Fast Emergency Response Towing Vessel for the BC Coast

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Outline

- In the news
- Needs Assessment
- Coast Guard Involvement
- Hull Form Development
- Propulsion System Design
- General Arrangement
- Structures
- Stability
- Seakeeping
- Spill Response
- Cost Estimation
- Conclusion
- Questions
In the News...

Stricken Russian ship Simushir off Canadian coast could lead to environmental disaster

Australian Spirit tanker adrift off Nova Scotia coast

Canadian Coast Guard says vessel carrying crude oil lost steering Tuesday evening

Oil container adrift off Haida Gwaii

Michael Allan McCrae | October 17, 2014

Simushir kept afloat by 'blind luck,' federal opposition argues

Russian cargo ship drifted toward the West Coast of Haida Gwaii last week after losing power

Simushir, fuel-laden Russian cargo ship, under tow off Haida Gwaii

More vessels expected to join the towing operation


Simushir incident raises concerns over readiness of B.C. emergency services

MARK HUME
VANCOUVER — The Globe and Mail
Published Wednesday, Oct. 22 2014, 8:00 AM EDT
Last updated Wednesday, Oct. 22 2014, 8:00 AM EDT

- Sensationalized, and created substantial public outcry
- Handled well given the circumstances but still highlights a need for a dedicated response vessel
There was a large focus on this issue at Mari-Tech 2015
- Two presentations regarding tanker safety
  - Tanker Safety On the Pacific Coast
  - Preventing the Spill: Tugs for tankers

It was discussed that a large fast ocean going vessel would be required.

The characteristics of our vessel fit this description to a high degree.
Current and Projected Shipping Traffic in Northern BC

- **Container Ships**
- **Bulk Carriers**
- **Cruise Ships**
- **LNG**
- **Tankers**

**Current**

**Projected**

*Courtesy of Captain Stephen Brown*
Area of Operation

- BC Coast
- Over 960 km (600 mi) from Victoria to the Alaska border
- Total of over 25,725 km (15,985 mi) of coastline
Area of Operation

- Incidents in Northern BC
Accident Data

Grounding, Collision, and Fire total over 50% of all accidents
Accident Data

Bulk Carriers, Barges, and Passenger create vast majority
Climatology data

- Collected Metadata from NOAA and Pilot charts for Haida Gwaii and the surrounding area
- Evaluated the average yearly values for Wind velocity and Wave height

<table>
<thead>
<tr>
<th>Wave Height (m)</th>
<th>Mean</th>
<th>66%</th>
<th>99%</th>
</tr>
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<tr>
<td>Average</td>
<td>1.5</td>
<td>2.7</td>
<td>4.7</td>
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<tr>
<td>Max</td>
<td>2.4</td>
<td>3.9</td>
<td>6.9</td>
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<td>Seastate</td>
<td>4</td>
<td>5</td>
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<table>
<thead>
<tr>
<th>Wind Velocity</th>
<th>Mean</th>
<th>66%</th>
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<td>Average (m/s)</td>
<td>7.2</td>
<td>11.6</td>
<td>20.5</td>
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<tr>
<td>Average (kt)</td>
<td>14.0</td>
<td>22.6</td>
<td>40.0</td>
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</tbody>
</table>
Bollard Pull

- Largest Expected Ships
  - 320,000 t VLCC
  - 200,000 t ULCV

- VLCC required to be escorted through BC waters by dedicated escort/rescue tugs
Bollard Pull Requirements

Requirements:
- Minimum 100 t of Static Bollard Pull

Assumptions:
- Fully Loaded Container Ship
- Wind, Wave and Current Forces All Acting Against the Bow of the Ship
Canadian Coast Guard Guidance

- Contacted CCG for Guidance on Mission Requirements

Roger Girouard, (ret’d) RAdm & Assist. Commissioner:

- Towing Capability
- General Utility (Maintenance Workhorse, Buoy-tending)
- Strap-on/Containerized Mission Capability
- Space for Augmentation Accommodation (IC, ER, RCMP & CBSA)
- Deep Water SAR
- Storage Space (Pollution Recovery, Re-supply Missions)
- Helicopter Capability
- Speed Requirements
CCG Services

- Search and Rescue (SAR)
- Aids to Navigation
- Environmental Response
- Maritime Security
- Waterways Management
- Icebreaking
- Marine Communication
- Traffic Services (MCTS)
Owners Requirements

Vessel Characteristics:

Basic Functions: Emergency Response and Towing, Environmental Protection, Firefighting, Search and Rescue, General CCG Duties

Classification: Lloyd’s Register

Flag: Canada

Owner: Canadian Coast Guard

Operating Regions: Pacific Northwest, Prince Rupert, Nearcoast up to 350 nm

Endurance: 21 days, 3500 nm

Crew: 15-18 people

Ship Operating Speeds: 14 knots (Cruise Speed) 18+ knots (Max Speed Calm Waters) 18 knots (Max Speed Sea State 4)

Bollard Pull: 100t+
Hullform Selection

The design drivers for the overall dimensions:

- **Seakeeping Requirements**
  - Mission capable in Sea State 6
  - Displacement hull required

- **Speed Requirements (18 knots)**
  - Displacement hull, therefore length was dictated by Froude number
  - Minimum length = 70m

