High Speed Connector

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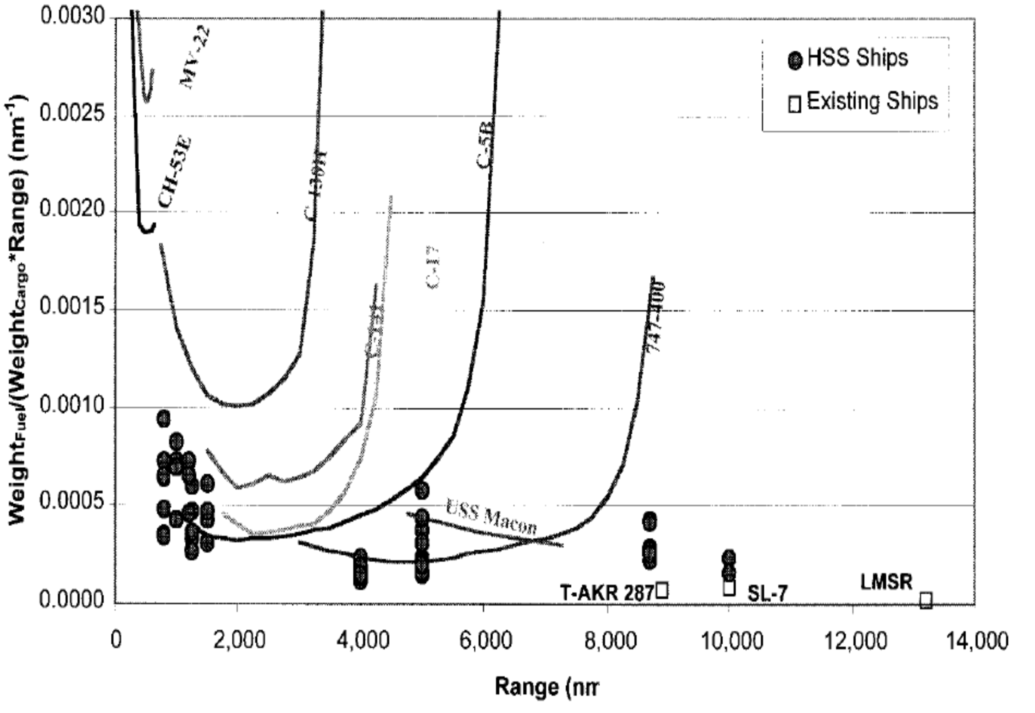
Initial Requirement

- Part of System of Systems
  - Intra-theater Connector within the Sea Basing Concept
  - High Speed, Agile, Versatile Platform
- Focused Logistics
  - "…ensure the delivery of the right equipment, supplies, and personnel to the right place, at the right time to support operational objectives."*
- Affordable
- Industry Standard vs. Navy Standard

*Note: CJCSM 31170.01, "Operation of the Joint Capabilities Integration and Development System", June 2003.

Required Capabilities

- Cargo:
  - 500-1000 ltons
- Speed >40 kts
- Range ~2000nm
- Interface: Roll-on-roll-off, Cargo, Vertical Movement of Cargo.
- Manning 20~30
- Navigational Agility:
  - Low Draft
- Limited Self-defense:
  - Air: point defense
  - Surface: visual range
  - Sub-surface: passive



$$R = \frac{Weight_{fuel}}{Weight_{c\arg o} * Range}$$

*Pegrum, M., Kennell, C. "Fuel Efficiency Comparison between High Speed Sealift Ships and Airlift Aircraft" Marine Technology, Vol. 39, April 2002

Generation of Competing Variants

Design of Experiments:

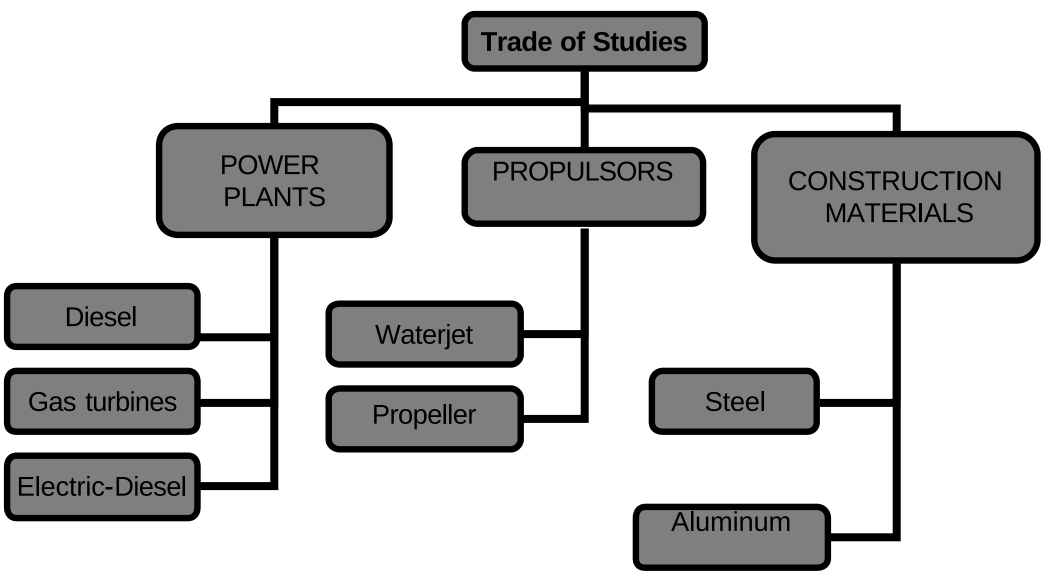
•Data points were produced with proper randomization for the execution of the experimental runs.

Developed Variants:

•Catamarans (26)
• Monohulls (27)
• Trimarans (28)

Range of operational requirements:

•Speed: 32 knots to 44 knots.
•Payload: 500 ltons to 1000 ltons.



Comparison of alternative solutions by means of:

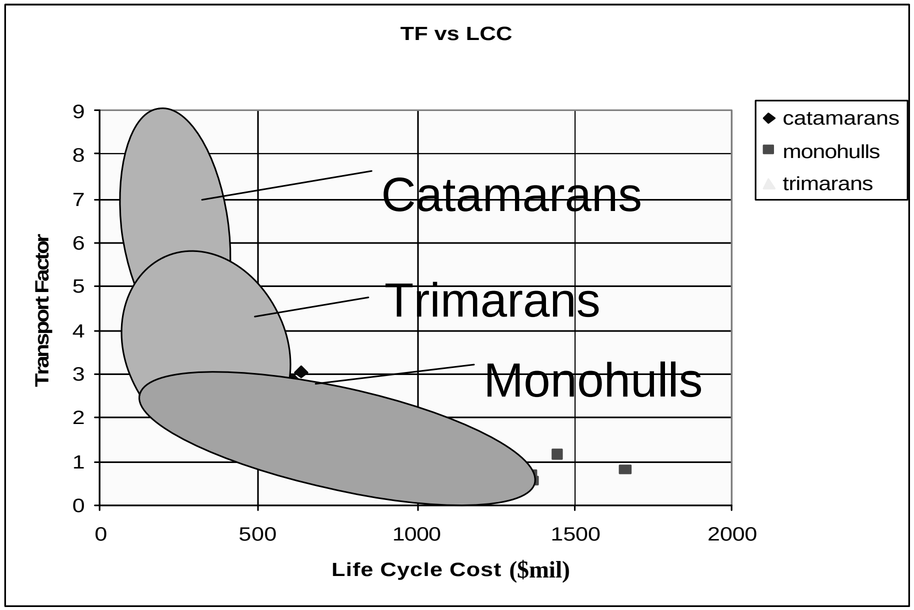
•Quantitative attributes (Transport Factor)

$$\text{TransportFactor} = \frac{\text{Payload}\cdot\text{Speed}}{\text{InstalledPower}}$$

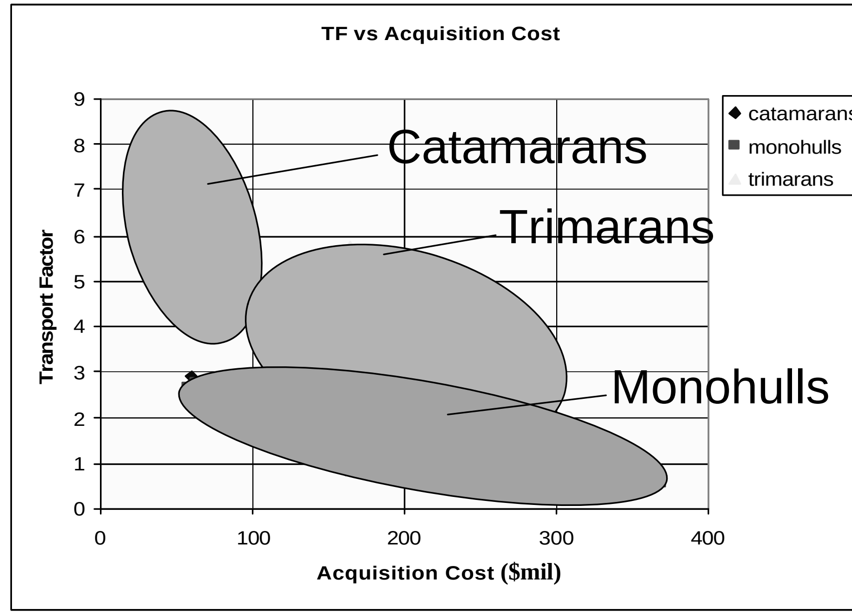
•Qualitative attributes
- •Seakeeping
- •Loading interface
- •Survivability
- •Feasibility
- •Ability to manufacture

