Increasing Arctic Accessibility Over the Next Twenty Years

Arctic Research Support and Logistics Workshop Report

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James Morison and Jacqueline Richter-Menge (workshop co-chairs)

Kristina Creek, Peter Griffith, Steven Oberbauer, Sophia Perdikaris,
Matthew Shupe, Craig Tweedie, and Helen Wiggins (eds.)

Acknowledgments

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Cover photo: The USCGC *Healy* breaks sea ice in the Bering Sea. Photo by Deanna Wheeler (PolarTREC 2009). Courtesy of ARCUS.

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Alicia Gillean observes Arctic ground squirrels. Atigun River near Toolik Field Station, Alaska. Photo by Alicia Gillean, courtesy of ARCUS.

Executive Summary

The impact of the warming climate is readily apparent in the Arctic: temperatures have increased more than elsewhere on Earth, sea ice has declined drastically, permafrost is degrading, and ecosystems are changing. Local communities must adapt to new norms. These changes, and the expectation of a continued increase in global temperatures through the twenty-first century, have elevated the socioeconomic and geopolitical importance of the Arctic. It is, therefore, straightforward to anticipate an increasing need for scientific research in the region and hence an increasing demand for logistical support. It is also apparent that this logistic support must provide more complete access to the Arctic—access that is Arctic-wide and year-round.

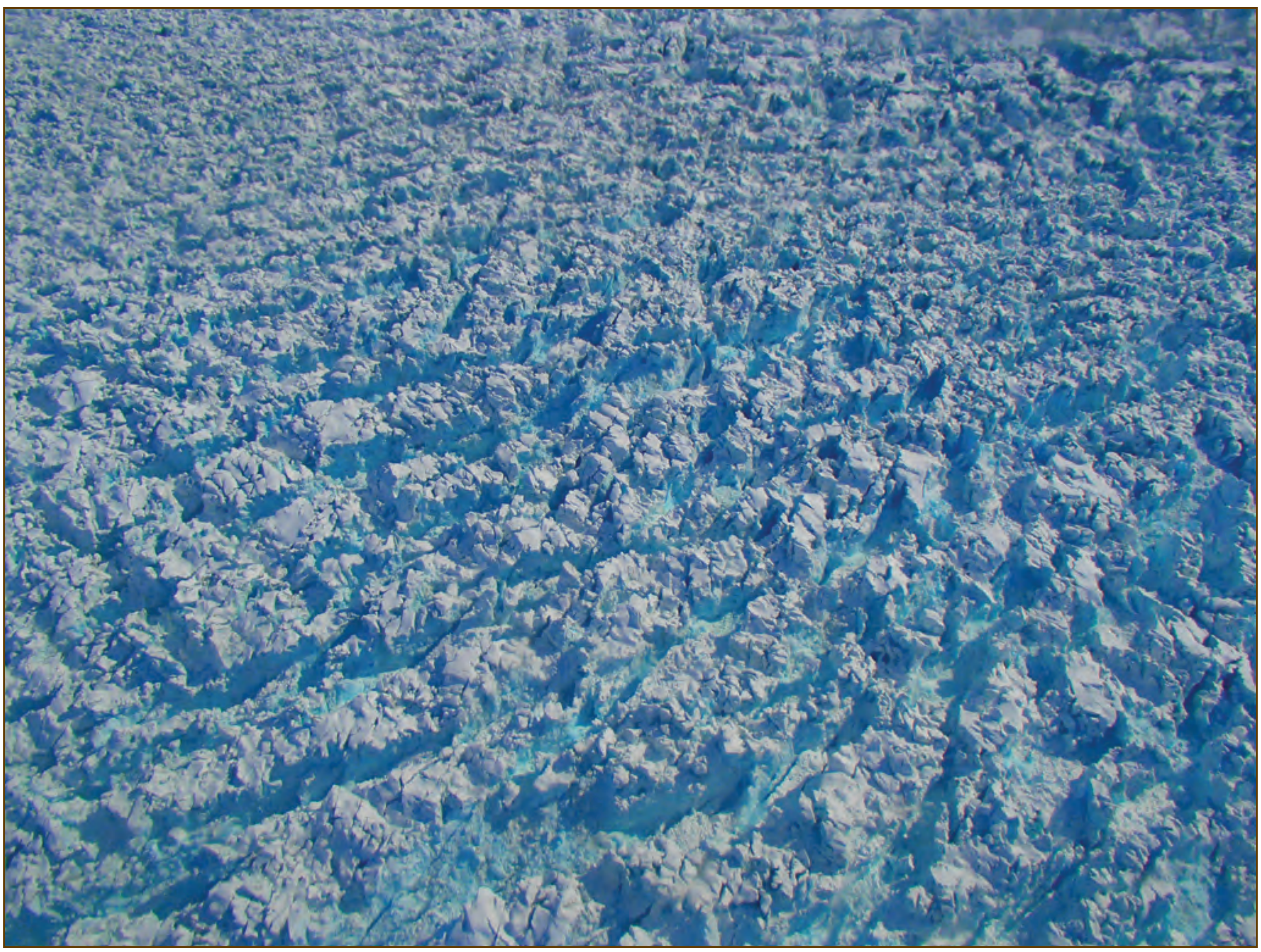
This report, largely informed by discussions at a workshop and feedback from many Arctic researchers, recommends that to meet the urgent demand for full access to the Arctic it is necessary to:

1. Sustain current capabilities while expanding new logistics resources, developing and implementing a strategic investment plan to maintain and advance critical facilities and technologies. These resources include marine vessels and sea-ice camps, terrestrial research hubs and smaller mobile camps, and aircraft. It is also necessary to strike an improved balance of advancements in communications requirements, technology development, and electrical power against the requirements for greener power generation and lower energy consumption.

2. Ensure the vitality of future Arctic research and logistics by facilitating the transfer of knowledge and capabilities to empower a new generation of Arctic research and logistics experts to design, lead, and implement future plans and initiatives. Further integration of members from local communities into Arctic research support and logistics will also provide unique opportunities to train, contribute to, and benefit from community knowledge. In developing the human resource capacity, it is important to build a research logistics culture that is founded on the principle that science needs are what drives logistics priorities.

3. Seek and take advantage of opportunities to improve the coordination of logistic resources, increasing interaction and partnerships across disciplinary, agency, organizational, and international boundaries. These efforts should aim to reduce duplication of effort in providing logistics, take full advantage of existing resources, and foster the highest quality science. In this vein, the results of this report should be shared beyond NSF to encourage new discussions and initiatives within the local, national, and international Arctic research and logistic communities.

Fundamentally, it should be recognized that the complexities of the Arctic environment and its communities, the reality of limited funding, and the rapidly increasing interest in the region require the development of support capabilities that are flexible and agile—Arctic research logistics support must respond to the pace of rapid change.



Crevasses of a glacier as seen from a P-3 Orion, flying over Greenland. Photo by Mark Buesing, courtesy of ARCUS.

1 Introduction

Logistics are critical to safely and effectively achieve the goals of a U.S. Arctic research program. We need look no further than the success of the National Science Foundation (NSF) Arctic Research Support and Logistics (RSL) program and the science it supports to prove this point. The 1997 report Logistics Recommendations for an Improved U.S. Arctic Research Capability (Schlosser et al., 1997) focused attention on logistical needs in the Arctic. The 1997 report also justified a $22 million increase to the NSF budget for Arctic logistics and led to the creation of the Arctic RSL program in 1999. The Arctic RSL program has a focused vision:

- improve safe access to the Arctic for research,
- increase efficiency and reduce costs through contracts and other agreements,
- save researchers' time and broaden participation in Arctic research,
- improve communication between Arctic researchers and Arctic communities, and
- develop relationships and agreements for improved access and efficiency.

The program is continually evolving and responding to shifting research priorities and logistics needs while also working strategically to anticipate researcher needs and facilitate access to the Arctic for researchers. The 2011 U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) analysis of Arctic research logistics recommendations (Knuth and Weale, 2011) examines the progress RSL has made toward its goals. Highlights include:

- The RSL program learned that the permitting process for researchers working near Toolik Field Station in Alaska was taking time. To expedite permitting, RSL worked with the Bureau of Land Management (BLM) to facilitate development of a cultural resources management plan, using surveys to define sensitive areas and develop resource maps that will expedite the review of permit applications.
- About one-third of all field projects supported by the RSL program are in Greenland. The RSL program has developed special capabilities for operating in Greenland, including an overland tractor traverse and a research

A word cloud depicting emphases from the report's recommendations.

station near the summit of the Greenland ice sheet. Other agencies, in particular the National Aeronautics and Space Administration (NASA), purchase field logistics support from the RSL program each year, taking advantage of the resources NSF has in place and the ability of agencies to work together through interagency agreements.

- NSF-supported research in Greenland has flourished in the last fifteen years with international collaborations resulting in the drilling of several ice cores as well as other successes. In that time, the government of Greenland has evolved and along the way the RSL program has maintained close communication on common interests and the basic research that NSF supports in Greenland.
- Safety is a key piece of logistics and one that the RSL program emphasizes strongly. RSL sponsored a workshop (http://rslriskworkshop.com/) in February 2014 to bring researchers, logistics providers, station operators, and other experts in the field to discuss Arctic field safety risk management. Overall the program has very few medical evacuations each year and strives to keep that number low by providing training and other tools for individuals to use to manage risk.

