

# Defence Research & Development Canada's work in the Arctic

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# Outline

- **What is Defence Research & Development Canada?**
- **A little history of DND's Arctic research**
- **The scope of DRDC's activities**
- **Some selected projects**
- **What might be the next step?**
- **Conclusion**

# About DRDC

- A Civilian Agency of the Department of National Defence
- What we do for defence and security:
  - Provide **strategic advice**
  - Address **operational issues**
  - Assist with **force development**
  - Pursue **leap-ahead** capabilities
  - Identify and bring to bear the best **innovators**
- Led by Assistant Deputy Minister (S&T)

# DRDC Key Facts

- 8 research centres located in 4 provinces
- 1,400 employees
- \$275 million operating budget





# DRDC Atlantic Research Centre



**Approx. 200 Staff**

**7 Military staff**

**63 Scientists**

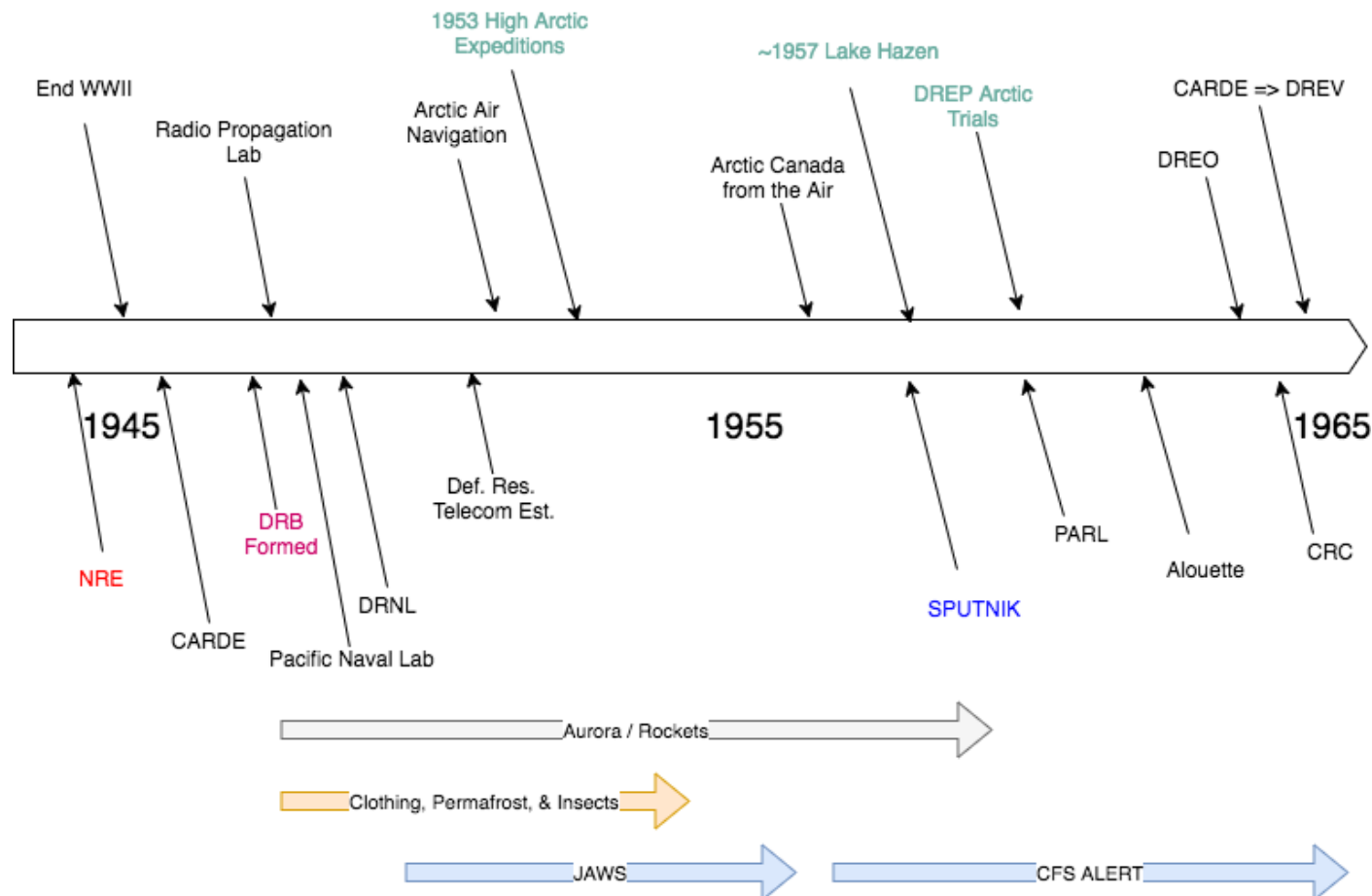
**75 Technical Support**

**30 Admin**

**Annual Budget ~ \$30 M**

**3 staff with NRC in Ottawa**

# Simplified Timeline



# The growth of DRNL

- In 1947, DRNL in Churchill expanded from one shack to three!

1947



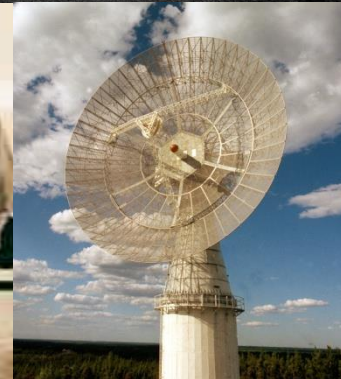
1951





# PARL – Prince Albert Radar Laboratory

- Driven by Sputnik and the need for Ballistic Missile Early Warning



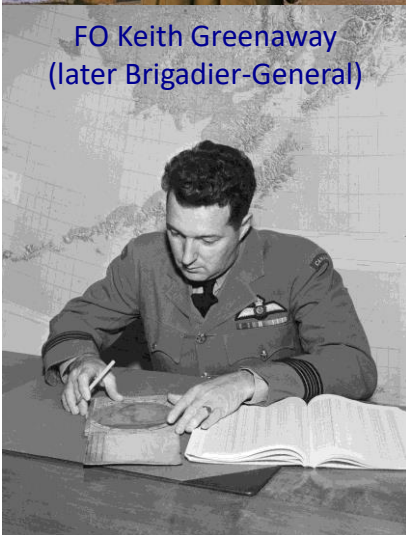


# Important People

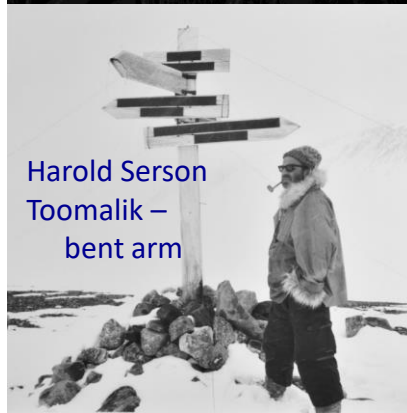
Geoffrey Hattersley-Smith



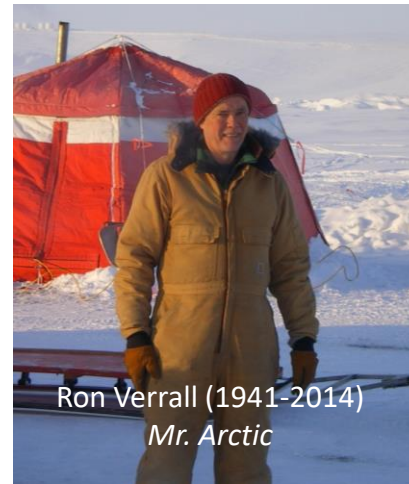
FO Keith Greenaway  
(later Brigadier-General)



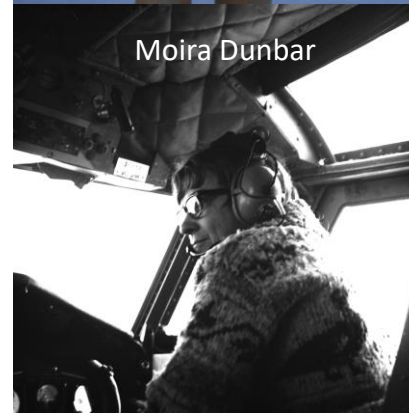
Al Milne



Harold Serson  
Toomalik –  
bent arm



Ron Verrall (1941-2014)  
*Mr. Arctic*



Moira Dunbar

# Scope

## The early days

- Glaciology especially ice shelves
- Geology
- Mapping
- Coastal exploration
- Bathymetry
- Ice cores
- Gravity
- Soils
- Geomagnetism
- Ice thickness and temperatures
- Water samples and temps
- Seismic measurements
- Tides
- Plant ecology and botany
- Meteorology
- Wildlife
- Archaeology
- Entomology

## Later work

- Ionospheric propagation
- Radar
- Environmental protection
- Ice drift
- SAR coastline detection
- GPS
- Emergency Locator Beacons!
- Mobility – mud, snow, ice
- Human performance
- Optics
- Auroral zone => Alouette satellites
- Rockets
- UW noise
- Under-ice propagation
- Surveillance options
- Ice shelves
- Ship noise
- Sovereignty
- Electromagnetics

# DRDC Support to Others

- Jim Milne and Al Tremblay with additional staff as needed
- Environment Canada's Polar Sunrise 2000 and Out On The Ice (OOTI) projects
- Science Applications Internal Corporation's Arctic Climate Observation using Underwater Sound (ACOUS)
- University of Washington's Polar Science Center (UW-PSC) and their North Pole Environmental Observatory (NPEO)
- Long Term Observatory (LTO)
- Lamont Doherty Earth Observatory (LDEO) projects
- International GreenIce, led by the Scottish Association for Marine Science and the follow-on GreenArc projects
- The Canadian Sea Ice Mass Balance Observatory (CASIMBO),
- Scripps Institution of Oceanography's Switchyard project,
- Department of Fisheries and Ocean's Canadian Archipelago Flow-Through (CAT) project,
- Canadian and Danish United Nations Convention on the Law Of the Sea (UNCLOS) projects
- The International PAM-ARCMIP (Polar Airborne Measurements and Arctic Regional Climate Model Simulation Project) to ground-truth data from the CRYOVEX2 satellite.



