Design and Development of Innovative Twin-Pod AUVs

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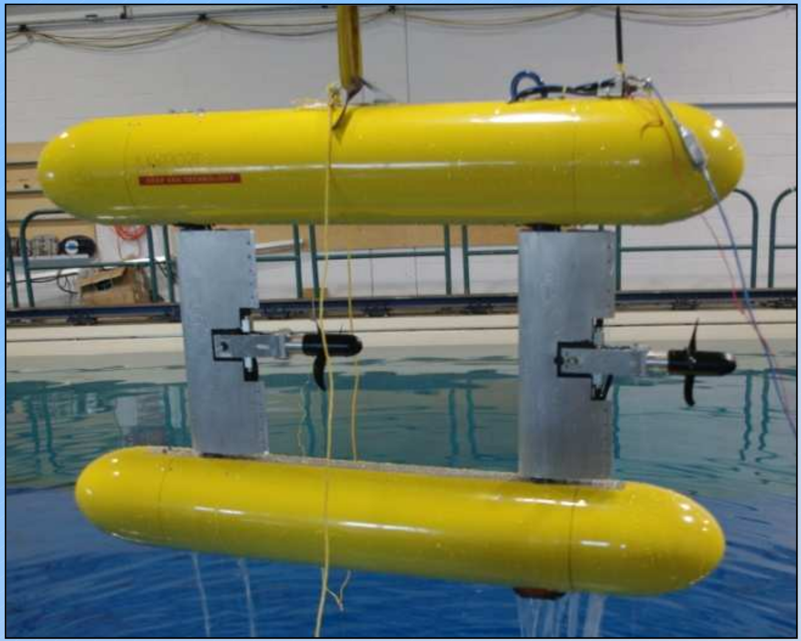
Outline

- Introduction
- Design and Development
- Expertise and Experiments
- Results and Lessons Learned
- Conclusions
- Future Plans

Introduction

- The SQX-500 AUV is a joint development between Marport Canada Inc, the NRC-IOT and Memorial University



- A passively stable and highly maneuverable platform, the unique and innovative features of the design presented several challenges

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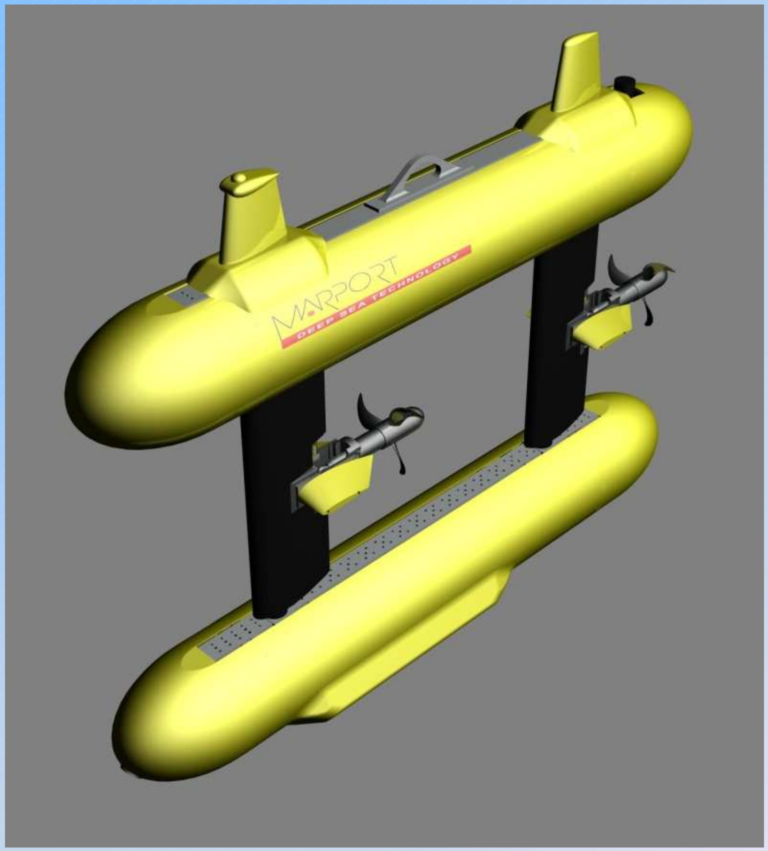
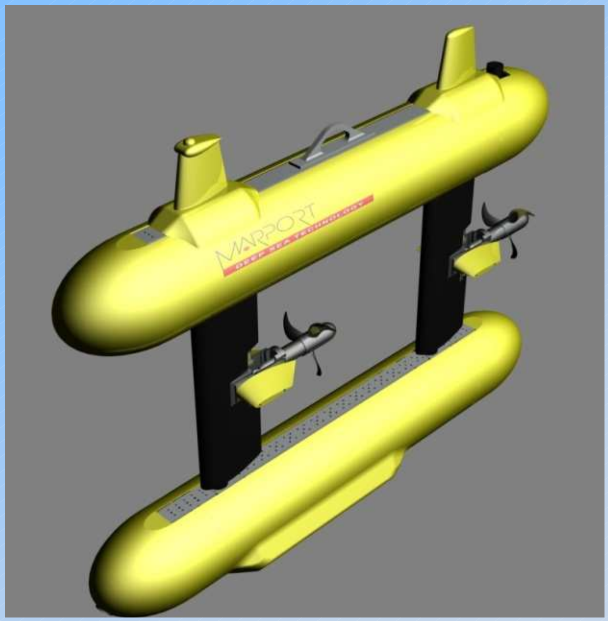
SQX-500 AUV Design Specifications

