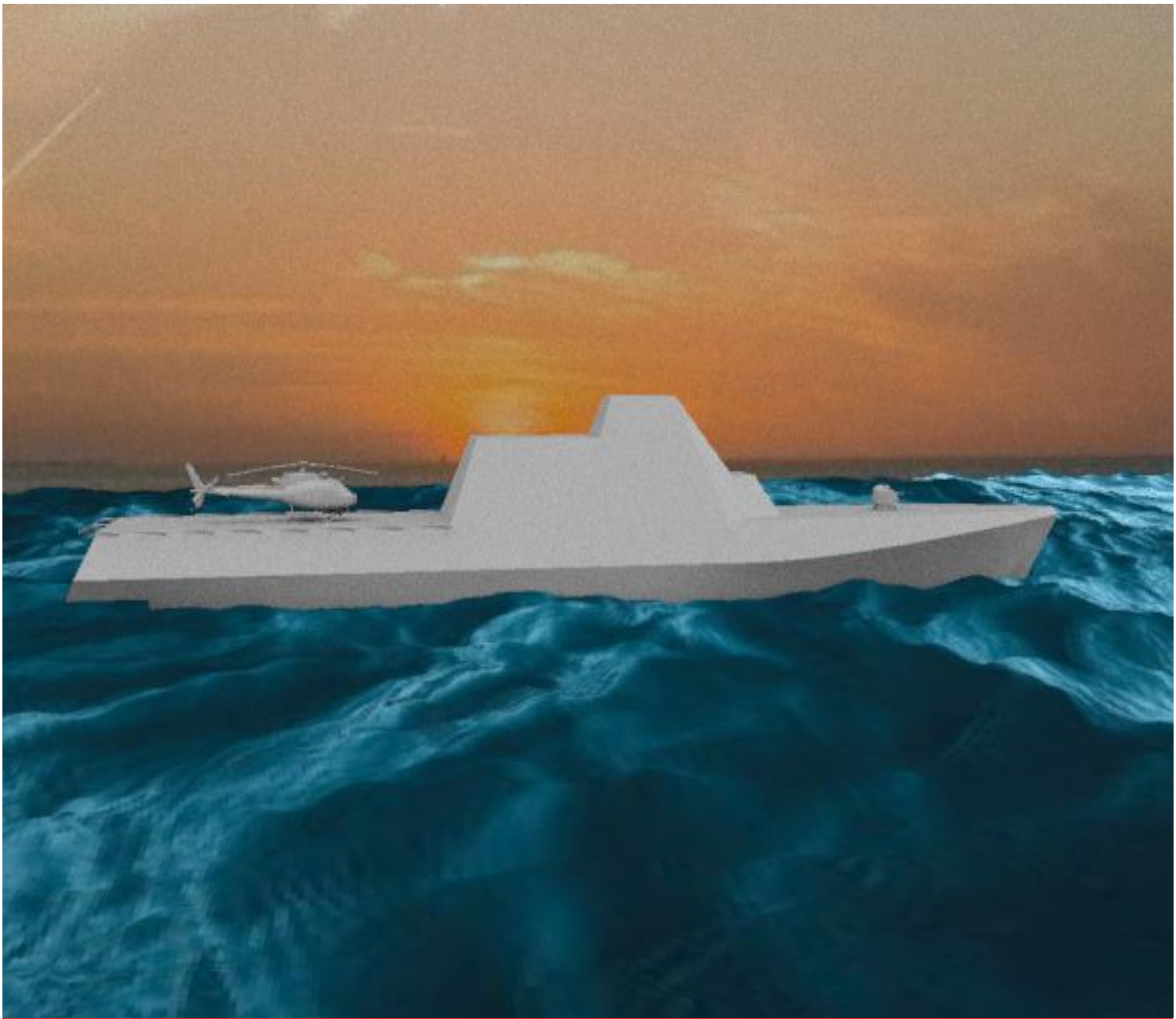

Dr. James A. Lisnyk Student Ship Design Competition 70 m OPV

Enrique Liccardi
Patricio Duhalde

UTN FRMDP May. 31, 22 SNAME

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National Technological University

Mar del Plata

James A. Lisnyk Student Design Competition

Student Team Members

The following members were part of the design team:

Student name	**Signature**
Enrique Liccardi	
Patricio Duhalde	Duhalde Patricio

National Technological University

Mar del Plata

James A. Lisnyk Student Design Competition

Faculty Advisor Statement

By this statement, I certify that the work done for this ship competition was completed by the student team members.

Faculty advisor

Duhalde Patricio

Student Patricio Duhalde

OWNER'S REQUIREMENTS FOR AN OFFSHORE PATROL VESSEL

INTRODUCTION

The Argentine seas are threatened by the illegal fishing, our navy doesn't have the necessary resources to address the problem. Considering this issue, we propose the development of an OPV project to regain the control of the Economic Exclusion Zone. The ship that we intend to design is more versatile and efficient, smaller and faster, to complement the new Kership-class ships acquired from France.

OBJECTIVES

- Control and protection of natural resources renewable and non-renewable
- Control and protection of maritime and river trade
- Support and protection of smaller units
- Transport of special forces
- Helicopter scout operations
- Humanitarian aid operations
- Maritime and river search and rescue operations (SAR)
- Supplying of Antarctic bases
- Naval presence

OPERATIONAL AREA

- Argentina's Exclusive Economic Zone (2.809.232 km²)
- Argentina's Antarctic Sector (1.461.597 km²)
- Argentina's SAR responsibility zone (16.100.000 km²)
- Home ports:
  - Mar del Plata Naval Base
  - Puerto Belgrano Naval Base
  - Ushuaia Naval Base

LIMITING PARTICULARS

- LOA: Maximum of 87 meters, limited by the LOA of the Kership-class OPV
- Beam: Reasonable minimum
- Draft: Max. of 7 meters, limited by the draft at Mar del Plata Naval Base
- Depth: Reasonable minimum
- Displacement: More than 500 tonnes

OTHER CHARACTERISTICS:

- Maximum speed: Trial speed at design draft – 35 knots
- Cruise speed: Trial speed at design draft – 12 knots
- Range: 8000 nautical miles at cruise speed

COMPLEMENT

- Estimated core crew: 30 - 50
- Estimated troops: 20 - 40

CLASSIFICATION

Det Norske Veritas

REGISTRY

Argentina

SPECIAL DESIGN CONSIDERATIONS

- Hull shall be designed intended for navigation in waters with ice conditions due to operations in Antarctic bases.
- Selection of propulsion plant will be combined diesel or gas (CODOG), gas turbines for maximum speed and diesel engines for cruise speed.
- Due to helicopter scout operation the deck should withstand helicopter landing operations, additionally due to supplying of Antarctic bases and humanitarian aid operations also the deck should have the capacity to lash one or two containers.
- At the stern should be an efficient mode to unload rigid inflatable boats.

APPLICABLE REGULATIONS

The ships shall meet all international regulations for load line, intact stability, dry cargo damage stability, and other SOLAS and MARPOL requirements for lifesaving, firefighting, and pollution regulations.

In developing the design, the future course of regulations directed to environmental issues shall be researched and responded to. Evaluations should include but are not limited to features regarding:

- Minimization of NOx and Sox emissions from the main and auxiliary engines.
- Provision for at-sea ballast water exchange or other effective measure of ballast management to minimize invasive species introductions.
- Disposal of sewage and waste material.

1. ACKNOLEDGEMENTS

I would like to thank the teachers and colleagues who gave me a hand during the development of the project.

UTN MAR DEL PLATA

- Engineer and Professor Martín A. D'elia
- Engineer and Professor Alejandro Vaccari
- Fellow student Joel Tolosa
- Fellow student Martin Lopez
- Fellow student Agustin Barragán

ARGENTINE NAVY

- Commander Oscar Luis Latorre
- Lieutenant Nicolás Cáceres
- And all the crew of the ARA Storni

COLOMBIAN NAVY

- Lieutenant (junior grade) Marco Zuluaga
- Midshipman Fernando Cabarcas
- And all the crew of the ARC 20 de Julio

We had the opportunity to visit the ARA Storni and ARC 20 de Julio vessels to internalize with this type of vessel, listen to the opinions of the crews, learn about the requirements of each navy, especially that of our country, physically see systems to be raised in our design, among many other things.

2. INTRODUCTION

National Defense is an essential and non-delegable obligation of the Argentine Republic, where all the necessary efforts must coincide to preserve the vital interests of the country.

Based on National Defense Law No. 23,554, as established in the allocation of resources in accordance with the National Defense Planning Cycle approved by Decree No. 1729/2007, which organizes and frames the process of strategic definition of defense, a projected norm that provides for a specific allocation of the affected resources so that they are destined for recovery, modernization and/or incorporation of material under the terms of article 19 of the Law on the Restructuring of the Armed Forces No. 24,948.

The nature of the international defense industry represents an opportunity to generate and develop both scientific and technological capabilities, acquires particular relevance in the field of technologies aimed at guaranteeing national sovereignty and ranging from transport, telecommunications and energy to developments in the satellite, aeronautics or space area, all transversal axes to the design and implementation of policies for defense.

It is necessary to provide our Armed Forces with the necessary material means so that the military instrument can fulfill its main mission as well as the subsidiary missions assigned to it by the current Argentine legal framework, guaranteeing an equipment plan that includes among its forecasts the surveillance and control of both traditional and future sovereign spaces.

The incorporation of this oceanic patrol vessel allows surveillance, control of the sea, defense of maritime resources and spaces, especially within the Argentine Exclusive Economic Zone (ZEEA) as well as being usually engaged in tasks of safeguarding human life at sea and in search and rescue operations (SAR). For the specific case of the Argentine Navy, these activities are under the area of action of the Maritime Patrol Division, which to date has at least 6 operational units (4 OPVs and 2 corvettes).

It is of the utmost importance for the Argentine Navy, since its mission is to enlist, train and sustain the means of the Naval Power of the Nation in order to guarantee its effective use in the framework of military planning.

It allows us to increase our maritime patrol capacity, the custody of existing resources, the training, the constant training of military personnel and the importance for the country of modernizing and adapting the nation's military instrument.

Participate in multilateral operations mandated by the United Nations or another international organization of which the Nation is a member.

Assist the national community or other countries in the face of natural and anthropic disasters.

Participate in internal security operations in accordance with the provisions of Internal Security Law No. 24,059.

Logistically support Antarctic activity.

Contribute to the surveillance and control of maritime and fluvial, jurisdictional and interesting spaces.

Produce the strategic operational intelligence and tactical intelligence necessary for the planning and conduct of military operations and specific technical intelligence.

Contribute to the enforcement authority of Law No. 24,922 (1998) – Federal Fisheries Regime in the Surveillance and Control of Fishing in Areas of National Jurisdiction to Prevent Illegal, Unreported and Unregulated Fishing.

Monitor and control scientific and technical research activities on non-living resources projected by foreign natural or legal persons or international organizations, in waters, bed and subsoil subject to national sovereignty, as established in Law No. 20,489 (1973), regulated by Decree No. 4915/73 and in the context of Law No. 24,922 (Federal Fisheries Regime) and Decree No. 748/99 (Regulation of Law No. 24,922).

Support the Naval Hydrography Service, through the training of specialized personnel, to cover the needs of the service and crew, operate and maintain the units that fulfill tasks for it.

To direct the system of training, training and certification of the crews of ships and naval devices of national registration as established in Law No. 22,392 (1979).

To carry out the tasks incumbent upon it as the implementing authority of the International Convention on Maritime Search and Rescue, adopted by Law No. 22,445 (1981).

FIELDS OF ACTION IN ARGENTINE JURISDICTIONAL SPACES

The continental, insular, maritime and air spaces where the Argentine Republic exercises its sovereign and jurisdictional rights, including its rivers and internal waters, with the scope assigned by national and international norms and treaties signed or to be signed by the Nation.

MARITIME AREAS OF INTEREST

The area of Maritime Search and Rescue in which the Argentine Republic has responsibility, in accordance with the provisions of Law No. 22,445.

