuhlman said. The network is intended to operate for a 30-year period. NEON provides data, protocols, education and training materials, and assets to the ecological research community. Examples provided by Kuhlman of NEON observations include exchange of carbon dioxide from the surface to the atmosphere (and vice versa), biomass buildup during the year, and aerial observations such as Light Detection and Ranging (LiDAR) and hyperspectral imaging. He noted that data, protocols, and processing algorithms are freely open to any investigators in the world through the NEON portal,[3] as are training materials and software tools developed for working with NEON data. Researchers are also provided access to NEON infrastructure and enhanced sampling at sites on a cost reimbursement basis.

Kuhlman described Battelle's matrix management structure for both its technical performance and support functions. A large portion of the program staff is fully funded by the program, but about 230 people each year are employed during the active field season. The matrix structure allows Battelle to draw from the additional 3,000 research and support staff available to any of the approximately 900 contracts Battelle performs in a typical year. Despite this broad matrix structure, instances occur when field staff with the right qualifications are difficult to find. Generally, however, Kuhlman said that the matrix structure allows for the ebb and flow of people and experts from project to project within Battelle, including human resources, contracts, financing, and purchasing. Charges to NEON program accounts are managed through Battelle's cost account managers, who are responsible for delivery on schedule and budgeting of their portions of the scope, as agreed to in the NEON Annual Performance Plan. According to Kuhlman, the management of NEON has not changed significantly since Battelle took over, but some of the structure has been streamlined as construction has wound down.

Figure 4.1 is a NEON organizational construct presented by Kuhlman. A chief scientist for the program sets scientific priorities as reflected in their Annual Performance Plan (NEON is evaluated by NSF in an annual site review). The chief scientist is assisted by an operations manager who is responsible for the "how" and "when" of accomplishing priorities within budget and on schedule, he said. Six functional program elements make up the lower tier of operations (Science, Field Science, Field Support, Instrumentation, Data Infrastructure, and Engagement). The instrumentation and science teams are responsible for implementing new instrumentation and best practices. Kuhlman stated that providing data is NEON's biggest form of user support, and that support comes largely through Battelle's data infrastructure and engagement teams.

[3] See https://data.neonscience.org/home.

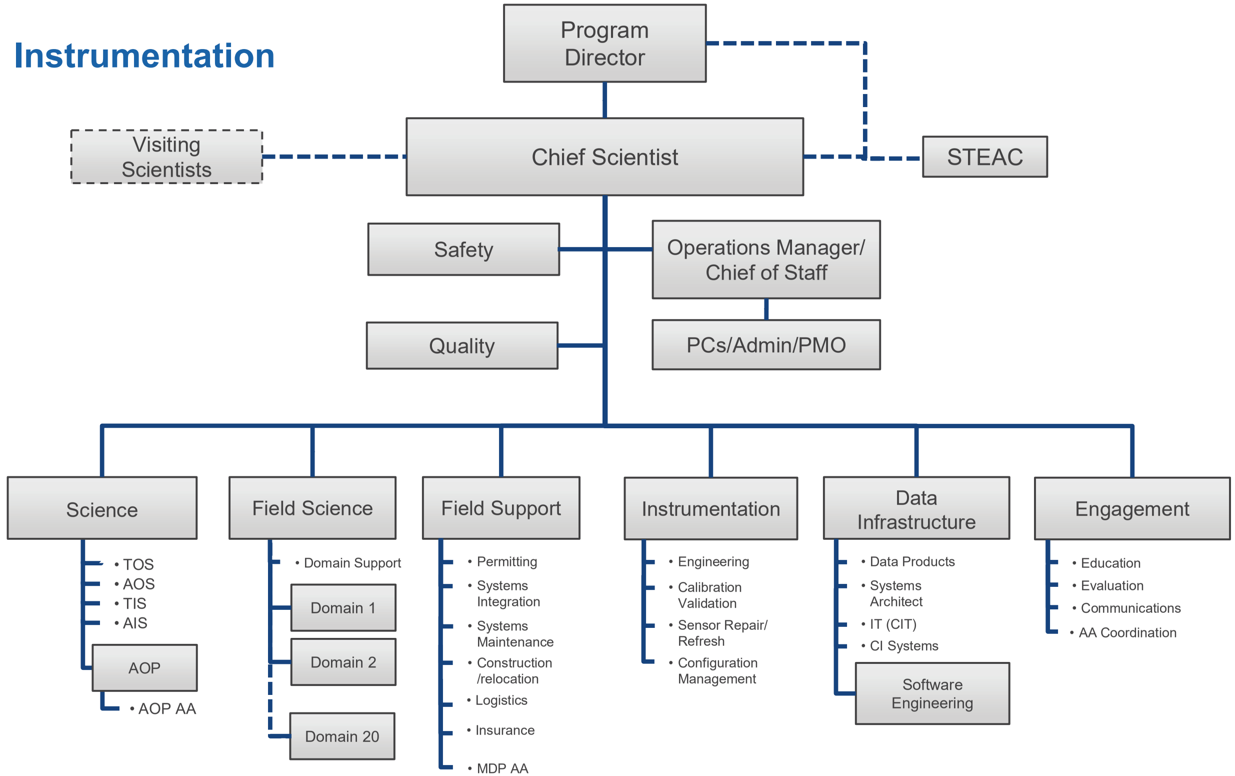

Figure 4.1. A simplified NEON organizational construct. NOTES: Finance, contracts, and accounting functions are simplified by the box labeled "PCs/Admin/PMO." AA = Assignable Assets; AIS = Aquatic Instrument System; AOP = Airborne Observation Platform; AOS = Aquatic Observation System; CI = Cyber Infrastructure; CIT = Corporate Information Technology; IT = Information Technology; MDP = Mobile Deployment Platform; PC = Project Controller; PMO = Project Management Office; STEAC = Science, Technology & Education Advisory Committee; TIS = Terrestrial Instrument System; TOS = Terrestrial Observation System. SOURCE: Kuhlman presentation, slide 8.

Kuhlman indicated that NEON has a strategic engagement plan that exceeds funding availability. The chief scientist prioritizes among activities in the plan. The engagement team has additional funding for activities (such as hosting a workshop aimed at increasing diversity in the data sciences in the environmental field). Permanent staff at each facility interact with site hosts and other researchers working at the sites. Staff also interact with the local education communities through lectures, training, seminars, data access, and assisting students with performing projects using NEON data. Battelle is in the early stages of implementing a tool to capture these types of activities in consistent ways.

Education and outreach are driven by the engagement team under the direct supervision of the chief scientist. Workforce development, focused on creation and formation of the next generation of ecologists, is largely an operation for the field science teams and scientific staff, along with the engagement teams. Figure 4.2, shared by Kuhlman, is a partial responsibility assignment matrix for facility operations. A program director, incorporated into the structure, resolves any disagreements regarding program implementation that may arise between the chief scientist and observatory director. The program director will identify a common course forward, then present that course to NSF for concurrence and to the community.

Kuhlman stated that the management of NEON is informed by that of other Battelle facilities. The manager of Battelle's National Laboratory Operations reports directly to Battelle's Chief Executive Officer, as does the NEON Contract Research Manager. Management of NEON and the National Laboratories have similarities, but additional requirements are imposed on the management of the National Laboratories. The directors of the National Laboratories each report to the respective boards responsible for the operations of each Laboratory. In all cases, there is an attempt to minimize the number of intermediaries between the functional organizations and the director.

NEON was conceived and initiated through a community-wide effort prior to Battelle's commencement of management responsibilities. According to Kuhlman, Battelle assumed this role with NEON when just under 25 percent of the construction program was complete. Battelle completed the remaining construction, and is now entering into the initial operations phase for the entire observatory. Battelle implemented an earned value management approach[4] and a bottom-up budget for each structure element, as well as an integrated master schedule to shift resources within and across the program as needed to maintain workflow. Battelle also implemented processes to manage change within the program that allows for flexibility and compromise so that the forward trajectory may be adjusted as appropriate. According to Kuhlman, NEON uses a Project Change Control Board that includes people from the parts of the program that either are impacted by or need to accommodate the change. Recommendations from the Project Change Control Board go to the Chief Scientist and Operations Manager.

According to Kuhlman, the cooperative agreement between Battelle and NSF calls for interaction with stakeholders through external advisory bodies. Battelle receives strategic advice regarding scientific and technical matter and direction through a Science Technology and Education Advisory Committee (STEAC). Kuhlman said that Battelle sends out a call for applications to serve on the STEAC. The applications are evaluated and voted on by the STEAC and accepted by Battelle. Approximately 12 STEAC members have a range of skills and serve 3-year terms. Battelle informs NSF of guidance received from the advisory committee and Battelle's response and rationale for the response.

[4] A technique for measuring project performance by combining measurements of project scope, schedule, and cost.

NEON Operations	Program Director	CS	OD	Operations Manager	Contracts Officer
Establish the scientific objectives and priorities for the Observatory	S	A/R	S	S	--
Develop and implement strategic community engagement plans and activities	S	A/R	S	S	--
Interface with the ecological science community for the development of Observatory scientific priorities	S	A/R	S	S	--
Interface with federal agencies, advisory groups, and science communities concerning Observatory operations	S	S	A/R	S	--
Represent Battelle's overall program performance to NSF	A/R	S	S	S	I
Represent NEON scientific plans and performance to NSF	S	A/R	S	S	I
Represent NEON program cost and schedule performance to NSF	S	S	R	A	I
Represent NEON contractual issues to NSF	S	S	S	S	A/R
Develop and implement NEON project plans	S	R	A	S	--
Manage scientific and technical performance	S	A/R	S	S	--
Scientific and technical review of applicable project plans and deliverables	S	A/R	S	S	--
Manage cost and schedule performance	S	S	S	A/R	--

Code	Stands for…	The person who…
R	Responsible	Performs the task
A	Accountable	Makes the final decisions and has ultimate ownership
C	Consults	Must be consulted before a decision or action has been taken
I	Inform	Must be informed that a decision or action has been taken
S	Supports	Provides support to the Responsible person

Figure 4.2. A partial accountability matrix for NEON operations that describes responsibilities across the management structure shown in Figure 4.1. NOTE: CS = Chief Scientist; OD = Observatory Director. SOURCE: Kuhlman presentation, side 13.

According to Kuhlman, additional tactical advice is received from 18 functional Technical Working Groups (TWGs) that are organized by topics spanned by the observatory. About 170 members were selected to serve in the TWGs, he indicated. They interact closely with Battelle science and domain staff and consider topics such as data protocols, best practices, and new instrumentation. Battelle receives further input on the science content of NEON through research community workshops, and through routine field staff interaction with local researchers, educators, and members of under-represented communities at field sites. Eighteen domain managers covering the 81 sites share information about effective practices, and materials are shared through a portal. He noted that NSF is developing plans for forming a user advisory group to NEON through the Directorate for Biological Sciences Advisory Committee.

The principal means by which NEON receives feedback, Kuhlman noted, is through the STEAC and through external community workshops. The STEAC is a body of external advisers to Battelle that meets monthly virtually, and twice per year in person, to develop and provide a strategic, longer-term vision and guidance for program evolution. They provide reports that Battelle shares with NSF, along with the actions taken by Battelle and responses about feasibility. The reports are posted online. STEAC's principal recommendations to date have been related to engagement and outreach. Battelle expects to receive more recommendations regarding science direction as the observatory matures. If STEAC makes a recommendation and NSF concurs, then Battelle will determine how to follow the recommendation. STEAC does not have authority to commit or direct resources on behalf of the program. However, the science team, through interaction with community members, will sometimes propose mechanisms for changes in focus or science direction to the advisory committee.

According to Kuhlman, Battelle currently assesses success in achieving community goals by determining whether NEON data outputs are consistent with goals established by the initial design. Battelle recognizes and has discussed with NSF that the initial design is 10 years old and may not be in complete alignment with current needs. Battelle statisticians study the data to determine the appropriateness of sampling designs. However, determining whether the observatory addresses community needs is currently a measure of numbers of publications and publication impacts, he indicated. Battelle depends on input from the STEAC and external community workshops to determine if the initial design meets demand.

MANAGEMENT OF NASA'S EARTH OBSERVING SYSTEM DATA AND INFORMATION SYSTEM (EOSDIS)

Jeanne Behnke, NASA Goddard Space Flight Center

Jeanne Behnke is the Earth Science Data and Information System (ESDIS) Project deputy manager for operations at the NASA Goddard Space Flight Center (GSFC). Behnke's presentation described the history and ongoing management of NASA's Earth Observing System Data and Information System (EOSDIS). She began her presentation by describing the evolution of the model for projects at NASA. In the 1980s, she said, a principal investigator in Earth sciences would develop all parts of a project, from instrumentation to data collection to analysis. An investigator would be contacted directly for any information or data about the project. NASA made changes to this under the Mission to Planet Earth Initiative[5] and initiated an open data policy to promote data usage by the community, including international partners.

[5] See https://www.hq.nasa.gov/office/nsp/mtpe.htm.