- **Stability Requirements**
  - Large towing force dictates a large area under GZ curve
  - Comply with regulations from CCG, and IMO
  - Towing Stability: Regulation required GM = 1.67m
Hullform Selection

- Considered multiple hull forms including both monohulls and catamarans

- Benefits of a Monohull
  - Simple construction
  - Large hull volume
  - Lower cost and complexity

- Benefits of a Catamaran
  - Lower residuary resistance
  - High Stability
  - Large Deck area
Hullform Selection

Advantages of Catamaran Hullform:

- High GM Value
  - Better Stability for Towing Operations

- Low Residuary Resistance
  - Lower Power Requirements

- Large Deck Area
  - Increased space for Multi-Mission Capabilities

Catamaran vs. Monohull Decision Matrix:

<table>
<thead>
<tr>
<th></th>
<th>Weight</th>
<th>Mono</th>
<th>Cat</th>
<th>Mono</th>
<th>Cat</th>
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<tr>
<td>Speed</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>12</td>
<td>16</td>
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<tr>
<td>Work area</td>
<td>3.5</td>
<td>3</td>
<td>4</td>
<td>10.5</td>
<td>14</td>
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<td>Seakeeping low sea states</td>
<td>3.5</td>
<td>3</td>
<td>4.5</td>
<td>10.5</td>
<td>15.75</td>
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<tr>
<td>Seakeeping high sea states</td>
<td>4.5</td>
<td>4</td>
<td>2</td>
<td>18</td>
<td>9</td>
</tr>
<tr>
<td>Cost</td>
<td>2.5</td>
<td>4</td>
<td>2</td>
<td>10</td>
<td>5</td>
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<tr>
<td>Maintenance</td>
<td>3</td>
<td>3</td>
<td>2.5</td>
<td>9</td>
<td>7.5</td>
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<td>Packagable mission capability</td>
<td>3.5</td>
<td>2</td>
<td>3.5</td>
<td>7</td>
<td>12.25</td>
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<tr>
<td>Towing capability</td>
<td>4</td>
<td>4.5</td>
<td>3</td>
<td>18</td>
<td>12</td>
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</table>

Advantages of Catamaran Hullform:

- High GM Value
  - Better Stability for Towing Operations

- Low Residuary Resistance
  - Lower Power Requirements

- Large Deck Area
  - Increased space for Multi-Mission Capabilities
Concept Weights and Volumes

Estimated weight with two methods
- *Kai Levander’s* method using coefficients derived from parent vessels (1,499 tonnes)
- Estimated weight through SWBS breakdown of parent vessel (1,850 tonnes)

**WEIGHTS**

<table>
<thead>
<tr>
<th>Weight Group:</th>
<th>Unit</th>
<th>Value</th>
<th>Coeff/Unit</th>
<th>Weight</th>
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<tr>
<td>Payload Related</td>
<td>No.</td>
<td>1.0 units</td>
<td>10</td>
<td>10</td>
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<tr>
<td>Buoy Crane</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Hull Structure</td>
<td>Hull Vol.</td>
<td>2,860 m³</td>
<td>0.122</td>
<td>349</td>
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<tr>
<td>Deckhouse</td>
<td>Dh Vol.</td>
<td>2,288 m³</td>
<td>0.053</td>
<td>120</td>
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<tr>
<td>Interior Outfitting</td>
<td>Area</td>
<td>560 m²</td>
<td>0.240</td>
<td>134</td>
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<tr>
<td>Machinery</td>
<td>Pp + Pa</td>
<td>8,200 kW</td>
<td>0.060</td>
<td>492</td>
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<tr>
<td>Ship Outfitting</td>
<td>Gross Vol.</td>
<td>5,148 m³</td>
<td>0.050</td>
<td>257</td>
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<tr>
<td><strong>Total</strong></td>
<td>Gross Vol.</td>
<td>5,148 m³</td>
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<td>Reserve</td>
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<td><strong>LIGHTWEIGHT</strong></td>
<td></td>
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<td>1,499</td>
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</tbody>
</table>
Hullform Development

- South Hampton catamaran series considered
- Delft 372 Hullform selected for better integration with anticipated propulsors
Final Lines Plan
Resistance

- Estimated by Two Empirical Methods
  - Southampton Catamaran Series
  - Holtrop Method

Effective Power:

- 18 knots
  - 3030 kW
  - Within 7.5%

- 14 knots
  - 1080 kW
  - Within 5%
Propulsion

- Initial Concepts
  - Waterjets
  - Voith Linear Jets
  - Twin Prop Z-Drives
  - Retractable Thrusters

- Ruled Out Due to Inability to Efficiently Meet Both Top Speed and Bollard Pull Requirements

- Twin Screw CPP Arrangement Selected
  - Maximize Propeller Diameter for each Demihull
  - Develop Full Power at Both Bollard Pull and Top Speed Conditions

- Next Steps
  - Open or Ducted Props?
  - Podded or Shafted Units?
Propulsion

- Open vs. Ducted Propeller Comparison
  - Same Diameter and Rpm
  - Compared Delivered Power Requirements for Top Speed and Bollard Pull Conditions

![Bar chart showing Delivered Power (kW) for Open CPP and CPP in 19a Nozzle]

