Theseus AUV Development

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Canada

Outline

- Brief overview of Defence Research & Development Canada
- Description of the Joint CA/US Spinnaker Project
- Theseus requirements
- Trials and test program
- Arctic mission
- Summary

Defence R&D Canada

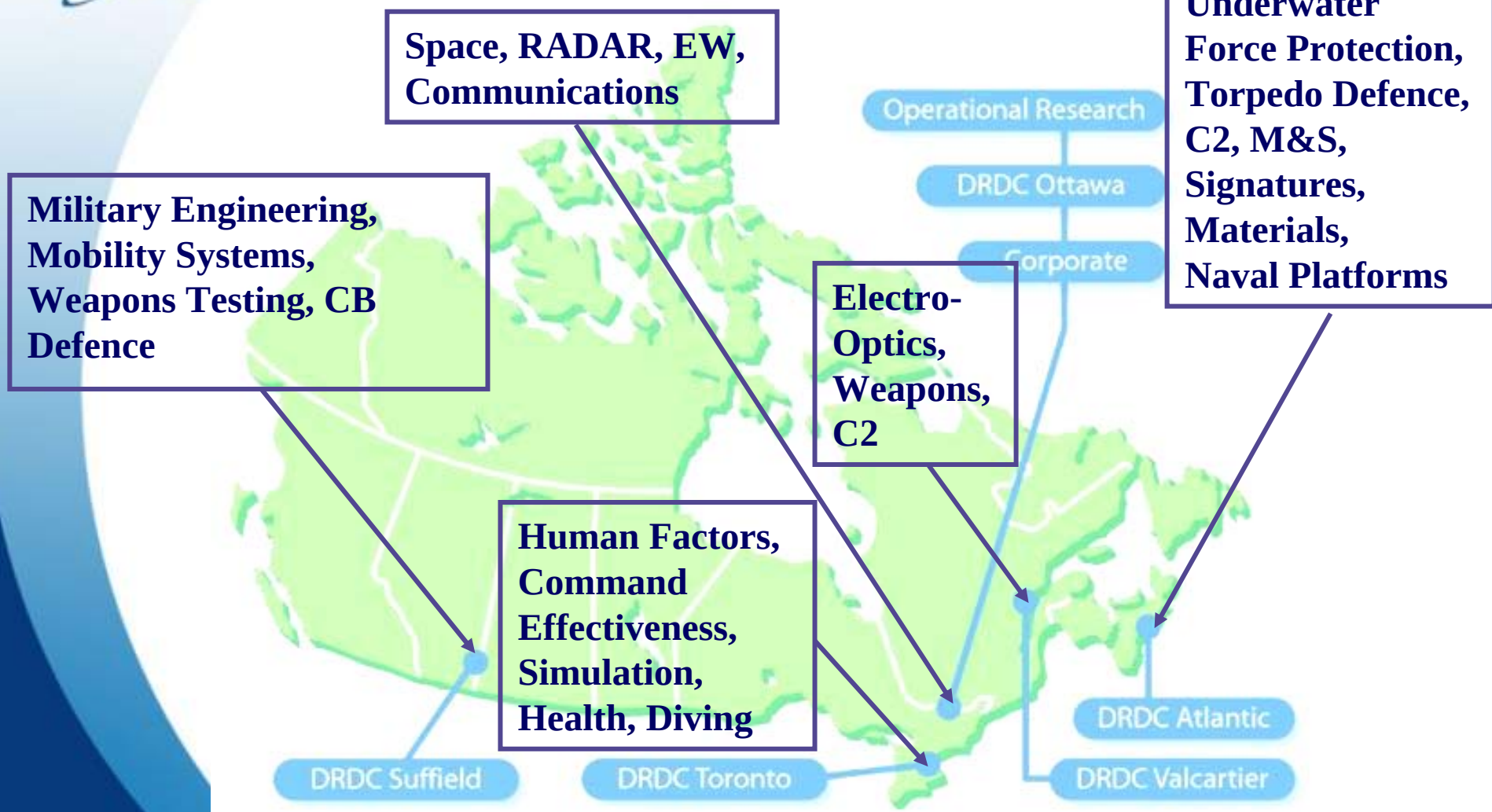
- DRDC is a ‘Departmental Agency’ of the Canadian Department of National Defence, since 1 April 2000
- DRDC operates five R&D Centres, plus the Centre for Operational Research and Analysis, and our corporate offices

DRDC Mission

To ensure that the Canadian Forces remains technologically prepared by:

- Providing expert S&T advice to decision makers
- Conducting R&D to support military operational success
- Enhancing the preparedness of the CF by assessing technological trends
- Contributing to the creation and maintenance of a Canadian defence S&T industrial capability
- Conducting S&T projects for clients external to DND

What Does DRDC Do?