The Argentine Antarctic Sector and those defined by the Convention on the Conservation of Antarctic Marine Living Resources.

Those provided by national and international laws for surveillance and control, such as Marine Protected Areas or others that are created.

Those not included in the above cases, on which the National Executive Power disposes. It contemplates all those that arise for the protection of citizens and national property in third countries, in international waters and international airspaces with the scope determined by international standards and treaties signed or to be signed by the Nation.

3. REPORT SUMMARY

In general, the preliminary characteristics of the project were determined by parametric analysis considering the requirements, a project spiral was produced in which the initial conditions obtained had to be reassessed.

Several programs were used, including:

- AutoCAD
- Maxsurf modules
- Rhino 6
- Microsoft Office
- ANSYS

Table 1. Principal Ship Characteristics

Displacement	Δ	750,6	tonnes
Volume displaced	∇	732,3	m^3
Length overall	Loa	70,00	m
Length at waterline	Lwl	62,00	m
Beam overall	Boa	10,00	m
Beam at waterline	Bwl	8,74	m
Draft	T	3,00	m
Block coefficient	Cb	0,449	-
Longitudinal prismatic coefficient	Cp	0,658	-
Middle section coefficient	Cm	0,685	-
Waterplane area coefficient	Cwp	0,764	-
Longitudinal center of buoyancy	Lcb	-2,76	m
Cruise speed	s	12	knots
Maximum speed	v	35	knots
Range	r	8.000	nmi
Endurance	d	30	days
Complement	c	10 O+30	crew
Propulsion	2 ABC 6DZC Diesel engine 2,652 MW 1 Zorya-Mashproekt Type UGT 15000+ or 1 GE LM2500 Gas turbine 20 MW		

4. DIMENSIONING

Reference vessels are at the data base in Appendix A.

PRINCIPAL DIMENSIONS

Length overall (L_{OA})

The total length of the ship is defined by the owner's requirements, for this project was stablished that the maximum length should not be more than 87 meters, limited by the L_{OA} of the Kership-class OPV, is adopted 70 meters.

Beam overall (B_{OA}): the maximum beam is calculated with the relation B_{OA}/L_{OA} average from the data base.

$$\mathrm{Boa} = \mathrm{Loa} \cdot \frac{\mathrm{Boa}}{\mathrm{Loa}} \tag{1}$$

Molded depth (D): the depth is calculated with the relation D/LOA average from the data base.

$$\mathrm{D} = \mathrm{Loa} \cdot \frac{\mathrm{D}}{\mathrm{Boa}} \tag{2}$$

Draft (T): the draft is calculated with the relation T/LOA average from the data base.

$$\mathrm{T} = \mathrm{Loa} \cdot \frac{\mathrm{T}}{\mathrm{Loa}} \tag{3}$$

Displacement (Δ): The full load displacement is calculated with the relation BOA/LOA average from the data base.

$$\Delta = \mathrm{Loa} \cdot \frac{\Delta}{\mathrm{Loa}} \tag{4}$$

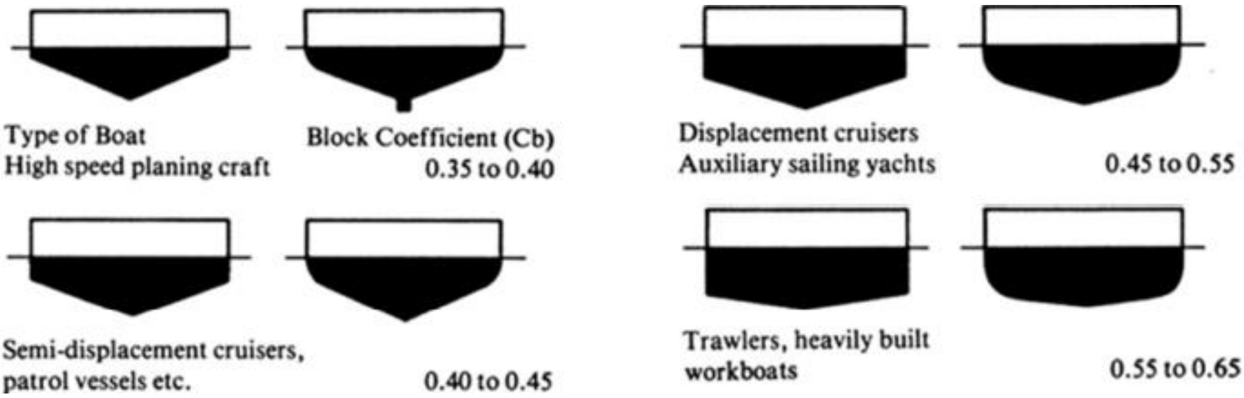
Table 2. Preliminary dimensions

Length overall	Loa	70	m
Displacement	Δ	702	tonnes
Volume displaced	∇	685	m^3
Beam overall	Boa	10,5	m
Depth	D	5,9	m
Draft	T	3	m
Cruise speed	s	12	knots
Maximum speed	v	35	knots

FORM COEFFICIENTS

Block coefficient (Cb)

The use of coefficients of shapes on boats fast is relative, since They are values that indicate hydrodynamic phenomena, but geometric. Usually in planing boats pure Cb does not usually exceed values of 0,40 static. For semi planing the Cb range it can be from 0,40 to 0,45. It's weird find vessels with block coefficient values greater than 0,50.



Estimation according Taylor – Green

$$Cb = 1 - 0{,}5 \cdot \left(\frac{B_{OA}}{L_{OA}} + 1\right) \tag{5}$$

Table 3. Estimated Block coefficient

Length overall	L_{OA}	70	m
Beam overall	B_{OA}	10	m
Block coefficient	**Cb**	**0,429**	**-**

Longitudinal prismatic coefficient (Cp)

As for the coefficient prismatic that relates the distribution of the value of displacement in general have values between start at 0,58 for low speeds up to 0,70 for the fastest. Fung gives the following formula to obtain the values of the prismatic coefficient (Cp) in function of the Froude number (Fn):

$$Cp = 0{,}5687 + 0{,}1538 \cdot Fn - 0{,}0701 \cdot Fn^2 \tag{6}$$

Table 4. Estimated Longitudinal prismatic coefficient

Length at waterline	L_{WL}	62	m
Maximum speed	v	35	knots
Froude number	Fn	0,730	-
Prismatic coefficient	**Cp**	**0,644**	**-**

Midship section coefficient (Cm)

$$Cm = \frac{Cb}{Cp} \tag{7}$$

5. HULL FORM

Fast monohulls operate at speeds corresponding to Froude number in excess of 0,5. This is also the case of modern naval ships, which tend to reduce their size at the same speed, since modern efficient weapons can be accommodated in smaller platforms. A common characteristic of this type of hull forms is the large immersed transom stern.

Some series have advantageous resistance performance in the semi-displacement or pre-planing speed regime (Froude Number range = 0,40 – 0,90), are:

- VWS D-Series, Berlin (Kracht, 1996)
- SKLAD series, Zagreb (Gamulin, 1996)
- AMECRC systematic series (Bojovic, 1997)
- NTUA series of double-chine hull forms (Grigoropoulos & Loukakis, 1999)

Due to CODAG Warp proposed propulsion configuration the best hull to allocate the refined propellers are the VWS D-Series due to its stern shape proper of semi displacement and semi planing hulls, the other series have a stern with a more flattened bottom proper of planing hulls.

VWS D-Series

The series originates from a twin-screw round bilge hull form and refers to relatively broad and short ships. Kracht (1992, 1996) reported on the resistance, wake and propulsion tests carried out with the 13 models of the series. All models had a common Lbp = 6,00 m. For each Cp value three models with common $10^3 C_\nabla = 3{,}00$ and varying B/T have been constructed, while a fourth model had B/T =3,75, as the parent one, and a $10^3 C_\nabla = 3{,}5$. Especially for Cp = 0,600 a fifth model with B/T =3,75 and $10^3 C_\nabla = 4{,}0$ was built. The body plan of the parent model is shown in Figure 1. Its form parameters are given in Table 5, while the variation of Cp and C_∇ coefficients and B/T ratio within the series is shown in Table 6.

Figure 1. Body plan of the parent model of D-Series (model 2521)

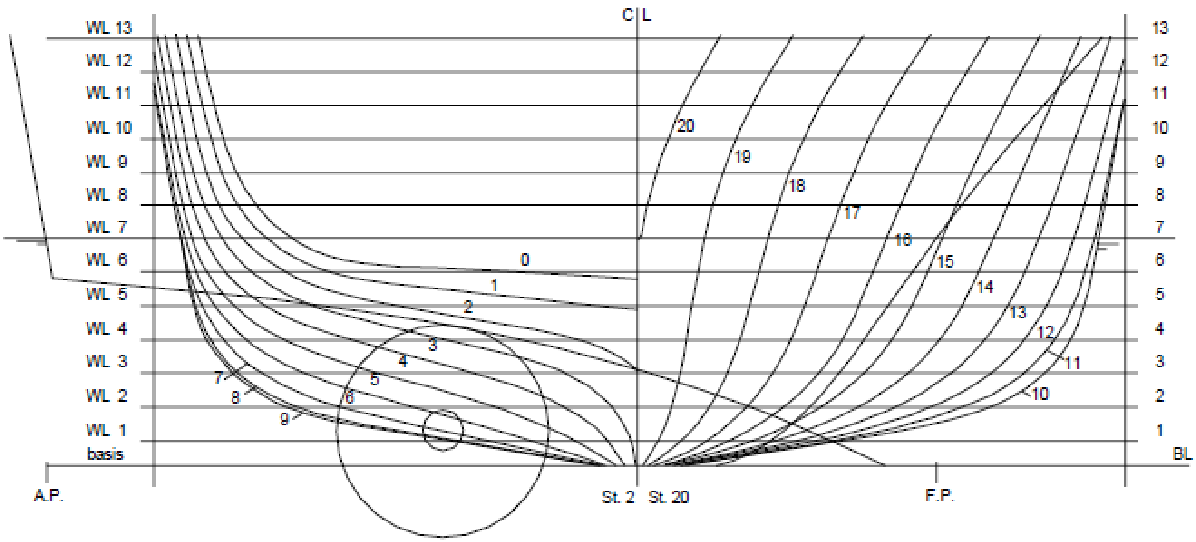


Table 5. Form parameters of parent hull form of D-Series

Parameter	Value
Prismatic Coefficient (Cp)	0,62
B/T ratio (amidships)	3,75
Slenderness coefficient $10^3 C_\nabla = 10^3 \nabla / LBP^3$	3,00
Sectional Coefficient CX at maximum section (St 9)	0,8065
Lcb/Lbp (forward of transom)	0,475

Table 6. Form parameters varied to generate D-Series

Cp	0,600	0,620	0,646
B/T	3,500	3,750	4,000
$10^3 C_\nabla$	3,000	3,500	4,000

The lines of the series were redesigned in Maxsurf Modeler and AutoCAD to obtain the final design of the hull; this was an iterative process that considered various modifications to the shape in order to obtain a modern design.