- Lower Overall Total Power Requirements for Ducted Propeller

- Next Steps
  - Improve Nozzle Efficiency?
Propulsion Optimization

- High Efficiency Nozzles

- Nautican Integrated Propulsion Units
  - Hydrodynamic Nozzle Profile
  - Pre-Swirl Stator for Added Efficiency

- Compared to Conventional 19a Nozzle Profile
  - Same Delivered Power
  - Same Diameter and RPM
Propulsion Optimization

Results
- 13% More Bollard Pull
- 23% More Thrust (at 18 knots)
Powering

- Main Challenge
  - Efficient Plant Design for all Modes of Operation

Delivered Power Requirements [kW]:

- 14 knot Cruise: 1890 kW
- Firefighting: 3000 kW
- 18 knot Transit: 4565 kW
- Bollard Pull: 4900 kW

- Large Power Differential between Operation Modes
Powering

- Initial Concepts
  - LNG/Dual Fuel Capability
  - Integrated or Diesel Electric
  - Conventional Diesel

- LNG Deemed not Feasible Due to Range/Endurance Requirements

- Benefits of Electric Plant Outweighed by Low Transmission Efficiencies and Increased Weight, Cost, and Complexity

- Conventional Geared Diesel Arrangement Selected
  - Two Engines per Shaft Connected to Combining Gearbox
  - Ability to Operate Efficiently Across Range of Operating Modes
Powering

Conventional Geared Diesel Arrangement

- “Father-Son” Arrangement
  - One Larger and One Smaller Engine Coupled to each Combining Gearbox

- Engine Sizing
  - Total Power Sized for Bollard Pull/Sprint Condition at 100% Load: (2x1200 kW + 2x1600 kW)
  - Total Installed Power: 5600 kW
  - Smaller Engines Sized for Cruise Speed at 85% Load: (2x1200 kW)
  - Larger Engines Coupled to Fire Pumps
Powering

Engine Selection: Medium or High Speed?

- Medium vs. High Speed Engines
  - High Speed: Low Cost and High Power to Weight
  - Medium Speed: Better Fuel Efficiency and Less Gearing Required

- Medium Speed Engines Selected
  - Higher Fuel and Transmission Efficiencies Outweighed the Increased Cost and Weight
Propulsion and Powering Summary

- Conventional Geared Diesel Arrangement
  - High Transmission Efficiency, Low Cost and Complexity

- Nautican High Efficiency Nozzles
  - Better Efficiency Across All Speed Ranges
  - Match Power Requirements for both Bollard Pull and Top Speed Conditions

- Combining Gearbox
  - Operate Efficiently at Both Cruise Speed and Full Power
  - Allows for Fire Pump Operation while Maintaining Full Maneuverability

- Medium Speed Engines
  - Better Fuel and Transmission Efficiencies
Auxiliary Machinery

- **Deck Winch: Markey Towing Winch**
  - Rated Power: 185 kW (Electric Drive)
  - Drum Capacity: 975 m (64 mm Cable)
  - Rated Line Pull: 160 t
  - Slipping Brake Pull: 185 t

- **Crane: Knuckleboom Configuration**
  - Capacity: 67 tonne-m
  - Max Span: 16 m
  - Max Capacity at Tip: 4200 kg

- **Fire Pumps: 2x Mechanically Driven**
  - Input Power: 1600 kW
  - Max Capacity: 3300 m³/hr
  - Max Head: 170 mlc

- **Bow Thrusters: 2x Tunnel Thrusters**
  - Power Rating: 250 kW Each
  - Diameter: 1 m
Electric Load Analysis

- Performed for Different Operating Modes to Size Generator Sets

- Generators Selected
  - 1x 550 ekW Main
  - 2x 250 ekW Auxiliary
  - 1x 100 ekW Emergency

- Maximum Power Required for Towing Operations
  - 685 kW Required Power
  - Utilizes 550 ekW Main and 1x 250 kW Auxiliary

Transit

- 35% Power Used
- 65% Power Available

Port

- 44% Power Used
- 56% Power Available

Positioning

- 23% Power Used
- 77% Power Available

Towing

- 14% Power Used
- 86% Power Available

Emergency

- 24% Power Used
- 76% Power Available
Fuel Consumption and Emissions

Fuel Consumption for Different Operating Modes

- **14 knot Cruise Speed**
  - Consumption: 11.5 m$^3$/d
  - Endurance: 21 days
  - Range: 3500+ nm

- **Maximum Bollard Pull/Sprint**
  - Consumption: 30.5 m$^3$/d
  - Endurance: 8 days

- **Emissions**
  - Vessel to Operate in IMO ECA Zone
  - EGR or SCR System Required to Meet EPA Tier III Requirements for Emissions
General Arrangement Overview
Working Area

- Main Deck - Utility area includes:
  - Wet Room
  - HVAC
  - SAR Store
  - Sick Bay
  - Stores
  - Survivor Area
  - Work Shop
  - MCR
  - Garbage
GA – Crew living Quarters

- Crew Accommodation
  - Exceeds ILC-MLC requirements
  - Has private washrooms
  - Pullman Bunk
  - Desk and work area
Living Quarters