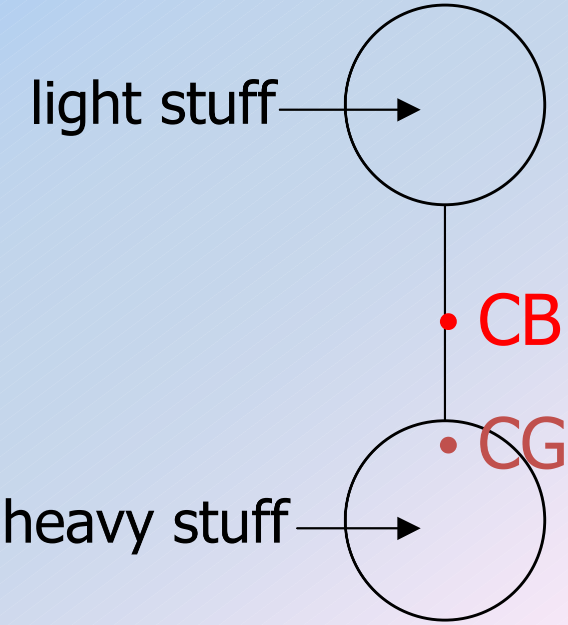
- Dimensions
  - 1.6 m, tip to tip
  - 83 cm high
  - 25 cm OD, each pod
  - Dry mass: ~100 kg
  - 500 m depth operational
  - 3.0 m/s maximum speed
  - 1.5 – 2.0 m/s cruise speed
  - 8 hr mission time at cruise speed
  - 2.2 kWh Li-Ion battery pack
  - 4 DOF hovering motion and control
  - Passively stable in pitch & roll
- Modular Payloads include:
  - Marport Dual-Frequency Sidescan Sonar
  - Colour Video Camera and LED Light (option)



SQX-500: General Arrangement

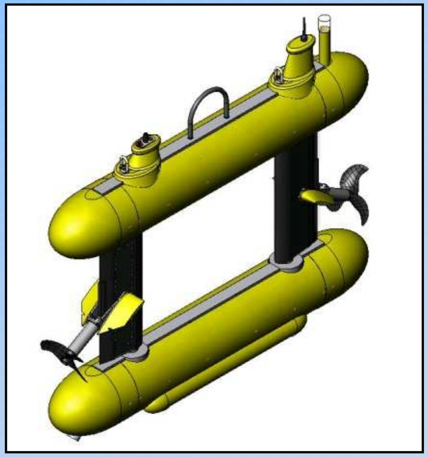
- Optimized for sonar payloads, esp. side looking
- Twin pod arrangement for high roll / pitch stability, i.e., large GM's (longitudinal & transverse metacentric heights)
- Twin rudder / elevator / thruster assemblies for axial thrusting control – hover, vertical motion, tight yaw, close in maneuvering
- Modular payload and hotel arrangement for flexibility