EOSDIS was originally designed to be a multi-mission operation for the Mission to Planet Earth platforms—including the Tropical Rainfall Measuring Mission[6] and the Terra,[7] Aqua,[8] and Aura[9] missions—composed of many functions including spacecraft operations, downlink receipt of data to Earth, processing, archiving, and distribution. Every NASA Earth science spacecraft developed since these changes were implemented was to be part of the EOSDIS system and the associated archive and distribution system would also be used for other data. Eventually, according to Behnke, the spacecraft operations component was moved elsewhere. EOSDIS now includes only interaction with data providers and users in the form of data processing, archiving, parsing, and distribution of data from all NASA Earth science missions. Behnke noted that at present, EOSDIS is a multi-mission operation system including about 95 missions and 30 petabytes of data in 438 million individual files. It delivers 1.6 billion data products to more than 3.1 million users around the world. Data are now available to users within 3 hours of satellite acquisition. EOSDIS has interoperable data archives, does science data processing and management, data access online through a common tool, and data transport to handle large downloads, she said.

Behnke described the presence of 12 discipline-oriented distributed active archive centers (DAACs) across the United States, operated by about 600 employees. The DAACs are key components of the EOSDIS charged primarily with the archiving and distribution of NASA's Earth science data collection. The metrics mentioned above are an aggregate of the work of all of the DAACs. She stated that some DAACs may need $10 million per year to operate while others may cost less than $1 million. These budgets depend on the volumes of data, traffic, data services, and sizes of individual data files. The ESDIS Project is able to shift funds and resources at the project level to cover, for example, staffing needs.

Behnke said much interaction occurs among the DAACS; for example, the DAACs may collaborate to bring systems engineers, user services groups, or outreach teams together for meetings, webinars, or online media activities. She stressed that communication across the entire science community can be difficult, so each DAAC has a user working group—a group of science users—that communicates throughout the year with its assigned DAAC and prepares a report to highlight data management, data collection, or science tools issues within the DAAC. This report is sent to the ESDIS Project and to NASA Headquarters for review and incorporation into the EOSDIS system.

According to Behnke, ESDIS conducts annual performance and budgeting exercises with NASA Headquarters and with GSFC. The EOSDIS is federally managed through contracts and interagency agreements, as well as working agreements with other NASA centers. The ESDIS Project provides user access to data from NASA's Earth science missions through the development and operation of the sciences systems of EOSDIS. The design of EOSDIS is informed by many stakeholders, including but not limited to the NASA Headquarters Earth Science Division, science teams, the Mission Operations Centers (e.g., providing information about new geolocations that need to be accounted in data processing as satellites age and deorbit), and the NASA Chief Information Office.

Behnke highlighted the Oak Ridge National Laboratory DAAC (a partnership with the Department of Energy), where approximately 1,400 individual data sets related to biogeochemical dynamics, ecological, and environmental processes from NASA-funded field campaign studies are archived and made available to all researchers. She also discussed the Alaska Satellite Facility (ASF) DAAC at the University of Alaska Fairbanks, where synthetic aperture radar products and data related to sea ice, polar processes, and geophysics are

[6] See https://pmm.nasa.gov/trmm.
[7] See https://terra.nasa.gov.
[8] See https://aqua.nasa.gov.
[9] See https://aura.gsfc.nasa.gov.

housed. The ASF also mirrors data from the European Space Agency's (ESA's) SENTINEL[10] program at that facility as part of a NASA/ESA bilateral agreement.

To demonstrate the volume of activity at a DAAC site, Behnke stated that the ASF DAAC distributed almost 65 terabytes of SENTINEL data in a recent 1-month period. During that month, more than 2,000 users from Brazil, Chile, Columbia, and Peru were registered, indicating use of the data for projects around the world. Users rely on the DAAC centers not only for data, but also for user support. Behnke stated that all indicators suggest that data sets will get larger in the near future. The current "on-premises" type of model employed by each DAAC will not be able to keep up with data archiving and demand, and more user support will likely be necessary, she noted. Given the volumes of data, NASA Headquarters recently directed EOSDIS to study and plan to move data operations to the commercial Cloud.

Moving to the commercial Cloud requires many new processes while continuing to operate under NASA's open data policy. For example, ESDIS has had to create software to avoid potentially expensive data egress charges from Cloud providers. In-house training was developed for ESDIS resource analysts to understand how to monitor cost status, Behnke continued. NASA Headquarters is also brokering discounts for the Agency with the commercial Cloud providers based on the amount of storage they expect to need, which means that ESDIS needs to provide accurate data volume estimates for this and future years. Plans are in place to test commercial Cloud applications by migrating 30 of their most popular products, she said. Those data will be available via the Cloud but also remain on premises until the data in the Cloud are deemed stable. As data are migrated to the Cloud, the DAACs need to encourage science users to do their processing within the Cloud framework. This means encouraging the use of various machine-to-machine interaction techniques (e.g., scripts). NASA Headquarters is also pushing for more data system software to be open source. Behnke mentioned that building application programming interfaces is important to the user community.

The Earth Sciences Data Systems at NASA Headquarters provides funding and direction to the project. Behnke described a system architecture model and listed the following sources of advice and user feedback:

- Opportunities for EOSDIS to test new interfaces, technologies, or methods from specific programs;
- EOSDIS staff communication with the science teams of new NASA missions to better understand data ingest and archive requirements;
- The National Academies of Sciences, Engineering, and Medicine's 2017-2027 decadal survey conducted for NASA (*Thriving on Our Changing Planet: A Decadal Strategy for Earth Observation from Space* [2018]);[11]
- Information technology and security directives from the Chief Information Office (which are becoming more difficult to accommodate as the program ages);
- Other agencies, such as the U.S. Geological Survey and the National Oceanic and Atmospheric Administration, and international partners;
- The ESDIS[12] project that is managed within EOSDIS system architecture;
- The American Customer Satisfaction Index, an independently contracted survey; and
- Science researchers and applications users.

[10] See https://sentinel.esa.int/web/sentinel/missions.
[11] See http://www.nap.edu/catalog/24938.
[12] See https://earthdata.nasa.gov/esdis.

MODERATED DISCUSSION WITH FACILITY MANAGERS

Following the presentations, Behnke, Clement, Detrick, and Miller sat on a panel and took questions from the workshop participants. The workshop planning committee's goal for this discussion was to provide a common understanding among workshop participants of the commonalities and differences among the management, governance, and decision-making models across the different facilities. The next sections summarize some of the key themes of the discussion.

Differences in Management Styles

Detrick stated that he was struck by the difference in management structures, governance approaches, and methodologies for community interactions amongst the different facilities. He summarized some of the differences by highlighting that IODP is an international consortium with different countries supporting different aspects of the program, and with evaluation of science proposals done internally, while the Incorporated Research Institutions for Seismology (IRIS) and UNAVCO are dependent on NSF to make science funding decisions. Detrick noted that each facility has adapted their operational models to suit their needs. He continued by stating that the matrix management model employed at NEON could work well with a large organization such as Battelle, but that IRIS and UNAVCO do not have sufficient staff resources to implement such a model. A workshop participant added that the size of the research community and its expectations also drive the management models.

Clement noted there are circumstances when it is practical to organize a facility as a corporation, but other circumstances for which the infrastructure of a university is beneficial. He cited being able to take advantage of the university's general counsel and human resources programs as a source of potential cost savings, although he did note that university-imposed requirements can impede facility processes. Clement said that a cross-facility examination of relative costs might be informative.

Jon Alberts, executive secretary of the University-National Oceanographic Laboratory System (UNOLS), gave a brief overview of UNOLS as another example of a scientific facility management structure. His comments are summarized in Box 4.2.

Joint Facility Committees

Detrick clarified that the structure of the Joint IRIS/UNAVCO Executive Committee, described by both Detrick and Miller in their presentations (see Chapter 3), was still being planned and implemented. He said that IRIS and UNAVCO subcommittees might meet face to face to address cross-cutting issues, but might also meet separately to handle issues unique to each facility. Meertens added that IRIS and UNAVCO facility managers have always participated in each other's committee meetings. Aster pointed out that joint IRIS/UNAVCO committees are not new; the IRIS Polar Network Science committee, for example, was established as a joint IRIS/UNAVCO committee. He said that the committee works well to address issues common to both facilities, and is effective at addressing issues of research communities without their own consortia (e.g., the glaciology community).

BOX 4.2
The University-National Oceanographic Laboratory System (UNOLS)

Jon Alberts, a workshop participant, briefly described another facility: the University-National Oceanographic Laboratory System (UNOLS). UNOLS is a consortium of 59 U.S. universities that coordinates the activities of oceanographic ships' schedules. UNOLS does not fund ship time, but rather facilitates the scheduling and operation of vessels for individual universities. The UNOLS organization currently consists of only five full-time and two part-time employees at The University of Rhode Island; most of the work of UNOLS is done through volunteer user committees such as the Marine Seismic Research Oversight Committee that provides oversight of the *R/V Langseth* at the Lamont-Doherty Earth Observatory. The University of Washington recently took over operation of the UNOLS office for the next 10 years, according to Alberts. UNOLS has organized itself to be a mechanism for communication between the marine science community and the funding agencies. Alberts described UNOLS as "lean and mean," but that there would be benefits of having the organization grow so that it could take on some of the tasks of the volunteers.

Another participant provided more detail, stating that UNOLS functions as an advisory structure to funding agencies. Funding of the academic research fleet involves interagency coordination, with the National Science Foundation handling the majority of the coordination. Funding goes directly to investigators rather than through UNOLS. The work of the organization is distributed among members and works well for community-based collaboration, according to the participant. He added, however, that UNOLS's model would be inappropriate for any of the organizations described so far in workshop presentations.

Effect of the EarthScope Plate Boundary Observatory on IRIS and UNAVCO Management

A workshop participant asked how completion of the Plate Boundary Observatory (PBO) and the EarthScope movable array impacts UNAVCO and IRIS. Miller responded that the biggest internal issues nearing the end of construction were related to staffing. Staffing levels had to be cut substantially when construction was over, but there was a need to incentivize staff to stay until the very end of construction. By realigning resources dedicated to field applications, geodetic infrastructure, and data, UNAVCO was able to restructure and move from a construction mode into an operations and management mode. With respect to future operations, Miller stated that UNAVCO is developing a strategy to integrate the PBO with networks constructed by UNAVCO in Mexico and the Caribbean under independent awards with NSF.

Detrick noted that the EarthScope movable array experiment continues, with subcontractors handling data processing. IRIS is in a similar stage that UNAVCO was in prior to the transition from construction to operations and maintenance. Instruments are to be removed completely by 2021, when the transportable experiment will end. No follow-on experiment is being planned. According to Detrick, IRIS will disband the group, perhaps incorporating some staff into other IRIS operations. It will have to restructure, much like UNAVCO did. IRIS successfully developed a new capability—the transportable array—but IRIS will likely lose the people implementing the array.

Facility Reviews and Feedback

According to Detrick, NSF's National Science Board instituted a policy that facility awards were to be renewed or re-competed every 5 years, depending on the circumstances around the facility. The 5-year proposal renewal is, in itself, a review. Individual IRIS and UNAVCO facility components may be reviewed more frequently. Miller pointed out that the facilities also undergo a management review every 5 to 10 years. Clement added that large facilities that receive funding from NSF's Major Research Equipment and Facilities Construction account undergo additional oversight to ensure that all aspects of the program are legal and appropriately documented. Meeting these requirements, noted Clement, could be challenging for a smaller facility such as UNOLS.

A workshop participant asked the panelists about approaches used to assess how well their respective boards provide guidance. Detrick responded that IRIS has no separate mechanism to directly assess performance of the board over time, but suggested that the periodic reviews of program elements, the contract renewal process, and NSF evaluations provide indirect information about how well the Board of Directors is doing as the body with principle responsibility for the organization. Clement responded that because operations of the *JOIDES Resolution* are embedded in a university, it does not have a board of directors. It does, however, have a facility board that includes representatives from each of its funding agencies, plus six scientists (three from the United States and three representing international partners). As part of the annual review, an NSF panel evaluates how effectively the facility board provides direction to the facility.

A participant noted that facilities that have boards of directors from the user community (e.g., IRIS and UNAVCO) have built-in mechanisms for successful incorporation of community feedback, but wondered how other facilities without such boards measure success. Some obvious metrics (e.g., numbers of publications) may take too long to measure to be useful. Another participant indicated that success might be measured by the number of new scientists coming into the field and serve on advisory committees, but this also requires a long time to measure. Detrick suggested the response to Board of Directors recommendations could be on a shorter timescale, again raising the example of the nodal sensors he described earlier (see Chapter 3), which occurred in only 3 years. If IRIS actions were not responsive to community needs, Detrick stated, IRIS standing committees would communicate with the IRIS Board of Directors, who, in turn, would develop a plan with facility management to address the given issue.

Implementing Recommendations and Managing Expectations

Clement described a project portfolio management process at the *JOIDES Resolution* facility that allows for assessment of benefits given a request to change instrumentation or data systems. Facility management considers who benefits from the change (e.g., internal or external customers), whether the change will affect one or multiple expeditions, or one or multiple scientific needs. Clement continued by describing that facility management then looks at available resources, and where changes could be implemented to the best satisfaction of the community. Detrick stated that the IRIS Board of Directors makes final decisions on budget priorities, and gives guidance to the standing committees. The standing committees, in turn, work with program managers to implement the priorities.