- Majority of Crew accommodation located on the first deck

- Also in this area:
  - Galley
  - Office
  - Fitness Room
  - Laundry Room
  - Washroom
Second Deck

- Jr. and Sr. Officers Bedrooms
- Auxiliary Generator room
- Additional Stores
- Captain and Chief engineers bedroom and dayroom
- Flex Space
  - Can be used for additional accommodation
- Washroom
- General Purpose office
Third Deck

- All Electronics moved away from bridge to reduce noise
- Incident command post with forward view
Bridge

- Windowed 360 degrees
  - Allows for good visibility to working deck.
  - All corners of the vessel are visible from one location in the bridge
Machinery Arrangement
Tankage Arrangement

- Minimal Ballast Water tanks due to high stability
- Auxiliary Tank can include Aviation fuel or skiff fuel
Structural Design

Classification Society: Lloyd’s Register
Material: Steel
Service Factor: G5 (350 nm range off coastline)
Pursuit speed: 18 knots
Sea state 6
Structural Design

Longitudinal Bending Moment

Twin hull transverse bending moment

Twin Hull Torsional Connecting Moment
Structural Design

Bending Moments

- Dynamic slamming moment (hogging)
- Vertical wave moment (hogging)
- Vertical wave moment (sagging)
- Dynamic slamming moment (sagging)
Structural Design

Shear Force

- Dynamic shear force (positive)
- Dynamic shear force (negative)
- Wave shear force (positive, sagging)
- Wave shear force (positive, hogging)
- Wave shear force (negative, sagging)
- Wave shear force (negative, hogging)
Structural Design

Load combinations

- Twin hull transverse bending moment
- Twin hull torsional connecting moment
- Rule bending moment
Structural Design

Load combinations Moment
[MNm]

- Head Seas
- Quartering Seas
- Beam Seas
## Structural Design

### Local Design Pressures

<table>
<thead>
<tr>
<th>Category/location</th>
<th>Symbol</th>
<th>Plating pressure [kNm]</th>
<th>Min. [kNm]</th>
<th>Symbol</th>
<th>Stiffener pressure, Primary [kNm]</th>
<th>Stiffener pressure, Secondary [kNm]</th>
<th>Min.</th>
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<tbody>
<tr>
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<td>Bottom shell</td>
<td>$P_{BP}$</td>
<td>181.61</td>
<td></td>
<td>$P_{BF}$</td>
<td>90.80</td>
<td>145.29</td>
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<tr>
<td>Outboard side shell</td>
<td>$P_{OSP}$</td>
<td>181.61</td>
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<td>$P_{OSF}$</td>
<td>90.80</td>
<td>145.29</td>
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<tr>
<td>Inboard side shell</td>
<td>$P_{ISP}$</td>
<td>181.61</td>
<td></td>
<td>$P_{ISF}$</td>
<td>90.80</td>
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<td>Wet deck</td>
<td>$P_{CP}$</td>
<td>181.61</td>
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<td>$P_{CF}$</td>
<td>90.80</td>
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<td>Weather deck</td>
<td>$P_{WDP}$</td>
<td>51.77</td>
<td>7</td>
<td>$P_{WCDF}$</td>
<td>25.88</td>
<td>41.42</td>
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<tr>
<td>Coachroof</td>
<td>$P_{CRP}$</td>
<td>51.77</td>
<td>7</td>
<td>$P_{CRF}$</td>
<td>25.88</td>
<td>41.42</td>
<td>7</td>
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<tr>
<td>Interior deck</td>
<td>$P_{IDP}$</td>
<td>43.14</td>
<td>3.5</td>
<td>$P_{IDF}$</td>
<td>21.57</td>
<td>34.51</td>
<td>3.5</td>
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<td>Deckhouses, bulwarks and superstructure</td>
<td>$P_{DHP}$</td>
<td>35.22</td>
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<td>$P_{DHF}$</td>
<td>17.61</td>
<td>28.18</td>
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<td>Inner bottom</td>
<td>$P_{IBP}$</td>
<td>163.01 10T</td>
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<td>$P_{IBF}$</td>
<td>90.80</td>
<td>145.29 10T</td>
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<td>Watertight and deep tank bulkheads</td>
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<td>$P_{BHF}$</td>
<td>68.40</td>
<td>47.09</td>
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</table>
Structural Design

Considerations

- Double bottom hull fore and aft of the machinery room
- Transverse web frames
- Transverse framing in the demi-hull
- Longitudinal framing along the weather deck and cross-deck structuring
- Side stringers to reinforce demi-hull
- Transverse and longitudinal watertight bulkheads
Structural Design

- Recommendations
Intact Stability

- Max Righting Arm Over 9m at 25 Degrees
- Large Area of Positive Stability
Damage Stability

- Damage Stability
Damage Stability

- Damage Stability
Seakeeping

- Sea State 6
Seakeeping

- Sea State 5
Seakeeping

- Sea State 4
## Final Weights and Volumes

<table>
<thead>
<tr>
<th>SWBS Group</th>
<th>Weight (tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 – Hull Structure</td>
<td>1,316</td>
</tr>
<tr>
<td>200 – Propulsion Plant</td>
<td>300</td>
</tr>
<tr>
<td>300 – Electric Plant</td>
<td>80</td>
</tr>
<tr>
<td>400 – Command &amp; Surveillance</td>
<td>15</td>
</tr>
<tr>
<td>500 – Auxiliary Systems</td>
<td>200</td>
</tr>
<tr>
<td>600 – Outfit &amp; Furnishings</td>
<td>180</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>2,091</strong></td>
</tr>
</tbody>
</table>