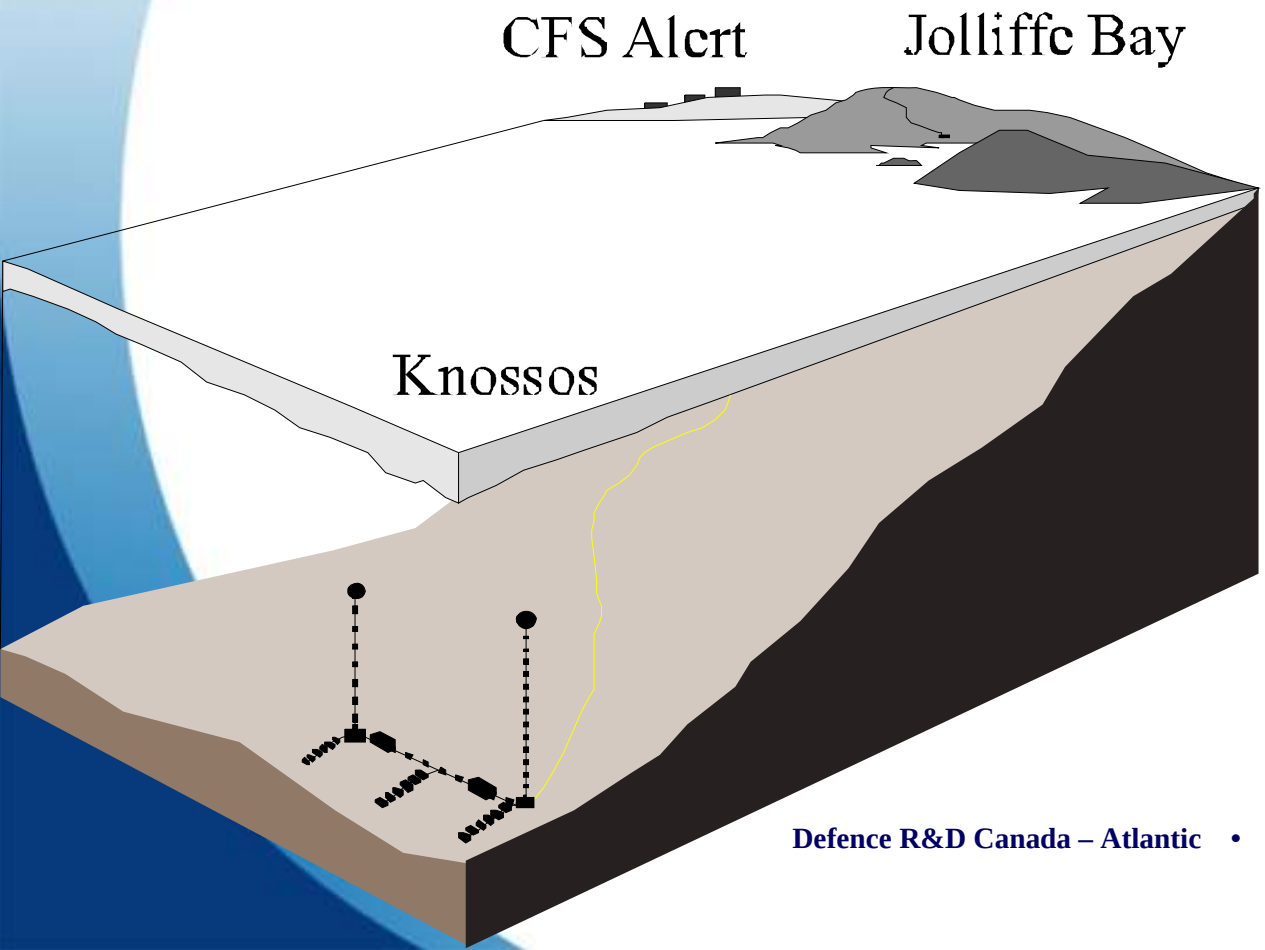


How Big is DRDC? (FY 03/04)

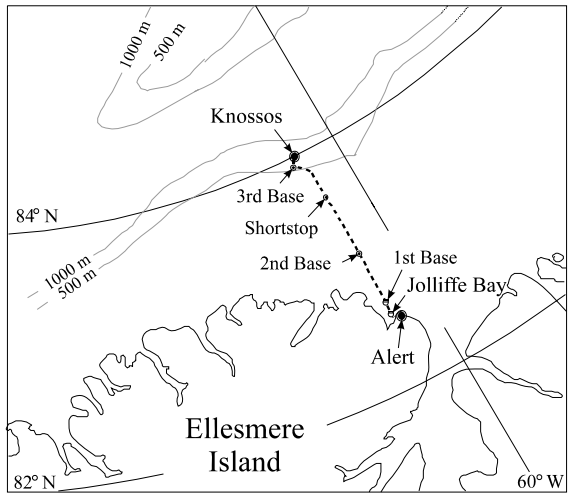
- ~ 1400 staff (civilian and military)
- 36 military billets
- $207M expenditures
- $10M revenue from outside DRDC budget allocations (approximately half from private sector)

Project Spinnaker

- Joint Canada-US project to lay an underwater acoustics sensor array under the Arctic Ice