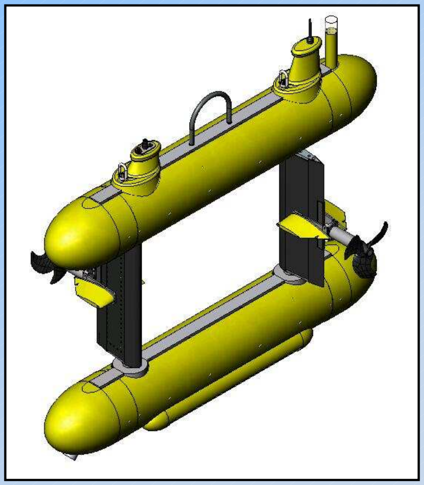


Propulsion / Control Capabilities

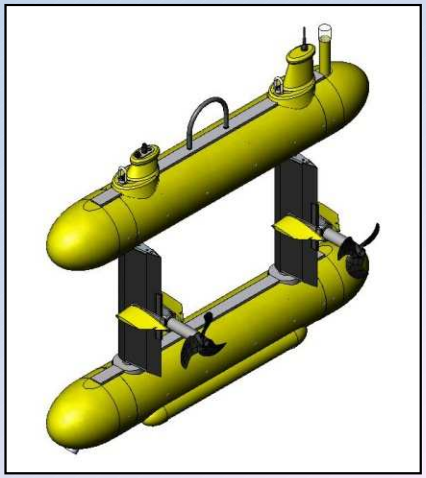
- Hovering & Vertical Motion



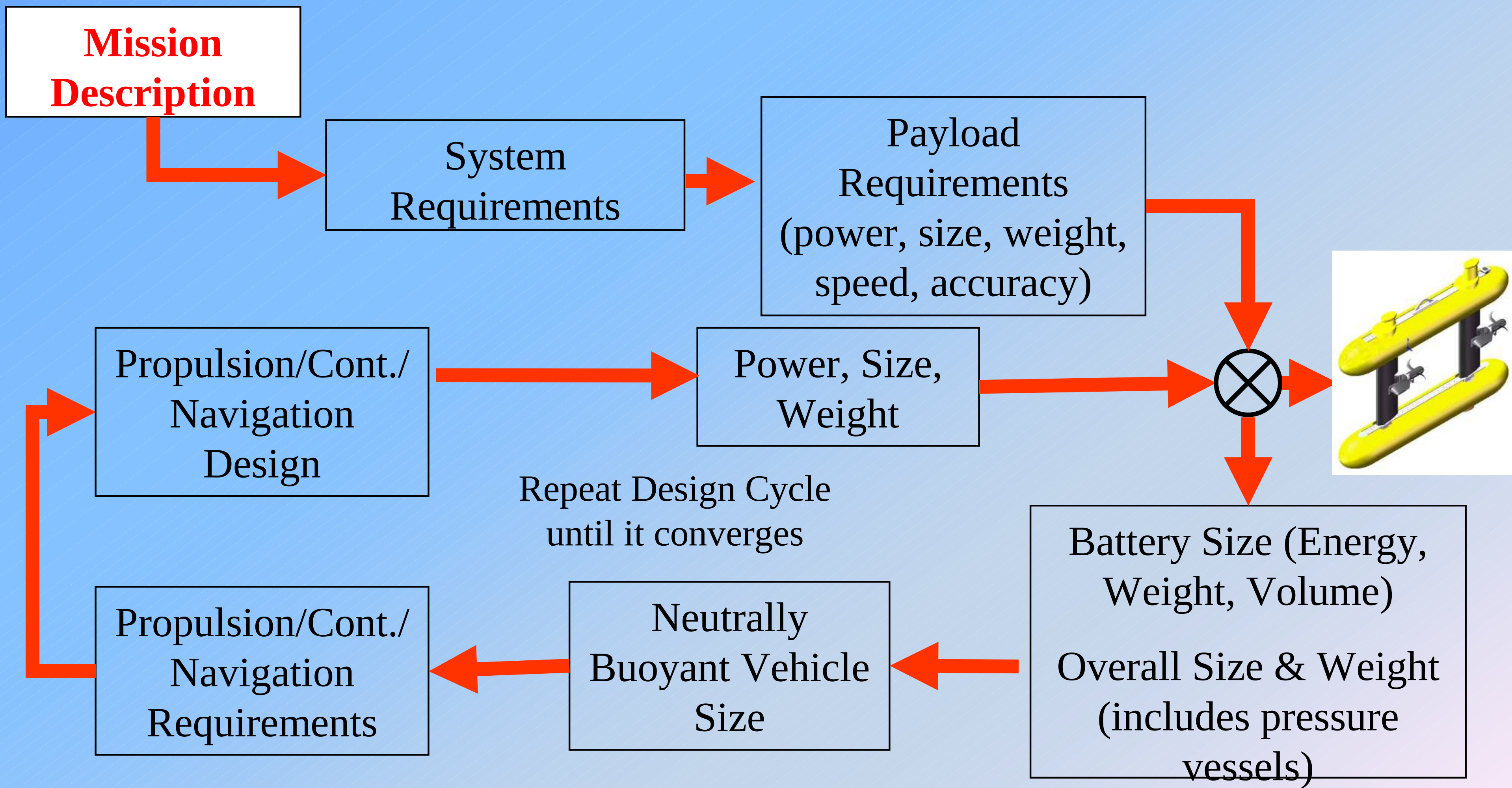
- Zero Turning Radius
  – i.e., turn on a dime