When asked how facilities manage scientific community expectations, Detrick responded that having IRIS governance committee members involved in strategic planning and budget prioritization is an effective way to manage community expectations. Those committee members make the difficult decisions, and then communicate the realities of what can and cannot be done to the broader community.

Training the Board of Directors

Miller explained that the UNAVCO Board of Directors created a training and development plan for board members that includes a rotation of topics over a 2-year cycle. The plan ensures that the board understands the full range of responsibilities and fiduciary oversight. UNAVCO takes advantage of external resources, and sometimes brings in external people to conduct the training. Detrick described that IRIS has three new board members join the board each year. At that time, IRIS has a 2- to 3-hour training session for new board members that includes discussion of both legal and fiduciary responsibilities of the board and individual board member responsibilities. On reflection, Kuhlman added later that training sessions for NEON board members has not been part of NEON operations, but that it would be something NEON would adopt, moving forward.

5

Advantages and Disadvantages of Management Models for Accommodating Seismological and Geodetic Facility Capabilities

Following the panel discussion, focus of the workshop shifted from considering management models in general to considering how they might be applied to seismological and geodetic facilities. Workshop participants were divided into four preassigned breakout groups (see Session 3 in the workshop agenda, Appendix B), and were given 1 hour to discuss how well seismological and geodetic facility capabilities, emerging research needs, and technical innovation might be accommodated by the various models. Each breakout group was assigned a moderator from the workshop planning committee and a rapporteur from the Catalyzing Opportunities for Research in the Earth Sciences (CORES) consensus study committee. The rapporteur for each group captured the main points of the group's discussion and presented those points in the plenary session that followed. All four breakout groups were given the same prompting questions to guide their discussions (see Box 5.1) to which the groups responded to varying extents. Discussions on related issues were welcomed by the moderators. The sections below summarize the brief reports provided by each of the breakout groups.

BOX 5.1
Prompting Questions for Session 3 Small Group Discussions

- What are the advantages and disadvantages of the various management models for accommodating instrumentation, user support services, data management, education and outreach, and workforce development?
- What elements of the management models do you think best accommodate and integrate technological innovation? Why?

SUMMARY OF BREAKOUT GROUP 1 DISCUSSION THEMES

Steve Jacobsen, Northwestern University

Line Management Versus Matrix Structure Management

Steve Jacobsen presented the discussion of Group 1, which compared line management (e.g., that of the Incorporated Research Institutions for Seismology [IRIS] and UNVACO) versus matrix management structures (e.g., Battelle and National Ecological Observatory Network [NEON]). When a line management structure is employed, leadership and program managers (departments) run the facilities and issue sub-awards as needed within their in-line functional areas. Administrative and technical expertise may be outsourced to keep overhead costs low. In a matrix management system, the matrix may be envisioned with rows that represent different areas of expertise or capacity distributed across columns that represent projects. Different projects might rely on the same groups of experts distributed across the rows—in other words, all projects draw on the same pool of experts across the facility. With this model, little outsourcing may be necessary.

Instrumentation

Jacobsen reported on the group's discussion about aging instrumentation and the advantages of in-house expertise for retooling and repurposing the instruments. In some cases, and with the National Science Foundation's (NSF's) approval, the instruments could be donated to schools in developing countries, for example. The group also discussed management issues that arise when new instrumentation is obtained, for example, accommodating new data streams or developing new software. He said that larger data sets may have to be handled, processed, and archived within the facility, requiring additional resources.

SUMMARY OF BREAKOUT GROUP 2 DISCUSSION THEMES

Shemin Ge, University of Colorado Boulder

Shemin Ge reported on her group's "free-flow" exchange of ideas. When discussing management structures, her group focused mostly on IRIS and UNAVCO and she presented the following overarching points:

- IRIS and UNAVCO engage the seismological and geodetic communities well.
- Assessments of whether IRIS and UNAVCO meet community goals is primarily through feedback among IRIS and UNAVCO board members and their respective research communities. Issues are identified and addressed through changes within each facility. Board members are held accountable if research community goals are not met through the election of new board members.
- The elected community-based advisory boards at IRIS and UNAVCO are effective in responding to community needs.

- EarthScope is a good example of how the facilities meet scientific goals of the research community.
- There are fundamental funding, institutional, and organizational differences between NSF and the National Aeronautics and Space Administration that inform how data are managed by their respective facilities.
- The current management structures of IRIS and UNAVCO promote education, outreach, and diversity, including gender diversity, on their boards.

Ge reported that IRIS and UNAVCO accommodate technical innovation by keeping "their ears to the community." The facilities used to prioritize broadband instrumentation, which is expensive and involve long-term experimentation. The research community now prioritizes faster solutions, and the facilities are responding by considering the tradeoffs associated with shorter-period, portable, and less expensive instrumentation. Ge reported that scientific innovation has become the norm for IRIS and UNAVCO.

SUMMARY OF BREAKOUT GROUP 3 DISCUSSION THEMES

George Gehrels, The University of Arizona

George Gehrels summarized his group's discussion and stated that all of the existing facilities described during the workshop were well organized, were managed mostly by domain experts rather than business managers, and received abundant community input. These factors give the research communities confidence that the facilities are science based. Gehrels reported that because IRIS and UNAVCO scientists do not generate and analyze data that go through their facilities, negative perceptions of IRIS and UNAVCO scientists having early access to the data are avoided. IRIS and UNAVCO management structures work well in response to change, as demonstrated through the development of EarthScope, according to Gehrels. His group's view was that IRIS's evolution from a small program to a much larger one seemed to go smoothly. UNAVCO management was challenged early on, he said, but seems to be functioning well now.

The group discussed how management could support technological innovation and Gehrels provided the following summarizing comments:

- Combining land and marine geophysical research is an opportunity that might be pursued by the research communities.
- Innovation requires close interaction between researchers (i.e., facility users), facility personnel, and facility management. This kind of interaction creates opportunities for science and for funding partnerships among agencies and organizations.
- Opportunities for using machine learning and artificial intelligence are important to explore.
- Users and scientists were viewed as the primary drivers of innovation occurring in facilities.
- Junior investigators help drive innovation and energize facilities and IRIS and UNAVCO engage them well.

SUMMARY OF BREAKOUT GROUP 4 DISCUSSION THEMES

Diana Elder, Northern Arizona University

Diana Elder said her group used the questions (see Box 5.1) to organize their discussion. The group described management models more generally than the other groups, and organized the presentation by the facility capabilities (instrumentation, user support services, data management, education and outreach, and workforce development). The overarching themes discussed by that group, as presented by Elder, are described below.

Instrumentation and User Support Services

Elder summarized her group's discussion with the following ideas:

- Consortium models offer advantages by providing a large instrument pool and dedicated managers.
- There are advantages to management models that provide easy access to instrumentation and facility expertise for early career investigators.
- There are advantages to management and governance models that incorporate advisory boards in facility decision making in terms of representing research community needs.
- Consortium models may be disadvantageous in terms of the long lead time needed to schedule experiments.
- Matrix models may be disadvantageous in terms of availability and accessibility of dedicated staff with particular expertise, especially for early-career investigators.

Data Management

Elder reported that her group saw a perceived advantage to having a strong connection between data collection, archiving, and servicing. Some participants raised concerns about the effects of those activities being managed by different entities, but others thought such arrangements have worked well. There is a need for research community trust in the organizations providing those different services.

Education and Outreach and Workforce Development

Elder indicated that her group saw advantages to a management system that allowed for close connections between scientists doing work in the field and facility education and outreach programs. She noted that the scientific community and the public are more easily inspired if there is a closer connection between scientists and outreach products. Some of the management models discussed during the workshop, and particularly the consortia, were able to build large communities of science educators. Consortia of universities, according to Elder's group, are the best places to build a scientific workforce.

Technological Innovation

Frequent, small community meetings were an important component of many of the facilities discussed during the workshop. Elder reported that her group considered it advantageous to have a management model that brings the community together regularly to highlight the state of the art.

6

General Comment Period

The workshop planning committee provided an opportunity for participants in the room to make public comments. Individuals were given 3 minutes each to comment on any relevant topic. Appendix E is an unedited transcript of those comments. Below is a list of commenters and the topics they raised.

- Maggie Benoit, National Science Foundation (NSF): Explanation of why NSF funded the workshop.
- Eric Webb, Sandia National Laboratory: Student intern programs, life-cycle costs of sustaining capabilities, and difficulty partnering with NSF.
- Michael Foote, The University of Chicago: Federal limitations on international collaborations.
- Jim Yoder, Woods Hole Oceanographic Institution: Small Business Innovative Research Program model.
- Doug Hollett, Melroy & Hollett Technology Partners, LLC: Increased interaction between applied engineering and research science communities.
- Egill Hauksson, California Institute of Technology: Fostering understanding of instrumentation among graduate students.
- Sergio Barrientos, National Seismological Center, University of Chile: Partnerships for sustaining operational standards of earthquake early warning systems.
- Glen Mattioli, UNAVCO: Response to Barrientos' question about partnerships.
- Rick Aster, Colorado State University: Continued response to Barrientos's question about partnerships.
- Kate Moran, Ocean Networks Canada: Partnerships in Canada (including answers to interjected questions from Hollett).
- Enrique Cabral-Cano, Instituto de Geofísica, Universidad Nacional Autónoma de México, Mexico: Governance as part of management, U.S./international collaborations.

- Xyoli Pérez-Campos, Instituto de Geofísica, Universidad Nacional Autónoma de México, Mexico: Balance of science and monitoring at a small facility.
- Ben Phillips, National Aeronautics and Space Administration (NASA): NASA scale of support of geodetic data systems.
- Andrea Donnellan, Jet Propulsion Laboratory: Complementary expertise incorporated into a management structure.
- Michael West, University of Alaska Fairbanks: Federal advocacy efforts through Incorporated Research Institutions for Seismology and UNAVCO.

7

Management Models for Future Seismological and Geodetic Facilities

The second day of the workshop focused on future seismological and geodetic facilities and the scientific advantages of different management structures that might be applied at them. The workshop planning committee once again preassigned workshop participants into one of four moderated breakout discussion groups (see Session 5 in the workshop agenda, provided in Appendix B). Two of the breakout groups discussed management structures that would be appropriate for distributed or partially distributed seismological and geodetic facility capabilities, and two groups discussed more centralized management structures for seismological and geodetic capabilities for which facilities might be combined. A moderator and a rapporteur were assigned for each group. Each group received prompting questions appropriate to their topic. Workshop participants were asked to focus on the scientific advantages and disadvantages of independent or centralized seismological and geodetic capabilities while also exploring management and decision-making structures that could be flexible in the face of new science and technology developments. Participants then reconvened in plenary, and rapporteurs provided their summaries.

This chapter is divided into three sections. The first section describes the summaries from the breakout groups that discussed management structures for independent seismological and geodetic capabilities. The second section describes the summaries from the groups that considered centralized seismological and geodetic capabilities. The third section presents the themes discussed during the plenary session.

MANAGEMENT STRUCTURES FOR INDEPENDENT SEISMOLOGICAL AND GEODETIC CAPABILITIES

Two of the breakout groups were assigned to consider management structures suitable for supporting the capabilities of independent seismological and geodetic facilities. Box 7.1 lists the prompting questions provided to the groups. Summaries of the key themes identified by group rapporteurs are provided in the sections that follow.

BOX 7.1
Prompting Questions Provided for Small Group Discussions on Management Structures for Independent Seismological and Geodetic Facility Capabilities

1. What are the scientific advantages of distributing seismological and geodetic capabilities (listed below) among multiple organizations (as is done at present)?
   a. instrumentation
   b. user support services
   c. data management
   d. education and outreach
   e. workforce development
2. What are disadvantages?
3. What can be learned from other scientific facilities about successful management practices to address future challenges and emerging capability needs?
4. What management model aspects discussed during the workshop might allow the current facilities greater flexibility to respond to future unexpected scientific needs or technology developments?

Summary of Breakout Group 1 Discussion Themes

Donna Whitney, University of Minnesota

Donna Whitney's report of her breakout group's dialogue is divided into discussions of the advantages and disadvantages of distributing capabilities among multiple facilities, and a discussion of how distributed management may or may not allow flexibility to respond to scientific and technology developments. Whitney stressed repeatedly that her group's discussions were about hypothetical rather than about existing seismological and geodetic facilities.

Advantages to Distributing Capabilities Among Multiple Facilities

Whitney reported her breakout group's discussion on the advantages and disadvantages of distributing capabilities among separate seismological and geodetic facilities. In terms of instrumentation, she said that distributed facilities allowed expertise to be spread out and more people trained in various instrumentation and techniques. It might also allow for better integration of skills associated with instrumentation and data management if the same personnel were responsible for both parts of the operation. Whitney reported that this would advance science, and might allow for greater flexibility and adaptability for instrumentation. In terms of user support services, Whitney reported that the distributed model may be the best way to support users because domain experts from the facilities could work with specialized user groups. This might lead to more innovation. Likewise, the group discussed that it may be advantageous to distribute capabilities among multiple facilities if the data are particular to different user groups, or if there is a need to focus on a particular type of data.