Dedicated to continuing its positive impact in supporting important Arctic research, the Arctic RSL program asked us to address the question:

> ***What logistic infrastructure needs to be in place to facilitate Arctic research over the next twenty years?***

Committed to the guiding principle that *science needs must drive logistics priorities*, it is important to understand, and respond to, the evolving directions of Arctic science. Clearly, it is a challenge to forecast the specific details of science needs over the next twenty years. This workshop did not address scientific priorities, because it was well beyond the scope of the workshop and similar efforts have been completed or are underway, such as the Study of Environmental Arctic Change (SEARCH) program goals (SEARCH Science Steering Committee, 2013; http://www.arcus.org/search-program/goals), the Interagency Arctic Research Policy Committee (IARPC) five-year plan (U.S. Executive Office, 2012), and the National Research Council's (NRC) Polar Research Board emerging questions report (NRC PRB, 2014).

However, we are confident in saying that ***the degree of urgency to conduct a diverse array of scientific investigations in the Arctic will continue to increase.*** This confidence is largely based on two fundamental principles. First, climate model projections show a continued increase in global temperatures through the twenty-first century and a distinctive polar amplification of these signals. Climate change is already apparent in the Arctic, where temperatures have increased more than elsewhere on Earth, the sea ice has drastically declined, permafrost thaw is accelerating, ecosystems are changing, and local communities are adapting to new norms (Jeffries et al., 2013). Increasingly, Arctic change is being recognized as an important catalyst of socioeconomic and environmental change outside of the Arctic. These changes contribute to the second fundamental principle: that the Arctic is becoming increasingly important

Carol Scott withdraws gas samples at the Petsikko wetland, south of Kevo Research Station, Finland. Photo by Abby Miller, courtesy of Carol Scott, courtesy of ARCUS.

Chantelle Rose with the CTD (Conductivity, Temperature, and Depth instrument). Aboard the USCG Cutter Healy. *Photo by Joel Llopiz, courtesy of Chantelle Rose, courtesy of ARCUS.*

from socioeconomic and geopolitical standpoints. This is evident in the U.S. Department of State appointment of an ambassador-level Arctic representative (Secretary Kerry, 2014). Declining sea ice opens the door to increased resource exploration, trans-Arctic shipping, and a host of other economic endeavors. Societal impacts can be felt at many scales, from the local, through changes in biological productivity and subsistence, to hemispheric, through potential impacts on large-scale weather patterns. Thus, the implications of Arctic change are far-reaching and increasingly important.

We are also confident in saying that ***increased access to the Arctic is a fundamental logistics requirement if we are to meet this urgent demand for increased research. Our access must grow to be Arctic-wide and year-round***—and the sooner the better. Likewise, the research-support logistics portfolio must evolve to keep pace with the increased demand and scope of scientific activities. In many cases the rate of Arctic change is outpacing our evolving understanding and representation of that change and challenging our abilities to respond. Over the past decade the Intergovernmental Panel on Climate Change (IPCC) has highlighted major deficiencies in our understanding of the Arctic climate system. These are related primarily to difficulties in characterizing many Arctic-specific processes, including feedbacks and climate dynamics (IPCC, 2014). As recognized by the SEARCH program (http://www.arcus.org/search-program), scientific investigations hold the key to our ability to observe, understand, and respond to the changing Arctic environment. These investigations will continue to involve long-term and short-term studies aimed at improving our knowledge of the complex Arctic environment, including the human communities living there.

To facilitate this report, the NSF RSL program funded a workshop on strategies and recommendations for Arctic research support and logistics. The Arctic Research Consortium of the U.S. (ARCUS; www.arcus.org) organized the workshop with guidance from an organizing committee. A survey was circulated to the Arctic community to help guide the development of the workshop agenda and topics, and three prior reports were also used as reference:

- the 1997 logistics report (Schlosser et al., 1997), which resulted in the creation of the NSF RSL program;
- the 2003 logistics report (Schlosser et al., 2003), which catalyzed implementation of SEARCH (www.arcus.org/search-program) and the Arctic Observing Network (AON); and
- the 2011 CRREL *Analyses of Arctic Research Support and Logistics Reports from 1997 and 2003* (Knuth and Weale, 2011), which analyzed the recommendations in the 1997 and 2003 reports and assessed which recommendations had been addressed.

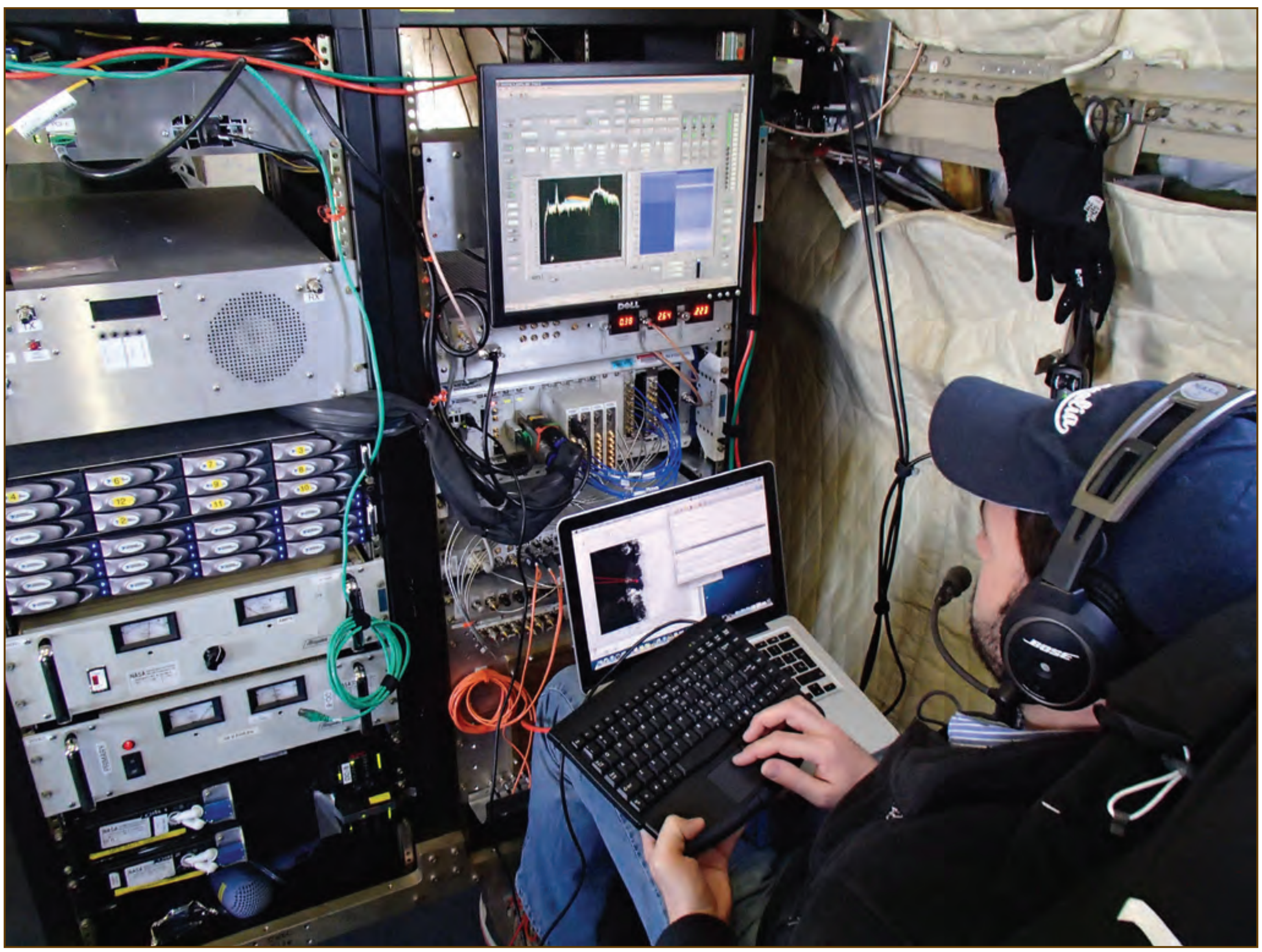
RSL Organizing Committee Members

Peter Griffith, NASA
James Morison, co-chair, University of Washington APL
Steven Oberbauer, Florida International University
Sophia Perdikaris, Brooklyn College
Jacqueline Richter-Menge, co-chair, CRREL
Matthew Shupe, NOAA
Craig Tweedie, University of Texas at El Paso
Helen Wiggins, ARCUS

Sixty-two participants attended and represented a diverse range of disciplines and perspectives (see Appendix A). The workshop was developed as a working meeting (see agenda in Appendix B), with an emphasis on breakout group discussions about:

- a shared vision of future logistics support;
- logistics needs for Arctic domains (terrestrial, marine, ice sheets, atmosphere, and social sciences);
- platforms and regions (Alaska, Greenland, marine operations, ice camps, and autonomous platforms);
- crosscutting issues (interagency coordination, international coordination, coordination of field opportunities and assets, capacity building, and maximizing safety/minimizing risk); and
- synthesis of the disciplinary and region-focused discussions into overarching recommendations.