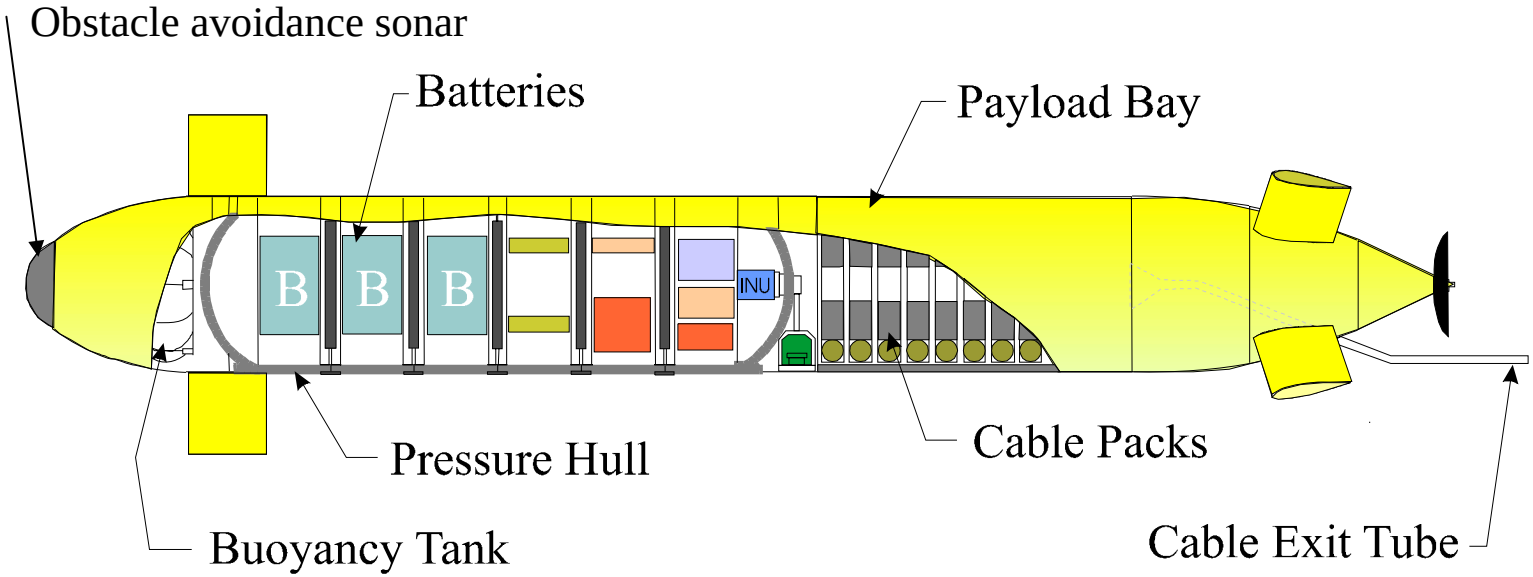
- Canada – AUV development
- US – sensor development



Theseus Vehicle Requirements

- 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

Theseus Vehicle Cross-section



Theseus Vehicle Configuration (1)

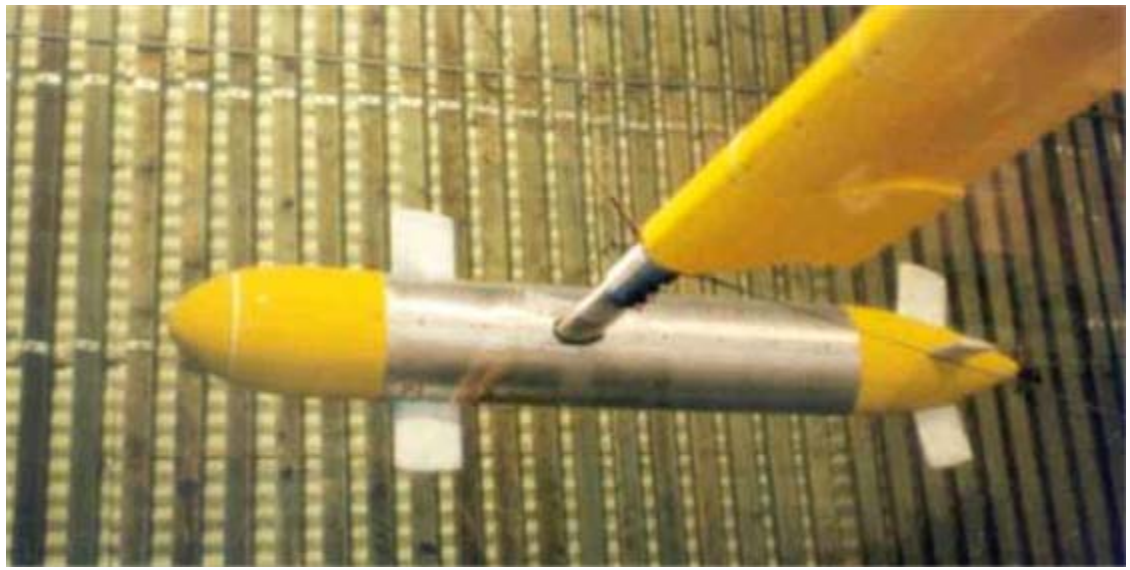
Length	10.7 m (35 feet)
Diameter	127 cm (50 inches)
Displacement	8600 kg (19,000 lbs)
Speed	2 m/s (4 knots)
Range	700 km (380 nm)
Maximum operating depth	425 m verified, 1000-m (3280-foot) design depth
Cable capacity	220 km
Navigational accuracy	achieved ~0.5% of distance travelled
Propulsion	6 hp brushless dc motor and gearbox / single 61 cm diameter propeller
Power	360kWh Silver Zinc battery pack consisting of 280 individual cells manufactured by Yardney. 450 km mission plus an additional 24 hours of hotel load with a safety factor of two.
Variable ballast	±95 kg (250 lbs) in each of 2 toroidal tanks, 1 fore and 1 aft
Controller	Proprietary real-time kernel running on MC68030 microprocessor
Navigation systems:Transit	Honeywell MAPS Inertial navigation unit EDO 3050 Doppler sonar (bottom tracking)

