

## NATIONAL SCIENCE FOUNDATION (NSF)

Advisory Committee for Polar Programs (AC-OPP)  
Spring Meeting, May 1-2, 2019  
National Science Foundation Headquarters  
2415 Eisenhower Avenue  
Alexandria VA 22314

## MINUTES

### Action Items Arising out of the Spring 2019 AC-OPP Meeting

1. The policy framework and contributions that NSF makes in the Arctic are to be included in the agenda for a future meeting.
2. Dr. Roberto Delgado and others will work with an AC-OPP subcommittee to assemble implementation recommendations from an NSF perspective to help the community focus on implementation of the principles for conducting research in the Arctic.
3. The topic of data sharing across polar programs, and across OPP and GEO, will be pursued in depth at a future meeting.
4. OPP will report back to AC-OPP on the experiment with removing proposal deadlines.
5. AC-OPP comments on the Polar Research Vessel Requirements Subcommittee Report (in particular, Section E) are to be submitted by June 30.
6. Section D of the Polar Research Vessel Requirements Subcommittee Report may be posted to the website and members may communicate that it is available there.
7. The Polar Research Vessel Requirements Subcommittee Report shall be completed in time to provide it to AC/GEO for its fall meeting.
8. The aging heavy cargo-lift fleet will be discussed at a future AC-OPP meeting.
9. Comments on the Arctic Portfolio Review can be sent to Dr. Lynch over the next month. Comments should not suggest major restructuring of the report.
10. AC-OPP members are to expeditiously email their top three title choices for the advisory overview document.
11. OPP will query members for an optimal time for the next meeting. Members should respond with dates when they will not be available during September and October.
12. AC-OPP members are to submit suggestions for future meetings.

### Attendance and Membership

AC-OPP Members Present:

Dr. Thomas J. Weingartner, College of Fisheries and Ocean Sciences, Institute of Marine Science (Ret), Chair, AC-OPP

Mr. Raymond V. Arnaudo, Department of State (Ret), member, Advisory Committee, Environmental Research & Education

Dr. Douglas Bartlett, Marine Biology Research Division, Scripps Institution of Oceanography, University of California at San Diego (telephone)  
Dr. Aron L. Crowell, Arctic Studies Center, Alaska Regional Program, Department of Anthropology, National Museum of Natural History, Smithsonian Institution  
Dr. Michael D. DeGrandpre, Department of Chemistry and Biochemistry, University of Montana, Missoula (telephone)  
Dr. Mark Flanner, Department of Climate and Space Sciences, University of Michigan, Ann Arbor  
Dr. Patrick Heimbach, Institute for Computational Engineering and Sciences, The University of Texas at Austin  
Mr. Alex Kosseff, American Mountain Guides Association, Boulder, Colorado  
Dr. Brice Loose, Graduate School of Oceanography, University of Rhode Island  
Dr. Amanda Lynch, Institute at Brown for Environment and Society, Brown University  
Dr. Michelle Mack, Center for Ecosystem Science and Society and the Department of Biological Sciences, Northern Arizona University (telephone)  
Dr. Adam Marsh, School of Marine Science, University of Delaware  
Mr. Christopher Mossey, Fermi National Accelerator Laboratory, Batavia, IL  
Dr. Meredith Nettles, Lamont-Doherty Earth Observatory, Columbia University  
Dr. Patricia Quinn, Pacific Marine Environmental Laboratory, National Oceanic and Atmospheric Administration (NOAA) (Telephone)  
Dr. Sharon Stammerjohn, Institute of Arctic and Alpine Research, University of Colorado  
Dr. Eric Steig, Earth and Space Sciences, College of the Environment, University of Washington  
Dr. Abigail Vieregg, Kavli Institute of Cosmological Physics, Eckhardt Research Centers, University of Chicago

AC-OPP Members absent:

Mr. Craig Fleener, Senior Advisor for Arctic Policy, Alaska Governor's Cabinet

Office of Polar Programs (OPP) and other NSF staff present:

Dr. Kelly Falkner, Director, OPP  
Dr. Greg Anderson, Program Director, Arctic System Sciences, OPP  
Dr. Scott Arnold, Senior Advisor, OPP  
Dr. Andrew Backe, Management and Program Analyst, OPP  
Dr. Scott Borg, Deputy Assistant Director, Geosciences (GEO)  
Dr. F. Fleming Crim, NSF Chief Operating Officer (COO)  
Dr. Paul Cutler, Program Director, Antarctic Glaciology, OPP  
Dr. Xujing Jia Davis, Arctic Sciences Section, Arctic Natural Sciences  
Dr. Roberto Delgado, Program Director, Arctic Observing Network, OPP  
Dr. William Easterling, Assistant Director, Directorate for Geosciences  
Mr. Jon M. Fentress, Safety & Health Officer, OPP  
Dr. Christian H. Fritsen, Program Director, Antarctic Organisms & Ecosystems  
Dr. Patrick Haggerty, Research Support & Logistics Program Manager, OPP  
Dr. Alexandra Isern, Program Director, Research & Logistics Integration, Antarctic Sciences, OPP

Ms. Pawnee C. Maiden, Administrative Officer, OPP  
Dr. Nature McGinn, Environmental Policy Specialist, Section for Polar Environment, Safety and Health, OPP  
Mr. Timothy McGovern, Ocean Projects Manager, OPP  
Dr. Peter Milne, Program Director, Ocean & Atmospheric, OPP  
Dr. Vladimir Papitashvili, Program Director, Antarctic Astrophysics and Geospace Sciences  
Dr. Polly Ann Penhale, Senior Advisor, Environment, OPP  
Dr. Elisabeth Rom, Polar Education Liaison, OPP  
Mr. Ben Roth, Facilities Engineering Project, Manager, AIL, OPP  
Mr. Paul Sheppard, Deputy Section Head, Antarctic Infrastructure and Logistics, OPP  
Ms. Stephanie Short, Section Head, AIL, OPP  
Mr. Simon Stephenson, Section Head, Arctic Sciences Section (ARC), OPP  
Ms. Beverly J. Walker, Science Assistant, OPP  
Dr. James Whitmore, Program Director, Division of Physics (MPS)

#### Speakers Joined over the Telephone

Dr. Daniel Marrone, University of Arizona, Department of Astronomy, Steward Observatory (telephone)  
Dr. James Swift, Chair, AC-OPP Ad Hoc Subcommittee on the U.S. Antarctic Program's Research Vessel Procurement (telephone)

### **Wednesday, May 1**

#### Opening Remarks and Introductions

Dr. Weingartner; Dr. Falkner

Dr. Falkner welcomed everyone to the meeting. She noted there were more items to discuss than could be included on the agenda. Her office has a list of topics for future meetings and she encouraged members to submit suggested additions. She asked those in attendance, in person and virtually, to introduce themselves.

Dr. Falkner said OPP has, on the whole, dropped proposal submission deadlines, which is an NSF trend. One result is far fewer proposals being submitted, which is positive if the quality and success rate increase. She suggested a full review of the implications at the fall AC-OPP meeting.

Dr. Arnold continued with a budget and polar programs presentation. He said the OPP budget will be finalized in the next couple weeks. The overall NSF budget increased from FY 2018 to 2019, topping \$8 billion for the first time. The 2020 request is down \$1 billion. Dr. Falkner added that planning has recently begun for the 2021 budget, as work continues on 2020. Congress, she said, determines the final appropriation; for the last two years, more was appropriated than what the White House requested.

Dr. Arnold also discussed the OPP budget. The 2019 request is \$534.54 million, which includes the first year of the Antarctic Infrastructure Modernization for Science (AIMS) construction

program at \$103.7 million. AIMS will be part of the Major Research Equipment and Facilities Construction (MREFC) budget. The 2020 request is substantially lower.

Dr. Arnaudo asked if there is a dialog with the White House during budget development. Dr. Falkner said NSF, in response to Office of Management and Budget (OMB) guidance, submits a draft budget to the White House in the August timeframe. NSF receives “passback” from OMB around Thanksgiving with questions and requests for information. OMB uses NSF’s response for its internal process to develop the president’s budget, which is usually released in February. Congress, she said, has its own sense of its responsibility for the budget. The NSF director’s congressional testimony on the budget is publicly available. NSF is part of the executive branch and lines up behind the budget. Congress can ask questions of NSF through the foundation’s Office of Legislative and Public Affairs and the National Science Board, but it is not legal for NSF to lobby; citizens may lobby. Congress is very supportive of polar programs, she said. When there is an appropriation late in the year, e.g., where there is a Continuing Resolution (CR), the agency has to determine what to do with funding over the request and polar programs has fared well in that. She thanked everyone for making sure the program is well connected with the community’s needs and can compellingly express them.

The government shutdown that occurred since the last AC-OPP meeting was not easy to weather. Some people can work during a shutdown on the basis of protecting lives or property. OPP had personnel working during the shut-down and the ability to add additional individuals if needed. Having pushed out funding to cover contract work in the Polar Regions, both the USAP and Arctic programs were able to continue working during the shut-down supporting the teams of scientists deployed. Rotating NSF staff who come from universities are not formally considered Federal employees and are allowed to do some work during the government shutdown. Many assistant directors are in that category. During the shutdown, they were able to review AIMS material, as members of the Director’s Review Board, prior to it going to the National Science Board (NSB). Otherwise, AIMS would have lost a year.

In February, the NSB approved \$410 million to overhaul McMurdo Station. Dr. Falkner thanked the program officer and the full team for working hard to keep things on track. The team also prepared to buy long lead-time items for the first construction year out of the chute. But OPP is still recovering from the shutdown, which caused a continuing mad scramble. The Navigating the New Arctic (NNA) initiative was also kept on track, with a deadline extension. There was a healthy response, she said, and thanked Dr. Anderson for his work on NNA.

Turning to staffing updates, Dr. Falkner said Dr. Xujing Jia Davis has been hired as Program Director for the Arctic Sciences Section and Dr. Isern as Section Head for the Antarctic Sciences Section. Dr. Fentress is now Acting Section Head for the Polar Environment, Safety and Health Section. Dr. Falkner thanked Dr. McGinn for having previously served in that role. Dr. William (Bill) Henriksen has retired as the Winter McMurdo Station Manager and Nadene Kennedy has retired as OPP’s Polar Coordination Specialist.

Dr. Falkner said there have been a number of high-profile banner events for polar programs and there has continued to be noteworthy science across the board. For example, OPP provided

support to the Walt Disney Company for filming Adélie penguins in Antarctica for a movie called “Penguins.” The footage, she said, is spectacular and is recommended viewing.

### AIMS Update

Ms. Short followed up on Dr. Falkner’s mention of AIMS, discussing moving the project from preliminary design review to February’s NSB authorization, and thanked the Antarctic Infrastructure and Logistics Section (AIL) team for its work, particularly during the government shutdown. She also discussed the full scope authorized by the NSB and the scope changes between preliminary design and the fully approved scope; a strong justification was provided to the board for all the major components as originally scoped for the project.

Dr. Weingartner asked about winter AIMS construction with Ms. Short responding that the facility will be enclosed to permit winter work. The McMurdo webcam provides views of pre-AIMS construction, including an addition to the science support center building, which will be the new home for information technology (IT) activities. Utilities and other work have also begun. Work continued until the end of March. Dr. Falkner said there is access via C-17 aircraft every four to six weeks throughout the year, which allows tradespeople to arrive and depart in the winter.

Dr. Vieregk asked about the difference between the original design and what was approved. Dr. Roth responded there were challenges related to budget and scope. A lot of value engineering went into the ultimate solution to not compromise functionality. One of the deliverables was that the functionality of the individual buildings was not affected. Originally, the fire station had drive-through bays but it was determined money could be saved on site work by having back-in capability for the fire equipment. Money was also saved by eliminating a warm storage component at the vehicle equipment operations center by having it inside the building. No functionality was lost.

### Antarctic Treaty

Dr. Penhale; Dr. Arnaudo

Dr. Penhale provided Antarctic Treaty system updates with a discussion of meetings of:

- The Committee for Environmental Protection (CEP) and the Antarctic Treaty Consultative Meeting (ATCM), July 1-11, 2019;
- The Scientific Committee and the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), on October 22-November 2, 2018.

