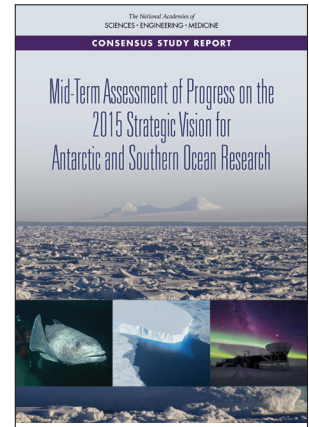




OCTOBER 2021

Mid-Term Assessment of Progress on the 2015 Strategic Vision for Antarctic and Southern Ocean Research



The Antarctic's unique environment and position on the globe make it a prime location to gain insights into how Earth and the universe operate. The cold dry atmosphere offers an unparalleled location for astrophysics research, and the extreme cold and arid conditions with prolonged dark-light cycles have resulted in unique evolutionary solutions by terrestrial and marine organisms. Antarctica is experiencing accelerating ice mass loss due to climate change and warming oceans, and the Southern Ocean plays a prominent role, affecting global sea level rise and the carbon cycle.

U.S. scientific research and related logistics in the Antarctic are supported by the U.S. Antarctic Program (USAP) within the National Science Foundation's (NSF's) Office of Polar Programs (OPP). In 2015, the National Academies of Sciences, Engineering, and Medicine (NASEM) helped guide the NSF Antarctic Sciences by identifying three strategic research priorities (see Box 1). This report provides a mid-term assessment of the progress towards those priorities.

This review took place between July 2020 and October 2021 during the COVID-19 pandemic. This global public health crisis has posed many challenges to the NSF Antarctic Science program because of safety and logistical concerns for the scientists and contractors in this extremely remote location. As a result, the committee primarily focused its mid-term assessment of progress on efforts between 2015 and March 2020, knowing the significant impacts the pandemic has

posed on the science enterprise overall, and especially on Antarctic field science. The committee focused its recommendations broadly on the remaining 5 years of the decadal strategic vision, understanding that NSF will need to consider these recommendations in the context of pandemic conditions that are continuing to evolve.

Box 1: Priorities for NSF's Antarctic Research in 2015 Report

A Strategic Vision for NSF Investments in Antarctic and Southern Ocean Research (NASEM, 2015) identified top priorities for "a core program of broad-based, investigator-driven research." The report identified three strategic research opportunities:

Priority I. How fast and by how much will sea level rise? The Changing Antarctic Ice Sheets Initiative:

- i. Understanding why ice sheets are changing now and how they will change in the future, and
- ii. Using multiple records of past ice sheet change to understand rates and processes.

Priority II. How do Antarctic biota evolve and adapt to the extreme and changing Antarctic environment? Decoding the genomic and transcriptomic bases of biological adaptation and response across Antarctic organisms and ecosystems.

Priority III. How did the universe begin and what are the underlying physical laws that govern its evolution and ultimate fate? A next-generation cosmic microwave background (CMB) program.

Progress on Priority I Research on Sea-Level Rise

Science questions related to the impact of melting ice sheets on sea-level rise are urgent, complex, and essential to global adaptation planning, requiring research initiatives that are ambitious in vision and funding. NASEM (2015) Priority I research addresses how fast and how much sea level will rise, including both a focus on current rates of ice sheet change and studies of past major ice sheet retreat episodes to better understand current events. The International Thwaites Glacier Collaboration (ITGC) is a large, multi-national research initiative that is making important progress, with a focus on understanding current ice sheet and ocean interactions as drivers of ongoing ice mass loss at the Thwaites Glacier and Amundsen Sea region in West Antarctica.



The U.S. Nathaniel B. Palmer research vessel sits in the water by the Thwaites Glacier front. Scientists on this ship collected data about Thwaites Glacier in 2019. SOURCE: Aleksandra Mazur.

Research progress in understanding the rates of sea level rise associated with past ice sheet collapse events is proceeding at a slower pace. Despite the important progress to date, the potential magnitude of the threats to humans posed by Antarctic ice sheet collapse demands a more aggressive, comprehensive, and ambitious research approach.

To more fully address the major science objectives of Priority I, NSF should:

Consider expanding initiatives beyond the ITGC to include the Wilkes Land sector of East Antarctica. Multiple studies since 2015 have demonstrated that parts of East Antarctica are rapidly losing mass and have a greater potential for contributions to sea level rise than West Antarctica.

Initiate additional international and inter-agency partnerships to enable ambitious Priority-

I-focused terrestrial- and marine-based science campaigns to progress, in parallel, in both West and East Antarctica. The ITGC and International Polar Year collaborations demonstrated that multidisciplinary projects that involve airborne, ship-based, drilling and ground-based work are best addressed (scientifically and logistically) by developing international and interagency collaborations.