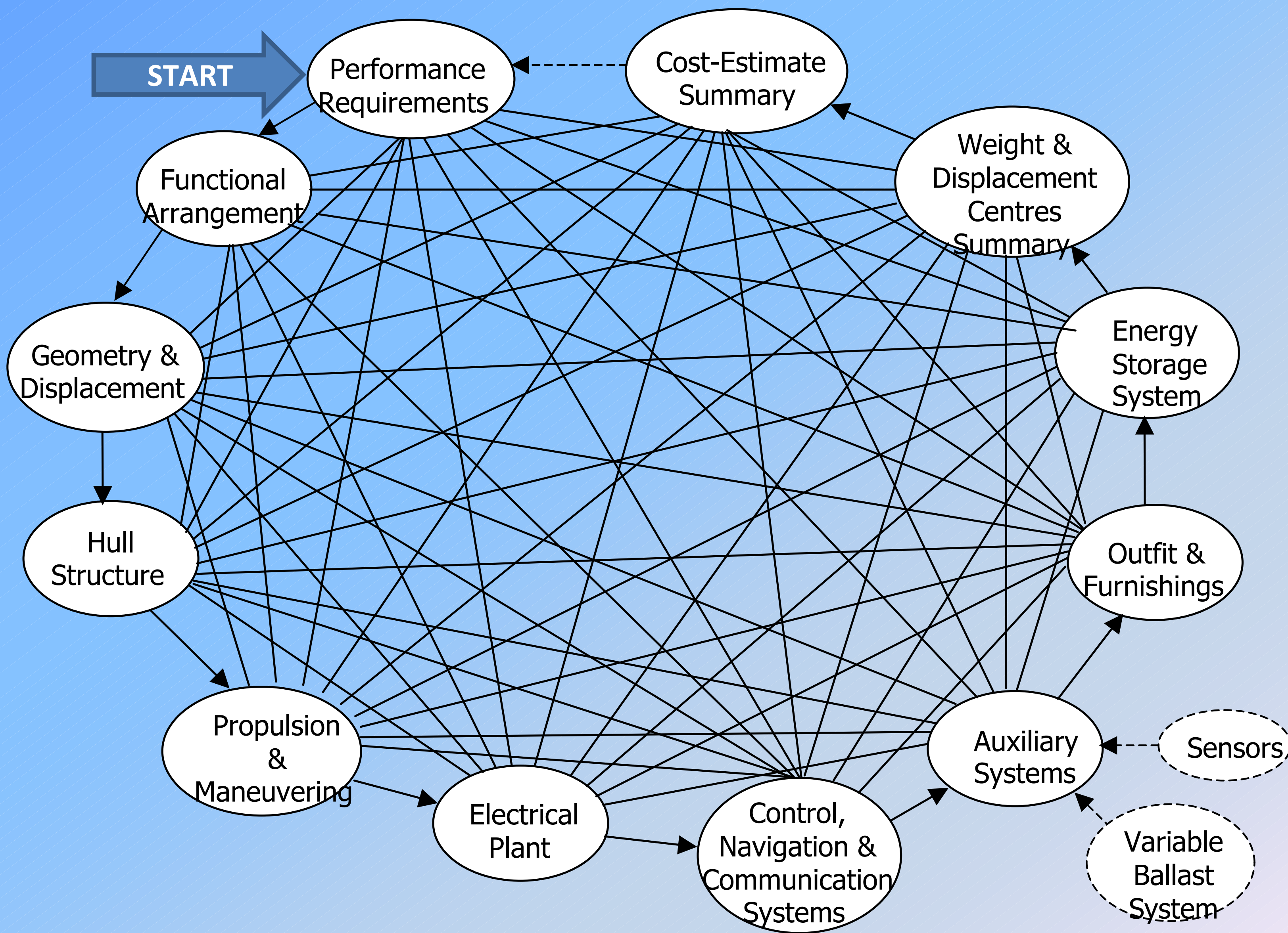
- Crabbing



Ideal Design Cycle for an AUV



What the Design Cycle is Really Like



The Interaction of the Elements of Design for an Underwater Vehicle

Design Challenges

- Estimates of hydrodynamic drag were required for propulsion system design, and control system optimization
- Little published data was available for twin pod vehicles, particularly at high angles of attack
- A custom propeller was desired, to improve propulsion efficiency

Expertise and Experiments

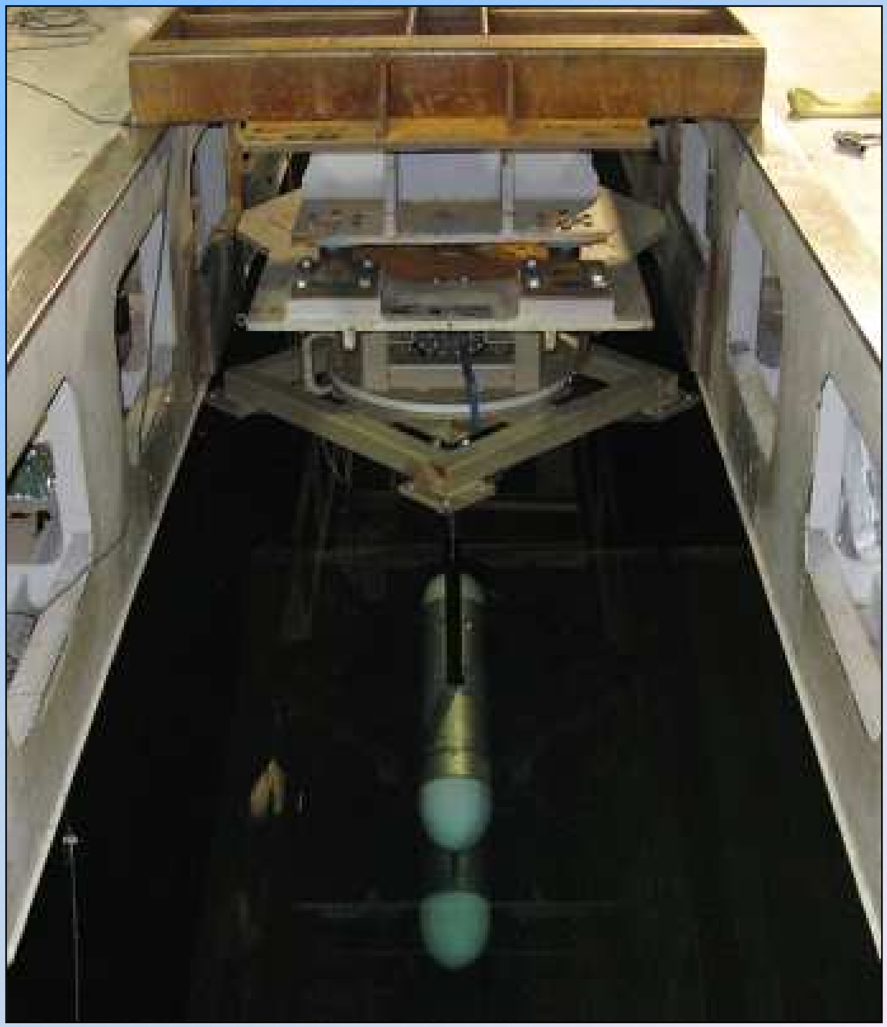
- To meet these challenges, researchers at the NRC-IOT and MUN were consulted, and an extensive set of tests was deemed necessary

- Experiments were performed using facilities and expertise at the NRC-IOT, Memorial University and the Marine Institute

- Experiments included scale model tests, passive stability characterization, propeller design and characterization, thruster testing, and finally full-scale self-propulsion tests