- Hull weight from 3D structural model
- Machinery weight from known equipment weights and scaled parent vessel data
- Remaining weights estimated from parent vessel
Oil Spill Response

- **Boom**
  - Booms on board: 1000 m
  - Oil recovery capacity: 800 m³
  - (The Canada Shipping act guidelines for oil spill equipment)

- **Oil Recovery Skimmer**
  - Clean out the spilled oil on sea surface
  - $Q = 150 \text{ m}^2/\text{hr}$

- **Bladder**
  - Towable bladders for recovered oil storage
  - Full Size: 650 m³
Oil Spill Response

- Containerized Oil Recovery Equipment
  - Package that contains the previous items
    (Boom, Skimmer, Bladder)
# Cost Analysis

## Construction Cost

<table>
<thead>
<tr>
<th>SWBS Section</th>
<th>Weight (tonnes)</th>
<th>Rate (Mhrs/tonne)</th>
<th>Labor Man Hour</th>
<th>Material Dollars</th>
<th>Labor Dollars</th>
<th>Total Construction Cost</th>
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</thead>
<tbody>
<tr>
<td>100 Hull</td>
<td>1,316</td>
<td>175</td>
<td>230,300</td>
<td>1,408,000</td>
<td>16,121,000</td>
<td>17,529,000</td>
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<td>200 Propulsion M/C</td>
<td>300</td>
<td>485</td>
<td>145,720</td>
<td>9,524,000</td>
<td>10,200,390</td>
<td>19,824,390</td>
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<tr>
<td>300 Electrical</td>
<td>80</td>
<td>761</td>
<td>60,877</td>
<td>3,200,000</td>
<td>4,261,374</td>
<td>7,461,374</td>
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<td>400 Command</td>
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<td>921</td>
<td>13,819</td>
<td>960,000</td>
<td>967,310</td>
<td>1,927,310</td>
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<tr>
<td>500 Auxiliary M/C</td>
<td>200</td>
<td>496</td>
<td>95,292</td>
<td>8,216,000</td>
<td>6,950,475</td>
<td>15,166,475</td>
</tr>
<tr>
<td>600 Outfit</td>
<td>180</td>
<td>230</td>
<td>41,436</td>
<td>2,888,000</td>
<td>2,900,500</td>
<td>5,788,500</td>
</tr>
<tr>
<td>Total:</td>
<td>2,091</td>
<td>283</td>
<td>591,444</td>
<td>26,296,000</td>
<td>41,401,000</td>
<td>67,697,000</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Title</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material Dollars</td>
<td>26,296,000</td>
<td>$CAD</td>
</tr>
<tr>
<td>Material Margin</td>
<td>2,629,600</td>
<td>$CAD</td>
</tr>
<tr>
<td>Material Markup</td>
<td>3,944,400</td>
<td>$CAD</td>
</tr>
<tr>
<td><strong>Total Material Cost</strong></td>
<td><strong>32,870,000</strong></td>
<td><strong>$CAD</strong></td>
</tr>
<tr>
<td>Labour Dollars</td>
<td>41,401,000</td>
<td>$CAD</td>
</tr>
<tr>
<td>Labor Margin</td>
<td>4,140,600</td>
<td>$CAD</td>
</tr>
<tr>
<td><strong>Total Labour Cost</strong></td>
<td><strong>45,541,600</strong></td>
<td><strong>$CAD</strong></td>
</tr>
<tr>
<td>Bid Price</td>
<td>78,411,600</td>
<td>$CAD</td>
</tr>
</tbody>
</table>
Cost Analysis

- Operating Cost

<table>
<thead>
<tr>
<th>Title</th>
<th>Value</th>
<th>Unit</th>
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</thead>
<tbody>
<tr>
<td>MDO</td>
<td>1,000</td>
<td>$CAD</td>
</tr>
<tr>
<td>Maintenance</td>
<td>791,367</td>
<td>$CAD/yr</td>
</tr>
<tr>
<td>Refit</td>
<td>120,000</td>
<td>$CAD/yr</td>
</tr>
<tr>
<td>Fuel</td>
<td>2,902,054</td>
<td>$CAD/yr</td>
</tr>
<tr>
<td>Total</td>
<td>3,813,421</td>
<td>$CAD/yr</td>
</tr>
</tbody>
</table>

Chart title

- Avg Maintenance Cost
- Avg Refit Cost
- Avg Fuel Cost

- Fuel Cost

- Refit Cost

- Maintenance Cost
Final Vessel Characteristics

Owners Requirements

Operating Speeds: Cruising 14 knots
Top Speed 18+ knots

Bollard Pull: 100+ tonnes

Stability: GM > 1.67 m

Basic Functionality: Environmental Protection, Firefighting, Search and Rescue, General CCG Duties

Endurance: 21 days, 3500nm
Conclusions and Recommendations

- Preliminary design meets or exceeds all owners requirements

- Catamaran hullform provides high stability, low resistance, and large deck area
  - Integral to design success

