Vision for the Canadian Arctic Research Initiative: Assessing the Opportunities

The International Expert Panel on Science Priorities for the Canadian Arctic Research Initiative

Council of Canadian Academies
Conseil des académies canadiennes

Science Advice in the Public Interest

VISION FOR THE CANADIAN ARCTIC RESEARCH INITIATIVE: ASSESSING THE OPPORTUNITIES

Report of the International Expert Panel on Science Priorities for the Canadian Arctic Research Initiative

THE COUNCIL OF CANADIAN ACADEMIES

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Elizabeth Dowdeswell
Chair, International Expert Panel on Science Priorities for the Canadian Arctic Research Initiative

Report Review

This report was reviewed in draft form by the three individuals listed below — selected by the Council of Canadian Academies for their diverse perspectives, areas of expertise, and experience in dealing with Northern issues.

The reviewers assessed the objectivity and quality of the report. Their submissions — which will remain confidential — were considered fully by the panel, and many of their suggestions were incorporated into the report. The reviewers were not asked to endorse the conclusions nor did they see the final draft of the report before its release. Responsibility for the final content of this report rests entirely with the authoring panel and the Council.

The Council wishes to thank the following individuals for their review of this report:

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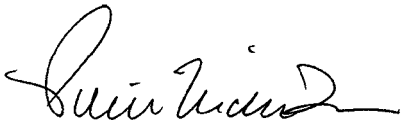

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Table of Contents

Executive Summary 2
Context for This Report 4
Mandate of the International Expert Panel 4
Creating New Opportunities and Responding to an International Obligation 5
Canada's Advantages in Arctic Science 5
Challenges Facing Canadian Arctic Science 7
Science Priorities for the Canadian Arctic Research Initiative 8
Additional Priority Themes 10
A New and Revitalized Approach to Arctic Science 12
Enabling Conditions for Success 13
Conclusions and Key Messages 16
Appendix A: Visioning Workshop report 18

Executive Summary

The Speech from the Throne of October 16, 2007, committed the Government of Canada to deliver a Northern Strategy, including the construction of a world-class arctic research station. Indian and Northern Affairs Canada, the lead federal department for this initiative, prepared a *Visioning Workshop* report on proposed scientific priorities for the station through consultation with stakeholders. The department then commissioned the Council of Canadian Academies to convene an independent international panel of experts to provide an external perspective on the key findings of the *Visioning Workshop* report. The International Expert Panel on Science Priorities for the Canadian Arctic Research Initiative (the panel) was asked to provide advice with respect to Canada's unique advantages and contributions to global polar science and to assess, from an international perspective, the science priorities proposed in the *Visioning Workshop* report.

The Canadian government's announcement to undertake the world-class Canadian Arctic Research Initiative (CARI), of which a research station(s) would be an integral component, creates an opportunity for Canada's arctic science to be on the cutting edge of arctic issues globally, including environmental science and resource development, in partnership with the peoples living in the Arctic. This commitment also responds to a clear international obligation to provide proactive stewardship of Canada's Arctic in view of its global environmental significance.

In considering the science program of the Canadian Arctic Research Initiative, Canada should build on its twin inherent advantages: (i) the rich variety of ecosystems that make up Canada's vast arctic terrain, and (ii) Canada's human capital, comprising its northern citizens together with its largely southern-based scientists and engineers. Taking into consideration these unique Canadian advantages, the panel considered the four science priorities proposed in the *Visioning Workshop* report: sustainable resource development; environmental science and stewardship; climate change; and healthy and sustainable communities. While sensible and

Figure 1

Photo provided courtesy of Sarah Zimmermann / Fisheries and Oceans Canada.

appropriate, the panel considers these to be themes rather than priorities. They are too general to provide practical direction over time for building a science program like the Canadian Arctic Research Initiative. Beyond the themes proposed, the panel recommends that "Observation and Monitoring" and "Technology" be recognized as additional themes that are significant in the Canadian context. In considering how to drill down to a more specific set of priorities, the panel agrees that CARI represents an outstanding opportunity to exploit those areas where Canada's unique advantages intersect with the rapidly emerging opportunities inherent in the six themes. While panel members offered examples of potential areas of focus, they consider it appropriate for Canadians to decide on their own precise arctic research priorities.

In reacting to the *Visioning Workshop* report, the panel considered the importance of defining a new approach to research and to identifying the key enabling conditions that are most likely to lead to long-term success for the Canadian Arctic Research Initiative. Integration, coordination and partnerships will be essential elements of a successful "CARI approach." The challenges of arctic research are too great for any one institution, country, discipline or stakeholder group to have success in going it alone. Key elements of the success of CARI are considered to be organizational flexibility, ability to attract talent, stable funding, access, data sharing, engaged governance, informed and transparent decision-making with respect to location and structure, and a plan for transition to sustain the momentum created by the International Polar Year.

KEY MESSAGES

The panel would highlight the following key messages from their deliberations to guide the next phase of development of the Canadian Arctic Research Initiative:

1. **Recognize Canada's international obligation with respect to arctic science.** From an international perspective, Canada's active development of, and participation in, a robust international arctic science program is a necessity. The obligation stems from Canada's position as steward of remarkable human and natural resources of crucial global importance. International arctic research efforts will not be successful without Canada's participation and, often, Canada's leadership.
2. **Seek synergy.** The design of the Canadian Arctic Research Initiative and its research programs should take into consideration the importance of creating a flexible environment that breaks down the silos of disciplines, methodologies, stakeholder interests and national approaches, and instead embraces an approach that seeks to find synergy among the efforts of all involved.
3. **Expand the definition of "cutting-edge" science.** Observation and long-term monitoring, together with the storage, presentation and analysis of the resulting data, are core research activities that enable science to move forward and predictions to be made. The activities of observation and monitoring are therefore an integral part of Canada's capacity to conduct cutting-edge arctic research.
4. **Assure sufficient long-term funding.** It is essential that sufficient, assured funds are provided to support ongoing operations of CARI infrastructure and programs. Inadequate operational funding to complement the investment of capital will cripple a leading-edge scientific program and jeopardize the long-term value of the Canadian Arctic Research Initiative.
5. **Engage in transparent decision-making from Day One.** Based on collective experience, the panel concluded that CARI will likely require a two-hub model with a logistical hub in a central, accessible location, as well as a scientific hub in an attractive and scientifically interesting area. However, it is essential to the long-term success of the initiative that there be a transparent decision-making process by which possible models and sites are considered and chosen.
6. **Start now.** To respond to fast-changing environmental and economic circumstances in the Arctic, new scientific knowledge is urgently needed. Moreover, it is critically important to maintain momentum throughout the roughly ten years from the end of the International Polar Year to the time when CARI facilities become fully operational. Therefore, while the Canadian Arctic Research Initiative is being more fully developed, key programs should be identified and supported from the outset. ■

Context for This Report

The Speech from the Throne of October 16, 2007, committed the Government of Canada to deliver a northern strategy, including the construction of a world-class arctic research station:

> *"…Our Government will bring forward an integrated northern strategy focused on strengthening Canada's sovereignty, protecting our environmental heritage, promoting economic and social development, and improving and devolving governance, so that northerners have greater control over their destinies…"*
>
> *"…Our Government will build a world-class arctic research station that will be on the cutting edge of arctic issues, including environmental science and resource development. This station will be built by Canadians, in Canada's Arctic, and it will be there to serve the world…."*

It is clear that the design of a Canadian Arctic Research Initiative and its associated facilities and science program must be driven by Canada's science priorities in the Arctic. As the lead department for this initiative, Indian and Northern Affairs Canada initiated a process to define those science priorities. As an initial step, this process included:

- the development of a series of synthesis papers to articulate Canada's arctic science needs and knowledge gaps;
- the hosting of a *Visioning Workshop* in Ottawa in May 2008 to engage a broad range of stakeholders and to distil the needs and challenges into a set of key priorities; and
- the production of a *Visioning Workshop* report to capture those priorities and the views expressed by the participating stakeholders.

Indian and Northern Affairs Canada then commissioned the Council of Canadian Academies to convene an independent International Expert Panel on Scientific Priorities for the Canadian Arctic Research Initiative to provide an external perspective on the findings contained in the report of the *Visioning Workshop*.

The panel was established by the Council of Canadian Academies and met in Helsinki, Finland, for an intensive two-day session in late July 2008. This report is the result of those deliberations, supplemented by subsequent electronic dialogue aimed at refining the panel's key observations. A draft of the panel's report was reviewed by three independent experts whose views were considered by the panel in drafting its final report.

OBSERVATION ON TERMINOLOGY

What is the nature of the new arctic research initiative being contemplated? The October 2007 Speech from the Throne refers to a "Canadian arctic research station" while the *Visioning Workshop* report refers more formally to a "Canadian High Arctic Research Station," or CHARS. The panel takes the view that the new initiative needs to encompass more than the High Arctic and should include the Canadian definition of the North for the purposes of the International Polar Year — the lands and waters north of the southern limit of discontinuous permafrost. The panel also believes that the new initiative needs to include much more than creation and operation of a research "station." Such terminology would imply a physical structure — or cluster of structures — in a single location. In view of the diversity of Canada's Arctic and the breadth of the appropriate research agenda — as well as for other reasons addressed later in this report — the panel believes that the new initiative must be conceived broadly from the outset. Accordingly it is recommended that the term "Canadian Arctic Research Initiative (CARI)" be used.

Mandate of the International Expert Panel

The report of the *Visioning Workshop* (Annex 1) was the key reference document provided to the International Expert Panel on Science Priorities for the Canadian Arctic Research Initiative. This report proposes four scientific priorities for CARI with technology as a cross-cutting theme. The four identified priorities were:

- sustainable resource development;
- environmental science and stewardship;
- climate change; and
- healthy and sustainable communities.

The panel was asked to assess the priorities identified in the report of the *Visioning Workshop* and to comment on the extent to which these priorities articulate Canada's global advantages in terms of arctic science. More specifically, the panel was asked to consider the following questions:

- What is Canada's unique advantage and contribution to global polar science?
- Are the proposed priorities the right ones for Canada in order to respond to pressing issues and challenges?
- What are the sub-categories for each priority where Canada should focus?

The panel was asked to take a broad interpretation of science so as to include:

- the natural, physical and engineering sciences, health and life sciences, and economic and social sciences; and
- the full process from determining the questions to carrying out the science (through observation and monitoring, research, and modelling and prediction), to applying and disseminating the findings of that science.

Also implicit in the terms of reference was the importance of incorporating traditional knowledge and ways of knowing of northern peoples into the science program of the Canadian Arctic Research Initiative.

While not specifically stated in the panel's terms of reference, in responding to the content of the report of the *Visioning Workshop* the panel also considered:

- the importance of how the Canadian Arctic Research Initiative is conceptualized and how the approach taken captures inherent opportunities for integration, coordination and interdisciplinarity;
- the importance of an arctic science and technology program that is broadly defined across the humanities, the social sciences, and the natural, engineering and health sciences; and
- the key enabling conditions that are most likely to lead to long-term success for CARI.

Creating New Opportunities and Responding to an International Obligation

The Canadian government's commitment to undertake a world-class Canadian Arctic Research Initiative — of which a research station(s) would be a cornerstone — creates an opportunity for Canada's arctic science to be on the cutting-edge of arctic issues globally, including environmental science and resource development, in partnership with the peoples living in the Arctic. This commitment also responds to a clear international obligation to provide proactive stewardship of Canada's Arctic. The vast geographical extent of the Canadian Arctic — its land, seas, ice and atmosphere — is remarkable for its ecological diversity. It contains many of the Arctic's different types of ecosystems, and in relative terms, represents a large part of the total circumpolar Arctic.

Canada's Arctic is often mistakenly perceived as isolated and remote, but this view is obsolete. The Arctic and sub-Arctic are tightly connected to other parts of Canada and the rest of the globe. All of the sciences illuminate the nature, mechanisms and extent of these global connections. Vast energy flows in the atmosphere and the oceans link the climate of Canada to distant locations in the southern hemisphere that then reverberate to impact directly on the weather and ecology of Canada. New little-known chemical contaminants emitted into the atmosphere thousands of kilometres away accumulate in the Arctic and enter human and animal food chains. Canada's northern peoples occupy a vital place in the stewardship, security and identity of the nation as a whole. Canada's original economic development owes much to northern activity — the fur trade, whaling and mining — which created global interdependencies. And once again, the future economic and environmental welfare of Canadians in southern Canada promises to be significantly affected by the development of arctic resources.

Science carried out in the Arctic has therefore entered a new phase where it tells us about some of Canada's most fundamental relationships with the rest of the globe. Without deeper knowledge of Canada's Arctic, understanding the Earth's atmospheric, oceanographic and life systems is severely hindered, and in some key research areas, remains out of reach. From an international perspective, Canada's active development of, and participation in, a robust international arctic science program is no longer a choice but, indeed, a necessity. It is an obligation that stems from Canada's position as steward of a remarkable global resource.

Canada's Advantages in Arctic Science

Canada's unique advantages with respect to arctic science offer an opportunity to make major contributions to the global and circumpolar research communities. Canada offers the potential to further understand regional and sub-regional processes and long-term conditions, and their relationships to global-scale systems. Such are these advantages that Canada's absence from international partnerships severely hinders, or in some cases makes impossible, adequate knowledge of the circumpolar and global environment.