Hull Selection
Transport Factor (TF) -vs- Cost

Life Cycle Cost



Acquisition Cost

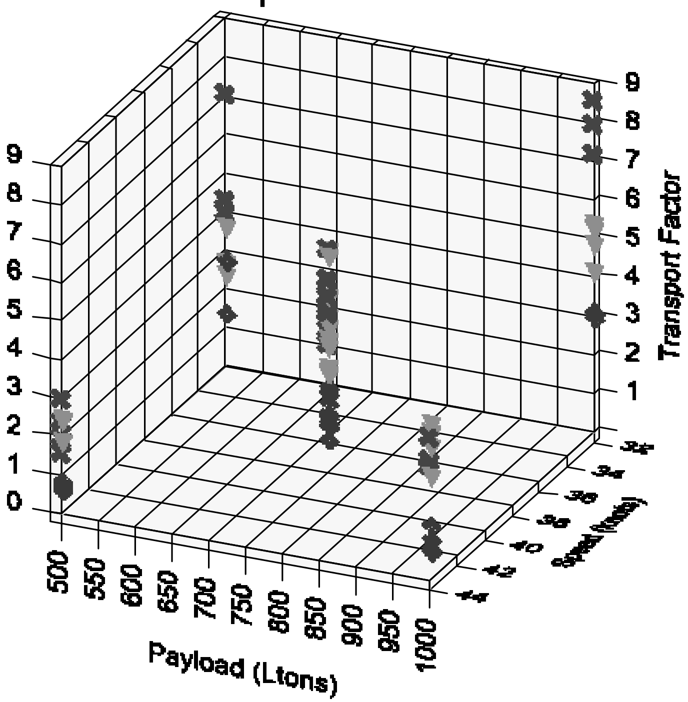


- Catamarans demonstrate the best combination of TF/LCC
- Trimarans give smaller TF for slightly lower LCC
- Monohulls represent the least attractive combination

- Trimarans demonstrate higher acquisition cost than catamarans due to high R&D
- Monohulls become more competitive in terms of acquisition cost

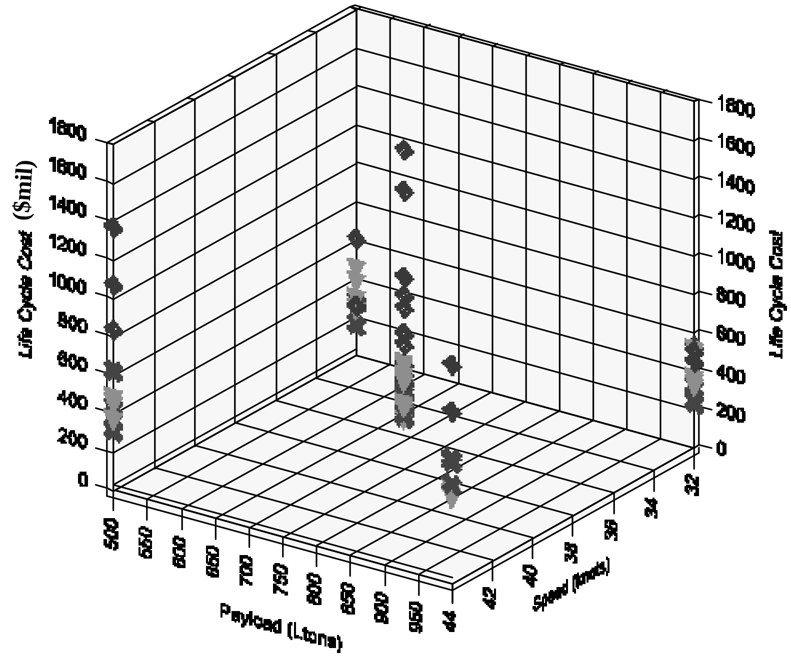
Hull Selection
TF and Cost in Speed-Payload Space

Transport Factor



- Catamaran
- Monohull
- Trimaran

Cost



- Monohulls: worst performance in all combinations of speed-payload
- Trimarans: excel only in High speed - High payload case
- Catamarans: best TF in the rest of Speed-Payload space

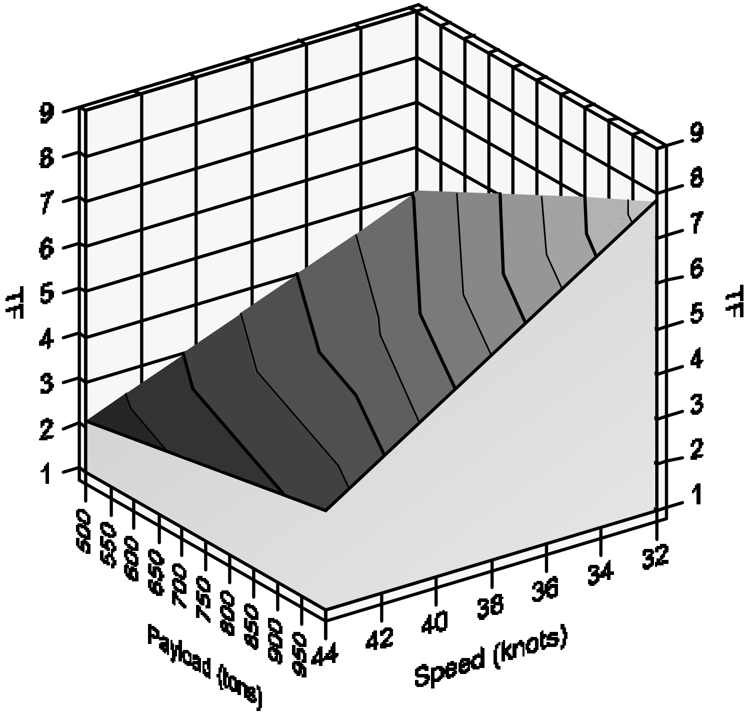
- Monohulls: worst solution in terms of LCC
- Trimarans: marginally lower LCC in High speed - High payload region
- Catamarans: lowest LCC in the rest of Speed-Payload space

Qualitative Analysis - Catamarans

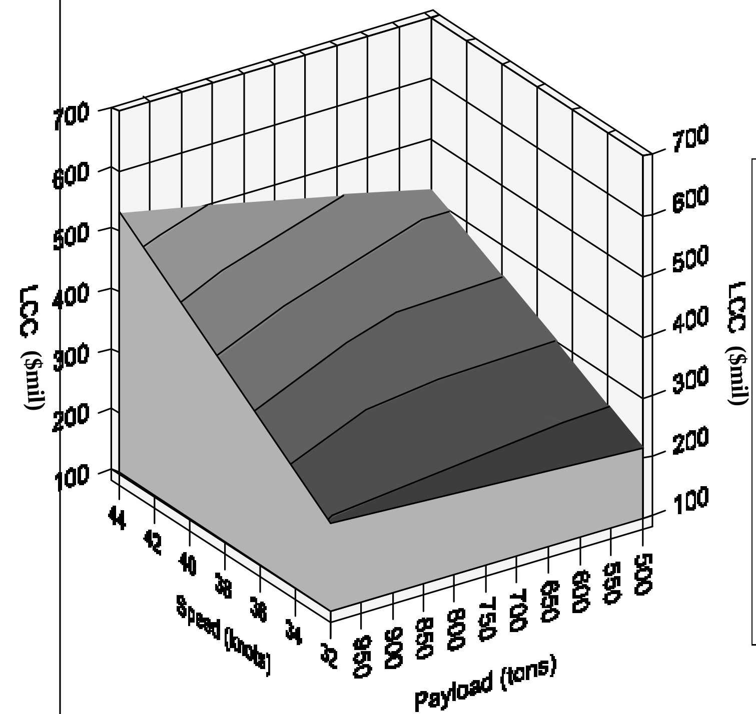
- Seakeeping Capability
  - Recent designs have demonstrated the ability to travel with 30 knots in sea state 6
- Loading interface
  - Lowest draft
  - Highest maneuverability
  - Best arrangeability due to rectangular configuration of cargo area
  - Lowest rolling angle
  - Capability for Vertical Access, Cargo Ramps for RO-RO
- Survivability
  - Large reserve cross-structure volume
  - Duplicated systems in fair separation
- Tested technology
  - 37 catamarans on 49 HSC were delivered on 2003
- Ability to manufacture
  - Demonstrated over a number of shipyards across US

TF and Cost for Catamarans

Transport Factor



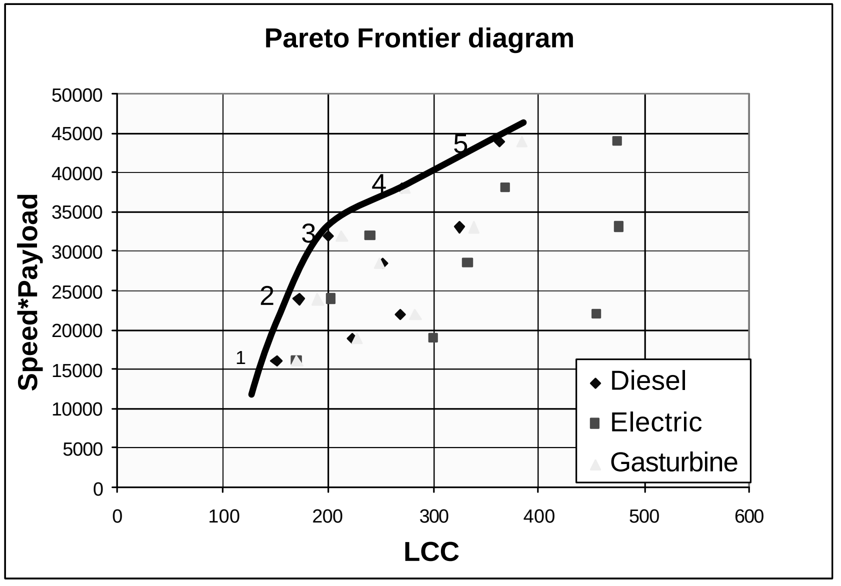
Cost

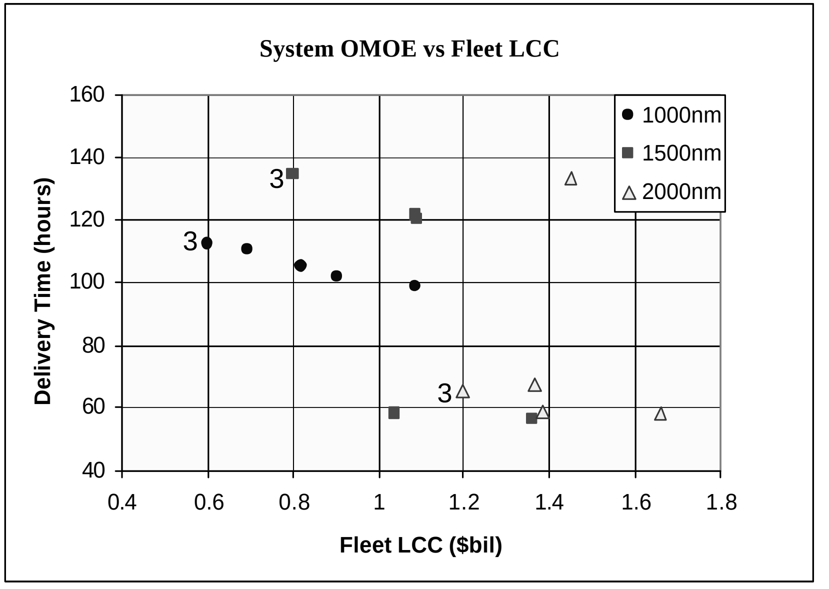


- Excellent performance in low speed regions
- Serious degradation with high speeds
- Low degradation with payload

