FUTURE SCIENCE OPPORTUNITIES IN ANTARCTICA AND THE SOUTHERN OCEAN

Statement of

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Chairman Hall, Ranking Member Johnson, and members of the Committee: Thank you for inviting me to speak to you today. My name is Warren Zapol and I am an anesthesiologist and the emeritus Anesthetist-in-Chief at Massachusetts General Hospital and the Reginald Jenney Professor of Anesthesia at Harvard Medical School; I am also the Director of the MGH Anesthesia Center for Critical Care Research.

I am speaking to you in my role as Chair of the report on "Future Science Opportunities in Antarctica and the Southern Ocean" issued by the National Research Council of the National Academy of Sciences (NAS). The Research Council is the operating arm of the National Academy of Sciences, National Academy of Engineering, and the Institute of Medicine of the National Academies, chartered by Congress in 1863 to advise the government on matters of science and technology. Our 2011 report laid out future research directions for scientific research for the next two decades on the continent of Antarctica and in the surrounding Southern Ocean (an area comprising about one third of Earth). We also highlighted several important opportunities that we felt could improve the efficiency and effectiveness of the Antarctic research endeavor. As you have learned, this report served as input for the National Science Foundation Blue Ribbon Panel report on "More and Better Science in Antarctica through Increased Logistical Effectiveness."

Our NAS report holds special credibility because it was prepared according to stringent NAS guidelines for balance, objectivity, and peer review, and because it was written by a group of volunteer experts that included both those who have done scientific research in the Antarctic region as well as those with no prior experience in Antarctica. Our group included preeminent scientists from a variety of disciplines, and included a Nobel Prize winner.

Allow me to begin with what is certain to be one of your first questions, and that is why is an anesthesiologist talking to you about research in Antarctica?

In the 1970s, I became fascinated by stories of Weddell seals diving to 600 meters depth in the Southern Ocean that could hold their breath for 90 minutes. Wouldn't this be a wonderful adaptation for our patients with pneumonia or heart attacks? How was this possible? To answer this question, I led a small team of multidisciplinary scientists and doctors to Antarctica to study seals by constructing and using specially designed diving microcomputers in their natural icy environment. Over the course of nine summer seasons in Antarctica, we learned how specialized storage of oxygen and nitrogen in seals played a critical role in allowing these remarkable animals to dive for extended periods without suffering from the bends, or hypoxia (low blood oxygen levels). We brought that knowledge back and eventually developed a treatment for hypoxic human newborn babies by breathing nitric oxide. This technique is now used to save the lives of around fifteen thousand U.S. babies each year. We also spun off a new startup company in Seattle making such specialized tracking and monitoring computers called "Wildlife Computers".

Discovery Science

But why tell you this story? The simple reason is that I think it is an important example of the power of discovery science. Allowing scientists to explore in Antarctica can lead to unanticipated discoveries. And the key point is that Antarctica is a place that is ripe for just these types of discoveries. There are large parts of the continent that have yet to be explored—as a

geologist colleague of mine likes to say, this is a place where you can pick up a rock and be confident that you are the first person to ever pick up that rock.

In our NAS report, the Committee highlighted four areas of science that will be important in discovery-driven scientific research in Antarctica and the Southern Ocean over the next two decades. Key science questions that we believed should drive Antarctic research over the next 10-20 years are:

(1) What can records preserved in Antarctica and the Southern Ocean reveal about past and future climates? Rocks, sediment cores, and ice cores from the Antarctic region hold a treasure trove of information about the history of Earth and its climate.

(2) *How has life adapted to the Antarctic and Southern Ocean environments?* Applying new tools in genomics, metagenomics, and proteomics to study the highly-adapted organisms in the Antarctic region could lead to new understanding on a host of illnesses and conditions that plague humans, such as heart attacks, strokes, and decompression sickness.

(3) What can the Antarctic platform reveal about the interactions between Earth and the space environment? Space weather—magnetic storms on the sun that can spew high-energy particles toward Earth—can disrupt the proper functioning of communications satellites in orbit, GPS systems, and even electrical power distribution systems on Earth's surface. This needs to be monitored; space weather is best viewed from the poles and the South Pole is far better for this than the shifting sea ice at the North Pole.

(4) *How did the Universe begin, what is it made of, and what determines its evolution?* Antarctica's atmospheric conditions allow scientists to view far out into the cosmos and

attempt to answer fundamental questions about the evolution and composition of the Universe. In addition, scientists have built an observatory on Antarctica's vast ice sheet at the South Pole to detect neutrinos—high-energy, nearly mass-less particles that may be a key piece of understanding as to how our Universe works.

