Canadian Arctic Through Flow
2009 Cruise to Nares Cardigan & Penny Straits

CCGS Henry Larsen

August 8 – September 1, 2009
Institute of Ocean Sciences Cruise 2009-05
Humfrey Melling – Chief Scientist
Fisheries & Oceans Canada

Supported by the Government of Canada Programme for International Polar Year
IPY 2006-SR1-CC-135

Also by the Canadian Federal Programme on Energy Research and Development, Nunavut Department of Economic Development & Transportation, Petro-Canada Ltd, Alberta Ingenuity Fund

Collaborating Institutions: Institute of Ocean Sciences, University of Delaware, University of Alberta, Oxford University, Oregon State University, National Research Council of Canada, Danish Technical University, Scottish Association for Marine Science, University of Manitoba
Science Plan: CCGS Henry Larsen, Canadian High Arctic, August 2009

International Polar Year – Canada

Chief Scientist
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Dates of Operation
8 August to 1 September 2009
Embarkation at Thule Greenland late on August 7, 2009.
Disembarkation at Resolute Bay on September 1, 2009.

Areas of Operation
1. Nares Strait, from Smith Sound to Hall Basin with focus on a section across Kennedy Channel at 80.5°N.
2. Cardigan Strait and Fram Sound.
3. Penny Strait

Components of the CATs Scientific Programme

Collection of Equipment Cache
Equipment needed for the multi-year ice properties component of CATs was cached at Alexandra Fjord in mid July. This equipment must be retrieved at the start in the expedition.
If ice permits entry of CCGS Henry Larsen into Alexandra Fjord, the recovery of this cache can be combined with the recovery of a tide gauge from the seafloor just west of Skraeling Island within the fjord.

Moorings in Nares Strait
12 oceanographic moorings supporting internally recording instruments measuring current, ice drift, ice thickness, tide, temperature and salinity are to be recovered from Nares Strait; 11 are in deep (350 m) water in Kennedy Channel & 1 in Alexandra Fjord (18 m).
The recovered instruments and mooring components are to be serviced on board.
Instruments are to be redeployed on oceanographic moorings at 9 sites; 7 will be placed in deep water west of Franklin Island, somewhat to the north of the original locations; 2 will be placed in shallow bays on Smith Sound.
This activity is the responsibility of DFO’s Institute of Ocean Sciences in collaboration with the University of Delaware.

Moorings in Cardigan Strait
3 oceanographic moorings supporting internally recording instruments measuring current, ice drift, tide, temperature and salinity are to be recovered from deep (100-200 m) water Cardigan Strait.
A search is to be conducted for a fourth mooring, not found in 2007 and thought to have moved up or down channel under influence of strong currents.
The recovered instruments and mooring components are to be serviced on board.
Instruments are to be re-deployed on oceanographic moorings at the same 3 sites.
This activity is the responsibility of DFO’s Institute of Ocean Sciences.
**Mooring in Penny Strait**
Internally recording instruments measuring current, ice drift, ice thickness, tide, temperature and salinity are to be deployed on a single oceanographic mooring in deep (150 m depth) water in Penny Strait.
This activity is the responsibility of DFO’s Institute of Ocean Sciences.

**Seawater Surveys by CTD**
Seawater properties are to be mapped via profiling CTD on sections at 5 locations along Nares Strait, 1 across Fram Sound (near Cardigan Strait) and 1 section across Penny Strait.
Profiles are to be acquired from surface to seabed at stations approximately 2.5 km apart.
Sections are to be repeated as practical to document change in the properties of water flow over time.
Sections are to be extended to shore across heavy pack ice using a portable CTD system transported by helicopter and deployed from the ice.
This activity is the responsibility of DFO’s Institute of Ocean Sciences.

**Sampling Seawater for Trace Chemical Analysis**
Samples of seawater are to be collected using a profiling CTD-rosette system on 4 sections across Nares Strait, 1 across Fram Sound (near Cardigan Strait) and 1 section across Penny Strait.
Samples to be acquired at as many as 12 levels at stations approximately 5 km apart.
Samples for dissolved oxygen concentration are to be analyzed on board. Samples are to be stored (cool or frozen) for later analysis of salt, dissolved nutrients, oxygen and barium concentrations.
This activity is the responsibility of DFO’s Institute of Ocean Sciences in collaboration with the Bedford Institute of Oceanography and Oregon State University.

**Petermann Ice Shelf**
Seawater temperature and salinity are to be measured across the full width of Petermann Fjord using CTD towed at shallow depth. At the same time, the CTD-rosette system will be used from the ship to acquire full-depth profiles of temperature, salinity and water samples at locations selected via the small-boat survey.
Soundings by CCGS Henry Larsen in the area are to be recorded for better depiction of seafloor topography in the mouth of the fjord.
Dr Jason Box of Ohio State University has requested that we visit time-lapse cameras on the cliff tops of Petermann Fjord where they are monitoring the ice shelf.
This activity is the responsibility of DFO’s Institute of Ocean Sciences in collaboration with Oxford University, the University of Delaware, Oregon State University and Ohio State University.

**Automatic weather stations**
Automatic weather stations were deployed in September 2006 at Cape Isabella and Pim Island on the eastern shore of Ellesmere Island. The stations were last serviced from CCGS Henry Larsen in August 2007. A third weather station was placed on Hans Island in May 2008.
The stations at Cape Isabella and Hans Island are to be serviced and left to operate for another 1-2 years. The station at Pim Island is to be retrieved. It will be replaced by an installation at Cape Baird at the tip of the Judge Daly Promontory at the northern end of Kennedy Channel.
This activity is the responsibility of DFO’s Institute of Ocean Sciences in collaboration with the Danish Technical University, the Scottish Association for Marine Science and the University of Manitoba.

**Multi-year Ice Properties**
Profiles of thickness are to be measured across selected multi-year ice floes using surface-based electromagnetic induction radar and drill holes, coincident with imaging by Radarsat.
Observations are to be carried out in Nares Strait, in Norwegian Bay and on the northern approaches to Penny Strait. Up to 14 multi-year ice floes will be measured.

A thermistor chain and GPS system is to be installed in two 10-m thick floes in Nares Strait and one 25-m thick pressure ridge in Penny Strait. The drift of these floes will be tracked using the GPS and temperature data will be downloaded remotely via satellite.

These activities are the responsibility of the Canadian National Research Council.

Sea-ice thickness is to be surveyed using an electromagnetic induction (EMI) sensor in an aerodynamic probe suspended on a tether beneath the ship’s helicopter. The plan is to complete flight lines of 100 km or more across multi-year pack ice in Nares Strait, Norwegian Bay, Belcher Channel and Maclean Strait.

