Working Document of the NPC Study:
Arctic Potential: Realizing the Promise of U.S. Arctic Oil and Gas Resources
Made Available March 27, 2015

Paper #5-4

SUMMARY OF CURRENT ICE CHARACTERIZATION RESEARCH: CANADA

Prepared for the
Technology & Operations Subgroup

On March 27, 2015, the National Petroleum Council (NPC) in approving its report, *Arctic Potential: Realizing the Promise of U.S. Arctic Oil and Gas Resources*, also approved the making available of certain materials used in the study process, including detailed, specific subject matter papers prepared or used by the study's Technology & Operations Subgroup. These Topic Papers were working documents that were part of the analyses that led to development of the summary results presented in the report's Executive Summary and Chapters.

These Topic Papers represent the views and conclusions of the authors. The National Petroleum Council has not endorsed or approved the statements and conclusions contained in these documents, but approved the publication of these materials as part of the study process.

The NPC believes that these papers will be of interest to the readers of the report and will help them better understand the results. These materials are being made available in the interest of transparency.

The attached paper is one of 46 such working documents used in the study analyses. Appendix D of the final NPC report provides a complete list of the 46 Topic Papers. The full papers can be viewed and downloaded from the report section of the NPC website (www.npc.org).

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Topic Paper

(Prepared for the National Petroleum Council Study on Research to Facilitate Prudent Arctic Development)

5-4	Summary of Current Ice Characterization Research: Canada
Author(s)	**Jim Bruce (Chevron)**
Reviewers	**Victor Garas (Exxon)** **Brad Campbell (Exxon)** **Michelle Johnston (NRC Canada)** **David Barber (University of Manitoba)** **Humfrey Melling (DFO – IOS Canada)**
Date: September 16, 2014	**Revision:** Final

SUMMARY

A number of programs are currently being undertaken in the Canadian Arctic that have a significant component involving either the monitoring of ice conditions in the Beaufort Sea or in the advancement of technologies associated with monitoring. The research identified in the paper is not intended to be an exhaustive listing of all programs underway but is an effort to identify the more prominent activities currently underway or completed in the past few years. The focus is on both data collection and modelling as well as advancing technologies related to sea ice monitoring.

Introduction

A number of programs are currently being undertaken in the Canadian Arctic that have a significant component involving either the monitoring of ice conditions in the Beaufort Sea or in the advancement of technologies associated with monitoring. The research identified in the paper is not intended to be an exhaustive listing of all programs underway but is an effort to identify the more prominent activities currently underway or completed in the past few years. The focus is on both data collection and modelling as well as advancing technologies related to sea ice monitoring.

Much of the research undertaken is the result of federal government funded programs through direct support of government scientists, academic researchers and private R&D organizations. Industry sponsored initiatives, either as solely funded activities or in partnership with government have played an important role in Canadian sea ice research.

Major Government Programs:

Beaufort Regional Environmental Assessment (BREA)

The BREA is a multi-stakeholder initiative to sponsor regional environmental and socio-economic research that will make historical information available and gather new information vital to the future management of oil and gas in the Beaufort Sea.

The key goal for BREA is to produce relevant scientific and socio-economic information that simplifies project-level environmental assessment and regulatory decision-making for oil and gas activities, while strengthening the relationship between environmental assessment and integrated management and planning in the region. This goal will be attained by:

- Developing an improved understanding of existing baseline scientific and socio-economic information and traditional knowledge for the region and identifying areas of limited knowledge;
- Using targeted scientific environmental effects studies and monitoring programs to complement existing programs and fill identified gaps in knowledge;
- Facilitating the management of regional environmental information related to oil and gas activities in the Beaufort Sea for all stakeholders through implementation of policies that recognize the contribution of regionally derived information in the regulatory process of project-specific applications; and
- Ensuring the baseline information will facilitate more efficient regulatory decisions in the offshore.

BREA Sea Ice Related Research:

Within the overall BREA program, a number of sea ice related research projects have been undertaken by government scientists, academic researchers and private R&D organizations:

Characterizing Deformed Multi-Year Ice in the Beaufort Sea, 2006-2014
Lead: Michelle Johnston, National Research Council

This project is investigating the thickness and strength of extreme ice features in the Beaufort Sea at ice depths (up to 12 m) where no information currently exists. The research will provide information needed to better engineer structures to withstand the impacts of deformed multi-year ice.

