Defence Research and Development Canada | Recherche et développement pour la défense Canada

Corrosion Related S&T Activities at DRDC Atlantic

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Workshop on Durability of Cables & Moorings in Tidal Flow, Halifax
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Canada

Outline

- Introduction
  - Who we are? What we do?
- Cathodic protection
  - Development of modelling tools for shipboard cathodic protection systems
- Corrosion
  - Failure investigation case study
  - Stray current interference
- Way ahead

Defence R&D Canada (DRDC)

'Departmental Agency' of the Canadian Department of National Defence

ASW, Mine & Torpedo Defence, M&S, Signatures, Materials, Air & Naval Platforms

Defecne R&D Canada – Atlantic Research Centre

- ~180 people.
- ~75 Scientists, ~70 Technical Supports
- People on both coasts (Halifax and Victoria) and in Ottawa.

Dockyard Laboratories

Laboratories in both Coasts to provide walk-in scientific support to CAF
People: 33 technical staff
Equipment: State-of-art materials characterization & evaluation capabilities

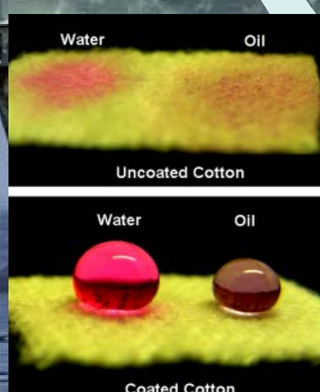
Capability

Directed Client Support

Affordable Sustainable Effective DND/CF

Partners Allies

Materials S&T



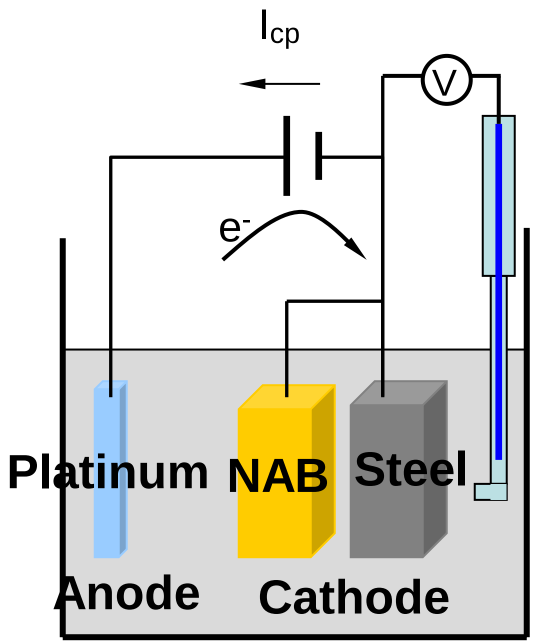
Leverage knowledge from OGDs, five-eyes and other partnerships

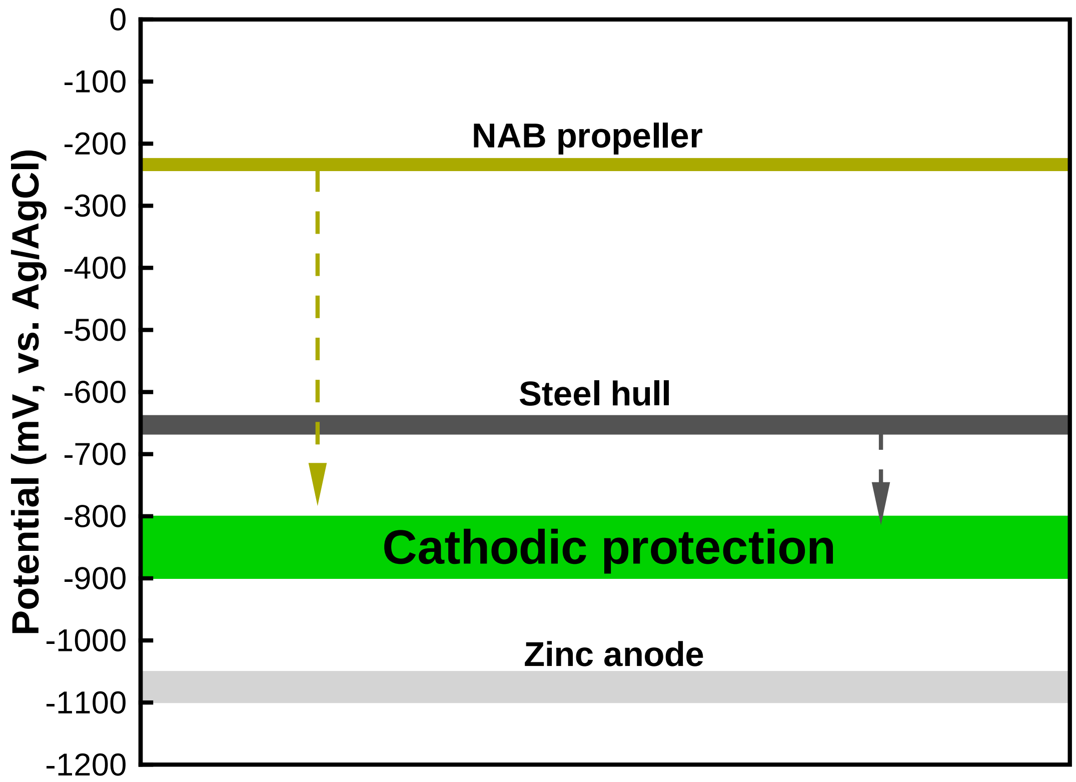
Development of Modelling Tools for Shipboard Cathodic Protection Systems

- Objectives
  - To evaluate and troubleshoot shipboard cathodic protection systems
  - To evaluate underwater electric potential (UEP) signatures associated with shipboard cathodic protection systems
  - To design/evaluate/verify new designs of shipboard cathodic protection systems
  - To provide guideline on how to manage/minimize the UEP
- Two quantitative assessment tools
  - Physical scale modelling
  - Numerical modelling

Cathodic Protection (CP)

- A technique to reduce the corrosion rate of a metal surface by making it the cathode of an electrochemical cell