Expand and continue international Thwaites Glacier region research. ITGC efforts are advancing well, despite COVID-19 associated challenges, and promise important and essential scientific advances on the physical processes driving the retreat of this sector of Antarctica, thereby reducing uncertainties in projections of sea level rise from Antarctica.

Issue a specific call for proposals directed toward increasing knowledge of past ice sheet behavior, rates of change, and climate forcing—information essential to place ongoing environmental change in context and accurately predict future sea level rise.

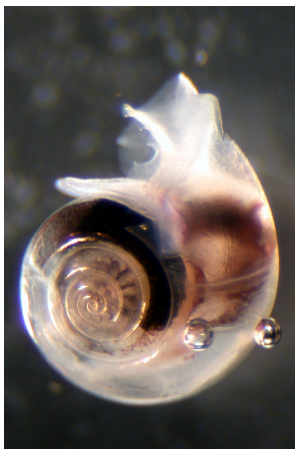
Increase support for interdisciplinary research and modeling efforts to advance progress toward Priority I objectives. Specifically, NSF should continue support for research to improve coupled atmosphere-ocean-ice-earth models, which need substantial additional development and data to improve parameterizations of important processes into an earth system modeling framework.

Progress on Priority II Research on Biological Adaptation

The application of omics (genomics, transcriptomics, proteomics, epigenomics, metabolomics, and others) to analyze the biology of evolutionary diversification, functional response, and cold adaptation is central to understanding Antarctic ecosystems and organisms and their sensitivity or resilience to climate change. Overall, progress has fallen short on the Priority II vision laid out in NASEM (2015). To date, NSF-sponsored omics research is generating advances in understanding Antarctic organisms and ecosystems through grants to individual investigators and small teams. However, lack of coordinated collection of omics data to community-defined standards can lead to incomplete genomes and transcriptomes that are of little value in a comparative sense. Community and partnership building, multidisciplinary training, and resource-sharing could stimulate this initiative.

To advance progress toward Priority II, NSF should:

Issue a targeted call for proposals. NSF should support coordinated projects that stimulate an Antarctic Genomics Initiative to make progress in the three areas of emphasis (1) sequencing the genomes of phylogenetically informed, ecologically important groups of organisms and assemblages, (2) sequencing transcriptomes of key organisms and assemblages to both assess their functional responses in natural and experimental settings and to obtain the expressed genome for taxa with exceedingly large genomes, and (3) support for advanced omics technologies (e.g., metabolomics, proteomics, epigenomics), which can accelerate hypothesis testing derived from genome-enabled efforts.



Studies of the shelled pteropod *Limacina helicina* (e) underscore the sensitivity of calcification processes to Southern Ocean acidification. SOURCE: (e) Gretchen Hofmann courtesy of NSF

on developing collaborative, multi-investigator omics research projects. OPP partnerships with other NSF directorates, other governmental agencies, international research organizations, and non-governmental genome advocacy organizations could be leveraged to enhance the funding and outcomes of Antarctic omics.

Evaluate opportunities to enhance access to organisms, samples, and data to advance Priority II science.

Efforts to improve access to biological samples will attract a broader research community to Antarctic sciences.

Emphasize community building and partnerships.

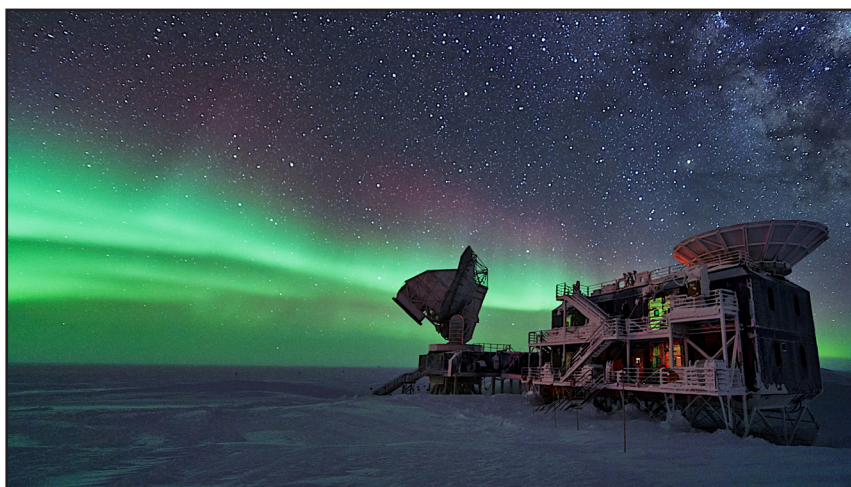
NSF can encourage and stimulate community building through a specific call for workshops focused

Progress on Priority III Research on the Origins of the Universe

Priority III from NASEM (2015) recommended a next-generation cosmic microwave background (CMB) program, partly located in Antarctica, to study the origins of the universe. CMB research at the South Pole has been flourishing for many years with two major experimental programs at the South Pole: the South Pole Telescope (SPT) and Background Imaging of Cosmic Extragalactic Polarization (BICEP)/Keck. Research at those sites has produced groundbreaking research, and continued research and planned improvements are expected to produce high impact results. For example, the BICEP Array, which is midway through construction, will provide a substantial step forward in sensitivity, and coordinated data analysis with the SPT will further enhance this sensitivity by reducing distortion of light by gravitational fields.