As part of this project, the work scope included developing the tools needed to probe to depths well below the top ice surface of thick multi-year ice, to collect data needed to improve engineering design codes and standards for offshore structures. The highest priority was given to characterizing deformed, multi-year ice hummocks, since they are the least understood type of sea ice feature. Since measurements began in 2006, more than 600 borehole strength tests have been conducted on 23 multi-year ice floes, culminating with the first strength measurements to be performed through a 12.7m thick multi-year hummock, from crest to keel. The data have since been used to obtain updated statistical distributions for the properties of old ice, and to explore the viability of using ice temperature as a proxy for ice strength. In addition, nearly 700 drill holes have been made on multi-year ice floes since the program began in 2006. The detailed thickness measurements revealed dramatic variations in the thickness of multi-year ice over relatively short distances (tens of metres), combined with a weak correlation between top and bottom ice surface topography. Hundreds of drill hole thicknesses were used to evaluate whether EM sensors (ground-based and helicopter-borne) can provide reliable thickness measurements on multi-year ice more than 6m thick. Primary funding for this work came from the Program of Energy Research and Development (PERD), Industry and the Beaufort Regional Environmental Assessment (BREA) and represents the second phase of a program initiated in 2000.

When first initiated (Phase 1) the National Research Council Canada (NRC) undertook a comprehensive program to measure seasonal changes in the properties of first-year ice and old ice. Initial efforts focused upon providing a scientific basis for Transport Canada's Arctic Ice Regime Shipping System (AIRSS), in terms of whether a 'bonus factor' should be used to account for a seasonal change in ice strength. The NRC conducted a series of on-ice field programs to capture temporal changes in the thickness, temperature, salinity and borehole strength of first-year ice and old ice. Measurements were conducted throughout summer and into fall, to quantify which ice types decreased in strength, and to what ice depth. Sampling sites included landfast first-year sea ice in the Arctic (74°N) and sub-Arctic Labrador (53°N), landfast second-year ice (74°N) and the uppermost several metres of numerous multi-year ice floes in the Canadian Arctic Archipelago. These results provide the only available strength measurements on first-year ice and old ice in summer and fall. As such, the data have continued relevance for evolving shipping rules (i.e. the IMO Polar Code). Transport Canada was the primary source of funding for this work.

Technologies utilized in this project included:

- ice thickness measurements along transects using drill-hole technique and various EM sensors (ground-based and helicopter borne)
- full thickness temperature chains on four multi-year ice floes more that 10m thick, to measure seasonal temperature and thickness variations
- ice temperatures and ice salinities from manually extracted cores
- borehole indentor system to measure vertical profile of borehole strength through full ice thickness
- ice drift using GPS technology
- ice floe characterization from RADARSAT

Distribution and Thickness of Different Sea Ice Types and Extreme Ice Features in the Beaufort Sea, 2011-2015
Lead: Christian Haas, York University

Among the most serious challenges to operating in the Beaufort Sea are widely varying sea ice types and severe ice conditions. This project is using electromagnetic surveys and drift beacons to perform large scale airborne ice thickness surveys to quantify the thickness and regional distribution of multi-year ice and extreme ice features in the Southern Beaufort Sea. The results of this research will improve understanding of how sea ice moves in response to winds and currents, and will contribute to the development of tools to predict ice drift. Being prepared for any and all eventualities is one of the realities facing regulators and industry contemplating offshore oil and gas exploration and drilling.

Quantifying Sea Ice Dynamics in the Beaufort Sea, 2012-2015
Lead: Chris Derksen, University of Waterloo

Sea ice within the Beaufort Sea region circulates according to the predominantly anti-cyclonic Beaufort Gyre, but very little quantitative information about sea ice motion exists. This project is deriving sea ice motion products for the Beaufort Sea region using the Canadian Ice Service's (CIS) operational archive of RADARSAT-1 and RADARSAT-2 imagery and Environment Canada's new sea ice motion tracking algorithm. The results of this analysis will establish a baseline sea ice motion dataset which can be used

to plan and support future offshore operations. Results will also provide BREA with information on regional changes in sea ice dynamics that have occurred within the context of changes in the sea ice regime of the Beaufort Sea region during recent decades, marked by pronounced warming trends in the region. In addition, the ice motion products will serve as validation for a new state-of-the-art atmosphere-ice-ocean model for operational sea ice forecasting in the Beaufort Sea, currently under development at Environment Canada.