- Very attractive choice for low speed regions
- High increase in LCC with speed

Vessel Performance –vs- Seabasing System Performance





Non Dominated Variants:
- Aluminum hull
- Waterjet propulsion
- Diesel Propulsion plant

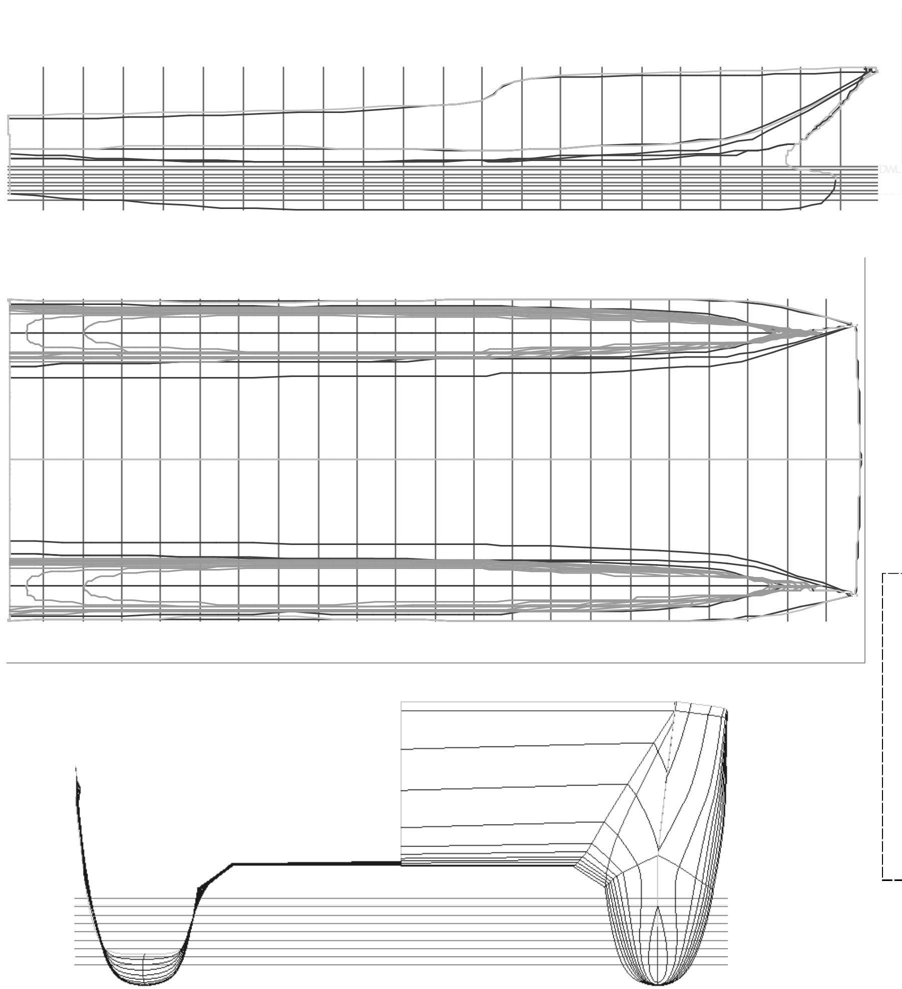
Optimization of overall system:
- Speed: 32knots
- Payload: 1000tons
- Number of required vessels: 4

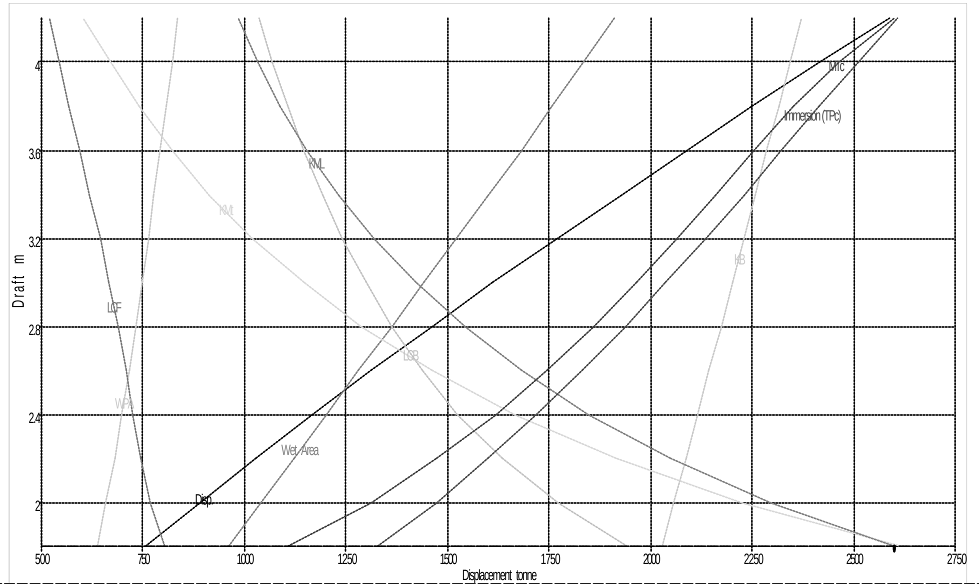
Geometry

- Round bilge hull FW
- Flat bottom AFT
- High L/B ratio
- Low draft
- Bulbous bow
- Raised wet deck
- Small bottom rake angle AF

Displacement	2222	Long Ton
Lwl	91.59	m
Beam	30.15	m
Draft	3.8	m
Cp	0.82	-
Cb	0.61	-
Cm	0.77	-
Cwp	0.83	-
LCB from zero pt	-3.1	m
LCF from zero pt	-5.1	m
KB	2.25	m
BMt	57.1	m
BMl	214.6	m
KMt	59.3	m
KMl	216.8	m
Immersion (TPc)	8.14	Long Ton/cm
MTc	52.6	Long Ton.m

Hydrostatics



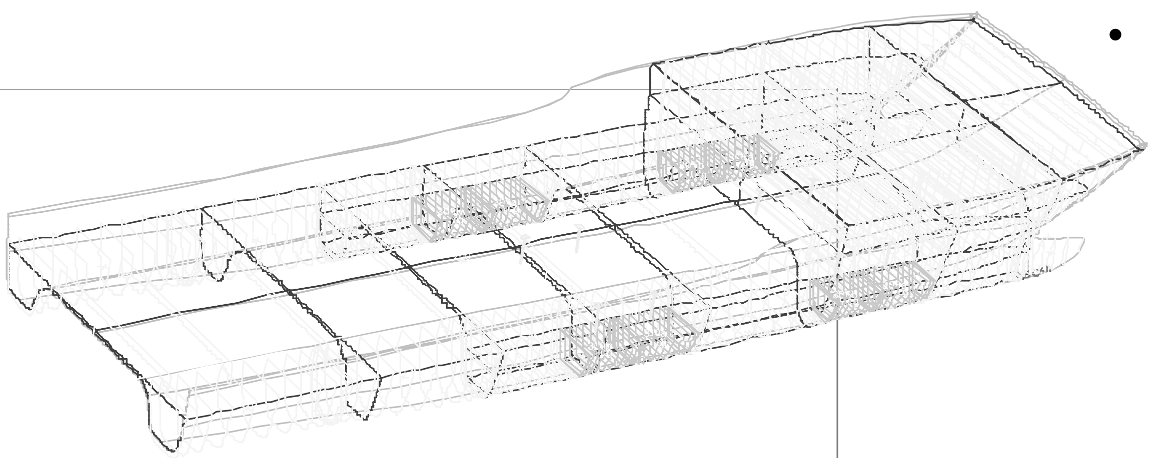


When draft increases:

- Displacement and WSA increase linearly due to vertical sides of hull
- LCB, LCF move back
- Transverse and longitudinal metacentric radii decrease resulting to lower but still more than efficient stability