This report was developed with input from workshop participants as well as the broader Arctic community. After constructing an initial outline, the organizing committee requested comments on topics and structure from the workshop participants. Those responses were taken under consideration in development of a full rough draft, which was distributed again to the workshop participants as well as to a broader audience for additional feedback (i.e., to researchers who were invited but unable to attend the workshop, and through an announcement inviting feedback via the ArcticInfo email list). Each section below includes background on the topic then lists recommendations in short bullet form. The overall approach focused on keeping the report brief; reports from the workshop breakout groups are available online (http://www.arcus.org/logistics/2013-workshop/report). Again, the workshop scope did not include discussions of scientific priorities nor those issues specific to safety (the subject of the NSF risk management workshop convened in February 2014). We do not expect that NSF RSL will or can implement every recommendation under its direct purview; we envision many of the recommendations to require ongoing discussions between NSF RSL, the Arctic research community, logistics providers, and other agencies and organizations.



Bruno Camps-Raga checks the radar. Aboard a P-3 Orion, flying over Greenland. Photo by Mark Buesing, courtesy of ARCUS.

This report summarizes a series of actionable recommendations that primarily address the need to increase access to the Arctic. These recommendations fall into three broad categories: (1) sustaining and expanding logistics resources, (2) building human capacity, and (3) facilitating opportunities to improve the coordination of logistics resources. In the section on sustaining and expanding resources, we discuss strategic investments to maintain and advance critical facilities and technologies. The human capacity section addresses the importance of retaining knowledge between generations. In the section on coordination opportunities, we consider approaches to increase interactions and partnerships across disciplinary, agency, organizational, and international boundaries. ***A key to these recommendations is the need to have a clear and transparent process between the science community, logistics providers, NSF, and other supporting partners to track progress and communicate related decisions.***

Given the breadth and scope of Arctic research, the logistics requirements cannot be determined by a single group of scientists at a single time. Priorities will necessarily be established through science planning processes, and these priorities will be balanced against resources and capabilities through careful planning by NSF and other agencies. This report presents many ideas about the research logistics needs of the future. More than ever before, achieving science objectives that demand ever-greater geographic and temporal access to the Arctic environment will require thoughtful and systematic planning processes that progress from sound science plans to research execution. This will require ever-closer communication among NSF, researchers, and logistics providers to produce efficient and effective research operations.

An iceberg in Prins Christian Sound, South Greenland. Photo by Bill Schmoker, courtesy of ARCUS.

2 Sustaining and Expanding Logistics Resources

In this section we discuss how to sustain and expand on the tools required to make observational measurements of the Arctic environment. These tools constitute the infrastructure of Arctic research logistics. For the purposes of this report, the recommendations are broken down into 2.1. Research Platforms for the Arctic Environment (addressing marine, terrestrial/cryosphere, and aircraft) and 2.2. Communications, Power, and Technology.

The infrastructure supporting Arctic research has been and will continue to be highly varied, depending on the specific research endeavor, and there is no "one size fits all" solution. Many of the tools have not changed in decades, but we will continue to find new tools and new ways of using old tools to explore the Arctic environment. Initially Arctic research was exploratory and observations were rare. A measurement collected at any time and place or any process-oriented experiment were considered an advance. In the last ten to fifteen years, with the recognition that the Arctic environment is changing and the concern for the role of the Arctic in global climate change, the need for sustained observations has become greater. With more repeat observations and advances in remote sensing, we have come to recognize that the geographical and temporal coverage must expand and the spatial resolution of our measurements must span multiple scales of time and space. Logistical support capabilities that enable distributed measurements in the field are important. With the fundamental changes in the environment, we also realize that key processes may have changed or new processes have become important, necessitating new process-oriented field campaigns. Therefore, as we consider each category of logistics tool, we must ask how it will fit in to a research world that will require more frequent observations at closer spacing and extending into heretofore under-sampled geographic areas. Below, we break down the tools into broad general categories. We are intentionally liberal in the definition of these categories in order to make sure no tool is left out.

2.1 Research Platforms for the Arctic Environment

> ***Research platforms serve as the hub for Arctic research advancements and therefore must be adequate in their design, distribution, and function.***

For the purposes of this report, we have broken Arctic platforms down into three realms: marine, terrestrial/cryosphere, and aircraft. Some research platforms (e.g., aircraft) might be used in several realms, but many, such as ships, are limited to one. In either event, the ways in which assets are used depends on the nature of the environment being explored. Existing research hubs should be utilized to their fullest extent.

2.1.1. The Marine Realm

This subsection addresses the specific needs of marine research within four categories: large icebreakers, small icebreakers and ice-strengthened ships, small vessels, and sea ice camps. In addition, although it did not specifically come up during discussion at the workshop, feedback from the wider community review of the report draft highlighted the importance of improving coastline and bathymetry mapping as a baseline dataset of critical importance to logistics planning, execution, and safety.

Large icebreakers: With respect to large icebreakers, a dominant theme in the workshop discussions was the need to address the aging U.S. icebreaker fleet. Large icebreakers have been key platforms for Arctic marine research for many years. They are particularly important where research surveys require large or heavy instrumentation, or the sea ice environment is unsuitable for other kinds of ships or platforms. However, the number of heavy U.S. icebreakers has dropped from two polar class ships plus the lighter U.S. Coast Guard (USCG) Cutter *Healy* to two: the USCG *Healy* and the recently overhauled USCG *Polar Star*.

Workshop participants felt that more icebreaker access is needed now, via additional resources and more efficient use of existing capabilities. An NRC report provides specific recommendations for the U.S. to "maintain dedicated, year-round icebreaker capability for the Arctic to support national security interests as well as science" (NRC, 2007, pp 123.).

Many workshop participants argued for a model other than Coast Guard ownership, such as the R/V *Sikuliaq*, which is under NSF ownership and is operated by the University of Alaska Fairbanks, in order to avoid the bureaucratic drawbacks

Emily Davenport, Heather Whitney, and Paul Walczak are dwarfed by the hull of the USCG Cutter Healy *on the Bering Sea. Photo by Emily Davenport, courtesy of ARCUS.*

of Coast Guard ownership (e.g., rapid rotation of crew that prevents capacity building). However, the workshop organizing committee recognizes that it may not be realistic to expect NSF to be wholly responsible for ship ownership. The NRC report and current discussions within the U.S. science and operational agencies provide the needed guidance to continue careful planning and a research-needs assessment to build sufficient U.S. icebreaker science capabilities. Since RSL does not have resources for acquiring and operating an interim full-time vessel, our future science will be constrained within the capacity of the existing U.S. fleet, supplemented by collaborative operations with the fleets of other Arctic nations. This further drives the need to develop effective working relationships with international Arctic research and logistics community through organizations such as the International Arctic Science Committee (IASC; http://www.iasc.info/).

Small icebreakers and ice-strengthened ships: Relatively small icebreakers and ice-strengthened ships are very useful for supporting work in the marginal ice zone (MIZ) where open ocean effects impact the sea ice environment and where process studies do not require heavy ice breaking. Such vessels include

NSF's Antarctic research and supply vessel the *Gould*, used in the Antarctic, and the new R/V *Sikuliaq* in the Arctic. We anticipate these vessels will be used intensely over the next twenty years as the extent of the MIZ expands.

Small vessels: Small vessels, which might include anything from medium-sized fishing boats to outboard-powered rigid inflatable boats, are very useful for supporting near-shore and coastal terrestrial research. These are generally chartered or rented, but some of the smaller vessels are purchased directly by grants. Several workshop participants expressed concern about the availability of such vessels and whether NSF should own some for project use. A specific small study is needed to see if there is great enough need in terms of science usage to justify the costs of such vessels and how they may be best managed. A range of marine field stations operated by government, academic, and nonprofit institutions may serve as useful models for the Arctic.

Sea ice camps: Sea ice camps have a long history in the Arctic.[1] They provide undisturbed and immediate access to the environment being studied and are ideal for observing and conducting year-round studies of physical and biological processes. With the aircraft operations made possible by a sea ice runway, instruments, drifting buoys, and even mooring can be deployed and surveys can be conducted over wide areas.

Bruce Taterka samples Toolik Lake, Alaska. Photo by Bruce Taterka, courtesy of ARCUS.

The logistics facilities requirements for an ice camp are relatively small. The logistics challenge and expense are in the labor and knowledge required to build the camp, the operation of aircraft, and the supply of fuel, provisions, and equipment to the camp. If the logistics and science planning are done together from the start, the camp can be configured to the science objectives at minimum cost.