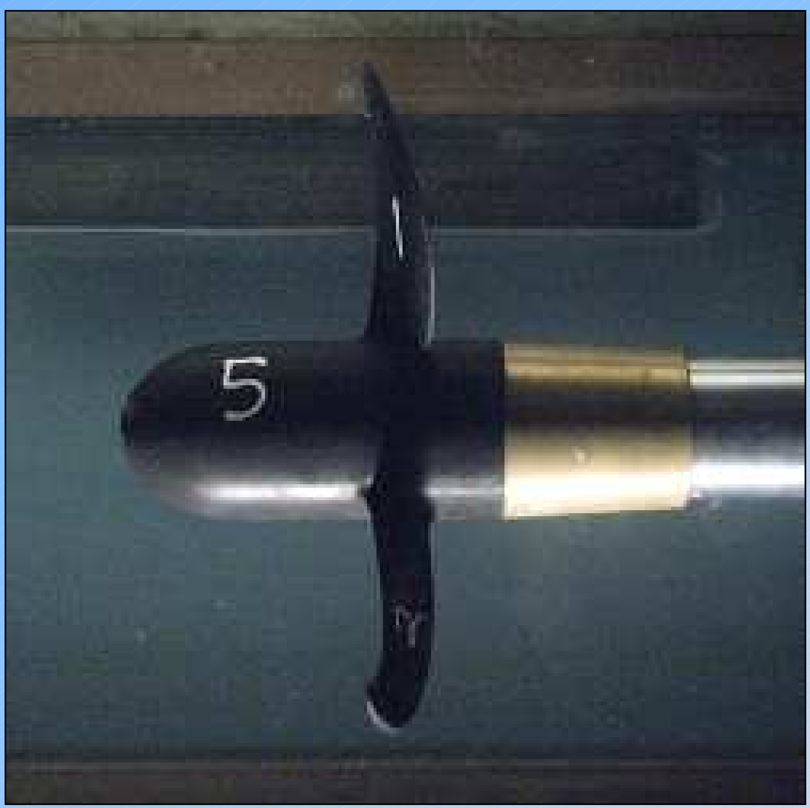
Scale Model Testing

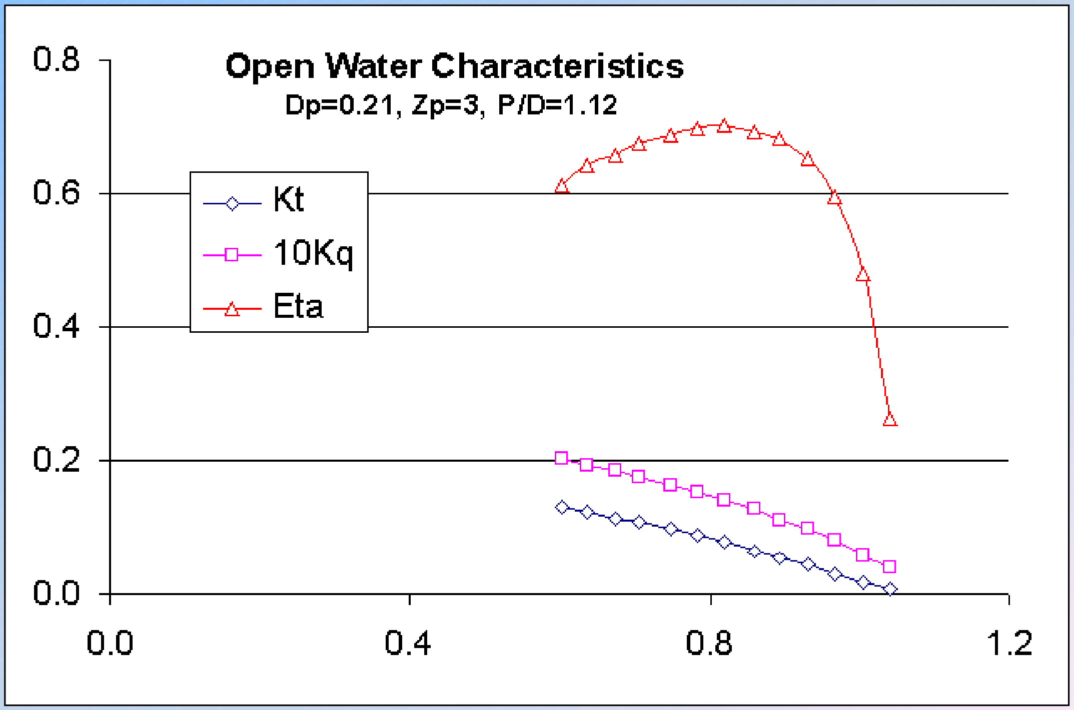
- Tests were performed in the NRC-IOT's 200m Clearwater Towing Tank
- Scale model was mounted to a 6DOF force balance, and towed to measure forward, transverse and heave drag
- Mounting to a yaw table allowed for varying AOA in each experiment, to get full 6DOF data



Propeller Testing

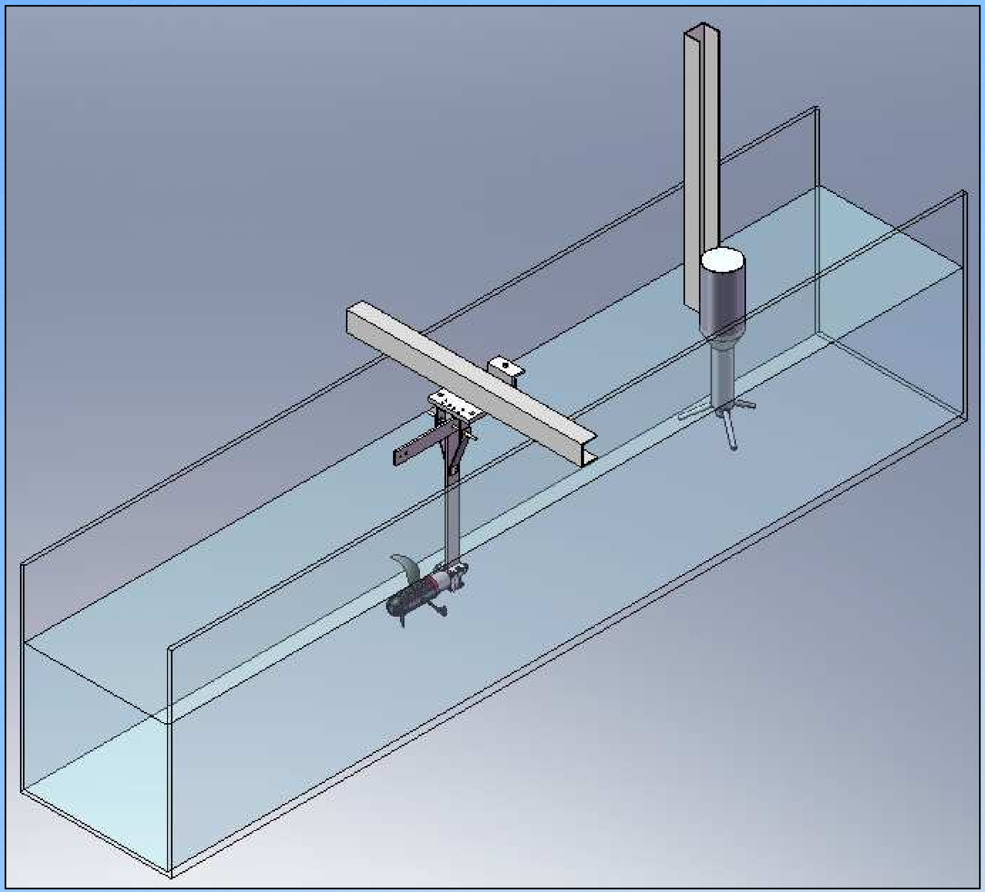
- Tests were performed in the NRC-IOT Cavitation Tunnel, measuring input torque, flow speed, output thrust and RPM to compare real world propeller performance with theoretical predictions