According to Whitney's group, education and outreach and workforce development are enhanced through distributing capabilities among multiple facilities in part because there would be more facilities, more people, and more scientists connected to these activities. The number and types of activities could be increased, as could the opportunity to reach different audiences. Workforce development might be enhanced because there is a greater spread of specialized skills and highly technical knowledge. Whitney described that there could be more entry points for employment, and opportunities for both stability and portability for the workforce. Capabilities distributed among multiple organizations might offer multiple opportunities to broaden participation in science among, for example, under-represented groups.

Disadvantages to Distributing Capabilities Among Multiple Facilities

There is increasing overlap of interests and research within seismology and geodesy, Whitney reported. She described how distributed capabilities might result in a silo mentality that inhibits the potential development or use of instrumentation that could be applied to research in both fields. Distributed capabilities might also result in a lack of cross-trained specialists. Distributing instrumentation capabilities may create obstacles to integration and collaboration, although Whitney noted that there are opportunities for integration and collaboration among facilities. Increased competition between facilities for funding might be an advantage or disadvantage, she reported. Hypothetically speaking, the biggest disadvantage to distributing user support capabilities among facilities is likely a duplication of efforts, which could inhibit sharing and may result in a lack of standardization.

Whitney noted that distributed systems may not recognize synergistic opportunities for enhanced education and outreach activities, but she said the group also discussed how this might be true for any facility management model.

Flexibility of Distributed Capabilities

Whitney reported that the current management structures for seismological and geodetic facilities are quite flexible. The community-based approaches allow for scientific agility and opportunity to focus on multiple science priorities. Distributed capabilities among facilities may also allow for greater flexibility to compete or re-compete for funding. However, her group noted that funding agencies have multiple facilities to administer. Her group wondered if separate organizations take full advantage of opportunities to collaborate on their increasingly overlapping portfolios, but she observed that separate facilities do not preclude cooperation among facilities. She cited the current cooperation between Seismological Facility for the Advancement of Geoscience (SAGE) and Geodetic Facility for the Advancement of Geoscience (GAGE) in data management as evidence.

Whitney concluded with her group's final thoughts: there are two well-functioning organizations that could evolve as needs arise and as scientific and technological capabilities emerge. Change could start with governance. A simplified, unified executive governance structure could enable and enhance the positive attributes of a distributed system.

Summary of Breakout Group 2 Discussion Themes

Bill Dietrich, University of California, Berkeley

Bill Dietrich's group considered the scientific advantages and disadvantages of distributed capabilities in light of the differences between seismology and geodesy. His group did not discuss SAGE and GAGE specifically, but did use those facilities as examples.

Advantages to Distributing Capabilities Among Multiple Facilities

In consideration of instrumentation, Dietrich reported his group's observation that seismological and geodetic instruments have different bandwidth, their site locations are different, there are differences in resolution at depth, and different expertise are involved. He noted areas of convergence—geodesy is aspiring to have dense deployments, but geodesy has different timescales of observation than seismology, different error and noise sources, different field practices, and different lengths of deployment. Although geodesy and seismology have overlapping elements in the questions to which they respond, he said, the science questions are very different.

According to Dietrich's group, distributed facilities offer advantages for user support services because there is a healthy competition among centers that can lead to better support. For example, response to user requests is timelier because the facilities are smaller and more streamlined. Dietrich reported that Robert Detrick's "dirt-to-desktop" concept (see Chapter 3) was compelling. It was desirable to have the same group of people managing the data from the time of its collection, to its storage, to making it available to the user. Logistically, distributed systems are advantageous because the data format requirements are different for different groups, and the expertise necessary for archiving those data may differ, as may the information technology security issues. Data products may be tailored for specific communities, and tools for distribution may be specialized, he said.

Dietrich reported on the value of having distributed data centers, and having them compete for funding in a manner similar to the Earth Observing System Data and Information System (EOSDIS) discipline-oriented distributed active archive centers (DAACs) model (see Chapter 4). He said that distributed data centers may offer proximity to various research institutions. Centers could have more access to specialized information by working more closely with scientists. The distributed data centers might offer advantages for education and outreach by increasing the number of organizations that reach the general local public, and by increasing opportunities for graduate students to engage directly. A greater number of domain scientists might have greater access to education and outreach professionals at the centers and achieve broader impacts.

The advantages of a distributed system in terms of workforce development include greater ability to train domain-specific specialists, Dietrich reported. The group noted that distributed facilities also make it easier to develop relationships with potential employers.

Disadvantages to Distributing Capabilities Among Multiple Facilities

According to Dietrich's report, disadvantages of distributed capabilities may include a lack of standardization of instrumentation and missed opportunities for cross-fertilization among scientific communities. There is potential for duplication of data management hardware (and cost) and duplication of information technology security resources. Redundant paperwork and increased bureaucracy were also described as disadvantages to distributed facilities.

Scientists working at the intersection of two facilities must work with two organizations, Dietrich relayed. Scientists will have multiple points of contact when trying to develop their plans, and procedures among facilities may conflict. Distributed capabilities also affect rapid response to events (e.g., earthquakes)—Dietrich described increased bureaucracy and a need to pull resources from multiple facilities. Distributing data capabilities also means that data sets are dispersed and may need to be brought together for certain investigations. If the distributed data facilities are not integrated, it is more difficult to integrate data sets, and more difficult to generate integrated data analysis tools, he said. Furthermore, Dietrich reported, other scientific communities (e.g., the meteorological community) may not know how to find and incorporate data stored in distributed facilities into their own work.

There are disadvantages to distributed capabilities in terms of education and outreach. Centralized education and outreach can produce broader materials with greater efficiency, according to Dietrich's report. In terms of workforce development, geographically distributed facilities might result in increased competition for competent staff.

Management Practices to Address Future Challenges and Allow Flexibility

When thinking about flexibility of the distributed capabilities, Dietrich's group focused on lessons learned from the EOSDIS DAAC. The geographic distribution of the data centers, and of expertise with programmatic oversight, allows the program to take advantage of scientific expertise across the country. Geographic distribution offers the possibility of going to where a capability is emerging, he said, and there is flexibility to re-compete for a single center or capability. Additionally, geographic distribution also has opportunities for broad educational outreach. Dietrich noted that the Incorporated Research Institutions for Seismology (IRIS) does distribute efforts, for example, the Portable Array Seismic Studies of the Continental Lithosphere (located at the New Mexico Institute of Mining and Technology), and work done elsewhere.

Dietrich's group considered how to respond to emerging efforts, raising the example of increased interest in distributed acoustic Doppler sensors. He said the breakout group wondered if the community response could be to find an independent scientific group that is working on the emerging topic and encourage them to develop it. Or is it more advantageous to bring that effort into a central facility? The DAAC model might be one that is applied here. Another example given by the group was that of the Department of Energy's large-scale active source testing. Active source experiments with National Laboratory partners is another option for development of emerging technology, he reported.

Flexibility in response to emerging science and technology might be achieved with tiered but geographically or topically distributed capabilities. Such a model could also allow for cross-fertilization. The group noted that an essential component of future seismological and geodetic facilities is a facility governed by a community board of directors or council.

MANAGEMENT STRUCTURES FOR CENTRALIZED SEISMOLOGICAL AND GEODETIC CAPABILITIES

The remaining two breakout groups were assigned to consider management structures suitable for supporting centralized seismological and geodetic capabilities. Box 7.2 lists the prompting questions provided to those groups. Summaries of the key themes identified by group rapporteurs are provided in the sections that follow.

Summary of Breakout Group 3 Discussion Themes

Carolina Lithgow-Bertelloni, University of California, Los Angeles

Carolina Lithgow-Bertelloni opened the summary of her group's discussion on centralizing some or all seismological and geodetic capabilities with the following statement: "Any contemplated merger should be one that [the] community/users are excited about."

Scientific Advantages of Centralized Seismological and Geodetic Capabilities

Lithgow-Bertelloni described how multi-disciplinary projects, particularly those in remote places (e.g., polar environments or the deep ocean), would benefit from centralized facilities providing access to multi-instrument platforms and field engineers with diverse areas of expertise. Centralization—perhaps organized using a matrix management structure—could result in having enough people and expertise to serve multiple projects and

BOX 7.2
Prompting Questions Provided for Small Group Discussions on Management Structures for Centralized Seismological and Geodetic Facility Capabilities

1. What are the scientific advantages of centralizing some or all of the seismological and geodetic capabilities listed below within a single managed facility?
    a. instrumentation
    b. user support services
    c. data management
    d. education and outreach
    e. workforce development
2. Which of these capabilities might not be centralized within a single facility to scientific advantage and why?
3. Which management and governance/decision-making structures might accommodate these unified capabilities, which could not, and why or why not?
4. 4. If only some of these capabilities might be centralized, what management structures might be necessary to accommodate all of the capabilities (i.e., those that might be unified and those that cannot)?

create a "one-stop shop" for equipment and logistical needs. Engineers in different domains might have an opportunity to interact more, investigators could prepare a single proposal package to request access to a single facility, and scheduling experiments might be easier, according to the group. And, whereas geodesy and seismology do not overlap perfectly, her group predicted that the intersection of geodesy and seismology instrumentation will increase with new technologies. In that case, she said, a centralized facility would be useful. Lithgow-Bertelloni also reported her group's observation that a centralized facility would provide economies of scale when purchasing new equipment.

In terms of logistics and user support services, Lithgow-Bertelloni reported that a centralized facility with a single pool of engineers would facilitate best practices for all instrumentation, for example, in terms of power supply, communications, and instrument enclosures. Likewise, centralization might simplify some logistics associated with international projects (e.g., import–export issues, customs, power requirements, and communications requirements). Centralized capabilities would allow for close coordination for large projects within the facility. Lithgow-Bertelloni said her group considered if centralization might improve communication with other institutions, such as the U.S. Geological Survey (USGS). IRIS already has a good relationship with the USGS (e.g., the Global Seismic Network), and UNAVCO is collaborating with the USGS on early warning applications. A bigger centralized facility might facilitate more of these collaborative efforts.

Lithgow-Bertelloni summarized her group's discussion about data management by saying that data distribution is not just about bytes of data. Her group agreed with the observations of others that maintaining a thread from data collection through archiving was important. Domain expertise remains important, and information needs and curation do not go away with a centralized facility. Her group observed that any efficiencies of centralization would not be gained as a result of reduced staff related to data management because individuals' expertise remains vital. Furthermore, she said, any contemplated merger of facilities would need to preserve the connections between the user community and the data. Her group noted that there could be new synergies as a result of centralized data management, for example, in the form of geospatially referenced data. Other benefits of centralized data management staffing might include the development of creative ways to curate and therefore examine data given the greater number of domain experts, or the development of new or specialized output for educators.

A centralized data management facility, or potentially pooled separate systems, might be advantageous for management of the greatly increased amounts of data that are anticipated, according to Lithgow-Bertelloni's report. It will be important to archive and manage those data, and also to work with those data where they reside. From a logistical point of view, a centralized facility might be able to negotiate better terms from vendors (e.g., commercial Cloud service providers).

In terms of education and outreach, Lithgow-Bertelloni reported a diversity of opinions. Centralization could be useful, but she described that there is already strong communication and collaboration between existing facilities and that centralized education and outreach may not necessarily represent efficiencies in terms of staffing needs. A centralized effort might, however, result in greater efficiencies for the public because it would not be necessary to go to multiple websites to download different products. Centralized education and outreach might also be more easily and better integrated with the outreach efforts of other institutions.

In terms of workforce development capabilities, Lithgow-Bertelloni's group observed that a centralized facility might better connect to undergraduate institutions, but might have more difficulty reaching those schools or institutions with large populations of under-represented individuals, regardless of the effectiveness of the facility's internship program. With respect to staff development, Lithgow-Bertelloni's group thought centralization could provide opportunities for all staff scientists to expand expertise. The larger critical mass would offer greater flexibility for staff so they could move around in their careers.

Management and Governance Structures to Accommodate Unified Capabilities

The group noted that governance will change if capabilities are unified. Workshop discussion from the previous day informed the group that there is widespread demand for effective community governance regardless of the facility configuration. With multiple awards, there are different management responsibilities, and multiple boards of directors that are each accountable to the National Science Foundation (NSF). If unified, there is one joint board and governance management team overseeing everything. However, because it is desirable to maintain domain expertise, a joint board will be large and more logistically cumbersome to operate, she said. The National Ecological Observatory Network (NEON) was mentioned as an example of how technical working groups could be formed for each discipline, but Lithgow-Bertelloni reported her group's concern about the layers of management that would likely be added to the structure.

Seismological and Geodetic Capabilities That Might Not Be Centralized

Lithgow-Bertelloni reported there could be some disadvantage to centralizing any seismological and geodetic facility capabilities because of the different domain expertise required and the different data needs. Her group's session ended with broad thoughts about caution being exercised with any centralization, that there be an equal commitment among partners, that the enthusiasm of the scientific communities is important, and that there is a commitment to maintaining domain expertise.