Theseus Vehicle Configuration (2)

Terminal Homing	Datasonics ACU-206 acoustic homing system. Ranges up to 10 km in 500m-deep water
Acoustic Telemetry	Datasonics Model ATM851 using Multiple Frequency Shift Keying (MFSK) plus error encoding operating in the 15 to 20 kHz band.
Fibre Optic Telemetry	Used on outbound leg of mission for vehicle status. Allows operator to assume control
Emergency Beacons	ORE 6702 acoustic transponder located in the tail section. Interrogated with ORE LXT ultrashort-base-line acoustic tracking system operating at 11kHz.
Obstacle Avoidance	Sonatech STA-013-1 forward-looking sonar. 5 by 4 beams.
Pressure hull	5 cm-thick Aluminum (7075), 4.5 m by 127 cm diameter in 5 sections plus end domes. Design depth 1000 m.
Payload Bay	Free-flooding fiberglass shell with syntactic foam lining, top half removable. Inner diam 114 cm, length 228 cm. Payload up to 1960 kg dry, 320 kg in water.
Current Payload	11 packs of 20 km cable, each weighing 60 kg in water. 11 toroidal compensation tanks fill as cable paid out. Tank inner diam 76 cm (30 in).
Transportability	Modular construction in sections under 1400 kg each.