This activity is the responsibility of the Department of Earth Sciences of the University of Alberta.

**Equipment Cache at Resolute**

Equipment used on CCGS Henry Larsen will be moved to the PCSP base in Resolute Bay for storage at the time the science team disembarks on September 1. This equipment will support continued in Penny Strait, Byam Martin Channel and Prince Gustaf Adolf Sea. Aircraft based in Resolute will be used in April 2010 and 2011 to reach these locations.

**IMAX Filming**

Cancelled on CCGS Henry Larsen.

Moved to CCGS Louis S St-Laurent, July 29 to August 6 on route from Resolute Bay to Cambridge Bay

**Distances and Times (approximate)**

<table>
<thead>
<tr>
<th>Distance</th>
<th>Distance (miles)</th>
<th>Time (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thule to Alexandra Fjord</td>
<td>190</td>
<td>0.7</td>
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<tr>
<td>Alexandra Fjord to KC line</td>
<td>135</td>
<td>0.5</td>
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<tr>
<td>KC line to Petermann Fjord</td>
<td>95</td>
<td>0.3</td>
</tr>
<tr>
<td>Petermann to Hans Island</td>
<td>60</td>
<td>0.2</td>
</tr>
<tr>
<td>Hans Is to Cardigan Strait</td>
<td>490</td>
<td>1.8</td>
</tr>
<tr>
<td>Cardigan to Penny Strait</td>
<td>150</td>
<td>0.5</td>
</tr>
<tr>
<td>Penny Strait to Resolute Bay</td>
<td>150</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Transit times based on 12 knots or 280 miles per day (i.e. no ice)

**Total travel distance from Thule to Resolute Bay:**

1270 nautical miles 4.5 days
Figure 1. Sites of scientific activity to be conducted from CCGS Henry Larsen during August 2009. The principal centres of activity are in southern Kennedy Channel between Greenland and Ellesmere Island at 80.5°N, in Cardigan Strait between Ellesmere and Devon Islands at 091°W and in Penny Strait at 98°W. Activities are listed in the preceding section and described in greater detail below.
Ship’s Equipment & Special Installations

CCGS Henry Larsen is not equipped for oceanographic work. The Institute of Ocean Sciences (DFO Science Branch) has supplied several items of deck equipment which were shipped by truck from Victoria to Saint John’s in June:

- Swann Work Winch Model 410 (s/n 1433), 30 hp, with 3140 m 3/16" 3x19 wire rope, metre counter and winch record binder. Weight 2700 lbs
- Swann Hydraulic Power Pack, 30 hp, complete with switchbox & hoses to fit winch. Weight 2000 lbs
- Workshop built within a 20-foot steel-clad cargo container, for installation on the foredeck (port side). Weight 6000 lb
- Instrument laboratory built within a 20-foot aluminum-clad cargo container, for installation on the boat deck (port side). Weight 5000 lb
- Light-weight CTD winch (110-volt electric) & block, with 2000 m of 1/8” single-conductor wire. Weight 400 lb

The fist four items were to be secured by the engineering and deck departments prior to ship’s departure in early July, and electrical and hydraulic lines connected, as appropriate.

We request use of the foredeck crane for lifting oceanographic moorings over the side, and for deploying the profiling CTD-rosette package under control of the Swan winch supplied by DFO Science. In the latter instance we request use of a suitable block from the ship’s equipment store.

We request the rigging of a boom from the forward corner of the house-works to support the lightweight block (our equipment) used to deploy the CTD without rosette from the port side (as in 2007).

As the mooring work progresses, we will use of a significant fraction of the foredeck for storing floats, anchor weight and other mooring components. All remaining free space on the starboard side will be used for staging moorings at times of recovery and deployment.

We request use of space on the towing deck and in the adjacent Salvage Diving Locker for staging gear used for on-ice measurements. We request workshop space as occasionally required for service, repairs, etc.

We request use of space on the helicopter deck and perhaps in the adjacent helicopter hanger for staging the large probe and other gear used for the aerial ice surveys. We request workshop space as occasionally required for service, repairs, etc.

We request use of the Special Navigation Chart Room behind the bridge for computer work, for the servicing and preparation of scientific instruments that can be carried conveniently to this level in the ship and for operating the system used to analyze dissolved oxygen in seawater samples.

We request storage space in the ship’s walk-in freezer for small volume of (non-toxic) seawater samples to be returned to Victoria for analysis.

We request that the ship’s complete AVOS weather record and position log be provided to the science party on completion of the expedition.

Small Boat Support Request

We request use of the rigid-hull inflatable boat close to the ship for retrieving equipment at the surface and for pulling moorings away from the ship as they are deployed.

We request use of the rigid-hull inflatable boat at intermediate distance from the ship for retrieving installations from shallow coastal locations.

We request use of the rigid-hull inflatable boat at intermediate distance from the ship for towing the fish-mounted CTD system to be used for mapping surface waters in Petermann Fjord.
Helicopter Support Request
To access to multi-year floes for thickness surveys and thermistor installation (personnel & equipment transfer):
   Maximum 14 days x 3 flying hours per day (one floe survey fills a working day).
To conduct aerial surveys of ice thickness (personnel, installed equipment and EMI probe on a tether):
   3-5 sorties of up to 3 hours each.
To service and/or install automatic weather stations at coastal sites (personnel & equipment transfer):
   4 locations for estimated 6 hours in total.
To support to small-boat operations near shore, depending on ice (slinging & personnel transfer):
   0-5 hours

Research Permits

Fisheries and Oceans Canada: Institute of Ocean Sciences Cruise No. 2009-05

Denmark Ministry of Foreign Affairs
Permission to work in Greenland waters was granted on 22 July 2009. JTF, File no.55.Dan.9-11.

Island Command Greenland
Permission to work in Greenland territorial waters was granted on 27 July 2009. File no.09-127 009,00.

Danish Agency for Science Technology and Innovation (former Danish Polar Centre)
Kirsten F. Eriksen, kfe@fi.dk +45 32 88 01 08
We were informed in 2006 and again in 2009 that a science permit is not required for marine research near Greenland. Nonetheless, we have provided the Danish Polar Centre with our work plans for 2009.

Nunavut Research Institute
Donna Kenneally, dkenneally@nac.nu.ca
Variation & forcing of fluxes through Nares Strait and Jones Sound – Nunavut Scientific Research Licence No. 0202409N-A received May 6, 2009 (replaces No. 0203207R-M, and valid until December 31, 2009)
Variation & forcing of fluxes through Nares Strait and Jones Sound – Nunavut Scientific Research Licence No. 0203207R-M received May 7, 2007 (replaces No. 0204406R-M, and valid until December 31, 2007)
Quantifying Changes in Multi-year Floes Drifting through the Arctic – Nunavut Scientific Research Licence No. 0204409R-M received July 27, 2009 (valid until December 31, 2009)
Automatic weather stations: Under SRL held by Professor David Barber, Arctic Net.