Table 7. Model results

Displacement	750,6	tonnes
Volume (displaced)	732,287	m^3
Draft Amidships	3,000	m
Immersed depth	3,011	m
WL Length	62,000	m
Beam max extents on WL	8,741	m
Wetted Area	572,888	m^2
Max sect. area	17,943	m^2
Waterpl. Area	414,302	m^2
Prismatic coeff. (Cp)	0,658	-
Block coeff. (Cb)	0,449	-
Max Sect. area coeff. (Cm)	0,685	-
Waterpl. area coeff. (Cwp)	0,764	-
LCB length from amidsh. (+ve fwd)	-2,760	m
LCF length from amidsh. (+ve fwd)	-4,093	m
LCB % from amidsh. (+ve fwd)	-4,452	% Lwl
LCF % from amidsh. (+ve fwd)	-6,601	% Lwl
KB	3,202	m
Displacement	750,6	tonnes
Volume (displaced)	732,287	m^3
Draft Amidships	3,000	m
Immersed depth	3,011	m
WL Length	62,000	m
Beam max extents on WL	8,741	m

Figure 2. Profile

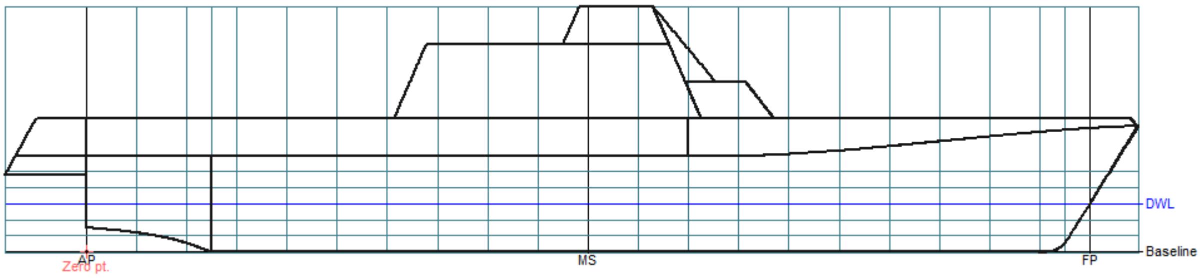


Figure 3. Plan

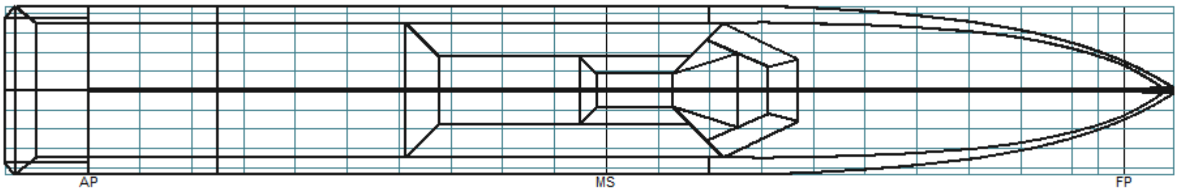


Figure 4. Transverse

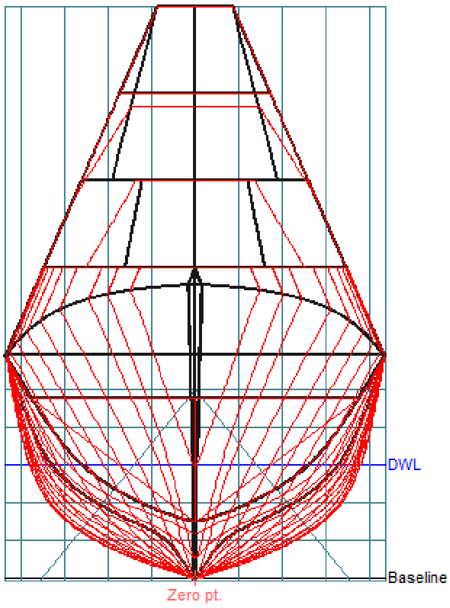
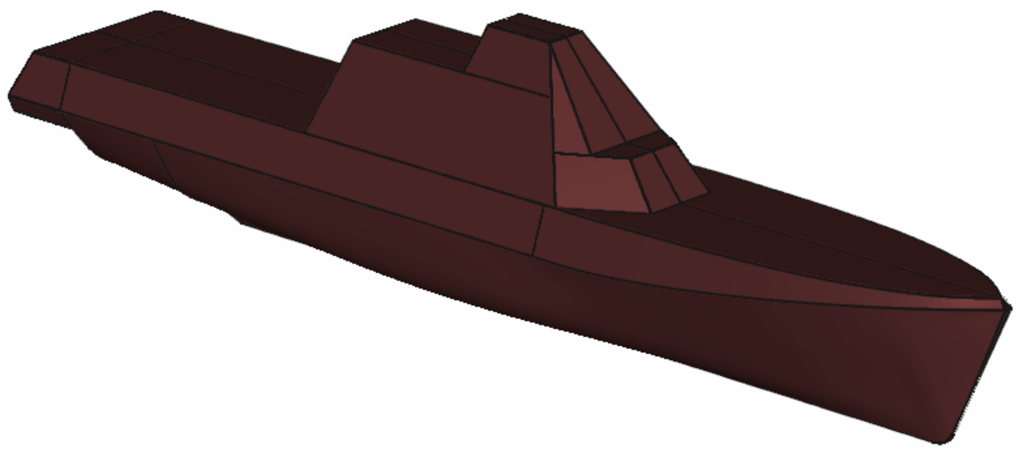


Figure 5. 3D

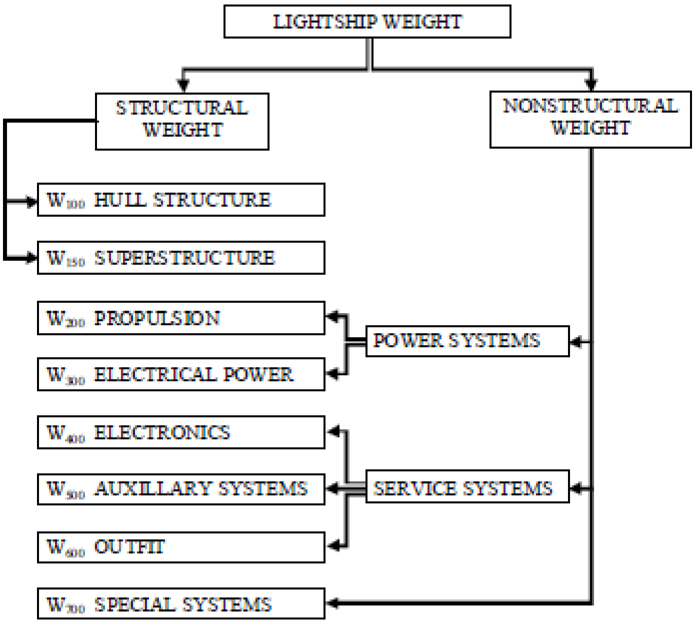


6. WEIGHTS ESTIMATE

Initial data were collected when study of the Maritime administration vessels was made by Grubisic et al. (1996). After completion of that work, new data were systematically gathered and added to the original database.

Data collected and saved in the database are quite variable regarding the applied system of weight breakdown, different origin, different practices, different countries, different rules, etc. Basically, the system of grouping is shown in Figure 6.

Figure 6. First level weight breakdown



STRUCTURAL WEIGHT MODEL

Weight of the hull structure is based on estimating plating area of the four major components, i.e. bottom, sides, deck and bulkheads. Relative surface weights are estimated due to the differences in pressure loading of specific area. This approach was developed by Grubisic and Begovic (2003) and applied to fast vessels. Four principal surface areas were estimated by expressions:

Bottom: $$S_1 = 2{,}825 \cdot \sqrt{\Delta_{FL} \cdot L_{WL}} \quad (8)$$

Sides: $$S_2 = 1{,}09 \cdot (2 \cdot L_{OA} + B_M) \cdot (D_X - T_X) \quad (9)$$

Deck: $$S_3 = 0{,}823 \cdot B_M \cdot (L_{OA} + L_{WL})/2 \quad (10)$$

Bulk: $$S_4 = 0{,}6 \cdot N_{WTB} \cdot B_M \cdot D_X \quad (11)$$

Since weight of each area is different a reduced surface area is predicted by considering the different loading of the respective parts of complete area:

$$S_R = S_1 + 0{,}73 \cdot S_2 + 0{,}69 \cdot S_3 + 0{,}65 \cdot S_4 \quad (12)$$

Neglecting the 4% difference of the respective lengths, the displacement correction factor is determined by:

$$f_{DIS} = 0{,}7 + 2{,}4 \cdot \frac{\nabla}{{L_{WL}}^2 - 15{,}8} \quad (13)$$

Correction for the influence of the T/D ratio is best described by:

$$C_{T/D} = 1{,}144 \cdot (T/D)^{0{,}244} \tag{14}$$

When applied to the database vessels (DB1) both correction factors are estimated to be in the range from minimal to maximal values as shown in Table 8:

Table 8. Correction factors

Correction factor	f_{DIS}	$C_{T/D}$
Minimum value	0,906	0,828
Maximum value	1,274	1,024

Effective surface area is estimated from the reduced surface area SR by correction for displacement and T/D, respectively. Finally, the new structural numeral is given by:

$$E_S = f_{DIS} \cdot C_{T/D} \cdot S_R \tag{15}$$

By the analogy with the Watson's and Gilfillan's method the value of the exponent is found to be 1,33. This is surprisingly close to the original exponent of 1,36. The structural weight is now determined by the equation:

$$W_K = K_0 \cdot {E_S}^{1{,}33} \tag{16}$$

The coefficient K0 is subsequently replaced by the three factors taking care of the service area, service type and structural material influence as given by:

$$W_S = K_S \cdot f_{SAR} \cdot f_{SRV} \cdot f_{MAT} \cdot {E_S}^{1{,}33}/1000 \tag{17}$$

The remaining factor KS describes each individual vessel and for general case is assumed to be unity. When prototype vessel is at hand the value of K0 may be determined from that data.

Other factors in(17)are determined as follows:

Service area notation is related to the bottom pressure via design pressure factor. The bottom pressure is related to the weight of bottom structure. Table 9is composed from the data given by the LR SSC rules (1996):

Table 9. LR SSC service areas definition

Service area notation	N_{LR}	Range to refuge N_M	Min. wave height $H_{1/3}$ m	Design pressure factor
G1	1	Sheltered waters	0,6	0,60
G2	2	20	1,0	0,75
G3	3	150	2,0	0,85
G4	4	250	4,0	1,00
G5	5	>250	>4,0	1,20
G6	6	Unrestricted service	>4,0	1,25

The vessels in the database were of variable origin and not built at the same time neither according to the consistent set of rules. Therefore, a best estimate of the corresponding service area notation is made. The influence of service area is estimated by comparing complete hull weights of the database vessels to the LR service area notation. The best correlation is found as in equation(18):

$$f_{SAR} = 0{,}7202 + 0{,}0628 \cdot N_{LR} \quad (18)$$

Service type factors determined from the data base vessels are shown in Table 10.

Table 10. Service type correction factor

Service type	f_{SVR}
MIL	1,007
MY	1,013
PATROL	1,089
WORK	1,384
SAR	1,439

Hull material factors are determined by fitting data for the respective database craft grouped by hull material. The analysis of database produced tentatively the hull material factors in Table 11.

Table 11. Structural material correction factor

Hull structural material	f_{MAT}
MILD STEEL	17,28
HTS	11,03
AL	7,86
FRP	11,36
FRPS	7,00
WLAM	9,00

Table 12. Structural weight

Displacement	Δ	750,6	tonnes
Volume displaced	∇	732	m^3
Length overall	L_{OA}	70,00	m
Length at waterline	L	62,00	m
Molded beam	B_M	10,00	m
Molded draught	D	5,90	m
Draft	T	3,00	m
N° of watertight bulkheads	N_{WTB}	6	-
Bottom	S1	609	m^2
Sides	S2	474	m^2
Deck	S3	543	m^2
Bulk	S4	212	m^2
Complete area	SR	1468	m^2
Displacement correction	f_{DIS}	1,159	-
T/D correction	$C_{T/D}$	0,970	-
Effective surface	ES	1651	m^2
Service area factor	f_{SAR}	1,097	-
Service type factor	f_{SRV}	1,007	-
Hull material factor	f_{MAT}	7,860	-
Structural weight	$\mathbf{W_{100}}$	**165,3**	**tonnes**

PROPUSLSION WEIGHT MODEL

The engines are selected so we know the weight of each one of them and the total weight of the propulsion machinery. This is composed of four gas turbines Vericor TF50B of 654 kg each and two marine dual fuel engines Wärtsilä6L20DF of 9.400 kg each giving a total weight of 21.416 kg.