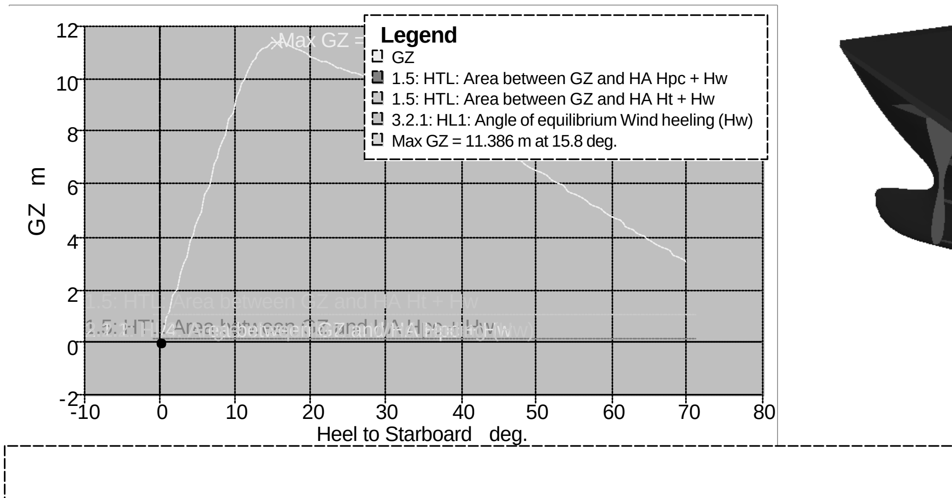
Equilibrium conditions

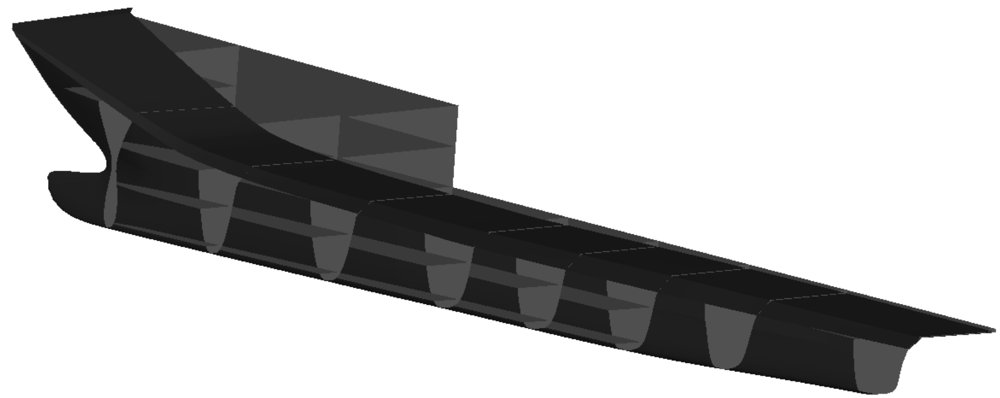
	Total Weight (ltons)	Draft (m)	LCG (m)
Empty of cargo - Low fuels	963.5	2.2	-0.66
Full of cargo - Low fuels	1959	3.4	-3.22
Full of cargo - Hi fuels	2219	3.8	-2.60



- Very large variation of characteristics with cargo
- Challenge to maintain neutral trim
  - In general, catamarans very sensitive due to small WPA
  - Usage of ballast tanks had to be avoided due to extra weight, system complexity, environmental considerations
- Tankage volume 140% of required for specified range
  - Negligible KG correction for free surface
  - Adaptability: replacing 130 tons of cargo with fuel will result to ~40% higher range

Intact and Damaged Stability





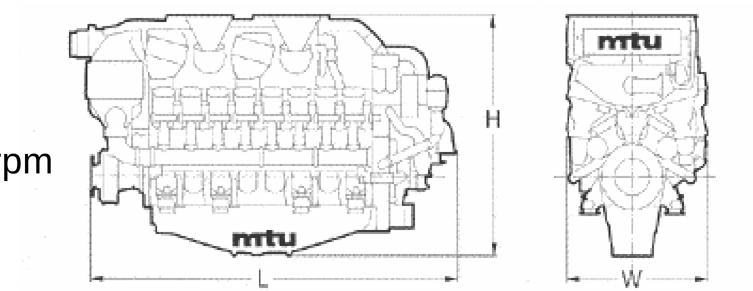
- Fulfills IMO Intact and Damaged stability requirements
- High max GZ value
- Low equilibrium angles
- Max GZ appears at a small angle of inclination due to
  - high metacentric height
  - extremely high beam/freeboard

- Double hull extending from FW perpendicular to FW machinery room
- Compartment subdivision: Designed for 15%LWL floodable length

Main machinery components

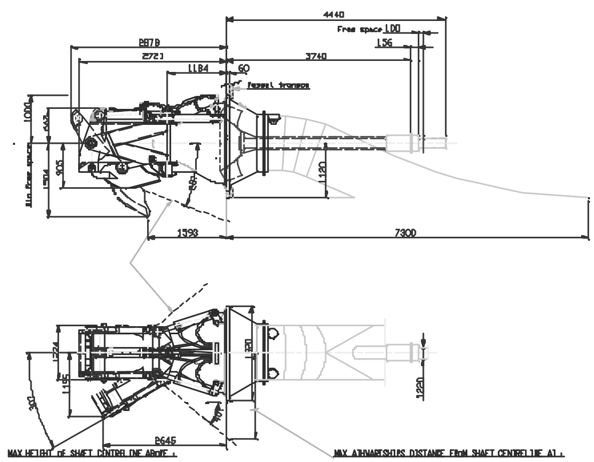
Main Engines

- •MTU 20V 1163 TB73L (x4)
- •Power: 6500kW(8710hp) at 1230rpm
- •SFC: 220gr/(kWhr)



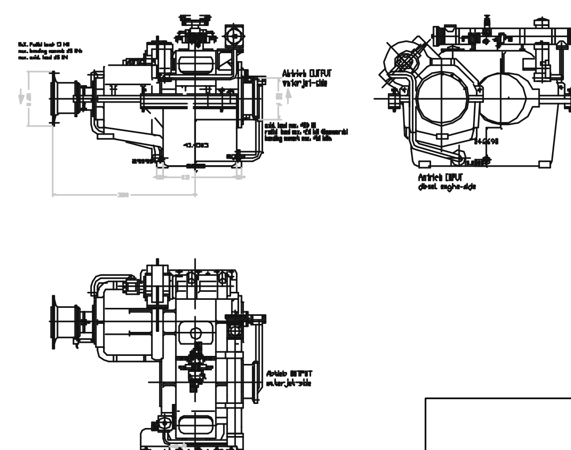
Waterjets

- •KaMeWa Quadruple 112SII (x4)
- •6500kW at 582 RPM
- •Steerable, Reversible
- •seven bladed impellers with skew



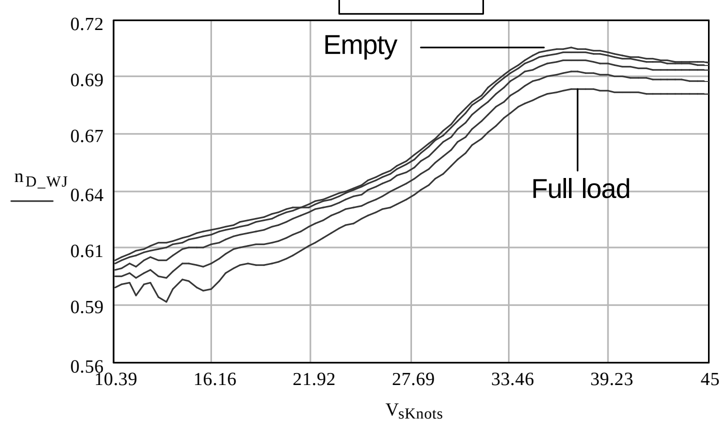
Gear Boxes

- •RENK ASL 53 (x4)
- •single-engine, non reversible
- •reduction ratio 2.05:1
- •Shaft offset on horizontal