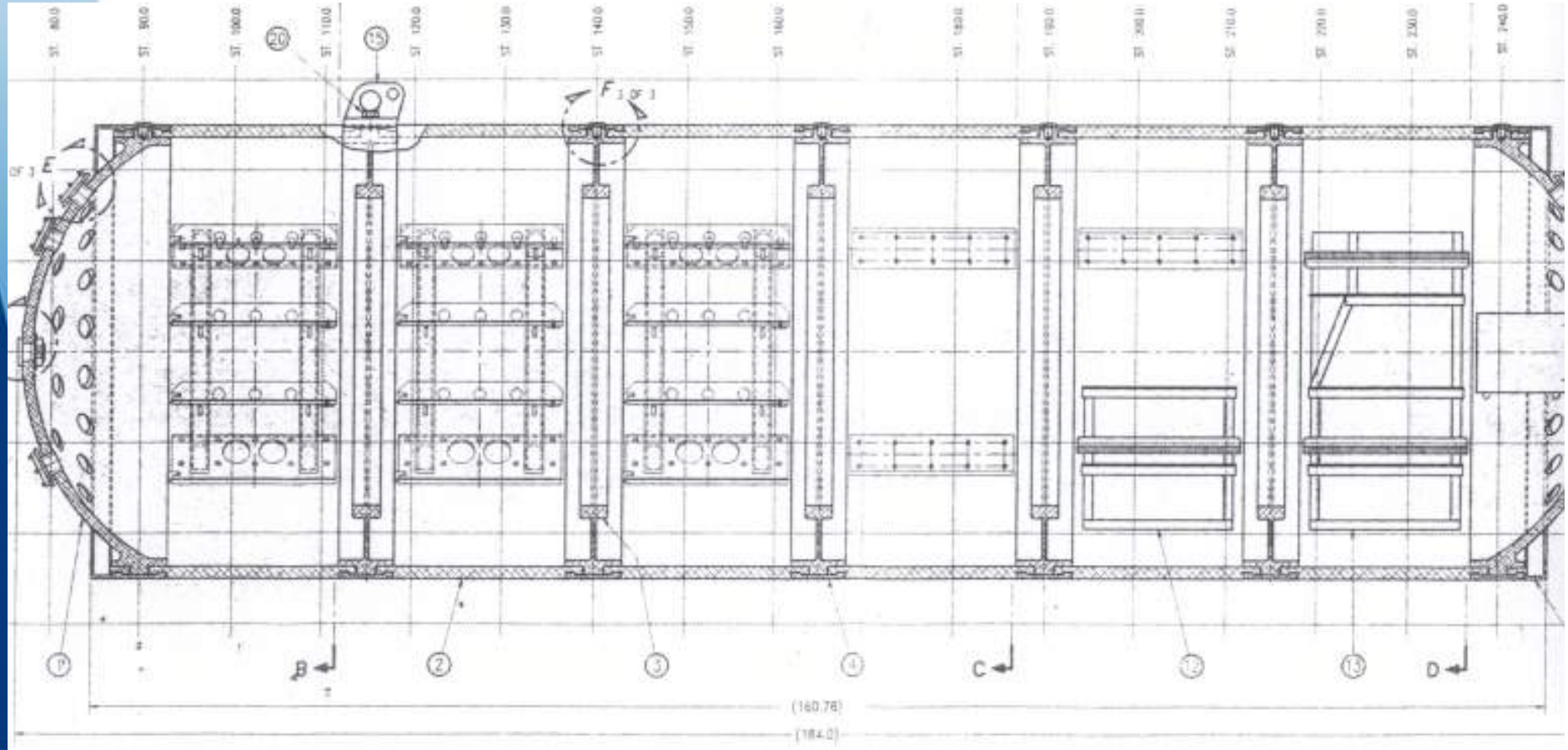
Theseus Development Highlights

- Hydrodynamic Model Testing
  - Model testing at NRC/IMD, looked at different tail, plane, and length configurations
  - hydrodynamics coefficients used in computer simulations

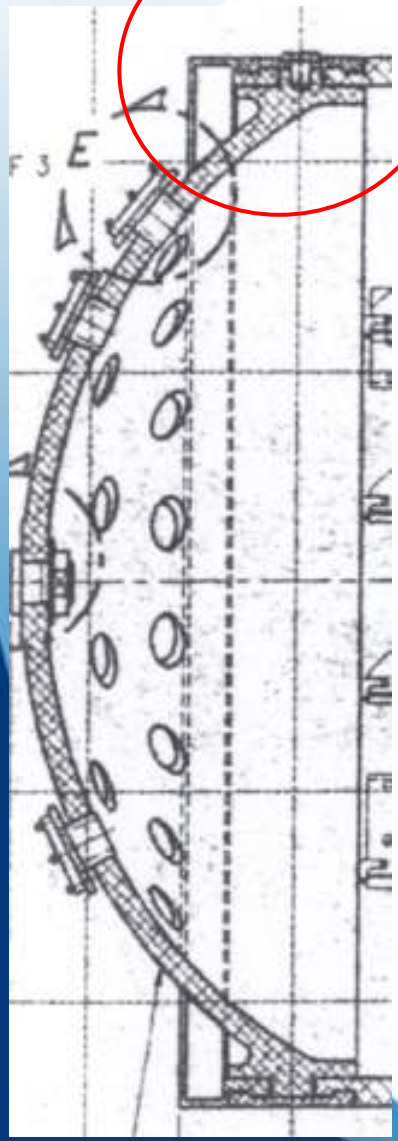


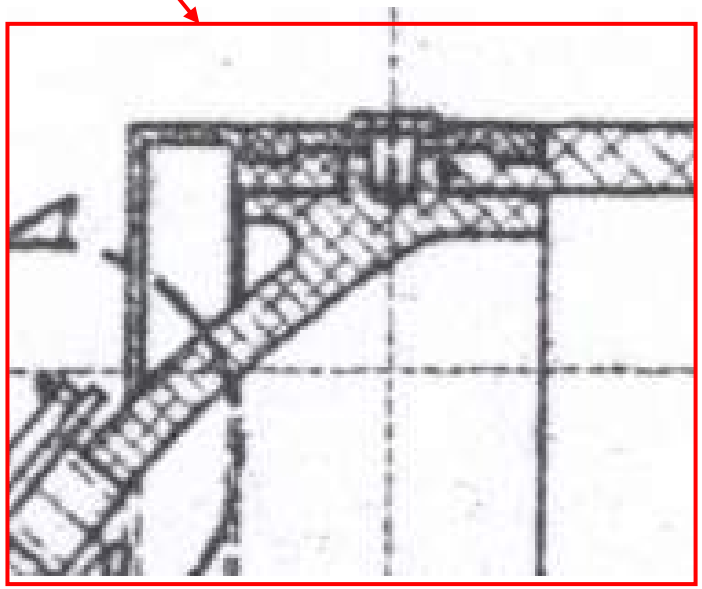
Theseus Development Highlights (2)

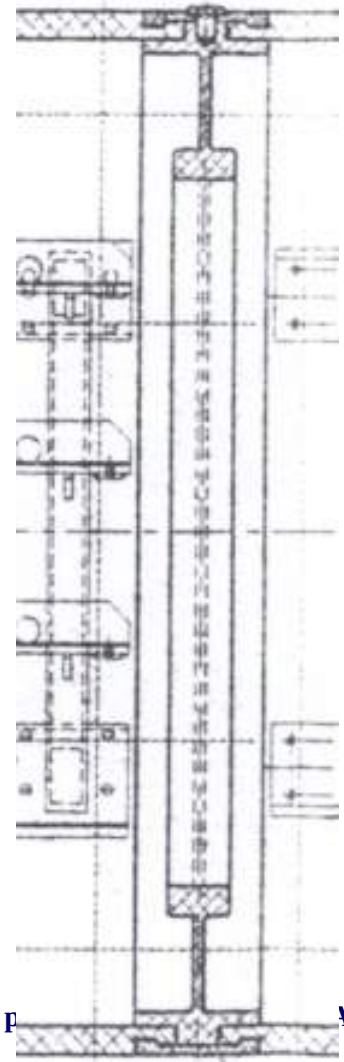
- Pressure hull design – require 1000 m depth rating
  - Finite element modeling
  - Full scale pressure testing of two hull sections (strain gauged to validate modeling)