ELECTRICAL POWER WEIGHT MODEL

Sometimes the weight of the electrical power group is hidden within engine room weight where it is taken together with propulsion power. Weight of the electrical power group is highly correlated to the cubic module irrespective of the ship type.

$$W_{300} = \frac{(L \cdot B \cdot D)^{1,24}}{592} \tag{19}$$

ELECTRONIC EQUIPMENT WEIGHT MODEL

Electronic equipment is very variable, and the rate of development is probably the highest in engineering practice. Besides it reflects the policy of the owner towards accepting new solutions. Database provided limited information that can be useful only at the very beginning:

$$W_{400} = 0,0365 + 0,0015 \cdot L \cdot B \cdot D \tag{20}$$

AUXILIARY MACHINERY WEIGHT MODEL

Auxiliary machinery systems are correlated with ship size and type, but it is very difficult to consider variability of owner's requirements. The best correlation was found as shown in the equation:

$$W_{500} = 0{,}000772 \cdot (L \cdot B)^{1{,}784} \tag{21}$$

OUTFIT WEIGHT MODEL

Weight of outfit is highly dependent on the equipment standard of the vessel. The best correlation was found relative to the length of the vessel:

$$W_{600} = 0{,}0097 \cdot L^{2{,}132} \tag{22}$$

SPECIAL SYSTEM WEIGHT MODEL

Weight of special systems was originally meant to relate to the armament only, but here we consider that W700 means all weight that is specific to the ship main purpose, i.e. passenger equipment for ferries, research equipment for research ships, etc. In principle this group is not meant to cover the equipment that is found on every type of vessel, only the specific weight for the purpose of vessel function. The best correlation was found with ship length, beam and draught:

$$W_{700} = 0{,}000333 \cdot (L \cdot B \cdot D)^{1{,}422} \tag{23}$$

LIGHTSHIP WEIGHT

Table 13. Lightship weight

Length at waterline	L	62,00	m
Molded beam	B	8,74	m
Draught	D	5,90	m
Total engine power	BKW	22.652	kW
Total electrical power	P_{EG}	1.000	kW
Structural weight	W_{100}	165,3	tonnes
Propulsion weight	W_{200}	109,5	tonnes
Electrical power weight	W_{300}	32,6	tonnes
Electronic equipment weight	W_{400}	4,8	tonnes
Auxiliary machinery weight	W_{500}	58,2	tonnes
Outfit weight	W_{600}	64,3	tonnes
Special system weight	W_{700}	32,1	tonnes
Total	$\mathbf{W_{LS}}$	**466,8**	**tonnes**

CENTER OF GRAVITY OF LIGHTSHIP

STRUCTURAL CENTER OF GRAVITY

The vertical center of gravity of the structure can be estimated using an equation proposed by Kupras for ships of length lower than 120 meters.

$$VCG = 0{,}01 \cdot D \cdot (46{,}6 + 0{,}135 \cdot (0{,}81 - Cb) \cdot (L/D)^2) \tag{24}$$

The longitudinal position of the basic structural weight will typically be slightly aft of the LCB position. Watson gives the suggestion (25) where both LCG and LCB are in percent ship length, plus forward of amidships.

$$\mathrm{LCG} = -0{,}15 + \mathrm{LCB} \tag{25}$$

Table 14. Structural center of gravity

Length at waterline	L	68,200	m
Depth	D	5,900	m
Beam at waterline	B	8,741	m
Block coefficient	Cb	0,450	-
Longitudinal center of buoyancy	LCB	-4,452	%
Vertical center of gravity	**VCG_S**	**3,133**	**m**
Longitudinal center of gravity	LCG_S	-4,602	%
Longitudinal center of gravity	**LCG_S**	**28,147**	**m**

MACHINERY CENTER OF GRAVITY

In this item we consider for the machinery the propulsion, the electrical power and the auxiliary machinery weight models in the same center of gravity.

The vertical center of the machinery weight will depend upon the inner bottom height h_{db} and the height of the overhead of the engine room D'. With these known, Kupras notes that the VCG of the machinery weight can be estimated as (26), which places the machinery VCG at 35% of the height within the engine room space.

$$\mathrm{VCG_M} = \mathrm{h_{db}} + 0{,}35 \cdot (\mathrm{D'} - \mathrm{h_{db}}) \tag{26}$$

Table 15. Machinery center of gravity

Overhead of engine room	D'	5,9	m
Inner bottom height	h_{db}	1,3	m
Vertical center of gravity	**VCG_M**	**2,910**	**m**

The longitudinal center of the machinery weight depends upon the overall layout of the vessel. For machinery aft vessels, the LCG can be taken near the after end of the main engines. With relatively lighter prime movers and longer shafting, the relative position of this center will move further aft.

OUTFIT CENTER OF GRAVITY

In this case we consider the rest of the weights models, outfit properly speaking, general to all ships, and special systems that are considered the outfit typical of the ship's activity.

The vertical center of the outfit weight is typically above the main deck and can be estimated using an equation proposed by Kupras for ships of L≤125 m.

$$\mathrm{VCG_O} = \mathrm{D} + 1{,}25 \tag{27}$$

Table 16. Outfit center of gravity

Main deck height	D	5,900	m
Vertical center of gravity	**VCG_O**	**7,150**	**m**

VARIABLE WEIGHTS MODEL

W800 comprises all variable weights including payload and all consumables. The deadweight items can be estimated from first principles and early decisions about the design of the vessel.

The selection of machinery type and prime mover permits the estimation of the Specific Fuel Consumption (SFC) (g/KWh) for the propulsion plant so that the fuel weight can be estimated using:

$$W_{EF} = \frac{P \cdot sfc \cdot R}{s} + 10\% \tag{28}$$

Table 17. Fuel

Engine MCR	P	1065	KW
N° of engines	n	1	
Fuel consumption	sfc	187	g/KWh
Range	R	8000	nmi
Cruise speed	s	12	knots
Marine diesel weight	**W_{EF}**	**146,0**	**tonnes**

In this case was considered for 12 knots using only one engine coupled to one propeller shaft plus one alternator for electrical power production at the cruise speed mentioned above.

Additionally, the fuel of the generators must be considered, in this case will be a total of three gensets but during only two will work continuously, leaving one for emergency.

$$W_{GF} = P \cdot sfc \cdot d + 10\% \tag{29}$$

Table 18. Gensets fuel

Engine MCR	P	500	KW
N° of gensets	n	1	
Fuel consumption	sfc	222	g/KWh
Days	d	28	
Marine diesel weight	**W_{GF}**	**82,1**	**tonnes**

The lube oil can be estimated as a 4% of the total fuel.

$$W_{LO} = 4\% \cdot W_{MDO} \tag{30}$$

Table 19. Lube oil

Marine diesel weight	W_F	228,1	tonnes
Lube oil weight	**W_{LO}**	**9,1**	**tonnes**

The weight of fresh water depends upon the designer's intent relative to onboard distillation and storage. Modern commercial vessels often just carry water for the entire voyage and eliminate the need to operate and maintain water-making equipment with a small crew. Naval vessels and cruise vessels obviously have much higher capacity demands making onboard distillation more of a necessity, in this case will consider water for only 5 days. Based on using 45 gallons per person/day, the total water tankage weight would need to be:

$$W_{FW} = 0{,}17 \cdot C \cdot d \tag{31}$$

Table 20. Fresh water

Complement	C	40	
Days	d	4	
Fresh water weight	$\mathbf{W_{FW}}$	**27,2**	**tonnes**

The weight of the crew and their effects can be estimated as(32) for naval vessel might use 0,18 t/person for officers and 0.104 t/person for enlisted.

$$W_{C\&E} = 0{,}18 \cdot C_O \cdot d + 0{,}18 \cdot C_E \cdot d \tag{32}$$

Table 21. Crew & effects

Enlisted	C_E	30	-
Officers	C_O	10	-
Crew & effects weight	$\mathbf{W_{C\&E}}$	**6,4**	**tonnes**

For the provisions, stores, and their packaging, naval vessel standards provide about 40 gallons water per person or accommodation/day and provisions and stores at about 0.0036 t/(person/day).

$$W_{PR} = 0{,}0036 \cdot C \cdot d \tag{33}$$

Table 22. Provisions

Complement	C	40	-
Days	d	30	-
Provisions weight	$\mathbf{W_{PR}}$	**4,3**	**tonnes**

Due the vessel's mission requires the use of a helicopter, we need to estimate the fuel used for this. The helicopter is an Eurocopter AS550 Fennec whit a capacity of 540 liters of Jet A-1 fuel.

$$W_H = \frac{V_f \cdot \rho \cdot n}{1000^2} \tag{34}$$

Table 23. Helicopter fuel

Volume	V_f	540,0	liters
Fuel density	ρ	840,0	g/liters
Number of trips	n	10	-
Helicopter fuel weight	$\mathbf{W_H}$	**4,5**	**tonnes**

For last we need to estimate the main (Leonardo's Marlin 40 mm Naval Gun) and secondary (Mk 38 Mod 3 Machine Gun System (MGS)) weapon ammunition.

$$W_A = W_{PP} \cdot n \tag{35}$$

Table 24. Main weapon ammunition

Weight per projectile	W_{PP}	2,5	kg
Number of rounds	n	1000	-
Main ammo weight	$\mathbf{W_A}$	**2,5**	**tonnes**

Table 25. Secondary weapon ammunition

Weight per projectile	W_{PP}	0,5	kg
Number of rounds	n	3360	-
Second. ammo weight	$\mathbf{W_A}$	**1,7**	**tonnes**

Table 26. Total deadweight

Marine diesel weight	W_F	228,1	tonnes
Lube oil weight	W_{LO}	9,1	tonnes
Fresh water weight	W_{FW}	27,2	tonnes
Crew & effects weight	$W_{C\&E}$	6,4	tonnes
Provisions weight	W_{PR}	4,3	tonnes
Helicopter fuel weight	W_H	4,5	tonnes
Ammunition weight	W_A	4,2	tonnes
Total	$\mathbf{W_{DWT}}$	**283,9**	**tonnes**

TOTAL WEIGHT

Table 27. Total weight

Lightship weight	W_{LS}	466,8	tonnes
Deadweight	W_{DWT}	283,9	tonnes
Total weight	$\mathbf{W_T}$	**750,7**	**tonnes**

MARGINS

Table 28. Tentative margins by weight groups

Structural weight (aluminum)	W_{100}	10	%
Propulsion system	W_{200}	10	%
Electrical power system	W_{300}	10	%
Electronic systems	W_{400}	50	%
Auxiliary systems	W_{500}	10	%
Outfit	W_{600}	12	%
Special systems	W_{700}	5	%
Deadweight	W_{800}	6	%

LOAD CONDITIONS

Table 29. Light weight condition

Item	Qty.	Unit mass (tonnes)	Total mass (tonnes)	Unit volume (m3)	Total volume (m3)	LCG (m)	TCG (m)	VCG (m)	Total F.S.M. (tonnes.m)
Lightship									
Structure - W_{100}	1	165,300	165,300			28,147	0,000	3,029	0,000
Propulsion - W_{200}	1	109,500	109,500			15,500	0,000	2,910	0,000
Electrical power - W_{300}	1	32,600	32,600			15,500	0,000	2,910	0,000
Electronics - W_{400}	1	4,800	4,800			33,225	0,000	13,950	0,000
Auxiliary - W_{500}	1	58,200	58,200			15,500	0,000	2,910	0,000
Outfit - W_{600}	1	64,300	64,300			31,000	0,000	7,150	0,000
Special system - W_{700}	1	32,100	32,100			31,000	0,000	7,150	0,000
Subsubtotal			466,800			23,362	0,000	3,941	0,000
Total Loadcase			466,800	410,966	295,454	23,362	0,000	3,941	0,000
FS correction								0,000	
VCG fluid								3,941	