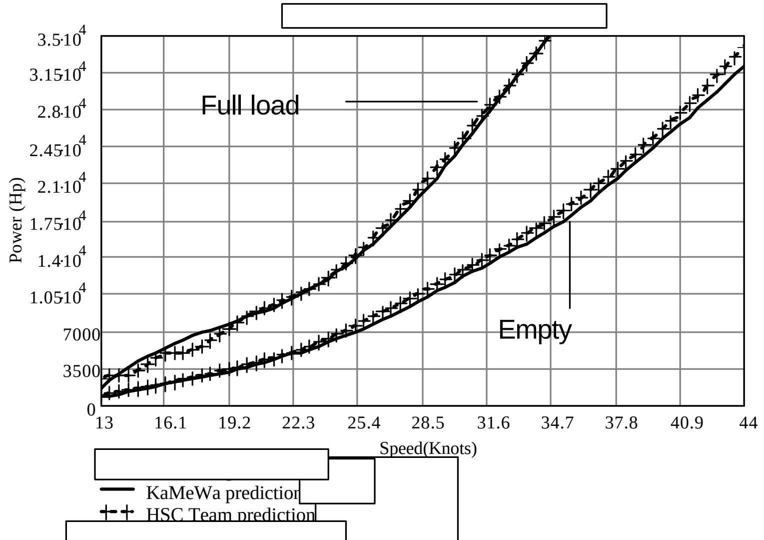


Resistance and Powering Prediction

Variation of overall propulsive coefficient with speed & draft



Power requirements

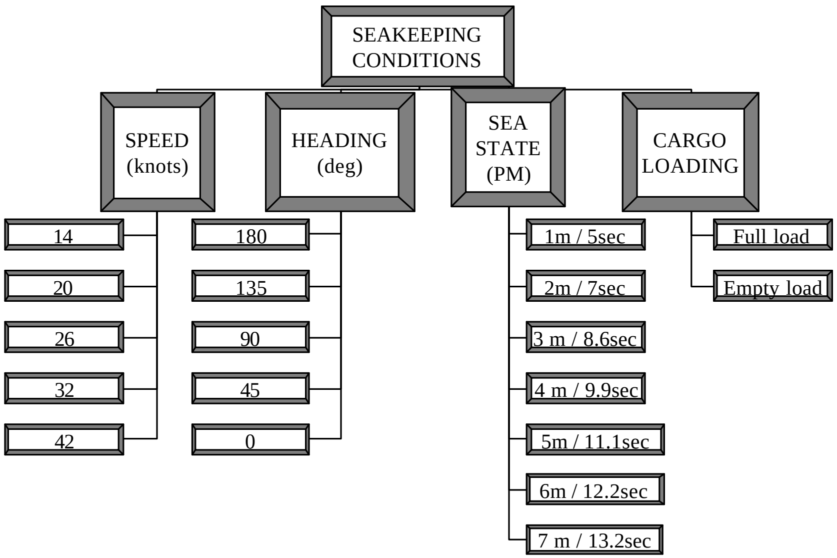


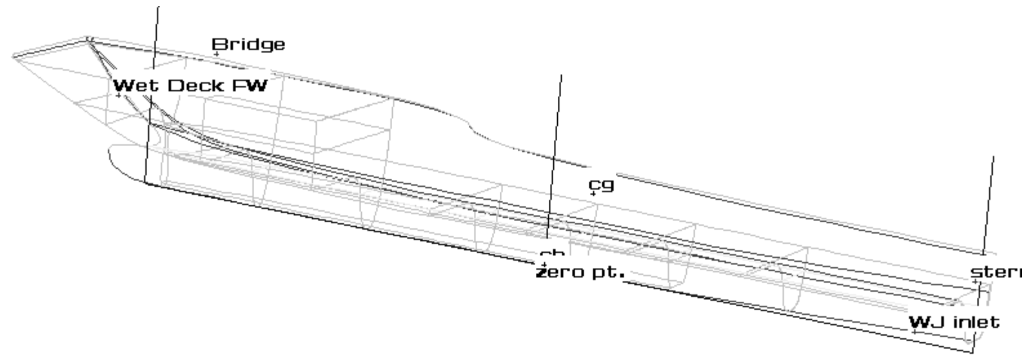
Achievable speeds

Condition	Speed (knots) Full	Speed (knots) Empty
After consumption of 10% margin	33	43.1
Sea Trials	34.1	44.1

Seakeeping Conditions and Criteria

Examined Conditions



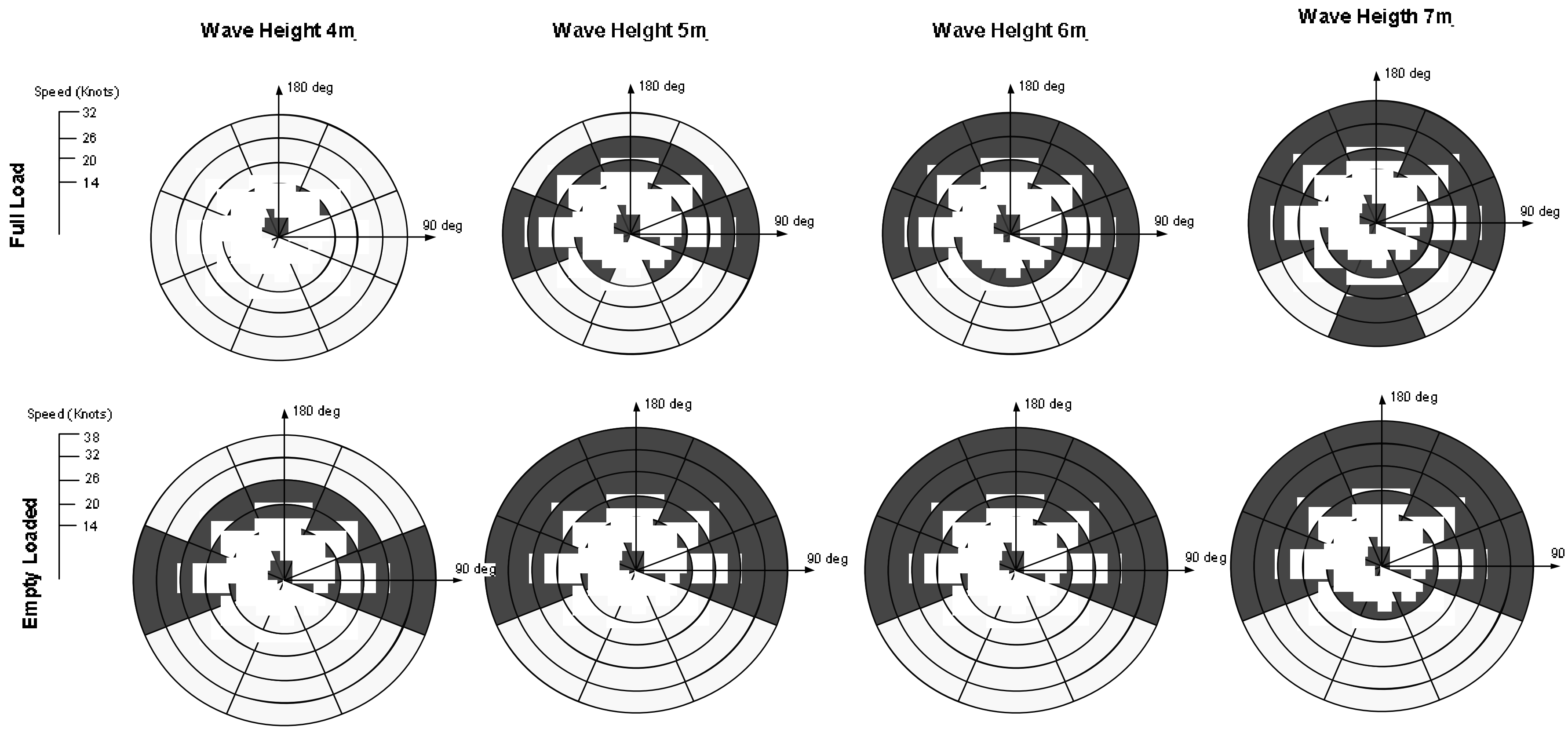


Criteria

- Roll angles
- Pitch angles
- Accelerations at the bridge
- Wet deck slamming
- Waterjet aeration
- Deck wetness at the stern

LOCATION	MEASURE (in significant values)	LIMIT VALUE	
		Full Load	Empty
CG	Roll angle (deg)	8	8
CG	Pitch angle (deg)	3	3
Bridge	Absolute vertical acceleration(m/sec^2)	0.5g	0.5g
Bridge	Lateral vertical acceleration (m/sec^2)	0.2g	0.2g
Wet deck FW	Relative vertical motion (m)	4.7	5.9
Stern ramp	Relative vertical motion (m)	2.1	3.7
WaterJet inlet	Relative vertical motion (m)	2.9	1.3

Seakeeping Results

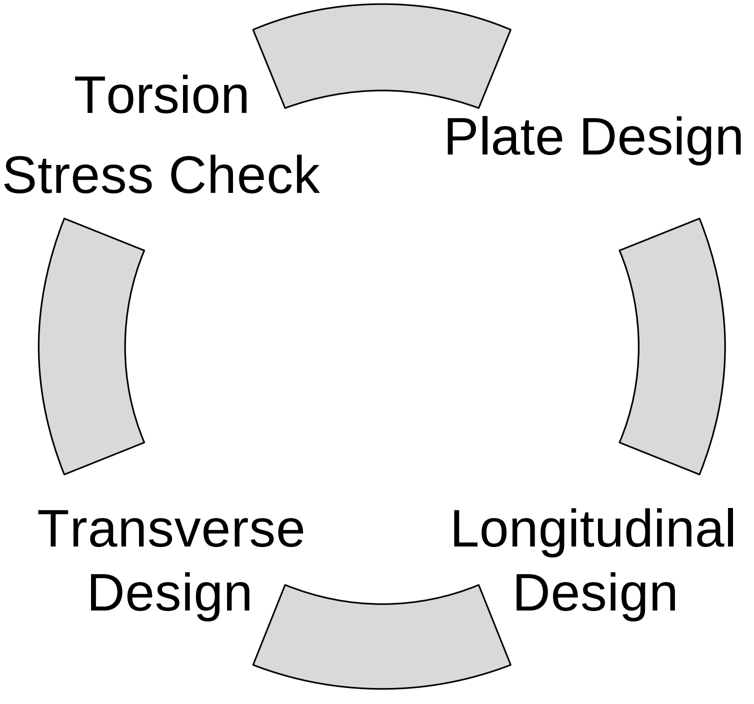


Unrestricted operation

Restricted operation

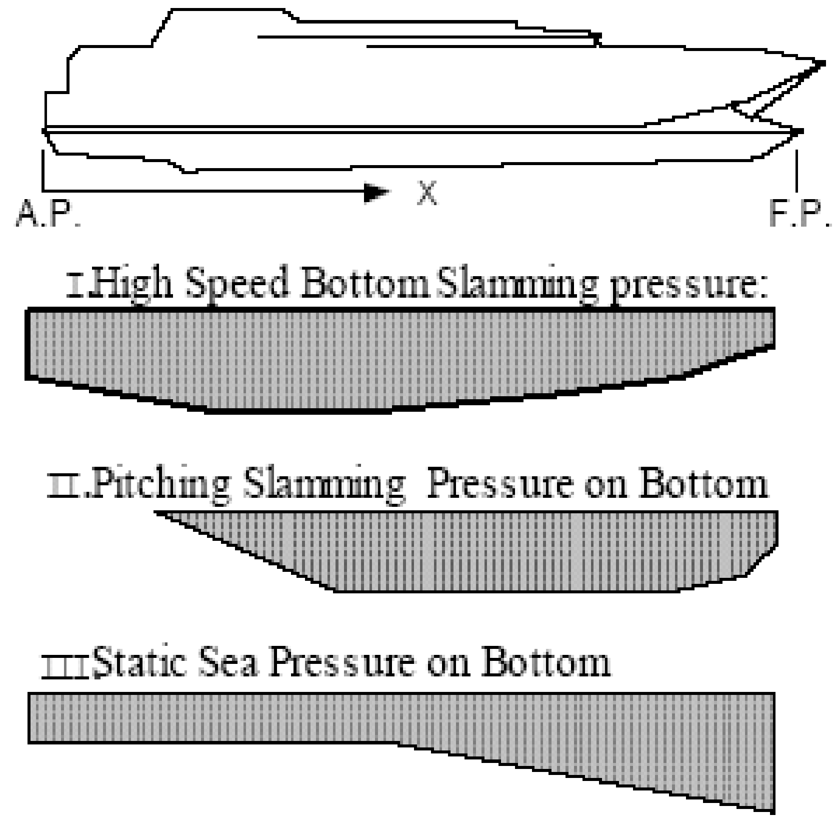
Structural Design

- Design Criteria
  - Based On Det Norske Veritas (DNV) High Speed Light Ship Rules.
- Iterative Process
  - Plate Design (boundary conditions: clamped-clamped)
  - Longitudinal Girder/Stiffener Design
  - Transverse Web Frame Design
  - Torsion Stress Check