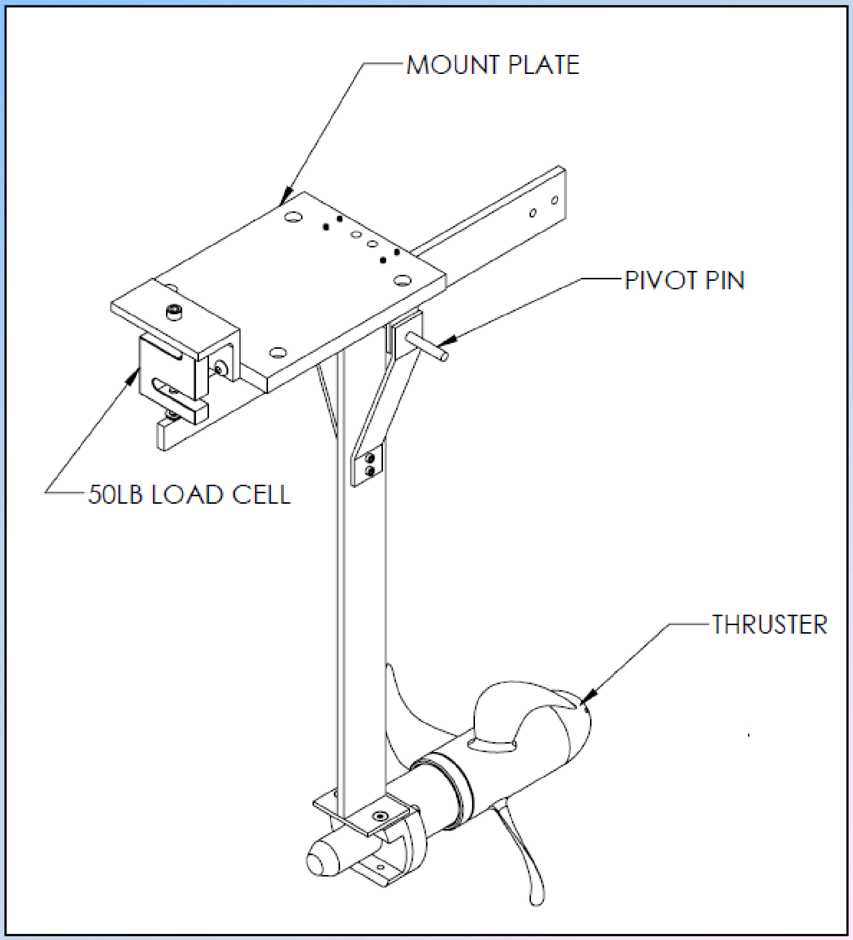




Thruster Flume Tank Testing

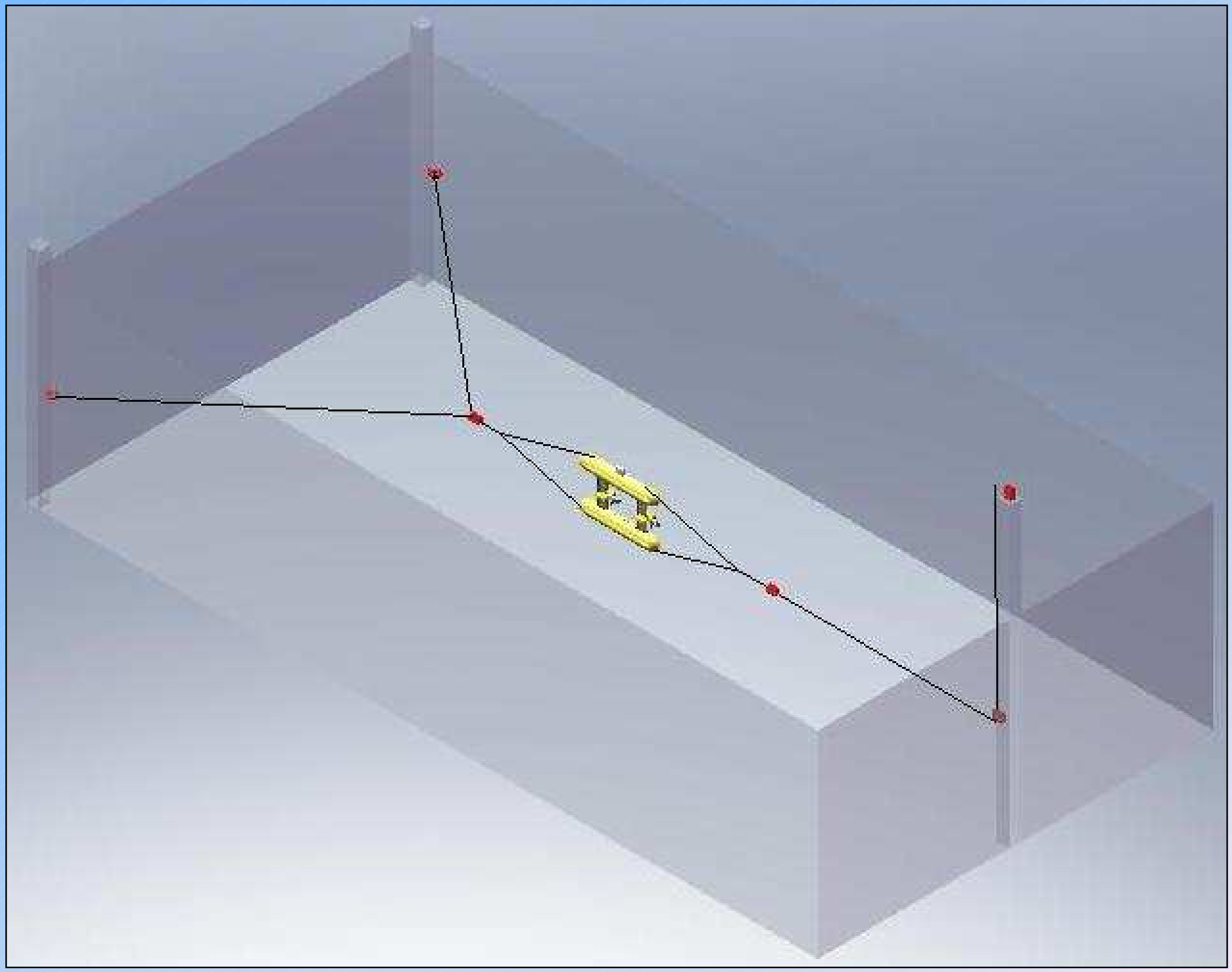
- Tests were performed in the Memorial University flume tank, measuring input power, output thrust, RPM and flow speed to characterize fully assembled drive train