Summary of Breakout Group 4 Discussion Themes

Michael Foote, The University of Chicago

Michael Foote summarized his group's discussion about centralized seismological and geodetic capabilities. His group chose not to use the prompting questions (see Box 7.2) to guide their discussion. A common theme of the group's discussion, Foote noted, was concern about excessive focus on areas of overlap in seismology and geodesy at the expensive of the fundamental elements of each.

The group noted that centralization does not necessarily mean geographic consolidation of all facility functions, but rather an administrative consolidation. He said that centralization of some instrumentation could be advantageous. Centralization also does not necessarily mean downsizing—the amount of work done by a joint operation will not necessarily decrease. He reported that the complementary work of the combined staffs could increase the quality of service, and that centralizing existing facilities might benefit from pulling smaller groups into the enterprise. Disadvantages to centralization were related to efficiency and agility in some areas. Foote reported that there may be increased administrative lag when trying to reallocate funds, for example, but efficiencies could be gained in terms of maintaining and distributing data. He stressed the importance of continuity of domain expertise throughout the data life cycle.

Education and outreach endeavors might benefit from centralized management by avoiding the need to "reinvent the wheel," Foote said. He stated that different science organizations may be independently trying to determine the best mechanisms for education and outreach. Foote added from his own experience that some of that reinvention may not be well informed by pedagogy.

With respect to workforce development, Foote reported that people joining an institution do not necessarily expect to stay there for their entire careers. With a merged or shared facility, the workforce may be exposed to a greater variety of experiences that could contribute to long-term career development. A question was raised during the group discussion about the ability to retain skilled staff of both organizations if seismological and geodetic functions are centralized—assuming a reduction in staffing is a requirement of the centralization. Staff also may choose to leave because of changes in the workplace environment.

Foote reported mixed opinions regarding whether the ability to respond to new opportunities would be enhanced or diminished by centralized capabilities. If centralization results in a larger administrative structure, it could be more difficult to get approvals needed to respond to new opportunities. On the other hand, money merged into a single fungible pool might make it easier to be flexible and respond more quickly. Foote reported agreement among the group, however, on governance: a community governance model was preferred with a board of directors selected by and accountable to its constituents.

PLENARY DISCUSSION

Following the reports from the breakout groups, the floor was opened to comments and group discussion. The following sections summarize some themes raised.

Maintaining Enthusiastic Staff Support

A workshop participant expanded on Lithgow-Bertelloni's remarks regarding the need for enthusiastic support from the user community for any merging of facilities. The participant added that staff of the facilities also need to be enthusiastic about changes. Another workshop participant added an example from personal experience: for strategic reasons, a company for which he worked decided to move all researchers from one part of the country to another. Of the 120 senior scientists, only one elected to move. According to the participant, it was a brilliant business plan, but because of poor execution the company lost a lot of talent.

Scientific Community Convergence at Workshops

One workshop participant stated that workshops held by both IRIS and UNAVCO allow for convergence across research communities, community feedback to the facilities, and the opportunity to build cultural and scientific connections over time. These can lead to greater efficiencies and commonalities. Meghan Miller of UNAVCO countered, however, that she and Bob Detrick of IRIS have independently tested levels of community overlap at their workshops and observed that other than staff and sponsors, there was only narrow overlap between the seismology and geodesy communities at those workshops, on the order of a dozen or less out of a workshop of 100 people or more.

Knowing How to Access Data

Behnke took issue with a speaker comment that people know where to get seismology or geodesy data. Behnke stated that someone unfamiliar with IRIS may insert "seismology" in an Internet search engine and receive numerous results of varying relevance. She suggested caution about assuming familiarity, citing this as a problem at EOSDIS. She also described that potential users may have difficulty locating data because EOSDIS terminology has been duplicated across agencies. Data related terminology may no longer be unique to EOSDIS data, or it may not be used consistently across agencies.

International Participation

A workshop participant brought up the importance of international participation on facility boards. Lucy Flesch reported that the UNAVCO Board of Directors includes member representatives from the Netherlands and New Zealand. The number of international members is driven by needs, as identified by the nominating committee. Lithgow-Bertelloni said that, based on her own experience with large international organizations and small organizations, unless international participation on boards is explicitly designated, there is a tendency to vote U.S. members onto boards.

Community Governance Models

While one participant noted that a common theme during the workshop was that community governance was a vital aspect of seismological and geodetic facilities, Bradford Clement of the International Ocean Discovery Program observed that community governance does not guarantee a well-run organization. At present, IRIS and UNAVCO seem to have excellent leadership and boards, he said, but that might not always be true for the future. Another workshop participant spoke against community governance by stating that although community input is vital, leadership is necessary when "democracy goes wrong." He said that leadership and oversight, and possibly redirection, needs to come from NSF. He did say he felt it appropriate to endorse current seismological and geodetic facility leadership for what they have done in the past few decades. Another workshop participant suggested that because the seismology and geodesy communities rely heavily on global instrumentation networks, scientists in those fields are forced to think beyond their focused research. For this reason, they may think about community research more broadly, and thus about community governance. He suggested this might be why community governance works for these research communities.

8

Observations Regarding Managing Facility Capabilities and Potential Uses for This Proceedings

The final session of the workshop included brief presentations from workshop planning committee members in which they briefly synthesized key workshop themes on one of three preassigned topics of seismological and geodetic facility instrumentation, user support services, data management, or education and outreach capabilities. The next four sections of this chapter encapsulate their comments. The final section describes potential uses for these proceedings.

INSTRUMENTATION

Tim Dixon, University of South Florida

Tim Dixon described two potentially problematic areas related to seismological and geodetic facility instrumentation. The first was related to retooling aging and potentially obsolete instrumentation. The second was related to adopting new technologies, which Dixon expressed may not happen often enough. Dixon expressed his hope that any discussion about the structure of future seismological and geodetic facilities include discussion about instrument upgrades and adoption of new technologies.

USER SUPPORT SERVICES

Holly Given, International Ocean Discovery Program

Holly Given described the importance of facility user support services to principal investigators by highlighting specific points that she attributed to various speakers throughout the workshop. She highlighted Flesch's statement that facilities are more than just brick and mortar, and that investments are also made in staff and in the entire scientific community. Given reminded participants of Michael Kuhlman's comments that user support services also include measurement protocols, data processing algorithms, and analysis software that might be used by the entire research community. Given recounted Detrick's statements that facilities provide better user support because of the domain expertise within facility management, and because of the guidance provided by the domain experts on facility Boards of Directors. She said that Aster amplified that sentiment by stating that no academic department can approach the level of experimental and technological support in training, development, and logistics needed for large and innovative projects that facilities such as the Incorporated Research Institutions for Seismology (IRIS) and UNAVCO are capable of handling. Facility services and capabilities have advanced beyond what the best-supported universities attain. Given echoed that sentiment based on her own experiences. She reiterated Aster's comments that the trained and experienced professional staff at the Seismological Facility for the Advancement of Geoscience (SAGE), Geodetic Facility for the Advancement of Geoscience (GAGE), and their sub-awardees also contribute their institutional memory, education, technological leadership, and strong service ethic. Given stated that the user support services provided by the facilities keeps principal investigators "blissfully ignorant" of all of the logistical arrangements that are necessary to allow complex science to be done in any remote location on Earth. She closed her comments by stating that those services are provided well right now.

DATA MANAGEMENT

Greg Beroza, Stanford University

Greg Beroza reiterated several participants' comments that there is an overriding need for domain expertise when determining how data are collected, how and in what formats they are stored, and how they are used. In whatever way future seismological and geodetic facilities are managed, he said, that domain expertise needs to be maintained. He also recounted that the large data volumes expected, perhaps in the next 5 years, represent big challenges for the facilities. Data collection rates are increasing dramatically as sensor costs decrease and as new types of sensing are available. Current data management approaches may not necessarily scale to the volumes of data coming in, he said. Beroza discussed the open questions around how and where those data will be stored, whether those data should be processed closer to where they are gathered, whether they should be processed in the Cloud, how those data could be made secure, and what the communities should do about high performance computing in general. He also wondered how data might be georeferenced, be made more machine discoverable, and be more accessible to scientists in different disciplines so that more expertise can be applied to interesting problems in seismology and geodesy. Beroza recounted comments by some participants that educators should also be able to access and use data more easily. Moving forward, Beroza suggested that choices about future seismological and geodetic facility management need to be made in light of these challenges as well as how to save, curate, and preserve older data before they are lost.

EDUCATION AND OUTREACH

Doug Hollett, Melroy & Hollett Technology Partners, LLC

Doug Hollett described that whatever the management structure of future seismological and geodetic facilities, education and outreach requires more thought. Education and outreach involve engaging with a diverse constituency that is highly interested in what the seismology and geodesy communities are doing. Hollett's point of view was that education and outreach programs need to be able to inform those people about the science in which the research communities are engaged, and in what ways that science impacts their daily lives. He recalled discussion of potential advantages raised for distributed education and outreach operations including being able to reach students, researchers, and the broader public through more "touch points." On the other hand, a centralized model might offer more or a broader set of materials. Hollett thought it interesting that multiple breakout groups warned of assuming that centralization equated to cost savings. He suggested that discussions continue about future seismological and geodetic facilities, as it is important to determine expected outcomes, levels of quality, and baseline measures and metrics for success. These considerations need to drive any decisions about future facility management, he added.

POTENTIAL USES FOR THIS WORKSHOP PROCEEDINGS

This workshop proceedings was prepared for the National Science Foundation (NSF) to provide information that will help in its attempts to sustainably support seismological and geodetic facility capabilities. During the general comment period, Maggie Benoit of NSF's Division of Earth Sciences (EAR) indicated that IRIS and UNAVCO have "provided incredibly fantastic operation and management of [NSF seismological and geodetic] facilities" (see Appendix E), and that NSF is not trying to "fix" that management. Rather NSF is exploring its own options for support of facility capabilities as technology evolves and research needs change. The workshop proceedings may also be used by the Catalyzing Opportunities for Research in the Earth Sciences Consensus Study Committee in deliberations regarding its second task: scientific infrastructure needed to advance the high-priority Earth science research, the current inventory of research infrastructure supported by EAR and other relevant areas of NSF, and analysis of capability. Based on the enthusiasm with which managers of different scientific facilities were willing to participate in the workshop, the workshop planning committee was hopeful that the resultant workshop proceedings would also be useful to scientific facility managers wishing to improve their own operations.

Appendix A

Workshop Planning Committee Member Biographies

DOUG HOLLETT (*Chair*) is president of Melroy & Hollett Technology Partners, LLC, which focuses on advanced technology and policy solutions in the aerospace and energy sectors, and is senior energy advisor at Nova Systems, an Australia systems engineering provider in the energy, aerospace and defense sectors. Additional engagements include advisor with SmartUQ, a Wisconsin uncertainty quantification company; advisor to FERVO, a California geothermal company; member of the Sandia National Laboratory Energy and Homeland Security Board; and the CSIRO Energy Advisory Committee (Australia). Mr. Hollett is the former Acting Assistant Secretary and Principal Deputy Assistant Secretary in the Office of Fossil Energy at the Department of Energy (DOE, 2016-17). Previously, he served as Deputy Assistant Secretary for Renewable Power in the Office of Energy Efficiency and Renewable Energy, where he oversaw research and development in solar, wind, geothermal, hydro, marine hydrokinetics and grid modernization. At DOE, Mr. Hollett also conceived and implemented the FORGE EGS test project for geothermal energy, and was co-chair of the SubTER geologic research initiative. Prior to government service, Doug had over 29 years in the oil and gas sector including Director Unconventional New Ventures, Manager International Exploration, and GM and VP Atlantic Canada with Marathon Oil. He holds a B.A. in geology from Williams College and an M.S. in geology from The University of Utah.

GREG C. BEROZA is the Wayne Loel Professor of Earth, Energy, and Environmental Sciences in the Department of Geophysics at Stanford University. His research concerns earthquake science broadly, with a focus on developing techniques for analyzing seismograms to understand how earthquakes work and to help quantify the hazards they pose. Since 2007 he has been first deputy director then co-director of the Southern California Earthquake Center (SCEC). His principal responsibility in that role is to chair the planning committee, which guides and coordinates the core research program of the SCEC collaboration. Since 2013 he has also been co-director of the Stanford Center for Induced and Triggered Seismicity. His current research includes using ambient field measurements for ground motion prediction, developing data-mining and machine-learning methods for earthquake detection and characterization, and understanding the systematics of induced, slow, and intermediate-depth earthquakes. He has authored more than 150 peer-reviewed scientific journal articles. Dr. Beroza was a National Science Foundation Presidential Young Investigator, has been fellow of the American Geophysical Union since 2008, was the Incorporated Research Institutions for Seismology/the Seismological Society of America Distinguished Lecturer in 2012, and was awarded the Beno Gutenberg Medal of the European Geosciences Union in 2014 for outstanding contributions to seismology. He holds a B.S. in Earth sciences from the University of California, Santa Cruz, and a Ph.D. from the Massachusetts Institute of Technology.