- Possibility to develop further into “class” of ships
  - Helicopter operation
  - General utility
  - Research

- Moving forward
  - CFD and FEA optimization
  - Consult with owner regarding preferred design options
Acknowledgements

• **Canadian Coast Guard**
  - Assistant Commissioner Roger Girouard

• **University of British Columbia**
  - Chris McKesson
  - Jon Mikkelson
  - Koskun Islam

• **Robert Allan Ltd.**
  - Robert Allan
  - Mike Phillips

• **Vard**
  - Dan McGreer

• **BC Chamber of Shipping**
  - Stephen Brown

• **Nautican**
  - Wayne Wingate
  - Elizabeth Boyd

• **Markey**
  - Scott Kreis
Thank You

Questions?
Backup Slides
## Volume Estimates

### SYSTEM DESIGN SUMMARY

#### FURNISHED AND INTERIOR SPACES

<table>
<thead>
<tr>
<th>Space Description</th>
<th>m³ per Crew</th>
<th>m³ per Crew</th>
<th>Area m²</th>
<th>Volume m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crew Facilities</td>
<td>16.5</td>
<td>46.3</td>
<td>298</td>
<td>833</td>
</tr>
<tr>
<td>Ship Service</td>
<td>6.2</td>
<td>14.8</td>
<td>111</td>
<td>267</td>
</tr>
<tr>
<td>Catering</td>
<td>2.9</td>
<td>8.0</td>
<td>51</td>
<td>144</td>
</tr>
<tr>
<td>Hotel Service</td>
<td>0.5</td>
<td>1.4</td>
<td>9</td>
<td>26</td>
</tr>
<tr>
<td><strong>Total Furnished Spaces</strong></td>
<td><strong>26.1</strong></td>
<td><strong>70.5</strong></td>
<td><strong>469</strong></td>
<td><strong>1,270</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Technical Spaces in Accommodation</th>
<th>m³ per Crew</th>
<th>m³ per Crew</th>
<th>Area m²</th>
<th>Volume m³</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5.3</td>
<td>14.7</td>
<td>95</td>
<td>265</td>
</tr>
<tr>
<td><strong>TOTAL INTERIOR SPACES</strong></td>
<td><strong>48.4</strong></td>
<td><strong>133.0</strong></td>
<td><strong>871</strong></td>
<td><strong>2,394</strong></td>
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</tbody>
</table>

#### TECHNICAL SPACES

<table>
<thead>
<tr>
<th>Space Description</th>
<th>m² per kW</th>
<th>m³ per kW</th>
<th>Area m²</th>
<th>Volume m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machinery Spaces</td>
<td>-</td>
<td>0.215</td>
<td>-</td>
<td>1,763</td>
</tr>
<tr>
<td>Switchboard Rooms, Emergency Gen., Battery Room</td>
<td>0.009</td>
<td>0.027</td>
<td>74</td>
<td>221</td>
</tr>
<tr>
<td>Workshops and Stores</td>
<td>0.005</td>
<td>0.015</td>
<td>41</td>
<td>123</td>
</tr>
<tr>
<td>Engine Casing and Funnel</td>
<td>0.00457317</td>
<td>0.01463415</td>
<td>38</td>
<td>120</td>
</tr>
<tr>
<td><strong>TOTAL TECHNICAL SPACES</strong></td>
<td><strong>0.019</strong></td>
<td><strong>0.272</strong></td>
<td><strong>152</strong></td>
<td><strong>2,227</strong></td>
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</table>

#### TANKS AND VOID SPACES

<table>
<thead>
<tr>
<th>Space Description</th>
<th>m² per DWT</th>
<th>m³ per DWT</th>
<th>Area m²</th>
<th>Volume m³</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TOTAL TANKS AND VOIDS</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1,763.6</td>
</tr>
</tbody>
</table>

#### OUTDOOR DECK SPACE

<table>
<thead>
<tr>
<th>Space Description</th>
<th>m³ per Crew</th>
<th>m³ per Crew</th>
<th>Area m²</th>
<th>Volume m³</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TOTAL DECK SPACES</strong></td>
<td><strong>13.5</strong></td>
<td><strong>21.0</strong></td>
<td><strong>243.0</strong></td>
<td><strong>378.0</strong></td>
</tr>
</tbody>
</table>

**System Based Volume Estimate - Kai Levander**

Parametric study of all ship areas and volumes.

Used to estimate weight and principle dimensions in early design.
Weight Estimates

- Estimated weight with two methods
  - From Kai Levander’s method
  - Systematically working through parent vessel baseline estimate and scaling