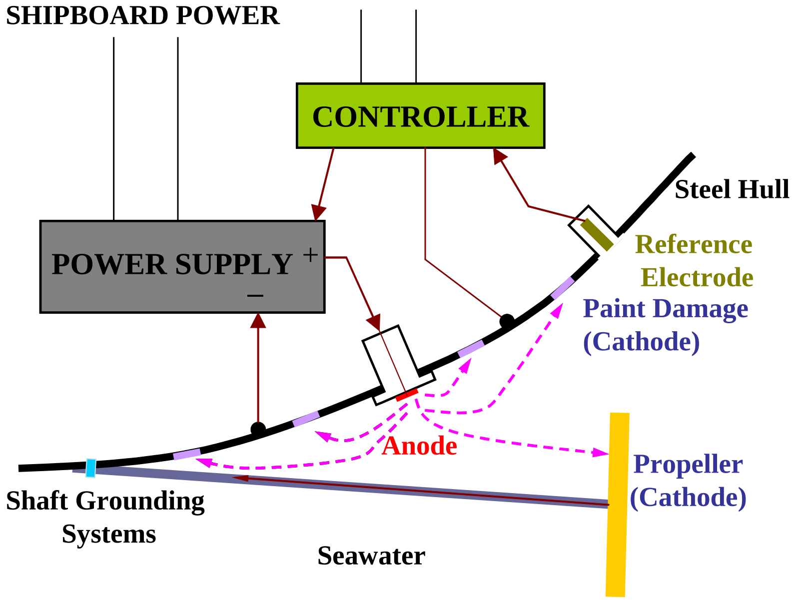
- Corrosion potential
  - Steel: -650 mV
  - Bronze: -220 mV
- Cathodic protection potential for steel: -850 mV

Two Types of Cathodic Protection

1. Sacrificial (Galvanic) anode

- Passive system
  - *Kingston* Class ship hulls
  - *Victoria* Class submarine hulls

2. Impressed current

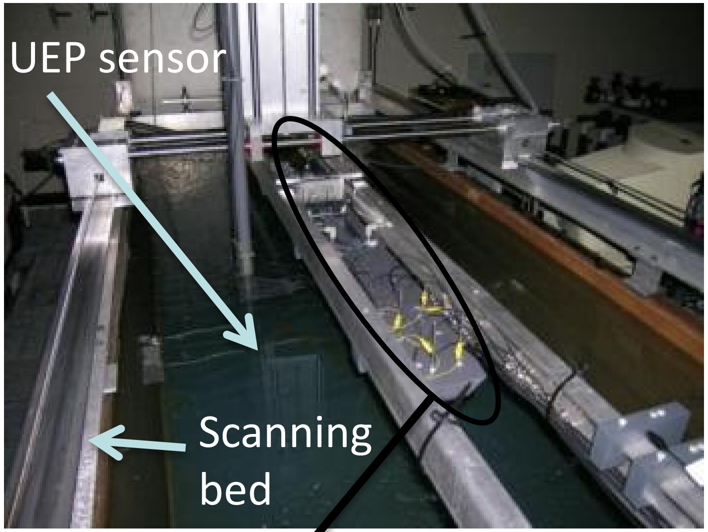


- Active system → -0.85 V
  - *Halifax* Class ship hulls
  - *Iroquois* Class ship Hulls

Development of modelling tools for shipboard cathodic protection systems

Physical Scale Modelling (PSM)

- A 1/100 scale shipboard impressed current cathodic protection (ICCP) model
- A 1/50 scale submarine hull cathodic protection model including rotating shaft and bladed propeller
- Scanning facility for underwater electric signature measurement



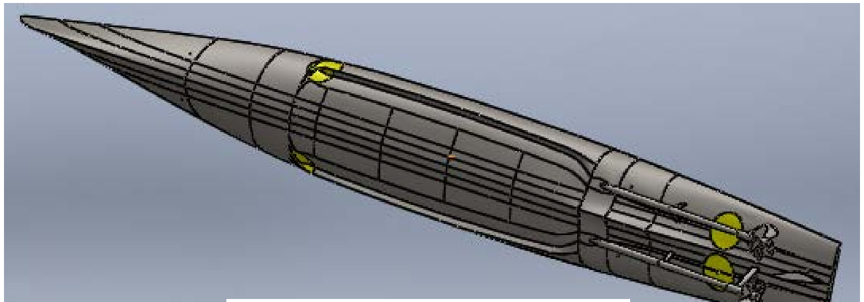
1/100 scale ICCP Physical Scale Model

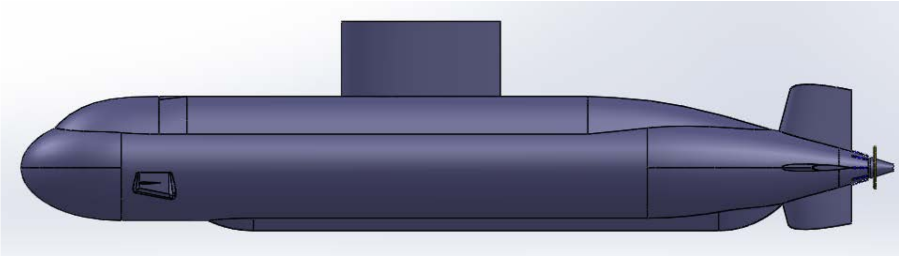
1/50 scale sub model

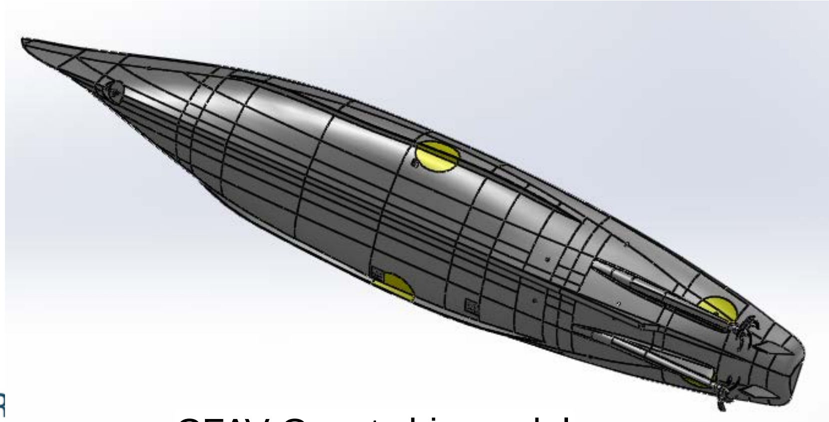
5-blade propellers

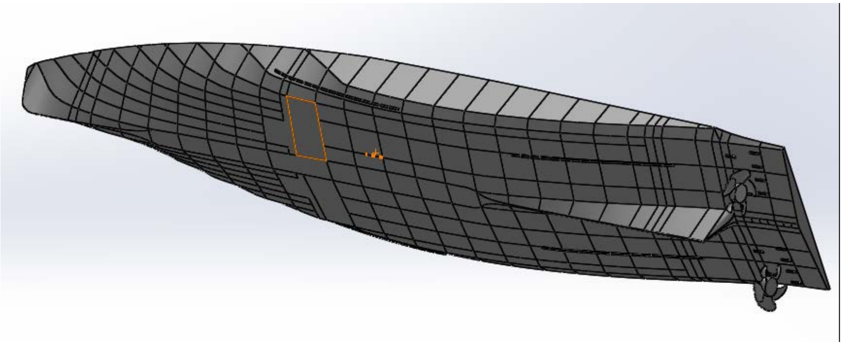
Numerical Modeling

- CPBEM
  - In-house boundary element code
  - ICCP, sacrificial anode cathodic protection and galvanic corrosion modelling
- CPMaster
  - Commercial finite element code
  - ICCP, sacrificial anode cathodic protection, galvanic corrosion, and stray current corrosion modelling
  - Underwater electric signature modelling