1. Sea ice camps, either with or without a supporting drift ship locked in the ice, were arguably the first Arctic Ocean research platforms. These include large, overwintering camps such as the Soviet North-Pole stations NP-1 to NP-39 and Russian NP-32 to NP-40, the U.S. Station Alpha (1957–1958), the multicamp Arctic Ice Dynamics Joint Experiment (AIDJEX; 1975–1976), and Surface Heat Budget of the Arctic Ocean (SHEBA; 1997–1998). They also include numerous springtime ice camps ranging from several weeks (e.g., the North Pole Environmental Observatory, 2000–2014) to months such as the numerous ONR-sponsored process-oriented camps, including Fram I–IV (1979, 1980, 1981, 1982), Arctic Internal Waves Experiment (AIWEX; 1985), Coordinated Eastern Arctic Experiment (CEAREX; 1988–1989), Leads Experiment (LeadEx;1991, 1992), and Sea Ice Mechanics Initiative (SIMI; 1993–1994). All but the earliest, Fram drift [Nansen, 1902] and SHEBA, have involved scientists essentially living on the sea ice in prefabricated buildings or tents and being supported to some degree by aircraft operating from a runway or skiway built on the ice. (J. Morison, pers. comm., 13 February 2014).

Cristina Galvan stands on the sea ice in front of the Polar Sea *icebreaker. Photo by Cristina Galvan, courtesy of ARCUS.*

As we anticipate more need for year-round access over increasingly broader geographic areas, it is crucial to maintain logistical expertise for setting up ice camps, which represent cost-effective gateways to unexplored Arctic regions and seasons. These can be essential, for example, for the deployments of autonomous (local, regional, or basin-wide) observational networks. The most important investment that NSF RSL can make to keep this option open is in training the next generation of investigators on how to use and maintain capabilities.

2.1.2. Terrestrial–Cryosphere Environment

This subsection highlights a few particular needs for terrestrial and ice sheet logistics, which differ from logistic operations in the marine realm because there are far more operational bases. In addition, these bases are mostly static and built in environments that are less dynamic than sea ice, are designed to address specific place-based research foci, and can typically operate at much lower cost than is possible in other realms. It is important to note, however, that much of the discussion surrounding the topic of terrestrial/cryospheric science logistics at the workshop focused on big-picture needs rather than specific details, which are arguably best met by local expert groups. Key discussion topics included ease of access and the need to make international research more feasible (see section 4.1);

communication and data transfer from the field (see section 2.2); and increased co-support between researchers and logistics providers (see section 3).

A key issue that applies to research in both terrestrial and cryosphere environments is the availability of equipment. Research can be slowed down or even halted by the lack of accessible equipment, particularly as pertains to mobile expeditions. We need to increase the availability of equipment (and backup systems), making equipment for various fields of study (e.g., drilling equipment for permafrost studies, remote power units for ecosystem studies) easily obtained on an as-needed basis. This is especially relevant to mobile camps.

Terrestrial: We need an improved model for small mobile camps to increase safety and reduce risk while maximizing the time spent on research rather than camp management. The camp experience currently varies a great deal depending on location. For a variety of disciplines, the need for small mobile camp support will likely increase in the near term. A great deal can be learned from other countries' progress in this area. The Swedish Arctic Research Program, for example, frequently conducts long-range expeditions in support of terrestrial research with a diverse range of marine, airborne, and land-based logistic platforms (Tweedie et al., 2006).

Dr. Susan Natali works at Site B in Healy, Alaska. Photo by John Wood, courtesy of ARCUS.

Regional and international logistics hubs remain critical. In addition to their crucial function in streamlining logistics operations, they foster education and outreach and informal networking as researchers travel to and from the field. Some of these hubs, such as Barrow, would benefit from a range of general-use equipment such as microscopes, balances, etc., which would greatly reduce costs to investigatory teams and provide high quality and reliable infrastructure that could benefit the research community for a sustained period of time.

As addressed above, discussions by the terrestrial/cryospheric science groups focused on big-picture challenges and generally avoided detailed and thematic or place-based discussion. Arguably, such discussion is best handled by local expert or advisory groups, and most prominent logistic hubs (e.g., Toolik, Summit) have well-organized and active advisory groups with a recognized common voice and a communication path to the NSF RSL

Program. Some stations (such as Barrow) do not, and crises such as the current housing shortage in Barrow may be better managed if such a group existed. For prominent research bases, a science and logistic advisory group should be formed to promote place-based, efficient, consolidated, and visionary advice to the NSF RSL program, independent of logistic contractors and founded on promoting effective and safe science and logistic solutions. At present, the strongest need for such a group is at Barrow, which serves as a logistics base for research activities that collectively amount to the largest federal expenditure allocated to place-based research in the U.S. Arctic.

Ice sheets: Implementing permanent logistics solutions for ice sheets requires careful consideration. The pristine environments on ice sheets must be carefully preserved, particularly for sensitive atmospheric measurements. Also, a balance must be struck between flexibility and safety, allowing researchers to collect necessary data while maintaining a reasonable standard of risk management.

Some researchers expressed concern over a tendency for logistics to overshadow research (e.g., the Science and Operations Barn at Summit Station). However, this issue was not explored thoroughly at the workshop. One suggestion for mitigating any potential imbalances is to gather regular input from groups of researchers about the logistics and future needs of the larger logistics hubs such as Summit Station.

2.1.3. Aircraft

Aircraft have a wide variety of uses in Arctic research and provide a key asset for achieving the vital goal of year-round, Arctic-wide access. Researchers need more airborne assets to get into the field reliably and quickly. Air support is required or preferable for many tasks, including recovering mobile installations and setting up short-term ice camps. Aircraft also serve an important role as observation platforms. We must develop strategies to ensure that current capabilities, honed through years of use, are preserved and expanded. This includes not only the aircraft themselves (e.g. Twin Otters, DC-3s) but also operators and regulatory requirements.

There are several challenges to maintaining aircraft capacity, foremost being that the Arctic research and logistics aircraft fleet is aging. The DHC-6 Twin Otter design is fifty years old, the Lockheed C-130 Hercules is sixty years old, the DC-3 design is seventy-nine years old, and we need to prepare for the eventual expiration of all LC-130s. New versions of the Twin Otter and Hercules are being built, and DC-3s are being modernized and equipped with turbine engines. However, these “new” aircraft are expensive and often need special equipment, such as wheel-skis, that is no longer in production.

The cadre of experienced crews is also aging. For some types of operations, such as sea ice landings, the number of experienced pilots is small and growing smaller with each retirement. Furthermore, the aircraft operations knowledge base is aging.

Additionally, the legal and underwriting landscape is changing. The days of unregulated bush flying are becoming a thing of the past. Insurers, unsure of the impact of changing environmental conditions on aviation operations, are imposing more restrictions on those that they insure.

At present, these issues are not under the control of NSF because, except for the LC-130s of the 109th Air National Guard squadron, many of our Arctic research and logistics aircraft are chartered from private industry through the Office of Aviation Services (OAS). However, there are steps NSF can take to address these issues.

A USCG C-130 banks around the Canadian Coast Guard ship Louis S. St-Laurent. *Aboard the USCG Cutter* Healy *in the Arctic Ocean. Photo by Bill Schmoker, courtesy of ARCUS.*

Recommendations for Section 2.1:

◊ Stress education and improved communication among aircraft operators, OAS, other agencies, and research logistics coordinators. NSF could sponsor workshops for these groups to get together and discuss the challenges and opportunities for improved availability of aviation resources in the Arctic.

◊ Identify backup assets (e.g., boats in Barrow) to be used in the event of equipment failure or other problems.

◊ Use comparable equipment at different locations for easy exchange in case of failure.

◊ Support action on the recommendation of a National Research Council report (NRC, 2007) and University-National Oceanographic Laboratory System report (UNOLS, 2012) to develop research icebreaker capabilities.

◊ Improve the process for identifying and chartering small boats for use in coastal waters in Barrow and other coastal regions (both in Alaska and pan-Arctic).

◊ Explore possible acquisition of more specialized aircraft. This has been considered with respect to converting one or more of NSF's C-130s to long-range heavy-lift research aircraft mainly for Antarctic work. Other potentially suitable aircraft include the Grand Caravan, a turbo-prop aircraft already used in Alaska.

◊ Deploy logistics specialists in field camps to manage aspects of day-to-day life and safety, freeing time for researchers to do science instead of camp management.

◊ Enhance current research hubs to better support smaller, remote field campaigns and, especially for prominent terrestrial hubs, establish formal science advisory committees that can forecast and report logistic challenges and help devise appropriate solutions for sustained and effective research efforts.