Radarsat Mapping of Extreme Ice Features in the Southern Beaufort Sea, 2011-2015
Lead: David Barber, University of Manitoba

There is growing global interest in marine shipping and oil and gas development in the Southern Beaufort Sea as ice cover in Arctic waters diminishes over the summer months. However, hazardous ice remains a risk to industrial operations in the region. This research is providing regionally relevant information on extreme ice features along the northwestern flank of the Canadian Arctic Archipelago. The University of Manitoba is leading a team of investigators that is using Radarsat technology to detect, monitor and eventually model the distribution and motion of hazardous ice features and their movement over significant oil and gas exploration licences in the area. This scientific knowledge will be married with information collected by local residents participating in a new community-based pilot program to monitor sea ice thickness.

Seasonal Forecasting of Ocean and Ice Conditions in the Beaufort Sea, 2011-2015
Lead: Gregory Flato, Environment Canada

Predicting the weather days in advance is standard fare in most parts of the country. But for oil and gas companies considering exploration and drilling activities in the Arctic, anticipating weather conditions over the coming year is extremely important. This project, led by Environment Canada, is creating a high-resolution forecasting system capable of predicting ocean and sea-ice conditions in the Beaufort Sea region from one to twelve months in advance. The research is providing enhanced regional detail in operational seasonal predictions and contributes directly to the development of improved climate prediction products. This will serve both regulators' and industry's operational needs, now and in the future.

Southern and Northeastern Beaufort Sea Marine Observatories, 2011-2014
Lead: Martin Fortier, ArcticNet

This initiative is establishing three oceanographic observatories, each composed of two moorings, to collect year-round marine observations of the Beaufort Sea using state-of-the-art instruments, including Doppler current meters, sediment traps, ice-profiling sonars, conductivity-temperature sensors and turbidity meters. Researchers are monitoring and interpreting the information generated on sea ice, ocean circulation and biogeochemical fluctuations throughout the region. The four-year project, led by ArcticNet and IMG-Golder (an Inuit-owned environmental and engineering company), is collecting data to gauge the physical conditions and variability of the Canadian Beaufort Sea year over year. This information will provide previously unavailable scientific evidence of oceanic and sea ice conditions,

enabling regulators to make informed decisions about potential environmental effects of exploration drilling in the Beaufort Sea.

BREA Publications

A full listing of publications can be accessed through the BREA website:
http://www.beaufortrea.ca/publications/

Program of Energy Research and Development (PERD)

PERD is a federal, interdepartmental program operated by Natural Resources Canada (NRCan). PERD funds research and development designed to ensure a sustainable energy future for Canada in the best interests of both our economy and our environment. PERD only provides funding to federal departments and agencies and as such, is not a general funding or grant program for companies, associations or individuals.

Sea Ice Research in current round of PERD funding:

Establishing requirements for exploratory drilling in ice-covered deep waters
Lead: Ivana Kubat, National Research Council

The proposed work for 2014-2015 will determine the ability of drillships to maintain heading under changes of ice movement direction and the associated requirements of the DP system and ice management. The work will also compare numerical simulation results, ice basin test data and available field measurements (from Sea Rose) and provide an evaluation of the reliability of station keeping modelling methods.

Reducing uncertainty in pack ice driving forces: Katie's Floeberg
Lead: Denise Sudom, National Research Council

The objective of this work is to develop the background information and analysis approaches necessary to refine the pack ice driving force, and reduce the ice load uncertainty. The two main tasks proposed include 1. collection of relevant data on extreme grounded ice features including past field observations, old satellite imagery and new, higher resolution satellite imagery, and 2. using three different techniques such as i) analytical models ii) bulk shear failure using cohesive properties of ice rubble and iii) fracture mechanics to estimate the pack ice forces that would have created these large grounded ice features

Changing sea-ice constraints on hydrocarbon development in Canada's Arctic
Lead: Humfrey Melling, DFO-IOS

There is limited information available about the extreme ice and storm waves in the Beaufort. The extreme ice record only spans two decades and the wave record is less than one. Hence it is difficult to calculate the hazards to offshore infrastructure from rare extreme ice features and storm waves. The main objective of this work is to collect new observations at 4 sites in the Beaufort Sea and 2 in the High Arctic to extend the records of sea-ice and wave hazards by one year, plus updated statistical analysis and interpretation of these records.