TIM H. DIXON is a professor in the School of Geosciences at the University of South Florida. His research uses satellite geodesy and remote sensing data to investigate changes in the Earth's land and water surfaces. These geodetic data allow for study of a variety of natural and anthropogenic processes, including strain accumulation on faults, volcano deformation, mountain building, coastal subsidence, ground water extraction, and glacier motion. He has conducted geological field investigations on several continents, participated in sea-going campaigns, organized global positioning system field programs, conducted glacier studies in Iceland and Greenland, and conducted volcano deformation studies in Central and South America. He is a fellow of the American Geophysical Union, the Geological Society of America (GSA), and the American Association for the Advancement of Science. He is the 2010 recipient of GSA's Woollard Award for excellence in geophysics. He previously worked at the National Aeronautics and Space Administration's (NASA's) Jet Propulsion Laboratory and at NASA Headquarters. Dr. Dixon received a B.Sc. with honors in geology from Western University and a Ph.D. from the Scripps Institution of Oceanography.

HOLLY GIVEN is a member of the management and professional staff at the Scripps Institution of Oceanography where she is director of the Science Support Office for the International Ocean Discovery Program (IODP), an international research collaboration using deep-sea drilling platforms to access geological samples and data to study the Earth system. A geophysicist with experience in academic, federal agency, international organization, and corporate settings, Dr. Given has a long history in the management of community-led research programs using large infrastructure. In the 1990s she led the implementation of the project IDA portion of the Incorporated Research Institutions for Seismology Global Seismographic Network. As a technical officer at the Comprehensive Nuclear-Test-Ban Treaty Organization, she established procedures to build and certify the Treaty's global verification networks. Since 2003, Dr. Given has worked primarily with the ocean science community. As a program director at Joint Oceanographic Institutions (later the Consortium for Ocean Leadership), she managed community participation in the IODP and then ran the planning office responsible for designing and building the Ocean Observatories Initiative. In 2008, Dr. Given served briefly as an elected member of the UNAVCO Board of Directors before becoming a rotating Program Director for the National Science Foundation's (NSF's) Integrative Graduate Education and Research Traineeships. Ms. Given has served on numerous program and management review committees for NSF, including EarthScope, National Ecological Observatory Network, EarthCube, and Blue Waters. She holds a B.S. in engineering physics from the University of Illinois and an M.S. and a Ph.D. in geophysics from the California Institute of Technology.

GENE HUBBARD is currently the senior vice president for Human Capital at RiVidium, Inc. RiVidium is a service-disabled, veteran-owned small business that provides human resources, logistics, information technology, and other services to client federal agencies. Mr. Hubbard started with RiVidium in July 2018 after more than 38 years of military and civilian public service. He is responsible for business development, growth (profit and loss), program management, capture management, and client services for the human capital business line. Mr. Hubbard has extensive experience in the life cycle of facilities management including design and construction, operations and maintenance, public works, and real estate programs, as well as extensive experience in human resources, financial management, information technology, and administrative services. His career includes federal Senior Executive Service (SES) assignments at the Mine Safety & Health Administration, the National Science Foundation, the Naval Facilities Engineering Command, the National Oceanic and Atmospheric Administration, and the National Aeronautics and Space Administration. Prior to entering the federal SES ranks, Mr. Hubbard served as the coordinator for program support at the Office of Adult and Community Education in Fairfax County, Virginia. Additionally, he served for more than 20 years of active duty as a commissioned officer in the U.S. Navy, primarily in the Navy Civil Engineer, with assignments of increasing responsibility stationed in various locations across the United States and overseas. Mr. Hubbard was a member of the Board of Directors for the Society of American Military Engineers and served as the vice chair of the Federal Facilities Council. He is a member of other professional societies, including the Society for Human Resource Management and the American Society for Public Administration. Mr. Hubbard has a B.S. in chemistry from the U.S. Naval Academy, an M.E. (civil engineering) from the University of Florida, and an M.P.A. from Troy University.

NETTIE LA BELLE-HAMER is the Geophysical Institute deputy director and director of the Alaska Satellite Facility (ASF) at the University of Alaska Fairbanks (UAF). Dr. La Belle-Hamer leads UAF's collaboration efforts with Sandia National Labs and private industry partners, bringing together many disparate discipline experts at UAF and across academia, industry, and governments. As UAF's lead in forming the Arctic GeoData Cooperative, she is working to bring together commercial, educational, and governmental partners to produce, enhance, and maintain authoritative, dynamic, geospatial information for the Arctic. In 1995, Dr. La Belle-Hamer became involved with the ASF as a contractor working on the National Aeronautics and Space Administration's development of a distributed Earth science data system. She became the science center manager at ASF in 2000 before taking on the directorship of the facility. Under her direction since 2002, ASF has grown into a strong program with a bright future in remote-sensing data access. Dr. La Belle-Hamer received her bachelor's degree in physics from the University of California, Berkeley, in 1985, and both her master's degree and Ph.D. in space physics at UAF in 1988 and 1994, respectively.

Appendix B

Workshop Agenda

DAY 1

SESSION 1
8:30 - 9:30
Current, Emerging, and Frontier Capabilities of Seismological and Geodetic Facilities
Moderator: Doug Hollett

Session Objective
Introduce workshop participants to the current and future capabilities of seismological and geodetic facilities as defined by the technical community in a 2015 community workshop report (https://tinyurl.com/Facilities2015).

8:30 am **Welcome and Introductions**
Doug Hollett, Workshop Committee Chair

8:40 am **Sponsor Expectations**
Lina Patino, Director, Division of Earth Sciences, National Science Foundation

DESCRIPTION OF SEISMOLOGICAL AND GEODETIC FACILITY CAPABILITIES

8:45 am **2015 Community Workshop**
Lucy Flesch, Purdue University

Description of Capabilities
Rick Aster, Colorado State University

9:05 am **Questions/Discussion**

SESSION 2a
9:30 - 12:55
Management and Decision-Making Models at Scientific Facilities
Moderator: Tim Dixon

Session Objective

Learn about and compare management and decision structures applied at multiple scientific facilities and consider advantages/disadvantages of aspects of those models for accommodating instrumentation, user support services, data management, education and outreach, and workforce development.

Prompting questions for speakers (provided prior to the workshop):

- What are the mission and capabilities/services offered by your facility?
- What management and governance or decision-making models does your facility employ?
- How does your facility management structure incorporate interactions with stakeholders to set priorities?
- How has the management model changed over time?
- Which elements of your management structure best accommodate instrumentation, user support services, data management, education and outreach, and workforce development capabilities?
- Are there weaknesses or gaps?
- What elements of the management model are designed to allow responsiveness to technological advances and emerging science? Have these been tested?

NSF-SUPPORTED SEISMOLOGICAL AND GEODETIC FACILITY MANAGEMENT: IRIS AND UNAVCO

9:30 am **Incorporated Research Institutions for Seismology (IRIS)**
Robert Detrick, President, IRIS

9:50 am **UNAVCO**
Meghan Miller, President, UNAVCO

10:10 am **Q&A with Panel of IRIS and UNAVCO Board Members/Staff**

IRIS	UNAVCO
Robert Detrick, President	*Meghan Miller, President*
Doug Wiens, Chair, Board of Directors	*Glen Mattioli, Director of Geodetic Infrastructure*
Bob Woodward, Director, Instrumentation Services	*Chuck Meertens, Director of Geodetic Data Services*

10:40 am **Break**

OTHER SCIENTIFIC FACILITIES

10:55 am **International Ocean Discovery Program (IODP)**
Bradford Clement, Director of Science Services, IODP

11:35 am **National Ecological Observatory Network**
Michael Kuhlman, Chief Scientist, Contract Research, Battelle

12:15 pm **National Aeronautics and Space Administration (NASA) Distributed Active Archive Centers**
Jeanne Behnke, Earth Science Data and Information Systems (ESDIS) Project Deputy Manager for Operations, Goddard Space Flight Center

12:55 pm **Working Lunch—Small Group Discussions**

SESSION 2b
1:40 - 2:40
Comparison of Management and Decision-Making Models
Moderator: Holly Given

Session Objective
Identify common and unique aspects of the management and governance/decision models for the facilities described earlier in the session.

1:40 pm **Panel Discussion with Facility Managers**
Robert Detrick, President, IRIS
Meghan Miller, President, UNAVCO
Bradford Clement, Director of Science Services, IODP
Michael Kuhlman, Chief Scientist, Contract Research, Battelle
Jeanne Behnke, ESDIS Project Deputy Manager for Operations, Goddard Space Flight Center

Potential questions for panelists:

- Which aspects of management models were similar across all of the facilities?
- Which management models were unique to specific facilities? Were these tailored to the unique scientific objectives?
- Similarly, are there aspects of the decision-making models that were similar across the facilities?
- Which aspects of the decision-making models were unique to specific facilities? Were these tailored to meet specific scientific objectives?
- Which management and decision-making models would not accommodate the scientific objectives of specific facilities?
- What aspects of other facilities might you consider adopting and why?

2:40 pm **Break**

SESSION 3

3:00 - 4:30

Management Models Appropriate for Seismological and Geodetic Facility Capability Management

Moderator: Doug Hollett

Session Objective

Identify management and decision models or aspects of them that might successfully be applied to seismological and geodetic facilities.

3:00 pm **Breakout Discussions**

Committee members and participants will be assigned to different groups; group rapporteurs will capture overarching themes and present in plenary.

Session 3 Breakout Groups

Group 1 **Moderator:** Greg Beroza **Rapporteur:** Steve Jacobsen	**Group 2** **Moderator:** Doug Hollett **Rapporteur:** Shemin Ge	**Group 3** **Moderator:** Tim Dixon **Rapporteur:** George Gehrels	**Group 4** **Moderator:** Holly Given **Rapporteur:** Diana Elder
Jeanne Behnke	Tim Dixon	Rick Aster	Jon Alberts
Enrique Cabral-Cano	Lucy Flesch	Dave Chadwell	Sergio Barrientos
Brad Clement	Alan Levander	Andrea Donnellan	Susan Eriksson
Bill Dietrich	Chuck Meertens	Michael Foote	Meghan Miller
Bob Detrick	Paul Morin	Mike Kuhlman	Ben Phillips
Rick Farnsworth	Susan Schwartz	Kate Moran	Michael West
Egill Hauksson	Kamini Singha	Xyoli Pérez-Campos	Donna Whitney
Carolina Lithgow-Bertelloni	Jim Yoder	Sandy Shor	Doug Wiens
Glen Mattioli		Bob Woodward	

Questions for small group discussion:

- What are the advantages and disadvantages of the various management models for accommodating instrumentation, user support services, data management, education and outreach, and workforce development?
- What elements of the management models do you think best accommodate and integrate technological innovation? Why?

3:45 pm **Reconvene for Plenary**

3:50 pm **Plenary: Summaries from Breakout Sessions**
Rapporteurs from each group will have 10 minutes to summarize key findings of their groups and answer questions from the audience.

SESSION 4—Open Microphone
4:30 - 5:00

Moderator: Doug Hollett
Participants are welcome to present comments on relevant topics (3 minute limit each)

5:00 pm **Open Sessions Adjourns**

DAY 2

SESSION 5a
8:30 - 10:40
Management Models for Future Seismological and Geodetic Facilities
Breakout Discussions

Session Objective
Breakout groups will consider the scientific advantages of the various management and decision structures for accommodating the seismological and geodetic instrumentation, user support services, data management, education and outreach, and workforce development capabilities.

8:30 am **Welcome and Overview of Day 1, Objectives for Day 2**
Doug Hollett, Workshop Committee Chair

8:40 am **Breakout Sessions: Management Models That Could Advance the Scientific Goals**
Workshop participants will be assigned to one of four groups for moderated discussion. Two of the groups will discuss Topic A, and the other two will discuss Topic B. At the designated time, the groups will convene for a final plenary, and rapporteurs from each group will summarize their group's discussion.

Session 5a Breakout Groups

Group 1 **Topic A** **Moderator:** Doug Hollett **Rapporteur:** Donna Whitney	**Group 2** **Topic A** **Moderator:** Holly Given **Rapporteur:** Bill Dietrich	**Group 3** **Topic B** **Moderator:** Greg Beroza **Rapporteur:** Carolina Lithgow-Bertelloni	**Group 4** **Topic B** **Moderator:** Tim Dixon **Rapporteur:** Michael Foote
Susan Eriksson	Jon Alberts	Rick Aster	Sergio Barrientos
George Gehrels	Tim Dixon	Enrique Cabral-Cano	Jeanne Behnke
Mike Kuhlman	Andrea Donnellan	Rick Farnsworth	Dave Chadwell
Chuck Meertens	Shemin Ge	Egill Hauksson	Brad Clement
Kate Moran	Alan Levander	Meghan Miller	Bob Detrick
Xyoli Pérez-Campos	Ben Phillips	Andrew Newman	Diana Elder
Michael West	Susan Schwartz	Kamini Singha	Lucy Flesch
Doug Wiens	Bob Woodward	Jim Yoder	Glen Mattioli
			Sandy Shor

TOPIC A: Management structures for independent seismological and geodetic capabilities

a. What are the scientific advantages of distributing seismological and geodetic capabilities (listed below) among multiple organizations (as is done at present)?
   i. instrumentation
   ii. user support services
   iii. data management
   iv. education and outreach
   v. workforce development

b. What are disadvantages?

c. What can be learned from other scientific facilities about successful management practices to address future challenges and emerging capability needs?

d. What management model aspects discussed during the workshop might allow the current facilities greater flexibility to respond to future unexpected scientific needs or technology developments?