Table 30. Full load condition

Item	Qty.	Unit mass (tonnes)	Total mass (tonnes)	Unit volume (m3)	Total volume (m3)	LCG (m)	TCG (m)	VCG (m)	Total F.S.M. (tonnes.m)
Lightship	1	466,800	466,8			23,362	0,000	3,941	0,000
Helicopter fuel									
Tank N°01 - Jet A-1	100%	2,275	2,275	2,708	2,708	16,430	-3,150	7,050	0,000
Tank N°02 - Jet A-1	100%	2,275	2,275	2,708	2,708	16,430	3,150	7,050	0,000
Subsubtotal	100%	4,550	4,550	5,416	5,416	16,430	0,000	7,050	0,000
Lube oil									
Tank N°03 - Lube Oil	100%	4,667	4,667	5,073	5,073	17,362	-1,026	1,481	0,000
Tank N°04 - Lube Oil	100%	4,667	4,667	5,073	5,073	17,362	1,026	1,481	0,000
Subsubtotal	100%	9,335	9,335	10,147	10,147	17,362	0,000	1,481	0,000
Fuel									
Tank N°05 - Diesel	100%	23,501	23,501	27,977	27,977	21,739	-1,057	1,429	0,000
Tank N°06 - Diesel	100%	23,501	23,501	27,977	27,977	21,739	1,057	1,429	0,000
Tank N°07 - Diesel	100%	24,373	24,373	29,016	29,016	27,902	-1,073	1,398	0,000
Tank N°08 - Diesel	100%	24,373	24,373	29,016	29,016	27,902	1,073	1,398	0,000
Tank N°09 - Diesel	100%	23,837	23,837	28,377	28,377	34,075	-1,062	1,417	0,000
Tank N°10 - Diesel	100%	23,837	23,837	28,377	28,377	34,075	1,062	1,417	0,000
Tank N°11 - Diesel	100%	22,127	22,127	26,342	26,342	40,245	-1,019	1,469	0,000
Tank N°12 - Diesel	100%	22,127	22,127	26,342	26,342	40,245	1,019	1,469	0,000
Tank N°13 - Diesel	100%	18,425	18,425	21,934	21,934	46,348	-0,892	1,536	0,000
Tank N°14 - Diesel	100%	18,425	18,425	21,934	21,934	46,348	0,892	1,536	0,000
Subsubtotal	100%	224,527	224,527	267,294	267,294	33,383	0,000	1,445	0,000
Fresh water									
Tank N°15 - Fresh Water	100%	14,078	14,078	14,078	14,078	53,227	-0,561	1,558	0,000
Tank N°16 - Fresh Water	100%	14,078	14,078	14,078	14,078	53,227	0,561	1,558	0,000
Subsubtotal	100%	28,157	28,157	28,157	28,157	53,227	0,000	1,558	0,000
Crew & effects	40	0,160	6,400			28,429	0,000	5,900	0,000
Provisions	1	4,300	4,300			28,429	0,000	3,624	0,000
Ammunition	1	4,200	4,200			51,15	0,000	4,025	0,000
Ballast									
Tank N°17 - Ballast	0%	7,684	0,000	7,496	0,000	27,854	-2,689	1,137	0,000
Tank N°18 - Ballast	0%	7,684	0,000	7,496	0,000	27,854	2,689	1,137	0,000
Tank N°19 - Ballast	0%	8,404	0,000	8,199	0,000	28,555	-2,854	1,136	0,000
Tank N°20 - Ballast	0%	8,404	0,000	8,199	0,000	28,555	2,854	1,136	0,000
Tank N°21 - Ballast	0%	14,189	0,000	13,843	0,000	31,017	-1,917	1,158	0,000
Tank N°22 - Ballast	0%	14,189	0,000	13,843	0,000	31,017	1,917	1,158	0,000
Tank N°23 - Ballast	0%	6,194	0,000	6,043	0,000	37,208	-1,917	1,509	0,000
Tank N°24 - Ballast	0%	6,194	0,000	6,043	0,000	37,208	1,917	1,509	0,000
Tank N°25 - Ballast	0%	0,799	0,000	0,780	0,000	43,446	-1,917	2,409	0,000
Tank N°26 - Ballast	0%	0,799	0,000	0,780	0,000	43,446	1,917	2,409	0,000
Tank N°27 - Ballast	0%	27,911	0,000	27,231	0,000	59,111	0,000	0,000	0,000
Subtotal	0%	102,451	0,000	99,952	0,000	0,000	0,000	0,000	0,000
Total Loadcase			748,268	410,966	311,014	27,604	0,000	3,106	0,000
FS correction								0,000	
VCG fluid								3,106	

Table 31. Arrival condition

Item	Qty.	Unit mass (tonnes)	Total mass (tonnes)	Unit volume (m3)	Total volume (m3)	LCG (m)	TCG (m)	VCG (m)	Total F.S.M. (tonnes.m)
Lightship	1	466,800	466,8			23,362	0,000	3,941	0,000
Helicopter fuel									
Tank N°01 - Jet A-1	10%	2,275	0,227	2,708	0,271	16,430	-3,150	6,465	0,074
Tank N°02 - Jet A-1	10%	2,275	0,227	2,708	0,271	16,430	3,150	6,465	0,074
Subsubtotal	10%	4,550	0,455	5,416	0,542	16,430	0,000	6,465	0,149
Lube oil									
Tank N°03 - Lube Oil	10%	4,667	0,467	5,073	0,507	17,368	-0,429	0,423	0,201
Tank N°04 - Lube Oil	10%	4,667	0,467	5,073	0,507	17,368	0,429	0,423	0,201
Subsubtotal	10%	9,335	0,933	10,147	1,015	17,368	0,000	0,423	0,402
Fuel									
Tank N°05 - Diesel	47,8%	23,501	11,233	27,977	13,373	21,783	-0,955	0,884	5,280
Tank N°06 - Diesel	47,8%	23,501	11,233	27,977	13,373	21,783	0,955	0,884	5,280
Tank N°07 - Diesel	0%	24,373	0,000	29,016	0,000	27,900	-0,025	0,000	0,000
Tank N°08 - Diesel	0%	24,373	0,000	29,016	0,000	27,900	0,025	0,000	0,000
Tank N°09 - Diesel	0%	23,837	0,000	28,377	0,000	34,100	-0,025	0,000	0,000
Tank N°10 - Diesel	0%	23,837	0,000	28,377	0,000	34,100	0,025	0,000	0,000
Tank N°11 - Diesel	0%	22,127	0,000	26,342	0,000	40,300	-0,025	0,000	0,000
Tank N°12 - Diesel	0%	22,127	0,000	26,342	0,000	40,300	0,025	0,000	0,000
Tank N°13 - Diesel	0%	18,425	0,000	21,934	0,000	46,500	-0,025	0,000	0,000
Tank N°14 - Diesel	0%	18,425	0,000	21,934	0,000	46,500	0,025	0,000	0,000
Subsubtotal	10%	224,527	22,467	267,294	26,746	21,783	0,000	0,884	10,561
Fresh water									
Tank N°15 - Fresh Water	10%	14,078	1,408	14,078	1,408	53,238	-0,206	0,427	0,140
Tank N°16 - Fresh Water	10%	14,078	1,408	14,078	1,408	53,238	0,206	0,427	0,140
Subsubtotal	10%	28,157	2,816	28,157	2,816	53,238	0,000	0,427	0,280
Crew & effects	40	0,160	6,400			28,429	0,000	5,900	0,000
Provisions	0,1	4,300	0,430			28,429	0,000	3,624	0,000
Ammunition	0,1	4,200	0,420			51,150	0,000	4,025	0,000
Ballast									
Tank N°17 - Ballast	100%	7,684	7,684	7,496	7,496	23,652	-3,299	2,009	0,000
Tank N°18 - Ballast	100%	7,684	7,684	7,496	7,496	23,652	3,299	2,009	0,000
Tank N°19 - Ballast	100%	8,404	8,404	8,199	8,199	29,450	-3,519	2,656	0,000
Tank N°20 - Ballast	100%	8,404	8,404	8,199	8,199	29,450	3,519	2,656	0,000
Tank N°21 - Ballast	100%	14,189	14,189	13,843	13,843	33,857	-3,468	2,725	0,000
Tank N°22 - Ballast	100%	14,189	14,189	13,843	13,843	33,857	3,468	2,725	0,000
Tank N°23 - Ballast	100%	6,194	6,194	6,043	6,043	39,663	-3,259	2,967	0,000
Tank N°24 - Ballast	100%	6,194	6,194	6,043	6,043	39,663	3,259	2,967	0,000
Tank N°25 - Ballast	100%	0,799	0,799	0,780	0,780	44,787	-3,053	3,297	0,000
Tank N°26 - Ballast	100%	0,799	0,799	0,780	0,780	44,787	3,053	3,297	0,000
Tank N°27 - Ballast	100%	27,911	27,911	27,231	27,231	60,357	0,000	4,246	0,000
Subtotal	100%	102,451	102,451	99,952	99,952	39,695	0,000	3,059	0,000
Total Loadcase			603,172	410,966	131,071	26,279	0,000	3,678	11,392
FS correction								0,019	
VCG fluid								3,697	

7. FLOODABLE LENGTH

Floodable length is calculated using Maxsurf Stability, whit the criteria for the compartments' permeability set according to DNV[1]. The analysis is set at the maximum displacement (750,6 tonnes) at an even keel, with a permeability of 95 % and a criteria that the margin line immersion is at the minimum freeboard (this is considered by the program as 76 mm from the margin line that in this case is considered the main deck at 5,9 meters from the base line), maximum angle of trim of 10 degrees, minimum transverse GM of 0,2 meters and minimum longitudinal GM of 0,2 meters. The curve defined by the numerical values are included in

.

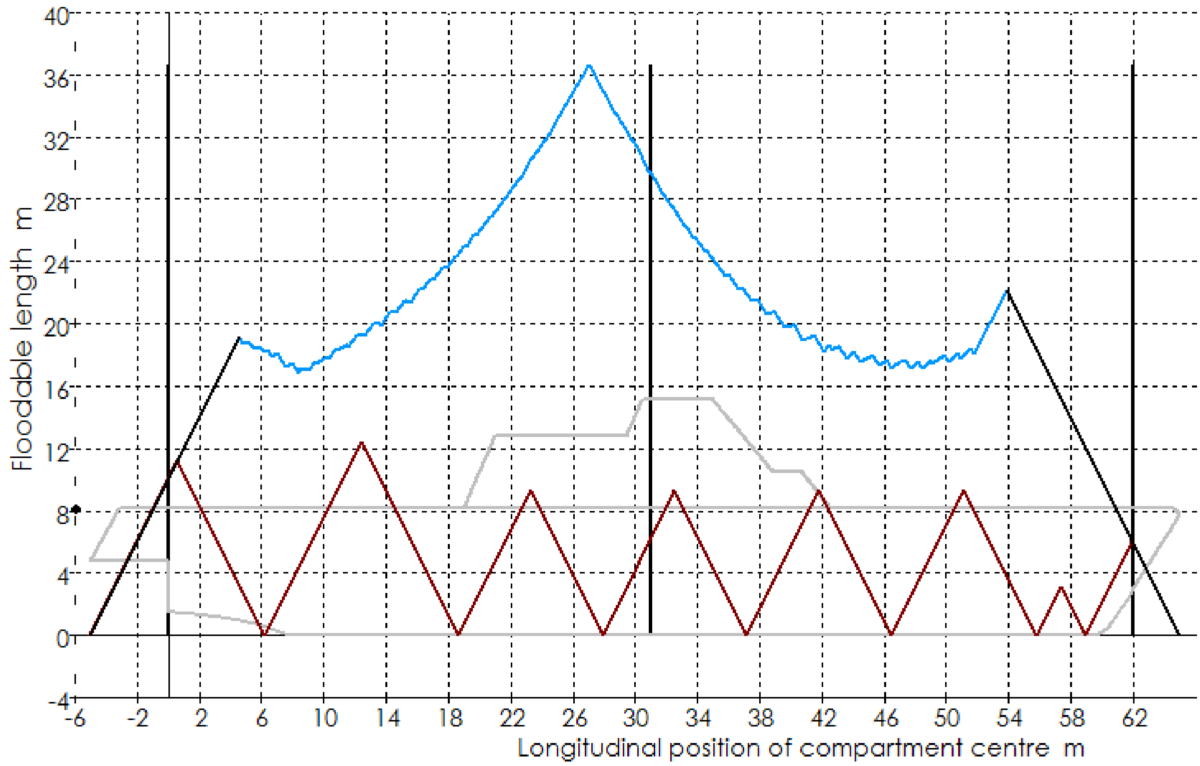
Table 32. Floodable length

Name	Long. Pos. (m)	Flood. Len. (m)
Displacement t		0,0000
LCG m		0,000
Permeability %		95
Station 00	0,000	10,00
Station 01	3,100	16,20
Station 02	6,200	18,21
Station 03	9,300	17,45
Station 04	12,400	19,29
Station 05	15,500	21,42
Station 06	18,600	24,44
Station 07	21,700	28,16
Station 08	24,800	32,80
Station 09	27,900	35,08
Station 10	31,000	29,66
Station 11	34,100	25,18
Station 12	37,200	21,81
Station 13	40,300	19,72
Station 14	43,400	18,11
Station 15	46,500	17,13
Station 16	49,600	17,85
Station 17	52,700	19,92
Station 18	55,800	18,40
Station 19	58,900	12,20
Station 20	62,000	6,00

[1] Rules for Ships/High Speed, Light Craft and Naval Surface Craft, January 2013 Pt.5 Ch.14 Sec.5 D204

The watertight subdivision adopted give as a result an acceptable floodable length curve. The peak at the turbine room compartment is just barely below the floodable length curve. This was concerning and was investigated further in the damage stability assessment. It should be noted that in reality, the permeability of the engine room would be less than 0.95 and as a substantial portion of the engine room is occupied by fuel tanks that would likely not all be damaged at once, the proximity between the engine room triangle and the floodable length curve is representative of an extreme case.