Northern Consultation
Drs Humfrey Melling and Michelle Johnston completed a tour of the North Baffin Region in June 2007. The tour was coordinated by DFO’s National Centre for Arctic Aquatic Research Excellence (N-CAARE) and visited Resolute Bay, Grise Fjord, Pond Inlet and Arctic Bay. Participants met with members of the local HTAs and discussed proposed and completed work at public meetings.
Colleagues Dr Ed Carmack and Dr Svein Vagle met with the Hamlet Council and HTA at Resolute Bay in May 2009 to discuss the Arctic marine science program of DFO’s Institute of Ocean Sciences.

Canadian Environmental Assessment Act
Screening document completed and signed by Robin Brown, Head Ocean Science Division, Pacific DFO.

6 August 2009
Ice Conditions in Nares Strait

Ice is land-locked in Nares Strait for several months in most winters. Typically in June or July, the tide loosens ice in Kennedy Channel and it begins to move back and forth with the current. In late July the ice bridge across Smith Sound collapses and prevailing winds and currents begin to flush ice southward into Baffin Bay. This initiates a progressive wave of ice clearing moving from south to north. However, lighter ice conditions are relatively short lived. As ice bridges further north progressively collapse, they release ice to clog the waters further south. When the northernmost bridge across Robeson Channel breaks, multi-year pack ice is free to invade from the Lincoln Sea. By early September navigation is difficult even as far south as Smith Sound.

No long-lived ice bridge formed within Nares Strait during the winter of 2008-09. Instead, a bridge formed across a much wider span in the Lincoln Sea in early January, and against odds remained in place until the end of the first week of July. This bridge blocked the inflow of old ice from the Lincoln Sea for six months, while continued export of floes from Nares Strait to Baffin Bay completely flushed old ice from the strait by mid March. Essentially ice-free conditions permitted the Greenpeace vessel Arctic Sunrise to travel unimpeded by ice to within a few miles of Alert in early July.

![Figure 2. Collapsing ice bridge across the Lincoln Sea on 7 July 2009. Note that waters along the full length of the strait were free of sea ice at this time. North is towards the upper right.](image)

When the CATs team was in Kennedy Channel in 2003 on USCGC Healy, the ship encountered a number of tabular bergs calved from the ice shelf in Petermann Fjord that summer. Since August 2003 very little ice has broken free of the shelf. The exception is a berg measuring 10 by 3.5 km that calved from the southwestern side of the ice front in mid July 2008; fragments of this are now in western Davis Strait. Since 2003, the ice front has advanced at a steady rate of about 1.2 km per year; the portion of the front remaining after last summer’s calving is about 7 km further seaward than at the time of our first visit in 2003. Cracks in the shelf raise speculation that the remaining projecting portion of the shelf (7 by 5.5 km), or perhaps larger, might drift free this summer. As shown in the picture below, some much smaller fragments have already broken off.
Conditions for navigation have deteriorated rapidly since the collapse of the ice bridge on 7 July 2009. Vast floes of old ice moving at 1 knot or faster have populated the entire strait in the last three weeks and are now (27 July) emerging into Baffin Bay. These unusual circumstances have created ice conditions for navigation that will be more difficult than average during the middle two weeks of August, when the Larsen is scheduled to be working in this area.

Figure 4. View looking south across the Petermann ice front towards Joe Island and Kennedy Channel. Note the small ice-shelf fragments in the foreground and cracks within the protruding lobe of the ice shelf (Jason Box).

Figure 3. Satellite view of Nares Strait on July 31, showing the stream of multi-year ice floes extending down the western side to Smith Sound at the edge of cloud. North is towards the upper right.

6 August 2009
Information on the Ocean & Atmosphere Component

Context
The Institute of Ocean Sciences (DFO) is leading this long-term collaborative project to measure flows of seawater and ice through the Canadian Arctic Archipelago. The project name is the Canadian Arctic Through-flow study (CATs). At present, there are instruments for this purpose across all four gateways for flow through the Canadian Archipelago: Nares Strait, Cardigan Strait, Lancaster Sound and Bellot Strait. Installations have been maintained in Cardigan Strait and Lancaster Sound since 1998. Nares Strait was instrumented for the first time in 2003 and Bellot Strait in 2007. During the period 2007-2011, the work is a component of the Canadian programme for the International Polar Year.

There are three CATs expeditions in the summer of 2009: one on CCGS des Groseilliers to Lancaster Sound; one on CCGS Henry Larsen to Nares Strait, Cardigan Strait and Penny Strait; one on CCGS Sir Wilfrid Laurier to Bellot Strait.

Each expedition is focussed on two primary activities: 1) Recovering, servicing and redeploying autonomous instruments for continuous long-term observation, either from sub-sea moorings or from towers on land; 2) Completion of surveys of seawater properties along the paths of flow across these arrays.

Moorings presently in Nares and Cardigan Straits were installed from CCGS Henry Larsen in August 2007 and CCGS des Groseilliers in September 2008.

Description of Activities

Operating Area
There are three operating areas for CCGS Henry Larsen in August 2009, Nares Strait, Cardigan Strait and Penny Strait. The emphasis is on the Kennedy Channel section of Nares Strait where most of the installations are operating. A few more are distributed along the strait from Smith Sound to Hall Basin; ocean property measurements will span the length of the strait.

Recovery and Deployment of Moorings
In the absence of pack ice, the recovery of an oceanographic mooring can be completed in an hour. However access to work sites may be blocked in seaways where pack ice is plentiful. We have budgeted time for stand-by time in the vicinity of moorings, waiting for accessible openings in the drifting pack within which moorings may be released to the surface. This wait-wait-go scenario is derived from past experience with CCG icebreakers in these areas: in Smith Sound in August 1998, 1999 and 2001, in Cardigan Strait in September 2000, 2002, 2005 and 2007, and in Kennedy Channel in August 2006 and 2007.

Obviously, our need to access particular locations and to wait for suitable ice conditions for mooring recovery will require patience, tactical flexibility and luck. We are obliged to adopt an opportunistic approach to work in this ice environment.

Seawater Surveys by CTD
We will use a small CTD (conductivity, temperature, depth) probe repeatedly during the cruise to measure basic physical properties of seawater within cross-sections of the straits. Approximately 100 CTD stations are planned. The nominal spacing of stations is 2.5 km. The surveys will provide a detailed map of the water within the Canadian Archipelago at the time of the expedition in August. They will also provide data for the calibration of similar sensors that have been (and will be) recording data from moorings over several years.