The United States sends a delegation to each meeting that includes numerous NSF staff. When Dr. Arnaudo was at the State Department he headed the delegations. Dr. Penhale is the U.S. representative for the Committee for Environmental Protection and attends CCAMLR for NSF.

The major contribution to the CEP was the submission of the “Draft Comprehensive Environmental Evaluation (CEE) for Continuation and Modernization of McMurdo Station Area

Activities,” which she compared to an environmental impact statement. The activities assessed include:

- McMurdo Station Master Plan projects, including the AIMS subset;
- Continuation of science and operations at McMurdo Station and sites supported from McMurdo Station.

The submission was made four months prior to the treaty meeting. The CEP reviewed the CEE and provided comments, which must be addressed before completing the evaluation. This must be done 60 days before starting any activity on the ice. The deadline will be met, Dr. Penhale said, adding that some of the comments will be challenging to address. She said the submission is very different from others the treaty has considered, which address a single project. The McMurdo plan, which has a longer timeframe, with less detail available for the outyears, refers to previous documents on assessed activities and commits to further environmental assessments as needed.

She next provided the major issues to be discussed at the CEP meeting:

- Joint Scientific Committee on Antarctic Research (SCAR)-CEP Workshop on Further Developing the Antarctic Protected Area System;
- Further discussions on assessing areas for potential Antarctic Specially Managed Areas (ASMA);
- Climate Change Response Plan;
- Harmonization of Marine Protection Initiatives between the ATCM and CCAMLR;
- Review and update of the CEP Clean-up Manual.

There are currently about 75 Antarctic specially protected areas and the workshop will assess whether important areas are all covered or, with climate change, should areas be set aside to not be visited for a long time to use as comparison for the future. The ASMAs are larger and have different types of activities that may conflict, preventing activities from reaching their potential. These areas have zones where, for example, tourists can camp. There are currently six ASMAs. The U.S. has been a proponent of three of them and has worked with other countries on others. The intersessional work has looked at how to implement the new guidelines for assessing and writing management plans. The Climate Change Response Plan identified areas where climate change may affect biodiversity or conservation of the Antarctic and develop responses, drawing on scientific advice that can be used by managers for management strategies. The top priority is non-native species. Related tasks would be education and communication of risks and taking action before material and people get to the Antarctic. Another issue is transferring species among Antarctic research sites. Microbial pathogens are another area of interest. A surveillance framework is also being developed for identifying non-native species. On the harmonization of initiatives between the ACTCM and CCAMLR, a meeting a few years ago determined the development of marine protected areas fell under the convention whereas the nearshore coastal marine areas fell under the Antarctic Treaty through the Antarctic specially managed program. The Ross Sea Region Marine Protected Area is the world’s largest marine protected area, adopted in 2016. The community has since developed a research and monitoring plan for this work. Its adoption by the convention has been blocked by Russia and China. The Antarctic Treaty put forth a resolution that the CEP should contribute to the research and monitoring plan and there was to be a formal working group, but that was blocked. She added that there was an

informal discussion group on how to move forward with nearshore and marine work that was led by New Zealand with the U.S. contributing. The Clean-up Manual, she said, was developed to address issues and protocol for protection of the Antarctic area by the obligation to clean up sites of past activities. The task has been completed and is bringing more modern techniques for waste management and remediation to the treaty area as options.

She turned next to the Antarctic Treaty Consultative Meeting's Major Topics:

- Aviation Activities in Antarctica
  - Governmental and Non-Governmental Activities;
  - Includes operation of Remotely Piloted Aircraft Systems (RPAS);
- Tourism and Non-governmental Activities;
- International Science Cooperation;
- Collection and Use of Biological Material (“biological prospecting”).

Aviation activity is increasing, particularly in the non-governmental area, including remotely piloted aircraft fixed wing and rotary. The Council of Managers of National Antarctic Programs (COMNAP), which Dr. Falkner chairs, was asked to develop an overview paper, which was submitted to the Antarctic Treaty. It found air activities are very important in supporting research work, as is advanced and accurate information on flight plans and timely data sharing for safety and efficiency. There is particular growth in helicopter tours. The season of air operations is increasing and there is a concern about national programs being called for emergency responses from tour activities if there is a big increase. There are a lot of technological advances that could be used to support safe operations. The major discussion now has to do with tourism and non-governmental activities. She recently attended a workshop that included tour operators and noted that tourism has been discussed and regulated for the length of the treaty with guidelines and binding measures developed, though not all are implemented. In the 2017 – 2018 season about 56,000 people visited the Antarctic, about 48,000 of whom landed. Thirty-three percent of visitors are from the U.S. China has 15 percent. Australia has 11 percent. The treaty is being faced with a huge growth in the tour industry. About 25 cruise ships operate in the Antarctic and that number will at least double in the next few years, with larger and more capable ships. It is getting very crowded already. Ships offer helicopter trips ashore, along with camping, kayaking and submersible rides. Managing this will be a big topic. On international science cooperation she said the U.S. has sent five papers to the Antarctic Treaty about U.S. international activities. Regarding biological prospecting, she said some parties are intent this be regulated in the treaty and others, including the U.S., do not see the utility in pursuing the regulation of collecting biological material.

Dr. Arnaudo continued the presentation with a discussion of CCAMLR, which was begun more than 40 years ago to monitor fishing and pioneered the concept of ecosystem management, which accounts for the relationship among harvested species (target species), related species (by-catch species) and dependent species (birds and seals dependent on target species). He said CCAMLR has been very successful. Currently, there is pressure mainly from Russia and China to say it is not about ecosystem management and he said the U.S. has to take the lead pushing back on this.

The area covered by the treaty is south of the Antarctic convergence and covers about 10 percent of the Earth's surface. It is divided into statistical areas, subareas and divisions. The boundaries take into account oceanographic and biological characteristics thought to contain discrete populations of species.

He said there needs to be more research, but long-term surveys require more fishing, in the absence of more funding for research cruises, which he doesn't see happening. The state of the fishing stock is generally good, he said.

Boats are primarily fishing for krill, but also Chilean sea bass. Levels for those fish are fairly carefully monitored.

Conservations measures include:

- Open/Closed Areas;
- Seasonal Limits and Closures;
- Catch Limits;
- Gear Types;
- Fishing Practices;
- Marine Protected Areas (MPAs).

Dr. Arnaudo discussed the Ross Sea region Marine Protected Areas (MPA), set up over strong objections from primarily China and Russia. There are some loopholes that allow fishing in an area set aside for no fishing. The protected area sets off warning signals for fishing countries worried about being shut out of more areas. Conservationist-minded countries without fisheries in the area want to set aside more areas for non-fishing, which Dr. Arnaudo said sounded like a good idea. With the help of China and Russia, agreement will be blocked, he predicted. The U.S. is unlikely to push for the more non-fishing areas, he said.

Proposals for new MPAs include:

- 2018 Antarctic Peninsula MPA (no agreement);
- 2016 Weddell Sea MPA (no agreement);
- 2012 East Antarctica MPA (no agreement);
- 2012 Ross Sea Region MPA (adopted 2016);
- 2009 South Orkney Islands Southern Shelf MPA (adopted 2009).

He listed current issues in CCAMLR as:

- Krill Fishery (2017-18 season);
  - 306,145 tons (highest level since early 1990's);
  - Need to make progress on development of management strategies for the krill fishery;
- Finfish Fishery for "Chilean Seabass" (2017-18 season);
  - 12,565 tons--Patagonian Toothfish;
  - 4,353 tons--Antarctic Toothfish;
- Illegal, unreported, and unregulated (IUU) Fishing;
  - Increased surveillance, some success;
  - Interpol's "Project Scale."

He said the increased catches are under watch by the scientific committee. The biggest limitation is that the area is not easy to fish. IUU fishing is a difficult problem because it is a hard place to monitor unidentified ships; there are generally no enforcement vessels. But there are observers on registered ships and there is a good reporting system. Dr. Penhale said Interpol has taken on IUU as a major task, which has been a major benefit to the Antarctic.

Dr. Penhale also discussed the climate change response strategy, including how to adapt fisheries management to take into account climate change and the proposed working group terms of reference, for which there is no consensus. The scientific committee wants to look at climate change in terms of how it might affect fishing, she said. She also discussed the safety of observers who report on activities, transshipment and capacity building. Dr. Arnaudo said transshipment at sea to a big container complicates monitoring.

*Discussion:*

Dr. Falkner said NSF is involved because much of what went into defining protected areas in the Ross Sea MPA was built on years of NSF-sponsored basic research on ecosystems. She said Dr. Penhale has been key in linking that information to the Antarctic Treaty system. NSF sister agencies have responsibilities under these treaties and Mr. McGovern has been key in helping National Oceanic and Atmospheric Administration (NOAA) gain ship access for some of its treaty obligations. There is a need, she said, to be aware of the bigger context in Antarctica. There is a different picture for the Arctic, which can be included in the agenda for a future meeting to summarize the policy framework and contributions that NSF makes.

Dr. Heimbach asked why the Ross Sea MPA was successful when the Weddell Sea MPA was not. Dr. Arnaudo said the Ross Sea was considered first, with a years-long struggle. Those opposed did not want a precedent set that would lead to fishing bans. Though there is not a lot of fishing in the Weddell Sea, the fishing nations will block it. Dr. Penhale added that the Ross Sea MPA succeeded thanks to high level engagement from government officials that is now not present.

Dr. Loose asked if there were non-governmental participants in the treaty. Dr. Arnaudo said non-governmental installations are allowed and that non-governmental organizations participate actively in the meetings, though they do not vote. Dr. Penhale said the U.S. delegations includes non-governmental representatives.

The Interagency Arctic Research Policy Committee (IARPC) Principles Document Presentation  
Dr. Nettles; Dr. Lynch; Dr. Delgado; Dr. Loose

Dr. Delgado provided an overview of the revision process of the principles for conducting Arctic research, which were originally adopted in 1990. In November 2018, IARPC completed the revision. Its goals were:

- To Revise and Strengthen the IARPC Principles;
- To Ensure Broad Participation in the Revision Process;
- To Promote Wide Dissemination and Practice of the IARPC Principles.

The revision was a widely supported interagency effort. The Principles Revision Working Group (PRWG) included representatives from IARPC, The Bureau of Ocean Energy Management (BOEM), NSF, The Centers for Disease Control and Prevention (CDC), The Cold Regions Research and Engineering Laboratory (CRREL), The Smithsonian Institution (SI), The Environmental Protection Agency (EPA), NOAA, The United States Geological Survey (USGS), and The United States Arctic Research Commission (USARC). Almost half of the Working Group members are based in Alaska.

The process began prior to September 2017 and included:

- Listening Sessions and Outreach at conferences in Alaska;
- Federal Register Notice (FRN) to Request Comments;
- Targeted Interviews and Broad Request for Comments;
- Webinar to Discuss the Process and Gather Comments;
- Produced a video to explain the process and need to gather input to revise the Principles;
- Revised draft circulated publicly (FRN) for comment;
  - Email alias, IARPC Website, Social Media;
- Revised and Re-circulated to IARPC Agencies;
- Revised Final Draft for IARPC Principals to Approve.

Hundreds of comments were received from various organizations and the five principles were developed for conducting research in the Arctic:

- Be Accountable;
- Establish Effective Communication;
- Respect Indigenous Knowledge and Cultures;
- Build and Sustain Relationships;
- Pursue Responsible Environmental Stewardship.

Following approval and acceptance by the Policy Committee, the Working Group began distribution and implementation, which included:

- Principles posted on the IARPC [website](#);
- ArcticInfo announced the new Principles;
- Briefed Arctic Policy Group (US Department of State);
- IARPC members are presenting the revised Principles at meetings and conferences;
- Each IARPC agency should distribute the Principles to its research community and develop a guidance framework.

The Working Group is currently in the process of:

- Drafting articles & news releases;
  - (e.g., SI Arctic Studies Center Newsletter, *Eos*, The International Arctic Social Sciences Association (IASSA) Newsletter);
- Preparing outreach card/flyer;
- Considering avenues to receive feedback on implementation.

In conclusion, Dr. Delgado made the following points:

- Agency representatives have commented that this document meets a current need to strengthen research collaborations between Arctic residents and scientists, and builds on the original [Goal 1];
- The IARPC Principles Revision Working Group engaged diverse Arctic stakeholders in the revision process using a broad array of communication tools [Goal 2];
- In November 2018, the IARPC Principals accepted the revised Principles for dissemination and implementation [Goal 3].