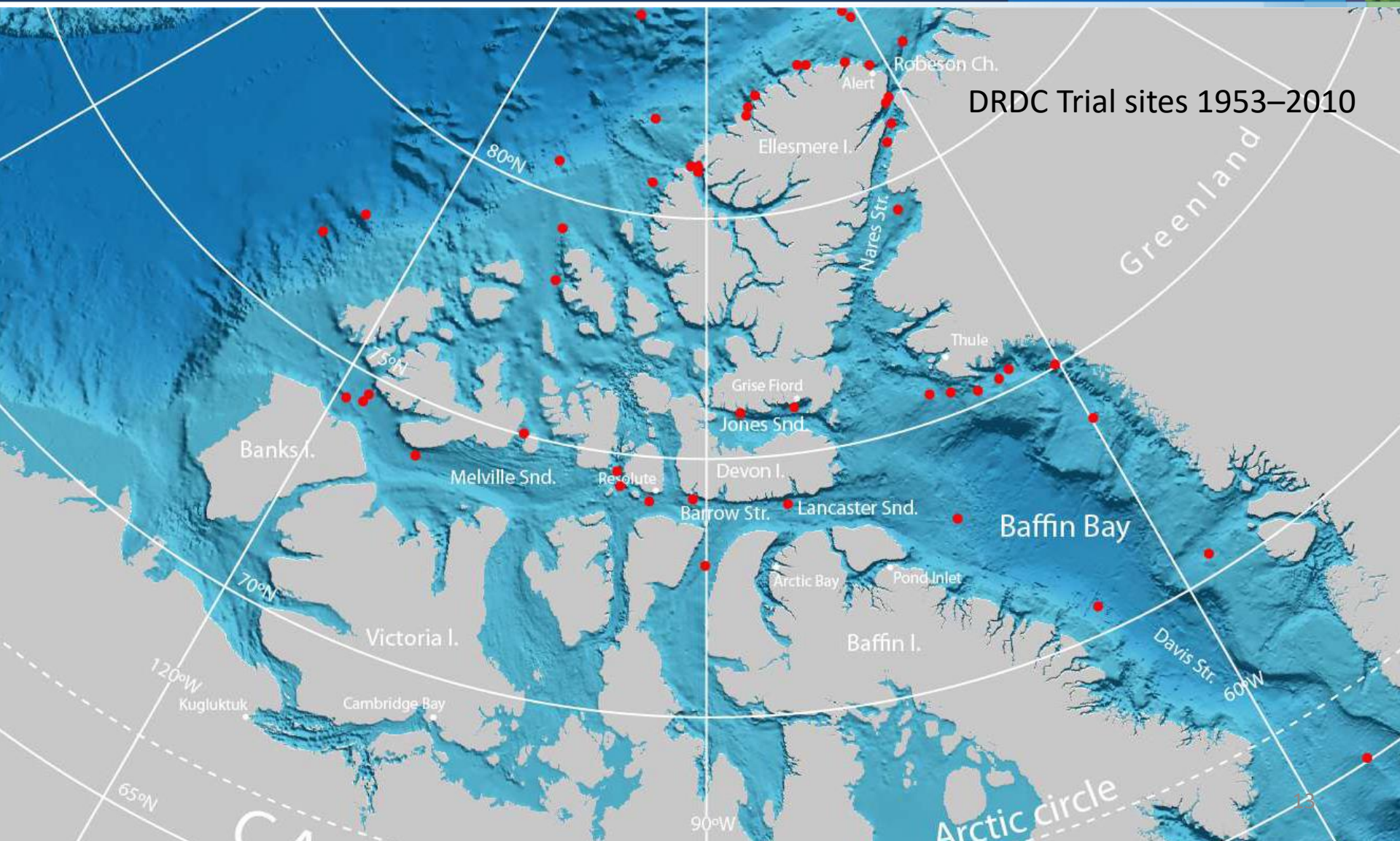
Jim Milne, Dan Wile, Gerry White



Al Tremblay



## DRDC Trial sites 1953–2010

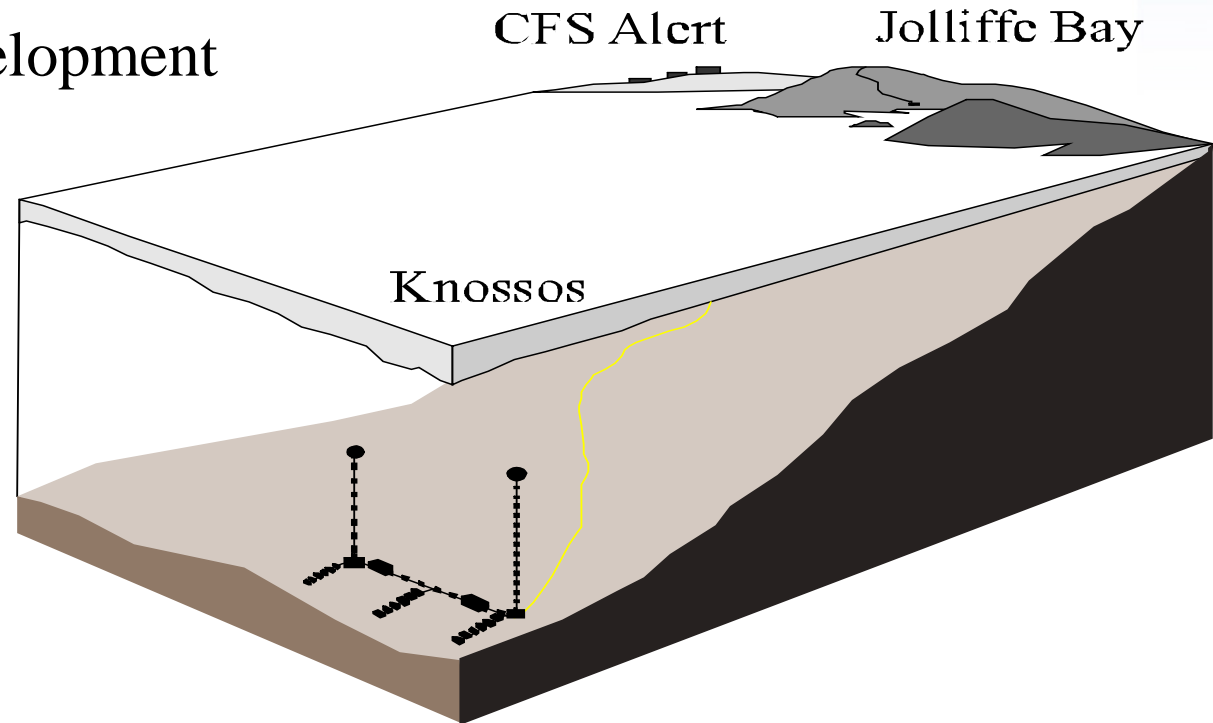




## Selected Projects

# Project Spinnaker

- Joint Canada-US project to lay an underwater acoustics sensor array under the Arctic Ice
- One of DRDC's most ambitious projects to date
- Canada – UUV development
- US – sensor development
- Shared logistics



# Canada's Contribution - Theseus UUV

- **Worlds largest UUV – 20,000 lbs**
- **Mission endurance over 500 km at 4 knot nominal speed**
- **Accurate navigation**
- **Lay 210 km of fiber optic cable**
- **Rest on the bottom or under the ice**
- **Operate at depths of 1000 m**
- **Capable of autonomous operation**
- **Fault management system**
- **Modular construction for shipping**