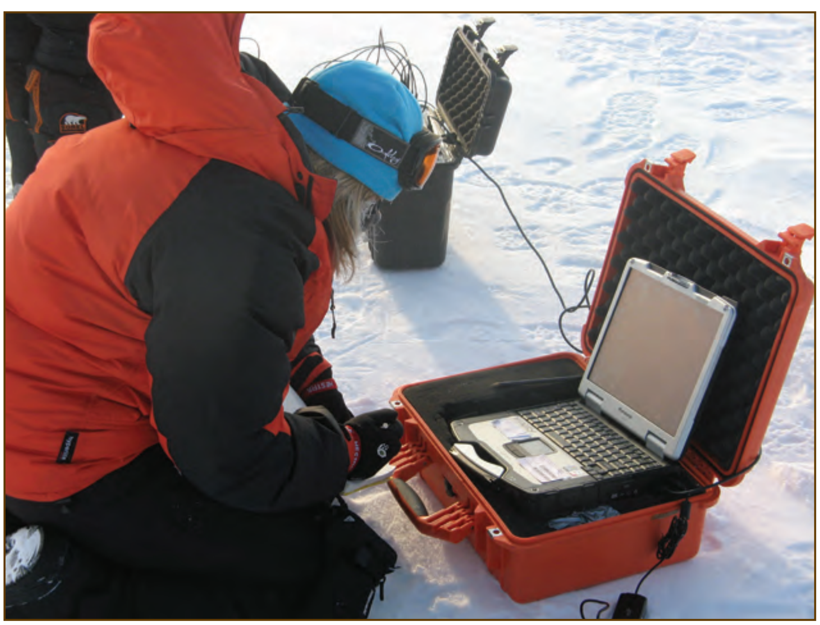
C-130 ready for take-off at Summit Station, Greenland. Photo by Jim Pottinger, courtesy of ARCUS.

2.2. Communications, Power, and Technology

> ***Aggressive advancements in infrastructure are required to meet the rapid increase in data volume and sophistication.***

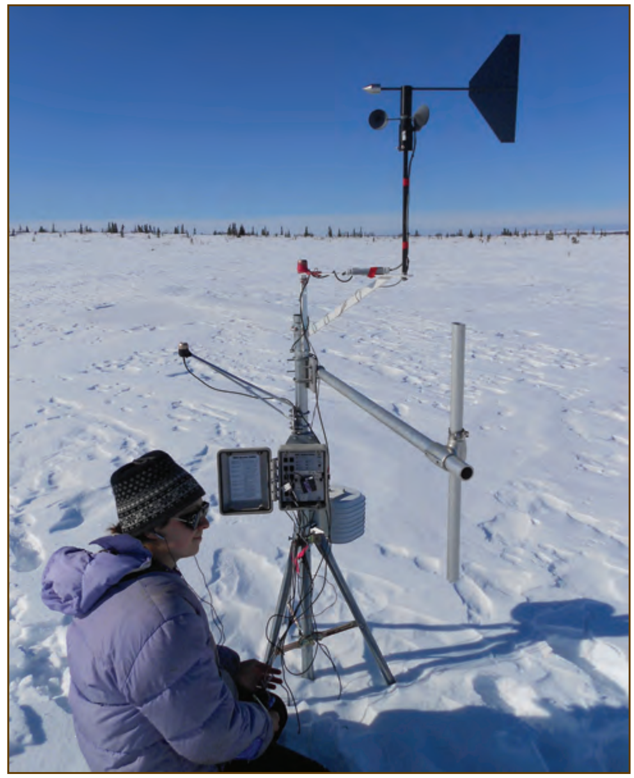
Innovations and demand for advanced communications, technology development, and electrical power present major challenges but also opportunities. As technological developments such as smart sensors and other cyber infrastructure advance, demand for both communication bandwidth and electrical power will increase against a backdrop of requirements for greener power generation and lower energy consumption.

An immediate challenge in the Arctic is the limited bandwidth, which is quickly maxed out by autonomous platforms, researchers with multiple digital devices, and potentially commercial industries as they expand in the Arctic. Satellite phone (e.g., Iridium) remains the only option in some situations, but depending on circumstances it can be expensive and limited. The bandwidth limitation is a serious issue and is already constraining options for some research. The RSL program needs to take advantage of any opportunities to increase bandwidth, such as partnering with the extractive industries that are increasing their activity in the Arctic and may finance improvements in the data transfer infrastructure. Canada is well along the path to installing fiber links to Inuvik, Whitehorse, and Yellowknife (DeMarban, 2013). Ultimately, the solution may require working with all stakeholders to convince commercial providers that the high demand justifies investment in infrastructure to increase bandwidth.



Holly Reay works on the computer in the field, near Barrow, Alaska. Photo by Betsy Wilkening, courtesy of ARCUS.

Innovations in sensor technologies and sampling platforms (e.g., gliders, autonomous buoys, unmanned aircraft systems) have had a tremendous impact on Arctic science over the past decade. An increase in the rate, density, and duration of deployments is expected as technologies are refined or further developed for field use (NRC, 2006). Changing scientific needs and expectations will create additional needs for such technology as new and improved systems are further developed, tested, and used. These advances will permit vastly greater coverage of the Arctic, but at the same time place additional demand on bandwidth.



Elizabeth Webb takes data from the HOBO weather station CiPEHR study site outside of Healy, Alaska. Photo by John Wood, courtesy of ARCUS.

Some sensor platforms requiring advanced engineering (for example, to ensure operation throughout the winter) could benefit from dedicated entities to develop, deploy, and manage these systems to make them more efficient and effective than individual researcher-controlled operations. Examples of similar modes of operation include the current deployment of differential global positioning systems (DGPS) and terrestrial LiDAR by UNAVCO and seismometers by Incorporated Research Institutions for Seismology (IRIS). Such an approach may offer opportunities to develop advanced sensors, such as those for biological and chemical phenomena that require complicated field-based calibration.

In many instances, the per-unit cost of sensor technologies is expected to decrease. Cost reductions are likely to come from using existing and new capacities for bulk-purchasing agreements and from enhanced collaboration with industry. It is important to note, however, that although the densities of autonomous sensors and sensor technologies will increase dramatically, this is not likely to (and should not) drive a decreased need for human presence in the field. Nonetheless, the addition of sensors will likely decrease the ecological footprint of sampling activities in the Arctic, but particular attention to increasing power delivery and reducing power needs will be needed to maximize this tradeoff.

We need to develop and improve autonomous instrumentation for observing the atmosphere. Challenges in this area (e.g., rime and precipitation) have severely limited observations in the past, but these issues can be addressed through engineering and more efficient energy use concepts.

Cyberinfrastructure will continue to play a key role in the advancement of Arctic science over the next decade. Multiple community efforts are underway to create a vision and implementation strategy for future cyberinfrastructure (European Single Sky ImPlementation, or ESSIP; EarthCube; etc.). These efforts recognize several principles that include the need to (1) embrace a distributed network of data, activities, and innovations rather than create an environment for "one-stop shopping"; (2) enhance interoperability between system components through the development and implementation of standards; and (3) engage and educate a new generation of scientists who are cyber-savvy. These principles align well with recommendations from a recent polar cyberinfrastructure workshop (Pundsack et al., 2013).

The increase in data collection by autonomous sensor platforms generates greater demands on cyberinfrastructure for archival and real-time visualization of data, along with the required supporting bandwidth. Access to previously collected data is critical for planning activities as well as for analysis, synthesis, and proposal activities. Thus, it is important to sustain efforts focused both on project-level information systems (e.g., Arctic Research Mapping Application or ARMAP, Alaska Ocean Observing System or AOOS) as well as data-oriented systems (e.g., Advanced Cooperative Arctic Data and Information Service or ACADIS, Geographic Information Network of Alaska or GINA, Polar Geospatial Center or PGC) and link these with common fields. Particular attention will need to

Hanna Axén, Dion Obermeyer, and John Whiting measure stream discharge on Linneelva. Isfjord Radio at Kapp Linne, Svalbard. Photo by Dan Frost, courtesy of ARCUS.

be given to supporting advanced discovery and access to quality assured, quality controlled scientific observations (e.g., International Arctic Systems for Observing the Atmosphere or IASOA). There is also a growing need for data to be made available in interactive websites where capacities for initial data discovery, mining, visualization, and fusion with other data are enhanced.

The electrical power demands of Arctic research are increasing for research hub infrastructure, field camps, and autonomous platforms, but researchers are rightfully under pressure to reduce their carbon footprint. Emissions from power generation are a direct impediment to certain types of atmospheric research. The deep cold and dark of winter still represents a major challenge for year-round operation of remote platforms. While progress in miniaturization will lower the power demands of some instrumentation, other instrumentation and experimental infrastructure will likely always have high electrical demands.

Opportunities in the area of power demand arise from the potential to lower a major cost of operation of facilities through more efficient use of power, such as waste heat capture, and through advances and reductions in costs of greener power such as solar and wind. Reductions in emissions or change to emission-free power generation will open opportunities for atmospheric research. Improved sensor efficiency, battery technology, and renewable power options for autonomous remote platforms will enable better seasonal coverage—possibly at lower cost.

Elizabeth Webb and John Krapek download data from the HOBO weather station at the CiPEHR research site at Eight Mile Lake, Healy, Alaska. Photo by Tom Lane, courtesy of ARCUS.