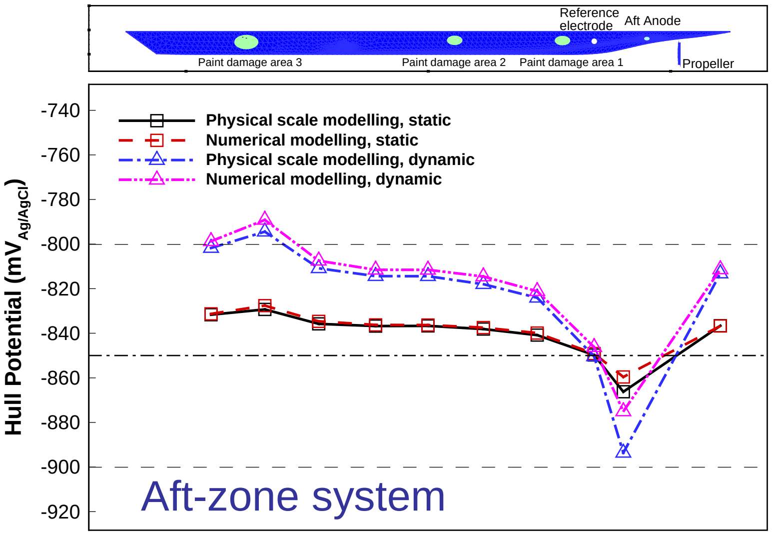

Halifax class ship model

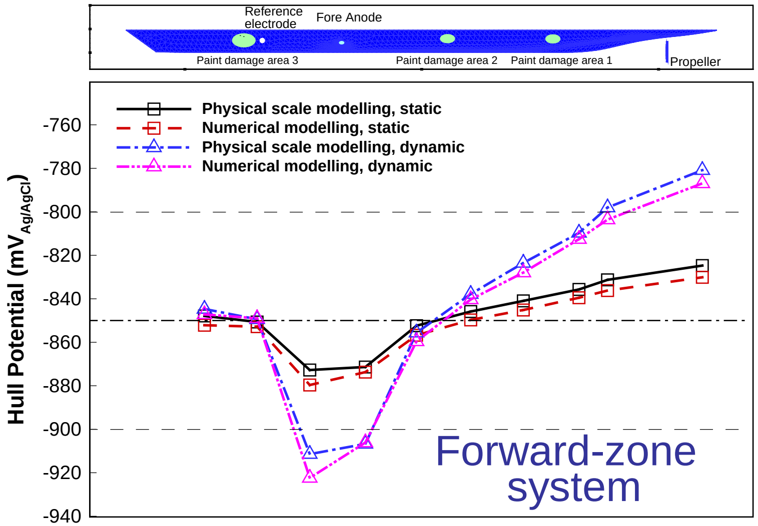

Submarine pressure hull model


CFAV Quest ship model

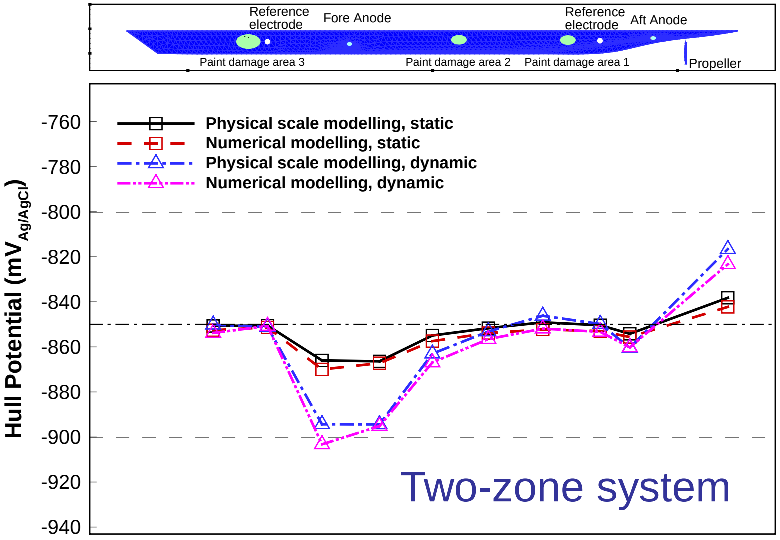

Kingston class ship model

Validation of Numerical Modelling Results with Physical Scale Modelling Data





- The comparison study has shown good agreement between the PSM results and numerical modeling results, in both simulated static and dynamic flow conditions.



Investigation of Corrosion Issues on the Underwater Hull on a Naval Ship

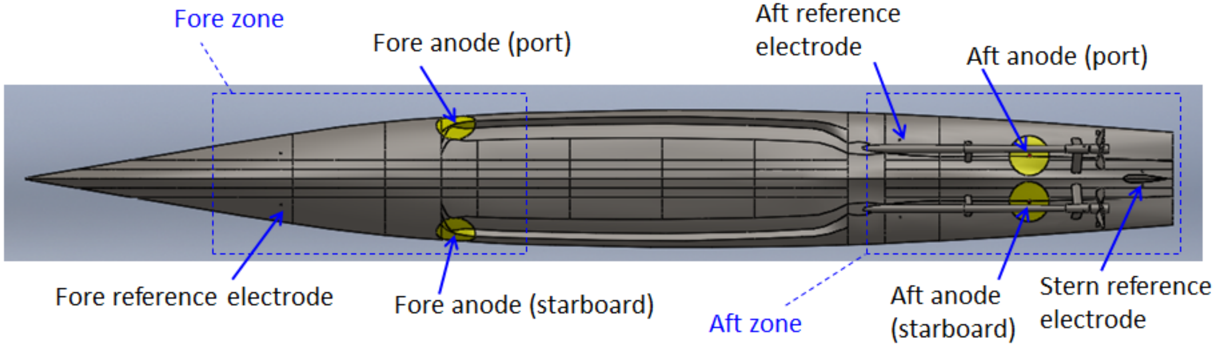
Corrosion Issues

- Pitting corrosion at the aft end of A-bracket bearing housings on both port and starboard sides
- Rust stains on the back surfaces of the A-bracket bearing housings
    - ➢Clear indication of active corrosion at these localized areas