*Discussion:*

Dr. Loose asked about foundation implementation of three of the five principles for conducting research in the Arctic, including establishing effective communication, which he said will require training.

Dr. Delgado responded that training is an excellent idea and would ideally begin at the proposal stage. He discussed possible online training webinars developed with Tribal organizations and the scientific community. Each agency, he added, will have its own take. Principal Investigators (PI) can be given guidance in association with an award to achieve the principles for conducting research.

Dr. Lynch praised the document and said it was useful for people doing research in the Arctic to have guiding principles clearly articulated. She said the devil is in the implementation. She said the Arctic portfolio review flagged for discussion issues such as managing expectations of the people you are working with. She raised the issue of engaging with communities in advance of an award that is not made and what happens at the end of the award if there is not a follow-on. She also discussed mismatch between the science that was going to be done and the community perspectives on how that would impact their activities, creating a toxic situation. Another issue the portfolio review talked about was the co-production of knowledge being a complex field of inquiry and how to do it properly and different ways of dealing with indigenous and non-indigenous communities and non-resident stakeholders. The NSF review process was going to be a key part of maintaining excellence in the implementation, which she said might need to be done through guidance for reviewers.

Dr. Delgado agreed about managing expectations and conflict management. There could be cases where researchers do due diligence but there isn't community acceptance. The researchers should not be penalized because of such lack of cooperation. Informing reviewers is key, he said, and guidance is being developed that will account for knowledge coproduction and working with indigenous communities.

Dr. Falkner asked about the original principles, which Dr. Delgado said were adopted in 1990. Dr. Falkner said the older document was much harder to digest and the revisions make it more straightforward and stressed the importance of appropriate implementation.

Dr. Crowell said there are several levels of people to talk to in setting up a project, including the local and regional political leadership. The first step is to meet with them to discuss your plan and get non-formal approval. There are also community scholars who are recognized locally as

having knowledge that fits the research area. It is important to ask about who these people might be who could become part of the project, formally or informally. Another important connection is to the local school and he suggested making presentations to an assembly or Tribal council, for example. This includes engaging local students at the high school or college level to help the community see benefits.

Dr. Nettles thanked the revision team and said the principles should apply worldwide. Implementation requirements will vary depending on the type of research conducted. She said the principles should apply even with remote sensing studies or limited on-ground observations. They are in the space and about the place where local communities live. Results should be communicated and the perspectives of the local community respected. She collects data where there are no people living, but the research is based in a town. That is a different engagement, but it is still important to use the principles as a guideline. Graduate school education is needed for researchers about going into someone's home territory to do their research. In Greenland there is an effort to bring research oversight from Denmark, from the permitting process through conduct of research ethics and reporting of research. She argued that the Working Group principles need to be applied internationally and supported a guidance framework and asked about NSF's role in developing the framework.

Dr. Delgado said NSF has a leading role. The training issue is key; incorporating an education component hasn't been considered but would be important to develop. Also, he saw the beginnings of international engagement. The State Department is working with the Arctic Council and its working groups and there are ongoing discussions about utilizing the principles in their efforts.

Dr. Falkner said she is hearing that the NSF community, via the AC-OPP, could benefit from a focus on them with respect to implementation.

Dr. Mack raised the importance of training. There have been some ad hoc trainings, which have been powerful. They brought natural scientists to work with anthropologists, community leaders and people who are more practiced at community interactions and knowledge coproduction. There is a need for students and PIs to receive training, she said, to change cultural practices. There is an opportunity for polar programs to offer thoughtful and careful training.

Dr. Weingartner said the planning for some programs can be very expensive and time consuming, with several months spent in community outreach before the proposal is written and visiting villages. And it may not be possible to write the proposal. He suggested assembling a list of resources so people will know where to go. He mentioned village councils, Tribal councils, a borough, the Alaska Eskimo Whaling Commission, and the Alaska Walrus Commission. Issues include meeting with them not sequentially, but not all together; who to meet; how to go about meeting with groups; and planning on meeting certain groups but winding up meeting others. The North Slope Borough Outreach Program could be a good resource. He also mentioned appearances on local radio programs and sending out fliers. Dr. Weingartner also raised the issue of scientific overload in villages. When offering to do a presentation at a community center in a tiny village he was asked what would be provided as a door prize. Shell, which had made a prior presentation, gave 10 gallons of gasoline. Another issue is the discussion of traditional

knowledge and the coproduction of knowledge. He said it can take more than a year to communicate across disciplines.

Dr. Crowell said Dr. Weingartner's last point was addressed by the point in the presentation about building and sustaining relationships. Ideally, there is a multi-year commitment to building a project. It may take quite a long time to get to know people and have effective understanding. He discussed a project where he was interested in carbon dating but a senior researcher on the project from the community said the dates don't matter as much as who was at a village and where it was.

Dr. Falkner suggested that Dr. Delgado and others work with an AC-OPP subgroup that could assemble implementation recommendations from an NSF perspective.

Dr. Loose suggested the discussion is part of a continuing process. The Arctic logistics providers are a valuable way to establish a means of communication and offer a buffer to the boom-bust cycle of researchers who come every summer. On education, he recommended the flow of indigenous knowledge into the network of science through conference participation and possibly as representatives in the review process at NSF. A bi-directional flow and engaging indigenous representatives in neutral environments would encourage a more natural interaction, he said.

Dr. Falkner thanked everyone and said the seeds of future activities had been planted.

#### Arctic Portfolio Review Subcommittee Report

Dr. Lynch; Mr. Stephenson

Dr. Lynch summarized the recommendations from the report. The committee was asked to:

- Recommend the critical programmatic capabilities needed to enable progress towards building a vibrant and relevant scientific program; and
- Recommend the balance of investments in the new portfolio of grant programs, facilities, and other activities within budgetary constraints.

Dr. Lynch said the committee, which she chaired, considered the relevant time period of relevance to be the coming decade. She said the first recommendation was easier to address than the second, where the committee could not reach agreement.

The committee membership was constituted in March 2018 with a balance of observational, experimental, analysis, and modeling researchers, with an equal gender balance, and including two early-career scientists and a member who had never received OPP funding. An attempt to determine the balance between social scientists and natural scientists was unsuccessful.

The committee recommended that ARC be re-constituted as three standing programs that invite proposals using one or more defined approaches. In the committee's review of the current portfolio, it was not always clear which program was doing what, whether it was doing what was intended, and whether potential proposers to those programs understood those factors. There was a sense in the analysis of missed opportunities—areas not addressed in the programs supported by the Arctic section that could increase the impact of the research.

The three standing programs would invite proposals using one or more defined approaches. The three programs would be:

- Natural Sciences and Systems (NSS), including disciplinary and inter-disciplinary research studying the Arctic and potentially connections to global systems;
- Social Sciences and Systems (SSS), including disciplinary and inter-disciplinary social sciences that encompass the Arctic and connections to the global system;
- An explicit Coupled Human-Natural Systems (CHNS) program that is explicitly inter-disciplinary that also spans across social and natural sciences.

She said it is possible to have inter-disciplinary research that is still all natural systems or all social systems. There are multiple disciplines within those two large groupings. It is possible to be inter-disciplinary without necessarily spanning the natural science/social science divide. The committee wanted to make it clear it was possible to be inter-disciplinary in many different ways.

The approaches articulate the types of science that could be supported under any of the three programs. The committee recommended that the three programs invite proposals using one or at most two of the following defined approaches:

1. Deep Dive Investigation;
2. Strategic Envisioning;
3. High-Risk and Exploratory Research;
4. Synthesis and Integration;
5. Long-Term Perspective.

The existing structure includes Arctic Natural Sciences (ANS), Arctic Observing Network (AON), Arctic Social Sciences Program (ASSP), along with additional programs associated with research and policy, polar cyber, education, and logistics.

These were reconstituted by the committee as NSS, SSS, and CHNS, which would be articulated through the five approaches, supported by key science enablers: education, cyber science and infrastructure, and logistics.

The committee also talked about community engagement and diversity and inclusion. Though they are not part of the proposed structure, they needed to be emphasized, Dr. Lynch said.

Turning to the balance of investments, she said this produced tension in the committee, particularly between natural sciences support and social sciences support. Opportunities need to be found to bring these communities together, she said. There is a lack of knowledge on both sides about common practices, appropriate research topics, how research has impact, and how it is communicated.

The committee agreed on the following conclusions:

- Field logistics is recognized as critical and should be supported at the current level;
- Existing field research facilities should be maintained but do not need to be expanded nor added to;

- Cyberinfrastructure needs serious investment, particularly with regard to innovative approaches to data services;
- CHNS can start small but should grow over time.

She added that about two thirds of the committee favored increasing the social sciences budget as there are disciplines not represented in OPP that would increase the program's impact.

The committee also made the following additional recommendations:

- Program managers should be encouraged to seek opportunities to include new scientific directions and under-represented disciplines;
- More attention should be paid to maintaining consistent institutional memory within ARC;
- Program managers should be encouraged to pay particular attention to proposals that include the development of theory, instrument, algorithm or other technology;
- The feasibility of Arctic Graduate Research Fellowships should be explored;
- NSF program managers should consider ways to support and assist Arctic investigators seeking to implement community engagement practices;
- Funding success rates should be routinely made public, and broken down by program within each Directorate, and this information included in new solicitations.

Mr. Stephenson said AC-OPP could accept the report as written, accept the report with modifications, or send it back for further review. He said there is a lot to like about the report from a program management point of view. The recommendations will encourage better support for the research community. He said he was concerned about some of the challenges, ARCs and AON particularly.

Dr. Weingartner asked about the tension between natural and social sciences and whether it was perceived that people from the social sciences were not applying to the Arctic program because they didn't see opportunities for what they thought was important.

Dr. Lynch said that was correct, adding that a community survey and other data showed that there were disciplinary areas not being supported in the social sciences program. The social sciences program was seen as having a particular flavor and that other disciplines may not apply. The committee found there were disciplines there internationally not represented in the ARC program. The larger proportion of those missing disciplines had a higher impact when looking at citations or reports.

In response to a question from Dr. Weingartner about the rationale for the concerns, Dr. Lynch said the success rate for social science proposals was higher than in other programs, therefore there was no reason to increase the funding. She said that was not true about the success rate. The other argument was that people in the other disciplines deemed to be missing were getting funded elsewhere, outside NSF. The idea was that the proposal pressure should drive everything and the programs with the lowest success rates should get the most money. But she said it was impossible to make an allocation based on that argument alone because variability is so high.

Dr. Weingartner asked if it was worth having a section of the report expressing the minority viewpoint. Dr. Lynch said the document tries to represent all views. It is a collective document without being entirely a consensus. The document stops short of saying the social sciences program should be increased by 50 percent, which is what several people on the committee felt.

Dr. Steig called the report masterful and said no significant changes should be made. He asked about the idea that within the natural sciences very different disciplines compete with one another when they are not comparable. Dr. Lynch said this did not come up in the committee. In the survey, some said that within the natural sciences there needed to be more granularity.

Dr. Steig also asked about the cyber infrastructure question, which he said was vague, and wondered if the discussion was mostly about data archiving or if the topic was larger. Dr. Lynch responded that what most animated the committee was having a smarter way of thinking about how databases interact, how they can be interrogated, and how you can do more with data in the cloud, which is under the rubric of data archiving. There was also a sense that being encouraged to engage more strongly in terms of algorithm development with computer scientists and doing the science as well as something that there could be more engagement with. The people who were more observationalists were less engaged by that than with archiving and retrieval but with the document the focus was more on archiving.

Dr. Steig said it has always bothered him that there is the Antarctic Glaciological Data Center and now there is the Antarctic program data center. He said it should be across polar programs to save resources and most of those using such data are not specific to a particular hemisphere.

Dr. Falkner said the discussion underscored that the topic should be pursued in depth and that it relates to many developments at the foundation and across OPP and GEO that are related to this discussion.

In response to a question about organizational structure, Dr. Lynch said the five approaches would be guidance to proposers to send strong messages about what kinds of research was being looked for. The thought was there would be multiple program managers within NSS, SSS and CHNS that would be fielding different types of solicitations. Newer investigators felt they didn't know which program to put their proposal into, so there was consideration of how to help proposers target their proposals to the right program.