Recommendations for Section 2.2:

- ◊ Improve bandwidth through partnerships with the increasing commercial development occurring in the Arctic, both from extraction industries and possibly from the data service industry.
- ◊ Link with the commercial fiber-optic cable planned to pass through the Alaska region.
- ◊ Work with other NSF programs to sustain efforts for data archiving, focused both on project-level information systems and data-oriented systems, and link these where possible.
- ◊ Improve communication to the research community regarding logistics resources made available through bulk purchasing agreements.
- ◊ Maximize efficiency of current power generation on permanent facilities to minimize costs and associated consequences (emissions, fuel transport risks, etc.). When possible, costs and efficiencies should be viewed over the long term rather than on the basis of short term, year-to-year budget constraints.
- ◊ Continue to support workshops for logistics providers and researchers on current advances in remote power generation and data transmission.
- ◊ Cooperate with other branches within the NSF to help fund technology development.

This gneiss bedrock has been worked by high speed flow which carries lots of sediment. Kangerlussuaq, Greenland. Photo by Mark Buesing, courtesy of ARCUS.

3 Capacity Building

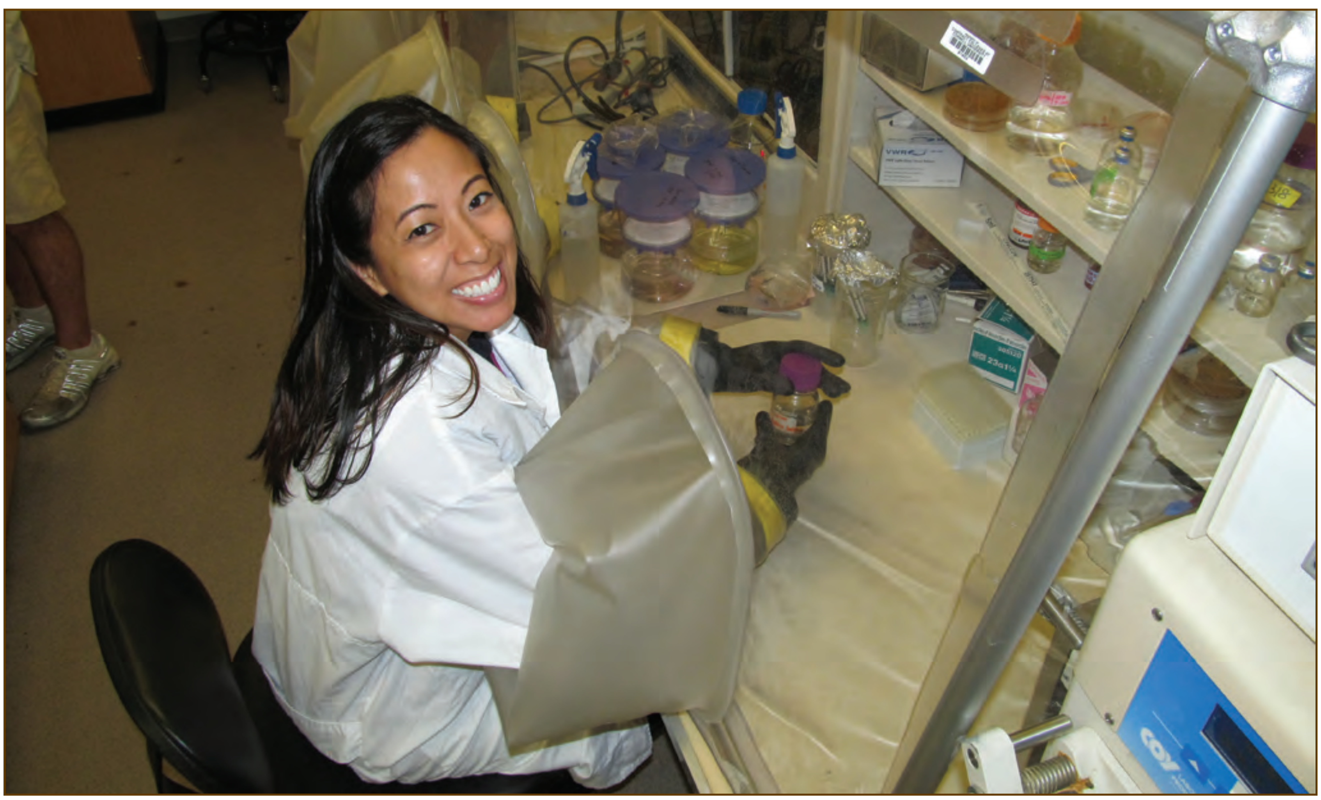
> ***Arctic logistics support only succeeds on the back of accumulated field experience and institutional knowledge.***

The importance of human capacity building was widely noted at the workshop. The vitality of future Arctic research depends on the ability of the research community to pass down knowledge and empower new generations to design, lead, and implement tomorrow's research endeavors. There is a particular need for long-term mentoring relationships between early career researchers and the experienced members of the community, serving a two-fold purpose: (1) to teach up-and-coming scientists the ropes of research, from proposal writing through team assessment and field safety all the way to project wrap-up; and (2) to ensure that institutional and historical knowledge is not lost upon the retirement of a single individual.

Such capabilities and institutional knowledge are particularly critical at this stage as Arctic research is becoming increasingly important and must adapt to the rapidly changing Arctic environment and stakeholder needs. While education, outreach, and training are all currently integrated into NSF Arctic science projects, more efforts should be made toward building human capacity within the Arctic logistics support community. Major components of this capacity building include clearly defining the roles of the logistics and research communities, clarifying the ways in which those roles should evolve, and ensuring the appropriate integration of research and logistics operations. Moreover, it is important to build a research logistics culture that, from the ground up, is founded on the principle that science needs are what drive logistics priorities.

To build and sustain a robust human capacity, more emphasis must be placed on recruiting, training, cultivating, and retaining logistics providers. Specific, specialized skills are an essential component of ongoing Arctic research support, particularly in extreme Arctic conditions and at remote sites such as ice camps. Just as NSF science projects must address broader impacts, NSF should consider similar requirements for logistics providers and contractors. Such impacts could take the form of enhanced development and training opportunities in order to promote and retain skilled future logistics providers. Retention is critical and there is no substitute for actual, on-the-ground experience in the Arctic. Special attention should be paid to making logistics-support positions long-term employment opportunities instead of temporary work assignments.

Similarly, capacity development is needed on the scientific side. There should be stronger support for scientific education and training opportunities built into the Arctic logistics support model. The value of these activities in the field should be recognized by logistics providers and factored into their operations plans. Supporting educational activities should be a key metric for evaluating logistics support, in addition to the common metrics of efficiency, fulfilling specific operational requirements, minimizing budgets, etc. Students and trainees are often less efficient in their field abilities, but the logistics structure must be designed to accommodate these critical developmental activities in the field. Lastly, it is imperative that logistics providers continue to offer field-training programs to enhance safety and prepare the next generation of scientists to develop plans and implement the field activities of the future.



Cristina Solis at the bio safety level 2 Angenent Lab in Ithaca, New York. Photo by Cristina Solis, courtesy of ARCUS.

Recommendations for Section 3:

- ◊ Explicitly designate some portion of the RSL and/or other NSF-program budgets for capacity-building activities (e.g., training, providing learning resources), both in support of future logistics providers and in providing field skills and experience to the science community.
- ◊ Structure logistics support in a way to promote and prioritize hands-on, in-the-field experience for students and trainees, rather than in a way that makes such opportunities difficult to attain.
- ◊ Strengthen outreach activities to draw potential new scientists and logistics providers.
- ◊ Logistics support training and documentation should start and end with statements that emphasize the concept that science needs drive logistics priorities.
- ◊ Established scientists need to mentor upcoming researchers through the process of doing good science, including the process of planning field campaigns.
- ◊ Foster training and mentoring relationships for early-career scientists that can be sustained over long periods of time—it takes many years to build the experience and knowledge to successfully plan and implement large field campaigns.
- ◊ Provide activities that foster information and knowledge sharing on best practices in Arctic research support and logistics (e.g., through websites, outreach).

Ice under pressure flows like pancake batter. Baffin Island, Canada. Photo by Mark Buesing, courtesy of ARCUS.

4 Opportunities for Improved Coordination of Resources

> ***We need to ensure we are using 100% of what we already have in place.***

Improved collaboration and coordination is needed to reduce duplication of effort in providing logistics, take full advantage of existing resources, and foster the highest quality science.

Coordination of logistics resources and services between partners operating at local, national, and international scales has greatly increased over the past decade. Continued progress will need to balance increasing governmental requirements for documented accountability with the flexibility required for meeting scientific needs, adapting to a changing Arctic, and using new logistics resources, partnerships, and technologies as these become available.

In this section, we examine specific opportunities that have the potential for improved coordination of resources, including international, interagency, and interdisciplinary collaborations as well as partnerships with local community and industry.

4.1. International Access and Collaboration

We support unimpeded access to all regions of the Arctic with clear mechanisms for coordination. We want improved international access and fewer administrative hurdles.

International coordination could be catalyzed through transnational governance, Arctic Council agreements, and improved intergovernmental partnering at all levels. Good examples include the International Network for Terrestrial Research and Monitoring in the Arctic (INTERACT; www.eu-interact.org) and IARPC (https://www.nsf.gov/geo/plr/arctic/iarpc/start.jsp). It is important to recognize that there are different models for successful logistics support in different areas due to variables such as access, international regulations, and research approaches.