TOPIC B: Management structures for centralized seismological and geodetic capabilities

a. What are the scientific advantages of centralizing some or all of the seismological and geodetic capabilities listed below within a single managed facility?
   i. instrumentation
   ii. user support services
   iii. data management
   iv. education and outreach
   v. workforce development

b. Which of these capabilities might not be centralized within a single facility to scientific advantage and why?

c. Which management and governance/decision-making structures might accommodate these unified capabilities, which could not, and why or why not?

d. If only some of these capabilities might be centralized, what management structures might be necessary to accommodate all of the capabilities (i.e., those that might be unified and those that cannot)?

SESSION 5b
11:00 - 12:30
Management Models for Future Seismological and Geodetic Facilities
Moderator: Greg Beroza

Plenary
Rapporteurs from each group will have 10 minutes to summarize respective discussions of their respective groups.

11:00 am **Breakout Group Summaries**
(10 minutes each followed by clarifying questions)

11:40 am **Plenary Discussion About Breakout Sessions**

FINAL SESSION
12:30 - 1:00
Summaries: Observations Regarding Managing Seismological and Geodetic Facility Capabilities

Planning committee members will summarize key discussion points raised regarding management of seismological and geodetic facility instrumentation, user support services, data management, education and outreach, and workforce development capabilities.

11:40 am **Observation About Managing:**

Instrumentation	*Tim Dixon*
User support services	*Holly Given*
Data management	*Greg Beroza*
Education and outreach	*Doug Hollett*
Workforce development	*Doug Hollett*

1:00 pm **Workshop Adjourns**

Appendix C

Workshop Presenter and Panelist Biographies

RICK ASTER is a professor and department head in the Geosciences Department at Colorado State University. He is a geoscientist with interests in geophysics, seismological imaging and source studies, and Earth processes encompassing earthquakes, volcanos, glaciers, oceans, and geology. Dr. Aster's research has drawn from significant seismological field studies in western North America, Italy, and Antarctica. He was the lead author on the widely used reference volume and textbook *Parameter Estimation and Inverse Problems*. He has been the president of the Seismological Society of America and is a member of the Incorporated Research Institutions for Seismology Board of Directors. He has a B.S. in electrical and computer engineering and physics and an M.S. in geophysics from the University of Wisconsin, and a Ph.D. in earth science from the University of California, San Diego.

JEANNE BEHNKE is the Earth Science Data and Information Systems Project deputy manager for Operations at the National Aeronautics and Space Administration (NASA) Goddard Space Flight Center. She has been at NASA since 1985. She holds a B.S. and an M.L.S. in information systems and science from the University of Maryland and an M.E. in software engineering from the University of Maryland University College.

BRADFORD CLEMENT is the director of Science Services for the International Ocean Discovery Program, located at Texas A&M University (TAMU). TAMU is the science operator for the *JOIDES Resolution* drillship. He is also a professor in the Department of Geology and Geophysics. Dr. Clement's research interests include polarity reversal of Earth's magnetic field, which he examines using paleomagnetic records collected in deep sea cores. He holds a B.S. in geology from the University of Georgia and an M.S. and a Ph.D. in geology from Columbia University.

ROBERT S. DETRICK is the president of the Incorporated Research Institutions for Seismology, a position he has held since 2014. Prior to this position, Dr. Detrick held positions as assistant administrator of the National Oceanic and Atmospheric Administration's

Office of Oceanic and Atmospheric Research, director of the National Science Foundation's Division of Earth Sciences, and vice president for Marine Facilities and Operations at Woods Hole Oceanographic Institution (WHOI). Dr. Detrick's research focused on marine geophysics and seismology, with a focus on mid-ocean ridges and oceanic crust. He is an American Geophysical Union fellow. He holds a B.S. in geology and physics from Lehigh University; an M.S. in marine geology from the University of California, San Diego; and a Ph.D. in oceanography from the Massachusetts Institute of Technology/WHOI Joint Program.

LUCY FLESCH is a professor in the Department of Earth, Atmospheric, and Planetary Sciences and associate dean of Academic Affairs for the College of Science at Purdue University. Her research interests include the kinematics and dynamics of the continental lithosphere, namely the interaction between the lithospheric crust and mantle, deformational driving forces of continental lithosphere, and the development of large plateaus. The modeling performed is all observationally based using geodetic, geologic and seismic data. Dr. Flesch is on the Board of Directors for UNAVCO. She has a B.S. in physics from Beloit College and an M.S. in mineral physics and a Ph.D. in geophysics from Stony Brook University.

MICHAEL KUHLMAN serves as the chief scientist of Battelle's Contract Research Business. He is responsible for ensuring the technical quality of Battelle's work and products, and the technical development of the scientific staff at Battelle. He also directs Battelle's Independent Research and Development program. Dr. Kuhlman serves as the program manager and principal investigator for the cooperative agreement between Battelle and the National Science Foundation for the operation of the National Ecological Observatory Network. This program comprises 81 sites across the United States, which produce 177 data streams available to the research community to enable better understanding of the drivers for and responses to ecological change at the continental scale. Dr. Kuhlman has more than 20 years of experience in fields such as chemical and biological weapons training, aerosol dissemination studies, and production facility assessments. He holds an M.S. and a Ph.D. in environmental sciences and engineering from the University of North Carolina.

GLEN MATTIOLI is the director of Geodetic Infrastructure at UNAVCO. He has held that position since 2012. He is also an adjunct professor in the Department of Earth and Environmental Sciences at The University of Texas at Arlington. Dr. Mattioli's research interests include neotectonics, earthquake and volcanic processes, and applications of real-time Global Navigation Satellite System observations. He has a B.A. from the University of Rochester and an M.S. and a Ph.D. from Northwestern University.

CHUCK MEERTENS is the director of Geodetic Data Services at UNAVCO, a position he has held for more than 15 years. He has been at UNAVCO since the early 1990s and has helped build the institution from its beginning stages. Dr. Meertens is involved in scalable real-time streaming analytics for machine learning for geoscience, deploying cyberinfrastructure in Cloud-based systems, data systems for satellite and airborne Light Detection and Ranging data, and many other topics. He has a B.A. in geology and physics from the

University of California, Santa Barbara, and an M.S. and a Ph.D. in geology from the University of Colorado Boulder.

MEGHAN MILLER is the president of NAVCO, a position she has held since 2008. Prior to that, she was a professor in the Department of Geological Sciences and dean of the College of the Sciences at Central Washington University. During Dr. Miller's tenure at UNAVCO, the geodesy community has published more than 1,600 peer-reviewed contributions that were supported by UNAVCO. Her research interests include GPS geodesy, active tectonics, and remote sensing. Dr. Miller received the 2018 Waldo E. Smith Award for "extraordinary service to geophysics." She holds a B.S. in geology from Yale University and a Ph.D. in geology from Stanford University.

LINA PATINO, division director for the National Science Foundation Division of Earth Sciences (EAR), previously served EAR as a program director, section head, and acting division director. She previously managed EAR's Education and Human Resources portfolio, and served as a detail in the Office of International Science and Engineering. Her research experience includes igneous petrology and geochemistry focused on the Central American subduction zone and incipient weathering of volcanic rocks. Dr. Patino earned her Ph.D. in geological sciences from Rutgers University.

DOUG WIENS is the Robert S. Brookings Distinguished Professor, Department of Earth & Planetary Sciences at Washington University. Dr. Wiens specializes in seismology and geophysics and has done extensive research on large, deep earthquakes in the Pacific Ocean. He is also researching the seismology of Antarctica. He has taught courses on Earth forces, seismology, environmental geophysics, and geodynamics. Dr. Wiens is the chair of the Incorporated Research Institutions for Seismology Board of Directors (elected 2017), an American Geophysical Union (AGU) fellow, and the AGU Seismology Section President. He has a B.A. in physics from Wheaton College and an M.S. and a Ph.D. in geological sciences from Northwestern University.

BOB WOODWARD is the director of Instrumentation Services for Incorporated Research Institutions for Seismology (IRIS). Dr. Woodward has been at IRIS for more than 10 years. Prior to joining IRIS, he worked on the Global Seismographic Network program with the U.S. Geological Survey and as a program manager at Scientific Applications International Corporation. He received a B.A. in geophysics and applied mathematics from the University of California, Berkeley, and a Ph.D. in Earth sciences from the Scripps Institution of Oceanography, University of California, San Diego.

Appendix D

Workshop Participant List

Key:
* - indicates Catalyizing Opportunities for Research in the Earth Sciences consensus study member
italics – indicates workshop planning committee member

Jon Alberts, The University of Rhode Island
Rick Aster, Colorado State University
Sergio Barrientos, National Seismological Center, Chile
Jeanne Behnke, National Aeronautics and Space Administration Goddard Space Flight Center
Maggie Benoit, National Science Foundation (NSF)
***Greg Beroza**, Stanford University**
Enrique Cabral-Cano, Instituto de Geofísica, Universidad Nacional Autónoma de México (UNAM), Mexico
Dave Chadwell, Scripps Institution of Oceanography
Remy Chappetta, Staff
Brad Clement, Texas A&M University
Robert Detrick, Incorporated Research Institutions for Seismology (IRIS)
Bill Dietrich, University of California, Berkeley*
***Tim Dixon**, University of South Florida**
Andrea Donnellan, Jet Propulsion Laboratory
Diana Elder, Northern Arizona University*
Susan Eriksson, Eriksson Associates
Sonia Esperança, NSF
Richard Farnsworth, National Radio Astronomy Observatory

Lucy Flesch, Purdue University
Michael Foote, The University of Chicago*
Shemin Ge, University of Colorado Boulder*
George Gehrels, The University of Arizona*
***Holly Given**, Scripps Institution of Oceanography*
Deb Glickson, Staff
Egill Hauksson, California Institute of Technology
***Doug Hollett**, Melroy & Hollett Technology Partners, LLC**
Steve Jacobsen, Northwestern University*
Russell Kelz, NSF
Michael Kuhlman, Battelle
Alan Levander, Rice University
Carolina Lithgow-Bertelloni, University of California, Los Angeles*
Sammantha Magsino, Staff
Erin Markovich, Staff
Glen Mattioli, UNAVCO
Chuck Meertens, UNAVCO
Meghan Miller, UNAVCO
Kate Moran, Ocean Networks Canada
Paul Morin, Polar Geospatial Center
Andrew Newman, Georgia Institute of Technology
Lina Patino, NSF
Xyoli Pérez-Campos, Instituto de Geofísica, UNAM, Mexico
Ben Phillips, NASA
Susan Schwartz, University of California, Santa Cruz
Sandy Shor, University of Hawaii
Erik Webb, Sandia National Laboratories
Michael West, University of Alaska Fairbanks
Donna Whitney, University of Minnesota*
Doug Wiens, Washington University
Bob Woodward, IRIS
Jim Yoder, Woods Hole Oceanographic Institution*

Appendix E

Transcript from Workshop General Comment Period

This appendix contains an unedited transcript of the comments made during workshop's general comment period. Workshop participants who chose to comment were asked to identify themselves and were allowed 3 minutes to express their views on any topic relevant to the workshop. The views of the commenters do not reflect those of the planning committee, the National Academies, or the workshop sponsors.

MAGGIE BENOIT
National Science Foundation

I have 30 seconds here. So, again, I am Maggie Benoit. I am the SAGE and GAGE program director. I am going to say something that I said during our breakout group just to give a little broader context because something I have heard over and over again and that people at NSF have heard several times is why are we here? If it ain't broke, don't fix it. Right? I think a lot of people have expressed that.

I want to be clear IRIS and UNAVCO have provided incredibly fantastic operations and management of our facilities. Their track record is very strong. That really isn't the question. From the way they have been operating things, that is not broken.

What I think you saw up here in these discussions is that there are a lot of needs that the community has. How to sustain our support of all of these diverse needs as the technology is changing and as the landscape of research is changing, how to do that in a thoughtful and sustainable way, that is what is broken. We are here to try to fix it. I just want to give that broader context of what really is a motivating factor for us being here and having these discussions.

I hope that helps a little bit in better understanding what our goal is here and how we are approaching these discussions. Thank you.

ERIC WEBB

Sandia National Laboratories

My name is Eric Webb. I am from Sandia National Labs. We have been the strong beneficiaries of the student intern programs through IRIS that have allowed us to hire extensively. I want to commend that part of the program and tell you that outside of the NSF community, outside of academia, there are those of us who are beneficiaries. We thank you for that.

The questions that I haven't heard discussed, which is really a process question connected to how we want to organize this, is how do we deal with the life-cycle costs of either building and sustaining or building and retiring capabilities within this system? I would ask NSF to think carefully about whether any of these organizational structures help with that particular problem.