Arctic Coastal Ocean Processes, Seasonal Ice and Storms

Lead: Will Perrie, DFO-IOS

The objectives of this project are to 1. Develop reliable wave models for the Beaufort Sea and shallow continental shelf off the MacKenzie Delta, including the marginal ice zone (MIZ) fully tested with *in situ* and remotely sensed data, 2. application of improved coupled ice/ocean/wave/atmosphere model system to estimate climate change for coastal ocean dynamics of the Arctic as well as severe storms, winds, on seasonal- to –decadal timescales, validated with *in situ* and remotely senses data, 3. estimate the role of storms, waves, swell and other ocean processes on summer ice retreat, using ice/ocean models to provide forecasts of estimated seasonal ice forecasts and also the changing sea ice regime of the Beaufort over the next decades.

ArcticNet

ArcticNet is a large research network funded by the Government of Canada through the Networks of Centres of Excellence (NCE) program; a joint initiative of the three granting Councils of Canada and Industry Canada. NCEs foster multi-disciplinary and multi-sector partnerships between academia, industry, government and not-for-profit organizations focused towards turning Canadian research and entrepreneurial talent into economic and social benefits for all Canadians. As part of its NCE mandate, ArcticNet brings together over 140 researchers in the natural, human health and social sciences from 30 Canadian universities with their partners from Inuit organizations, government and industry to study the impacts of climate change and modernization in the coastal Canadian Arctic.

ArcticNet researchers in the atmospheric, climatic, and marine geological and biological sciences use the Canadian research icebreaker CCGS Amundsen as their main sampling platform to access and study the coastal Canadian Arctic.

Sea Ice Research

Lead: David Barber, University of Manitoba

A major portion of the ArcticNet program involves the study of the sea-ice cover and the effects of a changing ice regime on the climate of the North and resulting impact on the marine eco-system as well as the social impacts of Northern residents. The project provides sea ice expertise and support to the coordinated ArcticNet Integrated Regional Impact Studies of the coastal Canadian Arctic through a range of individual research topics including but not limited to: utilizing satellite based SAR to track and characterize the ice cover in the southern Beaufort Sea, comparing ship based observations from the Amundsen to satellite based ice characterizations, tracking the decay and break-up processes of multi-year ice features and first year ridges. A number of projects have also been conducted, in collaboration with offshore lease holders (Imperial Oil, Exxon, BP) to undertake a multi-year data collection program specifically focused on the offshore lease blocks.

CCGS Amundsen

A critical component to ArcticNet activities is the dedicated availability of the CCGS Amundsen for annual summer expeditions to the Canadian Arctic. The ship's sophisticated equipment, lab facilities

helicopter support, small vessels and surface transport support make it a versatile research platform Arctic scientists to access the Beaufort Sea and conduct field experiments.

- 43 berths dedicated to researchers
- BO 105 helicopter
- Hull mounted multibeam sonar for seabed mapping
- GPR and EM sensors for airborne and surface based ice thickness measurements

ArcticNet Publications:

The ArcticNet Publications Database is a subset of the Arctic Science and Technology Information System (ASTIS) database housed at the Arctic Institute of North America in Calgary, Alberta. ArcticNet's refereed and non-refereed scientific publications can be accessed through this searchable archive.

Canadian Space Agency (CSA) - Earth Observation Applications Development Program (EOADP)

The mission of EOADP is to stimulate and maintain a self-sustaining, innovative, growing Canadian industry that is able to respond to mainstream user requirements and commercialize internationally. EOADP is an essential element for the development of Canadian EO and space related capabilities and essential for the exploitation of CSA supported EO missions. The program also prepares the industry to take advantage of CSA investments in new sensors.