Hull Details







Theseus Development Hightlights (3)

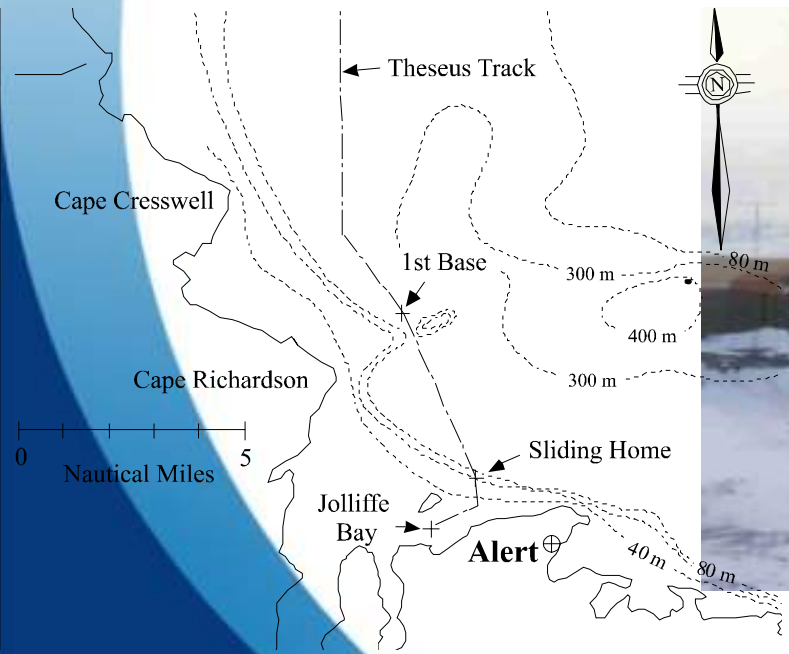
- Cable dispensing
  - Require just the right tension!
  - Too much – cable breaks & will not lie flat on the bottom
  - Too little – free falls from vehicle as altitude increased near the end of the mission
- Ballast compensation
  - Overall trim and weight of vehicle should not change during deployment
  - Each of the 11 cable packs (20 km) has a separate ballast tank

Theseus Development Hightlights (4)

- Manoeuvring
  - what if you lose a control surface?
  - Looked at plane configurations and control strategies
- Navigation
  - Will it thread the needle?
  - Mission workups at an underwater tracking range
  - < 0.5% distance traveled

The Arctic Mission!

- Equipment flown from Victoria to Alert on several C-130 Hercules flights
- Based out of Alert, equipment flown to the ice camp by helicopter



Site Preparation

- Need a nice flat piece of ice

Transfer Equipment

Final Camp Configuration

Big Ice Hole!

Hot water ice drill

~40 m^3 ice hole
(40,000 kg or 88 tons of ice)