The winch and rigging used for lowering the CTD from CCGS Henry Larsen in 2006 and 2007 is shown on the following page. Here a light-weight winch with 2000 m of 0.125” wire was mounted on its (reinforced) packing box just ahead of the house-works. The winch is electrically powered (110 V). The total load on the winch with 1000 m of wire out (deepest cast planned) is about 180 lb. The boom to support the block (our supply, not shown) was ship’s equipment originally used for landing personnel at canal locks.
Where heavy ice prevents the ship from completing a section to the coastline, the CTD equipment, an 1800-watt generator, a custom built lightweight winch and two operators will be moved to the ice by helicopter. CTD casts will be completed from the drifting pack between the ship’s position and the icebound shore. The time per station is approximately 30 minutes.

**Seawater Surveys by Sampling Rosette**

We will use a small 12-bottle rosette, equipped with an internally recording CTD probe, to collect samples of seawater at up to 12 levels in the water column. Approximately 35 rosette stations are planned. The nominal spacing of stations is 5 km. We propose to deploy the rosette from the foredeck on a 3/16” non-conducting wire under control of the DFO work winch. We propose to lower the rosette from a block suspended outboard using the ship’s crane.

The surveys will provide information on the chemical composition of seawater, necessary to deduce the origin of the water and its modification by mixing during its time in the Arctic Ocean.

**Petermann Ice Shelf**

We propose towing a CTD towed at shallow depth behind the ship’s FRC to measure near-surface seawater temperature and salinity across the full width of Petermann Fjord. The purpose is to locate and measure melt-water freshened outflow from beneath the ice shelf. Data from the CTD and a GPS receiver will be logged in an onboard laptop computer for real-time display and mission guidance.

We have built a configurable tow fish to house the CTD. Prior to use at Petermann, it will be necessary to test the fish in tow by the FRC at various speeds to find the best configuration of fish, its tow depth and the speed of the FRC that is optimum for a safe and efficient transect across the 17-km wide ice front.

Data from the survey will guide the choice of locations for seawater sampling from CCGS Henry Larsen along the survey path.

We would like to log GPS position and soundings from CCGS Henry Larsen as she approaches the ice shelf, moves along the ice front and departs. Restricted depth at a possible sill between the fjord and Hall Basin has important implications for the impact of warm ocean waters on the underside of the ice shelf.

This component of CATs is targeted at understanding the oceanic influence on the Greenland ice sheet. The shelf which is about 50 m thick at its terminus was about 600 m thick when it floated off bedrock a half century ago and 60-70 km up the fjord to the south-east. It has therefore lost about 90% of its thickness by
melting to the ocean during its slow (1200 m per year) travel down the fjord. The glacier is unusual in Greenland, where most glaciers lose ice mainly by calving, not melting.

Dr Jason Box of Ohio State University has requested that we visit by helicopter three time-lapse cameras on the cliff tops of Petermann Fjord, from where they are expected to document the imminent calving of a large tabular berg from the ice shelf. The purpose of the visit is retrieval of memory cards containing recent images. The cameras were installed by Dr Box, operating from the Greenpeace ship Arctic Sunrise, in early July 2009.

**Automatic weather stations**

At present, there are self-recording automatic weather stations at Cape Isabella and at Pim Island on Ellesmere Island and an Iridium reporting station at Hans Island. The latter is the outcome of collaboration between scientists in Canada and Denmark.

The stations at Cape Isabella and Hans Island are to be serviced and left to operate for another 1-2 years. The station at Pim Island will be retrieved. It will be replaced by an installation at Cape Baird at the tip of the Judge Daly Promontory at the northern end of Kennedy Channel.

We propose to work this aspect of the project using the helicopter to move two or three persons and equipment to each site. On-site time for data recovery, maintenance, set-up, photo-documentation and operational checks is estimated at 3-4 hours.

Concerns have been raised about the exact positions, elevations and reference direction for wind at existing stations. We will make careful measurements via GPS and altimeter to eliminate these uncertainties. The Iridium reporting stations (Hans Island and Cape Baird) will be configured for conformity with the global GTS weather reporting protocol, so that data become accessible in real-time to all interested users. To achieve this, some on-board testing of automatic weather station communications will be necessary prior to installation.

**Multi-year ice (on-ice component)**

This objectives are to measure the thickness of multi-year ridges and to install temperature chains, two of 10-m length and one of 25 m, fully through multi-year ice at three sites. Through satellite transmission of data, the latter will reveal the deterioration by melting of thick ice as it drifts southward.

The thickness of multi-year ice ridges will be measured both in two-inch diameter drill holes at 10-m spacing and using an EM-34 inductive sensor which operates at a frequencies of 6.4 kHz and 1.6 kHz; these are lower frequencies than used by the airborne EM-31 sensor (see below). We are interested in establishing the depth to which mechanical drilling is practical with a two-man team and in documenting the viability and limitations of the on-ice EM-34 and airborne EM-31 sensors for accurate measurement of ice thickness.

Following last year’s successful field campaign (based from Polar Continental Shelf Project), thermistor chains will be installed in three multi-year ice floes 10 m or more in thickness; one such installation will be reserved for a 25-m ridge near Penny Strait. Temperatures within the ice will be downloaded via satellite, and used to estimate the rate at which extremely thick multi-year ice thins as it drifts out of the Arctic.

We request use of the ship’s helicopter to move personnel and equipment to chosen old ice floes in the vicinity of the ship. We estimate no more than 3 hours flying per sortie for as many as 14 sorties. On-ice time at each site is about 8 hours.

Since we are not extracting ice cores this year, refrigerated space is not required.
**Multi-year Ice (aerial component)**

We have performed similar measurements in the Arctic, Antarctic, and over the Baltic Sea, using BO-105, MD-500, Bell-206 and AS-350 helicopters (Fig. 1). A comparable helicopter for carrying the scientific equipment and 1-2 scientists is required.

![Image of helicopter](image)

**Figure 1: EM bird operated from BO-105 helicopter**

The instrument is an ice thickness measurement device. It is a towed “bird” which is 3.4 m long and weighs 120 kg. It is to be suspended with a 20 m long cable fixed in an external load hook below the helicopter (Figure 2a). The instrument is based on the principle of low-frequency electromagnetic (EM) induction. It uses two operating frequencies of 3.6 and 112 kHz. It is not a radar system. There are no known problems with EM disturbance of helicopter instrumentation.