Summary

<table>
<thead>
<tr>
<th>Light Ship Summary</th>
<th>Ref. Vessel</th>
<th>Weight (MT)</th>
<th>LCG frame</th>
<th>LCG m</th>
<th>LCGaM m</th>
<th>VCG m</th>
<th>TCG m</th>
<th>L mom.</th>
<th>V mom.</th>
<th>T mom.</th>
<th>Weight % of Subtotal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total - Section 200 - Hull Structure and Details</td>
<td>941</td>
<td>57.2</td>
<td>31.4</td>
<td>37.47</td>
<td>6.54</td>
<td>0.00</td>
<td>28525</td>
<td>6148</td>
<td>0</td>
<td>50.8%</td>
<td></td>
</tr>
<tr>
<td>Total - Section 300 - Outfit &amp; Furnishings</td>
<td>111</td>
<td>67.3</td>
<td>37.02</td>
<td>37.02</td>
<td>8.28</td>
<td>0.00</td>
<td>5214</td>
<td>1163</td>
<td>0</td>
<td>7.6%</td>
<td></td>
</tr>
<tr>
<td>Total - Section 400 - Deck, Machinery and Outfit</td>
<td>283</td>
<td>53.7</td>
<td>29.85</td>
<td>29.85</td>
<td>8.42</td>
<td>-0.30</td>
<td>7915</td>
<td>2523</td>
<td>-101</td>
<td>14.5%</td>
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<tr>
<td>Total - Section 500 - Propulsion Machinery</td>
<td>300</td>
<td>36.1</td>
<td>19.64</td>
<td>24.94</td>
<td>3.02</td>
<td>0.00</td>
<td>5951</td>
<td>567</td>
<td>0</td>
<td>16.2%</td>
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<tr>
<td>Total - Section 600 - Electrical System</td>
<td>76</td>
<td>70.4</td>
<td>38.74</td>
<td>38.74</td>
<td>4.86</td>
<td>0.27</td>
<td>2523</td>
<td>367</td>
<td>20</td>
<td>4.7%</td>
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<tr>
<td>Total - Section 700 - Ship’s Services</td>
<td>39</td>
<td>56.6</td>
<td>31.14</td>
<td>37.34</td>
<td>6.20</td>
<td>0.00</td>
<td>3082</td>
<td>613</td>
<td>0</td>
<td>5.3%</td>
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<tr>
<td>Total - Section 800 - Domestic Services</td>
<td>24</td>
<td>67.4</td>
<td>37.06</td>
<td>37.06</td>
<td>1.09</td>
<td>0.00</td>
<td>873</td>
<td>167</td>
<td>0</td>
<td>1.3%</td>
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<tr>
<td>Total - Section 900 - Control, Communication, and Navigation</td>
<td>3</td>
<td>56.4</td>
<td>31.01</td>
<td>37.01</td>
<td>14.36</td>
<td>0.00</td>
<td>54</td>
<td>45</td>
<td>0</td>
<td>0.2%</td>
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<tr>
<td>Subtotal</td>
<td>1,850</td>
<td>54.7</td>
<td>30.08</td>
<td>30.08</td>
<td>6.45</td>
<td>-0.04</td>
<td>55882</td>
<td>11504</td>
<td>-51</td>
<td>100%</td>
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<tr>
<td>Design Margin</td>
<td>0%</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light Ship</td>
<td>1,850</td>
<td>54.7</td>
<td>30.08</td>
<td>30.08</td>
<td>6.45</td>
<td>-0.04</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Climatology data

- Collected Metadata from NOAA and Pilot charts for Haida Gwaii and the surrounding area
- Evaluated the average yearly values for Wind velocity and Wave height

<table>
<thead>
<tr>
<th>Wave Height (m)</th>
<th>Mean</th>
<th>66%</th>
<th>99%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>1.5</td>
<td>2.7</td>
<td>4.7</td>
</tr>
<tr>
<td>Max</td>
<td>2.4</td>
<td>3.9</td>
<td>6.9</td>
</tr>
<tr>
<td>Seastate</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Wind Velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average (m/s)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Average (kt)</td>
</tr>
</tbody>
</table>
Bollard Pull Calculations

- Wind Force
  \[ F = C_D \frac{1}{2} \rho V^2 A_W \]  (Blendermann (1996))

- Current Force
  \[ F = C_D \frac{1}{2} \rho V^2 A_C \]
  (Recommended Practices DNV-RP-H103 Towing Operations)

- Wave Force
  \[ F = \frac{1}{8} \rho g R^2 B H_s^2 \]
  (Recommended Practices DNV-RP-H103 Towing Operations)
Western Canada Marine Response Corporation (WCMRC)

- “In 1995, the [Canada Shipping Act](#) was amended to include regulations and standards to protect all navigable waters. It placed restrictions on tankers/barges of 150 tonnes and greater, on all ships 400 tonnes and greater, and on oil handling facilities that receive deliveries from these vessels.”

- “When these changes came into effect, Burrard Clean Operations, then a division of Western Canada Marine Response Corporation, was formed to respond to spills in British Columbia’s navigable waters.”
“Royal Canadian Marine Search and Rescue is a charity that saves lives on the water. We serve coastal and lake communities in British Columbia, providing year round rescue service and promoting boating safety for children and families.”