The panel agreed with the conclusion of the *Visioning Workshop* report that Canada's two principal advantages with respect to arctic science, in an international context, derive from:

1. Canada's vast geographical extent — meaning the absolute size and ecological diversity of the Canadian Arctic and its relative size, spanning a substantial part of the circumpolar Arctic; and
2. Canada's human capital comprising the knowledge base of northern inhabitants, the majority of whom are indigenous, and its excellent scientists and engineers, based primarily in southern universities or within government.

The panel agreed that the new Canadian Arctic Research Initiative must make the most of these unique advantages. Before considering the priorities as outlined in the report of the *Visioning Workshop*, the panel deliberated on potential research foci, which flow naturally from these advantages. While not intended to be exhaustive, the list of topics in Box 1 illustrates the depth of potential that exists.

BOX 1

It is the panel's view that meaningful progress with respect to cutting-edge arctic issues will require the effort of experts across the spectrum of scientific disciplines (social, behavioural, life, natural and engineering sciences) in concert with engagement of northern citizens and communities. Expanding on the particular Canadian advantages in this regard that could be further developed through the Canadian Arctic Research Initiative, the panel observed the following:

- The Canadian Arctic provides a vast and rich set of ecosystems through which to understand the responses of ecosystems and societies to climate change, including aspects of resilience. In this regard, there is significant and unique potential to draw on the research and observing traditions of Canada's arctic expertise — from the natural sciences, social sciences and humanities, as well as the indigenous knowledge traditions of northern peoples.
- Northern citizens have an innovative role to play in new partnerships to develop platforms and methods of long-term, community-based, environmental monitoring. Traditional knowledge, including indigenous languages, provides cultural tools uniquely suited to making precise observations for year-round monitoring of their arctic ecosystems. That knowledge itself is of inherent value and represents a research advantage in its own right.
- Indigenous languages are inherently valuable to northern peoples. They are endangered yet crucial to the vitality of their culture and are an integral part of Canada's human advantage in the Arctic. They represent a research priority in their own right.
- Research into, and application of, participatory approaches in the Canadian Arctic have made a contribution domestically and internationally to setting standards in the management of research projects and should continue.
- The position, diversity and historical context of development in Canada's Arctic provide an opportunity to study economic, social and political processes that have broad relevance around the globe.
- The Canadian social sciences and humanities community is well positioned to engage in interdisciplinary approaches to understanding how societies like those in the Arctic are being transformed as part of larger-scale phenomena — e.g., globalization, urbanization and migration, new gender roles and political self-determination — that are affecting many parts of the globe.
- The geographical position of Canada's Arctic means that it possesses several crucial locations for identifying new persistent organic pollutants and metals being introduced into the global system and for monitoring known contaminants. Currently Alert, in Nunavut, is the only location in arctic North America where this monitoring is conducted.
- The Canadian Arctic affords an opportunity to study the storage and bioaccumulation/bioaggregation of pollutants in the different levels of the food chain, moving beyond atmospheric measures.
- Canadian arctic science can provide essential baseline data for environmental processes against which to measure and assess potential and actual impact of resource development. Baseline data are crucial for developing evidence-based environmental regulations.
- Freshwater ecology studies at northern research stations provided embryonic research that helped inspire the Canadian-led "Barcode of Life" project that, through international partnerships, is sequencing the DNA of all living plants and animals.
- Canada occupies a strategic position for researching and monitoring interconnections and energy flows between the Arctic, Atlantic and Pacific oceans including: atmospheric and oceanic circulation; species migration; nutrient transport; and movement of resources and capital.
- The maze of channels in the Arctic Archipelago affords a unique setting to study coastal change. Canada may be the last country with land (its northern islands) in contact with multi-year ice.
- Canada has the expertise to develop new knowledge about permafrost both on land and under the sea — an advantage for studying greenhouse gas emissions, pipeline technologies, building design and construction, and wave erosion impact on coastlines where the sea ice is retreating.
- Canada's mainland Arctic hosts some of the world's largest storages of organic soil carbon. More than fifty gigatons of carbon are stored in sub-arctic and arctic peatlands, of which a large proportion is associated with permafrost melting — making it extremely sensitive to climate change. This geographical advantage is complemented with expertise in monitoring of greenhouse gas exchanges between land and atmosphere.
- The huge extent of the Canadian low arctic land mass positions Canada to provide a higher standard of atmospheric monitoring free from "marine signal" interference experienced by stations close to the oceans. This is a unique advantage for monitoring atmospheric effects of melting permafrost and associated greenhouse gas releases.
- Canada has world-class capacity to conduct studies related to solar wind and the aurora — knowledge that is important to give early warnings of solar storms that can severely impact technological systems such as satellite communication, GPS navigation and electrical power grids.

Challenges Facing Canadian Arctic Science

Notwithstanding Canada's considerable advantages and potential, there exist some significant Canadian challenges. A failure to take account of these could imperil the success of the Canadian Arctic Research Initiative. The panel observed that:

- There are many stakeholders and interests at play in Canada's North, making it challenging to reach consensus on approaches and priorities. In the context of the Canadian Arctic Research Initiative, this means that agreeing on the creation and location of facilities requires solutions that respond to a variety of contrasting interests, approaches, and priorities.
- Many of Canada's existing northern research facilities have either closed or deteriorated to such an extent that they now require urgent repairs and revitalization. The synthesis paper by the Canadian Polar Commission gives many examples of work that needs to be done immediately to revitalize existing facilities so that high-quality arctic research can continue in Canada. These repairs will need to be undertaken as soon as possible, in parallel with the creation of CARI, if Canada is to immediately improve its support for research in priority areas.
- Access and maintenance costs faced by scientists doing research in the Arctic are substantially higher than those experienced in other regions, a challenge that can deter potential participants and hinder the development of Canada's arctic knowledge base if not taken into account through strategic funding allocations by government and research councils — e.g., these allocations might include targeted research subsidies and travel grants for northern researchers.
- Currently, the availability of broadband in Canada's Arctic is far less extensive than in some other parts of the Arctic and certainly less than is required for the new scale of research recommended by the panel. The pricing structure of broadband is important to consider in the research context. Affordable broadband communications in Canada's northern territories will be an essential component of any future distributed observation system, as well as of the region's economic development. Since

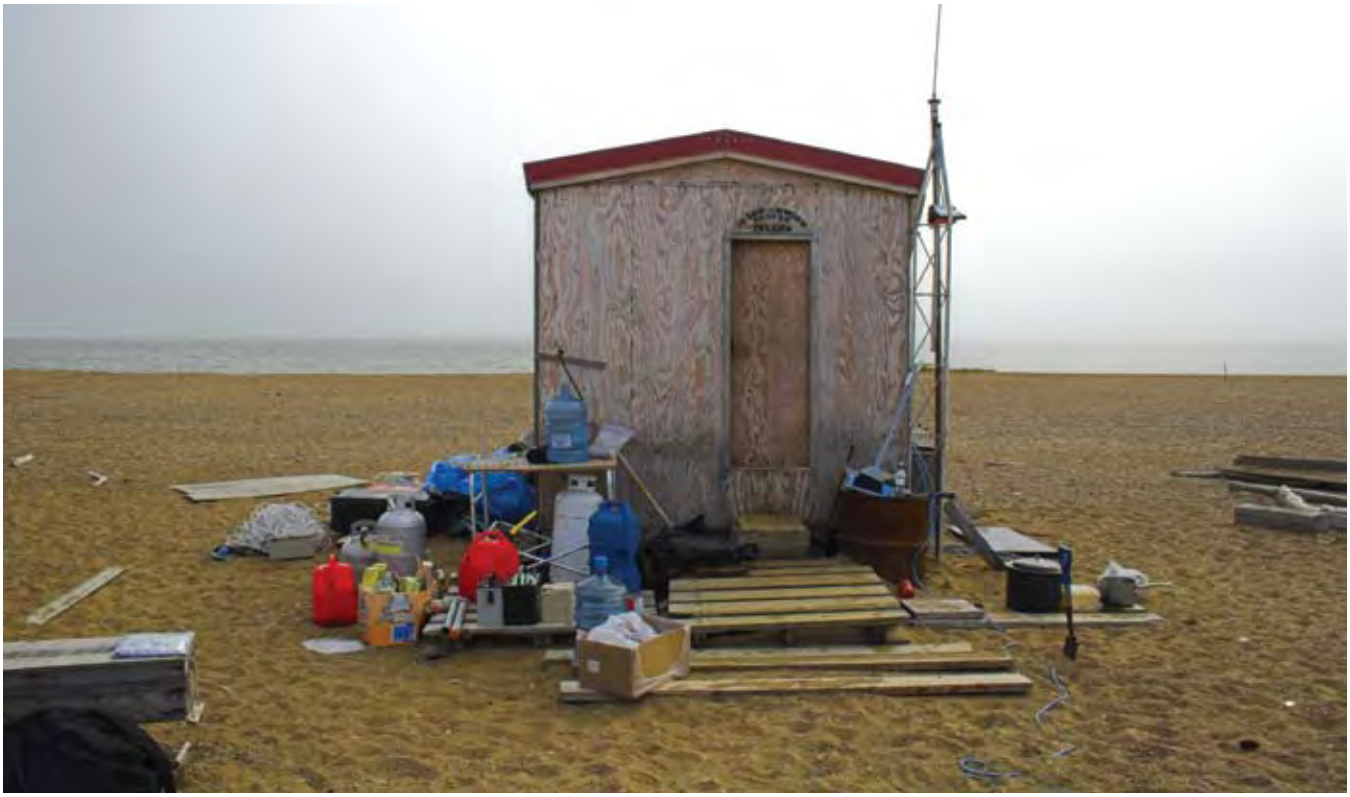

Figure 2

Photo provided courtesy of shutterstock.com.

wireless communications — e.g., via microwave and satellite — is an area where Canada has traditionally been a world leader, there is an opportunity in the contemporary Arctic to further develop and apply Canada's capabilities.

- Canada's northern citizens need access to publicly funded research to inform public policy discussions. Therefore, the Canadian Arctic Research Initiative needs to help to build the capacity to allow meaningful and constructive collaboration in the setting of community priorities for research, particularly as new models of governance evolve.

Science Priorities for the Canadian Arctic Research Initiative

The report of the *Visioning Workshop* proposed four scientific priorities, with technology as a cross-cutting theme. The four identified priorities are:

- sustainable resource development;
- environmental science and stewardship;
- climate change; and
- healthy and sustainable communities.

The panel would make four general observations with respect to these thematic priorities.

1) The four themes, while sensible and appropriate, are too general to provide practical direction over time for building a science initiative like the Canadian Arctic Research Initiative. The question remains how to map these four themes onto a concrete strategy and design for CARI in such a way that is inclusive and builds on Canada's recent demonstration of leadership in arctic science to fulfil the objectives of its northern strategy.

2) In the panel's opinion, and for reasons elaborated under "Additional Priority Themes," the group of thematic priorities should be augmented to include "Observation and Monitoring" and "Technology" with the latter treated as a theme in its own right and not simply as a cross-cutting theme.

3) The themes mainly reflect the natural and biomedical sciences. The panel recognizes the need for significant new research in the social sciences and humanities (including law and ethics). These disciplines are recognized by the "humanities and social sciences" sixth theme in the International Polar Year, a theme that Canada has championed. The humanities and social sciences are presented within the four themes of the *Visioning Workshop* report as practical methods to further the understanding of community issues, rather than being also seen as fields for research in their own right.

4) It is not possible for the panel to recommend priorities among the four proposed themes. The themes are interrelated, and where one stands in terms of priorities will depend on one's perspective and objectives. Moreover, it is not appropriate at this time for the panel to advise on the balance among the four research themes. The chosen balance is a decision that Canada has to make. In fact, the design and location(s) of CARI facilities will heavily influence the actual balance among the themes in practice. For now, the panel would give the four themes equal weight and offers the following observations on each.

CLIMATE CHANGE

Climate change is now the overarching issue that is framing how the Arctic, as a whole, is understood in its relationships with the rest of the globe.

- It is crucial to understand the interconnections of the atmosphere, cryosphere, biological, marine and terrestrial spheres. Scientists have become aware that each of these spheres is part of an inseparable, interacting whole. The impact of climate change on arctic carbon cycles — particularly the release of methane from melting permafrost — has major implications for ocean and atmospheric circulation worldwide since the dynamics are driven by gradients (i.e., differences of temperature, pressure, density or chemistry) between the Arctic and the tropics.
- The interdisciplinary systems science of biogeochemistry, involving the scientific study of the chemical, physical, geological and biological processes and reactions that govern the composition of the natural environment, as well as the cycles of matter and energy that transport the Earth's chemical components, will become increasingly important as we explore beyond the carbon cycle.
- Research on the resilience of arctic and sub-arctic ecosystems and on related policy strategies for arctic societies facing the impacts of climate change are areas of high priority, particularly given the need to understand and measure the dynamics of systems in which the pace of change is accelerating.
- The development of "down-scaled" models capable of accurate regional predictions based on the measurement of many variables across the full range of the Canadian North will require knowledge of the physical and biological mechanisms that modulate the overall trend of climate change from one region of the Arctic to another. Subsequent work to incorporate these mechanisms into

regional models will lead to a better understanding of how climate change can impact ecosystems across the region and will greatly enhance the capability of northern citizens to respond.