![Image of EM bird and helicopter panel](image)

**Figure 2: a) Load hook with EM bird attached (red hook with black cable). b) Laser altitude display for the pilot to control bird height.**

The bird is flown at an altitude of 10 to 20 m above the ice surface (Helicopter altitude ~ 100 ft) at 60 to 80 knots. During measurement flights, ascents to heights of > 200 m are required every 10 to 20 nautical miles for approx. 5 minutes. The bird has a laser altimeter which displays the distance between the bird and the surface to the pilot (Figure 2b). A power supply of 28 VDC and 16 A (450 W) is to be delivered from the helicopter. **The power supply and the load hook are the only interfaces with the helicopter.** Measured data are radio-transmitted from the bird to a notebook operated by a scientist in the helicopter. **With all helicopters, we guided all cables through the gap between one door and the frame, thus not requiring any mechanical / technical changes to the helicopter.**
For take-off and landing one person is required on the ground who can communicate with the pilot and guide him and has to control safe yielding of the 20 m tow cable. The same person, or one more ground person should secure the bird in the downwash (see also Figure 4). We have also landed the bird on the ice without any ground assistance.

**Figure 4:** Take off of the BO-105 with attached EM bird.

During landing the same number of persons is required to manoeuvre the bird into it’s trolley (Fig. 5) and to care for the save recovery of the tow cable.

**Figure 5:** Landing the system.

On the trolley the bird can easily be stored in the hangar even below the tail rotor of parked helicopters (Fig. 6a). Before and after operation the system is pushed out to the heli deck or inside the hangar respectively (Fig. 6b).

**Figure 6:** a) The bird stored in the hangar. b) Moving the system on the helicopter deck.
We propose round-trip flights of 1-3 hours duration over compact multi-year ice in Nares Strait, western Baffin Bay, Norwegian Bay, Belcher Channel and Mclean Strait, safety aspects and weather permitting (total flight time 10-15 hours).

Flight paths will include, where practical, over-flight of lines drilled for ice thickness by the on-ice party. For this reason, scheduling of both activities on the same day is desirable, with the on-ice activity being the first to start.

**Detailed Sub-Area Maps**

Figure 8. Locations in Smith Sound & Kane Basin. Shallow mooring (yellow), CTD & rosette station lines, weather station (cyan).
Figure 9 Locations near Cardigan Strait and Penny Strait. Deep mooring (red), CTD & rosette station lines.

Figure 10. Locations in Kennedy Channel, Hall Basin and Robeson Channel. Shallow mooring (yellow), CTD & rosette station lines, deep moorings (red), weather stations (cyan).
**Mooring Designs**

*Pressure Mooring (2 sites)*

The mooring is an unconventional design intended to provide a stable foundation for the pressure gauge (vertical movement limited to millimetres) during a 2-3 year deployment. The instrument is positioned as shallow as practical to avoid ice (18-20 m) and in a location chosen to minimize the risk from icebergs. Vulnerability was reduced by deploying in shallow bays that are covered by fast (non-drifting) ice for much of the year and relatively sheltered from in-drifting ice in summer. Discovery Harbour and Foulke Fjord were probably the best sites in this respect. Other possible sites were exposed to incursion of pack ice along some headings.

In 2003, the moorings were positioned by divers from Healy upon metal stakes hammered into the seafloor. Pressure recorders deployed in 2007 and planned for deployment in 2009 are secured on moorings of simpler design; divers are not required. Unlike conventional oceanographic moorings that float to the surface when a release is activated acoustically to disconnect the mooring from its anchor, the release of this mooring permits the surfacing of a tethered float. Recovery is achieved by pulling up on the tether to lift the non-buoyant mooring off the seafloor.

![Diagram of mooring](image)

Figure 11. Schematic diagram of the mooring that will be used in 2007 to deploy recording pressure gauges in shallow sheltered waters.
Ocean Current Mooring (6 to deploy)

This is a torsionally rigid mooring used to support an Acoustic Doppler Current Profiler (ADCP) and a temperature-salinity recorder. The mooring holds the sonar at fixed heading and pointing upward within a few degrees, even in strong current. There are two acoustic transponder-releases to provide redundancy in case of failure. The mooring used in Nares Strait is a lighter version of that used in Hell Gate and Cardigan Strait, where currents are 2-3 times stronger, reaching 3 m/s (6 kt) at times.

Temperature-Salinity Mooring (2 to deploy)

This is a taut-line mooring used to support temperature-salinity recorders at four levels between 30-m and 200-m depth. There is one acoustic transponder-release. Above 200-m depth, the buoyancy is small, so that the top of the mooring will pull down appreciably in strong current. This sensitivity is deliberate: since icebergs sweep larger volumes per unit time in strong current, pull-down in such conditions reduces the likelihood of strikes by icebergs. The mooring straightens at slack tide allowing observations closer to the surface. The mooring relies on strings of small plastic floats for buoyancy at upper levels, instead of conventional spherical floats, in order to reduce the likelihood of snagging on contact with drifting ice.
**Ice-thickness Mooring (2 to deploy)**

This is a taut-line mooring used to support an ice-profiling sonar (IPS) at 75-m depth. There are two acoustic transponder-releases. Because measurements by the IPS are degraded by pull-down and tilt of the instrument, this mooring has significant buoyancy. A necessary consequence of buoyancy is a heavy anchor; at 1800 lb, this is the heaviest among the four mooring types. The IPS has been placed at the shallowest depth consistent with safety in the occasional presence of icebergs. For deployments in 2009, there will be SBE37 temperature-salinity recorders in addition to IPS on these moorings.
Every line splice from 2003 that terminates in the cast-iron FSRG stopper eye will require 2 x 7/16” shackles.

Line spliced this year use a 2-chin-link stopper and require only 1 x 7/16” shackle

The non-stop-off end of lines spliced in 2003 has a 1/4” round nylon eye.

The non-stop-off end of lines spliced this year has a 5/16” nylon thimble (tear drop shape).

The 5/16 tear drop shape permits reversing a shackle through it, and is a little stronger.