Mr. Stephenson said the next step is that OPP would respond to AC-OPP and would answer how to implement or whether to implement the recommendations. The report has a lot of richness for the different areas, he said.

Dr. Flanner said he liked the simplicity and cleanliness of the proposed structure, which makes it clearer where to submit. He asked why the number of distinct investigators sharply decreases starting in about 2015. Mr. Stephenson said it was the result of not having a deadline and restrictions on proposals to ANS. Dr. Falkner said that was done to balance a workflow issue. She said OPP needs to report back how that experiment is proceeding. One of the objectives of going to no deadlines was to increase the success rate and diminish churn. A quick cut at success rates can produce misleading results. If a proposal is co-funded in another part of the agency,

none of the declines are credited against the funding. But you don't want to discourage people from co-funding across agencies. GEO's success rates look high and some of that has to do with GEO's successful management of community expectations. When putting in a proposal for ship time, there is a sense if the ship is going to be unavailable. There is a proactive sense of people understanding what they can and cannot propose.

Dr. Falkner said she looked forward to reporting back at a later meeting with more information on the no-deadlines issue. She suggested that if the report is adopted, that OPP respond at future meetings, saying it was the beginning of a conversation about how to better serve the community.

Dr. Falkner said that if the AC-OPP feels it wants to make adjustments before the report is finalized, Dr. Weingartner can work with members through email. She closed by saying the AC-OPP would return to this subject at the day's end.

#### Polar Research Vessel Requirements Subcommittee Report

Dr. Swift; Mr. McGovern

Mr. McGovern gave an overview of the two research vessels, the Laurence M. Gould (LMG) and the Nathaniel B. Palmer (NBP), noting that the LMG contract expires next year, having been on contract since 1998. The NBP contract expires in 2022, having been on contract since 1992. The subcommittee tapped a talented group of seagoing marine scientists and vessel operators, many with both Arctic and Antarctic experience. They assisted with determining the next steps for the vessels, which are approaching their end of service life. Options include extending contracts for the ships; or try to build new ships after determining their science mission requirements. A number of groups have examined the science mission requirements for polar research vessels over the last 10 to 15 years. The subcommittee took a more cohesive look given the current and projected budget situations as well as the evolving needs of science at sea. The result is a report of approximately 200 pages that was provided last week.

Dr. Swift complemented the committee members for their work. The studies in the scientific community have consistently determined that new research requires enhanced ship access to polar seas over much of the year, he said, adding that science drivers and mission requirements lead to fundamental ship science support specifications. This was tempered with a dose of realism regarding the current era in terms of budget expectations.

His interpretation of the NSF perspective is that there are ships nearing the end of contract. There are issues of support for the Antarctic Peninsula research being carried out and NSF has therefore been engaging the science and technical communities for input.

The issues NSF and OPP are facing with future ship issues are the same as those facing the academic fleet. Ships are costing more to construct and more to operate in an era of decreasing expectations in terms of flat Federal science and infrastructure support budgets. The academic fleet is large enough that it has been able to sustain a 25 percent trimming in recent years. But with two ships, trimming can have very significant impacts.

The subcommittee was asked to review specific documents having to do with the science mission requirements for polar research ships. That review was completed and recommendations made.

The subcommittee was also asked to prioritize the capabilities and operational requirements. An effort was made to assign priorities to the Science Mission Requirements (SMR). This was sometimes done in two levels, with one specification being optimal and another lesser specification being one that can be lived with.

The most difficult was considering the two-ship operational model and evaluating the advantages and disadvantages of moving to a one-ship operational model. The subcommittee made recommendations, noting that the choices will lead to significant impacts on the research program.

The subcommittee also engaged the scientific community and a summary of the outreach efforts is included in the report, along with the complete results in an appendix. There were 91 responses to the survey.

For his presentation, Dr. Swift highlighted two sections of the report:

- D. The U.S. Antarctic Program (USAP) Polar Research Ship Science Mission Requirements;
- E. US Antarctic Program Ship Support Options.

Section E is the where advice might be needed from AC-OPP and NSF regarding whether issues have been adequately addressed or need to consider other items. Numerical budgets, for example, were not considered, but rather the effect of tight budgets.

Dr. Swift said the SMRs were addressed in detail (87 pages) and provide important information for future ship specifications. Section D addresses each in a standard format.

Section E, the ship support options, was one of the more difficult areas to address, Dr. Swift said. The issues are:

- The two USAP ships are nearing end-of-contract; the NBP in particular is nearing the end of its design service life. Neither is up-to-date regarding some regulatory matters, and neither can readily be refit into compliance;
- The US scientific community has uniformly voiced strong support for Antarctic Peninsula region science (including support for Palmer Station), and the need for a (more) capable principal polar research ship;
- USAP ship operating costs are rising faster than are USAP budgets.

The Subcommittee examined:

- USAP use of its ships;
- Options for Palmer Station logistics support (using a 2010 study);
- British Antarctic Survey recent experience and decisions;
- Options for extending the service life of the NBP (using a 2015 study);
- Operational models for USAP ship support.

The subcommittee then made recommendations.

Section E.2 examined ship use in recent years. The report uses The University-National Oceanographic Laboratory System (UNOLS) definitions over calendar years 2009 – 2018. UNOLS helps coordinate the academic research fleet and Dr. Swift is the chairman of its fleet improvement committee. UNOLS has a method for defining an operating day and estimates of an optimal number of days for a given ship.

The LMG has been used for over 250 days for all but one year during this period, with 250 to 270 operational considered the optimum use for a ship of that size. About twice as many of the LMG's cruise legs each year support science and often include logistics support, with several expeditions each year (2 – 4) that are Palmer Station logistics only.

The NBP use is more variable but has picked up in recent years. The NBP should be working about 270 days per year. The NBP has some years with very heavy use (up to 327).

The LMG has met the UNOLS full optimal year criteria all but one year. The NBP met those criteria about 60 percent of the time; non-USAP use has increased ship use somewhat.

The USAP has been using the two ships at optimal or near optimal levels for 6 out of 10 years, and all but one of the most recent 6 years. This means the USAP is using its ships reasonably well.

Every austral summer the LMG and NBP were engaged simultaneously in science support at sea. There could be maximum impact (50 percent cut) on science during that critical time of year if the USAP reverted to a single ship and did not replace lost science support days with support from a non-USAP science ship.

The subcommittee made the following recommendations:

1. The RV Subcommittee strongly and unanimously supports a two-ship model to support USAP operations and research in the Southern Ocean;
2. Retain the LMG and NBP until their replacements are ready for service. Optimize their facilities (NBP) and operational framework while still in use by the USAP;
3. Enter into a new LMG charter agreement to open opportunities for science and logistics use by other nations. Specifically: Investigate entering into a long-term agreement with UK/BAS, for example using the LMG to carry out a small number of annual BAS station support visits and/or provide ship support for BAS Peninsula region science missions. Do not invest heavily in LMG upgrades or in extending its USAP service life;
4. If it is not feasible to design and construct a replacement for the NBP within the next 13 years, improve the ship's science support facilities and lengthen the expected service life (to 2032) via a Service Life Extension Program (SLEP). [Specific recommendations are listed and prioritized in the report.];
5. Future USAP ship operations should employ a two-ship model:
  - 1) one science station support and science ship to support the USAP's and other entities' Peninsula bases and marine science, and;

- 2) one larger, more capable ship to support wide-ranging polar science and logistics, plus being a competent global-class research ship in any ocean;  
 Planning for replacement ships should begin  $\approx$ 10 years (7 minimum) ahead and involve continual input and oversight from the US polar marine science community;  
 A study should be made of the overall total cost differential -design, construction, plus multiple years of operation -of supporting USAP and other US polar science with two identical polar research and support ships;
6. [Not provided in slide presentation.]
  7. If and only if it is determined by the support agencies that they cannot support the present two-ship mode of USAP marine support without serious impacts on polar science support, the Subcommittee recommends the following:
    - a. Retire the LMG (as a USAP ship) at the end of its present contract;
    - b. Revert to non-USAP ships to support Palmer Station and Peninsula region science;
    - c. Carry out principal logistics support for Palmer Station via a single ship, outfitted with sensors for the oceanographically-critical Drake Passage time series;
    - d. Marine science support for Palmer Station and nearby Antarctic Peninsula areas must be addressed. Provide local RV support. (A small ship may need to be hauled out during winter, which has implications for Palmer Station facilities.);
    - e. Form a new committee now to determine the needs and options for marine science support at and near Palmer Station and in the nearby Antarctic Peninsula region;
    - f. The Subcommittee unequivocally supports continued operation of a principal USAP polar science ship (presently the NBP) to support Ross Sea and southern-ocean-ranging US marine research, specifically without unduly restricting operations of that ship to the Antarctic Peninsula region at any time of year;
  8. The Subcommittee focused on two paths regarding a future polar research ship:
    1. There is enduring science community enthusiasm for a polar research ship with increased ice operation capability, endurance, berthing, storage, and science support facilities over those represented by the NBP. There would be a significant increase over the NBP in terms of construction and operation costs, especially resulting from providing the desired "PC3" ice operations capability;
    2. Only if #1 is not feasible, construct a new NBP-like ship meeting as many as feasible of the updated SMRs, but not with substantially increased ice capability, prioritizing new science capabilities of this ship to meet budget realities. Focus on capabilities that are the most general and will have the greatest impact on USAP science and logistics support. The ice class of the new ship should be similar to (or slightly greater than) that of the NBP, but sufficient to enable operations with an escort icebreaker. Any size increases over and above the NBP should be restricted to those required to meet regulatory requirements;

The new polar research vessel (RV) must be ready to enter service upon the NBP's retirement;  
 The new ship should be capable of docking at the new Palmer Station pier. The propulsion system should provide increased maneuverability. Hybrid diesel propulsion should be considered for quiet, low pollution operations. Open-ocean performance specifications should be as "kindly" as feasible;

- Some science mission requirements significantly impact ship construction and operating costs (e.g., icebreaking capacity, range and endurance, capacity for winter operations, the size of the human complement, and cargo capacity);  
Planning for replacement ships should begin  $\approx$ 10 years (7, minimum) ahead, and involve continual input and oversight from the US polar science community;  
The Leidos Vessel Studies report should be paid close attention in development of operational and design specifications for new USAP ships;
9. The USAP should evaluate alternative operational models for its ships, for example involving operation (or oversight of charter) by a principal ship-operating academic institution. Operating agreements should permit use of the ships for other science and support, including by other nations' Antarctic programs, when not in USAP use;
  10. A future LMG replacement should be designed to optimally support both USAP Antarctic Peninsula science and Palmer Station logistics. The LMG replacement should be outfitted for oceanographic research in a manner similar to the LMG.  
As an alternative to replacing the LMG with another Palmer Station-bound LMG-like ship, the USAP should investigate constructing and operating two identical NBP-sized ships;
  11. Consider operational models that permit occasional use of USAP ships for science and support missions by other nations' Antarctic programs (UK/BAS is specifically noted), when not in use by the USAP. Cooperative scheduling and barter or chartering could provide cost savings, increased flexibility and access to different capabilities in much the same way that the U.S. Academic Research Fleet or the cooperative arrangements in Europe and the Arctic do;  
The RV Subcommittee recommends that the USAP make expeditionary planning an explicit aspect of an appropriate portion of the available ship time:  
Create long-advance-notice opportunities for unique expeditions to regions of special interest, and/or winter and heavy ice operations (such as operations requiring an escort icebreaker), so that the science community could mobilize (workshops, proposals, etc.) in advance;  
(Escort icebreakers effectively and temporarily increase ice classification without the construction and long-term operation expenses of a higher ice class polar research ship.).

Dr. Swift turned next to the operational challenge of increasing winds and swell in the Southern Ocean, making operations there more difficult and making it an important factor in designing the Palmer replacement.

He also discussed incentives to increase ship size and the disadvantages that can accompany larger vessel size.

The subcommittee plans to pay close attention to advice from AC-OPP and NSF program managers advice regarding the draft report. He added that NSF and Congress have to decide whether to build a bigger Palmer or another Palmer.

