Unmanned Systems for Arctic Operations

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This presentation does not contain controlled goods.
Introduction

DRDC has been active with Arctic unmanned systems since the 1990’s:

- Theseus (1995, not discussed)
  - operational under-ice cable laying with 5’ diameter UUV

- Project Cornerstone (2010, 2011)
  - under-ice bathymetric mapping for UNCLOS claims

- Canadian Forces Joint Arctic Experiment (not discussed)
  - research & experimentation prior to operational needs assessment
  - larger in scope than just UUV includes USV and UAV
UNCLOS Claim for Canada

- EEZ (red line)
- potential extended continental shelf (white line)

- potential increase of 30% in EEZ area
- NRCan & DFO given mandate & funding to collect scientific data to establish outer limits of Canada’s EEZ
UNCLOS CAN Mission

Project Cornerstone

- Project Cornerstone - NRCan, DFO, and DND (includes DRDC) collaboration
- Data for UNCLOS submission is seismic & bathymetric
- Arctic seismic and bathymetric data collection is difficult
  - Unpredictable ice and weather conditions, remoteness
  - Routine data collection operations often unsuccessful
- Historically, variable success in bathy data collection with ice camps
  - Seek alternative methods that are less weather dependant
- DND proposes UUVs – mitigates risk due to poor weather
Project Cornerstone

Overview

- 2 UUVs (Yamoria, Qaujasati) procured from International Submarine Engineering Ltd. (Pt. Coquitlam, Canada)
  - based on their commercially available Explorer UUV

- development program adapted these UUVs for Arctic bathy mapping with deployment from an ice camp:
  - homing
  - positioning
  - variable ballast
  - underwater charging batteries and download of data
  - extended endurance

- UUVs in Arctic in 2010 and 2011 for bathy data collection
- UNCLOS Canadian submission due 2013
Concept of Operation
Locations (western high Arctic)

- 2 ice camps:
  - Borden Main Ice Camp: south of Borden Island
  - Remote Ice Camp: 300km NW of Main Camp

Map Pictures: Google Earth
Concept of Operation
Borden Main Ice Camp

- 78°15’N, 112°04’W (shore-fast)
- water depth: 120m
- ice thickness: 7 – 10 ft.
- heavy snow, temp < -25 C
- 5km offshore Borden Island, 2nd yr ice
- large camp ~ 40 people
Concept of Operation
Remote Ice Camp

- 79°N, 118-120°W (moving)
- water depth: ~2200-2300m
- ice thickness: 7-10 ft.
- less snow, temp -25 to -30°C
- 300km offshore Borden Island on moving ice
- smaller camp ~ 12 people
UUV Requirements
Given CONOPS, mission, and infrastructure

- long range: endurance of 400 km, 3 days in-water
- deep diving: designed for 5000 m water depths
- continuous in-water ops: weeks
- charging: in-water charging of 30 x lithium-ion batteries (1.8kWh each)
- homing system: guide UUV towards drifting ice camp
- positioning system: provide UUV with a position update (independent of INS)
- variable ballast system: park UUV under ice cap and not drift away in current or, settle it to the sea bottom
- modular design: transport to / from camps in small planes
- payload for bathy data: single beam echo sounder, multi-beam echo sounder
UUV Design
Based on Requirements

- Cornerstone UUVs:
  - length: 7.35m
  - dry weight: 800 kg
  - max speed: 5 knots (2.5m/s)
  - propulsion: single thruster, 2 bladed propeller (cannot hover)
  - nav sensors: INS; Doppler velocity log (DVL); depth sensor; GPS (surface)
UUV Development
Challenge: Navigation

- in addition to the expected underwater navigation challenges also high latitude ones with INS:
  - once launched into deep water the INS drifts as the UUV spirals down to DVL bottom-lock ranges
  - when UUV reaches remote ice camp the camp has drifted for 3 days and can be 20 – 30 km from where it was when UUV was launched

- **UUV has to localize the ice camp**
  monitoring at remote ice camp from long range
UUV Development
Challenge 1: Homing System

- UUV homes on camp that moves ~ 10 km / day
- Long Range Acoustic Beacon (LRAB) guides UUV to drifting ice hole from 50-100 km away
  - bearing of *acoustic source* calculated from 7 element hydrophone array in UUV nose
- UUV adjusts course from its waypoints towards *acoustic source* deployed at remote camp

DRDC long range acoustic beacon
Homing System (50 – 100 km range)
Challenge 1: Homing System – Results

Transit to Remote Camp

Ice Camp Approach

UUV starts homing

path under ice camp

1.6 km offset between ice camp GPS (red) and UUV nav position (blue)
UUV Development
Challenge 2: Short range positioning system

- position updates to UUV at ~ < 10km from ice hole
- solution: field of 6 modems surrounding ice camp (~1 km range) – UUV coms link to camp
  - UUV modem ranges the field and calculates UUV position (use range & modem positions)