- Climate change has the potential to alter the prevalence and severity of extreme events such as droughts, floods, storms and heat waves. Developing an understanding of our vulnerabilities to such events and developing the capacity to predict their likely human health and environmental consequences warrant particular attention.
- An important impact of climate change will be the changing nature of Canada's arctic waterways, particularly the Northwest Passage. Knowledge of arctic marine areas, in general, remains very poor, particularly the linkages among seabed topography where we have small-scale knowledge, ocean currents, sea ice movements and adaptive responses of marine ecosystems.

ENVIRONMENTAL SCIENCE AND STEWARDSHIP

The panel recommends expansion of the list of sub-topics included in the report of the *Visioning Workshop*, with particular attention to the inclusion of research elements related to the biosphere and to advancing stewardship.

- The interaction and coupling mechanisms between the biosphere and the physical environment are emerging as an important area of research in order to understand how changes in one sphere can create changes in the other, including impacts on the coupling mechanisms themselves. Modelling of these interactions has been increasingly important in quantifying linkages among sub-systems, and is beginning to generate predictions against which hypotheses can be tested.
- Greater thought needs to be given to how stewardship can be informed by research in certain fields beyond environmental science, *per se* — for example, law, traditional knowledge and ethics. The application of maritime law to the Arctic is an area where Canada has considerable expertise, but a much deeper understanding is required in areas of potentially overlapping jurisdictions such as the *United Nations Convention on the Law of the Sea*, environmental law, land claims agreements and human rights law.
- The concept of "co-management" with local inhabitants and with northern governments is relevant to the management and conduct of research, particularly as it relates to environmental stewardship. As an example, when scientists studied the toxicology of tranquilizer chemicals in polar bears, they initially focused on the tissues most directly affected, rather than studying the tissues actually eaten by Northerners.

SUSTAINABLE RESOURCE DEVELOPMENT

The drive to develop resources in the Arctic is escalating. Rising commodity prices present pressing and complex challenges to the arctic region, which represents forty per cent of the nation's land mass and contains fragile ecosystems inhabited by predominantly northern Aboriginal peoples. As one example, the recent boom in diamond production has made Canada the world's third largest producer, contributing significantly to the nation's gross domestic product. With the potential for many more billions from recoverable gas and light crude, Canada must rapidly develop a knowledge base to support responsible development. At the heart of this priority is the use of science to develop frameworks that produce "win-win" outcomes where sustainable livelihoods and the integrity of ecosystems are protected by identifying clear measures of the benefits and losses in the harvesting or extraction of renewable and non-renewable resources.

- Excellence in the development of frameworks for regulating the use of renewable resources and the extraction of non-renewable resources is an expected role for Canada and directly reflects Canada's international obligation as steward of a vast proportion of the Arctic.
- High-quality, science-based evidence is needed to design effective regulations. Therefore, there is an urgent need to establish environmental and socio-cultural baseline information to support development of frameworks for environmental impact assessments and strategic environmental assessments against which the potential and actual cumulative impacts of development activities can be measured and judged. Linking local evaluations to build a regional-scale set of baselines for the Canadian Arctic is a priority for all stakeholders (including industry) in order to establish proper regulatory regimes.
- The linkages between the priorities of resource development and of healthy and sustainable communities have not been fully explored. The sub-topics listed in the *Visioning Workshop* report make no mention of living resources (fisheries, mammals, plants, etc.), which are vitally important elements in the development equation, as is the need to protect them for sustainable livelihoods in the Arctic, including through eco-tourism.
- Resource development raises important ethical issues of consequence for sustaining the integrity of northern societies and ecosystems. For example, an understanding

of how inherent values ascribed to ecosystems are compatible (or incompatible) with valuations based on traditional use or commodification, is a complex issue that requires further legal and philosophical research.

HEALTHY AND SUSTAINABLE COMMUNITIES

The indigenous populations in Canada's North are, in effect, "sentinels." The direct and indirect impacts of climate change and resource development on their communities is clearly and visibly pronounced. It is therefore crucial that indigenous communities are partners in the design and conduct of research, particularly research related to individual and community health.

- There is a particular need for sustained long-term monitoring and surveillance of key health indicators across northern communities.
- Research capacity is needed to continue to develop a model of health research that extends from the "lab bench to bedside to community."
- There will be a need for circumpolar cooperation in carrying out research on healthy communities to learn from the successes of health policies and health-care delivery in other countries.
- The sub-topics listed in the *Visioning Workshop* report omit a number of important topics that the panel believes could be further developed within this theme. Areas of particular note are: community resilience and vulnerability (including linkages to mental health); economic analyses and operational research on health-care delivery systems; impacts of development, modernization, cultural change and climate change on health; ecology of infectious diseases in an arctic context; bioaccumulation of contaminants in the food chain; and paleontology to understand the historic development of communities.

Additional Priority Themes

The panel believes that the four proposed thematic priorities do not take full advantage of Canada's opportunities and do not fully respond to Canada's international obligations with respect to arctic science. The panel therefore suggests the inclusion of two further themes to create a more complete program for the Canadian Arctic Research Initiative.

OBSERVATION AND MONITORING

"Observation and Monitoring" is an indispensable core activity for building our knowledge base, understanding the environment, exercising stewardship and managing resource development.

The panel therefore recommends that "Observation and Monitoring" be explicitly recognized as an additional thematic priority in its own right, and that the design of the Canadian Arctic Research Initiative take into account the need to establish the means to regularly collect and monitor baseline data over time and across geography. Observation, monitoring, data collection and storage, analysis, modelling, and prediction

Figure 3

Photo provided courtesy of ArcticNet.

are core activities and are an integral part of Canada's capacity to conduct cutting-edge arctic research.

There is growing international acceptance that long-term monitoring of environmental phenomena is an indispensable core activity for understanding and managing the global environment. Only long-term monitoring can provide the disparate kinds of data needed to gain a systems understanding of climate and environmental change. These data, analyzed through computer modelling, provide the only way to link together all the contributing phenomena in order to develop an understanding of these complex systems.

Additionally, the data produced from long-term monitoring programs are essential building blocks for the kind of robust, evidence-based, regulatory regime that can support sustainable resource development in a highly sensitive environment. Canada is already party to a number of international efforts and Canada's commitment in this regard will need to be honoured over a long period. Currently, Canada lags behind other high-latitude countries in the scope, density and continuity of its environmental and geophysical monitoring networks in the Arctic, and this is preventing Canada from meeting accepted international standards such as those of the World Meteorological Organization.

Organizing fine-grain comprehensive observations through fieldwork and remote observation at the level of ecosystems will enable a new approach to the elucidation of many scientific problems. Building a picture of arctic ecosystems can begin to be organized from the bottom up instead of the traditional top down. This offers prospects for identifying environmental mechanisms and interactions at smaller scales that are most relevant to problems of forecasting, navigation, environmental assessment and adaptive resilience. Progress in many of the priority areas identified by the panel will depend on Canada's arctic science shifting to this scale of observation.

The panel therefore believes that a commitment to observation and monitoring as a core component of the mandate of the Canadian Arctic Research Initiative will reap great benefits both scientifically and in the service of broad human and environmental objectives. The technical challenge is to extend scientific coverage:

- from summer-only to year round;
- from short-term projects to long-term monitoring; and
- from geographically localized to spatially distributed across Canada's Arctic and sub-Arctic to provide coverage of all ecosystem types and societies.

Monitoring can increasingly be done using autonomous instruments equipped with telemetry devices that require only occasional human tending. Instrumentation and communications are important areas for research and development underpinning the development of new technologies for environmental monitoring.

TECHNOLOGY

The panel recommends that "Technology" be recognized explicitly as an additional thematic priority, rather than as a "supportive" cross-cutting theme. Technologies are crucial components in transforming and monitoring natural landscapes and the built environment. In the context of the Arctic, making progress in the other theme areas will depend in part on whether Canada has access to, or itself develops, the capabilities of precision instrument design, observation and data analysis and the communications technologies required to develop research platforms and information exchange on a level that currently does not exist in any country. This heralds a new opportunity to build collaborations among scientists, engineers, and northern citizens.

Currently, for example, remote-sensing developments and autonomous technologies (e.g., drones) are needed to create new data collection platforms. High specification broadband communications are essential for next-generation telemetry instrumentation. Economic development for northern citizens and provision of tele-health services would also be well served by such system improvements, providing secondary benefits.

- Monitoring technologies, as noted in the previous section, are continually developing and will enable entirely new kinds of measurements. These developments will generate very large data volumes and create the need for advanced means of organizing, documenting and analyzing data (e.g., data mining).
- The harnessing of Canada's strength in space-based, autonomous and remote-sensing technologies should represent an important asset for Canadian Arctic Research Initiative. Developing northern communications infrastructure is a priority for coordinating and carrying out northern science, as well as for the development of communities, expansion of health-care options and emergence of strong economies for northern societies.
- Further development of technology for building virtual organizations with the capacity to interconnect scientists and instrumentation distributed throughout the vast Canadian North (and internationally) can pay large dividends in terms of research productivity.
- Engineering and architecture projects focused on the arctic environment have the potential to make great

contributions to the safety and reliability of all aspects of human endeavour including responses to climate change, town planning, housing design, permafrost stability, water and air quality, etc.

- Technologies to support the safe transport of oil and gas in the Arctic will be key to environmentally responsible development. Canada urgently needs to develop a response capacity to deal with oil spills and other forms of toxic environmental contamination in the arctic context.
- The technology of "biomimicry" — the imitation of structures from the natural world to develop analogous technologies for human use — may represent an important source of innovation particularly well suited to northern circumstances.

A New and Revitalized Approach to Arctic Science

The panel, having considered the "what" of Canada's advantages and potential science priorities, deliberated on "how" the Canadian Arctic Research Initiative could be conceptualized and how the approach taken could capture inherent opportunities for integration, coordination and interdisciplinarity.

CREATING SYNERGY THROUGH INTEGRATION

The design of the Canadian Arctic Research Initiative and its research programs should take into consideration the importance of creating an environment that is conducive to breaking down the traditional silos that act as barriers to the integration of research efforts. Historically, research has often been fragmented along the lines of nations, disciplines, methodologies and themes. Recognizing the aspirations and research goals of all stakeholders, CARI can seek to find synergy among the efforts of all involved.

The right mix of people, in a shared environment and with a common goal, can be a powerful combination. Integration in science to produce cross-fertilization and exchange of ideas needs to be approached with the aim of linking research traditions rather than seeking a seamless unity. The linking of atmospheric chemistry and oceanography in the 1990s is a good example of two fields that needed to come together, but required considerable work to do so. The sharing of knowledge between field scientists and indigenous hunters, working closely together for decades, is another excellent example of integration. In practice, bringing researchers and other stakeholders to work side by side — in a research institute, through exchanges or colloquia, or in the field to explore the interstices between their disciplines and ways of thinking — can lead to new kinds of conversations, approaches and discoveries. The great challenge in such work is to seek common ground for integration, without losing the specific values and norms that lend credibility to different disciplines and approaches.

NATIONAL COORDINATION

The project basis of Canadian arctic science means that many research efforts are linked through individual efforts nationally and internationally in heterogeneous ways that lack national coordination. The Canadian Arctic Research Initiative presents an opportunity to create a national-scale body of knowledge that will enable Canadian arctic research to be shared far more widely among researchers, as well as with the public. The intent of the initiative is not to replace existing structures and linkages but to build on them. Different stakeholders will assign different priorities to research problems at different times, some more driven by national priorities than others. A national institution like the Canadian Arctic Research Initiative will find ways to assist in the identification and implementation of certain long-lasting, core programs of research. Fostering a sense of ownership among stakeholders through up-front involvement in priority-setting is crucial. The panel would also emphasize the importance of supporting some "uncoordinated" research — that is, there must be opportunities to pursue "blue sky" science with promise but with unanticipated outcomes.

FAIR PARTNERSHIPS

Northern citizens and institutions, many of whom are stewards of the land and sea, today legitimately expect to participate in research in a variety of roles including as leaders or co-investigators of their own projects. Some of CARI's research partnerships should enable research that addresses what are among the greatest economic and social disparities in Canada. Northern participation is also crucial from a legal standpoint where citizens are outright owners of the land. They expect to participate in assessing research needs and defining priorities in order to meet the practical needs of sustainable communities and livelihoods, and exercise their citizenship effectively.

Canada can draw many lessons from the past that show that it is not enough simply to place a research station in a community and expect it to make a positive contribution. Fair partnerships are the basis for high standards of excellence in the conduct of research. Existing codes of ethics published by such

organizations as the International Arctic Social Sciences Association, the International Finance Corporation, the Inuit Circumpolar Council and the Canadian granting agencies are intended as helpful guidelines. The Canadian Arctic Research Initiative should have the capacity to act as a resource in this regard.

NATIONAL AND INTERNATIONAL PARTNERSHIPS

The opportunity exists for the Canadian Arctic Research Initiative to develop as a central hub that will make Canadian arctic science more effective through partnerships. For example, collaborations between climate modellers and weather forecasters could lead to a far stronger evidence-based approach capable of beginning to make climatic predictions. Partnerships among indigenous observers, social scientists, natural scientists and engineers are capable of creating new frameworks for understanding Canada's environmental history and resource management strategies.