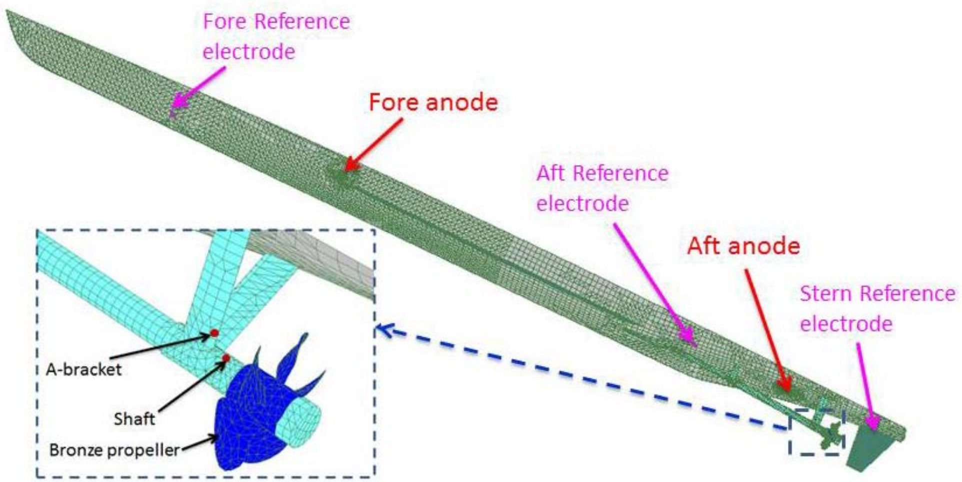
- **What caused the active corrosion?**

Shipboard ICCP System and Ship Model

- Two-zone four-anode ICCP system
  - Fore zone: two fore anodes and one fore reference electrode
  - Aft zone: two aft anodes and two reference electrodes
- Each zone can be operated independently
- Aft zone was not functioning for one year due to power supply issues

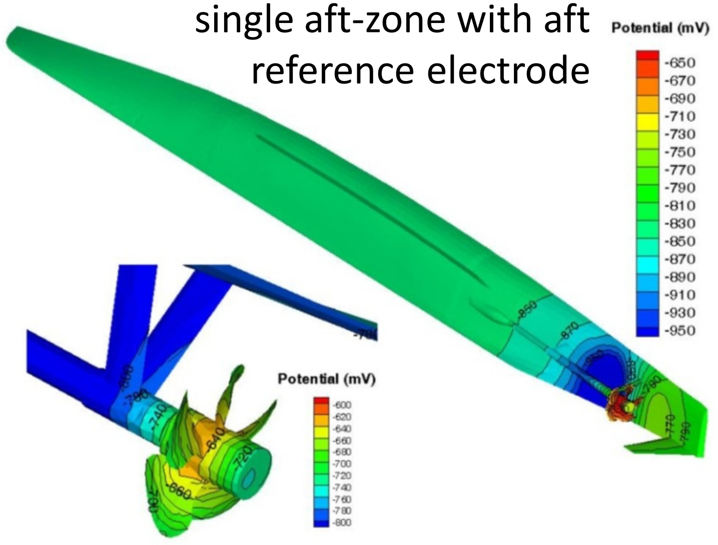


- The half ship model used because of the symmetry
- Two spots
  - On A-bracket
  - On shaft
- The bronze propeller served as the only cathode in the ICCP system

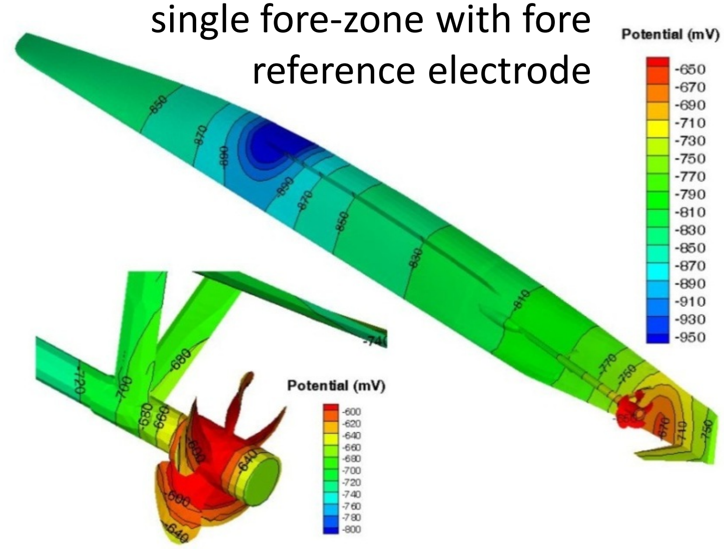


Hull Potential Contours

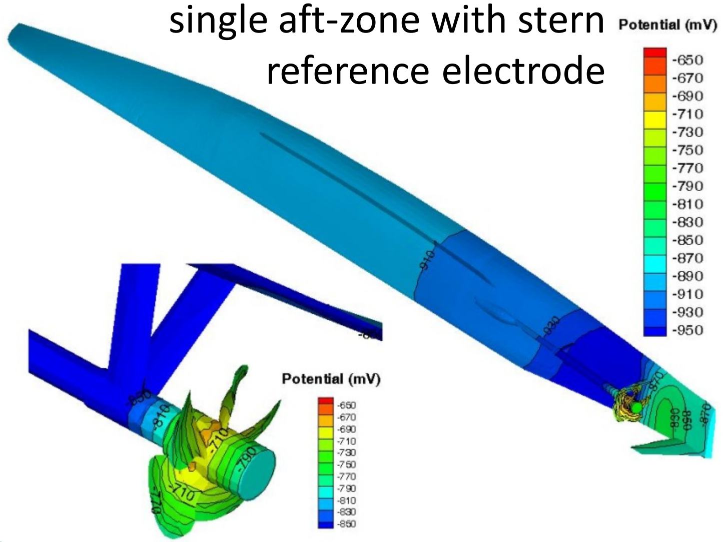
single aft-zone with aft reference electrode