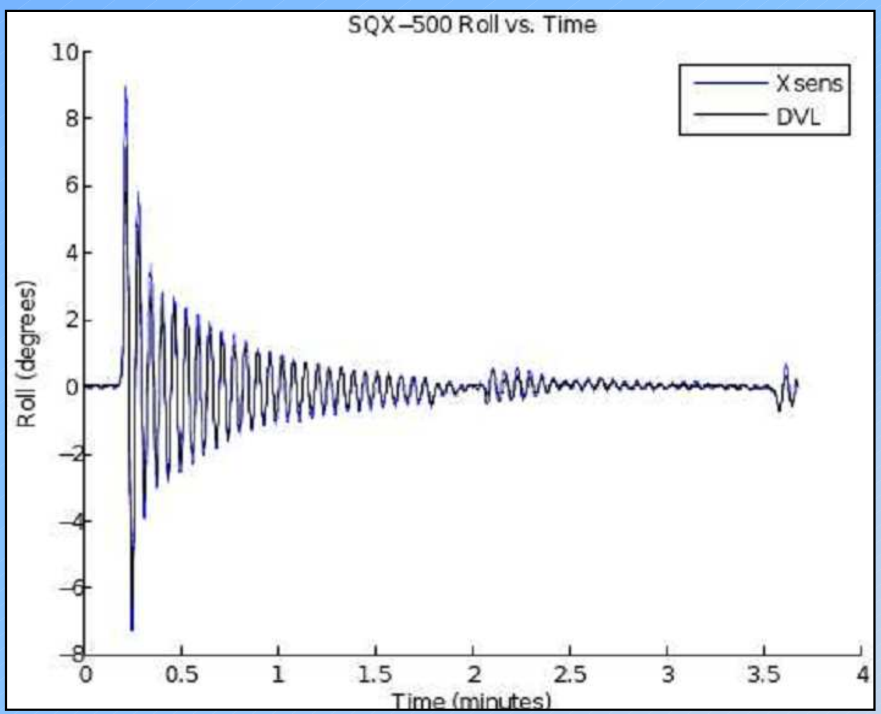
Full Scale Resistance Tests

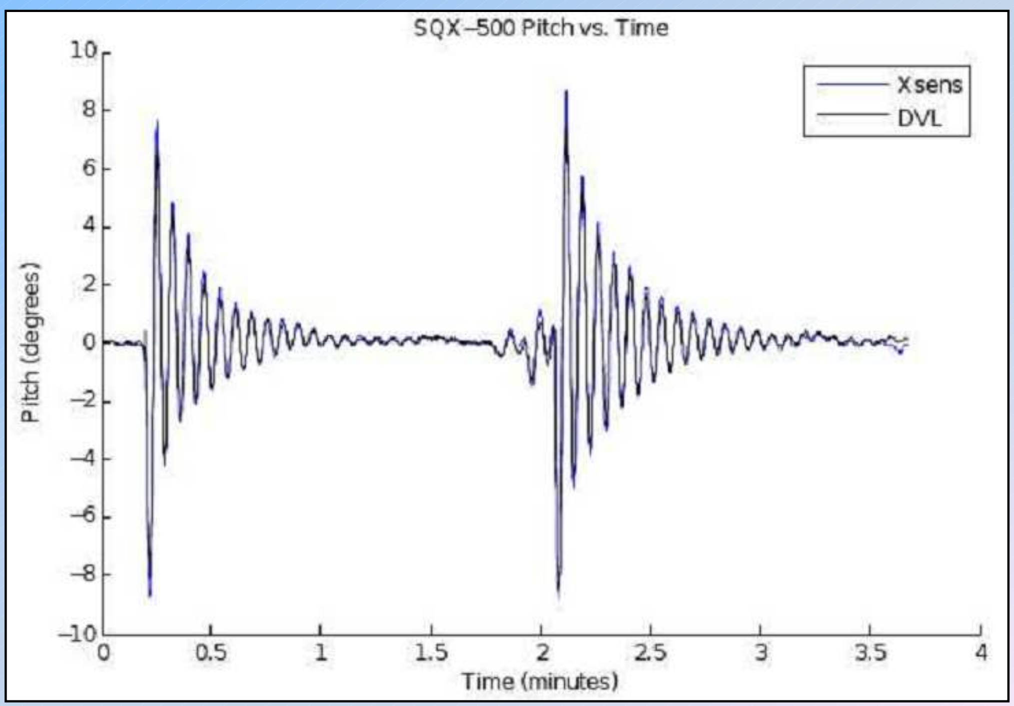
- Tests were performed in the Marine Institute flume tank, with single-point upstream and downstream load cells.