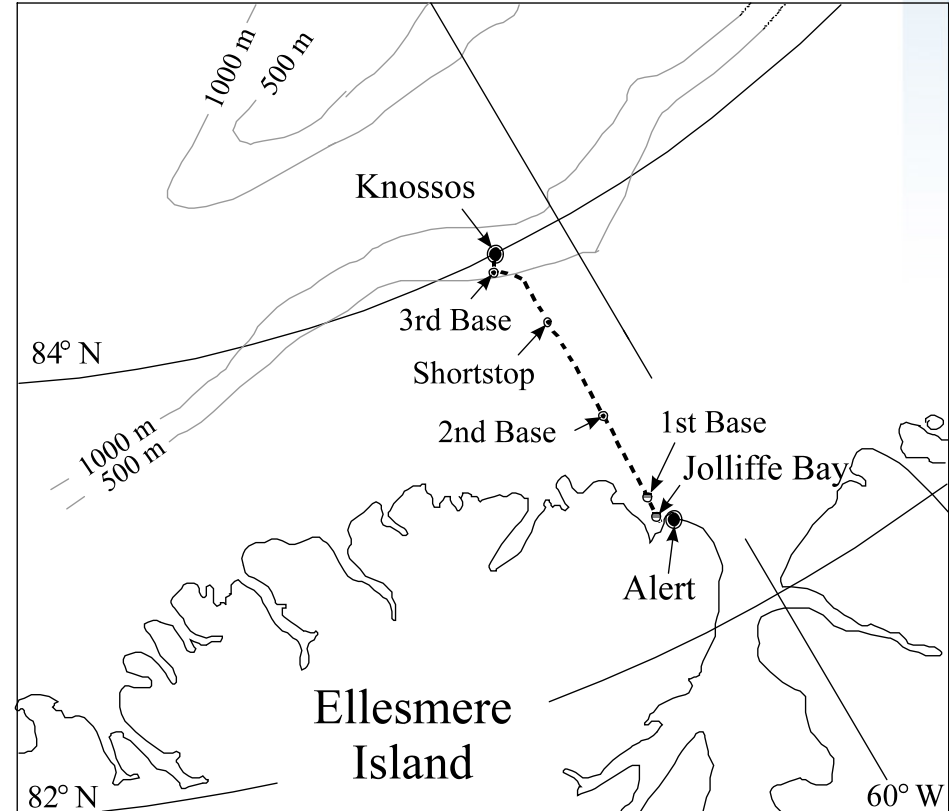
Jolliffe Bay - 1996





# How did it all end?

- Successfully laid 210 km of fiber optic cable
- At Knossos, Theseus navigated through triangle 200 m x 100 m.
- Fiber was captured in cradle system that was then pulled up through a hole in the ice.
- The fiber was cut and the sensors were attached (and operated for some time after)
- Vehicle returned back to Alert safely



# Project Cornerstone

## Objective:

*To use Autonomous underwater vehicles (AUVs) to collect high quality bathymetric data , in particular between the 2500 m contour line and the “foot of the slope”, in ice covered waters in the Arctic*

**Project Execution:** Inter-department MOU between DRDC, NRCan, and DFO

## ISE Vehicle launch and recovery from the ice near Borden Island in 2010



# Unique Homing requirement

- **AUV must return to a drifting ice camp that is moving at up to 10 km/day!**
  - For a 3 day mission, this is a total drift of up to 30 km!
- **We developed a custom 7-element hydrophone array that is mounted in the nose of the AUV**
- **Deployed a custom-built 1300 Hz, sound source in the water**
- **Using specialized software on the AUV, the bearing angle from the AUV to the ice camp is calculated**
- **Homing at ranges greater than 50 km**





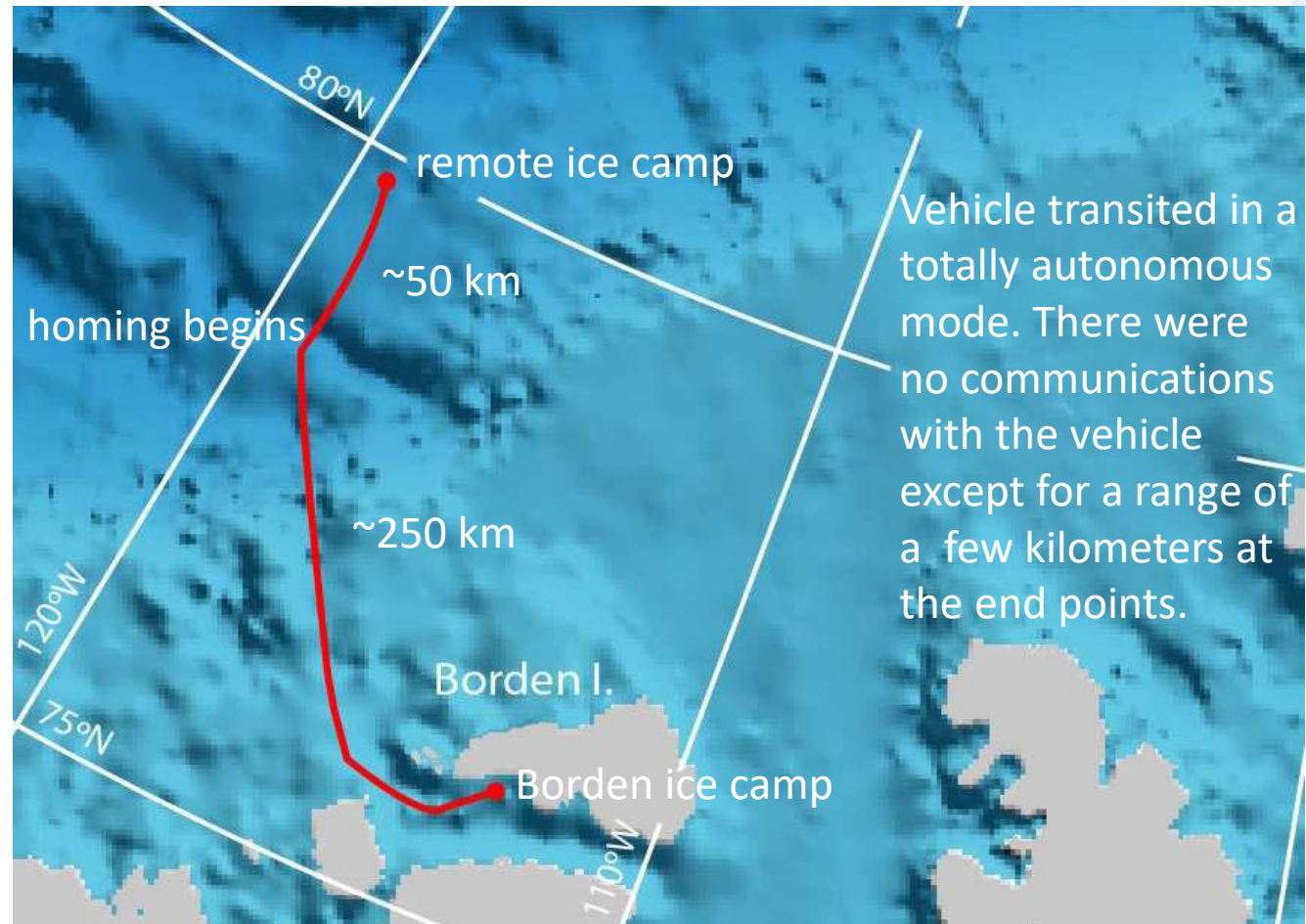
# Arctic AUV long-range homing

1st under-ice 300 km, Mar. 2010.

AUV homes from a range of 50 km to a moving ice camp.

>2000 m water depth at Remote Camp.

Trial included over 1000 km under-ice navigation.