*Discussion:*

Dr. Loose asked about the NSF sub-contract model continuing indefinitely. Mr. McGovern said there are no plans to change the model. The benefit of a contractor owning and operating the vessel is that the construction cost of the ship does not have to be provided up front. The downside is paying more if operating the ship for 30 years. Dr. Swift added that the contract could be overseen by a ship operator using a hybrid model. Mr. McGovern said there are many different ways to go about it and those discussions are ongoing.

Dr. Stammerjohn said there was compelling evidence and support for the two-ship operation, especially with the overlap in use during the summer season. She asked about partnerships with other international communities and sharing ship resources. Dr. Swift responded that the British have a shared interest and approach, and they are not able to support all their science and logistics operations. There is a shared interest in how both could optimally use two ships or how other resources might be introduced. NSF has a history of working with Great Britain. Although the financials are unknown, legally it probably could be done. Mr. McGovern said the challenge is having long-term agreements codified in a contract that can stand up to international court scrutiny. He mentioned a case where one party withdrew, leaving the U.S. in a bind. Whoever owns the ship controls the asset and the other nation is less in control. Part of the problem is everyone wants the asset in the summer.

Mr. Kosseff asked about the safety of the two vessels. Dr. Swift said the compliance issues are environmental. Mr. McGovern said the environmental and operational safety issues were related to the polar code, an international maritime organization initiative that many seagoing nations, including the U.S., are engaged in. The vessels are grandfathered in. As many of the safety requirements as possible are implemented. The Palmer was inspected in 2015 and was said to be very well taken care of and the hulls in very good shape.

Dr. Falkner said the polar code applies also to tourist vessels and partly accounts for why the number of vessels is going up; some are going to have to be retired to meet the code.

Dr. Loose asked about not presenting the single-ship scenario. Dr. Swift said if what was happening in the Division of Ocean Sciences (OCE) was that \$2 million of science money was being put in logistics to keep the ships going, that would be four research programs that would not be funded because of that decision to keep the two ships. To keep an optimal model for having ships in the water you can't support the science. It's a very hard choice. This is why the options need to be examined carefully. For example, one option is having a local research ship in the peninsula area with sensors on a supply vessel to make up enough of the difference and keep within the operational budget and save those hypothetical \$2 million a year. Coming up with a statement of how we can best support science in the peninsula area is a very important issue for the foundation for helping community morale and planning.

Dr. Falkner said Latin American colleagues have expressed options under development for more of a logistics service between the many stations in the peninsula and that is being watched carefully. There may be options in addition to the subcommittee's that will come into play at

some point but there are a lot of tensions with respect to the available resources and our ability to sustain the most competitive marine science.

Because the AC-OPP only recently received the lengthy report, more time will be needed to provide detailed comments. Dr. Swift said he was interested for now in the bigger picture, including what was left out and what could be discussed better. Dr. Weingartner said the critical things for AC-OPP to look at are the executive summary, the recommendations, and the science mission requirements. Dr. Swift said he was most interested in feedback on Section E. Dr. Weingartner asked for AC-OPP comments to be submitted within one month.

In response to a question from Dr. Stammerjohn, Dr. Falkner said the full committee approves the report and once approved it is posted as a final product. OPP would then work on preparing a response to present to AC-OPP. That, she added, may not at all be the end of the discussion with the community. Dr. Swift said he would like to release Section D as soon as feasible. Dr. Weingartner said he had no objection. Dr. Swift said UNOLS is working on the science mission requirements for the eventual replacement of three ships and they would benefit from reading his subcommittee's work. He said he would also like to get Section D to the Coast Guard, which is in the process of constructing a new icebreaker. Dr. Falkner said NSF has advised the Coast Guard on that vessel with respect to its science requirements, so it would be somewhat problematic to deliver Section D as our advisory committee to the Coast Guard. She reiterated that the subcommittee is advisory and the committee endorses or does not endorse as a committee. Referring back to the Arctic Portfolio Review report, she said there are other NSF entities that fund Arctic research and it isn't the remit of the committee to comb across all of NSF to do that. Dr. Swift said he understood and it could be worked out offline.

In response to a question from Dr. Loose about the Arctic Research Icebreaker Consortium (ARICE), Dr. Swift said there is brief mention in the report but did not have information on how it was functioning from the U.S. side. Dr. Weingartner said ARICE just took their first proposals this year but the report recommended it be looked at as an option.

Dr. Weingartner asked for confirmation that Section D can be provided to the UNOLS committee. Dr. Falkner said it can be posted to the site and people can be made aware it is there.

Dr. Swift said he would wait for written communication from Dr. Falkner or Dr. Weingartner regarding section D.

Dr. Falkner reiterated that the AC-OPP is being asked to provide comments on Section E by June 1.

Dr. Swift said it is actually not Section D, but the appendix that summarizes Section D, that he would like to post, which has only recommendations and does not contain sensitive material. Dr. Weingartner said another question is about whether Section E can be shared outside the AC-OPP. Dr. Swift said Section E is not ready to go. Dr. Falkner reiterated a question from the committee about whether members can consult their communities about the report and said the answer is yes, understanding that the report is still a draft. Dr. Nettles said some of the documents that come before AC-OPP have been made public for comment from the

communities and that that hasn't happened with what's done by the subcommittees. Dr. Falkner said this subcommittee consulted the community through a survey. Dr. Nettles asked if it was okay to share the draft with those who can provide useful input, or can it be shared more widely. Dr. Falkner said there are different ways to assure broader community input. It is okay for committee members to get an understanding from the broader community they represent in responding to the report.

Mr. McGovern said he pushed the subcommittee to provide the hard recommendations and the report provides the most value in assisting in making the tough decisions.

Dr. Falkner said she wanted to apologize to the community for how long and how intensively this topic has been under consideration in a large number of reports. Right now, the effort is to resolve the Southern Ocean component and there are a number of studies the subcommittee worked from and there were many kinds of community inputs included.

#### Advisory Overview Document

Dr. Weingartner; Dr. Falkner

Dr. Weingartner said work on the document was begun in June 2018 and a draft sent to the AC in September 2018, which was revised per AC comments and accepted by the AC in November 2018. Community comments were received through mid-February 2019 and the document revised and redistributed in mid-April. The question before the AC today is whether to approve the document.

The main issues in the revised draft:

- Purpose – not apparent who the audience is (this is now the first and separate section);
- Most suggestions on research drivers: paleo-, biogeochemistry, biological productivity.

Modifications were made to make the audience more apparent. Dr. Weingartner said many of the suggestions on research drivers focused on the trees rather than the forest but he made changes to make the drivers more comprehensive.

Dr. Weingartner said the main addition to the Purpose section was to ensure the importance of core, investigator-driven science.

Only minor modifications were made to introductory material.

For research drivers, text was added on the value of paleo-records and concern for West Antarctic (WA) and Greenland Ice Sheets; some topics were expanded to include biogeochemical cycles, productivity and ecosystem structure, and the influence of Antarctic on mid-latitude weather (e.g., monsoons and a citation).

For Infrastructure and logistics, the issue was to make sure there was sufficient and clean power for all the labs.

For Data and Cyberinfrastructure, the point was added that polar regions face severe bandwidth limitations, which inhibit the ability to adjust data-gathering protocols in near real time.

For Education and Diversity, the Antarctic Biology Training Program was modified to omit explicit mention of the academic institutions running the program. He suggested a further addition on training for people in the Arctic working with communities on engagement.

There were no comments received for the Synergistic Partnerships & Collaborations section or the Conclusion.

Dr. Weingartner said that once the AC's comments are received on the latest draft, another revision will be distributed and, if approved, will be final.

### *Discussion*

Dr. Crowell complemented the work done to incorporate the comments. He suggested adding another sentence into research driver No. 6, starting after line 226, to read: "Paleo research utilizing biological, biogeochemical, or isotopic proxies, both marine and terrestrial, can model these effects during earlier climate cycles."

Dr. Weingartner said that sentence can be included. But he added there are other techniques in addition to paleo and he does not want to favor one technique over others. It is not our job to say what tools investigators should be using.

Dr. Steig said the document is good and should be approved as is. Dr. Nettles said the sections on science drivers reads nicely, but said it is not clear who it is written for. She suggested having the one-paragraph summary in the Purpose and Introduction. She also questioned the title, *An Advisory Overview for the Office of Polar Programs*. She said Polar Programs was not the main audience. Dr. Falkner said the immediate audience was the GEO Advisory Committee (AC/GEO) and recommended delivering it by that group's fall meeting. She said it will be very useful for them. It will also be useful to the State Department and other agencies. Dr. Weingartner said different readers will go to different sections of the report for the information of interest to them. Dr. Falkner said report is useful for signaling to the other ACs that OPP interfaces with what the current OPP drivers are. Dr. Heimbach, a member of the Advisory Committee for Cyberinfrastructure (ACCI), said the document would help inform that group and the Office of Advanced Cyberinfrastructure (OAC) and help them see where they can make connections. Dr. Lynch said if the document is for a broader community, the photographs should depict OPP-funded research. Dr. Falkner agreed and said the current photos are placeholders. Dr. Stammerjohn suggested an alternative title: *The Office of Polar Programs: An Advisory Overview*. Dr. Lynch suggested taking the name from the purpose, which is a synthesis of priorities in polar research. Dr. Flanner suggested: *An Advisory Overview of the Office of Polar Programs*. Another suggestion was: *An Overview of the Possible Programs by the Advisory Committee*.

A question was also raised about updating the reference to science drivers in the table of contents. It was noted that the updates to the document helped with its geographic balance but

that it might still be an issue. Dr. Weingartner said he did not set out with the goal of complete balance. He tried to describe the critical issues and did not want to seemingly impose science issues unless they arose from prior reports, but added he'd missed an Antarctic report with critical concerns. Dr. Nettles said almost all the science drivers include both polar regions. Dr. Weingartner said the role of the Arctic on mid-latitude weather was included in an Academy document and it is frequently in the press. Dr. Nettles said known issues not in the press need more press coverage, which inclusion in the document will accomplish. She mentioned the hydrologic cycle in the Arctic and the carbon cycle and said global climate is affected by changes in both polar regions. Dr. Weingartner said that relates to permafrost; elsewhere in the document with respect to glaciers and sea ice and ice sheets, bio-geochemical cycles are targeted and overturned circulation cells, tied to the hydrologic cycle. Dr. Falkner suggested adding language to the upfront sentence on research drivers to note that though these questions have appeared with respect to studies of one pole or the other, they largely apply to both poles.

Dr. Heimbach said the images will be powerful additions to emphasize the report is about research at the poles, as opposed to polar research.

Dr. Falkner said the committee can return to revising the title tomorrow. She also asked if the report could be completed in time to provide it to AC/GEO in time for its fall meeting and Dr. Weingartner concurred.

#### Imaging a Black Hole!

Dr. Marrone

Dr. Vieregg introduced Dr. Marrone, who said the help of Polar Programs was essential and future observations will use the station in Greenland for additional observations. He showed the first direct image of a black hole, which previously only existed as artist conceptions, in movies, and so on. Previously there were emissions from the region around black holes that have been launched into space, but no one had been able to take an image that has detail on the scale of the event horizon, the point of no return, from which the universe is cut off, where gravity is so strong even light cannot escape. That was the goal of this project, which announced its initial results three weeks ago.

The project was a long-term collaboration of a couple hundred people. Dr. Marrone said he started working on the project in 2005. In many cases the key work is done by very junior people. The Event Horizon Team is also composed of many institutions.

The fundamental goal was to create a telescope capable of the angular resolution necessary to see detail in black holes. Two factors determine how large black holes are in the sky: the distance of the object and the mass of the object, which is calculated using the Schwarzschild radius. There are only two objects where the resolution that can be achieved with the event horizon telescope is one or two Schwarzschild radii. The expected apparent size of a black hole is about five Schwarzschild radii in diameter. So, if a resolution of one to two Schwarzschild radii can be achieved, the event horizon can be resolved, and it is possible to see the black hole's structure.

Imaging a black hole enables testing General Relativity in a regime where it has not been tested before, at the very strongest limit of gravity just outside black holes that are the size of our solar system. Important astrophysical problems can also be solved, including the structure of accretion and jet launching.

The problem with imaging a black hole is that they are very small on the sky. The apparent size of the biggest two in the universe in angular size is equivalent to a bagel on the surface of the moon, requiring resolution a couple thousand times better than the Hubble Space Telescope can achieve. The area of sky is one-hundred-millionth of a degree.