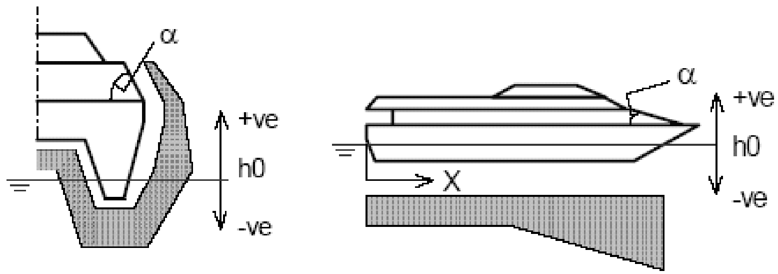
Loading Stresses

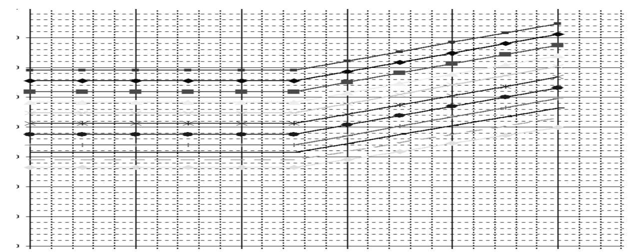
- Major Factors
  - Speed
  - Loading Condition
  - Sea State Condition
  - Geometry (length, width, draft)
- Stress Due To
  - Water Pressure
  - Longitudinal Bending
  - Slamming (bottom, cross-structure)
  - Forward Motion (bow bottom, side)
  - Vehicle Loading



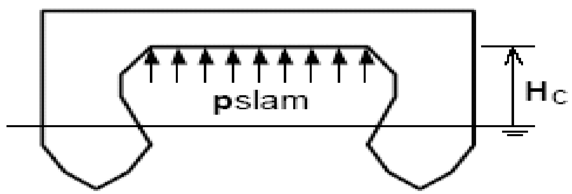
Loading Stresses (cont.)

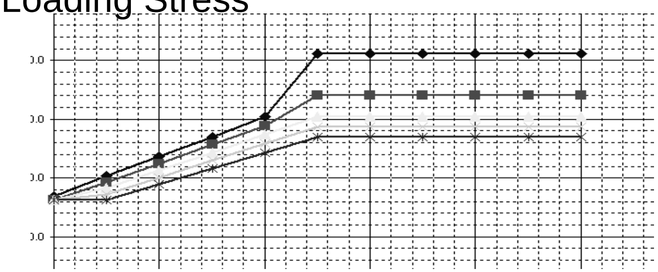
Sea Pressure Loading Stress



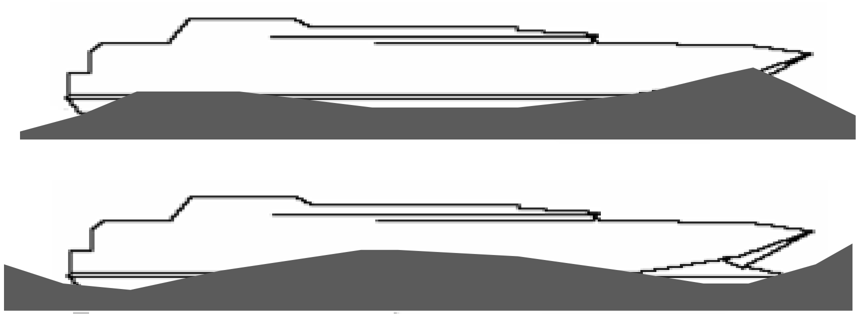


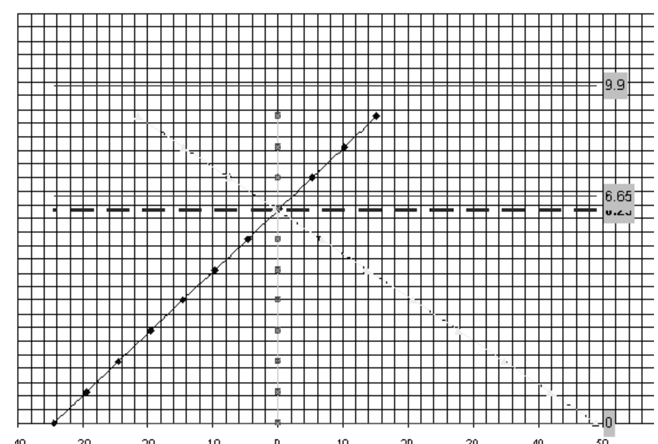
Slamming Pressure Loading Stress





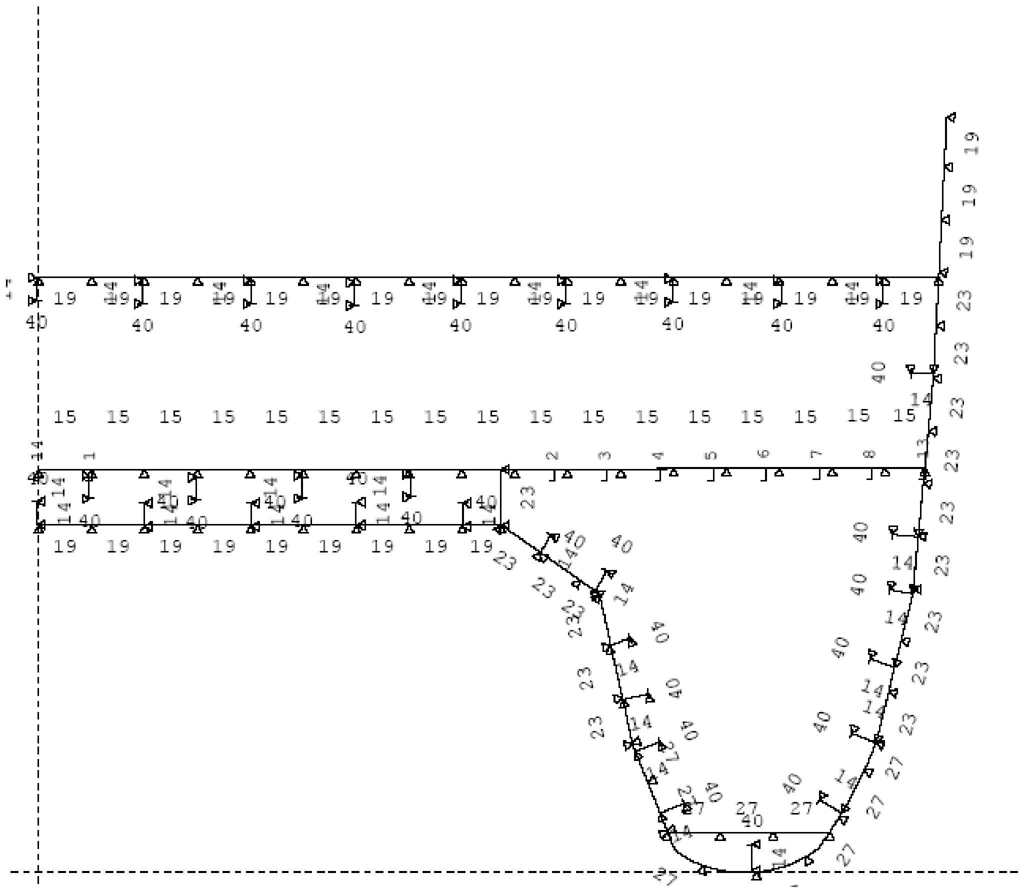
Longitudinal Bending Stress





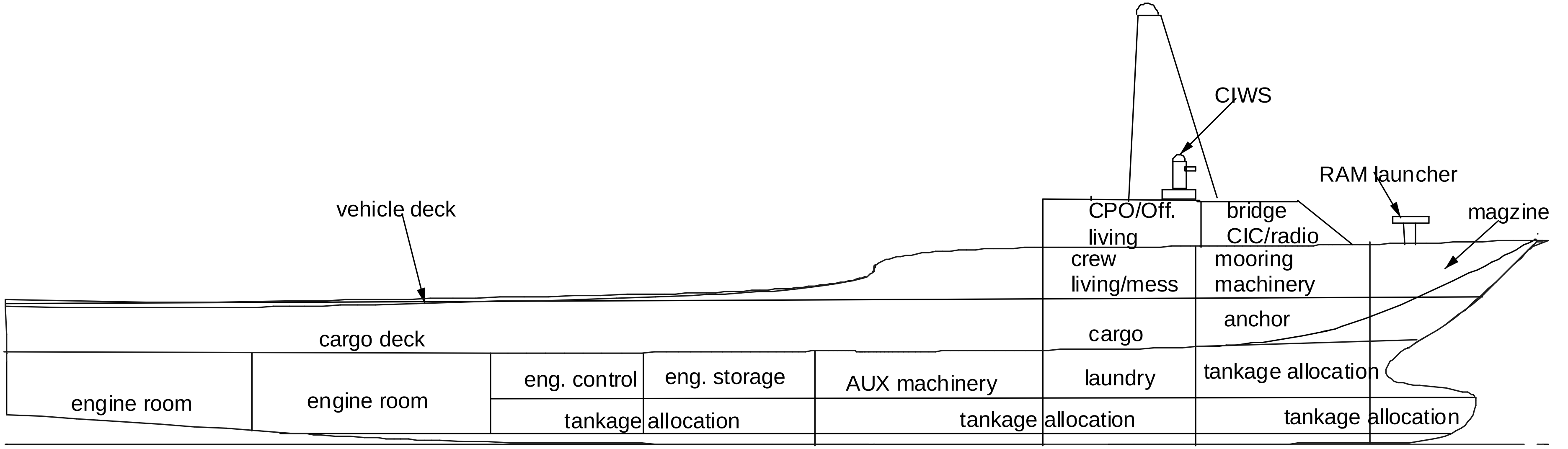
Scantling Design Results

- Material
  - Aluminum Alloy 3008H18
  - Density: 2730 kg per cubic meter
  - Yielding stress 225 Mpa
- Plate (5x1.849 m)
  - 27mm
  - 23mm
  - 19mm
- Stiffener
  - Type 243 CY FdaTb Fundia TB 160x40 (two sizes)
- Webframe
  - Same type (two sizes).
- Safety Factor >3
  - Maxi stress 72 Mpa in Web frame with torsion