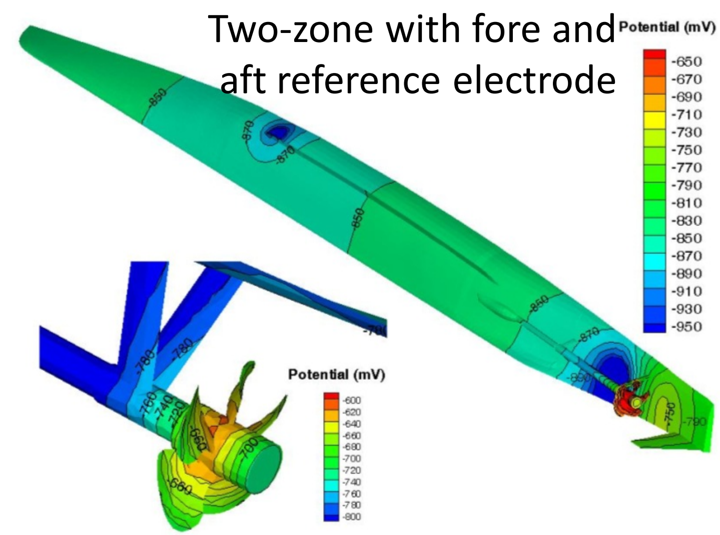
single fore-zone with fore reference electrode



single aft-zone with stern reference electrode

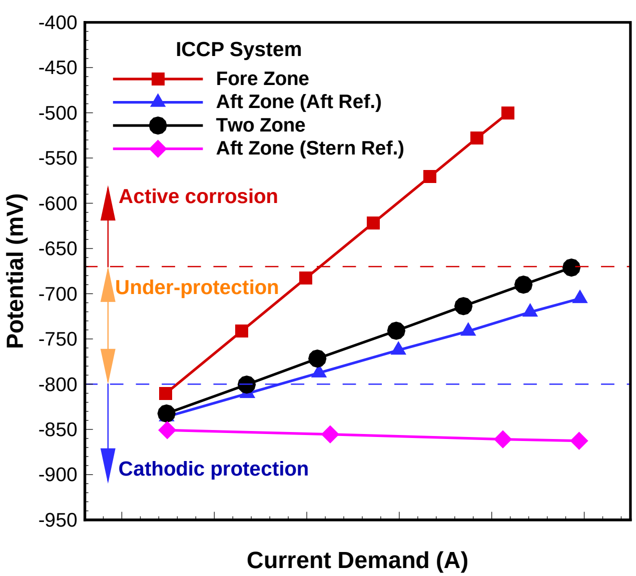


Two-zone with fore and aft reference electrode

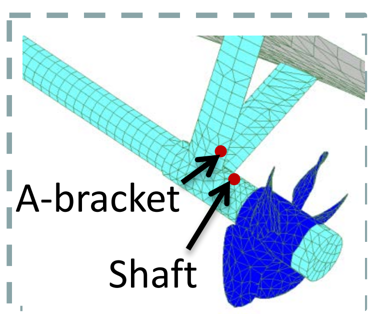


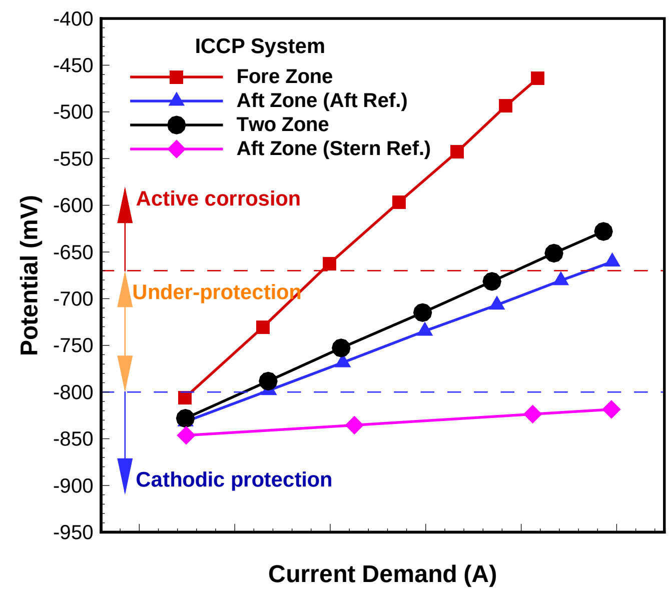
Effect of ICCP Operating Mode and Current Demand on Level of Cathodic Protection

- The active corrosion was due to inadequate cathodic protection (CP).
- The aft zone of the ICCP system was not functioning for one year. The numerical modelling results indicate that use of the fore zone of the ICCP system alone will not be able to provide adequate CP to the stern of the hull and the appendages located close to the propellers.
- Use of the aft zone of the ICCP system with the stern reference electrode will be able to improve the level of CP at the stern and on the appendages located near the propellers and bring the potentials in these areas to the -850 mV limit.



A-bracket



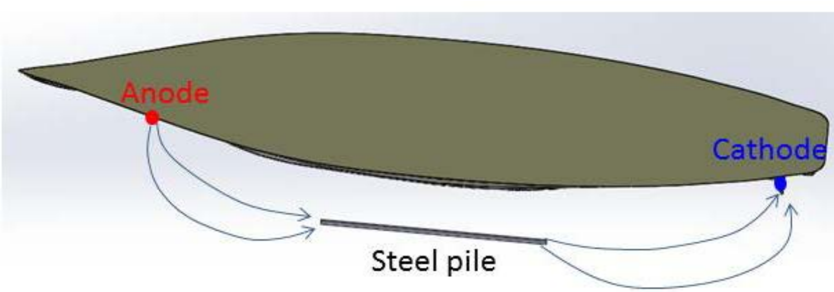


Shaft

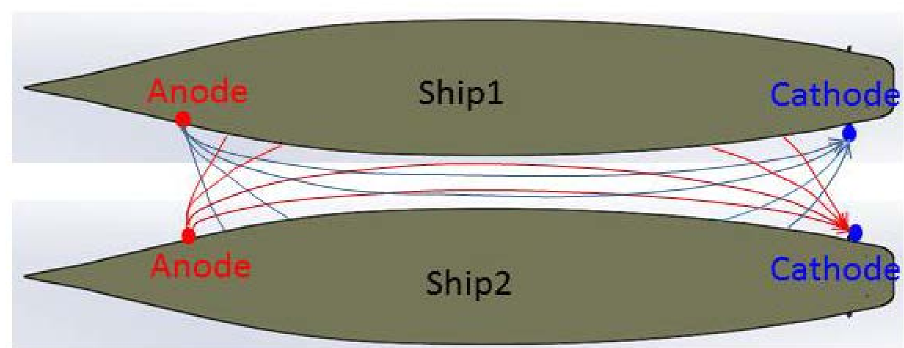
Modelling Stray Current Interference to Shipboard Cathodic Protection System