- Freewave radios transmit information back to camp
Positioning System (< 10 km range)
Challenge 2: Short range positioning – Results

UUV (red) & positioning system (blue)
results for test mission

UUV (blue) and positioning system (red) results for box current at start of test run
UUV Development
Challenge 3: Variable Ballast System

- concept of operation requires the UUV park under the ice cap at the end of each mission
- fault management also requires the ability to park on the sea bottom
- solution: develop novel variable ballast system
  - rating of 5000 m
  - titanium sphere
  - double pumps
Charge/Download at Remote Ice Hole
Challenge 4: in-water charging, download, align

- need in-water charging after each mission
- data also downloaded prior to return trip to main ice camp
- require ability to rotate UUV to re-align its INU as needed

- solution: novel pole assembly developed to latch onto the UUV & facilitate charging, download & alignment
Outcomes

- one UUV assembled at main ice camp [completed]
- in-water testing of UUV [completed]
  - 3 test missions (2 were 7 km in length, final was 115 km length)
- UUV transit mission *from main to remote camp* [completed]
  - distance of 300km, water depths up to 2600 m, navigate from main camp out Wilkins Straight to remote camp
  - transit also collected data in a survey area of interest

UUV assembly at the main ice camp
Outcomes Cont.

- **UUV survey mission** [completed]
  - 310 km, water depths up to 3300 m; along survey line
  - setup of the main and remote camp delayed by weather; consequently, only one survey completed

- **UUV return transit mission** [completed]
  - navigate from remote camp back to main camp;
  - also collected data in survey area of interest

- need another trial to collect more survey data
Cornerstone 2010 Summary

- Logistics: transport, setup, & UUV operation proven in Arctic
- UUV executed three Arctic operational missions
  - Transit to, survey and return transit missions
- UUV operated in water depths under ice of 3300 m
- UUV broke new records in:
  - Under-ice endurance (300 km/mission, >1000 km total)
  - Continuous in water operations (Apr 12 – 21; 10 days)
  - Repeated homing to moving ice camp
  - In-water download & battery recharging
- Significant delays due to weather
- Successes & lessons learned provide excellent basis for 2011
Project Cornerstone 2011

Overview

- combination seismic and bathymetric data collection
- joint Canada (CCGS LSSL) / US (USCGC Healy)
  - Healy acquired multi-beam bathymetric & CHIRP sub-bottom sonar data
  - LSSL used seismic stream and air guns to collect data on sedimentary layer thicknesses
- UUV collect multi-beam and single beam
UUV Mission Planning in the Arctic Fault Responses

- mission criteria: range, sensors, height, depth, energy reserves, etc.
- determine UUV fault responses
- fault responses quite different for Arctic operations:
  - cannot always surface as a response behavior to a fault
  - if turning around, where will ship be?
  - park on bottom or under ice?
  - ignore fault and continue mission?
  - depends on fault and potential impact
  - loss of UUV entirely possible
- many levels of checks and validations needed
LSSL Infrastructure
UUV Operations

Challenges:
- Difficult to deploy large, heavy or delicate equipment in these ice conditions.
- Ice can close in within seconds and crush equipment and cables.
Environmental Conditions

Sever Spur Area:

- Heavy ridging in the Sever Spur area.
- > 9/10ths covered.
- Large, thick ice flows.
- Ships entered this area for the first time.
- Requires two ice breakers to assist each other.
- Cold temps even in summer -22C Wind chill.
UUV Ship-based Launch

Launch Site:
- Ice rapidly moving in/around the ships, with small open water clearings.
- An artificial created opening would close in too fast.
- Had to find natural Ice Pond.

- Minimal in water checks, Quick release required.
- Ballasted heavy to sink and clear hull and tow-sled.
- Circle at 50m depth until satisfied – good to go.
UUV Survey Mission

Survey Route - 110 km survey of Sever Spur – Southern Portion.

Survey Objectives:
• Map the foot of the slope.
• Transit the gap to confirm existence.
• Chart data based on gravity readings.
• Depth of 3500 m.
UUV Ship-Based Recovery

- ROV will not work in heavy ice
- ship has to be brought to the UUV to break the ice
UUV Ship-based Recovery
Using man basket

Recovery Challenges and solutions:
Unsafe to work on the ice and no small boats.
Requires ship based method to hook on lift lines.
Cornerstone 2011 Summary

- collected valuable foot-of-the-slope data
- launched & recovered UUV in heavy ice 3 times
- completed:
  - 6 hour test mission
  - 21 hour survey mission
- UUV depths at 3600 m (1st mission) and 3500 m (2nd mission)
- INS operational up to 88.30 N
- UUV homing & tracking from a ship at > 20 km
- deep water, long range acoustic coms > 10 km
- UUV ship-based Arctic operations are possible
Questions?