Main program objectives are:

- Increase accessibility and use of satellite data
- Stimulate the development of innovative applications
- Increase the level of expertise and competitiveness of Canadian industry
- Prepare the Canadian industry to benefit from the technology advances in Earth Observation

Sea Ice Characterization and Monitoring Programs

CHOIRS: Characterization of Hazardous Ocean Ice using RADARSAT and Ice Profiling Sonar
Contractor: ASL Environmental Sciences

The objectives of this project is to use ASL's moored upward looking Ice Profiling Sonar technology together with high resolution quad-polarized SAR data from RADARSAT-2 to demonstrate enhanced ice information products

EXICE: Detection and Monitoring of Extreme Ice Features in the Canadian Arctic
Contractor: C-CORE

EXICE proposes an examination of detection and monitoring of extreme ice features via the complementary use of RADARSAT-2 in combination with other satellite imagery. Extreme ice features are present throughout the Canadian Arctic and pose threats to navigation, subsea infrastructure and resource development. Substantial efforts have been expended to understand the physical characteristics of these ice features. EXICE aims to address information needs of the Canadian Ice

Service and the National Energy Board and involves the participation of the NRC and the Department of Fisheries and Oceans.

Canadian High Arctic Research Station (CHARS)

CHARS is presently under construction in the community of Cambridge Bay, NU and is envisioned to provide a world-class hub for science and technology in Canada's North. The new facility will provide a suite of services for science and technology in Canada's North including a technology development centre, traditional knowledge centre, and advanced laboratories. The current CHARS Science and Technology Plan (2014/15 to 2018/19) identifies research focused on "Environmental Stewardship and Climate Change - Predicting the impacts of changing ice, permafrost, and snow on shipping, infrastructure, and communities". Details on specific research are limited at this time but key deliverables of the research program are to understand the processes leading to changes that are occurring in ice, snow, and permafrost across the Arctic and the impact of these changes on shipping, infrastructure (e.g. ice roads, buildings, and runways) and local ecosystems, as well as global processes.

Canadian Ice Service (CIS)

Remote Sensing Research

Current remote sensing research initiatives underway at CIS, in anticipation of the upcoming SAR constellations and other current and future EO missions relevant to sea ice monitoring are described below.

The assimilation of remote sensing data will be a valuable advancement in sea ice analysis for CIS. The development of advanced remote sensing techniques is also a strong research thrust at CIS, in particular the exploitation of SAR data. The Sentinel-1 and RCM constellations will significantly increase the amount of imagery available to CIS in the Canadian marine domain on a yearly basis.

Automated SAR Classification

There are two different methodologies being presently examined for automated or semi-automated classification. One methodology, being developed in conjunction with MDA Systems Ltd, derives sea ice information from co- and cross-polarized (HH and HV) ScanSAR Wide RADARSAT-2 images using a multichannel data fusion algorithm. This method is designed for sea ice-water separation and sea ice type classification using spectral and textural information from both the HH and HV channel.

The second methodology being examined uses the MAp-Guided Ice Classification (MAGIC) software system has been designed and built by Prof. David Clausi at the University of Waterloo. MAGIC is the development platform used to implement the necessary computer vision algorithms to solve the current ice/water classification problem using RADARSAT-2 SAR imagery (Clausi, 2010).

Compact Polarimetry

The availability of a compact polarimetry (CP) mode aboard the Radarsat Constellation Mission (RCM) will provide an alternative to current single- and dual-polarization SAR modes. It is understood that fully polarimetric SAR modes and associated analyses have the ability to fully explain and describe sea ice scattering. These high power modes on existing missions (e.g., RADARSAT-2), however useful for providing improved ice information, are of little operational value to the CIS and other ice services due to their narrow swath widths. RCM's CP mode has the potential to provide polarimetric-like ice information at surveillance swath widths (i.e. over 100's kms). This mode may represent an important improvement over the range and type of ice information that can be extracted over large operational areas. CIS will be working with the Canadian Space Agency and Natural Resource Canada's Canada Centre for Remote Sensing to establish a pre-launch understanding of the potential of this new mode for operational ice monitoring.

SAR Ice Motion

The CIS' Automated Sea Ice Tracking System (CIS-ASITS) computes the two main components of ice movement (translation and rotation) from two overlapping SAR images that are sequential in time. The CIS-ASITS employs a phase-correlation approach to estimate both the translational and rotational components of any sea ice motion. The original algorithm has recently been ported to a new language in an effort to increase the computational speed and make it ready for full operational implementation. CIS hopes to run this algorithm on many or all incoming SAR images.