Canada has long been an active participant in international scientific fora, and has made commitments. But Canada has acquired a reputation among arctic nations for failing to match words with deeds. This initiative provides an opportunity to recommit to fellow arctic nations, to build on the results of the International Polar Year, and to reassert Canada's place in international polar research organizations.

CAPACITY BUILDING

The panel considered whether the Canadian Arctic Research Initiative should have a formal educational role, given that graduate training has been a significant activity at Canadian research stations in the past. Graduate students will do research work at CARI but this can happen through links with existing universities and does not require CARI itself to become a formal educational institution. While the mission of CARI should be largely restricted to the performance of research, it will have to nurture a relationship with the spectrum of arctic stakeholders to maintain community and political support. At the very least, regular opportunities for stakeholder engagement and broad dissemination of science within northern communities should be organized. CARI will have an obligation to develop partnerships with northern governments, community organizations and private sector organizations to support knowledge-sharing mechanisms and to nurture capacity building in arctic Canada. CARI will not succeed in this by acting alone but it can act as a catalyst and an organizing power.

Enabling Conditions for Success

The panel considered the key enabling conditions that are most likely to lead to long-term success for the Canadian Arctic Research Initiative. CARI is best thought of as an organizing framework with a number of interacting components, and not simply as a physical structure at a particular location. A core task for CARI must be to bring together, integrate and coordinate Canada's fragmented arctic research, monitoring and technology communities. The designers of CARI should consider the importance of a number of key success factors including the following:

- organizational flexibility;
- being a magnet for scientific excellence;
- access and coverage;
- data sharing;
- long-term stable funding;
- governance;
- structure and location(s); and
- transition.

The panel made the following preliminary observations on each success factor.

ORGANIZATIONAL FLEXIBILITY

The design of the Canadian Arctic Research Initiative should consider the need for sufficient organizational and operational flexibility to respond to shifting priorities. The research problems that appeal to leading arctic researchers seeking to distinguish themselves academically will inevitably evolve, sometimes rapidly. National and international priorities will vary as the seriousness of particular environmental challenges is confronted. Scientific and technical challenges for future resource development will change, as will the relative importance of particular baseline characteristics. New generations of instrumentation and methods of observing will make possible new kinds of studies. For all these reasons, CARI will need the capacity to reconfigure itself to support new areas of scientific research. A process should be developed to assess periodically (perhaps on a decadal basis) whether the physical infrastructure of CARI remains optimal for the support of forefront research and discovery.

BEING A MAGNET FOR SCIENTIFIC EXCELLENCE

A key requirement is to design the structure of the Canadian Arctic Research Initiative so as to attract the best senior scientists, the leaders of research programs and the brightest

young early-career scientists. In the past two decades, many brilliant researchers avoided the Arctic because of a lack of funding and low career prospects. Following the surge of arctic research and enthusiasm generated by the International Polar Year, Canada has a fresh opportunity to encourage the development of early-career researchers. The design of the research initiative and associated research station(s), the facilities (including accommodations), the communications capabilities and transportation access to field sites will be pivotal to attracting and retaining talent. Although the costs associated with doing arctic research will remain high and are, in fact, likely to increase, CARI can demonstrate that a scientific career in arctic research is promising. Support for the career development of senior researchers, including those permanently based in the field, will be vital for sustaining the quality and reputation of the Canadian Arctic Research Initiative.

ACCESS AND COVERAGE

The diversity of Canada's arctic ecosystems also presents a considerable organizational challenge. In the past, the regional coverage of arctic research has often been patchy because scientists have tended to select a limited geographical range of sites to which they can gain access, study specific problems and processes, and make repeated visits to carry out intensive, and when possible, longitudinal studies. Some scientists can do this by working near a research station, but many others need to work *in situ* in specific environmental conditions, depending on their disciplines and projects. Cost has played a major role in limiting site selection. Many researchers have been forced to follow the main commercial air corridors that, in effect, create sampling biases. Ensuring that Canada can, for the first time, acquire a comprehensive regional knowledge rather than the patchwork sampling hitherto possible, will go a long way to improving Canada's ability to meet its national and international obligations. Ensuring appropriate funding models will be a critical component in thinking through CARI's structure and implementation.

DATA SHARING

The success of the Canadian Arctic Research Initiative depends in large part on whether the research it supports can, in practice, be easily accessible to its science partners and to other stakeholders. The station should create a central database (or databases), supported by the development of data-mining tools, and should consider making freely accessible a set of core variables for all scientists using CARI research. Some of the variables may also serve the need for reporting to international programs. The *quid pro quo* for scientists using CARI data is that they should furnish CARI with their own data and related publications.

LONG-TERM STABLE FUNDING

The long-term stability and dependability of funding is a prerequisite for Canada's arctic science ambitions to ensure that long-term research and monitoring can be planned and executed successfully and that international obligations can be consistently met. Inadequate operational funding would cripple a leading-edge scientific program and put in jeopardy the long-term observation and monitoring and core research programs that would be a major element of the value of the entire Canadian Arctic Research Initiative. The long-term continuity of funding is perhaps even more important to the success of CARI than the absolute sums allocated in any given year. For understanding the Arctic in its global context, uninterrupted longitudinal studies over decades, rather than for single seasons, are assuming far greater importance. This is a significant concern since, to date, support for Canadian arctic research has tended to be largely project-oriented. CARI funding should represent a departure from past budgeting practices where, as most mature researchers can recall, flagship programs have been severely damaged because the initial promising support was eroded over time.

Beyond the capital costs of CARI, it is essential that sufficient, assured funds are provided to support ongoing operations. CARI will need a central, well-equipped logistics base with about fifty per cent of the resources for arctic research reserved for logistics, basic support infrastructure and maintenance. Operations should also include the establishment of infrastructure in Canada to develop and maintain important international linkages. CARI must have the funds available to encourage the sharing and exchange of researchers and information with other countries.

The funding for construction and basic operations of CARI should be provided by Canada alone since the negotiation of international funding and facilities-sharing agreements is very likely to be fraught with complications and delay. A successful Canadian Arctic Research Initiative will enable Canada to build effective and balanced reciprocal agreements with arctic and antarctic research programs and facilities of other nations in ways that will strengthen scientific research both in Canada and internationally.

GOVERNANCE

To ensure that world-class science will be done under the Canadian Arctic Research Initiative, the organization will need to secure the type of leadership that can attract top-flight scientists. With proper management and design, CARI could be, and must become, a "magnet for scientific excellence." The initial nucleus will then create the environment that will attract more talent in a self-reinforcing cycle. Regarding governance, the panel recommends the establishment of an eminent international scientific advisory committee and a board (with broad representation for national stakeholders) that is genuinely interested in the mission of CARI. The senior management of CARI should be able to call upon the advisory committee and board, when seeking to provide input to the Canadian granting councils about the structure of arctic research funding. The governance model should also allow for the broadest possible range of future funding sources, including from outside Canada, as noted above. Finally, there should be a large degree of independence from direct government influence.

STRUCTURE AND LOCATION(S)

The criteria that should govern the site choice will depend on the combination and relative weighting of science priorities that Canada ultimately chooses — e.g., the implications of the opening of the Northwest Passage, the melting of carbon-rich permafrost, healthy community development, etc. For example, health research should be undertaken in partnership with Canada's northern citizens, which means that research sites are essentially the communities and towns of the Arctic

Figure 4

Photo provided courtesy of Christina Stachulak.

and sub-Arctic, and not one single location. It is therefore perhaps more important to define, at the outset, a set of constraints on the structure and location(s) of CARI facilities rather than simply generate a long list of possible options. In defining these constraints, key questions include: whether the main physical facility would be located in an environmentally sensitive area vulnerable to industrial damage or climate change-induced rapid impacts; whether an area sufficiently distanced from development to provide stable long-term baselines is advantageous over potentially unstable areas that may move to new environmental states; whether location should take advantage of the infrastructure and amenities of a relatively urbanized setting, which would offer a different kind of support for scientists and families seeking longer periods of residence; and whether the political geography of sovereignty is a strong consideration.

Based on collective experience, the panel concluded that the Canadian Arctic Research Initiative will likely require a two-hub model with a logistical hub in a central, accessible location as well as a scientific hub in an attractive and scientifically interesting area. There is evidence that other circumpolar countries are moving toward a more distributed hub-and-spoke model. It is important to bear in mind that such a model requires intermediate infrastructure — e.g., to connect the hub via the spokes to other facilities — and funds will therefore need to be provided to support that intermediate infrastructure. It is essential that there be a transparent decision process by which possible models and sites are considered and chosen. Whatever decision is eventually taken, it will be important to ensure that the development remains sensitive to its own environmental footprint and is subject to a robust environmental impact assessment of the magnitude that would be expected of a facility destined to be on the cutting-edge of arctic science in service of environmental science and stewardship.

TRANSITION

It is critically important to build on the momentum gained from the International Polar Year. Canada supported forty-four separate research projects, all in the Arctic, selected from more than three hundred submitted proposals. These cover a wide range of scientific topics; they include the social, health and natural sciences, the principal investigators of which include northern citizens, and among them, indigenous researchers. Most of these projects will be terminated at the end of their fixed-term funding, with researchers beginning to look for their next challenges. Individually and collectively, they represent a new surge of scientific endeavour to which the Canadian Arctic Research Initiative needs to respond. The many Canadian university-based and government researchers who have been mobilized during the International Polar Year need to remain engaged, while northern citizens need new opportunities to acquire both the research capacity and access to new knowledge that is necessary to meet their pressing needs. The most successful work needs to receive fresh encouragement and emerging early-career talent needs to be nurtured. Building the CARI science program should start now by taking immediate steps to build new national and international partnerships and priority research programs. These should be sufficiently developed such that they are well established by the time the construction of CARI's facilities is complete and fully operational (roughly ten years' time). Initiating one or more long-term core programs immediately will also send an important signal that CARI will not simply impoverish what already exists. The method in which the early actions associated with CARI are announced will send a critical message to the arctic science community. It is essential to get off on the right foot.

Conclusions and Key Messages

The opportunity inherent for Canada in the development of the Canadian Arctic Research Initiative is enviable. Through its deliberations, the panel has attempted to fulfil its mandate and to offer the Government of Canada its collective advice to support the development phase for this globally important initiative. In conclusion, the panel would highlight the following key messages from its deliberations.

1. **Recognize Canada's international obligation with respect to arctic science.** From an international perspective, Canada's active development of, and participation in, a robust international arctic science program is a necessity. The obligation stems from Canada's position as steward of remarkable human and natural resources of crucial global importance. International arctic research efforts will not be successful without Canada's participation and, often, Canada's leadership.

2. **Seek synergy.** The design of the Canadian Arctic Research Initiative and its research programs should take into consideration the importance of creating a flexible environment that breaks down the silos of disciplines, methodologies, stakeholder interests and national approaches, and instead embraces an approach that seeks to find synergy among the efforts of all involved.

3. **Expand the definition of "cutting-edge" science.** Observation and long-term monitoring, together with the storage, presentation and analysis of the resulting data, are core research activities that enable science to move forward and predictions to be made. The activities of observation and monitoring are therefore an integral part of Canada's capacity to conduct cutting-edge arctic research.

4. **Assure sufficient long-term funding.** It is essential that sufficient, assured funds are provided to support ongoing operations of CARI infrastructure and programs. Inadequate operational funding to complement the investment of capital will cripple a leading-edge scientific program and jeopardize the long-term value of the Canadian Arctic Research Initiative.

5. **Engage in transparent decision-making from Day One.** Based on collective experience, the panel concluded that CARI will likely require a two-hub model with a logistical hub in a central, accessible location, as well as a scientific hub in an attractive and scientifically interesting area. However, it is essential to the long-term success of the initiative that there be a transparent decision-making process by which possible models and sites are considered and chosen.

6. **Start now.** To respond to fast-changing environmental and economic circumstances in the Arctic, new scientific knowledge is urgently needed. Moreover, it is critically important to maintain momentum throughout the roughly ten years from the end of the International Polar Year to the time when CARI's facilities become fully operational. Therefore, while the Canadian Arctic Research Initiative is being more fully developed, key programs should be identified and supported from the outset. ■

Appendix A

VISIONING WORKSHOP REPORT – DEFINING SCIENCE PRIORITIES FOR CANADA'S NEW ARCTIC SCIENCE STATION

Foreword

An Arctic Science Visioning Workshop was held in Ottawa May 12 and 13, 2008 to inform the development of Science and Technology (S&T) priorities for Canada's future Arctic Research Station*. The workshop engaged a broad range of stakeholders from academia, government, the private sector, and aboriginal organizations to discuss the science needs for Canada in the Arctic and distil them into a small number of key priorities for the station. (See Annex 1 for Participants List). Participants evaluated Canada's Arctic science niche, the critical and emerging issues for Arctic science, and the required capacity and enabling environment to deliver on the science priorities. This report represents a synthesis of the advice and input received at the Workshop.

Indian and Northern Affairs Canada (INAC) leads the planning effort for Canada's future High Arctic Research Station as a signature deliverable of the Northern Strategy. There are four key elements to support the development of the station: Science program, Logistics/Infrastructure, Governance, and Engagement.