Passive Stability Testing

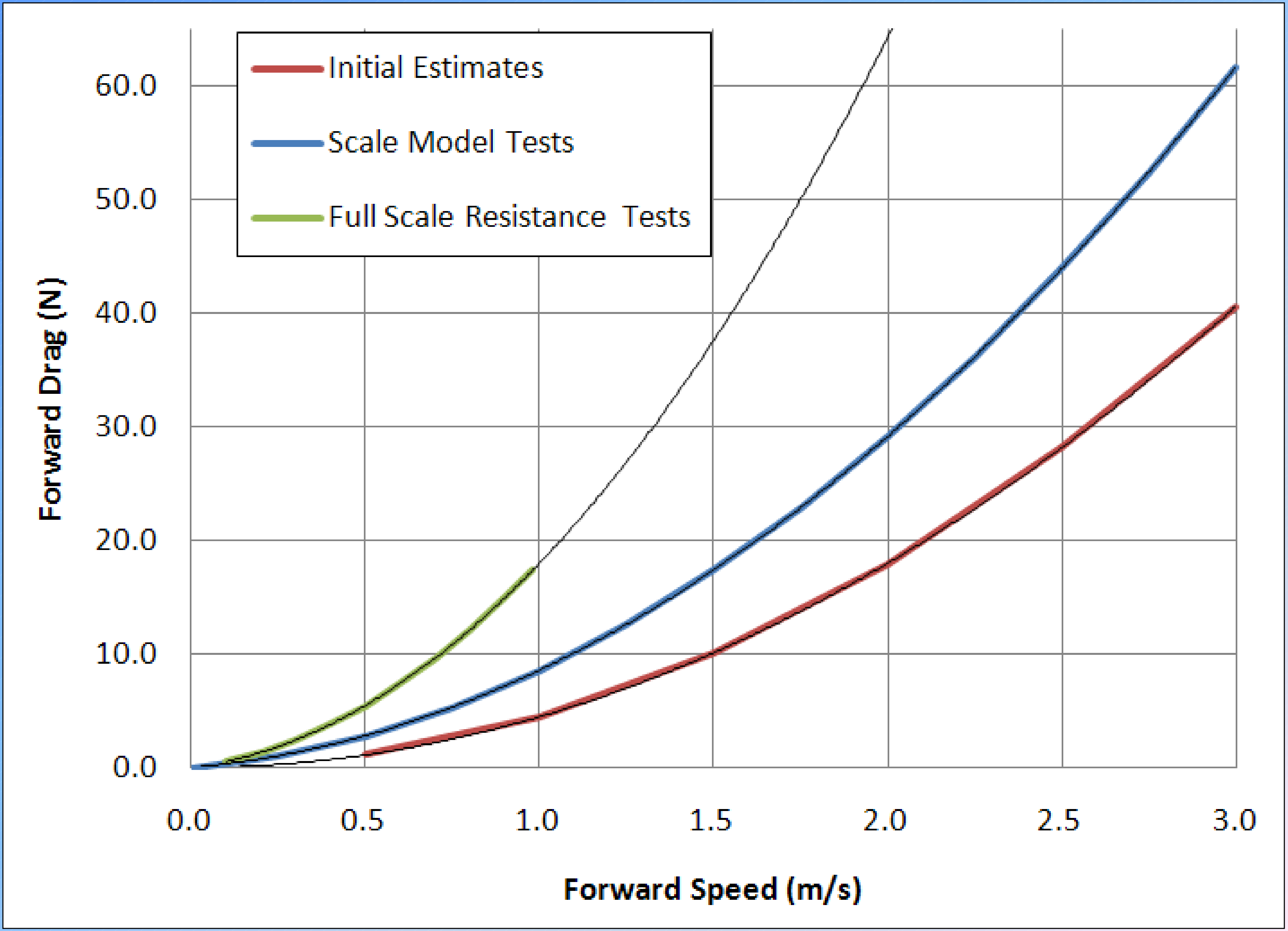
- Roll and pitch oscillations were measured using two internal inertial sensors in an untethered vehicle, in calm water, to measure damping coefficients





Results

- Extensive sets of hydrodynamic characterization tests were performed, at various points in design cycle, some producing redundant data sets.
- Results from tests varied significantly in quality, accuracy, and cost (facilities, equipment, etc.)
- A comparison of all tests and respective results was performed, comparing the “value” of each test, and the necessity


Initial Estimates
Scale Model Tests
Full Scale Resistance Tests
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Forward Drag (N)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Forward Speed (m/s)

Conclusions

- Theoretical propeller data closely matched real-world performance. Future propeller characterization not always necessary
- Lower-cost single-point load cell experiments provide high value data, however in some cases full 6DOF experiments are required.
- Actual drag was consistently higher than theoretical, and “rules of thumb” tend to dominant design decisions. This can be quantified with further testing.

Future Plans

- Development of an SQX-3000 (3000 m depth rating) scheduled to begin in 2011
- Possible military applications of SQX-type vehicles for MCM applications
- Further testing, characterization and modeling of SQX-500 for improved control and advanced maneuvering

Questions?