Data Fusion

Two critical issues are related to an expected increase in data from the new satellite constellations: being able to fully exploit the data from different sensors and the ability to efficiently automate data processing and produce useful products. Research is underway at CIS looking at the fusion of MODIS and AMSR-E data using a regression based method; and an IHS based method to fuse RADARSAT-2 and MODIS. These methods will be transferable to future sensors.

Government Sponsored Satellite Development

RADARSAT Constellation Mission (RCM)

The RCM is the evolution of the RADARSAT Program with the objective of ensuring data continuity, improved operational use of SAR and improved system reliability. The three-satellite configuration will provide complete coverage of Canada's land and oceans offering an average daily revisit, as well as daily access to 95% of the world to Canadian and International users.

The following points list the main areas where the Constellation system will be different from RADARSAT-2:

- The Constellation is conceived as a government-owned system, providing a large amount of data to government departments for operational monitoring over wide areas.

- The ground segment is driven by requirements for fast data delivery of images acquired over Canada, and for fast tasking over international areas.
- The majority of acquisitions in Canada concerns large areas to be covered on seasonal basis and therefore most of the acquisitions will be pre-planned.

Of particular interest, in Beaufort and Chukchi Sea regions, is the multiple imaging potential of the constellation as compared to RADARSAT-2. Additionally, the CP data (described under CIS research) will provide good performance in classifying ice types.

Private Sector Research

Petroleum Research Newfoundland and Labrador (PRNL) Sponsored Programs

Petroleum Research is a federally-incorporated, not-for-profit organization that facilitates research and technology development and delivers value to member companies by identifying opportunities, developing proposals, and funding and managing the execution of projects on behalf of the Newfoundland and Labrador offshore oil and gas industry. Through PRNL's Ice Management work program, a number of projects focusing on improving technologies for ice detection and drift forecasting, plus others, are or have taken place in the past few years. Those of particular relevancy are:

Enhanced Iceberg and Sea Ice Drift Forecasting
Contractor: C-CORE

The objectives of the project were to: define industry needs for iceberg and sea ice forecasts, including the most important factors and the associated time and space scales of interest; benchmark existing capabilities of forecasting models that are currently available and being used, including strengths and limitations in terms of the industry needs; determine the sensitivity and expected improvements in accuracy of ice drift models to new developments, and the expected benefits to current and future oil industry operations; and evaluate the benefits of including more real-time data into the ice drift forecast models. Additionally the project scope included the development of a scope of work, execution plan and cost estimates for possible future phases including: identification and evaluation of new and enhanced technologies and methods; data analysis, development of improved models and software and validation; field demonstration and evaluation of models and equipment and technology integration and training. At this stage only the first phase has been completed with decisions on future phases pending.

Near Real-time Ice Thickness Measurement Technology Development
Contractors: PAL and C-CORE

The project goal was to identify technology for acquiring, processing and reporting in near real time, ice thickness over a wide swath A practical solution is an airborne multi-radar system. The activities of this feasibility study included a through literature review, a survey of client requirements, and an investigation of available commercial sensors. Results of the study recommended the development of a prototype instrument to combine two commercial radar sensors – an impulse radar for ice thickness

profile measurements and a polarimetric synthetic aperture radar (polSAR) for surveying large swaths. The impulse radar data will calibrate the SAR data and output a map of ice thickness over the surveyed area. The final package would be suitable for deployment on an aircraft. The proposed technology development would see an integrated sensing unit using advanced algorithms, processes, and models based on the radar data to generate tactical, near real time ice thickness maps for offshore operators.

Enhanced Satellite Radar-Based Iceberg Detection and Sea Ice Monitoring
Contractor: C-CORE

A multi-year research program with a goal to develop automated techniques to optimize the effectiveness of satellite radar for sea ice and iceberg monitoring and integrate satellite-derived products into existing operations specifically for the oil and gas industry. The emphasis was to develop capabilities of benefit to Grand Banks operations that could also be used in other frontier Arctic regions. Major elements of this work have included algorithm and software development, field validation, demonstration and training. Based on the outcomes of the project, recommendations have been made on sea ice and iceberg services, satellite data types for these services and information requirements necessary for successful delivery of the services.