The federal *Ad Hoc Committee of Deputy Ministers on the Arctic* provided clear direction that the development of this station and associated science program must be driven by the S&T priorities for Canada. To initiate the determination of these priorities, Fisheries and Oceans Canada coordinated federal departments and agencies in the preparation of science needs scoping papers specific to their mandate and responsibilities in Canada's Arctic. (See Annex 2 for contributors.) The federal scoping papers were then synthesized as an input to the Visioning Workshop. Three other papers also served as inputs: (a) a view of the grand challenges facing Arctic research in Canada; (b) an Inuit perspective on addressing those challenges and; (c) a study of logistics and infrastructure to support Northern research. (See Annex 3 for the papers.)

The next step in this process is an international validation of the science and technology priorities as articulated at the workshop. The Council of Canadian Academies will convene an international panel of eminent Arctic science experts. The International Panel will review the priorities and provide high-level advice regarding those priorities, the role of the Research Station in the global science community, and alignment with key international initiatives (e.g. International Conference on Arctic Research Planning - ICARP II).

The Visioning Workshop defined a concise set of S&T priorities for the station as well as key approaches and considerations to ensure success in delivering on those priorities. The participants' contribution of time, insight, and energy to this process is gratefully acknowledged. INAC will continue to engage the diverse stakeholder community as the department moves forward in developing the station and associated science program.

Introduction

The Arctic is a unique and important part of the Earth system, environmentally, socially, economically and politically. At a time when polar environments and communities are experiencing unforeseen rates of change and escalating projections for future change, the global research community is being asked to produce expedient knowledge and information in order to understand and adapt to those changes.

The northern territories in Canada represent almost 40% of our country's landmass and a significant portion of the overall global Arctic. The expanse of islands in the Canadian Arctic Archipelago contributes to the longest coastline of any country in the world. Northern ecosystems present significant diversity across terrestrial, marine, and freshwater gradients. However, the diversity of Canada's north is not limited to the natural environment. Close to 110,000 people live in Canada's north, which includes a growing indigenous population rich in culture and heritage.

There is significant pressure, but also potentially vast benefits, for Canadians to enable excellent scientific practice to produce sound information, knowledge, and advice for the key issues facing Canada's North. With a substantial International Polar Year 2007-2008 (IPY) investment for Arctic S&T, Canada has

* Throughout this report, various references are utilized for the Arctic Research Station initiative, including the Canadian High Arctic Research Station (CHARS), the Arctic Research Station, Canada's new or future Arctic Science Station and the station. The details of this initiative, including a formal name or defining structure, have not yet been determined and as such, various references are used interchangeably to support the flow of the document.

built new and existing research expertise and capacity and plays a leading role on the world stage. Canada's leadership in IPY is complemented by the delivery of a number of other successful Arctic S&T programs, including the ArcticNet Network of Centres of Excellence, the Northern Contaminants Program and the Polar Continental Shelf Project. However, the current capacity of researchers – world-class though they may be – in any one area does not constitute a robust system of Arctic S&T for Canada.

The Speech from the Throne in October 2007 highlighted key commitments to the objectives of Canada's Northern Strategy, and specifically to the establishment of a new Research Station:

> *"… the North needs new attention. New opportunities are emerging across the Arctic, and new challenges from other shores. Our Government will bring forward an integrated northern strategy focused on strengthening Canada's sovereignty, protecting our environmental heritage, promoting economic and social development, and improving and devolving governance, so that northerners have greater control over their destinies…"*
>
> *"Our Government will build a world-class arctic research station that will be on the cutting edge of arctic issues, including environmental science and resource development. This station will be built by Canadians, in Canada's Arctic, and it will be there to serve the world."*

The four components of the Northern Strategy are core federal priorities. Science and technology underpin all four. In order to vigorously protect Canada's Arctic sovereignty as international interest in the region increases, the government must consider strengthening its Arctic presence, being an Arctic knowledge leader, and seeking certainty over the country's boundaries. To encourage investment and regulatory steps to address growing world demand for natural resources, the government must undertake regulatory improvement, improve economic and social conditions, and develop necessary infrastructure. To adapt to climate change challenges and ensure sensitive ecosystems are protected for future generations, the government must maintain global leadership in Arctic science, fostering adaptation to climate change and ensuring preservation of sensitive ecology. Finally, to provide Northerners with more control over their own economic and political destiny, the government must strive for devolution, settling land claim settlements and supporting human capacity development. Canada's future Arctic research station is an opportunity to harness the momentum of collective scientific efforts for an enhanced capacity to understand and respond to the growing challenges and opportunities facing the North.

By focusing on a small number of S&T priorities, the Arctic research station and associated science program will ensure Canada delivers scientific excellence for the issues of greatest interest in our country. In planning for this initiative, the physical infrastructure is being considered along with an associated science program which together, will enhance the existing Canadian capacity for polar S&T. This report begins the process to define Canada's unique niche in Arctic S&T in order to drive the development of a world-class research station.

CANADA'S UNIQUE ADVANTAGES IN ARCTIC SCIENCE

Workshop participants consistently noted two main advantages for science inherent in Canada's Arctic: the breadth and diversity of the ecosystems that comprise Canada's North and the 110,000 people for whom the Arctic is home.

The scale of the Canadian Arctic dwarfs that of any other country's Northern territory save Russia. Within this vast realm, the heterogeneity of marine, freshwater, terrestrial, and coastal conditions produce ecosystems from Arctic deserts to boreal forests. A long and complex coastline; coupled terrestrial/coastal/marine systems; freshwater, sea water, and frozen water in all its forms; and underlying gradients in temperature, precipitation, and geology present significant opportunities for both specific and comparative study. The size of the Canadian Arctic presents unique opportunities for linking models and process studies across scales – from local to regional to global. As well, this area presents a unique and harsh climate, which is not present at relative latitudes in other circumpolar countries. The pristine nature of much of Canada's Arctic also supports investigation into the effects of climate change and other anthropogenic impacts. These characteristics make Canada's Arctic a powerful "natural laboratory".

The *human dimension* of Canada's Arctic presents a key advantage for science in the Canadian North. Aboriginal peoples have developed traditional and local knowledge over thousands of years of residence in the North that can inform and complement modern science. Living year-round in the Arctic, Northerners can extend the research season effectively and efficiently. Northerners need and value science to help them understand, manage, and adapt to the precipitous changes in the North as the future of the Arctic is their future. Northerners' experience in engaging in the science conducted in their communities – as mandated through the land-claims process represents a unique advantage for Canadian

science – Arctic or otherwise. In Canada, recent and significant efforts have been made to promote scientific and cultural linkages by supporting holistic and cross-disciplinary research and engaging Northerners as stakeholders.

Workshop Products

1 – SCIENCE PRIORITIES

The Canadian Government has stated that *world-class research excellence* is Canada's standard. This can be achieved only by focusing on priorities – targeting basic and applied research in areas of strength and opportunity. For the Arctic research station, this means determining priorities that define Canada's niche in Arctic science. The May 12-13, 2008 Visioning Workshop made a substantial contribution in this respect.

The complement of workshop participants represented expertise diverse in scientific discipline, institutional experience and geographic scope; which provided an accurate sense of Arctic S&T issues in Canada. The participants evaluated the broad spectrum of inputs and identified a small number of S&T issues for the Canadian High Arctic Research Station (See Annex 4). These priorities were further distilled down to the following four broad S&T priorities for this report and complemented by details in the *Approach* and *Enabling* sections.

Although the issues presented within each priority appear autonomous, the interconnected nature of systems is a key consideration for each priority. The requirement to support multi-disciplinary studies in the Arctic across (i.e. natural and social sciences) and within (i.e. biological, physical and health sciences) disciplines cannot be overstated.

These four priorities are consistent with other national and international programming and priority setting forums for S&T, in general, and Arctic S&T, in particular, including references in the Speech from the Throne, the Northern Strategy, the priorities for the Government of Canada's program for International Polar Year, the Government of Canada's S&T Strategy and some of the science plans in the Second International Conference on Arctic Research Planning (ICARP II) overview report.

Role of Technology

Technology was identified by participants as having a significant role to play across all four priorities – either in enabling Arctic science in these areas or in realizing environmental, economic, or social benefit in the North directly through innovation and commercialization. Therefore, Technology is captured as a cross-cutting area rather than a priority in itself.

In terms of supporting the science carried out through the station, advances in technologies such as remote sensing, information management and communications, robotics, and monitoring could help make research and related scientific activities more effective and efficient across all four priorities. Canada's strength in these areas – as demonstrated by RADARSAT 2, the world-class instrument design and development for atmospheric monitoring at PEARL, and the Neptune project at the University of Victoria – could be further fostered by the station. Participants suggested that it was unlikely that the station would play a key role in the innovation of new technologies, given the critical mass of funding and expertise typically required to develop new products and services. However, the station could serve as a place for testing and adaptation of technologies as well as showcasing and marketing. The particular strengths in this area are adaptation of existing technologies to the extreme conditions of Canada's Arctic and opportunities to enhance Northern sustainability (e.g. energy efficiency).

Priorities

Sustainable Resource Development	Environmental Science and Stewardship	Climate Change	Healthy and Sustainable Communities

Technology

Table 1
Priorities and Technology

Overall, it was highlighted that Canada's S&T priorities for the Arctic will change and evolve over time – as new knowledge and new challenges emerge. These four priorities could provide a broad platform on which to build Canada's new Arctic research station and its associated S&T program. They are presented in more detail in the next section.

2 – APPROACH

In addition to the convergence on a small number of S&T priorities, participants voiced strong consensus during the workshop on factors they contended were integral to the successful delivery of these priorities and the development of the CHARS. They maintained that the *approach* to undertaking S&T in Canada's North is inherently as important as the type of science being conducted at the station. The approach to doing science would define the global advantage for Canada's new research station even more than the S&T program itself. Insights on how the station and science program could be built to leverage the rare opportunity for an integrated science system in Canada's North are detailed in the "Approach" section below.

3 – ENABLING CONDITIONS

Realizing the full potential of the future Arctic Research Station over both the short and the long term will require fostering key *enabling conditions*. In particular, it will require ensuring that the current peak in science activity in Canada's North, fuelled by International Polar Year, is harnessed effectively through interim investments in advance of the launch of the station to create and sustain the next generation of polar scientists. These factors are discussed in the "Enabling conditions" section below.

1 – Science & Technology Priorities

The following sections detail the context for each of the priorities; the rationale for each priority in the north, examples of the type of science that could be included in the priority as well as Canada's existing and potential strength in the area. The lists are provided for illustrative purposes only and not intended as a definitive scope of the S&T program for the High Arctic Research Station, as a future governance model will be established for such a task.

1.1 – SUSTAINABLE RESOURCE DEVELOPMENT

Science for what?

The Arctic is exceptionally rich in natural resources. The Northwest Territories, Nunavut and the Arctic offshore area hold an estimated one-third of this country's conventionally recoverable energy resources of natural gas and one-quarter of the remaining recoverable light crude oil. Only a tiny fraction of these energy resources have been tapped. As well, a number of major mining development projects are underway and being proposed across the North and announcements have recently been made for infrastructure to support a growing fisheries sector.

A more accessible Arctic and the high market demand for energy products and minerals are at the origin of increased resource exploration and expanding industrial development in many regions in the Canadian Arctic. While these factors contribute to a positive outlook for northern economic development, there is a keen expectation by Northerners and Canadians alike that any potential development in this pristine area is carefully measured against the combined environmental, social and political costs.

There are particular engineering, safety and transportation challenges associated with resource development in the north due to the remote locations, harsh climate, sensitive ecosystems, sea ice dynamics and instability of permafrost. To ensure economic viability in northern development, industry often undertakes projects of immense scope and scale, thereby placing pressure on social, economic and physical infrastructure and increasing the environmental footprint.

Ensuring northern resource development is both sustainable and respective of the unique environmental conditions is a major challenge which requires high quality and relevant scientific knowledge to assess the trade-offs among various goals of the biological, economic and social systems.

What science?

The following list identifies examples of existing efforts and potential future opportunities for Canada to deliver Sustainable Resource Development in the North. It is important to note that the Sustainable Resource Development priority presents unique opportunities for technology development and interdisciplinary study teams, including key partnerships with industry.

- Assessing the energy potential in the Arctic:
  - » Conventional (sedimentary basin)
  - » Unconventional and renewable (gas hydrates, tidal, wind, hydroelectric, solar, biofuel, and other renewable energy)
  - » Resource potential mapping
- Energy demand management and energy efficiency
- Resource Extraction, Manufacturing, and Transportation
  - » Permafrost
  - » Weather and ice forecasting
  - » Waste management
  - » Infrastructure
- Cold climate technologies
- Regulation
- Impact Management (Environmental, Social, Cultural and Economic)
- Emergency prevention, preparedness, and response
- Environmental reclamation and remediation

CANADA'S UNIQUE ADVANTAGE

Workshop participants highlighted cold climate technologies as a specific strength and area of ongoing focus for Canada to help address the challenges posed by sustainable resource development. Innovative technologies could expand capabilities, increase safety factors and decrease environmental impact.

Canada has substantial knowledge in the S&T applications related to natural resources, and in particular to mining and energy. For example, the recent experience with mining operations in the Northwest Territories has resulted in state-of-the-art infrastructure. As well, institutions such as the National Research Council of Canada are collaborating with industry and academic sectors to deliver cutting edge cold climate technologies to test and evaluate their products in conditions that simulate northern environments.

S&T under this priority encourages the establishment of public-private sector partnerships. The industry sector is becoming a major user of research results and early engagement with this sector will be important for partnered research efforts and knowledge transfer.