Figure 7. Floodable length curve



8. STRUCTURAL MID-SHIP SECTION

The midship section of a ship represents the most critical structural parameter of the vessel, its global strength. To assess how much of the bending moment (hog and sag) the vessel can tolerate, it is important to assess the structural strength of the mid-ship section.

The bending stress experienced by the midship section and the structural arrangement of this is calculated from DNV-RU-HSLC Pt.3 Ch.1. Edition August 2021. The material used is aluminum NV-5052 H34.

LONGITUDINAL BENDING, SHEARING AND AXIAL LOADS

High speed mode – crest landing

$$M_B = \frac{\Delta}{2} \cdot (g_0 + a_{cg}) \cdot \left(e_w - \frac{l_s}{4}\right) \tag{36}$$

Table 33. Bending moment crest landing

Displacement	Δ	750,60	tonnes
Vertical acc. at L_{cg}	a_{cg}	5,31	m/s^2
half of the distance from L_{cg}	e_w	15,50	m
Long. extension of slamming	l_s	22,20	m
Gravity	g_0	9,81	m/s^2
Bending moment	M_B	**56.441**	**kNm**

High speed mode – hollow landing

$$M_B = \frac{\Delta}{2} \cdot (g_0 + a_{cg}) \cdot (e_r - e_w) \tag{37}$$

Table 34. Bending moment hollow landing

Displacement	Δ	750,60	tonnes
Vertical acc. at L_{cg}	a_{cg}	5,31	m/s^2
half of the distance from L_{cg}	e_w	15,50	m
Mean distance from $A_R/2$ to L_{cg}	e_r	23,25	m
Gravity	g_0	9,81	m/s^2
Bending moment	M_B	**-43.966**	**kNm**

Hogging and sagging bending moments

$$\begin{aligned} &M_{SW} = 0{,}11 \cdot C_W \cdot L^2 \cdot B \cdot Cb \text{ in hogging if not known} \\ &M_{SW} = 0 \text{ in sagging if not known} \\ &M_W = 0{,}19 \cdot C_W \cdot L^2 \cdot B \cdot Cb \text{ in hogging} \\ &M_W = 0{,}14 \cdot C_W \cdot L^2 \cdot B \cdot (Cb + 0{,}7) \text{ in sagging} \end{aligned} \tag{38}$$

Table 35. Bending moment hogging and sagging

Wave coefficient	Cw	4,960	-
Length at waterline	L	62,000	m
Beam at waterline	B	8,741	m
Block coefficient	Cb	0,450	-
Still water bending moment	M_{sw}	8.250	kNm
Wave bending moment hogging	M_w	14.249	kNm
Wave bending moment sagging	M_w	26.832	kNm
Bending moments (still water + wave)	**M_{tot}**	**35.082**	**kNm**

HULL SECTION MODULUS REQUIREMENT

$$Z = \frac{M}{\sigma} \cdot 10^3 \tag{39}$$

Table 36. Minimum section modulus

Maximum moment	M_{max}	56.441	kN
Material factor	f1	0,69	
175 f1 N/mm² in general	σ	121	N/mm²
Minimum modulus	**Z_{min}**	**467.418**	**cm³**

The maximum moment is the maximum value from the longitudinal midship bending moment in kNm from DNV, sagging or hogging bending moment, hollow landing or crest landing bending moment or maximum still water + wave bending moment for high speed displacement craft and semi-planing craft in the displacement mode.

Where calculating the moment of inertia and section modulus of the midship section, the effective sectional area of continuous longitudinal strength members is in general the net area after deduction of openings. Superstructures which do not form a strength deck are not to be included in the net section. This applies also to deckhouses and bulwarks.

PLATING

Buckling strength requirements are related to longitudinal hull girder stresses. Panels subjected to other compressive, shear or biaxial stresses will be specially considered.

Minimum thickness for plating, stiffeners, girders and web frames.

$$t = \frac{t + k \cdot L}{\sqrt{f}} \cdot \frac{s}{s_R} \tag{40}$$

Table 37. Plating

Length	L	62,00	m
Material factor	f1	0,690	-
Actual stiffener spacing	s	0,620	m
Basic stiffener spacing	sR	0,324	m
Relation	s/sR	1	-

Item	**t0 (mm)**	**k**	**t (mm)**	**$t_{adopted}$ (mm)**
Bottom, bilge and side to loaded water line	4	0,03	6,24	**7**
Strength deck weather part forward of amidships	3	0,03	5,24	**6**
Inner bottom	3	0,03	5,24	**6**
Tank bulkhead	3	0,03	5,24	**6**
Bottom center girder	3	0,05	6,73	**7**
Bottom side girders, floors, brackets and stiffeners	3	0,03	5,24	**6**
Longitudinals	3	0,03	5,24	**6**
Double bottom floors and girders	3	0,02	4,49	**5**

STIFFENERS

Minimum section modulus

The section modulus of longitudinals, beams, frames and other stiffeners subjected to lateral pressure is not to be less than:

$$Z = \frac{m \cdot l^2 \cdot s \cdot p}{\sigma} \tag{41}$$

Table 38. Stiffeners

Bending stress	σ	110,4	N/mm²
Design pressure	p	59,76	kN/m²

Item	s (m)	l (m)	m	**Z (cm3)**
Bottom transverse members	0,620	1,150	100	**45**
Side vertical members	0,620	1,150	100	**45**
Deck transverse members	0,620	1,150	100	**45**

The section selected for all the stiffeners is L 75 x 12,7 mm.

WEB FRAMES AND GIRDER SYSTEMS

In this section the general requirements for simple girders and procedures for the calculations of complex girder systems are given.

Minimum section modulus

$$Z = \frac{m \cdot S^2 \cdot b \cdot p}{\sigma} \quad (42)$$

Table 39. Minimum modulus of web frames & girders

Bending stress	σ	110,4	N/mm²
Design pressure	p	59,76	kN/m²

Item	s (m)	b (m)	m	**Z (cm³)**
Web frames	3,100	1,150	100	**599**
Floors	3,100	1,150	100	**599**
Longitudinal girders bottom	1,150	3,100	100	**222**
Longitudinal girders side	1,150	3,100	100	**222**

For floors and web frames the section selected is L 300 x 12,7 x 150 x 25,4 mm, and for longitudinal girders the section selected is L 150 x 12,7 x 75 x 25,4 mm.

MID-SHIP SECTION MODULUS

The section obtained in the

give us a section modulus for the top and the bottom of:

Table 40. Mid-ship section modulus

Minimum modulus	Z_{min}	467.418	cm³
Actual top modulus	Z_{top}	544.383	cm³
Actual bottom modulus	Z_{bottom}	-556.772	cm³

The effective breadth of the attached plating was considered in the actual net section modulus for the yielding check of stiffeners.

9. SPEED VS. POWER ANALYSIS

Due the two very different speeds of the vessel, cruise speed for long range and maximum speed for chasing o escaping, are needed two methods to estimate the resistance. For the first one we used is Holtrop method designed for predicting the resistance of tankers, general cargo ships, fishing vessels, tugs, container ships and frigates, for the second one we used Savistky pre-planing is useful for estimating the resistance of a planing hull before it gets ‘onto the plane’; i.e. its pre-planing resistance. This two resistance prediction methods were compared whit the Slender Body method included in Maxsurf Resistance.

Is considered valid the resistance given by Holtrop method between 0 to 24 knots, and for Savistky pre-planning method between 24 to 35 knots.