Stray Current

- Definition - Current flowing through paths other than intended circuit
- Sources of stray current
  - Unprotected steel piles in the vicinity of a ship
    - Present a low resistance path
  - A ship along side a jetty
    - The electrostatic field affected by the jetty CP system
  - A ship along side another ship
    - The electrostatic field affected by the second ship’s CP system



Steel pile near a ship



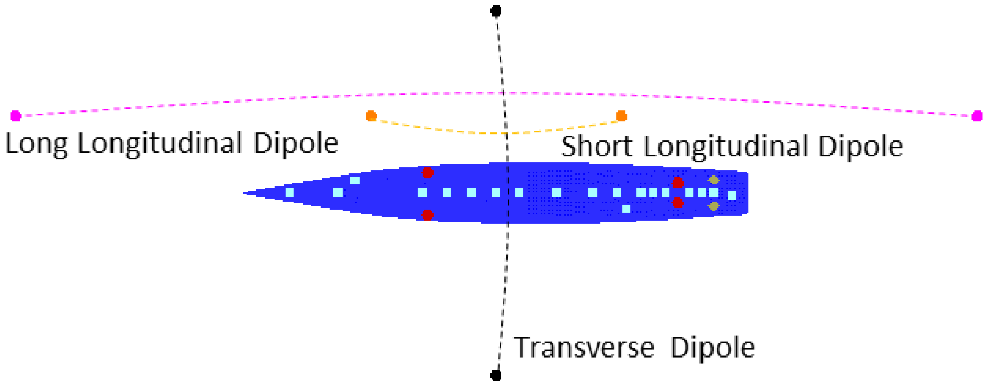
Ship 1 along side Ship 2

Objectives

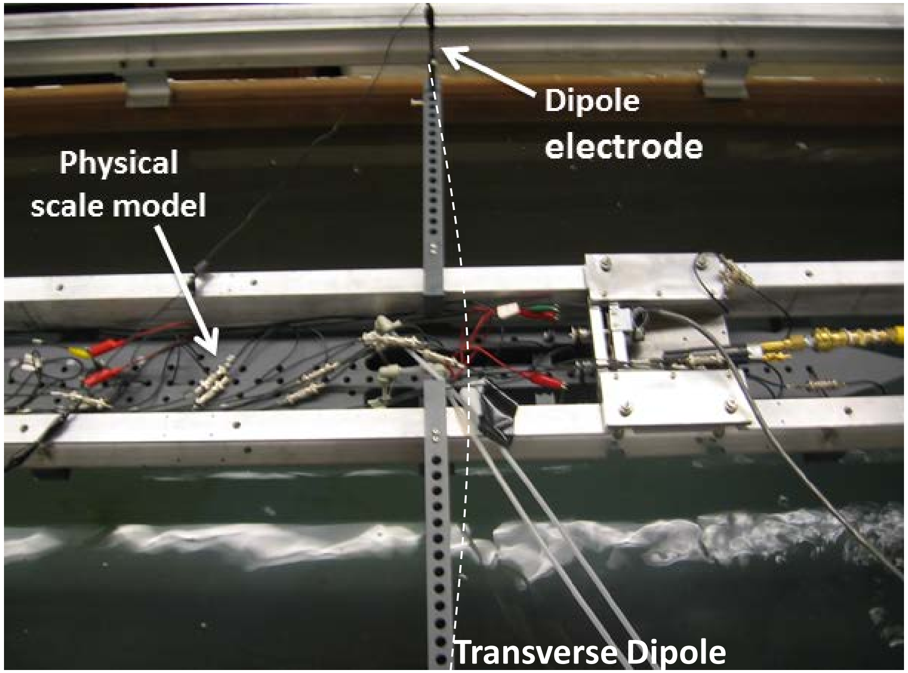
- To evaluate the effect of external current sources on the performance of a shipboard impressed current cathodic protection (ICCP) system using physical scale modelling and numerical modelling techniques

Physical Scale Model and Stray Current Source Configuration

- Physical scale model
  - 1/100 scale ship mode
  - Two-zone four-anode ICCP system
  - Twenty reference electrodes for model hull potential mapping

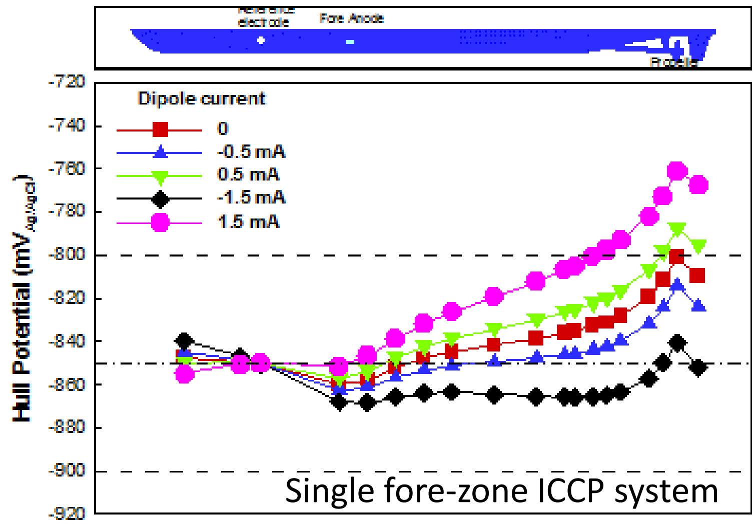


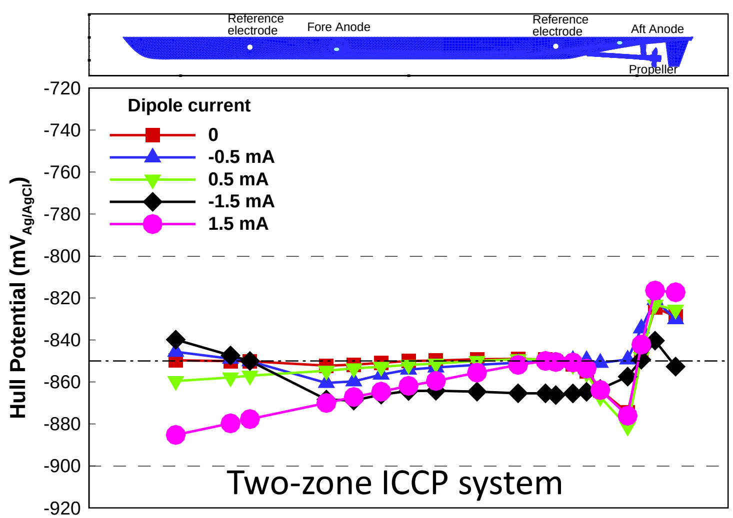
- Stray current source configuration
  - The stray current was introduced using a dipole consisting of two graphite electrodes
  - Three dipole layouts
    - i. Transverse Dipole
    - ii. Short Longitudinal Dipole
    - iii. Long Longitudinal Dipole