Organizations such as IASC, the Association of Polar Early Career Scientists (APECS; http://apecs.is/), and the Arctic Council have greatly enhanced information exchange, planning, and interchange; ongoing efforts by these and other organizations may facilitate policies and procedures that will benefit national efforts. The U.S. has made significant advances in the development of capacities to forecast, track, and optimize logistics resources through software tools such as ARMAP (http://www.armap.org/). This technology and its underlying interoperability standards should be freely shared with other countries. An interesting new logistics model has been developed within the European Union–funded project INTERACT, which supports transnational access to more than sixty terrestrial field stations in the Arctic. Although the U.S. is represented by the partnership of the Barrow and Toolik Lake field stations, we need to expand U.S. funding opportunities to allow U.S. researchers free and easy access to other Arctic field stations and their associated long-term data.

Carrie Harris processes the day's collection. Kaktovik, Alaska. Photo by Jill Smith, courtesy of ARCUS.

Recommendations for Section 4.1:

- ◊ **Encourage scientists in Arctic nations to make measurements themselves but promote, where possible, common science objectives driving the research; i.e., each country funds its own scientists. This will be an important approach for field science in the Russian Arctic.**
- ◊ **The Forum of Arctic Research Operators (FARO; http://faro-arctic.org/) organizes funders to discuss where icebreakers are going; this could be expanded to work for broader coordination, including partnerships for use of non-U.S. icebreakers.**
- ◊ **Provide funds for rapid response opportunities for researcher salaries for participation in international science expeditions.**
- ◊ **Develop international agreements to alleviate costs and other issues (e.g., export agreements) that make it difficult to get science samples and gear into and out of the field. The current situation is a disincentive to international science.**
- ◊ **Enlist logistics providers' assistance in navigating the requirements for permitting; although researchers hold responsibility for adhering to proper permitting requirements, the research community needs more readily available information on various permitting processes.**
- ◊ **Develop mechanisms for international archival data exchange (e.g., bathymetric data) and shared satellite imagery, including international funding solicitations. This should include making current U.S. data sharing tools broadly available.**
- ◊ **Encourage forums where representatives from national science programs can come together for the free exchange of technology and ideas. An existing example would be the annual Polar Technology Conference (http://polartech.datatransport.org/).**
- ◊ **Explore U.S. partnerships with established international science programs (e.g., INTERACT; http://www.eu-interact.org/) to allow U.S. researchers improved access to data and field stations throughout the Arctic.**

The upcoming U.S. chairmanship of the Arctic Council (2015–2018) opens a window of opportunity to advance the recommendations above.

4.2. Interagency Cooperation

> ***Scientists will benefit from successful logistics coordination only if state and federal agencies—not just NSF—work together at the project, program, and budgetary levels.***

Nationally, there is a fundamental need to improve communication and exchange of knowledge both between and within state and federal agencies. IARPC recently released a five-year Arctic Research Plan (U.S. Executive Office, 2012) that outlines how the federal government will organize itself to coordinate studies to better understand and predict environmental changes in the Arctic. It provides a road map for unprecedented collaboration between agencies on high-impact research activities.

It is expected that NSF will coordinate closely with other agencies. To develop long-term solutions, however, there is a fundamental need for all agencies to use interoperable information systems to track agency activities and improve efficiencies in resource allocation and sharing, permitting, data collection, education and outreach, data archiving and documentation, and activity forecasting. For example, using and expanding the standards established by the Alaska Data Integration Working Group could enhance knowledge exchange between agencies.

Improved coordination and information sharing that targets a broader audience is also likely to enhance interaction with science efforts with foci greater than just the Arctic, such as NSF's National Ecologic Observatories Network (NEON), The U.S. Department of Energy's (DOE) Next Generation Ecosystem Experiment (NGEE), and NASA's Arctic Boreal Vulnerability Experiment (ABoVE). This has the potential to improve the Arctic science community's connection to national and global efforts and enhance the scientific merit and relevance of Arctic-centric research efforts.

Different agency science cultures lead to different logistics cultures (e.g., large coordinated experiments versus smaller independent projects). Mission-based agencies have research and operational logistics assets that could potentially be leveraged for research.

Recommendations for Section 4.2:

- ◊ Coordination, such as that through IARPC, should not stop at the committee/principal level. NSF program managers should more actively engage with the program managers of "mission-oriented" agencies (e.g., NASA, National Oceanic and Atmospheric Administration or NOAA, DOE) so that collaborative interdisciplinary science is promoted and financially supported. For example, NSF program managers could be more involved with the U.S. Global Change Research Program Carbon Cycle Interagency Working Group (CCIWG) and the North American Carbon Program; there are many other examples that could be identified.
- ◊ Use tools already in place for multiagency funding, such as the National Ocean Partnership Program.
- ◊ Summarize lessons learned from successful interagency cooperative efforts such as the Impacts of Climate on the Eco-Systems and Chemistry of the Arctic Pacific Environment project (ICESCAPE; https://www.espo.nasa.gov/icescape/) and Operation IceBridge (http://www.nasa.gov/mission_pages/icebridge).
- ◊ Identify lessons learned from the North Slope Science Initiative (NSSI; http://northslope.org/) efforts for industry, state, and federal cooperation.
- ◊ Build capacity within IARPC for information harvesting and canvassing for shared needs. Formalize the informal discussions that are ongoing between agencies, involve broader audiences for participation in these discussions, increase transparency, and address roadblocks (e.g., agency cost sharing).
- ◊ Convene an IARPC logistics implementation/collaboration team of interagency representatives and researchers to hold regular discussions about logistics needs, ideas, and progress.
- ◊ Build capacity for easier cost sharing and reimbursement among the agencies. For example, can a third-party entity play an expanded role in reducing the cost reimbursement roadblocks? (For example, Toolik is easy due to central administration at the University of Alaska Fairbanks, but Barrow is difficult because of multiple entry points through multiple agencies.)
- ◊ Consider military support for science: leverage science and operational support for science activities by military assets.
- ◊ Improve communication from federal agencies to the broader research communities.

4.3. Interdisciplinary Collaboration

> ***Significant and timely advancement in our understanding of the inherently complex Arctic system demands an active, ongoing commitment to fostering interdisciplinary collaborations.***

We must continue to promote interdisciplinary science through all aspects of research design and implementation. Interdisciplinary work should be conceived from the standpoint of research questions of common interest so that research objectives and activities are clearly integrated and embedded.

The optimal efficiency of the science planning and implementation "life cycle" for Arctic system science has historically been established via multidisciplinary conferences (e.g., Arctic System Science or ARCSS All-Hands meetings and the Arctic Forum), which are beyond the capacity of any one researcher or project to coordinate. In recent years these meetings have all but disappeared, and with them we have lost capacity for developing, showcasing, and reporting on shared scientific visions, community consensus, and forecasts of logistics needs, especially for complicated, large-scale efforts spanning multiple disciplines. This has arguably coincided with the science community making increasingly convincing arguments for improved interdisciplinarity and interagency cooperation. Other considerations relevant to the RSL program have the capacity to enhance the interdisciplinary and collaboration potential in Arctic science, including co-location of sensor deployments and design of housing and other station research facilities.

Dave Silverstone, Tim Godaire, and Karl Kreuta work on setting up a permanent meteorological station atop the Mount Hunter Ice Divide. Photo by Seth Campbell, courtesy of Ken Williams, courtesy of ARCUS.

Recommendations for Section 4.3:

◊ Rebuild the capacity for convening regular in-person all-hands science meetings within the operational capacities supported by the NSF Arctic Research Support and Logistics Program, including increased travel budgets for agency program officers and others.

◊ Reinforce and embed a culture for promoting interdisciplinary science in all RSL activities, including, for example, appropriate co-location of sensors, technological exchange and development, research infrastructure design that promotes collaboration, leveraging historically logistic-centric activities like traverses for science, and documentation and dispersion of planned and ongoing activities with other agencies and international counterparts. One suggestion would be to develop an RSL Arctic logistics calendar.

◊ Encourage the scientific community to propose interdisciplinary science and projects to funding agencies, either as full proposals or as supplement requests to current projects.

◊ Develop training programs and opportunities for interdisciplinary science.

◊ Funding agencies could offer place-based awards connected to existing or desired research and logistics hub locations that focus on interdisciplinary questions (e.g., land-ocean-atmosphere connections at Barrow or biophysical linkages in a Greenland fjord).

◊ Recognize and encourage the role that existing research stations and shared housing can have in fostering interdisciplinary exchange. The design of new infrastructure should promote cross-disciplinary encounters through architectural design practice that promotes interdisciplinarity.

◊ Coordinate field schedules to maximize opportunities for interdisciplinary work.

4.4. Partnerships

> ***Strategic partnerships are key to realizing logistic and economic efficiencies in support of Arctic research.***

Further integration of local communities into Arctic research support and logistics will provide opportunities to train, contribute to, and benefit from local community knowledge. Science activities have sometimes been viewed as a detriment to communities, as these activities are typically supported by outside logistics organizations and can have limited local interactions.