Global Change

But discovery is only half of the story. The other half relates to the role of Antarctica in our Earth system. Over the past century, temperatures on land and in the ocean have started to increase. Sea level is rising and global weather patterns are shifting, altering the chemical and biological systems of the planet. The climate and geography of Antarctica are important influences on these processes and provide a unique environment in which to monitor change.

In addition to being a place to observe changes in the Earth system, Antarctica is a key part of many processes in the Earth's system. The Southern Ocean is where a large part of the deep water of the global ocean circulation is formed and where a large amount of carbon dioxide is exchanged with the atmosphere. Antarctica's ice sheets hold about 90 percent of the world's ice and fresh water, and if all of this ice were to melt, global sea levels would rise by more than 60 meters. Understanding the changes happening in Antarctica and the Southern Ocean is crucial to avoiding surprises impacting the rest of our world.

The Committee highlighted four questions in Antarctic research that will be important for global change science over the next two decades. Those are:

(1) *How will Antarctica contribute to changes in global sea level?* Antarctica's ice sheets hold about 90 percent of the world's ice and fresh water, and if all this ice were to melt,

global sea levels would rise by more than 60 meters; therefore, scientists need to monitor and understand what is happening to Antarctic's ice sheets.

(2) *What is the role of Antarctica and the Southern Ocean in the global climate system?* The Antarctic region plays a critical role in Earth's climate, including ocean currents, atmospheric circulation, and the carbon cycle, and more information on Antarctica's influence over globally interacting systems is needed to better understand our global climate system and how it might change in the future.

(3) *What is the response of Antarctic biota and ecosystems to change?* Antarctic ecosystems are relatively simple, making it easier to detect the impacts on these ecosystems from factors like pollution, ocean acidification, invasive species, increases in UV radiation, and most critically, human-induced climate change. Changes in the ecosystems of the Antarctic region may be a harbinger of the changes to come elsewhere, and therefore monitoring Antarctic change will allow scientists to better predict future global changes.

(4) *What role has Antarctica played in changing the planet in the past?* Geologically, the Antarctic continent was once part of a massive supercontinent. Antarctica has played a central role in previous changes in Earth's climate and in both atmospheric and oceanic circulation, so understanding the history and future of the Antarctic continent is key to understanding our planet's geological history and future.

Recommendations

In addition to these four directions in global change research and four directions in discovery science, our committee examined opportunities for making research science in Antarctica and the Southern Ocean more effective and efficient. Conducting research in the harsh environmental

conditions of Antarctica is logistically challenging. Substantial resources are needed to establish and maintain the infrastructure needed to provide heat, light, transportation, and drinking water, while at the same time minimizing pollution of the environment and ensuring the safety of researchers. The Committee identified opportunities to sustain and improve the science program in Antarctica and the Southern Ocean in the coming two decades, and made six specific recommendations:

1. **Lead the development of a large-scale, interdisciplinary observing network and support a new generation of earth system models:** To better predict future conditions, scientists need a network of observing systems that can collect and record data on the ongoing changes in the Antarctic region's atmosphere, ice sheets, oceans, and ecosystems. This network should be able to measure and record ongoing changes to develop an understanding of the causes of change and to provide inputs for models that will enable U.S. scientists to better project the global impacts of a changing Antarctic environment. The envisioned observing network shares many characteristics with previous initiatives, such as the Arctic Observing Network (AON) or the proposed Pan-Antarctic Observing System (PAntOS). There is also an inherent need for improved sharing of data and information. Improvements in the collection, management, archiving, and exchange of information will allow data to be used for multiple purposes by a variety of stakeholders. In addition, improvements in scientific models of the Antarctic region are urgently needed to strengthen the simulation and prediction of future global climate patterns. These initiatives will require interdisciplinary approaches at the system scale that would be best addressed with a coordinated, long-term, international effort. Given the scope of the research program and to support infrastructure in the Antarctic region,

the United States has the opportunity to play a leading role in developing a large scale, interdisciplinary observing network and earth system models that can accurately simulate the conditions of the Antarctic region.

2. **Continue to support a wide variety of basic research in Antarctica and the Southern Ocean to yield a new generation of discoveries:** Antarctica and the Southern Ocean provide a natural laboratory for scientific discovery. The tiny air bubbles trapped within the ice hold a record of the planet's atmosphere through time, the living things in the ocean and on land can teach scientists about survival strategies in extreme environments, and Antarctica provides an excellent platform for looking out to the solar system and the Universe beyond. This type of scientific research should continue to be supported.