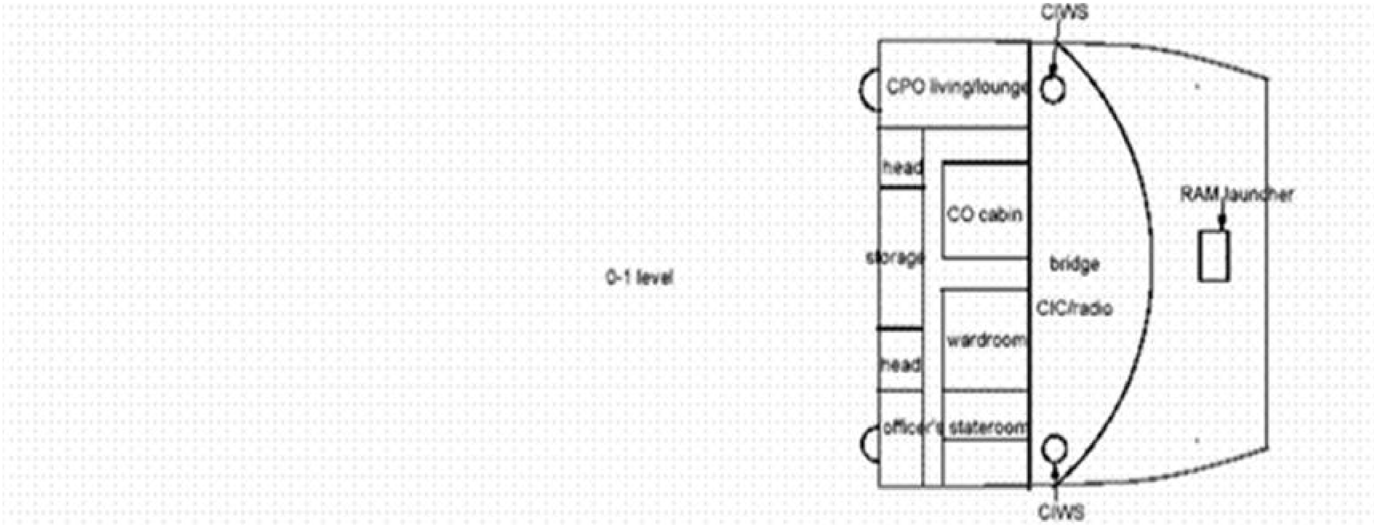


Arrangement

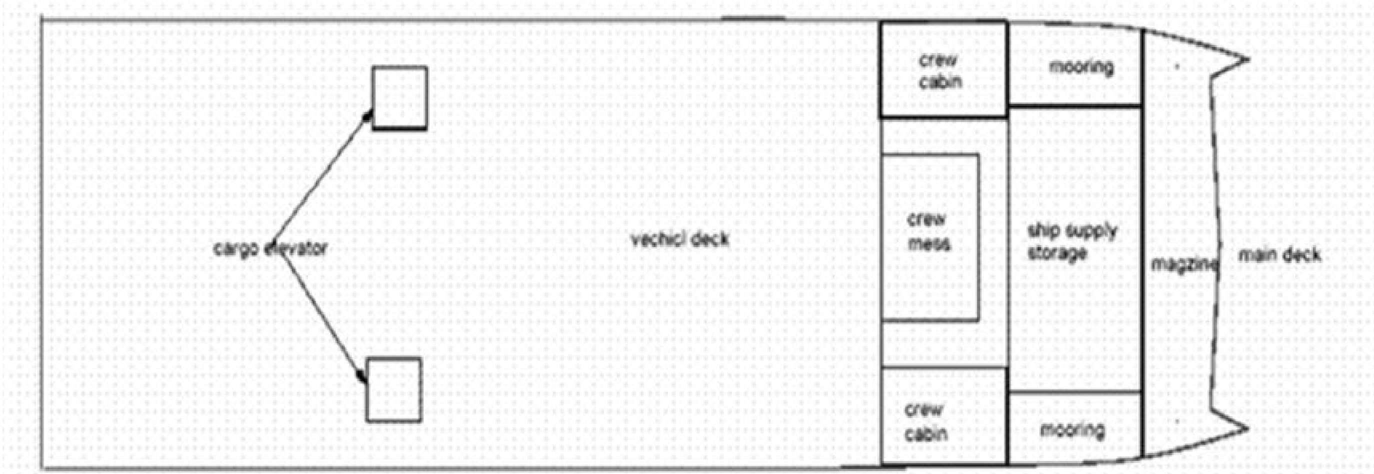
Profile View



Arrangement (cont.)