Figure 8. Speed vs. resistance curve

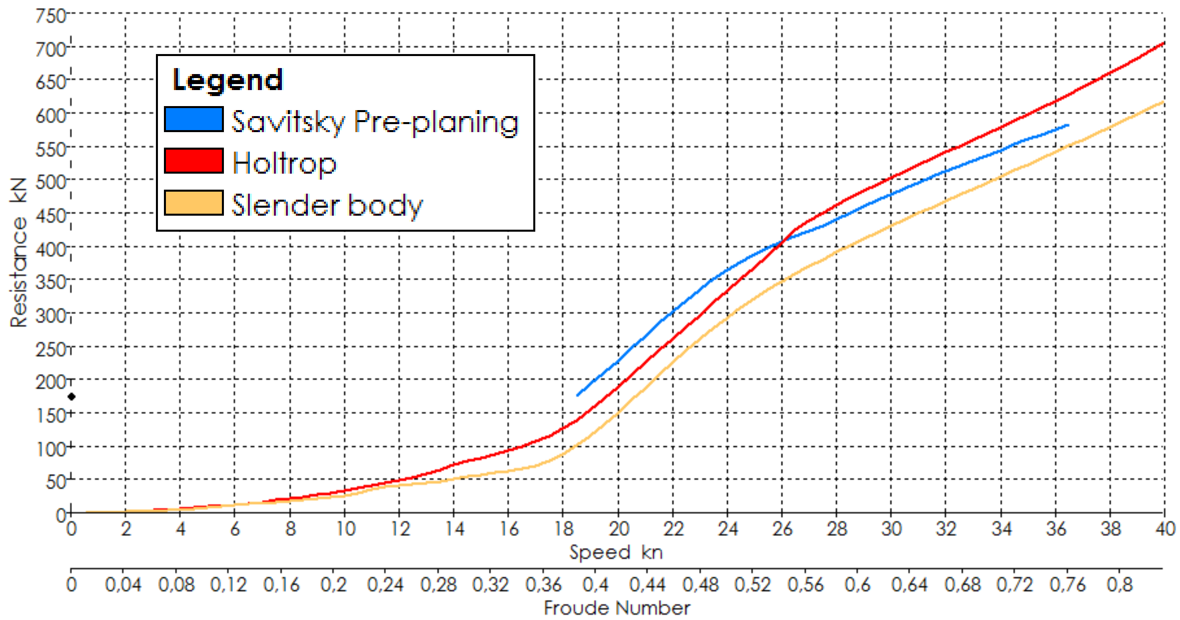


Figure 9. Speed vs. power curve

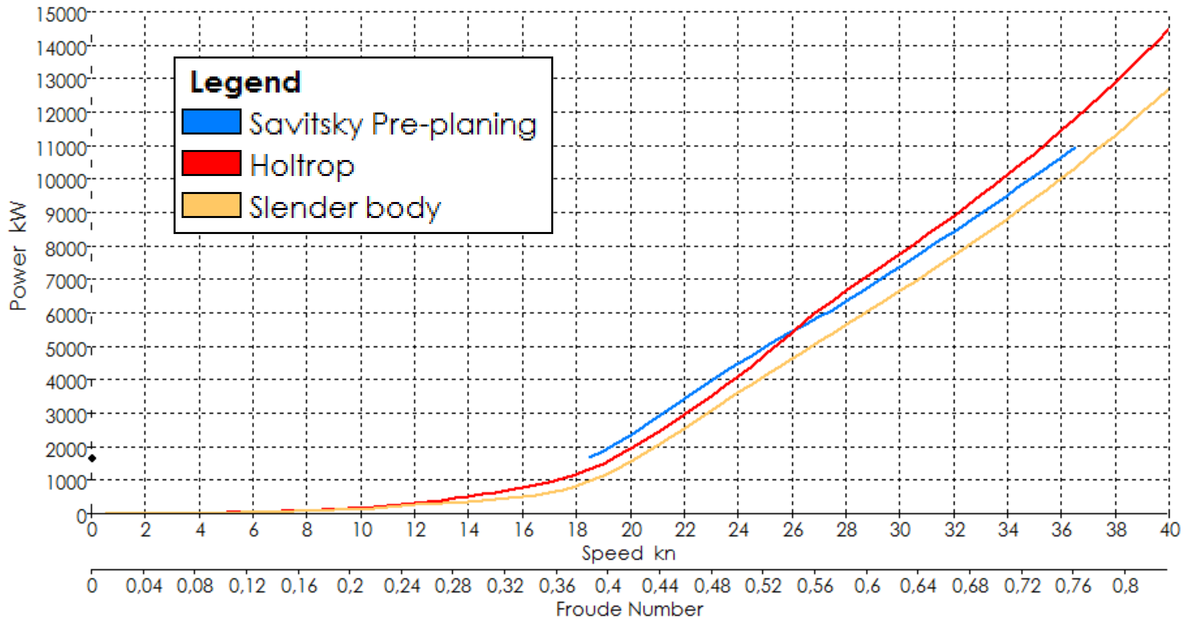


Table 41. Speed vs Resistance & SKW

Speed (knots)	Fn Lwl	Fn Vol.	Savistky pre-planning (kN)	Savistky pre-planning (kW)	Holtrop (kN)	Holtrop (kW)	Slender body (kN)	Slender body (kW)
0	0,000	0,000	--	--	--	--	--	--
1	0,021	0,055	--	--	0,4	0	0,4	0
2	0,042	0,109	--	--	1,6	2	1,3	1
3	0,063	0,164	--	--	3,4	5	2,7	4
4	0,083	0,219	--	--	5,8	12	4,6	9
5	0,104	0,274	--	--	8,8	23	7,6	19
6	0,125	0,328	--	--	12,3	38	10,8	33
7	0,146	0,383	--	--	16,4	59	14,3	52
8	0,167	0,438	--	--	21,0	87	17,2	71
9	0,188	0,492	--	--	26,4	122	21,5	99
10	0,209	0,547	--	--	32,7	168	25,7	132
11	0,229	0,602	--	--	40,0	226	34,9	197
12	0,250	0,657	--	--	48,5	299	41,5	256
13	0,271	0,711	--	--	59,1	395	44,6	299
14	0,292	0,766	--	--	71,4	514	50,4	363
15	0,313	0,821	--	--	82,5	636	56,9	439
16	0,334	0,875	--	--	93,1	767	62,5	514
17	0,355	0,930	--	--	106,7	933	70,9	620
18	0,376	0,985	--	--	126,1	1.167	88,0	815
19	0,396	1,040	192,6	1.882	153,3	1.499	115,2	1.126
20	0,417	1,094	228,6	2.352	188,9	1.943	149,9	1.542
21	0,438	1,149	265,7	2.870	225,0	2.431	187,8	2.029
22	0,459	1,204	302,5	3.424	261,1	2.955	225,3	2.550
23	0,480	1,259	334,4	3.956	297,0	3.514	260,5	3.082
24	0,501	1,313	364,1	4.495	332,8	4.109	292,4	3.610
25	0,522	1,368	386,9	4.976	368,4	4.738	320,9	4.128
26	0,542	1,423	406,8	5.441	405,9	5.430	346,6	4.636
27	0,563	1,477	422,4	5.867	437,5	6.076	369,9	5.137
28	0,584	1,532	440,1	6.339	461,7	6.650	391,3	5.637
29	0,605	1,587	459,3	6.852	483,3	7.210	411,4	6.138
30	0,626	1,642	477,7	7.372	503,2	7.766	430,7	6.647
31	0,647	1,696	495,8	7.906	522,1	8.327	449,4	7.167
32	0,668	1,751	511,5	8.420	540,7	8.902	467,8	7.700
33	0,688	1,806	527,2	8.951	559,3	9.496	486,0	8.251
34	0,709	1,860	544,2	9.518	578,2	10.114	504,3	8.820
35	0,730	1,915	560,5	10.092	597,6	10.760	522,7	9.411
36	0,751	1,970	575,0	10.649	617,6	11.438	541,1	10.021

Table 42. Power estimation suitability

	Savistky	**Holtrop**	**Slender body**	**Actual**
$L/V^{1/3}$	3,07 – 12,4	-	4 – no limit	6,89
ie	3,7 – 28,6	-	-	10,9
L/B	2,52 – 18,26	3,9 - 15	-	7,09
B/T	1,7 – 9,8	2,4 – 4,0	-	2,91
At/Ax	0 – 1	-	-	0,30
LCG/L	-6,56% - 0,3%	-	-	-0,072 %
Cp	-	0,55 – 0,85	-	0,658

10. ELECTRICAL LOAD ANALYSIS

The Electrical Power Load Analysis (EPLA) for Surface Ships of the department of the navy Naval Sea Systems Command (NAVSEA), Washington Navy Shard data sheet is used.

The document lists typical load factors for calculating ship demand power, divided in six groups, and five ship operating conditions.

Demand power groups:

- Propulsion Plant
- Electric Plant
- Command & surveillance
- Auxiliary Systems
- Outfit and Furnishings
- Armament

Ship operating conditions:

- Anchor. An anchor condition is a ship operating condition in which the ship supplies all electric power while the ship is at anchor.
- A shore condition is a ship operating condition in which the ship receives all electric power from a shore facility or a tender.
- Cruising. A cruising condition is a ship operating condition corresponding to:
    a) Condition III Wartime Cruising as defined by the ship's requirements documents, for combatants.
    b) Cruising at a specified cruising speed; has self-defense capability (if provided) but is not at general quarters for non-combatants.
- Functional. A functional condition is a ship operating condition in which the ship is performing its designed function. The following are examples of a functional condition:
    a) Battle for destroyers and frigates.
    b) Air operation for aircraft carriers.
    c) Debarking operation for cargo and amphibious warfare ships.
    d) Replenishment-at-sea of ships for combat support and store ships.
    e) Tending operations for tenders and repair ships.
- Emergency. An emergency condition is a ship operating condition in which the ship is on emergency generator with ship service generators down. The emergency generators, as a minimum, supply loads associated with the following: for surface combatant, emergency ship control and selected self-defense weapons.

The breakdown of the electrical balance of each group is in the Appendix G

Table 43. Total electrical load

SWBS Group	Load (kW)				
	Anchor	**Shore**	**Cruising**	**Functional**	**Emergency**
1 - Propulsion Plant	39	11	248	263	10
2 - Electric Plant	100	87	50	59	33
3 - Command & surveillance	50	5	115	161	103
4 - Auxiliary Systems	85	61	107	105	39
5 - Outfit and Furnishings	123	107	133	113	13
6 - Armament	2	2	1	33	30
Total	**399**	**273**	**654**	**734**	**228**

The systems that are not specific to the ship or for which information was not available were not taken into account.

For anchor load condition, one genset will cover the needs. For shore load condition, the ship will cover the needs by connecting to the dock or can use the emergency genset. At cruising speed, a single diesel engine would be used for propulsion at 12 knots, this one coupled to a shaft tail generator to cover cruising load condition, plus one genset. At maximum speed, the two gensets will cover functional load condition. For emergency load condition, the ship must have an emergency genset.

Table 44. Gensets and alternators

Item	Units	Model	Brand	Data
Tail alternator	2	G2R 400 SSA/4	Cramaco	520 kW at 50 Hz
Gensets	2	D16 MG / S5L1MF41	Volvo Penta	525 kW at 50 Hz
Emergency genset	1	300EFOZCS	Kohler	300 Kw at 50 Hz

Conclusion

As can be seen, there is an oversizing of the electrical power, this is due to the fact that at this stage of the project we do not have all the complete data of all the systems, and it also gives us a margin to face an eventual combat situation, one or more of the systems could fail or be damaged.

11. INTACT STABILITY

Vessels with class notation Naval or Naval Support (Stab) shall comply with the requirements for stability, watertight and weathertight integrity applicable for main class with the modifications specified in Rules for classification: High speed and light craft — DNV-RU-HSLC Pt.5 Ch.7. Section 5 – Stability, watertight and weathertight integrity.

LOADING CONDITIONS

Compliance with the intact and damage stability criteria shall be demonstrated for the loading conditions shown in Table 45, and for any conditions of loading in the operating range between full load and minimum operating condition that will give poorer stability.

Table 45. Loading conditions

Load item	*Full load condition*	*Minimum operating condition*
Vessel's complement*	All persons with effects on board	All persons with effects on board
Ammunition	Magazines and ready service stowages filled to maximum capacity	1/3 of full load ammunition with maximum quantities in ready service stowage and remainder in magazines
Mines	Maximum number on board	Maximum number on board
Missiles	Maximum number on board	Least favourable quantity and disposition is assumed
Torpedoes	Maximum number on board	Least favourable quantity and disposition is assumed
Aircraft	All on board	All on board
Provisions	Stores filled	1/3 of full load
General stores	All on board	2/3 of full load
Lubrication oil	95% of maximum capacity	2/3 of full load
Fuel oil	95% of maximum capacity	Least favourable realistic disposition (Normally 5%)
Aviation fuel	95% of maximum capacity	1/2 of full load
Feed water	95% of maximum capacity	1/2 of full load and least favourable disposition
Fresh water	95% of maximum capacity	1/2 of full load and least favourable disposition
Bilge water tanks	Empty **	Empty **
Trim and ballast tanks	Empty **	Empty, unless full tanks are needed in order to obtain a favourable trim and/or sufficient stability **
Roll damping tanks	Filled to operating capacity	Filled to operating capacity
Overflow tank	1/2 full	Empty
Septic tanks	Empty	Empty
* The centre of gravity of the vessel's complement with effects is taken to be at deck level, 1. deck, mass 120 kg/ person ** Design conditions may be used.		

The load conditions are shown in Appendix H.

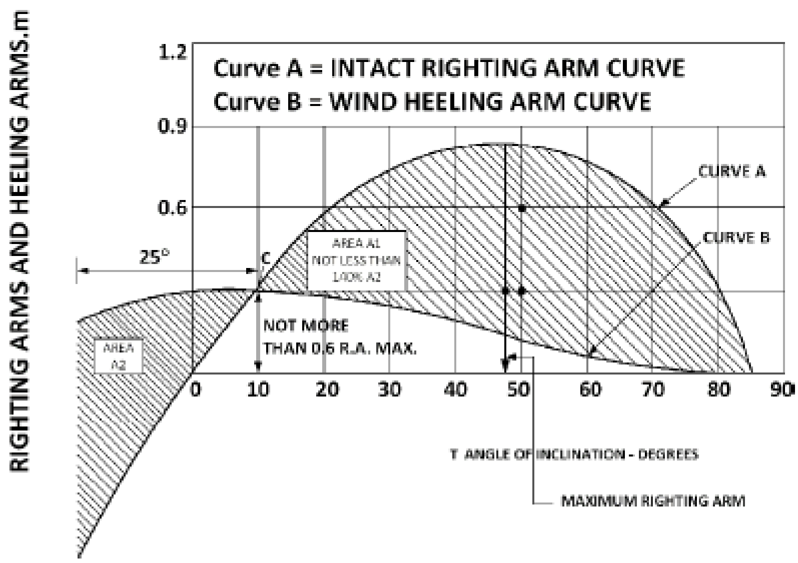
STABILITY CRITERIA

These stability conditions assume the vessel to be heeled over by the force of the wind alone until equilibrium occurs and then roll 25° from this point to windward.