- A network of about 1,000 volunteers
- 42 Rescue Stations
- 60 dedicated search and rescue vessels
<table>
<thead>
<tr>
<th>Weight Group:</th>
<th>Unit</th>
<th>Value</th>
<th>Coeff. t/unit</th>
<th>Weight tonne</th>
</tr>
</thead>
<tbody>
<tr>
<td>Payload Related</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bouy Crane</td>
<td>No.</td>
<td>1.0 units</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Hull Structure</td>
<td>Hull Vol.</td>
<td>3,871 m³</td>
<td>0.14</td>
<td>542</td>
</tr>
<tr>
<td>Deckhouse</td>
<td>Dh Vol.</td>
<td>2,892 m³</td>
<td>0.08</td>
<td>231</td>
</tr>
<tr>
<td>Interior Outfitting</td>
<td>Area</td>
<td>469 m²</td>
<td>0.28</td>
<td>131</td>
</tr>
<tr>
<td>Machinery</td>
<td>Pp + Pa</td>
<td>8,200 kW</td>
<td>0.07</td>
<td>574</td>
</tr>
<tr>
<td>Ship Outfitting</td>
<td>Gross Vol.</td>
<td>6,763 m³</td>
<td>0.01</td>
<td>81</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>Gross Vol.</td>
<td>6,763 m³</td>
<td></td>
<td><strong>1,570</strong></td>
</tr>
<tr>
<td>Reserve</td>
<td></td>
<td>5% of weight</td>
<td></td>
<td>78</td>
</tr>
<tr>
<td><strong>LIGHTWEIGHT</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>1,648</strong></td>
</tr>
</tbody>
</table>
## Scantling (Plate thickness, example)

<table>
<thead>
<tr>
<th>Bottom</th>
<th></th>
<th>Side outboard</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>s</td>
<td>550 [mm]</td>
<td>s</td>
<td>550 [mm]</td>
</tr>
<tr>
<td>$A_R$</td>
<td>11.4272 [-]</td>
<td>$A_R$</td>
<td>11.4272 [-]</td>
</tr>
<tr>
<td>$\beta$</td>
<td>1 [-]</td>
<td>$\beta$</td>
<td>1 [-]</td>
</tr>
<tr>
<td>h</td>
<td>5 [mm]</td>
<td>h</td>
<td>5 [mm]</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>0.990909091 [-]</td>
<td>$\gamma$</td>
<td>0.990909091 [-]</td>
</tr>
<tr>
<td>$f_\sigma$</td>
<td>0.85 [-]</td>
<td>$f_\sigma$</td>
<td>0.85 [-]</td>
</tr>
<tr>
<td>$t_p$</td>
<td>11.64 [mm]</td>
<td>$t_p$</td>
<td>11.64 [mm]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Weather deck</th>
<th>Watertight bulkhead, $P_1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>s</td>
<td>500 [mm]</td>
</tr>
<tr>
<td>$A_R$</td>
<td>11.4272 [-]</td>
</tr>
<tr>
<td>$\beta$</td>
<td>1 [-]</td>
</tr>
<tr>
<td>h</td>
<td>0 [mm]</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>1 [-]</td>
</tr>
<tr>
<td>$f_\sigma$</td>
<td>0.85 [-]</td>
</tr>
<tr>
<td>$t_p$</td>
<td>5.70 [mm]</td>
</tr>
</tbody>
</table>
# Scantling (Stiffener example)

## Trans. Framing - Primary structure

<table>
<thead>
<tr>
<th>Bottom transverse web frame</th>
<th>Side outboard transverse web frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>s 2200.00 [mm]</td>
<td>s 2200.00 [mm]</td>
</tr>
<tr>
<td>Φ_{Z,mid} 0.04 [-]</td>
<td>Φ_{Z,mid} 0.04 [-]</td>
</tr>
<tr>
<td>Φ_{I,mid} 0.002604 [-]</td>
<td>Φ_{I,mid} 0.002604 [-]</td>
</tr>
<tr>
<td>Φ_{A,end} 0.50 [-]</td>
<td>Φ_{A,end} 0.50 [-]</td>
</tr>
<tr>
<td>l 2.20 [m]</td>
<td>l 3.30 [m]</td>
</tr>
<tr>
<td>l_e 2.20 [m]</td>
<td>l_e 3.60 [m]</td>
</tr>
<tr>
<td>f_σ 0.65 [-]</td>
<td>f_σ 0.65 [-]</td>
</tr>
<tr>
<td>f_δ 1000.00 [-]</td>
<td>f_δ 1000.00 [-]</td>
</tr>
<tr>
<td>f_t 0.65 [-]</td>
<td>f_t 0.65 [-]</td>
</tr>
<tr>
<td>Z_{mid} 264 [cm^3]</td>
<td>Z_{mid} 706.23 [cm^3]</td>
</tr>
<tr>
<td>I_{mid} 2,770 [cm^4]</td>
<td>I_{mid} 12,136.05 [cm^4]</td>
</tr>
<tr>
<td>A_{end} 25 [cm^2]</td>
<td>A_{end} 40.77 [cm^2]</td>
</tr>
<tr>
<td>Selection WEB 400x120x12x8 [mm]</td>
<td>Selection WEB 400x120x12x8 [mm]</td>
</tr>
<tr>
<td>Z 416 [cm^3]</td>
<td>Z 416 [cm^3]</td>
</tr>
<tr>
<td>I 9,730 [cm^4]</td>
<td>I 9,730 [cm^4]</td>
</tr>
<tr>
<td>A 57.60 [cm^2]</td>
<td>A 57.60 [cm^2]</td>
</tr>
<tr>
<td>Mass 45.22 [kg/m]</td>
<td>Mass 45.22 [kg/m]</td>
</tr>
</tbody>
</table>
Works Cited