IPS4 in short case
Pieps with pressure switch
Grapping loop
30° float (modified S0369)
Rope guide
2 bolts with isolation sleeve
Battery case (40”) in frame
Isolation sleeve in frame
FSRG stop-off eye 2 x 7/16” shackle

Stop-off point

SBE37SM
1/4” nylon thimble
7/16” & 1/2” shackles

30° float (S0369)
1/2” shackle
7/16” shackle
1.5 T Esmet swivel
7/16” shackle
3/8” chain stopper (2 links)
5/16” nylon & steel thimble

Stop-off point

Lift point

SBE37SM
219 m for KS03
266 m for KS05

(Include if units are available)
5/16” nylon & steel thimble
2 x 7/16” shackle

1/4” nylon thimble
FSRG stop-off eye
2 x 7/16” shackle

1/4” nylon thimble
FSRG stop-off eye
2 x 7/16” shackle

1/4” nylon thimble
FSRG stop-off eye
2 x 7/16” shackle

1/4” nylon thimble
7/16” shackle
3/8” chain stopper (3 links)
1/2” shackle

24” float (IO-3820)
1/2” shackle
7/16” shackle
1.5 T Esmet swivel
2 x 7/16” shackles back to back
Tandem 866A release transponder with swing link of 1/2” steel plate

2 x 10 mm 316L SS shackle
Cross beam w/ isolation bushings
3/4” drop link
3/4” nylon thimble

1/2” shackle
7/16” shackle
1.5 T Esmet swivel
2 x 7/16” shackles back to back
Tandem 866A release transponder with swing link of 1/2” steel plate

2 x 10 mm 316L SS shackle
Cross beam w/ isolation bushings
3/4” drop link
3/4” nylon thimble

SBE37SM
(Include if units are available)
5/16” nylon & steel thimble
2 x 7/16” shackle

1/4” nylon thimble
FSRG stop-off eye
2 x 7/16” shackle

1/4” nylon thimble
FSRG stop-off eye
2 x 7/16” shackle

1/4” nylon thimble
FSRG stop-off eye
2 x 7/16” shackle

1/4” nylon thimble
7/16” shackle
3/8” chain stopper (3 links)
1/2” shackle

24” float (IO-3820)
1/2” shackle
7/16” shackle
1.5 T Esmet swivel
2 x 7/16” shackles back to back
Tandem 866A release transponder with swing link of 1/2” steel plate

2 x 10 mm 316L SS shackle
Cross beam w/ isolation bushings
3/4” drop link
3/4” nylon thimble

3/4” nylon thimble
3/4” shackle
1800-lb chain clump
Hybrid Ocean Current and Ice Thickness Mooring (1 to deploy: Penny Strait)

Grappling loop (poly rope)
IPS4 Ice-profiling Sonar
Stainless steel frame
5 Viny floats w/ plywood stops
Bumper hose w/ clamps
Pieps beacon w/ bracket

Isolation bushing kit
7/16" shackle
1/2" shackle
1.5T bronze swivel
1/2" shackle
3 long links 1/2" chain
7/16" shackle
1/4" plastic eye

Lift point
Stop-off point

5 m: 1/4" kevlar

52 m

SS22 steel float
1/2" shackle
3 long links 1/2" chain
7/16" shackle
1/4" plastic eye

Lift point
Stop-off point

62 m: 1/4" kevlar

115 m

SS28 steel float
1/2" shackle
1/2" shackle
1.5T bronze swivel
1/2" shackle
3 long links 1/2" chain
7/16" shackle
1/4" plastic eye

Lift point
Stop-off point

30 m: 1/4" kevlar

25, 5, 10-m lengths for depth adjustment

Lift point
Stop-off point

SBE37-5M

Battery case (40") in frame
Tandem 501AR releases with aluminium swing link
Torsionally rigid backbone
Universal joint
Cruciform base
1000-lb chain clump

Stop-offs have been positioned for anchor-first deployment. Move stop-offs to above the floats for anchor-last deployment.

May 13, 2009

ACW Mooring
2009-2010
Penny Strait
76° 40' N, 098° 00' W
Inclination: 88.3°
H = 1761 nT
**Observational ‘Picket Fence’ in Kennedy Channel**

The two cross-sectional plots below show the present disposition of instrumented moorings across the southern end of Kennedy Channel, and the smaller array to be deployed this August across the narrower section between the western end of Franklin Island and the Ellesmere coast, about 30 km north-east of the present array.

![Figure 13. Arrangement of moorings with instruments for measuring and recording ocean current, ocean temperature & salinity and ice thickness in a section across Kennedy Channel at Franklin Island, 2009-2011.](image1)

![Figure 14. Arrangement of moorings with instruments for measuring and recording ocean current, ocean temperature & salinity and ice thickness in a section across the southern end of Kennedy Channel. The diagram shows the array deployed in 2007.](image2)
**Observational ‘Picket Fence’ in Cardigan Strait**

![Diagram of undersea moorings in Cardigan Strait](image)

**Recovering Moorings for Current, Temperature-Salinity & Ice Thickness**

**According to Plan**

Our procedure for retrieving instruments moored in the deep water of Arctic channels is oceanographic standard practice, with concessions to the risks and impediments posed by drifting pack ice.

We start with a strategic assessment of ice cover near the site of the mooring. The outcome of the assessment is a decision whether to move the ship to the site at this time. The decision will be guided in part by the usual considerations – daylight, weather, workday, etc. – and in part by information about pack ice at the location and on route to it – concentration, floe size, ice type, rate of drift – derived from ice charts, satellite imagery and perhaps aerial reconnaissance.

Once the ship is positioned by GPS at the location of the mooring and stopped, we place a hydrophone over the side to communicate with the acoustic transponder-release(s). The releases used in Nares Strait have been modified for increased longevity by turning off the main electronics for 2 minutes out of 3. Since the release is only capable of “hearing” and responding when turned on, repeated transmissions over an interval of several minutes are required to catch the transponder in its ON state, and to switch it to an “Enabled” condition when it is fully attentive.

In difficult ice, we may wish to interrogate the acoustic transponder from two or more locations of the ship in order to establish the exact position of the mooring relative to the ship and to any ice floes in the vicinity.

If ice cover at the site is appreciable, surfacing of the mooring following anchor release must be timed to coincide with the presence of ice-free water over the location. The speed and direction of ice drift are useful knowledge in this decision. Ice drift can be measured by tracking ice floes on the ship’s radar. Note that rising mooring will drift with the tide, but will not be influenced by wind as is the ice.

Estimates of the time between anchor release and surfacing of the top mooring component differs with the depth and surplus buoyancy of the mooring, as follows:

---

6 August 2009
Ocean current mooring: 4 min from 350 m
Temperature-salinity mooring: 30-60 s from 30 m (nominal)
Ice-thickness mooring: 60-100 s from 100 m

The mooring is released from its anchor via a coded acoustic transmission following a favourable tactical assessment of the ice hazard.

After being sighted at the surface, the mooring must be secured and brought to the ship’s crane using the ship’s boat. Simple moorings (such as the ADCP) may be hoisted to the deck in a single lift. The long-line moorings can be drawn in manually, with a few crane lifts necessary for heavier components.

Possible Need to Drag

As a last resort, it is sometimes possible to recover by dragging moorings that cannot be remotely released from their anchors to float to the surface. For taut-line moorings, the objective is to cut the mooring line as close as possible to the seabed, via abrasion with the rough dragging wire. For the ADCP moorings, which stand only 3 m above the seabed, the objective is to lodge the hooks trailing on the drag wire into the mooring assembly for a lift to the surface.