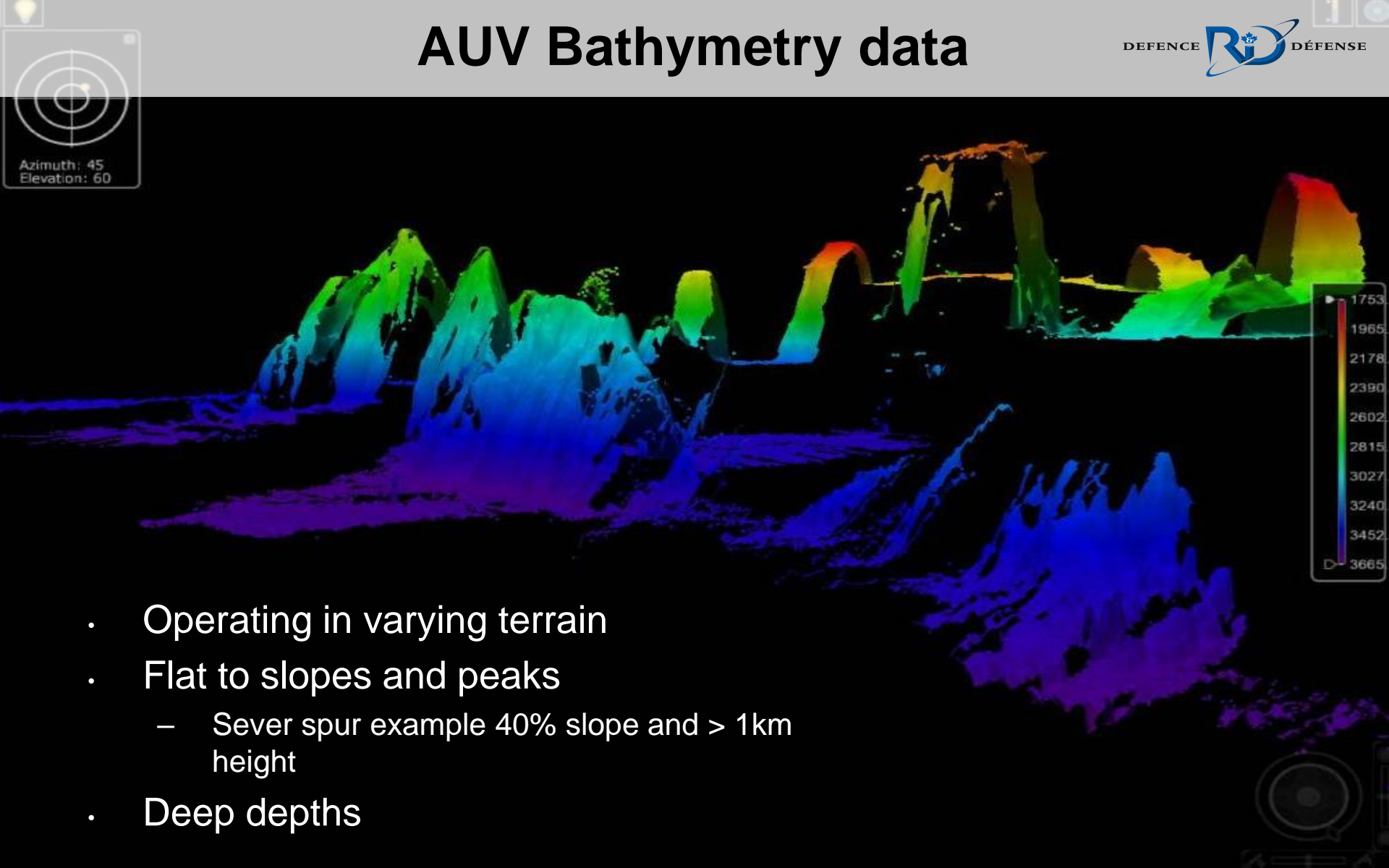


# What was accomplished?

- Completed >500 km of critical bathymetric measurements.
- In total, the AUV traveled over 1000 km during a continuous operating period of 10 days, at water depths of over 3300 m under the ice. It also successfully homed to a moving ice camp from a distance of 50 km
  - Note, each of these achievements is remarkable.
  - Collectively they represent a world record for under-ice operations in the arctic, and have provided critical data for Canada's UNCLOS submission.



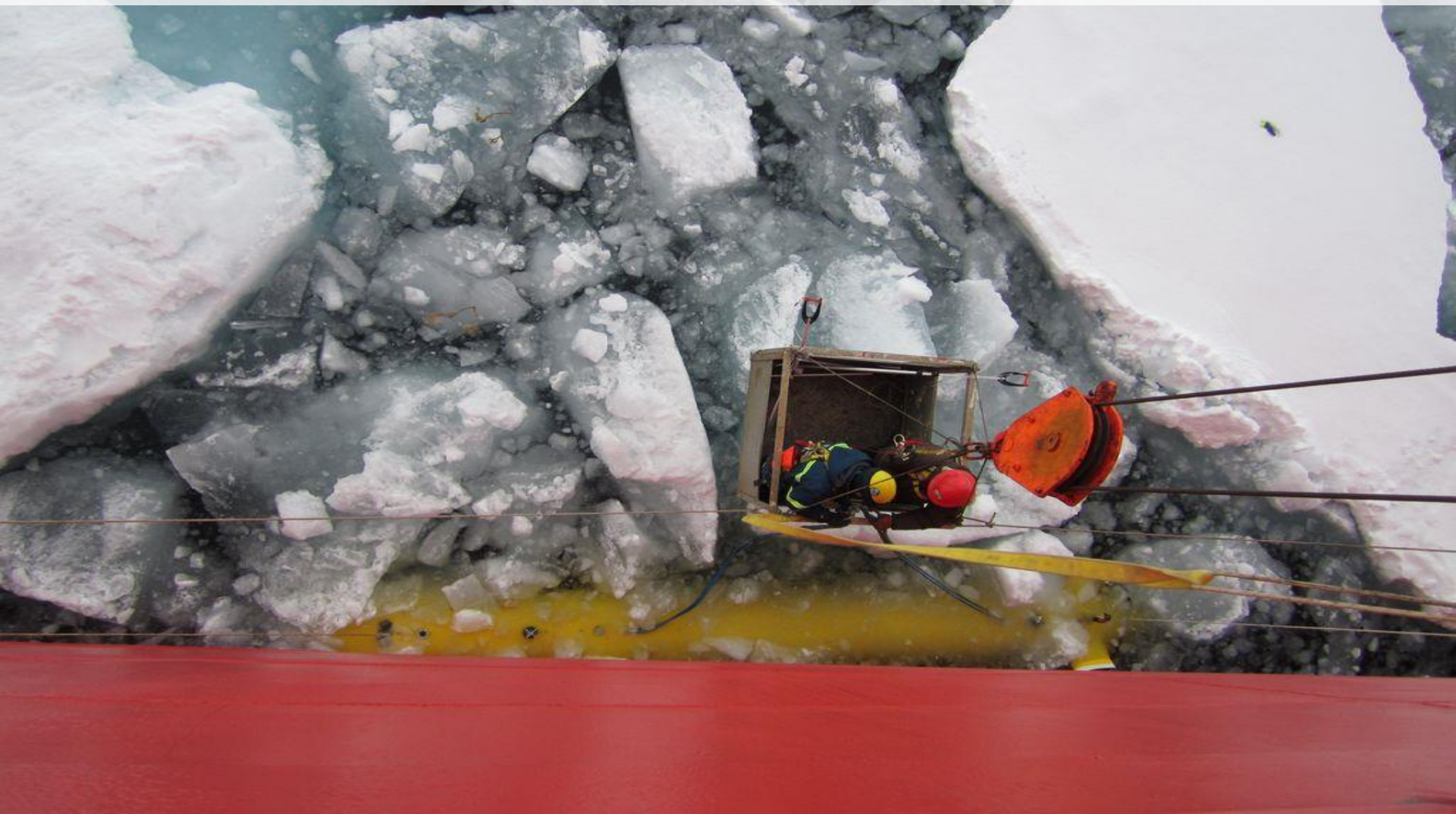
# AUV Bathymetry data



- Operating in varying terrain
- Flat to slopes and peaks
  - Sever spur example 40% slope and > 1km height
- Deep depths



# Vehicle Launch and recovery from a ship in 2011





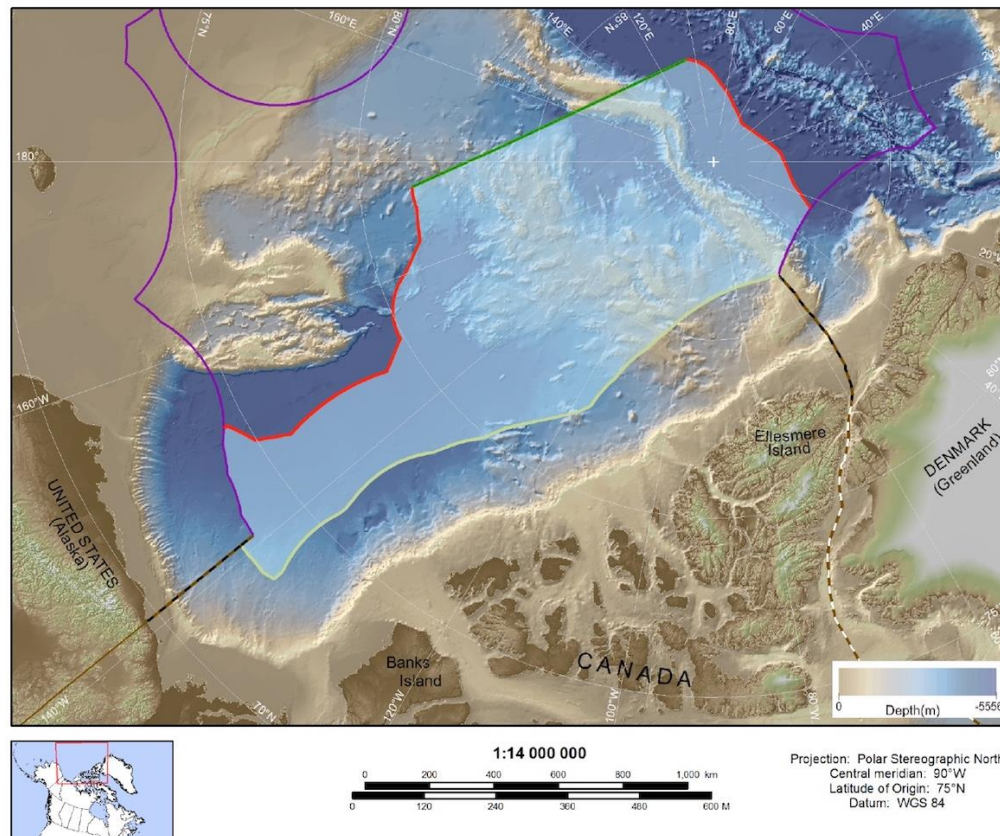
# AUV Mission – Data Results



## North Ridge

- Notice slight elevation change.
- Not as flat as chart gravity readings suggested.