Dual-Polarized Ice Hazard Radar
Contractor: Rutter

Program to further advance the development of an integrated dual polarized ice navigation and detection radar. The project has included field trials of the system in the Canadian Arctic and NE Greenland with further development planned. This has been a multi-year program with additional support from other funding agencies (PERD, Transport Canada) and support in kind from the Canadian Coast Guard and industry supported field expeditions.

Private Technology Development

Ice Profiling Sonar (IPS)
ASL Environmental Ltd.

ASL Environmental Ltd. are providers of the industry standard ice profiling sonar moorings used globally. Since its original concept development by Humfrey Melling of DFO ASL has undertaken a number of advancements to the IPS to improve its overall functionality and accuracy. These have been summarized in the following:

Advances in Moored Upward Looking Sonar Systems for Long Term Measurement of Arctic Ice and Oceanography: http://www.aslenv.com/reports/IPS-Oceans2013.pdf

Ice Drift Beacons
Canatec Consultants

Function
Satellite telemetered, GPS position beacon for measuring short or long term drift of sea-ice and icebergs in remote polar areas with extremely low temperatures.

Signalling
- **Satellite Telemetry:** GPS fixes received and transmitted via Iridium satellites.
- **Messaging Latency:** through Iridium, less than 15 seconds.
- **Sampling Rate:** Standard is every 2 hours or every 15 minutes. Can be set differently on order, or changed remotely during operation, by user.
- **Accuracy:** GPS position accuracy 1.8 m Circular Error Probable (CEP). Barometric pressure accuracy is +/- 0.3 hPa; temperature accuracy +/- 0.1°C.
- **Temperature:** Beacons operate down to -40 °C. Data are recorded while temperatures go lower and transmitted when beacon warms up. Accuracy of position fix declines somewhat, below -35°C.
- **Signalling Capability**: Transmits under 1m dry snow cover, 5 cm water saturated snow cover; transmits while floating.
- **Sensors:** Can be equipped with air pressure or external temperature sensor.

Power Supply
- **Batteries**: Lithium chemistry non-rechargeable
- **Life Span:** Beacons can be designed to operate for up to 2 years in polar conditions at 2 hour sampling rate. Variable sampling rate can be used to optimize battery lifespan. Extra battery pack can be built in to increase life.

Versions
- **Air-drop:** Cylindrical package is dropped from helicopter or fixed wing unpressurized aircraft, at 155 m. Parachute deploys automatically and separates upon landing. Drop accuracy about 30 m radius in light cross wind conditions, down to 8 m with no wind. Beacon communicates in any landing orientation
- **Hand-Placed:** Can be dropped from ship or helicopter from up to 6 m height, or placed by hand directly on ice.
- **In-Ice**: designed to be buried part way into ice to keep batteries warmer and extend operating life. Needs 8” hand auger to make hole in ice.
- **UAV-deployed**: small, lightweight version for dropping by drone, with 3 week lifespan in temperatures around 0° C.
- **Meltout-Refreeze**: conical type housing for enhanced ability to survive refreeze conditions.

Academic Research Facilities

Sea-ice Environmental Research Facility (SERF) – University of Manitoba

The Sea-ice Environmental Research Facility (SERF) is the first experimental sea-ice facility in Canada. Located on the campus of the University of Manitoba, the main feature of the SERF facility is an outdoor seawater pool (60 feet long, 30 feet wide and 8 feet deep). It is equipped with a movable roof to control snow cover and ice growth, and various sensors and instruments to allow real-time monitoring. The SERF facility also includes a trailer laboratory and a storage building.

By fabricating and growing sea ice under various controlled conditions, mesocosm-scale studies will be carried out at SERF to enhance our fundamental understanding of how sea ice forms and melts on polar oceans, and to gain insight into the processes that regulate the exchange of energy and matter between the ocean and atmosphere. Along with the concurrent field studies onboard the Canadian Research Icebreaker Amundsen in the Arctic Ocean, experimental studies at SERF will improve our ability to predict the impact of the rapid sea-ice loss on the marine ecosystem, on Arctic and global climates, on transport and biogeochemical cycles of greenhouse gases and contaminants, and on the human use of sea ice.

SERF is funded by the Canada Foundation for Innovation, the Manitoba Research and Innovation Fund, and the University of Manitoba. The project is led by Drs. Fei Wang, Tim Papakyriakou, David Barber, and Soren Rysgaard.