Attempts in 2001, 2006 and 2007 to drag for moorings in Nares Strait that would not release have been challenging and unsuccessful. There will be no such requests in 2009.

Recover Moorings for Pressure

According to Plan

We start with a strategic assessment of ice at the mooring site. Since the pressure moorings are in shallow uncharted waters near shore, the assessment considers presence/absence of ice at the mooring, the feasibility of ship’s approach within a few miles and the practicality of reaching the mooring site by rigid hull inflatable (fast, if little ice) or by small boat slung in by helicopter.

Once at the GPS location of the mooring, we place a hydrophone over the side to communicate with the acoustic transponder-release. Since the transponders have been modified for increased longevity by turning off the main electronics for 2 minutes out of 3, the release is not always capable of “hearing” and responding. Therefore transmissions repeated over an interval of several minutes are required to catch the release in its ON state, and to switch it to an “Enabled” condition when it is fully attentive.

With these moorings, a coded acoustic transmission releases a pick-up buoy on a tether linking it to the instruments 20 m below. The tether may be used to lift the instruments off the seabed and raise them to the surface. This is easiest if the boat is more or less directly over the installation.

Possible Need to Drag

For various reasons, there is some possibility that we will retrieve the shallow pressure-gauge moorings by grappling from the recovery boat.

The shallow depth of the pressure-mooring sites (18-20 m) allows a better directed approach to recovery by grappling. We carry a small rotary-scan sonar (Imagenex) with an effective range of about 30 m, which may permit “finding” the mooring on the seabed. We also carry an underwater video camera with lights. With this assistance it may be possible to “fish” for the mooring with grappling hook. Otherwise, these imaging devices will be helpful in confirming the presence or absence of the mooring (often a big uncertainty with dead moorings), and in setting the drag line at the correct location. Since there are no components to cut on the pressure mooring, we drag with a polypropylene rope and grappling hook, with the objective of snagging the mooring and lifting it to the surface.

Deploy Moorings for Current

These moorings are completely assembled on deck. For deployment, they are lifted over the side, lowered to the water surface and cut loose to free-fall to the seabed (2 minutes for a depth of 400 m). These moorings can be readily deployed even in heavy ice, requiring only a few square metres of ice-free water adjacent to the hull.
When the mooring has reached the seabed, we interrogate the transponder-release to verify its operability before setting it to sleep and leaving the site.

Figure 16. A long-range ADCP ready for deployment via the A-frame of USCGC Healy in August 2003.

**Deploy Moorings for Temperature-Salinity and Ice Thickness**

Temperature-salinity recorders and ice-profiling sonar are deployed on taut-line moorings several hundred metres in length. Although it is possible to deploy such moorings anchor first in heavy ice, this requires an A-frame and a capstan winch, with which we will not be equipped on the CCGS Henry Larsen. Thus, all taut-line moorings deployed in 2009 will be deployed anchor last. This method requires an expanse of ice-free water sufficient to stretch out the length of the mooring along the sea surface. In the adjacent picture, the float strings forming the upper sections of a temperature-salinity mooring are paid out from the stern of the Healy.

The work deck on Healy is at the stern. This setup allowed the mooring to be streamed out behind the ship as it moved slowly forward towards the drop location. On CCGS Henry Larsen, where work is conducted from the foredeck, this approach is not practical. Instead, we use the ship’s boat to pull the mooring out from the starboard side of the ship as it is passed over the side. When the final lift is on the crane and over the side and the ship at the desired location for deployment, the ship’s boat casts off the top end of the mooring, and the final lift is cut loose.

Figure 17. Float strings forming the upper sections of a temperature-salinity mooring are paid out from the stern of the Healy
Figure 18. The final lift (float, tandem release assembly, drop line and anchor clump) of an ice-thickness mooring is shown on the crane, prior to its drop to the sea floor. Mooring floats appear in the background.

**Deploy Moorings for Pressure**

The pressure recorder mooring for deployment in 2009 consists of two lightweight (less than 100 lb) components separated by a 100-foot weighted ground line. The moorings is designed for 18-m water depth.

The method of deployment is straightforward:

1. Locate an 18-m water depth in the chosen sheltered location. Determine in which direction the water deepens most rapidly. Since the second element of the mooring stands higher off the seabed, it should be placed in the deepest water within 100 feet of the pressure recorder.
2. Lift 1 comprises the ballast cradle plus the pressure recorder, weighing a total of 57 lb in air and 20 lb in water. This assembly is lowered to the seabed in the appropriate depth using the weighted ground line.
3. The boat is moved into deeper water, paying out the weighted ground line on the way.
4. Lift 2 comprise the deadweight anchor, a Benthos 867A transponding release, a Viny 12B-3 float, weighing a total of 91 lb in air and 20 lb in water. The second lift is dropped from the surface when the ground line is fully deployed and taut to the pressure recorder.

**Information on Multi-year Ice Testing**

**Objective**

The objective of this work is measurement of the geometrical and thermal properties of multi-year ice floes, specifically floe thickness and internal temperature. If practical we would like to re-visit floes sampled during the first week, in order to document change during August, the month of most rapid ice warming and ablation.

This work is being conducted as a collaborative effort among DFO, NRC and various industrial partners. It is relevant to the federal Program of Energy Research and Development (PERD) in relation to safe Arctic hydrocarbon development and transportation.

**Study Area**

The observations will be conducted on old ice floes drifting in two areas of focus, Nares Strait (80°N) and Penny Strait (76°).

Sampling of each multi-year ice floe will require approximately 8 hours. The work will be conducted during down time in the mooring programme, or if practical, simultaneously with it.

**Sampling Methodology**

The work involves measuring ice thickness along a number of transects, which will be traversed on foot. The ice thickness will be measured by drilling 2” holes through the ice with a gas-powered auger with extension rods and again using an electromagnetic induction sensor. The ice-thickness work can be done by Michelle Johnston and two technicians over the course of a day. It requires only about 100 kg of equipment: 15 m of 50 mm stainless steel auger flighting and extension rods, a gas-powered drill, the EM-34 thickness radar and the ice corer. For this work, the floes can either be accessed directly from the ship or via helicopter.
**Ice Temperature and Changing Thickness**

This component is designed to provide information on how quickly thick multi-year ice melts in summer and how much it recovers (new ice forms on the underside of the floe) during the winter. Three chains of thermistors will be positioned in bore holes through very thick portions of multi-year ice floes, two in Nares Strait and one near Penny Strait. The temperature chains will extend through the full thickness of ice to monitor changes in the ice as the floes drift south. The temperature chains will be supported by flotation buoys (1.3 m across) that, once they melt free of the ice, are practical for recovery. We are aiming to deploy the single 25-m long chain in a multi-year pressure ridge of comparable thickness near Penny Strait. Since this ridge will likely not travel far before freezing into fast for the winter, it may be possible to re-visit in the spring of 2010 to recover instrumentation and conduct further thickness measurements.