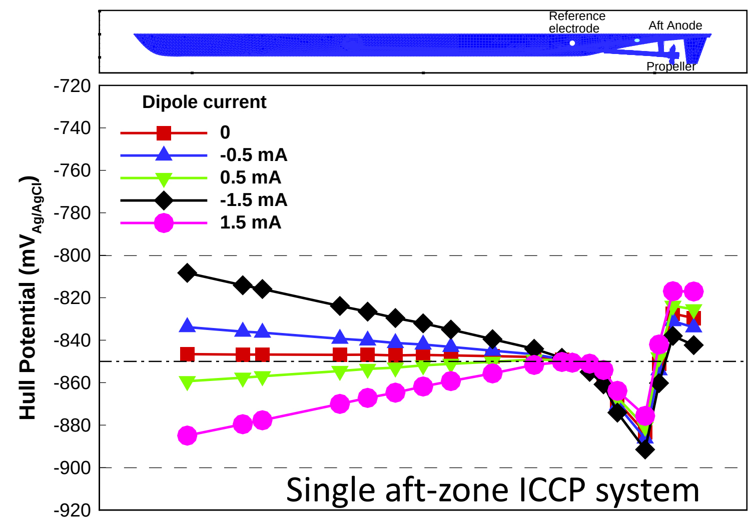


Effect of Shipboard ICCP Operating Mode on ICCP Response to Stray Current Interference

- Single-zone ICCP systems have limited capability to compensate for stray current interference and, therefore, are potentially subject to under-protection in the presence of stray current.
- A two-zone ICCP system is more tolerant with respect to offsetting stray current interference than single-zone ICCP systems.



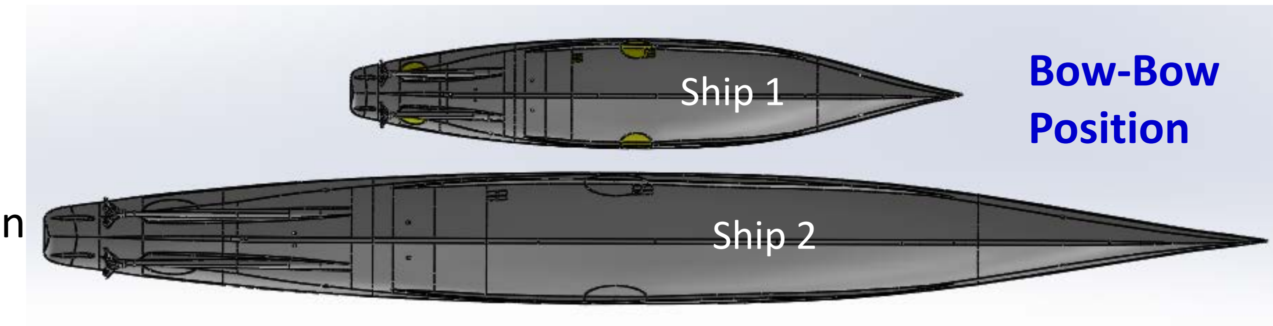


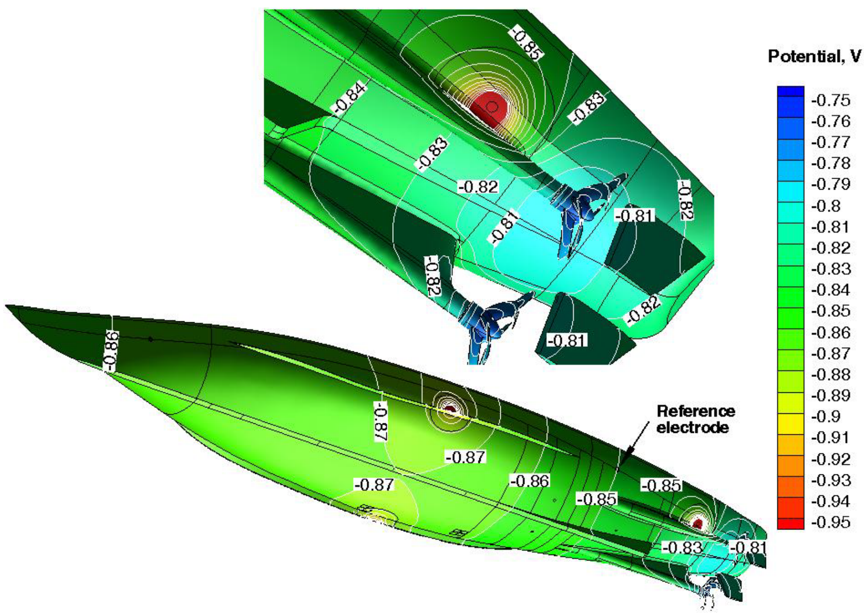


Stray current source: Long Longitudinal dipole

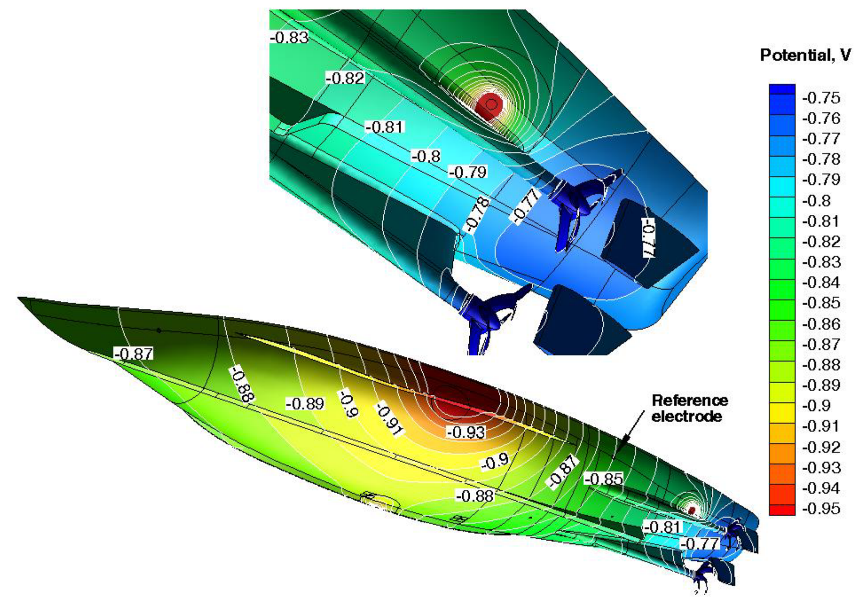
Demonstration on Stray Current Interference between Two Ships Using Numerical Modelling Technique (1/2)