One means for better integrating science support activities into local communities, to the mutual benefit of both the science and the communities, is to formally engage local logistics experts as both service providers and technical support to maintain instrumentation. Long-term (multiyear contracts) commitments are highly preferable, as they indicate ongoing support from the science community. Local providers understand the local conditions, how best to manage them, how to minimize risk, and the availability and appropriate use of local resources. They are a means for better engaging extended communities, being an efficient conduit for outreach, and building community support for scientific research. This type of community integration can help science activities to positively contribute to local economies via employment opportunities and local commerce. All of these serve to foster an exchange of ideas with local communities, improve the general image of science research, and minimize community fatigue.

Additionally, researchers should initiate communication with local communities as early as possible. Rather than bringing locals into the conversation after the fact, we should be promoting face-to-face contact with the community prior to the development of a proposal, explaining to residents what the researchers want to learn. This opens the lines of respect and communication and may generate valuable input to help shape the proposal or yield ideas for easy add-on data collection that the community itself is interested in.

Another type of partnership that should be enhanced is that with private industries. With increased levels of resource extraction and other activities in the Arctic (more ships, airplanes, trucks), this provides an opportunity to expand Arctic observations. Arctic research agencies or programs could partner with, or encourage, private companies to include observational components to their planned activities that benefit both industry and science (e.g., planes and ships report conditions). Can we achieve 1% of industry budget for science?

Recommendations for Section 4.4:

- ◊ Embed community liaisons and centralize communication to ease confusion and avoid conflict with local subsistence efforts and traditions.
- ◊ Maintain and develop creative and ethical means for deployment of assets in more remote locations, as research expands into increasingly remote sites. Researchers can refer to the NSF document on conducting research in the Arctic (http://www.nsf.gov/geo/plr/arctic/conduct.jsp).
- ◊ Establish community-based interpretation centers and regional coordination of outreach, including coordination of social media materials.
- ◊ Both researchers and logistics providers should cultivate local and regional connections and formally engage local logistics providers.
- ◊ When and where possible, scientists should transfer responsibilities to local, subcontracted organizations, such as Ukpeaġvik Iñupiat Corporation's UMIAQ in Barrow. This kind of community integration is most effective when it is smaller scale. Large-scale infrastructure can be inefficient and requires a great deal of funding.
- ◊ Explore new partnerships with industry. For example, the Belgian Princess Elizabeth Station in Antarctica is the only 100% renewable-energy-powered scientific research station on the planet and was built largely through donations and support from private industry.

The CTD (conductivity, temperature, and depth instrument) at dusk. Aboard the USCGC Healy *on the Chukchi Sea. Photo by Andrea Skloss, courtesy of ARCUS.*

Stian Alesandrini carries equipment for the geology team. Cierva Point, Antarctica. Photo by Nell Herrmann, courtesy of ARCUS.

5 Summary and Next Steps

The Research Support and Logistics workshop was successful in providing guidance to develop a shared vision of, and recommendations for, future logistics support. The key themes that emerged from the workshop are:

- Science needs must drive logistics requirements—this was a fundamental premise to all discussions, even though the workshop purposely did not address what the science priorities should be.
- Research, and therefore logistics, needs to be Arctic-wide and year-round.
- Logistics capabilities need to be flexible and agile, and we need to take full advantage of existing capabilities, emerging technologies, and the desire and willingness of the next generation of researcher and logistician to learn and succeed.

The workshop process did not aim to prioritize the set of recommendations that emerged from discussions, as any prioritization would be dependent on discipline, geographic area, or agency perspective. There are, however, some recommendations that cut across those disciplinary, geographic, and organizational boundaries, such as those listed as capacity building (Section 3) and coordination (Section 4). The organizing committee recognizes that not all of the recommendations can be implemented by the NSF RSL program alone given mission and funding constraints; many will require and benefit from cooperation with other NSF programs and other agencies and organizations.

We also need to ensure a sustained and transparent process for communication among NSF, other agencies, the Arctic research community, and logistics providers. The effective implementation of the recommendations will require continued cooperation to ensure activities are responsive to science needs. These ongoing discussions can be facilitated by ad hoc working groups, topical workshops, and other communication tools (e.g., teleconferences, email lists, webpages).

The recommendations within this report, coupled with a process to continue the dialog about Arctic research support and logistics, will prepare us to meet the demand of a rapidly changing and increasingly important Arctic.

The Watson River flows out of the Russell Glacier in Greenland. Photo by Mark Buesing, courtesy of ARCUS.

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Appendix B
Workshop Agenda

Final Agenda

Sunday, 6 October 2013
Registration & workshop namebadge/materials pick-up available 6:00–8:00 pm, outside Gallery II Meeting Room.

Monday, 7 October 2013

8:30 am Opening plenary: introductory talks

- Welcome and purpose of the workshop from the workshop co-chairs (Jackie Richter-Menge)
- Comments from NSF (Jen Mercer)
- Comments from the Interagency Arctic Research Policy Committee (Sandra Starkweather)
- Science drivers of logistics needs; results of community survey (Jamie Morison)
- Brief review of community survey results (Matthew Shupe)
- Plan for the day and details for Break-out session I (Jackie Richter-Menge)

10:15 am Break

10:30 am Break-out session I: A shared vision of future logistics support (Break-out group leads TBD; groups will be pre-assigned)

- Group members introduce themselves/ice-breaker, review break-out group 'ground rules'
- Envision arctic field research 10 or 20 years from now in an ideal world (i.e., no funding constraints) – what does field research 'look like'?
- What logistics support is in place?
- How is the support delivered?
- How would it be the same or different from today?

12:00 pm Lunch (on your own)

1:15 pm Plenary: break-out group reports, discussion, the plan for Break-out session II

2:15 pm Break-out session II: Logistics needs for arctic domains: terrestrial, marine, ice sheets, atmosphere, social sciences)

- Introductions
- What's needed in the long term (10–20 years) do the best science in each domain? (from expensive, long-term investments to smaller investments or needs)
- Are there logistics limitations that are preventing the best science?
- What are the more immediate or small-scale needs?
- May need to start prioritizing needs

3:45 pm Report to plenary and discussion, begin to highlight common themes

5:00 pm Adjourn for day

Organizing Committee meets in evening

Tuesday, 8 October 2013

8:30 am Morning Plenary: Recap of yesterday, today's plans

9:00 am Break-out session III: Platforms (Participants can select which break-out group to join. Break as needed).

1. Alaska sector (includes Toolik, Barrow, other hubs, and remote locations)
2. Greenland sector (includes Summit and remote locations)
3. Marine operations (includes research ships, oceanographic studies, etc.)
4. Ice camps (short term and long term, shore fast)
5. Autonomous platforms in ocean, air, ice, and land (AUV, UAS, buoys, automated stations, satellites)

- Introductions
- What's needed in the long term (10-20 years) for each tool/platform to support the best science? (from expensive, long-term investments to smaller investments or needs)
- What are the more immediate or small-scale needs?
- May need to prioritize needs

11:00 am Report to plenary, discussion, and the plan for the afternoon

12:15 pm Lunch (on your own)

1:30 pm Break-out session IV: Cross-cutting issues (Break as needed.)

1. Interagency coordination (including public and public sectors)
2. International coordination
3. High-level coordination of field opportunities and assets (e.g. improved communication)

4. Capacity building (e.g., training new researchers and logistic providers)
5. Maximizing safety/minimizing risk

- Introductions (if needed)
- For each cross-cutting topic, what is the vision of the best-case scenario in 5-10 years?
- What specific steps or actions need to be done to achieve that vision?

3:30 pm Report to plenary and discussion

5:00 pm Adjourn for day

5:15-6:45 pm Reception at National Science Foundation Headquarters Atrium (4201 Wilson Boulevard, 1 block from hotel)

Wednesday, 9 October 2013

8:30 am Morning Plenary: Recap of yesterday and today's plans

9:00 am Break-out session V: Synthesis and prioritization of previous days' discussion, discussion of workshop products Groups to draft two items: 1) An "elevator speech" that sums up key recommendations 2) Draft table of contents for report

10:30 am Break

10:45 am Plenary discussion: final workshop recommendations and key points

11:45 am Wrap-up: plan for products, timeline, responsibilities

12:00 pm Workshop adjourns

Appendix C
Breakout Groups

Additional materials in the form of breakout group notes and presentations are available online, at http://www.arcus.org/logistics/2013-workshop/report. The breakout sessions were divided as follows:

Breakout Session #1: A Shared Vision of Future Logistics Support (six groups)

Breakout Session #2: Logistics Needs for Arctic Domains

- Terrestrial
- Marine
- Atmosphere
- Social Sciences
- Ice Sheets
- Coastal

Breakout Session #3: Platforms

- Alaska
- Marine
- Greenland
- Ice Camps
- Autonomous Platforms

Breakout Session #4: Cross-Cutting Issues

- Interagency Coordination
- International Coordination
- Field Opportunities and Assets
- Capacity Building
- Maximizing Safety and Minimizing Risk
- Interdisciplinary

Breakout Session #5: Synthesis and Prioritization (five groups)