1 – Science & Technology Priorities

1.2 – ENVIRONMENTAL SCIENCE AND STEWARDSHIP

Science for what?

Canada's Arctic comprises a wide array of marine, coastal, and terrestrial ecosystems ranging from open ocean, to Arctic desert, to boreal forests. S&T can provide the foundation for managing this vast landscape along with its archipelago and its unique wildlife through long-term monitoring, process studies, and modelling, and, more importantly, through the integration of all three. Environmental science seeks to understand the characteristics of particular species (e.g. thick-billed murres), processes (e.g. bioaccumulation of mercury in fatty tissues), or ecosystems (e.g. tundra grasslands) and what factors and interactions drive their occurrence and change over time and space. Studies range from local (one metre by one metre vegetation plots) to global (comparing biodiversity indicators across precipitation and temperature gradients) and from one-time observations to decades-long research projects.

Monitoring provides knowledge on "what" is happening in these systems - on the status and trends of key variables. In addition to monitoring of current conditions, scientists can extend the time scale back by hundreds or even thousands of years using paleo approaches. Genomics, similarly, can provide insights into past processes as well as providing insights on current pressures.

Process studies and modelling help to tease out the "why" - the causes and effects of trends, of changes, or of consistency in the face of change – at the local, regional, and global scale. Causes could be human (e.g. changes in hunting pressure on wildlife populations), natural (e.g. background fluctuations in temperature), or anthropogenic (e.g. resource development impacts or climate change). Short term observational time series may be useful for some process studies. However, long term data sets are required to develop an environmental prediction and modeling capacity that is multi-scale (hours to decades and kilometres to global) and multidisciplinary in order to advance understanding of how Arctic systems work, how they are changing, and how they feed back into global processes and climate.

The diversity of the Canadian North represents an unparalleled opportunity to engage in coupled terrestrial/coastal/atmospheric/aquatic studies across gradients of temperature, daylight, and precipitation and across temporal scales from minutes to millennia and spatial scales from metres to global. Such integrated, systems approaches were highly recommended by workshop participants as being necessary to understand the challenges now facing the North, and, more broadly the globe. Such approaches build on the successful executive of the International Polar Year. Single discipline or single species studies are proving insufficient to understanding the complex, interrelated changes have been seen consistently in the Arctic for several years. Approaches that linked the poles were lauded by workshop participants as providing the potential for even greater advances through comparative analysis.

Given the vast and remote geography of Canada's Arctic, many gaps exist in current baseline environmental data sets. Long-term data are not available for many ecosystems. The surge of scientific activity during IPY has provided an opportunity to establish an integrated baseline data set and a foundation network of observatory sites for Canada's Arctic and to better understand the key ecosystems and components which are ideal for sustained observations. All of the paper inputs for the Visioning Workshop and workshop participants messages emphasized the need for sustained observations in Canada's Arctic to better understand the systems and respond to recent and future changes (environmental, social, economical, political or otherwise).

Such data and information would be necessary for application in a number of ways, including (but not limited to):

- environmental impact assessments;
- predicting and modeling future environmental changes and state of the environment reporting;
- identification of resource potential;
- security, search and rescue and disaster response;
- operational weather and ice forecasting;
- stock assessments and species at risk assessments;
- responsibilities under land claims agreements and settlements in the North;
- reporting to Northerners on key areas of interest including food security;
- domestic regulatory and legislative responsibilities;
- Canada's international obligations.

What science?

Canada presently undertakes a broad array of observations in the North. In order to advance our national and global understanding of Arctic ecosystems and communities, observational efforts and process studies must be enhanced, coordinated, and sustained to provide data on the magnitude and variation required.

The S&T fostered by the Environmental Science and Stewardship priority would provide critical inputs to the remaining priorities for the CHARS. Additional detail regarding the multi-disciplinary nature of programs is highlighted in the Approach section.

The following list identifies examples of existing efforts and potential future opportunities for Canada to deliver Environmental Science and Stewardship in the North:

- Atmospheric sciences
- Cryospheric systems
  - » Sea-lake-river ice
  - » Snow cover and solid precipitation
  - » Glaciers, ice caps and ice sheets
  - » Frozen ground and permafrost
- Coastal (sea level, erosion, sedimentation)
- Aquatic sciences
  - » Marine sciences and the Arctic ocean (salinity, circulation, acidification of oceans, biological productivity, invasive species, marine geology and seabed features, industrial presence)
  - » Freshwater
  - » Hydrology
  - » Water quality and quantity
- Terrestrial ecosystems: land processes and vegetation
- Topographic mapping and hydrographical charting
- Status and trends of wildlife
- Biodiversity
- Food chain
- Pollution of the Arctic environment by toxic substances and the long range transport of contaminants
- Status, trends, linkages and pathways
  - » Coupling of interactions of various systems (Lithosphere, hydrosphere, cryosphere and atmosphere) across range of space and time scales

Canada's unique advantage

The geography of Canada's Arctic ecosystems is complex, diverse, and vast. The remoteness and harsh climate incur operational and financial challenges to scientific study, including the collection of data, sustaining observations over time, and maintaining comprehensive observation systems. Such challenges have resulted in the development of a legacy of Canadian Arctic research and a Canadian capacity for delivering technical and scientific excellence in issues related to Environmental Science and Stewardship. The Visioning Workshop highlighted a number of opportunities to build upon our existing strengths; the most prominent advantage identified was the people of Northern Canada.

Not only does Canada have world class Arctic scientists, it also has the long standing northern aboriginal populations who can provide significant contributions to knowledge of both Arctic and national and global systems. These cultures provide the research world with a unique and intricate knowledge about Arctic ecosystems.

Partnering with indigenous peoples and communities in all aspects of scientific activity from priority setting to analysis and reporting encourages active participation out of which new knowledge can be gained, general theory developed, and policy-relevant recommendations for pressing issues can emerge. Scoping papers for numerous departments and agencies highlighted existing Community-Based Monitoring programs. Properly designed community monitoring elements can extend the spatial and temporal coverage of components and activities executed by the science community, thereby providing for a better foundation and wider understanding of Arctic ecosystems.

A further unique advantage for Canada is the timely opportunity to participate and lead global forums. Canada is actively engaged in the international process to develop recommendations for Sustaining Arctic Observing Networks (SAON), as part of a legacy for IPY. By demonstrating global leadership and support for this collective effort, Canada can ensure our national objectives are captured in the recommendations and the process to define the required observing sites and networks, mechanisms for sustaining observing networks, as well as enhanced connections between modeling, monitoring and open and timely access to data.

Finally, the Environmental Science and Stewardship priority could utilize a number of cutting-edge technologies for data collection, including space-based technologies, multisensor networks and autonomous unmanned vehicles. For example, the Canadian Space Agency through Radarsat 1 and 2, enables synthetic aperture radar observations (day/night, all weather) for Arctic landmass and ice monitoring, for both general and specific areas of interest. Advanced and robust information and communications technologies were seen by workshop participants to be critical to monitoring the arctic, to leveraging the data, and to integrating across studies – within Canada and globally.

1 – Science & Technology Priorities

1.3 – CLIMATE CHANGE

Science for what?

Climate Change remains a priority unto itself as it is a cross-cutting issue that overlays all aspects of the other three priorities. Impacts of climate change will be felt first and foremost in polar regions. The Arctic has already experienced significant changes to its climate that are producing cascading effects on physical, biological, economic and social systems. For these reasons, workshop participants highlighted the pressing need to maintain a dedicated focus on Climate Change.

The role of polar regions in global systems provides a key understanding of the pace and scope of climate change required to understand and predict the variability and impacts both in the Arctic and around the world. Glaciers and ice sheets of the polar regions are repositories of climate (and related) records. Climate change will have implications on all areas of study (including natural, social and health) and these implications will pose significant challenges – and opportunities – for sensitive Arctic ecosystems and communities. As the development of climate change is better understood and its potential impacts defined, it will be necessary to study the required adaptations and adaptive capacities of communities.

What science?

Climate change science seeks to enhance understanding of the causes, nature, timing and consequences of climate change through better knowledge of Earth system processes including atmospheric physics and chemistry and the links between atmospheric, terrestrial, marine, and cyrospheric systems. Through scientific observations, long-term monitoring, and analyses, a better understanding of the Earth's past and present climate and the magnitude and extent of climate variability and change is developed and used to test and to improve models that support mitigation and adaption efforts. Increasingly, climate change science is integrating from local and regional scale observations and process studies to understand the impacts of changes at those scales on

global systems. Conversely, the consequences of global changes are evident as they read out at local and regional scales. This requires a tight integration among the monitoring, process research, and modelling done by environmental sciences and those working on climate processes at the global scale.

The following list identifies examples of existing efforts and potential future opportunities for Canada to deliver on the Climate Change priority. Integration of knowledge and information between this and the other priorities is essential as Climate Change is not limited to any one issue:

- Understanding the role of Arctic ecosystems and processes in global climate variability and change
  - » Carbon cycle
  - » Water cycle
  - » Precipitation and snow cover
  - » Atmospheric chemistry and pollutants
  - » Aerosols and clouds
  - » Changes in the behaviour of land and ocean species
- Predictive and modeling capacity at all scales with increasing confidence
- Impacts and Adaptation
  - » Impacts and feedbacks from ecosystem change
  - » Emergency preparedness
  - » Transportation and Shipping as a result of the opening of the Northwest Passage
  - » Infrastructure
  - » Regional assessments
  - » Adaptive capacity and resilience

Canada's unique advantage

Canada's Arctic provides one of the best platforms to study high latitude climate processes which are proving to be critical to global climate models. Climate change is happening faster and with greater intensity at the poles than had been predicted. Canada's North holds important clues to the future of the planet's climate and will provide insights on how ecosystems and humans adapt to climate change as the Arctic lives through many of these changes first.

Modeling improvements require substantially enhanced observation and validation capacity to improve understanding of multiple climate processes. The IPCC advances greater confidence in model projections over their last report due to advances in climate science and computer-based modelling capacity and extended observational periods. A key area of focus for adaptation planning is moving the output from the global circulation models back down to regional modeling and adjusting (downscaling) with the use of historical observations. Fundamental to this work is the long term sustainability of meteorological observation networks.

Northerners and their communities are witnessing and experiencing the effects of climate change first hand. Local knowledge of the rate and intensity of the impacts of climate change is a valuable contribution to our overall understanding. As well, it is essential to engage communities to ensure that mitigation measures and adaptive capacities are appropriate and utilized.

Given the significant impacts from climate change already being seen in the North, the role of technology in adapting to these changes is critical. Designing new infrastructure and retro-fitting or relocating existing facilities to address permafrost melting and changes in coastal conditions is essential to the viability of communities and resource development in the North. Providing predictive information about the weather and wildlife populations will be increasingly important to Northerners as conditions continue to shift from historical norms undermining traditional knowledge.

1 – Science & Technology Priorities

1.4 – HEALTHY AND SUSTAINABLE COMMUNITIES

Science for what?

Recent and ongoing research is showing that despite advances in the provision of medical services, the health status of the Canadian northern population remains significantly worse than the national average. It is important to note that these changes in health status are also significantly linked to, or affected by, the dramatic social, cultural, economic and political change going on in many regions associated with processes of modernity.

The Health and Well-being of Northern Communities is one of two priorities for Canada's program for IPY and as such, baseline data and new research studies, unique to Canadian interests, are emerging and forthcoming. The CHARS represents an opportunity to continue the scientific effort and build a capacity to respond to the urgent need to understand determinants and trends in health and well being in many regions and communities undergoing forms of rapid change.

What science?

The following list identifies examples of existing efforts and potential future opportunities for Canada to deliver on the Community Health and Well-being priority:

- Human and Public Health
  - » Health and disease surveillance (including health determinants and cohort studies of chronic, acute and new diseases)
  - » Epidemiological studies
  - » Telehealth/Telemedicine
- Contaminants
  - » Pathways and long range transport
  - » Human exposure and vulnerability
- Communities and Infrastructure
  - » Energy (including unconventional and renewable)
  - » Water
  - » Waste
  - » Housing
  - » Food production, harvesting and security, including aquaculture
  - » Communications
  - » Social economy and socio-economic development

Canada's unique advantage

Health and related life sciences is identified as one of Canada's S&T strengths including the major components of the health sciences (e.g. cancer research and control; neuroscience; circulatory and respiratory health; infectious diseases and immunity) and emerging multidisciplinary fields such as Aboriginal health; age and genomics. The impact of interaction between genes and the environment could be used to develop strategies that promote health and prevent disease in Northern populations.

Workshop participants noted the requirement in Canada's northern and remote regions for provisions of mobile and telehealth services. The Public Health Agency of Canada has developed a mobile laboratory model which could play a role in identification and tracking of infectious disease agents in the North. Further, one of Canada's strengths has been associated with its ability to mobilize the research icebreaker CCGS Amundsen as a floating health research clinic to visit Arctic communities, the vast majority of which are located along coastlines.

The success of achieving objectives for Community Health and Well-Being in Northern Canada requires the integration of emerging issues and innovative approaches. Improvements in information and communications technologies (ICT) were deemed to be critical to advancing health outcomes in the North.