3. **Design and implement improved mechanisms for international collaboration**: Over the past half century, collaborations between nations, across disciplinary boundaries, between public and private sectors and between science and logistics personnel have helped research in Antarctica become a large and successful international scientific enterprise. The International Polar Year, held from 2007-2008, demonstrated how successful international collaboration can facilitate research that no single nation could complete alone. This report examines opportunities to enhance international collaboration, with the overall conclusion that by working together, scientists from many nations can reach their goals more quickly and more affordably.

4. **Exploit the host of emerging technologies including cyberinfrastructure and developing novel and robust sensors:** Advances in energy and technology can make scientific research in the Antarctic region more cost effective, allowing a greater

proportion of funds to be used to support research rather than to establish and maintain infrastructure. For example, most of the energy required to power research stations and field camps and to transport people and materials comes from burning fossil fuels. In addition to the cost of the fuel, the combustion of fossil fuels pollutes the air, and fuel leaks during storage and transport have the potential to contaminate the surrounding environment. Innovations such as more cost-effective overland transportation systems for fuel, or the use of wind power generators, promise to reduce the cost and pollution associated with fuel transport.

5. **Coordinate an integrated polar educational program**: Antarctica and the Southern Ocean offer great opportunities for inspiring popular interest in science in much the same way as space exploration did in the latter half of the 20th century. The National Science Foundation has supported a broad range of educational efforts to spark interest in polar science, including television specials, radio programs, and a multimedia presentation that toured U.S. science centers, museums, and schools. These efforts not only increase public awareness and understanding of the research taking place in Antarctica, but can help to inspire future generations of polar scientists. Building upon existing educational activities to develop a more integrated polar educational program, which would encompass all learners including K-12, undergraduates, graduate students, early career investigators, and life-long learners, would help engage the next generation of scientists and engineers required to support an economically competitive nation and foster a scientifically literate U.S. public.

6. **Continue strong logistical support for Antarctic science**: The Committee encourages the National Science Foundation-led Blue Ribbon Panel to develop a plan to support Antarctic science over the next two decades with the following goals:

    - Improve the efficiency of the support provided by contractors and enhance the oversight and management of contractors by the scientific community

    - Increase the flexibility and mobility of the support system to work in a continent- and ocean-wide manner, utilizing as much of the year and continent as possible, and fostering innovative "cutting-edge" science

    - Maintain, develop, and enhance the unique logistical assets of the U.S., including the research stations, aircraft, research vessels, and icebreakers.

Closing

The committee worked hard to identify these six recommendations that, together, will maintain our Nation's leadership in Antarctic science. After identifying the scientific questions in the first section, our group realized that a need for observations underpinned many of these questions, such that the proposed interdisciplinary observing system, although ambitious, was the key element in progress on the widest array of scientific issues and will prove invaluable over time. The committee was not charged with examining the costs of their recommendations, but our thinking was clearly influenced by the reality of limited resources.

As mentioned above, our committee wrote its report as input to the Blue Ribbon Panel, so our committee did not have the opportunity to comment as a group on the report from the Blue Ribbon Panel. As such, I can only offer my personal views on the results of their report. First, I

believe they did a stellar job, and in particular that they carefully listened to our committee's recommendations for more observations and for increased flexibility in the logistical support of science in the Antarctic region. The one area that I feel they could have paid more attention to was the need for more clearly defined and better communication channels and interaction between NSF leadership, the logistical support contractor, and working scientists in Antarctica. I can also tell you that I have heard that many in the science community are worried about the potential impacts of the Blue Ribbon Panel's recommendations on the conduct of science. With limited resources, we need to assure a balance between improving our capability to support our future presence in Antarctica and the actual conduct of research today.

To conclude, despite the challenges of working in the harsh environment of Antarctica and the Southern Ocean, this region offers great insights into our changing planet and is an invaluable platform for scientists to make new discoveries. Preserving the unique environment of the Antarctic region for new observations and experimental science requires a continued commitment to stewardship. Making use of international and multidisciplinary collaboration, emerging technologies and developing robust sensors, and educational opportunities, the next 20 years of Antarctic and Southern Ocean research have the potential to advance our understanding of this planet, and beyond. A robust and efficient U.S. Antarctic Program is needed to realize this potential.

In closing, the Antarctic region is a remarkable and truly amazing place, a place ripe for scientific discoveries that should be allowed to flourish there. What is more, Antarctica is an important part of our changing world, and we need to be watching it as it changes.

Thank you very much for your attention. I would be happy to answer your questions.