To image a black hole, it has to be possible to see down the event horizon. For the average black hole, it is not possible to see down clearly. All the gas accreting onto it glows and it is like looking through the surface of the sun to see down to the event horizon. You can't see through the gas. It just so happens, for the two black holes that are the largest on the sky, rather than seeing glowing gas from the jets or swirling gas, at 1 millimeter wavelength we can see the shadow of the black hole directly, with the light disappearing into it and gas swirling around it.

The Event Horizon Team created a radio telescope the size of the Earth's diameter using a technique called Very Long Baseline Interferometry (VLBI). Telescopes spread around the world are simultaneously pointed at the same object. The light arriving at each telescope is precisely digitized, requiring \$250,000 atomic clocks at each site. The data are stored on more than half a ton of harddrives, which are shipped to a central application-specific supercomputer.

Dr. Marrone described the interferometry used to make the image, explaining that the more telescope pairs there are, the more information is gathered for the image. As the Earth rotates, more telescopes come into view and there are more baselines, with more components of the image. Each telescope pair measures the complex Fourier component of the image. The South Pole telescope greatly extends the array north-south, which increases resolution in the north-south direction.

The project was aided by the growth of technology during its course. The detector, or mixer, at each site has become much more sensitive since 2007. Atomic clocks also became commercially available during this period, as did 10 TB hermetically sealed drives. Digital signal processing technology also improved from 4Gbit/sec to 64Gbit/sec. Each site now has a petabyte of storage capacity.

Many of the sites are standard radio observatories that do proposal-based radio astronomy. The South Pole Telescope (SPT) is a different kind of facility. But with an NSF grant and OPP support, 7,000 pounds of equipment were brought to the SPT to get the experiment working for its first successful test in 2015.

By 2017 all the sites were ready. For an observation, a couple weeks are set aside at nearly all of the world's submillimeter telescopes. Each site has an Event Horizon Team, except for the South Pole. Instead, the winter-overs were trained. Also key was continuous text-based communication with the South Pole. Dr. Marrone said he and a colleague each sent 10,000 messages in a week.

He also noted that the South Pole has perfect weather for submillimeter observations, unlike other sites.

In one week, 5 petabytes of data were collected. The petabyte of data collected at the South Pole had to sit in crates for months until the first flights out. Dr. Marrone explained how all the data is used to recreate the telescope, correcting for small timing errors between sites, accounting for the ice sheet motion and differences in frequency, dramatically reducing data volume, correcting the response of the instruments and the atmosphere and reducing residual imperfections from the data and further dramatically reducing data volume, until finally completing the imaging process.

The image of M87 was almost exactly what the team expected, but that says a lot. The central depression is the shadow of the black hole. There is also a north-south asymmetry. And surrounding the black hole shadow is a narrow ring of emission from surrounding plasma that is about to disappear into the black hole, though it could be flowing outward.

In the 1970s papers were published on what would happen if you could shine light behind a black hole. The black hole bends the path of that light and concentrates it along lines that graze the event horizon and a ring of emission might be expected. Dr. Marrone also explained the shadow in terms of light going towards the black hole from us along parallel lines. Even light from the side will fall into the black hole and light from above and below the black hole get bent by gravity and disappear into the event horizon, creating the shadow effect. When we look towards the black hole, we're seeing light not just from above and below it, but from points behind it and all around it. We're seeing the front, back, top, and the bottom all at once because of the bending of light.

Dr. Marrone showed a general-relativistic magnetohydrodynamical (GRMHD) simulation, which is what the Event Horizon Team imagined it might see with infinite resolution, which has a ring of light which is the photon ring and the central black hole shadow. But observing it with the telescope in a simulated sense, you get an image that looks much like the Event Horizon Team's final image. He described the final image as a discovery and a confirmation, as well as a relief.

He also described how the north-south asymmetry teaches about how the black hole spins. The fact that the southern half looks brighter than the northern half tells us the black hole is spinning like a top with its angular momentum vectors so the disk of material orbiting it and the spin of it is going clockwise as seen from us, which causes the bottom half, which is moving slightly towards us, to have a doppler shift which makes it brighter and the northern half, which is moving slightly away from us nearly at the speed of light, to look dimmer, which was new information.

The Event Horizon Team was also able to test General Relativity in a limited sense. The team thinks it knows the black hole's mass. General Relativity tells us how big its shadow should appear. There are two answers for the black hole's mass, one from looking at gas going around the center of M87 and one that comes from looking at the motion of stars near the center. The team's measurement of the size lines up well and tells that General Relativity is doing a good job of predicting the size of the shadow. The predicted shadow size is very close to what was observed. Sagittarius A\* is the black hole at the center of the Milky Way, which is 1,000 times

closer and 1,000 times less massive, which means it is the same angular size on the sky. Stars have been directly observed going around it for 20 years and it is known to high precision the mass of Sagittarius A\* and with an unambiguous mass, the Event Horizon Team will be able to much more precisely test General Relativity when the data are released.

To improve the array the Event Horizon Team can go to higher frequency shorter wavelength, which was demonstrated in January at the SPT, which will make the image considerably sharper.

New sites are also being added, including the Greenland Telescope (GLT). The next observation will be in April 2020 and in less than two years after that there will be even better pictures of both black holes.

### *Discussion*

In response to a question from Dr. Heimbach about the data requirement for the new wavelength, Dr. Marrone said adding the new frequency does not increase the data, though they may record more. He calculated transmitting the data with SPT's bandwidth cap would take 13 years.

Dr. Loose asked how unprecedented the weather window was and about the frequency of future black hole images. Dr. Marrone said with the telescopes in Spain, Hawaii, Arizona, New Mexico, Chile, the South Pole, Greenland and France, you have to be very lucky to have good weather at all those sites. But observations were made in less than perfect weather. In 2018, there were no dates as good as in 2017, but good data were collected. Water is the enemy and in Antarctica there is no water in the atmosphere, so the SPT can always be counted on.

Dr. Weingartner asked about the number of observation days. Dr. Marrone said the Event Horizon Team relies on the telescopes to lend their facilities and comes to \$1 million of observing time per night. From four nights it is possible to create four images, though with more observations it may be possible to see things orbiting the drain, which would take about a week. For Sagittarius A\* that time scale is 30 minutes, but the changing source structure makes the data analysis difficult.

Dr. Steig asked if the observations have to be taken at a certain time of the year. Dr. Marrone said both weather and direction are factors. March and April provide the best weather for all the sites. December might be better, but the sun passes almost right over Sagittarius A\* at that time.

Dr. Nettles asked about the time window for reconstructing the data. Dr. Marrone said each of the four days of M87 observations were reconstructed separately.

Dr. Flanner asked if multiple teams did their own independent reconstructions of the image and whether they differed. Dr. Marrone said the same data were given to four independent teams because interferometry does not actually take pictures and there is no unique answer for how to make an image and there are many approaches. In the summer of 2018, the images were revealed to all the teams and they looked basically the same. The differences come from choices about what to emphasize in making the image, but fundamentally they are the same. All the images have been published.

Dr. Falkner asked about putting the Greenland telescope at Summit Station. Dr. Marrone said that site is much better, though the Thule Air Base in March and April has worked out okay. Currently, GLT is just used for this experiment and it could be doing more astrophysics and higher frequencies can be used there (690 GHz). That could only be done at Chile, the South Pole, and Summit Station, so there are advantages to that site.

Dr. Weingartner asked about plasma ejected from the black hole. Dr. Marrone said as gas is falling towards the black hole, all its electrons get stripped out, so there is a sea of electrons and atomic nuclei falling in. Charged particles take the small amount of ambient magnetic field from the galaxy and as they fall closer that magnetic field gets packed closer and closer and gets much stronger. By the time you get to the black hole, there is highly magnetized plasma. If that material falls into the event horizon, it drags those magnetic field lines with it, disappearing into the black hole, which is spinning and winds them up, creating a magnetic funnel. So, there are very strong forces pulling the magnetized material, some of which will miss the black hole and be shot out along the field lines. It isn't fully understood how this works, which is why seeing the magnetic structure directly through the polarized emission will help scientists determine how those jets start at the bottom.

#### Astrophysics at South Pole: Neutrino & Cosmic Microwave Background (CMB) Research

Dr. Vieregg

Dr. Vieregg discussed the intersection between astronomy and physics. In the astronomy community there is a decadal survey to get input from the community on the interesting science that should be done in the next 10 years. The decadal survey committee uses the input from NSF, the Department of Energy (DOE) and The National Aeronautics and Space Administration (NASA) and prioritizes the instruments that might be built. That process is ongoing, with white papers currently being written on what instruments should be built.

Dr. Falkner said there will be a discussion tomorrow on NSF's Windows on the Universe, which is one of the Big Ideas. NSF uses the term multi-messenger astrophysics.

Dr. Vieregg said one place where astronomy and physics overlaps is related to Windows on the Universe and is why that Big Idea exists. It is a forefront of research, where astronomical observations can be used to learn about physics. One way is to combine measurements from different telescopes, whether looking at light, gravitational waves or neutrinos. All of that science will be incorporated into the decadal survey. Dr. Vieregg agreed with Dr. Falkner that this represents an evolution in the field. Dr. Falkner noted that the NSF's director, Dr. France Córdova, is an astronomer and the Event Horizon Team's project took more than a decade and OPP has had programs that have been decades in the making and took big risks, leading to major transformations. She also remarked on linking facilities in near real time all over the planet. The first source of cosmic ray discovery that came out of IceCube was the result of that kind of linking of telescopes in space and on the planet; the scale of coordination was inspiring. More and more of what OPP is sponsoring has demonstrated an important connection to the rest of the planet. The South Pole telescope was built in a way to be adaptable for different experiments, permitting its use in the black hole observations.

Dr. Papitashvili said the proposal that was the first jacket he signed at NSF was for \$17.8 million and he felt responsible for bringing it to life. There was also \$5 million to \$6 million in logistical support. He said telescopes were inexpensive compared to satellites. Dr. Borg said that at the time there were issues of the telescope being big enough for OPP to make a request under what was then MREFC. There were efforts to keep it out of that because of the protracted process. It was identified as a high priority for polar, building on the fact that a similar telescope had been recommended in a decadal survey at the end of the 1990s. It emerged as a high priority and we wanted to control our fate and it turned out to be a good investment, he said. The Center for Astrophysical Research in Antarctica (CARA) Science and Technology Centers Program (STC) was winding down and this was before NSF changed the STC rules to control those funds centrally rather than use them to grow the program. The skills to determine logistical costs were not as good as they are now. He had estimated between \$26 million and \$28 million. Within a year or two, an addition was considered to make it a 10-meter telescope, though it was originally funded as an 8-meter telescope. Dr. Borg said he was surprised it wasn't 10 meters from the start because of the articulation of what could be done with the large size. That seemed like a good investment. The efforts that were related to that were an impetus that helped OPP to not have to maintain a large cryogenic facility at South Pole, which would now be costing a lot of money to keep liquid helium around for the winter. He questioned the scale of benefit without SPT's interest in solving the problem. He said the telescope was ambitious and one of the high-risk things NSF should be doing.

Dr. Vieregg resumed her presentation on the largest scale projects at the South Pole. The South Pole is the best site in the world for measuring two probes of astrophysics, cosmology and particle physics:

1. Measuring the oldest light in the universe (the Cosmic Microwave Background) to learn about the early universe, the evolution and content of the universe, and fundamental physics;
2. Measuring high energy astrophysical neutrinos to learn about the astrophysics of the highest energy sources and probe fundamental physics using multi-messenger astronomy.

Beginning with CMB, she described the exponential expansion, or inflation, that is believed to have occurred in a tiny fraction of a second after the Big Bang when space itself expanded faster than the speed of light. The hot dense plasma that existed after the Big Bang expanded and cooled and the light from the plasma is believed to be oldest in the universe and is called the CMB. This was followed by stars and galaxy clusters. Since light travels at a finite speed, the farther away you look, the farther back in time you are looking.

The cosmic microwave background is homogenous, isotropic and spatially flat. If you turn up the contrast you can observe features where it is hotter and cooler. From measurements of the CMB and other things, a model was created called  $\Lambda$ CDM, which is the standard cosmological model. The lambda stands for dark energy, which is driving the expansion of the universe. CDM stands for dark matter, which pulls things together. The model has six parameters, which can be used to describe the structure and evolution of the universe. CMB can be used to probe the fraction of dark matter and dark energy and answer other questions.