# Nunatsiaq News May 24, 2019



# Northern Watch Technology Demonstration

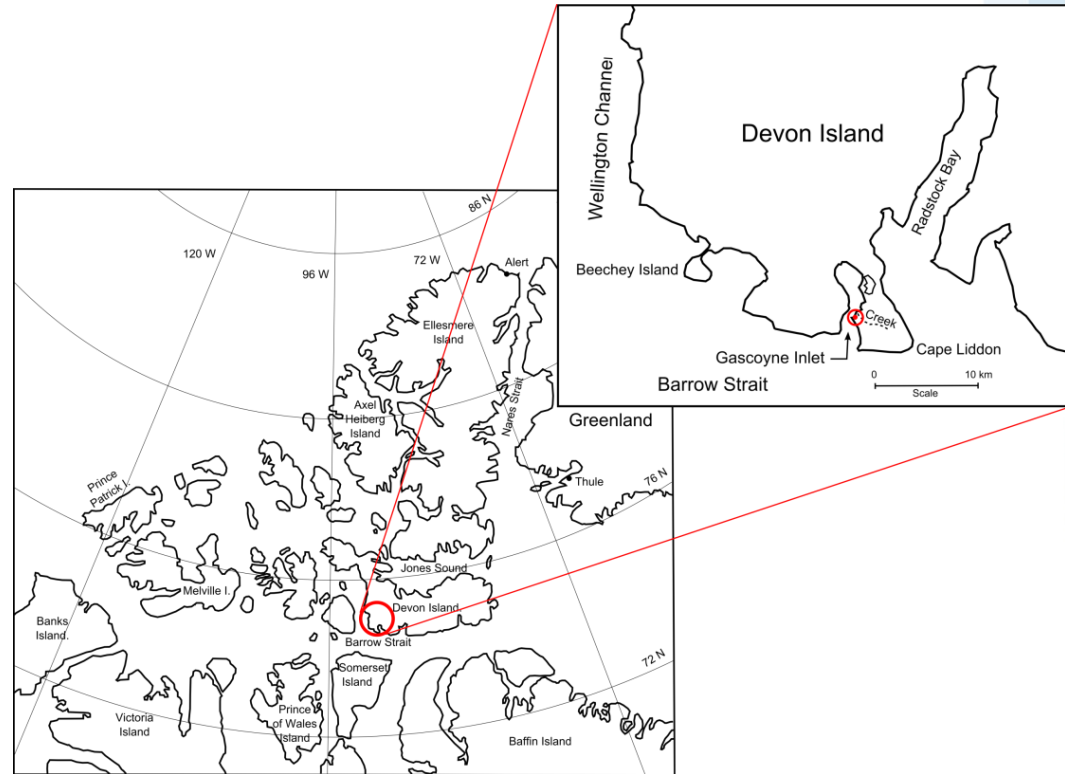
- A remotely controlled, integrated surveillance system for Arctic choke points
- Began in 2007 and ended March 2016 (wasn't continuous)
- Overall it was a relatively successful project, but it faced a number of difficulties along the way





# A choke point surveillance area

- Devon Island, Barrow Strait
- Barrow Strait is ~70 km wide, hundreds of kilometres long
- Uninhabited island
- Nearest support ~100 km away in Resolute





# Gascoyne Inlet Camp and Barrow Strait



# NW Supporters



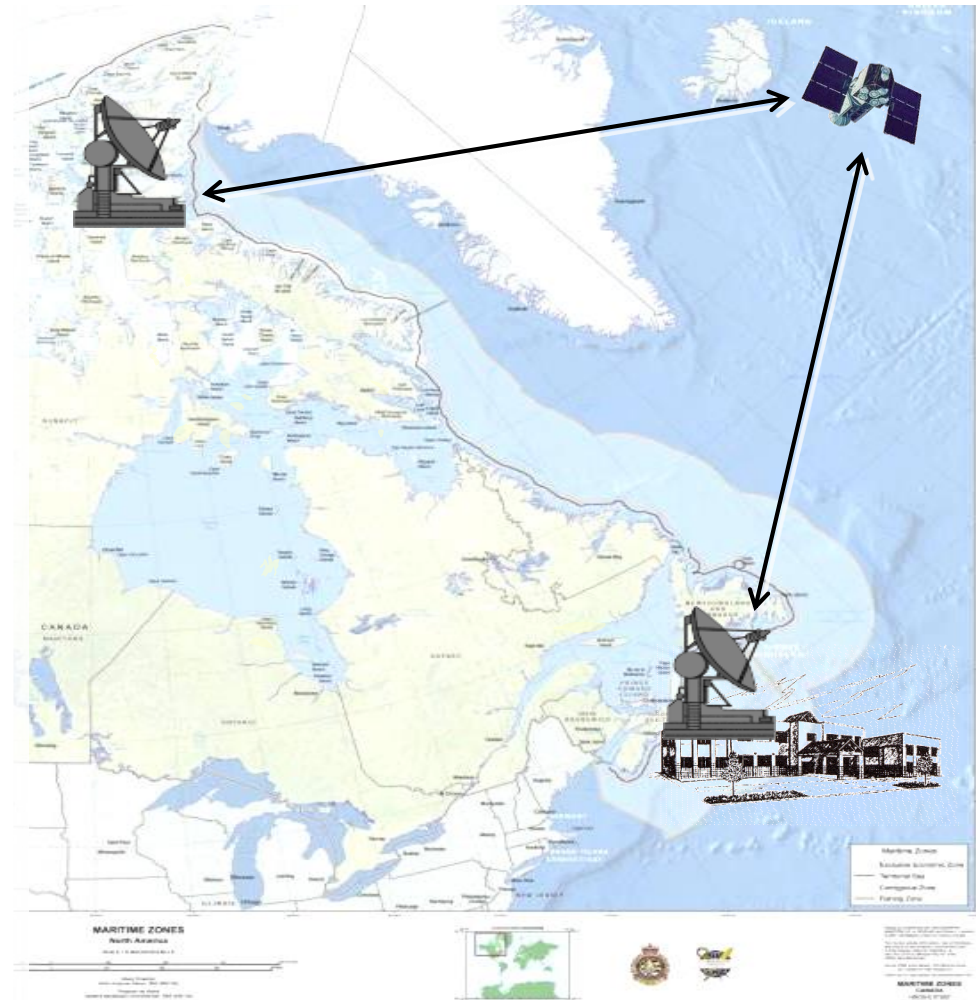


# UW Array System



# Demonstration of Persistent Unattended Surveillance

- Surveillance of Barrow Strait from Southern Control Centre (Halifax): 10 Aug – 11 Sept
  - Underwater arrays operational from 26 Aug – 11 Sept
- Emulation of unattended surveillance
- Operations at unclass level
- Demonstrated:
  - Compilation of a local-area surveillance picture
  - Dissemination of surveillance data
  - Remote monitoring and control
  - Management of satellite bandwidth
- System operated with high reliability





# CAUSE Project Background and Objectives

- **Objective:**
  - Investigate and demonstrate sensor systems for wide-area underwater and under-ice surveillance in the Arctic (includes Arctic Basin and Canadian Archipelago)
- **Deliverables:**
  - Technology demos and advice on UW/under-ice surveillance technologies and methodologies
- **Time:** 5 years (15 Jun 2015 – 31 Mar 2020)
  - Definition ended Dec 2016; Implementation Charter approved Sept 2017
- **Approved funding:**
  - \$11,134.1k (FY19/20) budget
  - \$25,648k Implementation Phase (FY17/18 – FY19/20) budget
- **Client:** Canadian Joint Operations Command (CJOC)
  - Chief of Staff Operations (COS Ops) – Continental Operations

# Digital Acoustic Surveillance Array (DASA)

- 94 element, 1650-m long array
- Intended for LF operations
- Array components significant improvement over NW arrays

Just 1 of the  
array segments!  
Total array is  
more than 3  
times longer!