The scientific community has made progress in the design of CMB-S4, a central component of Priority III that includes telescopes at both the South Pole and in Chile. CMB-S4 would provide another order of magnitude step forward in the search for the imprints of gravitational waves from the expected inflationary origin of the universe.

Inadequate levels of funding and planning for logistical support pose a threat to the rate of progress of ongoing Antarctic CMB research and the pace of construction of the Antarctic CMB-S4 components. Effective communication and collaboration between NSF logistics and the CMB-S4 planning team will be essential for future timely implementation. NSF should support timely two-way communication between NSF logistics planning teams and scientists, in which trade-offs between support options are explored. These discussions need to occur earlier in the experiment planning process so that effects on research plans and designs can be incorporated in a timely way.



The South Pole Telescope (center) and the Dark Sector Lab, with BICEP3 on the roof, as seen along the walk from South Pole Station. SOURCE: Geoffrey Chen, University of New South Wales.

Cross-Cutting Research-Wide Issues for NSF

The Antarctic and its surrounding ocean are remote, harsh environments, and access to Antarctica remains one of the largest hurdles for researchers. Across all three strategic priorities and the core science program, logistical considerations limit the pace of research and the geographic breadth of science. Increasing aircraft costs have recently contributed to a reduction in the number of missions and flight hours, creating challenges for deep field access.

The scientific community is deeply concerned about sustaining an adequate Antarctic science program over the next 5-10 years given these logistic constraints, the age of the USAP research vessels, and the lack of a polar-class icebreaker. Prior to the pandemic, several funded projects were seriously delayed, and highly rated proposals have been declined due to logistical constraints. The recent announcement of formal planning for a new U.S. icebreaker research vessel, however, indicates a potentially improved capability in the future by approximately 2030.

To address concerns within the scientific community, NSF should:

Conduct a transparent review of logistic capacity for Antarctic sciences. A review of anticipated resource demands from the three strategic priorities and other research initiatives relative to logistical capacity would identify resource constraints and competing demands. This analysis would support science planning and decision making at a program level while improving transparency with investigators and

encouraging proposals aligned with logistical realities. Analyses with a 5- to 10-year outlook could motivate strategies, such as partnerships, to reduce logistical constraints and balance demands.

Improve communication and coordination between OPP, logistics managers, and the scientific community. Clear communication of logistical constraints would enable investigators—and especially early-career researchers—to develop more successful proposals. The recent proactive engagement of NSF OPP program officers via virtual office hours and participation in smaller workshops and conferences is an important step toward this objective. OPP should also consider developing a forum to engage the broad science community in discussions of logistical realities and facilitate scientific community input on priorities, support strategies, and trade-offs.

Ambitious diversity, equity, and inclusion (DEI) goals will strengthen Antarctic science by bringing together a broad community of researchers with diverse perspectives to address strategic priorities. To address serious shortfalls in DEI in Antarctic Sciences, NSF should identify robust, evidence-based strategies and integrate DEI goals into funding and reporting requirements, thereby supporting systemic community change. NSF should work with DEI professionals to promote diversity goals through clear expectations in funding announcements, reporting requirements, and the sharing of best practices. NSF should actively seek to broaden the pool of scientists working in Antarctica and support mentoring of early career scientists and others new to polar science.

COMMITTEE ON A MID-TERM ASSESSMENT OF NSF PROGRESS ON THE 2015 STRATEGIC VISION FOR ANTARCTIC AND SOUTHERN OCEAN RESEARCH

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For More Information . . . This Consensus Study Report Highlights was prepared by the National Academies of Sciences, Engineering, and Medicine based on the Consensus Study Report Mid-Term Assessment of NSF Progress on the 2015 Strategic Vision for Antarctic and Southern Ocean Research (2021). The study was sponsored by The National Science Foundation. Any opinions, findings, conclusions, or recommendations expressed in this publication do not necessarily reflect the views of any organization or agency that provided support for the project. Copies of the Consensus Study Report are available from the National Academies Press, (800) 624-6242; <http://www.nap.edu> or via the Polar Research Board web page at <http://www.nationalacademies.org/prb/polar-research-board>.