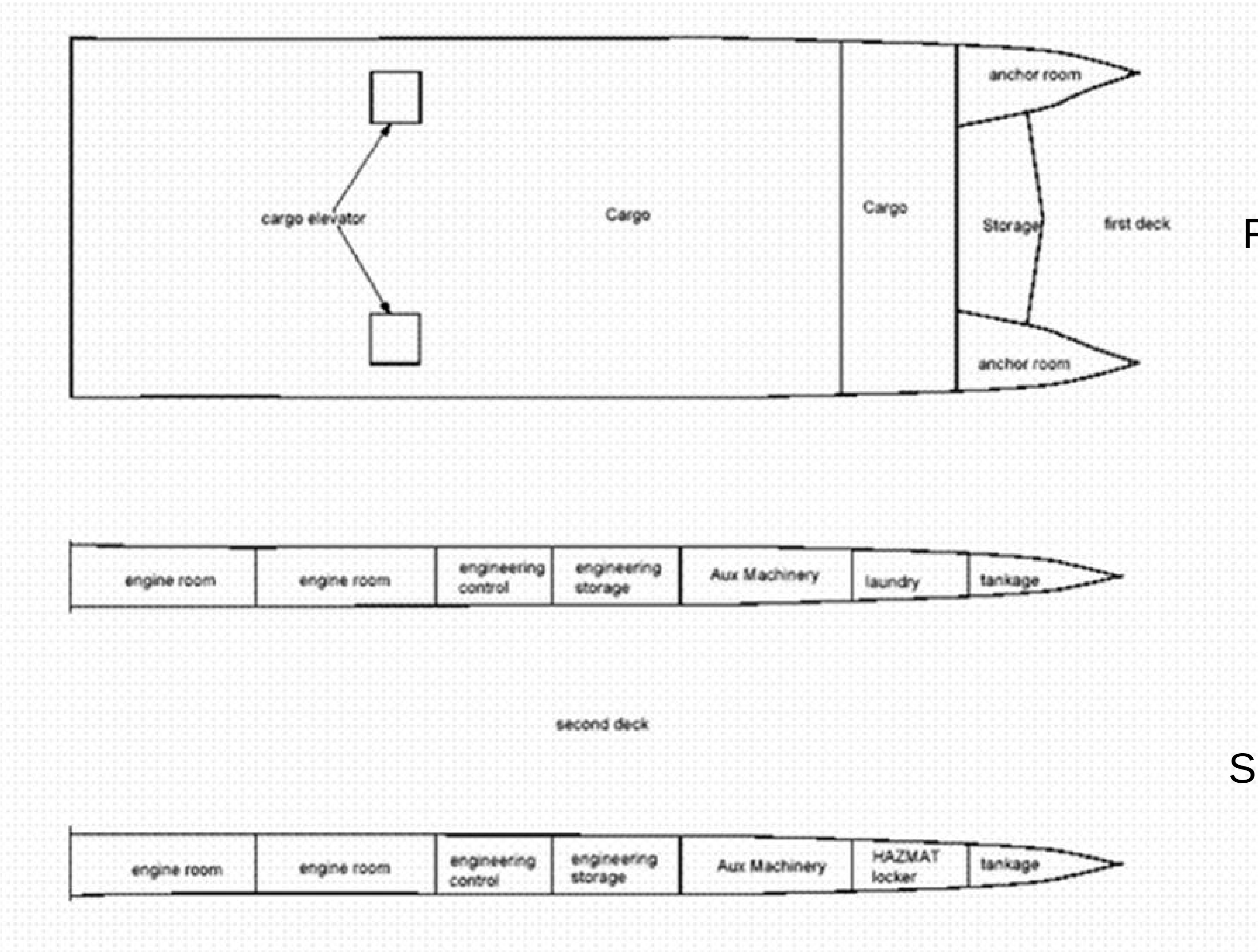


O-1 level



Main Deck

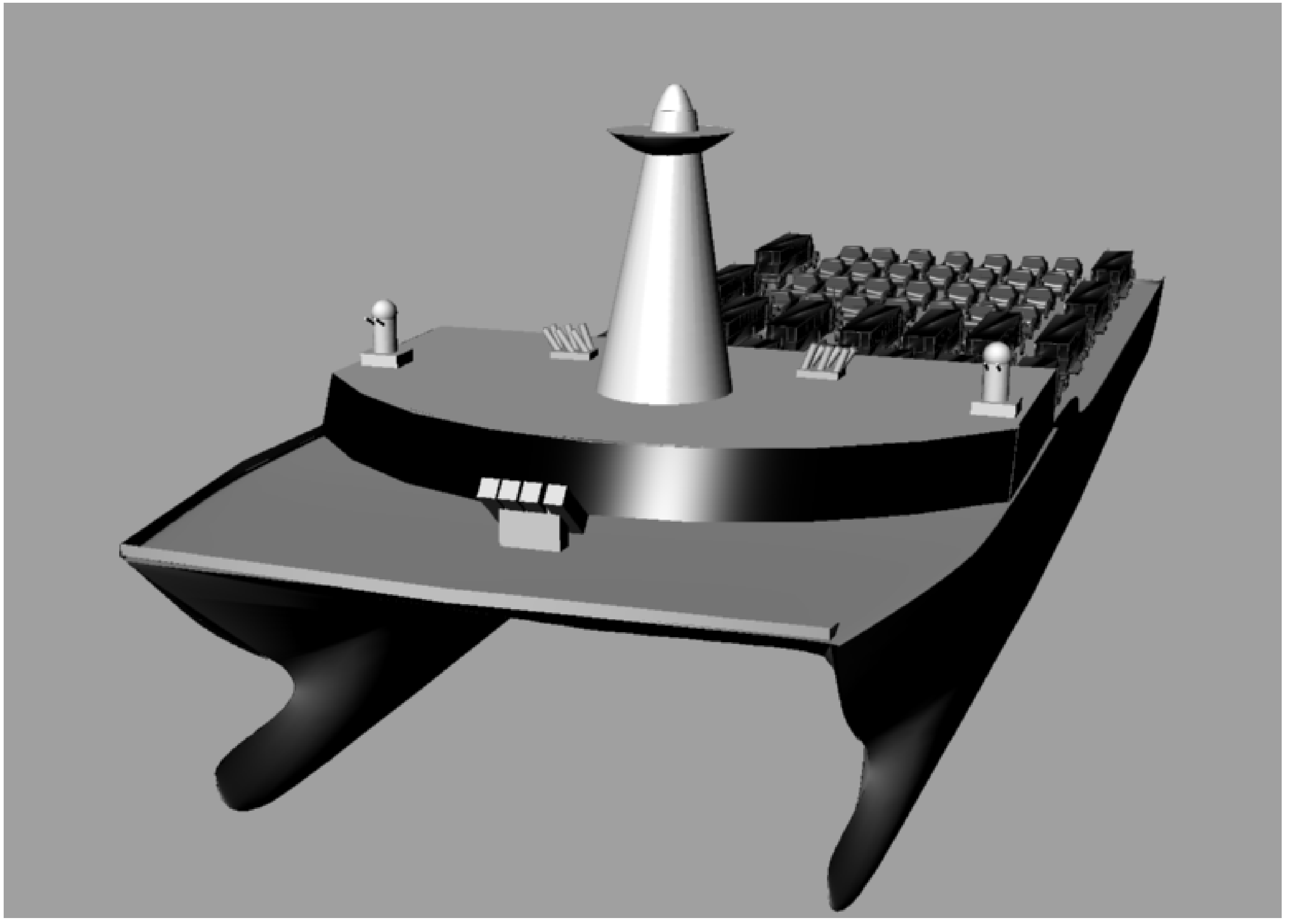
Arrangement (cont.)



First Deck

Second Deck

Arrangement (cont.)



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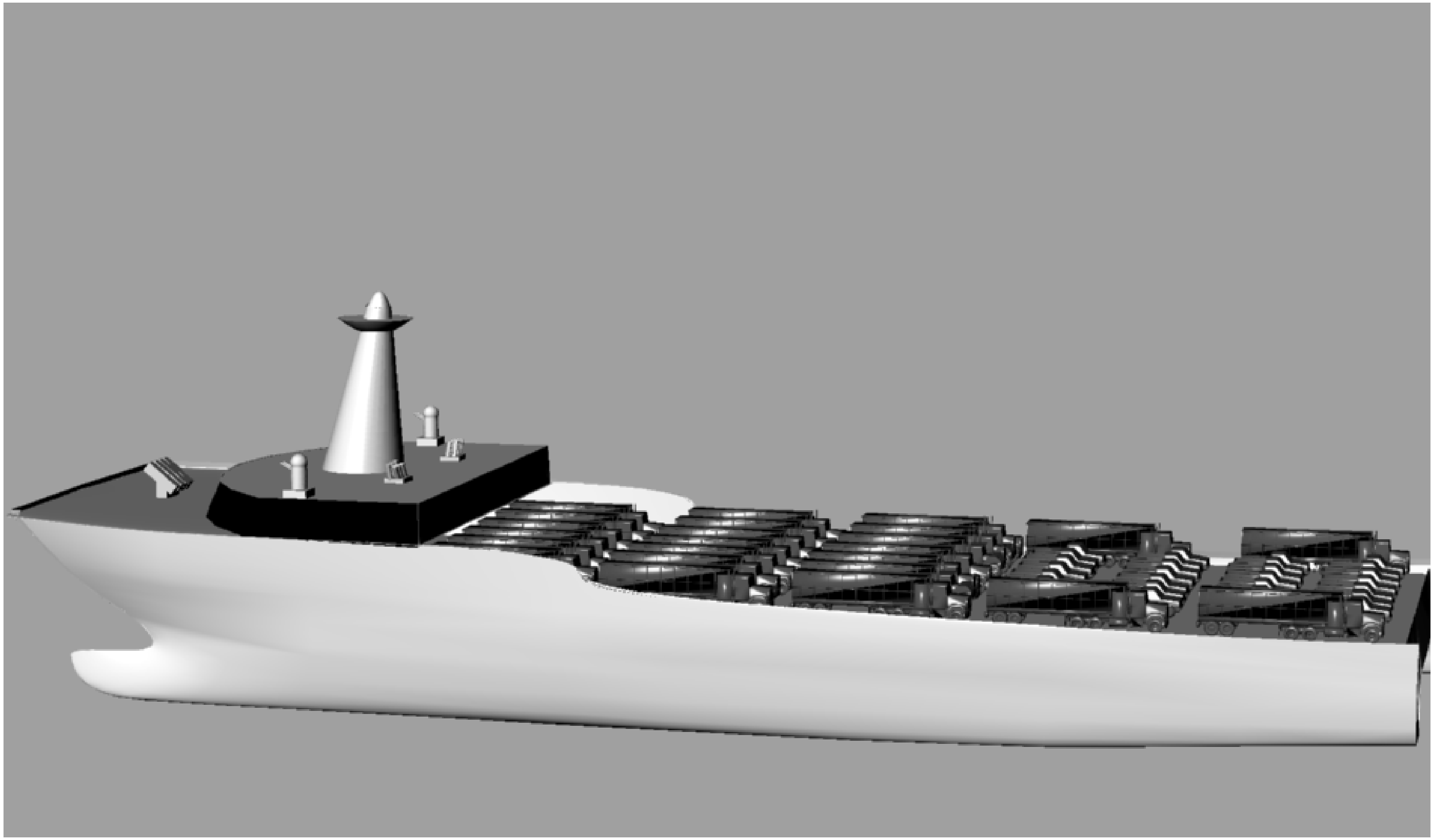
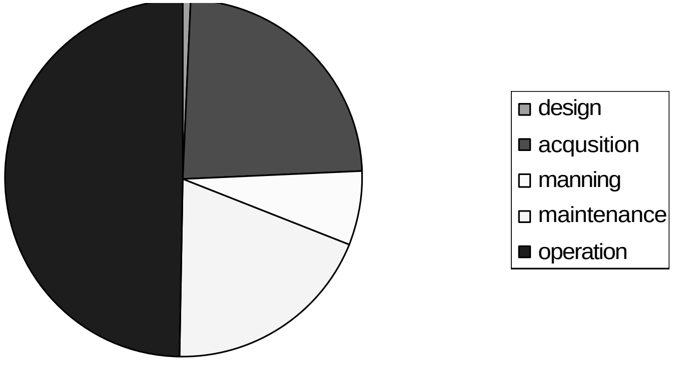


Cost

- Parametric ESWBS weight groups
  - Material Cost
  - Labor Cost
- Adjusted for individual items
  - Engines
  - Gensets
  - Gear boxes, cables.
- Life Cycle Cost (in 2005 US dollar)
  - 20-year span
  - 4-ship class
  - Including
    - Design: 4.42 million
    - Acquisition: 186.5 million
    - Manning: 3.95 million/year
    - Maintenance: 11.5 million/year
    - Operational Cost: 29.5 million/year
  - Total 780.12 million/195 million per ship.
  - Annual cost per ship: 9.75 million

Production Number	Cost Per Ship ($Million)
ship#1	59.8606
ship#2	42.393
ship#3	42.1831
ship#4	42.0616
Total	186.4983



Conclusion

- Success
  - Achieved payload of 1000 ltons.
  - Partially achieved speed goal of >40 knots.
  - Low-draft, agile, inexpensive and versatile.
- Future Works
  - To consider the dynamic stress load of the ramp to the stern structure
  - To design propulsion system and control for dynamic station-keeping while unloading.

	Threshold	Goal	Achieved
Speed	32kts	>40kts	34-44kts
Payload	500 ltons	1000 ltons	1000 ltoons
Range	2000 nm	2000 nm	2100 nm
Cost	150 million	50 million	46 million

Principal Ship Characteristics		
Displacement	**2222**	**LT**
Draft (Full Load)	**3.8**	**m**
LWL	**91.6**	**m**
Beam WL	**30.15**	**m**
Manning	**29**	**Personnel**
Power Plant	**4**	**MTU 20V 1163 TB7.3L Diesels**
Propulsion	**4**	**KaMeWa Quadruple 112 SII waterjets**
Speed - Full Load	**34**	**Knots**
Speed - Light Ship	**44**	**Knots**
Range (Full load, max speed)	**2100**	**nm**

Questions?