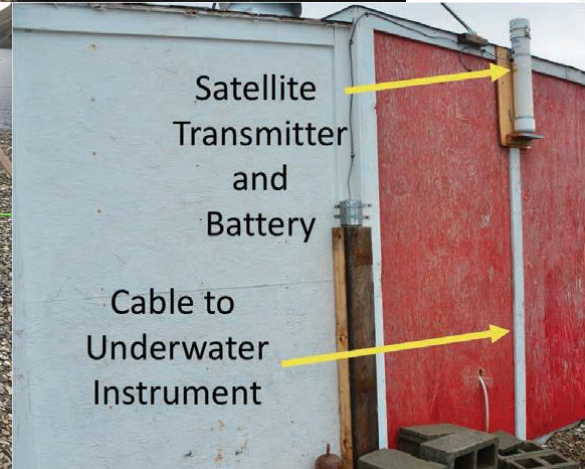
# CANMET Energy and Power

- **Direct methanol fuel cell installation to run NW arrays**
- **Planned to operate for a year**
- **Shut-down occurred after 3.5 months**
  - Bear damage, Iridium issues, fuel seals, VPN issue, controller issue
- **Bears damaged the solar panel wiring**
- **Iridium data rates**
  - 128 kB/sec advertised
  - 5-6 kB/sec peak attained, typical rate 0.2 kB/sec => single satellite and channel!
- **To date, SSC has not provided VPN access**
- **Fuel bottles lose vacuum seal**
- **Proprietary SCADA-pack controller difficulties**



# Observatory & Field Site Study

- **ONC provided a survey of four field sites suitable for Observatory installation**
- **A major Resolute-to-Gascoyne Inlet observatory has been proposed**
- **Small test observatory at Gascoyne Inlet using split-pipe**
  - Failed in late winter of first year (2017)
  - Bear damage
  - UW unit and cable OK!
  - Operation restored in 2018
  - Will be refurbished for 2 year continued operations



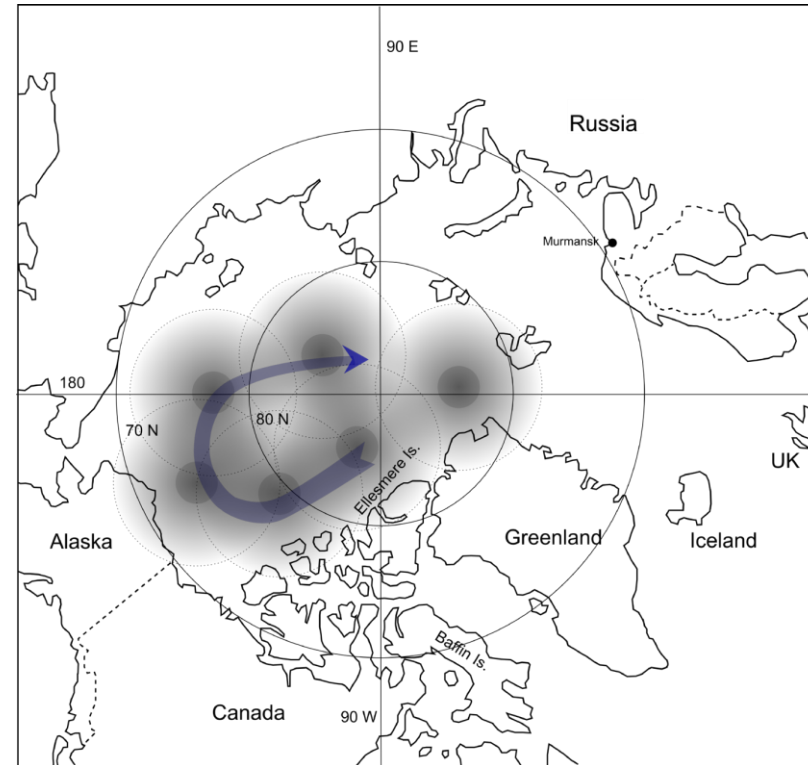


# Communications

- **Satellite / Terrestrial**
  - Iridium
    - Very poor results
    - Problems with our licensing, which did not provide proper data accounts
    - Poor polar coverage
- **Underwater**
  - CMRE Study
    - Provided some useful results, but not easily used by AUVs and smaller nodes
    - Chose to employ higher frequencies that don't propagate best in the environment
  - DRDC-CARLETON
    - Developing narrow-bandwidth (5 Hz) long-range scheme with multiple modulation methods and adaptive probabilistic decoder
    - Very low data rate
    - Initial testing at CFMETR was highly successful 100%
    - Need to increase range and stress the system further
    - Perfectly suitable for a high-efficiency, light-weight, resonant transducer that an AUV could carry

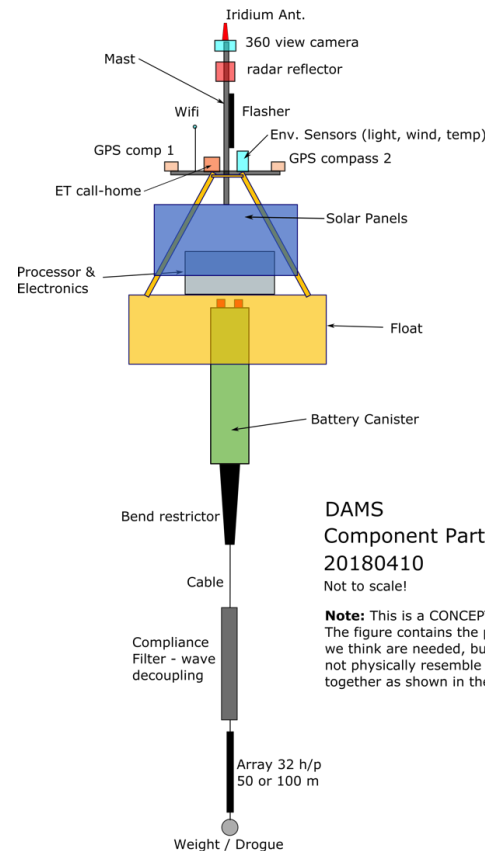
# DAMS Concept

- Sketch of DAMS drifting VLA deployment concept
- On-board detection and tracking
- Perhaps 12 DAMS units freely drifting in the Arctic gyre
- 6-18 month life between launch and recovery
- Refurbish and redeploy units annually
- Anti-tamper scuttle
- Coverage from 2—1000 km



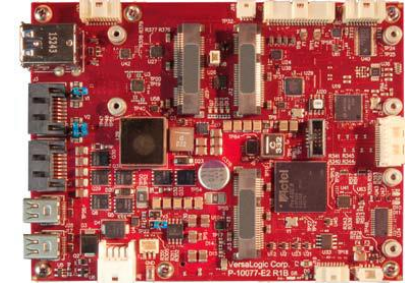
# Drifting Arctic Monitoring System (DAMS)

- DAMS proof-of-concept demonstrator is being built by in-house effort
- Current DAMS uses available parts
  - 50-m array UARPS
  - 500-m array is possible
- System Test Bed processor in the buoy
  - AIS & ADS-B receivers, Iridium comms, Freewave, WiFi, many non-acoustic sensors



DAMS  
Component Parts  
20180410  
Not to scale!

**Note:** This is a CONCEPT sketch. The figure contains the parts that we think are needed, but they may not physically resemble or be put together as shown in the sketch.



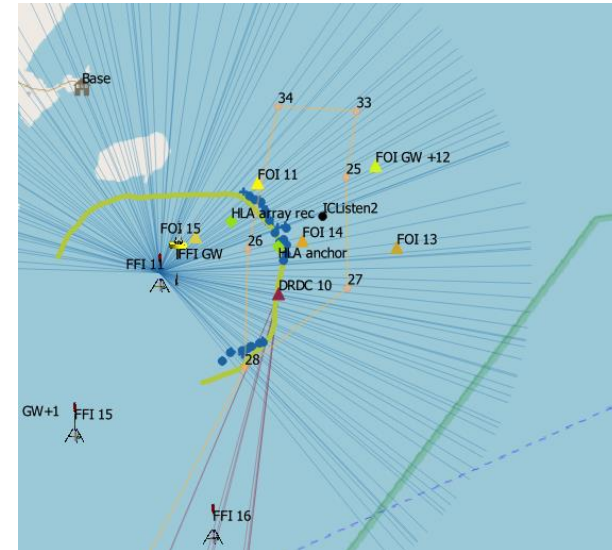
Blackbird high-end  
embedded processor





# DUSN Sweden 2018

- One of our best trials ever!
- Recently completed with NO and SWE. (Sept. 2018)
- First ever on-board demonstration of distributed detection and target tracking
- NO / CA nodes 100% compatible despite very different physical and electronic construction with different sensing capabilities



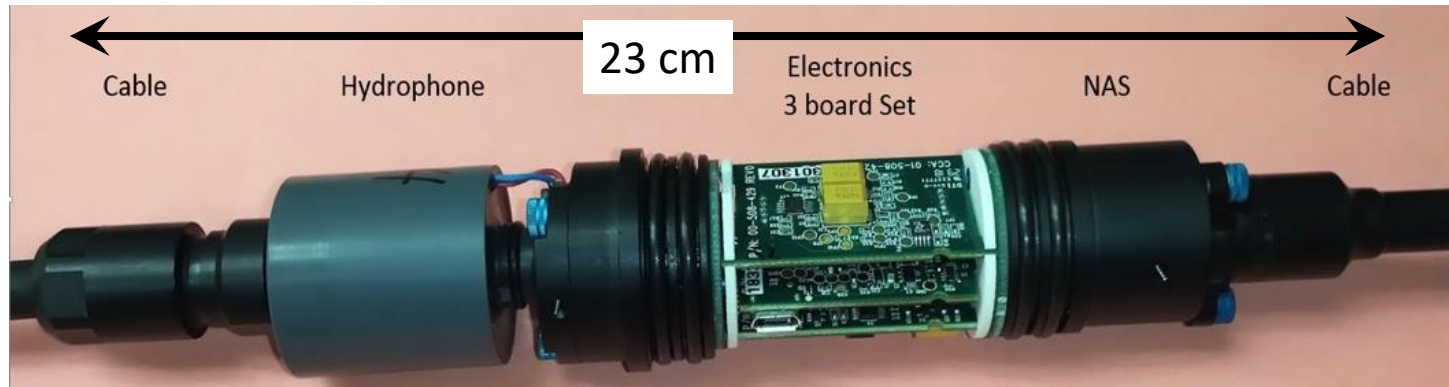
# GTI LF Source Update

- Successful LF source prototype demonstrated at Seneca Lake in December 2017.
- Deliverables include family of four LF sources.
- Hardware production currently on schedule to support final project trial in late Spring 2019.
- Modelling team characterizing impact of today's changing Arctic on LF acoustic surveillance systems.
- Project outcomes: technology viability assessment, site-specific performance analysis, & strategic utilization options.