Maybe I will make one more comment. Those of us who are not in the NSF system—I can't propose to NSF. We don't get money from NSF. We are a partner to NSF—want to make sure that the structures that get taken forward for these kinds of research investments are structured in a way that make it easy for us to partner with you.

We have extensive capabilities. We have our own initiatives. It is not always easy to be a good partner with the NSF programs.

MICHAEL FOOTE

The University of Chicago

One thing that has been on my mind a lot lately, and universities everywhere, are federal laws that potentially have a chilling effect on our ability to do international collaborations. That is important to a lot of the activities we have been talking about today.

There is this Office of Foreign Asset Control, OFAC. It keeps essentially a bad guy list. If even unwittingly you have any interaction with those people, it could seriously jeopardize your life and your career. I don't know the answers, but I think for the kinds of programs that we are talking about this is going to be an increasing threat. It is going to suck up more of the management effort. If you have $170 million NASA budget, you can take 100th of a percent of that and hire a bunch of lawyers. It is going to be a challenge for other organizations.

JIM YODER

Woods Hole Oceanographic Institution

I was thinking about innovation. In the field that I was interested in some years ago, which was making optical measurements in the ocean, there is ONR Small Business Innovative Research program, [which] just made tremendous contributions to how the instrumentation was advanced. I don't think we talked about that much. These are small companies that hired university Ph.Ds. and other graduates. They were operating as a private company so they could take a design, they could do the research on the instrumentation, work with university scientists to see if measurements were realistic, and then figure out how to make these things and then produce them.

Not to a large number of—they didn't produce millions of them, but they could make money off of it. I think that was a—totally changed how this particular field makes measurements in the field. It was quite a nice example of how you could engage the private sector to really help advance the field.

DOUG HOLLETT

Melroy & Hollett Technology Partners, LLC

I come from perhaps more of an applied background in recent years. One thing I am particularly interested in is seeing more of a sort of wiring between that applied side—you know, we talked about engineering and the comment that engineering is not innovative. I really disagree.

The opportunity to be talking with that community and saying if you can make something that does this, we can do this. Whether it is wide gap semiconductors, high temperature electronics, fiber optics in the strain application we talked about earlier, nanomaterials in subsurface—there are a lot of areas the engineering community is pursuing. I know everybody has their own interactions with that community, but I think there is an opportunity for the geoscience community to be way, way more organized and inform that community for the benefit of the kinds of programs we are talking about here.

EGILL HAUKSSON

California Institute of Technology

My name is Egill Hauksson. I am with Cal Tech. I just wanted to raise the issue similar to what the last speaker did, of the need of having grad students who know about instrumentation and seismometers and actually able to do—develop instrumentation as part of their Ph.D. Nowadays, most students, they go on a workstation, push some buttons, and data appears. They have no idea where it came from and how it came to be and what are the shortcomings and what are the strengths of that data which they are downloading.

Somehow, I think we, as a community, probably through IRIS and UNAVCO, need to somehow foster students who want to tinker and play with instruments.

SERGIO BARRIENTOS

National Seismological Center, Chile

My name is Sergio Barrientos. I am coming from the University of Chile. Our model is totally different than you have been talking here. I won't explain it, but I have a couple of questions. Maybe one question for UNAVCO and IRIS, particularly in that area of recapitalization.

The developments are done, are improved by the scientific community and then they are adopted by the community—adopted by other users. I am thinking, for instance, on early warning—earthquake early warning. There are some instruments, some facilities that were developed for science, that were developed for the advancement of science, and then they come to be sort of adopted by the community. They could fund an upgrade or they could establish these facilities and maintain them in the long term.

My question is how do you get these agreements with these sort of actors in society that can sustain the long-term operational standards of this equipment? Do you have a voice or an idea on how we can follow?

GLEN MATTIOLI

UNAVCO

This is something at UNAVCO we have been working on for quite some time because we have a permanent network of stations along the western part of North America. These stations could also be used for earthquake early warning and tsunami warning. I have been chastised when I gave my talk at SSA to say that all tsunami warning is early so I shouldn't say that.

What we have tried to do is broker new partnerships with the agencies, the mission-oriented agencies that are responsible for these activities. We first started talking to the USGS. The USGS had its own internal process to examine what assets were available to them in situ right now that were paid for and developed by the NSF. Then, eventually, they invited us to participate in the Shake Alert program. They have been providing a small amount of assets to help upgrade the existing facilities that the NSF has originally built and operated for the last 10 years.

It is really a drop in the bucket, to be frank. You know, we have close to 1,300 stations, about 900 of which are real-time one hertz stations. USGS has provided upgrades for 39 of them.

We also have been trying to work with NOAA, but it has been a little bit more difficult to operate with NOAA. The USGS, of course, was an original partner in EarthScope. We have a memorandum of understanding with the USGS at UNAVCO, which was vetted by the NSF and the USGS simultaneously.

It is very difficult to do this. We have—literally, I have spent probably 25 percent of my time over the last few years to try to move this forward, maybe even more.

RICK ASTER

Colorado State University

From the seismological side, we also work very diligently and hard with our partners. We have had some successes. They don't come easy, but the U.S. Geological Survey has a mandate to monitor the world and the nation's seismicity. We have used that connection many, many times to build long-term partnerships. In some cases, hand off instrumentation through basically working very closely with their organizational structures and their advisory boards and our colleagues in the seismological community. So, we have had some success in this.

Other agencies we have worked hard with are the Department of Defense for Global Seismic Monitoring with some success and the Department of Energy in our partnerships at Livermore and the other national labs.

Yes, it is hard work, but it is really part and parcel of what we do as a community.

The facilities have always played a very important role in brokering those connections with their expertise on the technological and the operational side of instrumentation. It is hard work, but it is viewed as part and parcel of what we should be doing as a community in the interest of national security and public safety.

KATE MORAN

Ocean Networks Canada

I just wanted to build on this discussion about partnerships. That is one of the things that my organization has been advancing as much as possible. We do partner in the Canadian government with other federal departments, in addition to our foundational scientific funding. We have been able now to install a very dense earthquake early warning network that sits on top of our scientific instrumentation.

What we have learned from that is that it is not only partnering with the federal government and the provincial government in Canada, who is responsible for the alerting, it is the fact that we have now engaged industry partners, particularly large infrastructure operators who are big advocates in Ottawa and in the province of British Columbia. It is those external validators that are helping us move forward very rapidly. In fact, we now are collocating these earthquake early warning sensors not only offshore, but particularly on land with—collocating with GNSS so that should we have the big one, we will be able to actually get a better estimate of magnitude than with those disparately located sensors, just to give you an example.

I think it would be important for the future structure to be able to have a free hand in growing those partnerships. When you do engage at that scale, everyone is on your side.

Hollett: So, I'm going to ask a question. Kate, I am just curious how did you do that, engage those infrastructure owners?

Moran: I hired two people who do it on a regular basis. About 4 years ago, we started by just going to Vancouver, inviting the—I think it was the Business Council—to bring some stakeholders to the table. We simply asked them what would you do with 30 seconds. That is how it started and then it grew from there.

Hollett: These are marine operators, highways, bridges.

Moran: It is the airport, BC Hydro, Fortis, port, BC ferries, the Association of Building Operators, the fire chiefs.

Hollett: The reason I ask is this ties a little bit to something that Jim and I were talking about earlier, which is trying to do a better job of articulating—this may be a bigger geoscience question—why should you—you being sort of a broad, general community or population—why should you care? Why should you care about the geosciences? Why should you care about what we are doing?

Moran: I think we do a really, really good job talking to ourselves. I am not convinced that we do—you know, this is despite all of the outreach we do—is talking to those communities that actually have a more acute investment, community interest level. We do in pockets, in certain places, but I don't think we do it as broadly as sometimes we can.

That is why I am really, really interested in that. That has impacts on the workforce development. It has impacts on the funding levels and engagement. It has—it crosses everything we are talking about. That is pretty neat.

ENRIQUE CABRAL-CANO

Instituto de Geofísica, Universidad Nacional Autónoma de México, Mexico

Good afternoon. Enrique Cabral at UNAM in Mexico. I just wanted to share some thoughts I have been having in the last hours. Let me give you some food for thought for this workshop. Maybe you can reflect on those in the coming hours and tomorrow. Let me give you some context so this can be a little bit more clear.

In the past breakout session, it became clear to me that governance is and should be part of; should be an integral part of the facilities management. That is because it is part of the driving force of it. That is one.

The other one would be that the community has been very effective and successful building networks which go outside the U.S. boundaries. That is something that everybody—we all should be happy for that, but that entails some challenges.

The other thing is that from what I see, the U.S. is rapidly becoming not the only large investor in observational facilities internationally. I am looking at China, for example. The Nature has run a series of Chinese things in the last issues. The numbers are just staggering for what they are investing. They are not only—I think they have, at least in Mexico, they haven't invested heavily in Earth sciences, but I see that it may not be too long until it starts to be that.

In this context, the international organizations that have helped to build this international network should be seen more as partners, which we—at some point, we are all—we feel like we are there. This should reflect on the governance of these facilities. That is what I want to go to my first point.

I think that there are some links that have not been fully developed yet. In particular, I think that the governance should include international partners. I can see that there might be some discussions for and against that. I think that if there—if we are looking for some long-term sustainability and good relationships and they are to be maintained and kept with people like us, which are partners, I think we should start looking into these—integrate that part into the governance model and administration for these facilities. Thank you.

XYOLI PÉREZ-CAMPOS

Instituto de Geofísica, Universidad Nacional Autónoma de México, Mexico

Hello, everybody. My name is Xyoli Pérez-Campos, also from the UNAM of Mexico. Currently, I am the head of the National Seismological Network. What I wanted to share with you is I have been very interested in all of the discussion during the day. But then I come from a facility that has transitioned from being focused only on seismic monitoring then kind of research facilitator and now it is on the real-time seismic monitoring again. We are trying to push to be also the main provider for data for science and good quality data for science.

Now, we are on the path to a new transition. All of this discussion has been very useful for me because I am getting all of these ideas of having a scientific board or different ways to manage the center and what could be useful for Mexico.

But then what I want to kind of share with you was my internal thoughts on how to transition from being a real-time focus on getting the information to authorities and public on seismic monitoring and the other side of the spectrum that is basic science and scientific, goal-oriented facility—so where those two facilities merge and try to become—we don't have the resources that you have. You want the resources from NASA. We don't even have the resources from IRIS or UNAVCO. If I can get that, then I might have enough stations in the country to help the science to improve.

Hard to balance basic science and monitoring. That could be our challenge in our countries. Thank you.

BEN PHILLIPS

National Aeronautics and Space Administration

Ben Phillips from NASA Headquarters. I just wanted to provide a little bit of perspective on the scale of support for our geodetic data systems. Jeanne mentioned a big number that has resonated with a lot of you. Just to sort of scale appropriately, so CDDIS, the Coastal Dynamics Data Information System that Jeanne referred to that houses our geodetic data, the funding there is a fraction of a percent of what Jeanne referred to.

I think what is relevant for your discussions here is that that is one of a dozen DAACs that operates under this larger EOSDIS management structure. There are some opportunities for them to leverage from scale for things like purchase power for Cloud services that you heard about. It is a different management structure, but as Jeanne said, these are still the data products that are generated by various missions, connected to core disciplines. They can't be extracted from one another so there are all of these conduits for input and interaction to make sure that connectivity remains.

So you have an additional sort of management structure that requires other types of interfaces, but I guess I just wanted to encourage you not to get too hung up on that scale issue. When it comes to our community, here, and the kind of science problems and data that we are working with, the scale is not so different. What is different is that you have this larger construct where there are some leveraging opportunities.

ANDREA DONNELLAN

Jet Propulsion Laboratory

I'm Andrea Donnellan from JPL, another big elephant in the room I guess. I think it gives us some perspective coming from NASA and JPL. One thing I haven't heard here: I heard in our discussion of our breakout is the idea of merging organizations or making them work more closely together [as that] can drive innovation because you are drawing on different fields and the intersection between them.

One thing I haven't heard discussion of is management structure. I know at JPL and many organizations, you have a president and a vice president or a director and deputy director. We have that all the way down the management chain at JPL. I think we should consider how that management is constructed. If you have a president and a vice president, you can divide the load. You can divide working styles. You can bring expertise from both disciplines. I just want to make sure that idea of complementary expertise is considered into this discussion.

MICHAEL WEST
University of Alaska Fairbanks

I just wanted to make sure everyone in the room is aware of the federal advocacy efforts that go on through IRIS and UNAVCO. In addition to the community-driven and sponsor projects that are carried out, as 501(c)(3)s, both organizations have the ability to do direct federal advocacy that benefits the community in a lot of ways.

Sometimes it is for very specific projects like recapitalizing the Global Seismographic Network over the course of many years. Sometimes it is broader than that, like being an additional voice of arguing against some of the restrictions in the America Competes Act of a few years ago.

Those are things that as we look at different management models, I can't really say how different management models would accommodate those kinds of things. I think it is important to recognize [that] they don't often get put on the front page of the annual summary for these organizations, but they are really important.