**Automatic Weather Stations**

Nares Strait, separating Ellesmere Island from Greenland, has unique severe weather. Strong winds that result from air-flow channeling by high surrounding terrain are challenging to forecast and hazardous to operations. For example, hurricane-force winds devastated the CATs field camp in April 2005, resulting in its abandonment. Such wind events may occur as often as 5-10 times per month during the winter and spring. Winds in the strait also play a role in the transport of Arctic Ocean water and ice southward towards Baffin Bay. Data will improve our ability to forecast wind and weather in Nares Strait, with benefits for safety of operations and improved knowledge of the ocean and ice dynamics of the region.

Two automatic weather stations were deployed on the Ellesmere side of Smith Sound in September 2006, at Pim Island and at Cape Isabella and serviced from CCGS Henry Larsen in August 2007. A third was deployed on Hans Island in May 2008. We plan to visit these sites in 2009 by helicopter from CCGS Henry Larsen and complete tasks from a sequence of graduated difficulty, depending on how well the equipment has fared during 15-24 months of operation in this hostile environment.

1) Take some pictures of the weather station and the site to document its condition before remediation.
2) Determine the exact position and elevation of the site, and the geographic heading of the reference direction for wind.
3) Assess and repair possible damage to the installation, if necessary returning parts to the ship.
4) Determine if the sensors are visibly damaged. If the wind sensor is no longer operable, dismantle the installation and bring all parts back to the ship.
5) If there is no visible damage to sensors and the tripod looks as if it can withstand a second year of operation, leave the sensors on the tower.
6) Download the data from the on-site logger. Check the record for realistic values and for operation throughout the dark period in winter, when batteries are not re-charged by the solar panels.
7) Photograph the renovated weather station and depart.

A new automatic weather station will be established further north on Ellesmere Island at Cape Baird on Hall Basin.

**Shoreline Pick-ups**

*Alexandra Fjord*

There is a cache here placed via PCSP aircraft from Resolute Bay in mid July 2009. The cache contains much of the equipment needed for the multi-year ice testing activity lead by Michelle Johnston. For this reason, the cache must be retrieved early in the expedition.

There are 8 boxes of equipment, with a total weight of 720 lb. The heaviest single item is 150 lb. The bulkiest item is 34” x 30” x 10”. The longest item is 72”. 
Locations of Installations

Moorings to Recover from Nares Strait

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<tr>
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Moorings to Recover from Cardigan Strait

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Automatic weather stations

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**Moorings to Deploy in Nares Strait**

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**Moorings to Deploy in Cardigan Strait**

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**Moorings to Deploy in Penny Strait**

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<tbody>
<tr>
<td>ACW09-8</td>
<td>76</td>
<td>40.000 N</td>
<td>098 00.000 W</td>
<td>150</td>
</tr>
</tbody>
</table>

**Stations on Cross-sections for Water Sampling**

→ To be provided

**Stations on Cross-sections for CTD Profiling**

→ To be provided
Shipments of Scientific Equipment

**Fisheries and Oceans Canada**
Institute of Ocean Sciences, 9860 West Saanich Road, Sidney BC, V8L 4B2
Ron Lindsay (250-363-6592) LindsayR@dfo-mpo.gc.ca

**National Research Council of Canada**
Canadian Hydraulics Centre, Bldg M-32, Montreal Road, Ottawa, K1A 0R6
Michelle Johnston, (613-990-5141) Michelle.Johnston@nrc-cnrc.gc.ca

**University of Alberta**
University of Alberta 1-26 ESB
Edmonton, AB, T6G 2E3
Christian Haas (780-492-8171) chaas@ualberta.ca

**University of Delaware**
112 Robinson Hall, College of Marine Studies
Newark DE 19716 USA
Andreas Muenchow, (302-831-0742) /(302-757-1699) cell. muenchow@udel.edu

Hazardous Materials (in small quantities)
Triton-X cleaning solution
Scotch Kote (for underwater splices)
BR Type lithium cell, model 123
AF24173 Anti-Foulant capsule
Ethanol & WD-40 (NRC)
Weld-on glue #40 and #4
Krylon water-based spray paint (2 cases)
### Supernumeraries on the Science Team

<table>
<thead>
<tr>
<th></th>
<th>Name</th>
<th>Gender</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Humfrey Melling</td>
<td>M</td>
<td>Chief scientist</td>
</tr>
<tr>
<td>2</td>
<td>Andreas Münchow</td>
<td>M</td>
<td>USA Lead scientist</td>
</tr>
<tr>
<td>3</td>
<td>Helen Woollings</td>
<td>F</td>
<td>Scientist: oceanography</td>
</tr>
<tr>
<td>4</td>
<td>Michelle Johnston</td>
<td>F</td>
<td>Scientist: ice properties</td>
</tr>
<tr>
<td>5</td>
<td>David Spear</td>
<td>M</td>
<td>Technician: mooring</td>
</tr>
<tr>
<td>6</td>
<td>David A. Riedel</td>
<td>M</td>
<td>Scientist: support</td>
</tr>
<tr>
<td>7</td>
<td>Ron W. Lindsay</td>
<td>M</td>
<td>Technician: electronics</td>
</tr>
<tr>
<td>8</td>
<td>Jonathon Poole</td>
<td>M</td>
<td>Technician: equipment</td>
</tr>
<tr>
<td>9</td>
<td>Linda White</td>
<td>F</td>
<td>Technician: water sampling &amp; analysis</td>
</tr>
<tr>
<td>10</td>
<td>Berit Rabe</td>
<td>F</td>
<td>Student: oceanography</td>
</tr>
<tr>
<td>11</td>
<td>Patricia Ryan</td>
<td>F</td>
<td>Student: oceanography</td>
</tr>
<tr>
<td>12</td>
<td>Peter Davis</td>
<td>M</td>
<td>Student: oceanography</td>
</tr>
<tr>
<td>13</td>
<td>Richard Lanthier</td>
<td>M</td>
<td>Technician: ice programme</td>
</tr>
<tr>
<td>14</td>
<td>Carl Fillon</td>
<td>M</td>
<td>Technician: ice programme</td>
</tr>
<tr>
<td>15</td>
<td>Justin Beckers</td>
<td>M</td>
<td>Student: glaciology</td>
</tr>
<tr>
<td>16</td>
<td>Benjamin Lange</td>
<td>M</td>
<td>Student: glaciology</td>
</tr>
</tbody>
</table>