# GTI Low5 UUV towed array Update

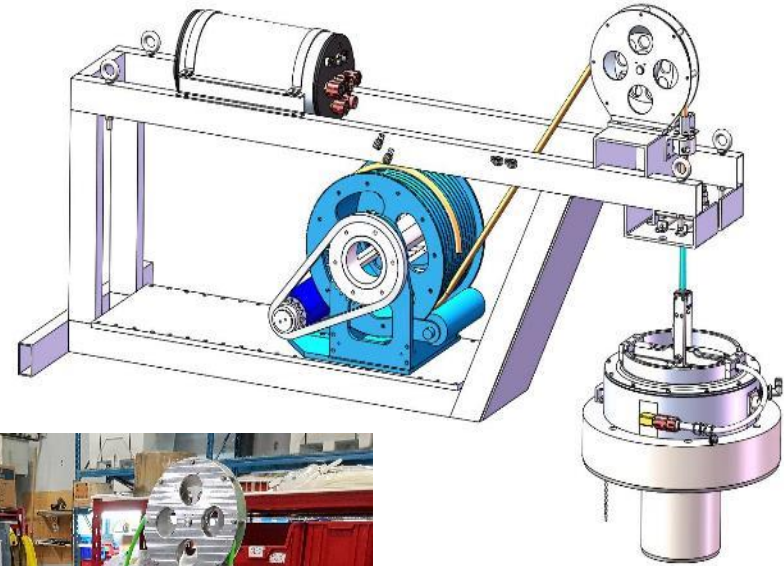
- Low drag, low power, low mass, low frequency, low-speed stability.
- 30N drag, 2.5W, 40kg, 10-200Hz, 2 kn (550 m)
- Prototype successfully tested in October 2018.
- On schedule for final project trial in late Spring 2019.
- Propagation models, Channel capacity models & Detection models being applied for performance estimates in northern environments





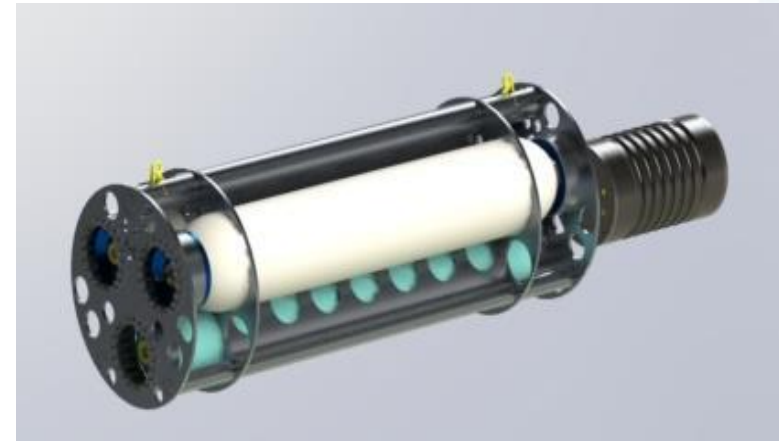
# AUV Suction Anchor

- Designed to enable AUV to positively anchor and enter a power saving, quiet mode.
- Prototype unit has been built and tested
- Completed factory caisson testing in mud and sand over a range of pull angles
- Additional testing December 2018
- Open water testing in Q2 2019
- AUV version ready end of 2019
- Developing future applications as a platform for seafloor sampling and geotechnical analysis



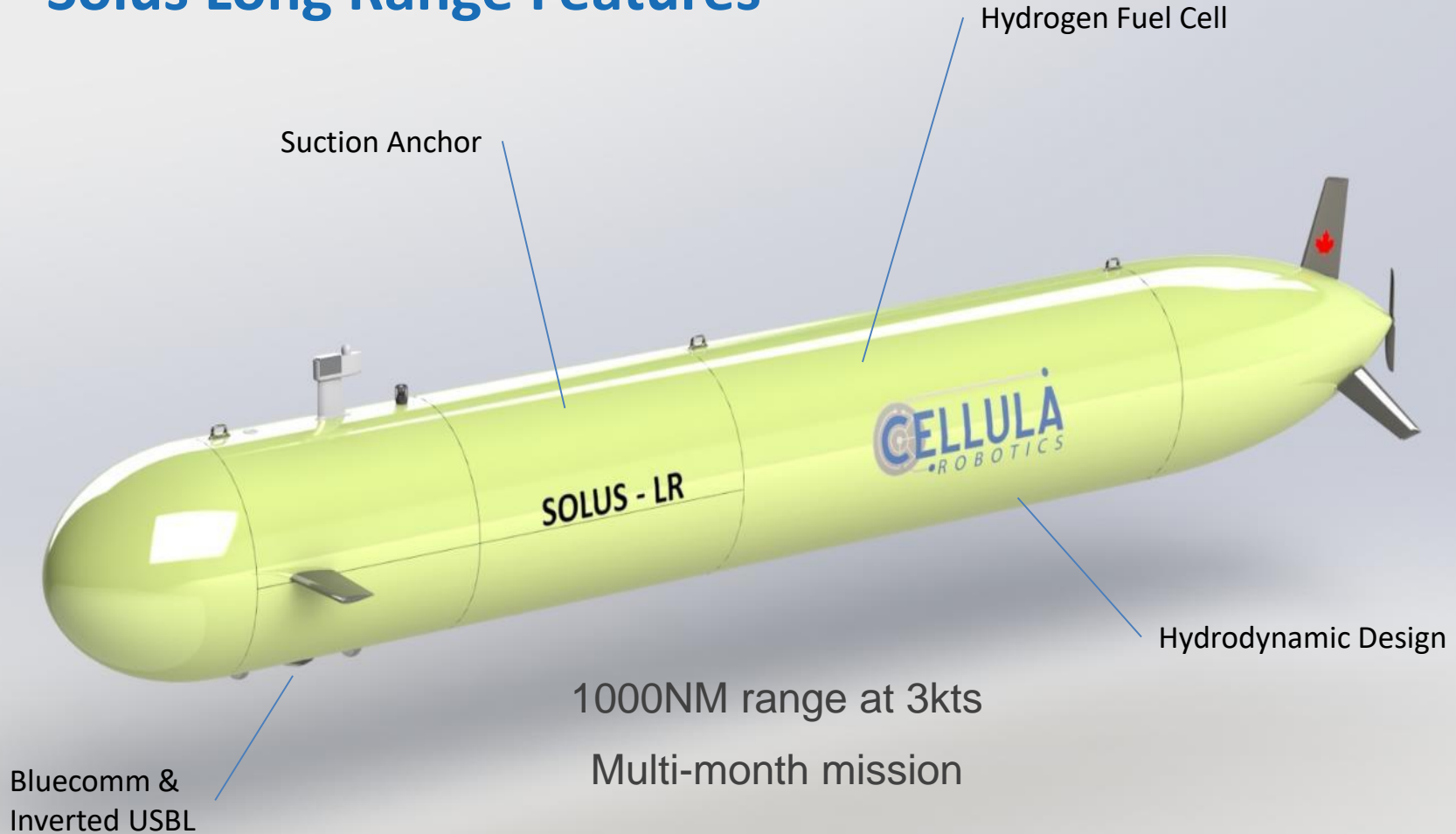
# AUV Fuel Cell

- First prototype used DMFC with  $\text{H}_2\text{O}_2$  oxygen source
- Tested under pressure to 3000m
- Remained energy positive at 3000m and would exceed energy density of Li-ion for shallow water applications
- Challenging to adapt a COTS DMFC unit



- Second design uses a PEM stack with high pressure bottled Hydrogen and Oxygen
- AUV design in progress
- Modified COTS PEM stack, 690 bar Hydrogen, 550 bar Oxygen tanks
- Predicting 2-3 times energy design of Li-ion at 200kWhr capacity