2 – Approach

Several key themes related to **how** science and technology are done (rather than **what** S&T are done) emerged from the workshop:

- The opportunity for integration
- The need for coordination
- Strengthening the use and uptake of science
- Leveraging the "people advantage" in the North

Participants advanced these as essential elements for the success of the CHARS. They suggested that the approach to undertaking science and technology in Canada's North is inherently as important as the type of science being conducted. Given the complex and interconnected nature of Arctic issues, the S&T program for the station must be integrative and interdisciplinary in nature and designed for knowledge uptake. The quality and innovation of the science carried out at the station will be influenced, of course, by the calibre of the scientists and infrastructure. However, the more important measures of impact will assess the nature of the interactions between those scientists and between the scientists and the users of science, and the extent to which synergies are supported across disciplines, sectors, and players by the built and social infrastructure the station provides.

THE OPPORTUNITY FOR INTEGRATION

The issues facing the Arctic – such as climate change, resource development, and social transformations – are complex and interconnected. Conventional research and monitoring are necessary, but not sufficient to tackle the challenges at hand. The solutions require interdisciplinary and interactive approaches to engage world-class expertise across disciplines, sectors, stakeholders and communities. Science in silos – be those disciplinary, sectoral, or regional – will not solve the pressing issues in the Arctic. Instead, integrative, solutions-oriented, and socially interactive science is needed.

The science and technology supported by the Arctic research station should be integrated:

- across disciplines (across natural, physical, health, social sciences)
- across domains (marine, atmospheric, terrestrial, space…)
- across pure and applied science
- across modern science, traditional knowledge, and local knowledge
- across data sources (remotely sensed, systematic monitoring, field and process studies, laboratory analyses)
- across scientific process (monitoring, research, modelling and prediction, technology development, dissemination and use)
- across players (government, academics, Northerners, international, industry)
- across scales (down from global models and up from local studies), North to south, across poles

In short, we are looking for a new and ambitious approach to science for CHARS, unlike the traditional scientific practices of the past. The scientists who come forward to work there must be highly connected visionaries within their own cultures and fields of expertise, and they must set the bar high for others to follow.

The federal government can lead on the development of the science infrastructure, monitoring and research capacity to harness efforts in government, universities, the private sector, and communities to create lasting solutions through the CHARS initiative. By designing the research, monitoring, and infrastructure components in a consultative and coordinated manner, the station will produce results that are world class, comprehensive, and meaningful to stakeholders while engaging decision makers and society at large.

Science programs have developed over a century and a half in the South. They have been largely developed on an ad hoc basis responding to particular regional- or issue-specific needs, for example, acid rain. Because of this, they do not form an integrated whole. The new Arctic Research Station presents the opportunity to step back from this piecemeal approach and to build an integrated system for Arctic S&T – across scientific domains; across monitoring, modelling, research, and application; and across ecosystems. Of course, S&T infrastructure and long-standing science and observation programs already exist in the North. Nonetheless, the Arctic Research Station and associated S&T program would represent a threshold increase in investment thereby creating the impetus to look at the conduct of S&T in the North from a holistic perspective. New technologies, new approaches, new kinds of science all merit consideration in evaluating the potential for a more integrated system for S&T in Canada's North.

The workshop identified several places to start developing this integration:

- Continue an inclusive process for planning the science program for CHARS;
- Build the CHARS science program on the best that southern and northern science has to offer including the output from IPY; and
- Continue to support existing successful science programs in the North from all sectors where they complement CHARS in addressing Canada's Arctic science priorities.

The need for coordination – the station as enabler

Participants agreed that doing S&T in the North can be hard and expensive. Transportation, food, and accommodation costs are high. Doing integrative, interdisciplinary research is hard anywhere. Crossing disciplinary and organizational barriers is talked about a lot, but not often realized. The station could play a key role in removing barriers, firstly, to doing research in the Arctic and, secondly, to doing innovative, horizontal, interdisciplinary S&T.

Participants contended that greater coordination was required for Arctic S&T in Canada. They suggested that as a new institution in the North, the Arctic Research Station could play a significant "enabler" role in this regard. Establishing a highly respected polar science capacity in Canada is critical to connect effectively to other performers of polar science in the world. Canada's recent investments in major science initiatives, such as ArcticNet and the International Polar Year, have increased our global presence and outputs. Maintaining a leadership position in Arctic S&T will require support for programming and a coordinated connection to the global community.

Canada's experience with IPY and the Network Centres of Excellence (e.g. ArcticNet) demonstrates our capacity to coordinate successful, multidisciplinary science initiatives that address high priority information needs. Several large and unique "consortia" of researchers who are attempting science on a grand scale have been fostered. By combining forces and jointly seeking and obtaining larger resources, these scientists have created programs that are both more resilient to set-backs and more able to take advantage of opportunities.

Workshop participants felt that such science is likely to result in "a bigger bang for the buck". Canada also leads the world on inclusion of traditional knowledge about polar systems in research and shared this approach in shaping the international approach to IPY. These kinds of efficiencies and synergies could be promoted through coordination provided by the research station to build a better system for S&T in the North.

Coordination does not necessarily mean centralization, but it does require both direct, and active, management as well as indirect support through the creation of enabling conditions and tools. Direct coordination can be provided through mechanisms such as science priorities and plans, through funding, through services (e.g. information management, brokering of assets such as ship time, coordination of licensing and permitting), conferences, workshops, and active management of relationships and interactions. Indirect coordination can be achieved through the provision of collaboration tools and spaces (both physical and virtual), project registries, and tools and protocols for data management.

The Arctic Research Station, by virtue of being a unique facility, will have particular coordination requirements. Procedures and standards will need to be set and followed for many aspects of the CHARS operation. Large budgets will need to be administrated. Legal and liability issues related to working in a harsh and unforgiving environment will need to be managed. Performance will need to be measured. International engagement will be required. The need to develop policy and management coordination for S&T conducted at, or with the support of, the station raises the opportunity to evaluate and streamline these for Canadian Arctic S&T as a whole. A national coordination function at, or associated with, the station was recommended by workshop participants.

Participants highlighted, in particular, the need for better management of Arctic data and information. Data will be a national resource of great value to users around the world, and must be managed in an open, timely and accessible manner. Significant efforts are being invested in improving Arctic data management through IPY to ensure that all data will be properly quality controlled, archived, managed and made widely and appropriately accessible for current and future use. Of particular note is the recent establishment of the Polar Data Catalogue for metadata developed in coordination with the ArcticNet Network of Centres of Excellence and the Canadian Cryospheric Information Network. The station could assume the mantle of that leadership.

It was acknowledged at the workshop that there will never be enough resources to undertake monitoring and science programs in the North analogous to those in the South. However, stronger coordination of Arctic S&T could allow lessons learned from the south and the north to inform the development of an integrated system of Arctic S&T that makes the most effective and efficient use of limited resources – reducing duplication and competition. Monitoring systems, for example, could be designed to leverage efficiencies – both cost and scientific - of co-location, to optimize scaling from local through regional to global, and to ensure effective representation of the Arctic's diversity. The upfront cost of coordination – in terms of time, energy, and money, could realize faster and more reliable Northern S&T results and actual savings of resources.

Strengthening the use and uptake of science

More and more, science and technology is required to inform all manner of human activities: decision making, environmental assessment, regulation, sustainable development, capacity building, economic advances and management. However, the transfer of scientific knowledge to application does not come without effort. The relevance of science and technology is ensured in part by the articulation of S&T priorities and the development of S&T plans. However, the need to address and plan for knowledge use and application from the outset of a research project is increasingly recognized and was advocated by participants at the workshop. The science-policy interface and the research-application interface are the focus of considerable academic effort, and engaging users in the design, conduct, and application of S&T is an emerging practice to strengthen these interactions. Canada has a significant advantage it could leverage in promoting this approach through its experiences in community-based monitoring and co-management in the North and in initiatives participants to the workshop termed "co-science" such as the Northern Contaminants Program and Canada's projects under International Polar Year.

Participants also strongly advocated increased attention to communication and outreach. To be useful, S&T needs to be understood and used – by other scientists, by communities, and by decision makers. To be funded and supported, S&T needs the interest and approval of the general public. To draw the next generation of scientists to the North, the opportunities and magic of Arctic S&T must be conveyed to the youth of Canada. Getting these messages out requires focused attention and particular skill sets. The Arctic Research Station could contribute to the successful transfer of Arctic S&T by facilitating communication and outreach by scientists and by directly brokering, translating, and disseminating the S&T conducted at, or with the support of, the station. Given the highly specialized nature of S&T communications and

outreach, participants suggested the development of dedicated capacity at the research station to support this function rather than simply directing scientists to improve their own communications efforts.

Creating a "People Advantage" in the North through capacity building

Throughout the supporting documentation for the Visioning Workshop, and at the Workshop itself, there was a clear enunciation of the belief that a Research Station in Canada's North must be closely linked to Canada's Northern peoples. Northerners have important skills and knowledge that are critical to the conduct of S&T in the Arctic. They already provide important logistical capacity and research support to scientists who come to work in the North. They know the land and how to live on it. They know the history of places and wildlife. They provide an important "people advantage" to S&T in the North that could be further enhanced through programs and opportunities at the Arctic Research Station. These could include:

- improved S&T education and training for Northerners,
- education and training by Northerners about traditional knowledge, working in the North, safety and security,
- participation in S&T through community-based monitoring and field work,
- enhancing the interface between "modern" S&T and traditional knowledge,
- applying S&T in decision making and management,
- the creation of employment and industry to support the S&T undertaken in the North (e.g. technicians in labs, guides, logistics and infrastructure provision such as at the new Ittaq Heritage and Research Committee facility at Clyde River, and;
- leadership in Arctic S&T.

Through linkages with Arctic colleges and, perhaps, as the core of an emerging University, the CHARS could provide opportunities for developing the next generation of Arctic scientists, and in particular, for engaging more Northerners in Arctic S&T. As a hub for scientific activities in the Arctic, the research station could provide a ready source of the latest information to be used as the basis of education and outreach initiatives. CHARS was seen, therefore, as having the potential to provide an ideal platform for outreach to communities – for learning but also for improved adaptive management in northern communities.

Workshop participants acknowledged that not all research is necessarily of concern and interest to Northerners but there should be opportunities for engagement where Northerners want to or need to be involved.

At present, not many Northerners are going into careers in S&T. Of those who do pursue studies in S&T, many don't return to the Arctic to work. There exists a fundamental opportunity to reverse this trend by providing interesting employment opportunities in the North. By strengthening the capacity for Northerners to use, participate and work in S&T in the North, the Arctic Research Station could contribute to a stronger indigenous scientific capacity and a stronger Northern economy.

CANADA'S TRADITIONAL KNOWLEDGE ADVANTAGE

> *"It is not sufficient to study the North from afar. Broadening our own understanding of the North, and drawing upon traditional knowledge as well as modern science, will improve our collective ability to operate in an environment that is fragile to begin with, and undergoing serious and rapid change."*
>
> (Territorial Northern Vision, A Stronger North and a Better Canada, 2007)

Special attention must be paid to the emerging and evolving relationship between traditional knowledge (TK) and science, and in particular the approach and training of people working at the interface between the two. Participants to the Visioning Workshop communicated a desire for TK to be used more effectively in parallel with modern science and not as another data point to be validated or rejected by that science, as is sometimes the case today. This approach requires a paradigm shift in the relationship between the two ways of knowing that may emerge out of improved awareness of TK achieved through educational training specific to the realities of scientific researchers. The promotion of collaborative research environments, including the development of a specialized TK Centre within the station, was clearly articulated at the workshop. Activity and interaction between indigenous peoples and scientists can help foster this dynamic, as well as recognizing and promoting good practices from examples of successful relationships.

Benefits of improved relationships flow both ways: scientists may benefit by refinement of their questions to local conditions while local people may benefit from hands-on exposure to the culture of science and its outputs. Making science useful to

local peoples can provide them with another perspective on their environment and the changes taking place therein that may ultimately provide valuable knowledge for coping with, and adapting to, environmental change. Ideally, the application of local science may contribute to the improvement of social and physical infrastructure that is essential for enabling sustainable communities, one of the science priorities for CHARS.

3 – Enabling conditions

Recognizing that science priorities will evolve over the lifetime of the station, a number of enabling conditions were highlighted at the workshop that would ensure that the infrastructure, logistics, and location remain responsive to science drivers. Human resources capacity, funding, governance, and infrastructure all need to be addressed to ensure that the vision for CHARS is adequately supported and ultimately achievable. Attention to these enabling conditions will help foster a dynamic, high-calibre staff and the appropriate facilities and equipment to underpin the roles of the research station and realize the opportunities it creates.

However, workshop participants were clear that Canada should not wait for the establishment of the research station before addressing the enabling components. Outreach, training, and educational development now could support the required capacity to staff the station, leverage the "people advantage" that Northerners can provide, and to foster a new generation of polar scientists to use the new station. Further, the maintenance and enhancement of existing infrastructure can be a key activity which complements the new hub for Arctic S&T when it is launched. Designing and developing an integrated Arctic monitoring system so that foundational data is available to support the researchers when the doors open at the new station will take substantial advance consultation between domains and stakeholders and time to fund and implement. The station could play a key role of enhancing the existing observational efforts in Northern Canada.