Dr. Vieregg showed a snapshot of the universe at 380,000 years that carries the imprint of inflationary parameters, light relics and more. One of the main motivations for the telescopes at the South Pole is testing the theory of inflation in the early universe. She said inflation generates two types of waves, gravitational waves and density waves. The goal is to measure inflation. The CMB is as far back as you can look. To measure inflation, regular light cannot be used. Instead, gravitational waves can be observed. Those gravitational waves slightly affect what the CMB looks like. This can be done with a very precise measurement of CMB. Some small fraction of the CMB photons were deflected in the distance to Earth. Measuring the polarization of the CMB allows measuring the effect that its propagation through the large-scale structure of the universe had on it. This effect was first detected by the SPT in 2013.

From measuring this gravitational lensing from the CMB it is possible to make measurements of how the structure in the universe formed. CMB is a backlight behind all structure in the universe. It is also possible to measure the sum of light species (neutrino) mass and understand early properties of dark energy.

There are a number of CMB telescopes at the South Pole, including the Keck Array, which is soon to become the Background Imaging of Cosmic Extragalactic Polarization (BICEP) Array, BICEP3 and the SPT. For the past 15 years the South Pole has been the premier site on the ground for cosmic microwave background observations because of its dry, stable atmosphere at high altitude. Also, the same patch of sky is always visible.

The SPT operates at three frequencies and has been observing for 12 seasons. The cameras were updated from 960 detectors to 1600 in 2012 and 16,000 in 2017. The limits of quantum mechanics prevent the quality of detectors from improving. To increase sensitivity, more detectors have to be added.

Dr. Vieregg showed maps made by a satellite (Planck) and SPT. The angular resolution of SPT is much better and show galaxy clusters and it was the first telescope to discover such clusters. The SPT has been an amazing source of science from astrophysics to cosmology and included the first observation of the polarization of the CMB in 2013.

The telescope has a new camera called SPT-3G. SPT works in concert with BICEP to do joint analysis for better measurements. BICEP has a refracting telescope, with a small aperture, built to target the signal from inflation in the very early universe. BICEP2 ran from 2010 to 2012 and the Keck Array from 2012 to 2017, which was the equivalent of five BICEP2's. BICEP 3 packed in more detectors and BICEP Array (2018) is the equivalent of four BICEP3's. Dr. Vieregg also showed sketches of BICEP Arrays under construction.

Dr. Vieregg discussed a plot showing the status of CMB polarization measurements which she said shows that the error bars are the smallest for the South Pole because of the quality of the site.

Turning to the next-generation CMB experiment called CMB-S4 (stage four):

- A next generation ground-based program to pursue inflation, neutrino properties, dark radiation, dark energy and new discoveries;
- Greater than tenfold increase in sensitivity of the combined Stage 3 experiments (>100x current Stage 2) to cross critical science thresholds;
- O(500,000) detectors spanning 30-300 GHz using multiple telescopes, large and small, at South Pole and Chile to map most of the sky, as well as deep targeted fields;
- Broad participation of the CMB community, including the existing CMB experiments, National Labs and the High Energy Physics community.

Although using astronomical observations, the science is about fundamental physics. A decadal type survey for physics that occurred five years ago (The Particle Physics Project Prioritization Panel or P5) recommended CMB-S4 in all funding scenarios. CMB-S4 will include Chile, which has wider sky coverage. Dr. Vieregg said she was excited about the neutrino mass measurements because CMB-S4 will be able to make a precise enough measurement to determine the neutrino mass hierarchy.

CMB-S4 will have two different kinds of surveys, with two different kinds of telescopes at two different sites. She also discussed building infrastructure at the South Pole to support up to 18 BICEP Array type telescope and one six-meter telescope.

Next, she turned to a discussion of searches for ultra-high energy neutrinos, which are fundamental particles made as a byproduct of nuclear reactions that zoom through most of the universe without being detected. Only neutrinos can reach the earth from distant sources so to see far away energetic sources, detecting neutrinos is necessary. Also, neutrinos can provide new views of astrophysical sources.

IceCube was built to observe neutrinos and has 86 strings of detectors under the surface. IceCube saw the first astrophysical neutrinos in 2013. IceCube is at the South Pole because it needs an enormous volume of clear, stable dense material to use as a detector and ice is the best. In Greenland the ice is too dusty for this optical detection technique. IceCube is also starting to do multi-messenger astronomy in real time with the goal of observing interesting events with multiple telescopes of different kinds simultaneously. In September 2017, IceCube sent out an alert of neutrino energy and a number of gamma ray telescopes turned to that place on the sky and observed a flaring blazar, which is a black hole at the center of the galaxy that is spinning that makes jets of particles in our direction.

Dr. Vieregg also discussed the Radio Neutrino Observatory (RNO) to measure the highest energy neutrinos. This is a complementary technique of looking for radio signals from neutrino interactions. It extends the reach of neutrino telescopes to the highest energies (above where IceCube reaches). There are currently five stations at the South Pole, with a proposal for 61 stations of radio antennas at a depth of 60-100m, spaced 1.25 km apart.

IceCube has been funded for an upgrade that includes seven additional densely packed strings in its center with deployment starting in 2021. The science goals are to study the properties of neutrinos and the technology goal is precision calibration of instrumentation response for a major upgrade called IceCube-Gen2, which will be the next generation IceCube. Dr. Vieregg said this

will take IceCube from discovery to astronomy. By building a detector that is a factor of 10 larger, it will be possible to correlate events with sources to learn about the astrophysics that is driving those sources. IceCube-Gen2 will be a multi-component facility to reach the broadest range of neutrino energies with a design that incorporates optical and radio detectors. It will include a radio array and a surface array. The production and deployment schedule call for the IceCube upgrade to start deployment in 2021 and the RNO would start in 2022 and IceCube-Gen2 is expected in 2025.

During the next 10 years, two MREFC-scale instruments are planned for the South Pole (CMB-S4 and IceCube-Gen2). The logistics requirements to support these are manageable but may require expansion of some capabilities. The power required for CMB-S4 will be larger than previous CMB experiments, the data transfer (over satellite) required for IceCube-Gen2 and CMB-S4 will be larger than before. There will also be much cargo to move over the next 10 years, along with summer population support during deployment years.

In conclusion, Dr. Vieregg said the South Pole is the best site in the world for the two different probes of astrophysics, cosmology and particle physics, and has advanced the understanding of the universe. The next 10 years will bring two major projects to the South Pole, but the investments are still in the design and research and development phase. But both CMB-S4 and IceCube-Gen2 will enter into the astronomy decadal survey. She said that in her view the instruments are worth the investment.

### *Discussion*

Dr. Steig asked about the capacity for logistics support. Dr. Falkner noted there is an aging heavy cargo-lift fleet, which is another subject that can be discussed at a future meeting. This is a subject that is being worked on, she said. At the South Pole she saw the Traverse fleet come in with a prototype sled that worked well, and she expressed optimism for an increased capacity. She raised the issue of power requirements that will require an expansion at a time when the program is pressed to overhaul McMurdo Station.

Dr. Quinn asked what fraction of the research OPP supports versus other programs. The joint session with MPS tomorrow will discuss that, Dr. Falkner said.

Mr. Arnaudo asked how much funding will be needed. Dr. Falkner said about \$30 million for the 10-meter telescope with the logistics and Dr. Borg said \$243 from NSF for IceCube with a substantial additional contribution from foreign colleagues. He emphasized the power issue, noting the supply will have to be doubled. He said he was delighted to see there are challenges for the younger generation. Dr. Falkner said IceCube is an OPP budget line item, with \$3.5 million in operational costs matched with MPS; also, people are funded through both programs to do science.

Dr. Loose asked about seeing back to the expansion of the universe. Dr. Vieregg said you can only see as far back as the light will allow. The light from further back is scattered and is like a brick wall. The science is testing a model of the Hot Big Bang, which predicts a microwave bath at 2.7 Kelvin. Looking at that light, that is confirmed.

Dr. Lynch asked at what point will it be possible to say dark matter is not just a glitch in the theory. Dr. Vieregg said that from what has been measured of the CMB those are good enough to make measurements of the power spectrum, which is how blobby the CMB is. That depends on the fraction of the universe made of dark matter. There are also other measurements of dark matter, including rotation curves of galaxies, that are consistent with the idea that there is much more matter in galaxies than can be seen.

In response to a question from Dr. Weingartner about other countries involved in IceCube, Dr. Papitashvili said 12 countries and 15 institutions. Dr. Weingartner also asked about Tibet or a location in the Himalayas for telescopes. Dr. Vieregg said there have been site surveys for CMB telescopes and sites in Tibet are good, but not as good as Chile or the South Pole, which takes the cake. Summit Station in Greenland has also been evaluated. About four winter months at that site are comparable to the decent months at South Pole.

Dr. Heimbach asked about observations from space. Dr. Vieregg responded that the science return for CMB would not be worth the investment, which would be astronomical. What you can do from the ground you should, she said. Dr. Falkner also raised the improvements in detector technology that advantage ground-based observation. Dr. Vieregg agreed, pointing to the ability to upgrade ground-based detectors.

Dr. Falkner closed the day's meeting by looking forward to tomorrow's discussions with MPS, which will include how NSF works cross-unit relationships and asked members to listen with the thought of whether there are ways to improve that process to serve the community.

## **Thursday, May 2**

### Advisory Overview Document

Dr. Weingartner; Dr. Falkner

Dr. Weingartner said AC-OPP members would have an opportunity to comment on the ship subcommittee report. He asked for comments by the third week of May.

For the Arctic Portfolio Review, AC-OPP can accept it as is, ask for it to be rewritten, or provide comments to her committee over the next month. Dr. Stammerjohn asked for the opportunity to send in suggestions. Dr. Weingartner provided these options: the report can be accepted as it is and members submit comments, or comments submitted, and a vote made by email whether to accept or reject the report. Upon input from a committee member, Dr. Weingartner said a decision would be made now to accept and comments provided during the next month to Dr. Lynch. Comments should not suggest major restructuring of the report.

Turning to the advisory report, Dr. Weingartner said a sentence would be added to the education section encouraging the development of assistance in outreach to the communities. The committee then considered a list of proposed report titles without coming to a conclusion.

## Joint Session with MPS

AC-OPP members joined the AC-MPS meeting underway in a nearby room.

## Preparations for Meeting with NSF Chief Operating Officer

Dr. Weingartner; Dr. Falkner

AC-OPP developed a list of questions to pose to the NSF Chief Operating Officer, Dr. Crim, during his appearance before the committee. The committee also heard from Dr. Easterling.

Dr. Easterling said when he arrived at NSF in June 2017, he started a conversation with his division directors, including Dr. Falkner, about the next generation research questions, building off the report, *Dynamic Earth: GEO Imperatives & Frontiers, 2015-2020*. He found common themes expressed around coastal, geological, atmospheric, oceanic processes, trans-ocean land subduction zone dynamics and understanding major earthquakes and tsunamis with a hope to better predict what happens to severe coastal storms as they transition from a maritime to a terrestrial environment, especially when making contact with urban surfaces. There is also the issue of sea level rise and what is driving the geographic differences in rates and extent and the impact. He noted that coasts are where the largest population growth is and will be perhaps for centuries to come.

These discussions became the basis of a new NSF thrust that has been widely cross directorate but generally under GEO. It is called the Coastlines and People Initiative (CoPe). CoPe has been developed by a working group led by Dr. Amanda Adams in the Atmospheric and Geospace Sciences (AGS) division. There have been four workshops that found community support for the initiative. CoPe will take the form of a series of hubs that will be interdisciplinary teams of scientists focusing on a set of scientific challenges around understanding the geological processes as hazards and the variability that will pose challenges to coastal communities and resource systems.