- Ship 1: Single-zone four-anode ICCP system
- Ship 2 single zone two-anode ICCP system
- Potential under-protection predicted near the stern





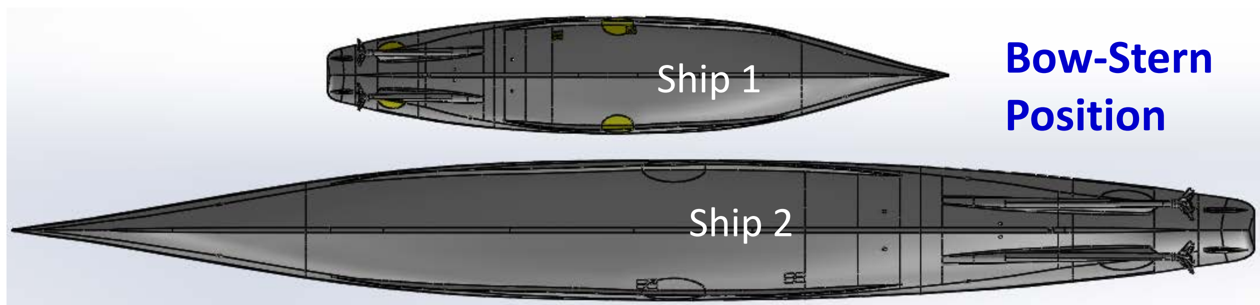
Potential contour on Ship 1 (without stray current interference)

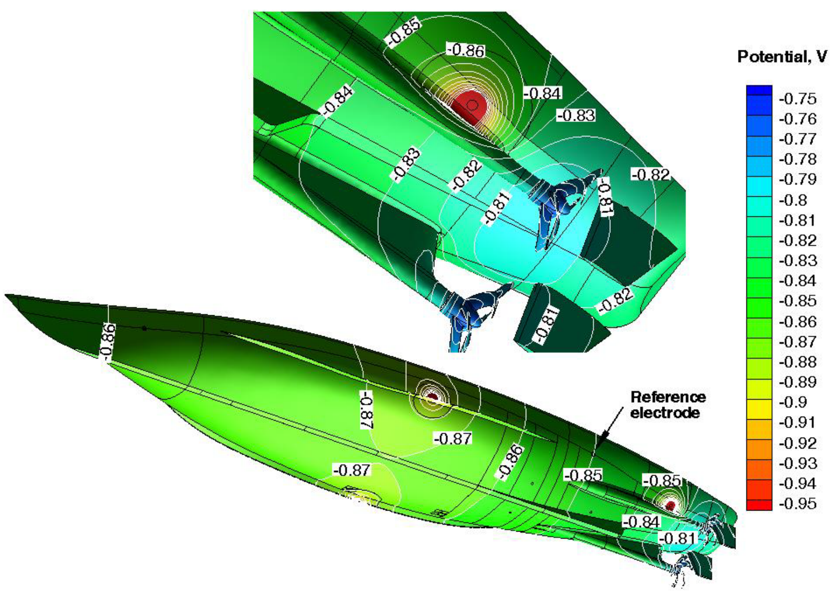


Potential contour on Ship 1 (with stray current interference)

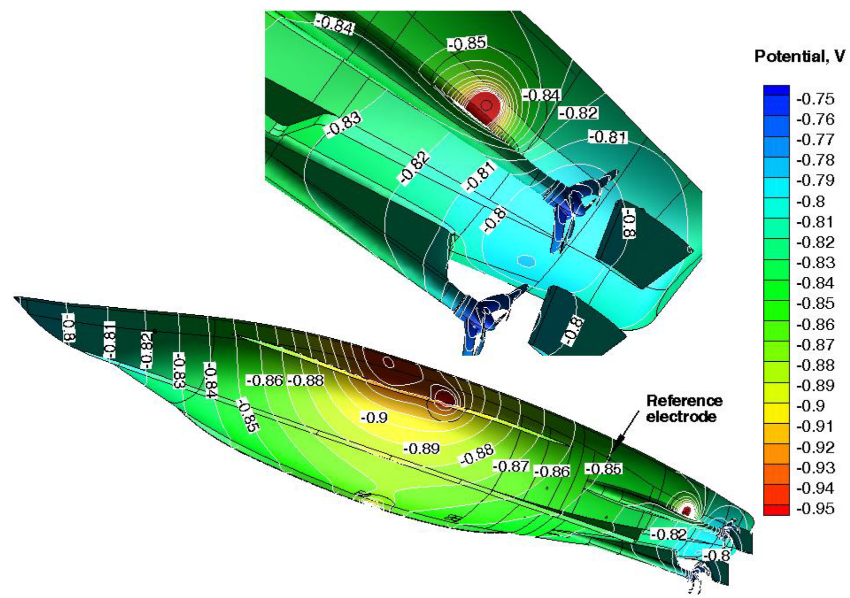
Demonstration on Stray Current Interference between Two Ships Using Numerical Modelling Technique(2/2)

- More positive potentials predicted near the bow but no under-protection issues





Potential contour on Ship 1
(without stray current interference)



Potential contour on Ship 1
(with stray current interference)

In Summary….

- Physical scale modelling and numerical modelling tools and expertise have been developed for
  - Design verification and validation of shipboard cathodcic protections systems on naval platforms
  - Corrosion failure investigations and trouble-shooting shipboard cathodic protection systems
  - Addressing potential stray current interference issues
- Future studies will be focused on
  - Corrosion related underwater electric signatures
    - Development of onboard underwater electric signature determination module (as part of ship signature management system)
  - Corrosion monitoring techniques
  - Continuing to provide direct client support to the Navy on cathodic protection, corrosion failure investigation, materials selection, etc.

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