# Solus Long Range Features





# CANAPE overview

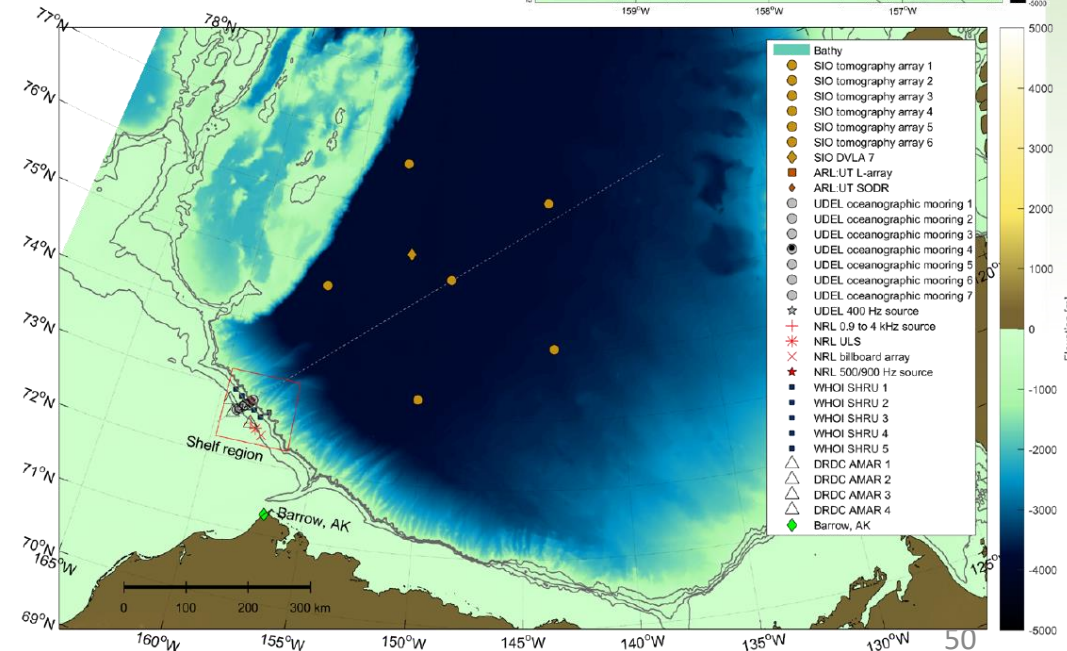
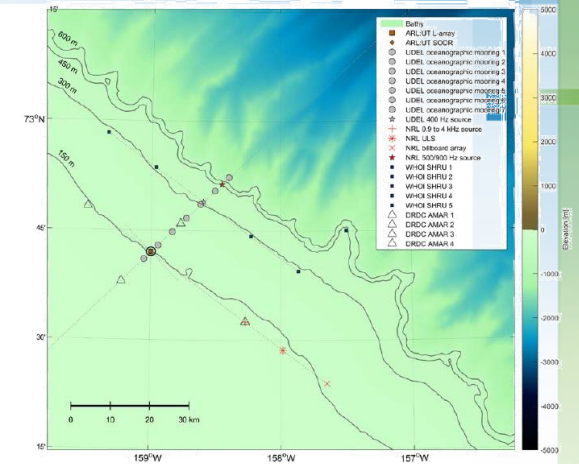
- Canada Basin Ambient Noise and Propagation Experiment
- Shallow water experiment coincident with large-scale tomography experiment in Basin
- October 2016 – September 2017

## ■ Deep water

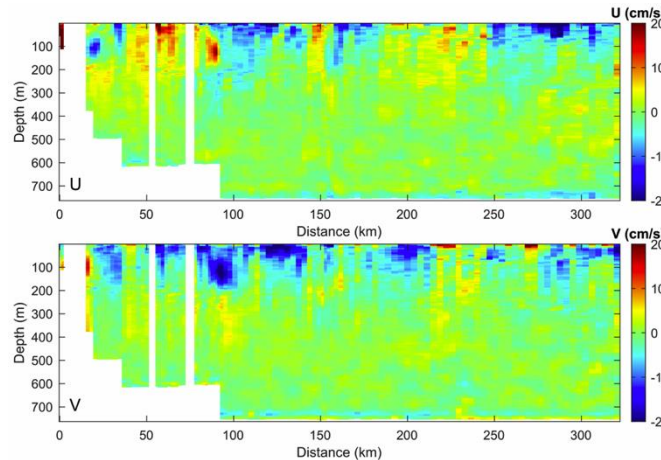
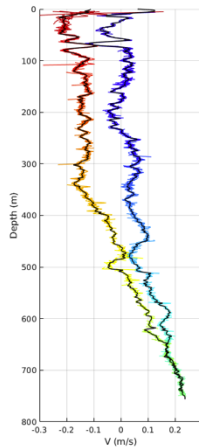
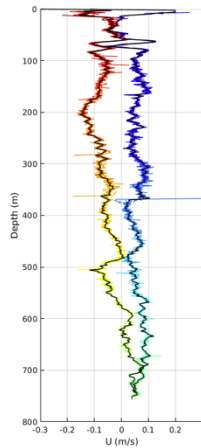
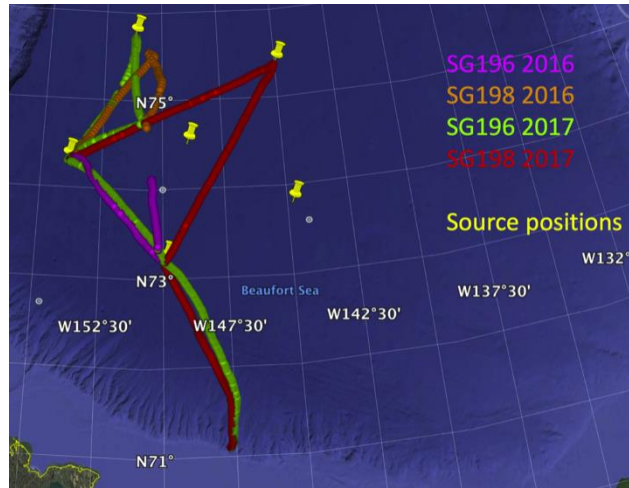
- 6 tomographic arrays, 1 DVLA (Worcester, SIO)
- ~3800 m water depth, 200-400 km separation

## ■ Shallow water

- 3 sources
- 11 receivers
- Ice/ocean moorings



# Canada BASin Glider Experiment (CABAGE)



- Applied Physics Laboratory, Univ. of Washington
- Sarah Webster co-PI
- Improved navigation of under-ice vehicles by acoustic signal time-of-arrival navigation with on-board ADCP water mass motion estimation.
- Simultaneous inversion of the collected data for the velocity profiles and glider motion has been accomplished.
- On-going work is now attempting to incorporate the velocity profile and non-linear vehicle model to provide a consistent AUV position estimate.

# What's next?

- CAATEX – Coordinated Arctic Acoustic Thermometry EXperiment
- Communications
  - Long-range UW acoustics
  - StarLink and other options
- Persistent AUVs
  - Solus
- AUV towed array systems
  - Solus and Low-Five
- Networked Ocean Basins
  - Baffin Bay Observing System
  - Arctic Ocean Observing System

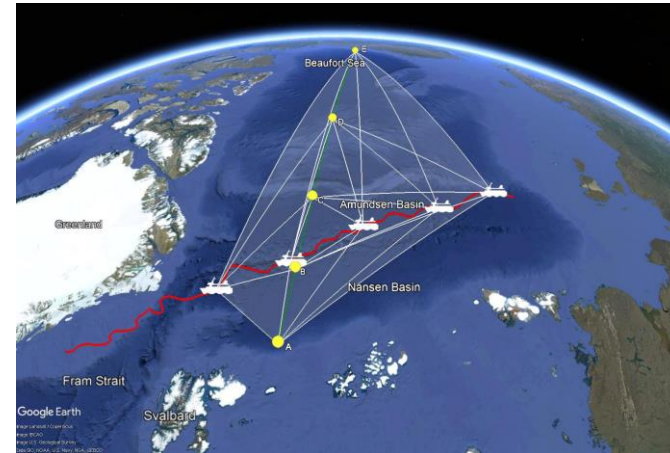


Photo by Marco Langbroek, Leiden, the Netherlands.

Nicole Mortillaro · CBC News · Posted: May 27, 2019  
6:16 PM ET | Last Updated: May 27



# Conclusions

- Long history of Arctic research in a wide variety of fields
- DRDC provides significant Arctic sovereignty activities for DND
- Some high-risk projects were undertaken with surprisingly good results
- Alouette, PARL, AUVs, and array systems all significant accomplishments
- Changing conditions in the Arctic and in DRDC are leaving us with some doubt as to what will follow our current work
  - More basic Arctic personnel capabilities, but reduced Arctic skills
- A lack of an Arctic Research program is in my opinion an issue
  - It makes retention of skills difficult
  - Lack of continuity in application of successes to the next project

# And sometimes it goes wrong!



# Questions?