A Dear Colleague Letter (DCL) was released two weeks ago calling for research coordination networks and a limited number of Early Concept Grants for Exploratory Research (EAGERS), and conferences and workshops to further refine the research questions, including in a full-blown solicitation. There will also be internships to encourage cross-agency participation. NOAA leadership is very interested in participating, including the director of the National Weather Service (NWS) and the NOAA chief scientist. DOE has asked to be considered as a potential partner and the United States Geological Survey (USGS) is also interested. CoPe builds on understanding coastal dynamics from Coastal Science, Engineering, and Education for Sustainability (SEES) and the more recent program, Prediction of and Resilience against Extreme Events (PREEVENTS). Sometime in the next two to three years there is expected to be a set of hubs around the U.S. that will focus on a wide range of geophysical variability hazards and their interactions with urban systems. The Directorate for Engineering (ENG) is a major participant in CoPe.

In response to a question from Dr. Heimbach, Dr. Easterling said NOAA's reaction was that they were excited, and that the NSF initiative was overdue. The Gulf Coast Research Program at the National Academies has also expressed interest in partnering.

In response to a question from Dr. Mack about the U.S. focus and the Arctic coastline, Dr. Easterling said the Arctic is a very interesting place to do the kind of science expected to come out of CoPe. If a proposal was received that proposed compelling science in the Arctic, it would be considered for CoPe funding. The Arctic is seen, in part, as belonging to the U.S., but belonging to no one and it needs to be understood better through CoPe. Dr. Falkner said a solicitation would also be relevant to NNA. She said the foundation does not want to stovepipe and where there is overlap it will work to find the right home for proposals that cover these topical areas.

#### Wrap-Up Discussion and Looking Forward to Fall Tasking

Dr. Weingartner; Dr. Falkner

Dr. Weingartner briefly ran down the questions developed for the committee's meeting with Dr. Crim and Dr. Falkner offered suggestions for additional topics.

Dr. Falkner next provided background information on the development of the advisory overview document. Member of Congress are interested in helping NSF promote its science and being sure the foundation is governing itself through well-justified processes, such as decadal surveys. Such documents help them push back against colleagues who might be less supportive and avert micromanagement of NSF's science work.

Dr. Falkner said she was very pleased with the advisory overview document, with the AC having reduced hundreds or thousands of pages of reports to about 15 pages. She said it would be very useful.

Dr. Easterling, continuing his discussion from earlier in the day, referenced the report, *Dynamic Earth*, which recommended a number of must-do research priorities. He had challenged AC/GEO to write a follow-on summary of the next big questions for the coming 5 to 10 years. AC/GEO has been working on this addendum and it should be available in draft form this summer, with the final report scheduled for the start of the new fiscal year. AC-OPP's efforts to produce a similar document are welcome and will make a nice complement to the AC/GEO document.

Dr. Easterling also suggested AC-OPP might ask Dr. Crim how the committee can help the foundation achieve its goals.

Next, Ms. Walker initiated a resumed discussion of titles for the advisory overview document, which added another choice to the running list: *Science From the Poles: An Overview of Advisory Studies for the Office of Polar Programs*.

With the committee still unable to agree on a title, Dr. Weingartner asked members to submit their top three choices by email.

## Meeting with NSF Chief Operating Officer

Dr. Crim

Dr. Falkner and Dr. Weingartner welcomed Dr. Crim and AC-OPP members introduced themselves.

Dr. Crim briefly reviewed his background and said Dr. Córdova is in Brazil, where she is chairing the Global Research Council, which includes the heads of science agencies from around the world.

Dr. Crim discussed the black hole image, which he called a grand achievement that reflects continued support of an idea until it comes to fruition. It is good for the whole agency when something this high profile happens. He also discussed the origins of the press conference announcing the black hole image. The head of NSF's Office of Legislative and Public Affairs was instrumental in advocating for publicizing the announcement and coordinating the announcement.

Turning to the budget, Dr. Crim said the fiscal year 2019 budget is as close to being enacted as possible. Dr. Córdova has testified in Congress on the president's reduced 2020 budget to one group of appropriators and will soon appear again. The 2020 budget reflects some priorities that do a lot that is important to the foundation. He said conversations are ongoing with Congress and it will be a tumultuous year.

Turning to the Office of Science and Technology Policy (OSTP), he said Dr. Kelvin Droegemeier was confirmed to head the office just prior to the government shutdown. Dr. Droegemeier has been emphasizing public-private partnerships and reducing administrative burden. Dr. Córdova has a close working relationship with OSTP and the White House and is a co-chair of the National Science and Technology Council (NSTC).

Dr. Crim discussed NSF's Convergence Accelerators (C-Accel), which identify areas in which it is possible to go quickly from use-inspired basic research to a deliverable. The first two are on the Future of Work and the requirements of the data revolution. The latter includes the Open Knowledge Network that would make data from all facilitates as available and interoperable as possible. The former includes AI and Future Jobs. There is also work being done on the National Talent Ecosystem.

NSF's sexual harassment policy requires grantees report any action regarding a PI or co-PI that prevents them from conducting their research. He said it is an important issue that is going to involve much stakeholder involvement. The director and others in the foundation, including Dr. Falkner, have provided important leadership. The foundation wanted to identify the area where it had authority to take action. The foundation is funding the university for the PI's research. If that PI can't take care of students and can't conduct the research, the university is not providing what the award was given for. Action ranges from finding an alternate PI that causes as little disruption as possible for the students and includes escalating actions.

Dr. Crim said the NSB is preparing a report on creating a workforce at all levels, not just Ph.D. scientists but also skilled technical workers with community college degrees and technical institution graduates. For advanced manufacturing, the country is going to need a technical workforce with very different skills. This was discussed at a meeting last fall with the Business-Higher Education Forum (BHEF). He also noted that NSF matched a \$10 million award from Boeing on workforce development.

Another topic receiving considerable attention, he said, is partnering with non-profits, philanthropies and industry, in addition to the foundation's primary partners, which are universities and other agencies.

Dr. Crim closed his remarks by saying that ACs are very valuable for the advice they provide and passing on what is on their minds and what they hear from their communities. AC-OPP, he said, is effectively using its subcommittees to think hard about particular programs and thanked the committee for its work on developing the advisory overview document.

He also thanked committee members whose terms are ending for their work on the AC.

### *Discussion*

Dr. Nettles complemented NSF for having a plan in place to handle the government shutdown and asked about foundation-wide plans for resilience in the face future shocks. Dr. Crim distinguished categories of employees for determining furloughs. 1) Exempt employees are those whose salary has already been paid. Some contractors are also exempt. 2) Excepted people are allowed to continue for reasons of life, safety and protection of property. The largest number of excepted people are in OPP. During the shutdown, NSF tried to assess what grantees needed to keep going, with keeping facilities open presenting the biggest challenge. NSF was able to handle it because it was allowed to refill some accounts and briefly open the bank for people to draw money down. This was possible because there was funding from the CR. One of the changes NSF is making is to work out ways to have sufficient buffer capacity in facilities to ride out a shutdown.

Dr. Weingartner said the AC believes NSF needs to do more to advertise to the public the long list of good things it does. He said people he has talked to in the private sector are surprised that at NSF, one's competitors review and evaluate proposed projects. This type of thing needs to be better publicized, as does the economic consequences of NSF-funded research. Dr. Crim said NSF has been ramping up its social media presence so young people who are advising members of Congress, young faculty, and undergraduates and graduate students hear this kind of message. Every week NSF puts out video on four basic discoveries and he asked how this can attract more viewers. The ability to speak to very diverse audiences is also needed. The economic argument has sound research behind it. About 50 percent to 80 percent grows out of science and technology, he said. He recommended committee members view "[The Miracle Machine](#)" talk that Eric Lander presented at the National Math Festival in 2015.

Dr. Weingartner said AC members are mandated to promote outreach in their fields, but he does not know of a consistent way to be successful at that. He said that NSF receives less publicity for

science results stemming from its funding than NASA does for its. NSF has initiated a branding campaign and when a reporter does not mention NSF backing, the reporter is contacted. The foundation refers to “the NSF South Pole Telescope” in its announcements but editors remove the NSF reference, yet will refer to the “NASA Hubble Space Telescope.”

Dr. Steig suggested making it easy for researchers with NSF support to know who to call and get a response. He said he tried and failed to get NSF to publicize a study he worked on that also received NASA funding. But NASA did publicize it and it is now cited as a NASA study. Dr. Steig had contacted a program officer who had connected him to public relations at NSF, who he said was very slow in responding. Dr. Crim said this is what the foundation is working to change. Dr. Steig said it is important to convey that to those working on NSF-funded research.

Dr. Nettles suggested working with university media offices to assure they include credit for NSF. Dr. Crowell added that NSF’s communications with its awardees could also stipulate that they are responsible for making it publicly known. Dr. Borg said there is similar language in award letters, which are not carefully read. Dr. Falkner said NSF outreach contacts need to be communicated more clearly.

Mr. Arnaudo asked why the security at the NSF headquarters building is so rigorous and said it should be relaxed. Dr. Crim this is vexing the foundation and it is being worked on. The General Services Administration (GSA) wanted NSF to move to its current new facility in part so it could have the appropriate level of security for a building with 1,600 people. That number determines the level of security. Accommodations have been made for recurring visitors from other government agencies. Most frustrating is that the security employees, who work for a contractor, are not customer friendly, which is the result of poor training. Dr. Falkner said she had received a death threat from the Flat Earth Society and the guards were very helpful in helping to handle the situation. She suggested enhancing one’s relationship with the guards, so they understand better the people they protect. Dr. Crim agreed and said a number of guards are friendly. A number of people at the foundation receive death threats, he added.

Dr. Heimbach asked about big data, including data beyond individual agencies and countries. Dr. Crim said the goal of the Open Knowledge Network ties together many sources of data. NSF and NASA have many data sharing arrangements and many NSF telescopes have international partners, so there are models for doing that data sharing. But he said this is a critical aspect of doing science going forward. He also mentioned the tension between intellectual property and open data.

Dr. Marsh asked about having controls against invalid data in an open network. Dr. Crim said curation is going to be an issue for open data and discussed the efforts that will be required to curate those data. He also discussed reproducibility and replicability of data and what it means for different communities. It is important that data be robust and reliable. In some disciplines this means replicating the analysis or reproducing the experiment. In other areas making the same measurement again often happens when making the next measurement. In some areas, publishing reproduced and failed experiments is important. In other areas it will involve correcting the literature by making a measurement and finding it wrong. Each community needs to think about what it needs to do to make data reliable, such as publishing analysis code.

Dr. Mack expressed the AC's interest in the new notification requirements for reporting harassment and commend the leadership that OPP staff provided. The committee encourages the proactive planning and design of the analysis of reporting data to determine the efficacy of the new reporting requirement, she said. Dr. Crim responded that there is not much data yet available to analyze. The requirement only applies to new awards and continuations. It will take about three years to be completely promulgated. NSF plans to analyze the data when it is available and will look to discern any influence on institutions. But he said one change that is being observed is communication between university Title 9 offices and sponsored research offices.

Dr. Lynch asked if there is a supporting strategy for helping PIs more effectively with the goal of enhancing diversity and inclusion in the science, technology, engineering, and mathematics (STEM) workforce with a particular view towards ways in which Broader Impacts (BI) can be used as a vehicle. Dr. Crim responded by referencing one of the Big Ideas, Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science (INCLUDES). He said he has great hopes for INCLUDES. He said not every PI is going to do something expansive regarding diversity, but NSF should be recognizing and rewarding PIs that do. He added that there is a continuing discussion in the foundation about how to treat BI.

Mr. Arnaudo asked about the government's recent attention to Chinese scientists who are Americans passing information to the Chinese government. Dr. Crim said the director has been giving this significant attention. There are a few cases in which intellectual property or norms of science and confidentiality have been violated, but many more where that has not occurred. Many of the people thinking about this are not from the scientific community. The NSF is actively involved in education and discussions on this. NSF and other agencies are sensitive to the value extracted from openness and international science and the vector points toward more global science. But the U.S. wants reciprocity, data sharing and fair play.

Dr. Weingartner thanked Dr. Crim and said he should feel free to let the AC know how it can assist NSF. Dr. Crim said he appreciates the AC's work and said not to hesitate in communicating.

Dr. Falkner said OPP will query members for an optimal time for the next meeting. Members should respond to with dates when they will be unavailable in the September and October time frame.

Dr. Weingartner confirmed that voting on the title of the advisory overview document would be handled by email and asked that it be done expeditiously. He also asked members to send in suggestions for future meetings.

The meeting was adjourned.