Putting down the floor and vehicle rails

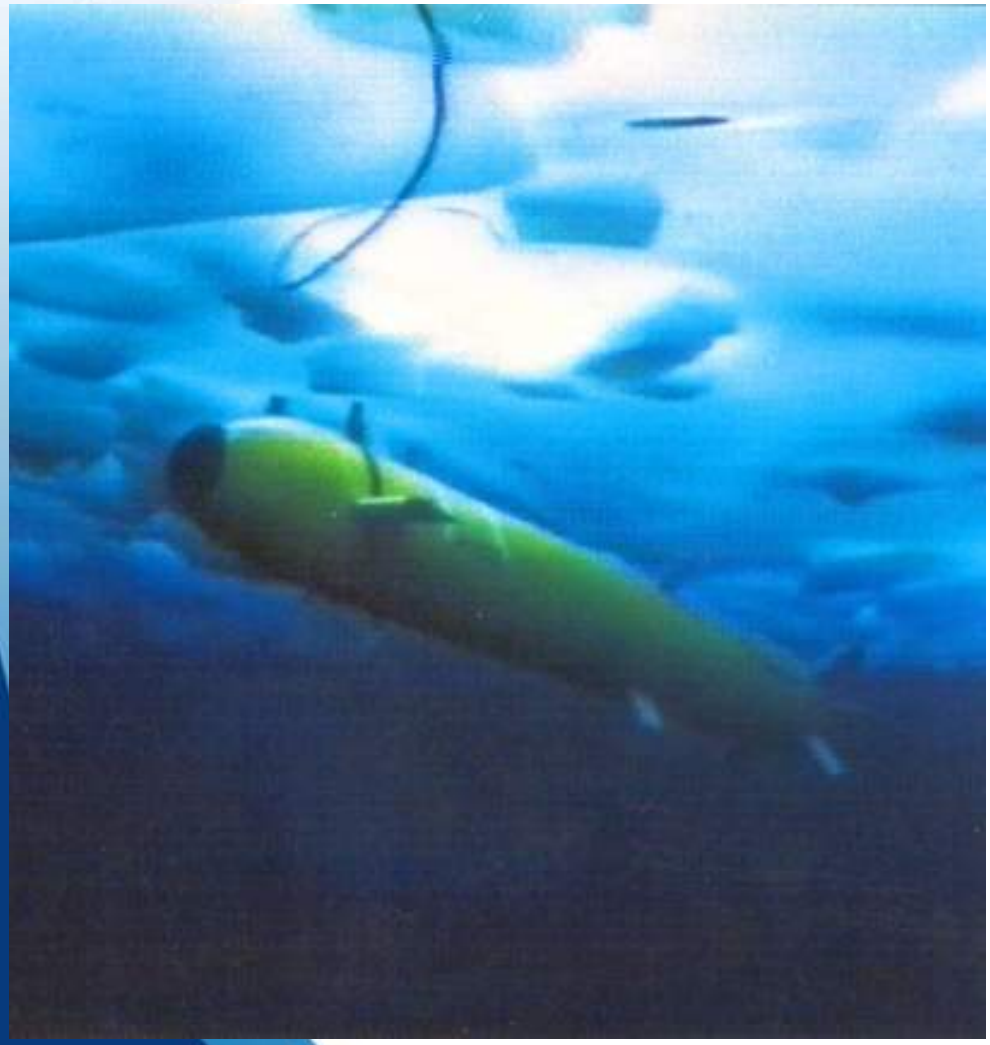
Vehicle rails for assembly of Theseus

Floor keeps the hole from expanding

Vehicle Assembly

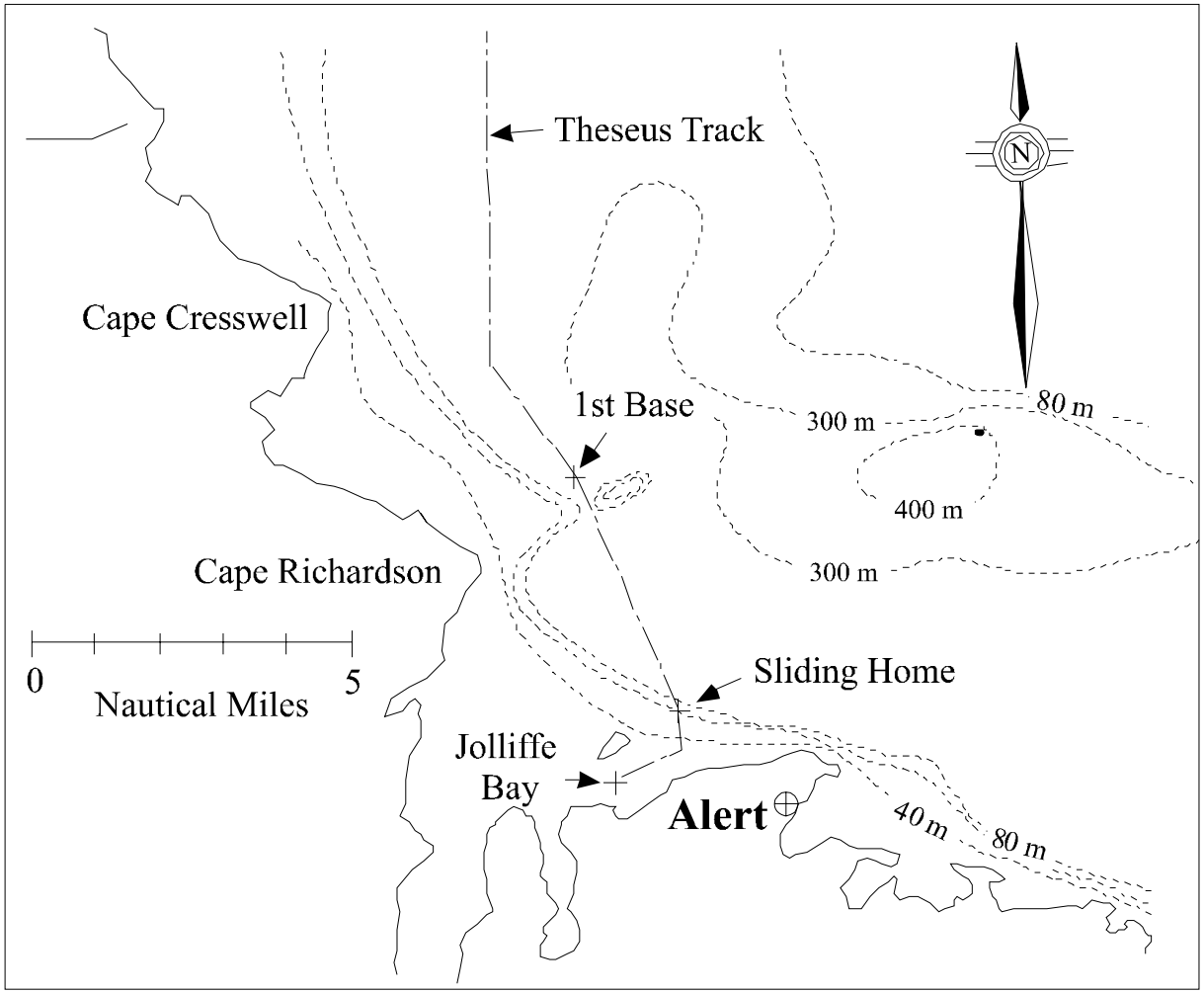
Vehicle Command & Control

Vehicle Launch



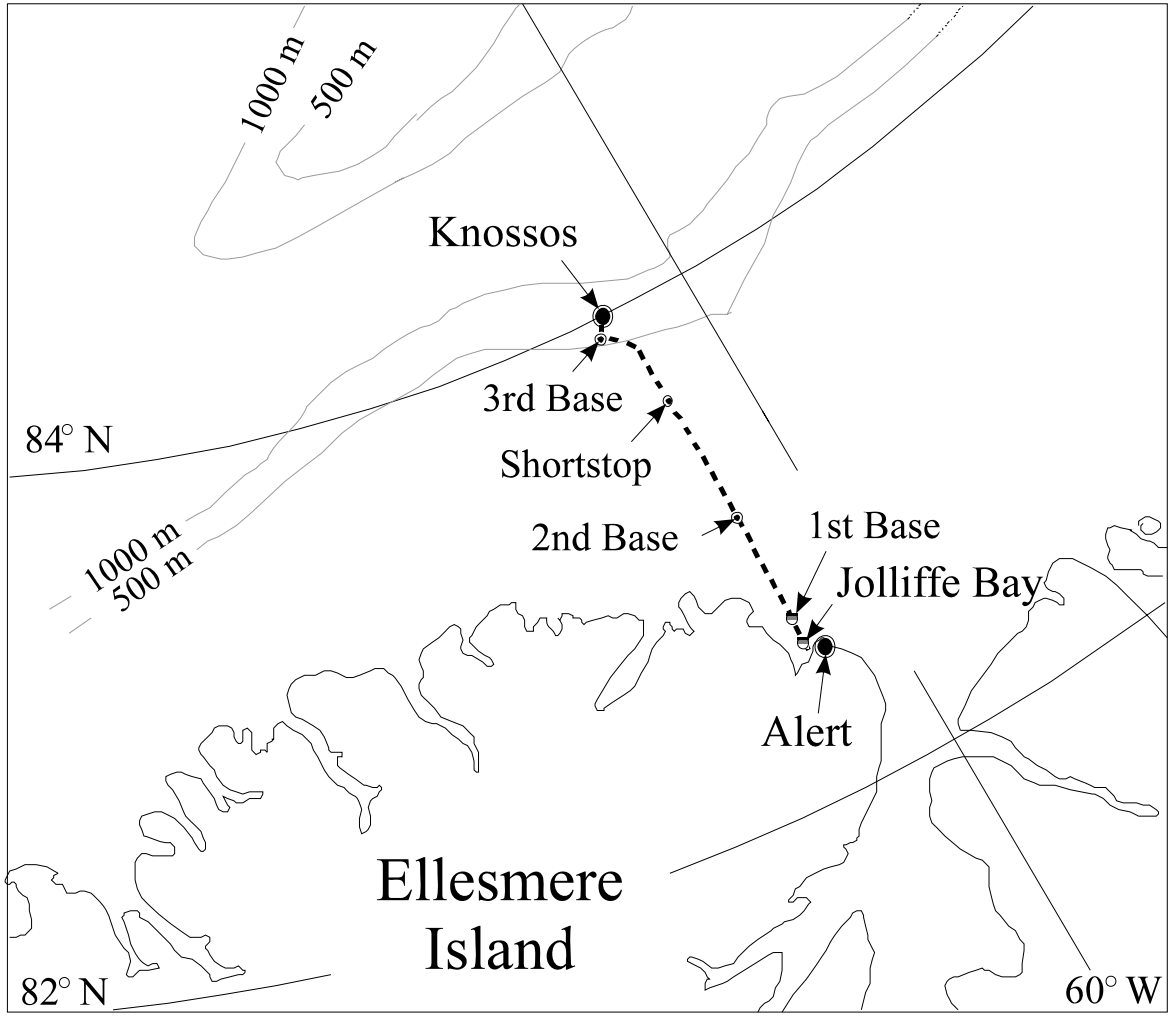
The Start of the Mission

The Mission Outbound



The Mission Outbound (2)

Navigation updates at each base & shortstop



Threading the Eye of the Needle

- After 210 km of travel, required to navigate through triangle 200 m x 100 m.
- Fiber is captured in cradle system that is then pulled up through a hole in the ice.
- The fiber is cut and the sensors are attached
- Vehicle turns around and heads for home
- Monitor progress at each navigation update point
- Otherwise – just wait (29 hours!)

While we wait

Showed the US how to play hockey!

Watch for friends

In Summary

- Mission was a success!
  - Vehicle returned safely, and
  - The sensors were connected and operational for several months
- Unfortunately, the cable eventually failed
- Cable appeared to fail from fatique – places where cable was suspended and currents caused strumming
- In the following year a second mission layed a second cable, made several splices to the first cable, and smashed up Theseus ….

(but that is another story!)

Questions?