Canada has invested heavily in International Polar Year. This has resulted in a significant spike in science undertaken in the North and substantial interest in Arctic research. The Arctic research station represents an opportunity to create a lasting legacy from Canada's IPY commitment. However, the new research station will take a number of years to design and build. If the investment and interest generated by IPY is to benefit the new station, it will be critical that this momentum be sustained in the interval before the doors of the new facility open. In essence, a "succession plan" is needed for IPY. In particular, workshop participants noted that staffing will be a significant issue for the new station, as a large portion of the Arctic science community is moving into retirement. A sustained investment needs to start now to encourage the next generation of scientists to commit to Northern research as a career. Upgrading existing Arctic science infrastructure now will lay the groundwork for the station as the centre of a viable system for Arctic S&T.

ENSURING THE HUMAN RESOURCE CAPACITY TO RUN THE STATION

A broad range of skills and functions in addition to scientists will be required to run the station and its associated S&T program. Capacity will need to be either built in the North or attracted to the North in areas of science administration, field work, geomatics, trades and mechanics, information management, education and outreach, and knowledge translation. Many of these roles are highly technical and will require specialty training and ongoing skill development. All are in short supply in the North. Partnerships with Northern organizations could be explored to develop the workforce for the station. Many workshop participants advised that efforts must start now to ensure the availability of sufficient trained staff for the launch of the CHARS and its continued operation. This could take place through a dialogue with Northern colleges to target relevant programs and encourage relevant curriculum development for the skill sets required for the station – and for the expanding industrial activities in the North more generally.

ENSURING THE FUNDING BASE TO RUN THE STATION

Ultimately, a functional enabling environment includes an appropriate level of predictable, long-term financial resources to get the job done and provide certainty to partners – whether from industry, communities, or other countries. Participants were clear that the operational funding for the station, in particular, cannot be project-based. A longterm commitment to sustained funding for science, monitoring and operations will affect the success of the CHARS initiative because it will signal whether or not Canada truly aims to achieve world-class status in Arctic science.

Participants recommended that a core science program be established at the station. The station should be more than just a staging base or service provided to scientists travelling through to their field sites. The coordination and management of a long-term monitoring network for the Arctic and core baseline studies could be facilitated by the station. A dedicated

interdisciplinary team of scientists working at the station to manage the core science and monitoring programs could be a significant innovative feature of the new facility.

GOVERNING THE STATION

An inclusive governance structure will be critical to the success of the station as the existing, dispersed institutional structures that manage Arctic S&T in Canada cannot provide the level of integration and coordination needed for this new era of Arctic S&T. The governance structure(s) must be able to engage and partner with a multitude of players - Northern Aboriginal organizations, industry, government and university researchers, territorial and provincial science users (e.g. practitioners of northern land use planning, wildlife management, etc.) - to ensure the science program addresses the grand challenges for the North and Canada. This will help guide the alignment of research with the evolving science priorities for CHARS and ensure that the science that is conducted is timely and relevant to the ultimate users of that information.

New institutional models may be needed to manage and fund the station – such as public/private partnerships (PPPs), or consortia. The challenges to integration across sectors and institutions need to be address in the organizational model(s) chosen for the station. Processes for allocating funds for science and logistics supports need to be defined for the station. The roles of the granting councils would need to be clarified relative to those of the station.

A DISTRIBUTED MODEL

Throughout the early consultations on CHARS, all stakeholders – university researchers, Northerners, industry and federal researchers – have emphasized the importance of creating a distributed system for support of Arctic science: a "hub and spoke" model. Workshop participants contended that the vastness and diversity of Canada's Arctic and the expectation that different regions will be the focal points for science over time necessitate this configuration.

Further, consultations with the international polar science community have made clear that there is no one "model" of the perfect Arctic research station out there for Canada to copy. We need to define our needs, define our niche, and make a research station that fits Canada's Arctic.

The hub and spoke model would make use of existing facilities and seek to coordinate relationships among them to better utilize Canada's collective investments in the North. It would address the existing transportation challenges in the Arctic (e.g. to go from the eastern to the western Arctic you typically have to go south). It would also facilitate improved access to remote research sites, support for operational networks (e.g. weather data for improved forecasting capacity), and provide a flexible spatial arrangement to meet the needs of the variety of scientific disciplines that conduct research and monitoring in the North. A consortium approach to managing the hub and spokes could produce economies of scale.

The station, and in particular, the laboratory components, should be flexible, modular, mobile, and reconfigurable. This will allow the station to support the evolution not only in science priorities, but also in the technology to do science. The station should act as a major communications centre for Arctic S&T – linking ships, satellites, field stations, and communities. Spokes could specialize in one kind of science or focus on staging – providing the logistical support to get scientists in and out of the field.

Participants were clear that the new research station must complement and enhance existing S&T infrastructure in the north, not starve it. Recognizing that the station could never meet all the needs of scientists in the North, it was recommended that existing facilities and infrastructure be rationalized and funded to create a sustainable system for science support in the north. Consideration should be given to the continuity of long-run datasets that are vital to understanding change in the Arctic that are associated with some of the existing infrastructure when designing the overall system. Further, a strong relationship between scientific institutions and northern communities would foster many key objectives highlighted in this report. New federal investments should complement and enhance the overall system for Northern science and the contributions of partners.

Conclusion

The announcement of an Arctic Research Station for Canada generated much excitement in the Canadian and international Arctic science community. The Station presents innumerable possibilities for delivering scientific excellence and innovative logistics and infrastructure in support of cutting-edge issues. As perhaps the single most significant investment in Arctic S&T in Canada's history, the Station must play a catalytic role for Northern S&T - nationally and globally.

To ensure its world-class stature, Canada as a country must define a clear niche for the Arctic Research Station. The decision to develop a small number of S&T priorities for Canada's Arctic to drive the planning for the station is a critical step for ensuring it is efficient and well utilized by the national and international S&T communities and that it delivers

excellent and relevant S&T outcomes. The four S&T priorities highlighted in this report could provide the necessary direction to define the niche for Canada in Arctic S&T that will be exploited through the station. It is anticipated that a future scientific governance model will be created to drill further into the details of the priorities.

Part of the niche for Canada in Arctic S&T was how science and technology would be undertaken at the station according to workshop participants. They argued that there was as much innovation to be leveraged in the approach to S&T as in the priorities defined for the station. Integrative methods that engaged Northerners in interdisciplinary science were recommended as the leading-edge of S&T – whether Arctic or otherwise. Canada's considerable experience in multidisciplinary science in the Arctic and in co-management and "co-science" in the North put this country at the forefront of these new developments. The experience and knowledge of Canada's Arctic peoples and their participation in S&T comprise an important advantage for this country.

The vastness and diversity of Canada's Arctic represents the second key advantage for this country in Northern S&T. Workshop participants argued that leveraging that advantage will require a hub and spoke, or distributed network, approach to S&T in the North. The station must be developed as the central node in an overall Arctic science system for Canada.

Realizing the opportunity that the station represents will require sustaining the momentum of Canada's considerable IPY investment to build a new generation of researchers keen to establish their careers in Canada's North. Participants noted several key milestones for the development of the station. The final IPY conference to be hosted by Canada represents one opportunity to demonstrate Canadian leadership in Arctic S&T. The IPY legacy initiative, Sustaining Arctic Observing Networks (SAON), is another important venue where Canada could lead. The celebrations for Canada's sesquicentennial in 2017 afford a timeline of note closer to home.

Annex 1

Participants of the May 12-13, 2008 Visioning Workshop in Ottawa

Paul Aklakha	C-CORE
Michel Allard	ULaval, Director, Centre des Études Nordiques
Andrew Applejohn	Aurora Research Institute
Harvey Artsob	PHAC
David Barber	Univ Manitoba, Assoc Dean Research, Geography/Earth Science
Karen Barnes	Yukon College
Benoit Beauchamp	U Calgary, Professor and AINA Executive Director
Mairi Best	NEPTUNE Canada
Steve Bigras	CPC
Patrick Borbey	INAC
David Brock	UWO, PhD candidate (Geography/Political Science)
Ian Church	Government of Yukon
Suzanne Dobson	NRC - Rapporteur
Bill Doidge	Nunavik Research Centre, Makivik Corporation, Director
Marianne Douglas	U Alberta, Dir. Canadian Circumpolar Institute; Earth and Atmospheric Sciences
Elizabeth Dowdeswell	Council of Canadian Academies
Kathleen Fischer	INAC, IPY
LeeAnn Fishbank	Churchill Northern Studies Centre
Louis Fortier	ULaval, ArcticNet Scientific Director
Martin Fortier	Laval U, Executive Director, ArcticNet
Chris Furgal	Trent University, Environmental Health
Martin Godbout	Genome Canada
Mike Hammill	DFO
Greg Henry	UBC, Geography
David Hik	U Alberta, Biological Sciences, IPY Program Office
Paul Johnston	PRECARN
Jeff Kinder	IC – Rapporteur
Danielle Labonte	INAC
Daniel Lebel	NRCan
John Leggat	CFN Consultants
Georgina Lloyd	INAC
Robie Macdonald	DFO
Lee Mandeville	Dene Nation
Norman Marcotte	NSERC
Sébastien Marcotte	NRCan – Rapporteur
Gordon McBean	U Western Ontario
Ann McMillan	DFO - Rapporteur
Stephanie Meakin	Inuit Circumpolar Council
Rick Meyers	Mining Association of Canada
Jim Mitchell	Sussex Circle
Scot Nickels	Inuit Tapiriit Kanatami, Director, Science
Thomas Piekutowski	Canadian Space Agency
Shealagh Pope	INAC
Jeff Reading	Canadian Institute of Health Research
Brenda Saunders	EC - Rapporteur
Russel Shearer	INAC, NCP
Christina Stachulak	Council of Canadian Academies
Ryan Stark	British High Commission, Sr. Scientific Advisor
Ivan Taylor	DRDC
Jon Thorleifson	DRDC
Bliss Tracy	HC
Judy Watling	Policy Research Initiative
Wendy Watson-Wright	DFO
Mary Williams	NRC
Fred Wrona	EC
Nick Xenos	INAC

Annex 2

Departments that prepared scoping papers as input to the synthesis paper by Dr. David Hik and Dr. Marianne Douglas, *Planning for a Canadian High Arctic Research Station: A Synthesis of the Arctic Science Needs Scoping Papers Prepared by Federal Departments and Agencies*:

- Fisheries and Oceans Canada (DFO)
- Department of National Defence (DND)
- Environment Canada (EC)
- Health Canada, including the Canadian Institute of Health Research
- Indian and Northern Affairs Canada (INAC)
- Industry Canada portfolio with input from the Canadian Space Agency, National Research Council, Natural Sciences and Engineering Research Council of Canada, Social Sciences and Humanities Research Council of Canada and Statistics Canada
- Natural Resources Canada (NRCan)
- Parks Canada (PC)
- Public Health Agency of Canada (PHAC)
- Transport Canada and Infrastructure Canada

Annex 3

Context papers which served as input to the May 12-13, 2008 Visioning Workshop:

- *Planning for a Canadian High Arctic Research Station: A Synthesis of the Arctic Science Needs Scoping Papers Prepared by Federal Departments and Agencies* prepared by Dr. Marianne Douglas and Dr. David Hik at the University of Alberta.
- *Identifying Canada's Global Science Advantage in Addressing the Grand Research Challenges Facing the Canadian Arctic* prepared by Dr. Louis Fortier and Dr. Martin Fortier from the ArcticNet Network of Centres of Excellence at the University of Laval.
- *Identifying Canada's Global Science Advantage in Addressing the Grand Challenges facing the Canadian Arctic: An Inuit Perspective* prepared by Ms. Stephanie Meakin and Mr. Scot Nickels of the Inuit Circumpolar Conference and the Inuit Tapiriit Kanatami respectively.
- *Study of Logistics and Infrastructure in Support of Northern Research Working Paper* prepared by the Canadian Polar Commission as part of an ongoing assessment.

Annex 4

Visioning Workshop Science Priorities Plenary Session May 13, 2008

Group 1	Group 2	Group 3	Group 4	Group 5
Enabling co-science			Education and outreach	
			Increased scientific knowledge of Arctic – all systems	
Understand environmental heritage	Canadian Arctic Ecosystems	Environment stewardship		Polar environment and climate stability
	Arctic ocean			
Adapting to impacts of climate change	High latitude climate processes	(climate change as cross-cutting theme)	Climate change effects and implications on Arctic	Polar environment and climate stability
Foster sustainable resource development	Responsible resource development	Resource development	Cold regions engineering research to ensure sustainable resource development	
Ensuring Sustainable communities	Sustainable communities	Sustainable northern communities	People of the North: sustainablity and health of Northern communities	Human dimension – sustainable communities
		Health	People of the North: sustainablity and health of Northern communities	Human dimension – human health and resilience
Bolstering Sovereignty and security				
				Emerging Arctic economy
	Northern engineering research	Cold climate and remote uses Technology	Cold regions engineering research to ensure sustainable resource development	

Annex 5

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Industry Canada (2007) *Mobilizing Science and Technology to Canada's Advantage*. Government of Canada, Ottawa, ON

The Council of Canadian Academies Committee on the State of Science & Technology in Canada (2006) *The State of Science & Technology in Canada: Summary and Main Findings*. The Council of Canadian Academies, Ottawa, ON

Premier's Offices of the Government of Yukon, Northwest Territories, and Nunavut (2007) *A Northern Vision: A Stronger North and a Better Canada*.