The stability is considered satisfactory if:

1) The heeling arm at the intersection of the righting and heeling arm curve, point C in Figure 10, is not greater than six tenths of the maximum righting arm. See Figure 10.
2) The angle of heel corresponding to point C in Figure 10 does not exceed 15°.
3) The area A1 indicated in Figure 10 is not less than 1.4 A2 where the area A2 extends 25° to windward from point C. The area A1 is limited to the angle at which down flooding occur.
4) The range of the GZ curve is at least 70°.
5) The GZ-curve is positive over the complete range.

Figure 10. Stability criteria



HEELING ARM

$$t_W = \frac{0{,}02 \cdot cos^2(\theta)}{1000 \cdot \Delta} \cdot \sum_{i=1}^{n} {V_i}^2 \cdot A_i \cdot l_i = A \cdot cos^2(\theta) \tag{43}$$

Table 46. Full load condition

Wind lateral projected area vertical center	VCA_W	6,959	m
Underwater lateral projected area vertical center	VCA_U	1,663	m
$VCA_W - VCA_U$	l_i	5,296	m
Wind speed	V_i	80	knots
Displacement	Δ	734,9	tonnes
Wind lateral projected area	A_i	452,9	m^2
Coefficient	**A**	0,418	m

Table 47. Minimum operating condition

Wind lateral projected area vertical center	VCA_W	7,009	m
Underwater lateral projected area vertical center	VCA_U	1,718	m
$VCA_W - VCA_U$	l_i	5,291	m
Wind speed	V_i	80	knots
Displacement	Δ	612,3	tonnes
Wind lateral projected area	A_i	473,3	m^2
Coefficient	**A**	0,523	m

Full load condition

Figure 11. Full load condition – Intact stability curve

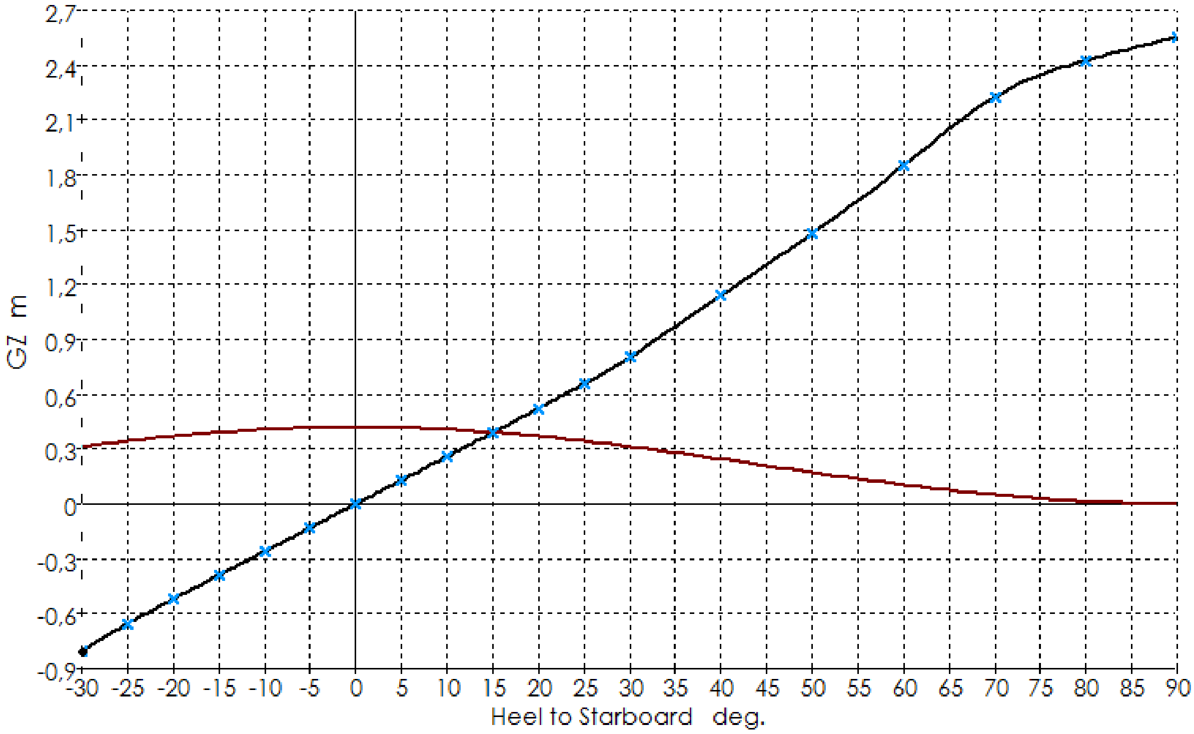


Table 48. Full load condition results

Criteria	Value		Actual	Status	Margin
a) Ratio of GZ (intersection) / GZ (Max)	60,00	%	15,26	Pass	+74,57 %
b) Angle of Heel at Equilibrium	15,0	deg	15,0	Pass	+0,03 %
c) Ratio of Area A1/Area A2 >1,4	140,00	%	651,93	Pass	+365,66 %
d) Range of GZ curve	70,0	deg	75,0	Pass	+7,15 %

Minimum operating condition

Figure 12. Minimum operating condition – Intact stability curve

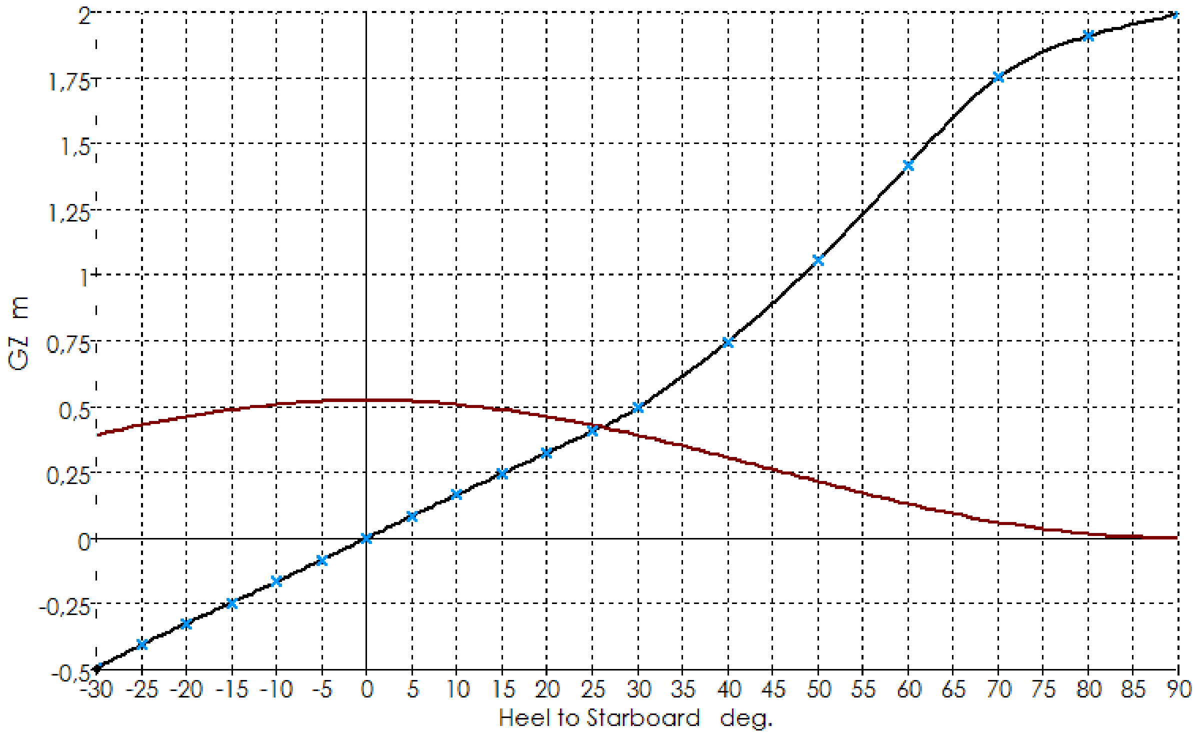


Table 49. Minimum operating condition results

Criteria	Value		Actual	Status	Margin
a) Ratio of GZ (intersection) / GZ (Max)	60,00	%	21,18	Pass	+64,70 %
b) Angle of Heel at Equilibrium	15,0	deg	26,1	Fail	-73,97 %
c) Ratio of Area A1/Area A2 >1,4	140,00	%	525,60	Pass	+275,43 %
d) Range of GZ curve	70,0	deg	63,9	Fail	-8,71 %

SOLUTION

Due de fail to pass two of the criteria at the minimum operating condition it's proposed several systems to comply whit this condition, plus considering the characteristics of the Drake Passage, known worldwide for its hostility and difficulty to navigate, which must cross to reach the Antarctic bases. There are permanently storms from West to East at least once a week, for this reason navigation is made to the Orcadas base, sailing in the same direction of the sea currents and the storm, avoiding fighting against the current.

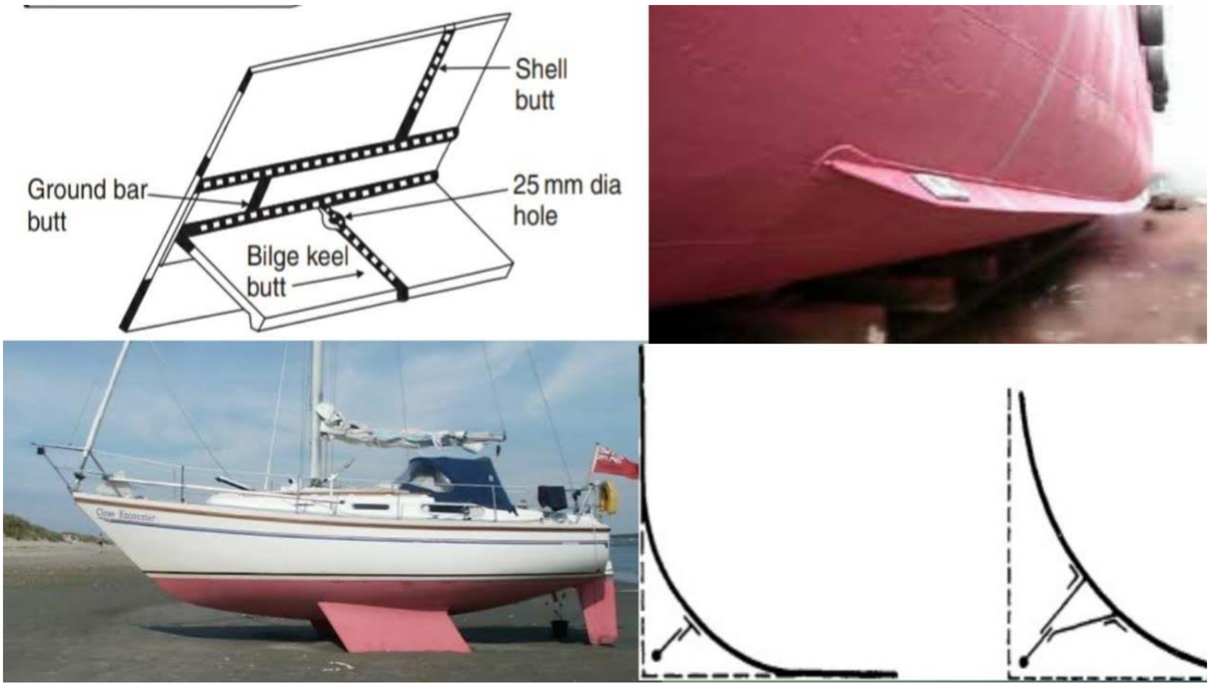
Roll motion stabilization can be achieved in conventional ships by changing their hull forms, however, reduction in roll amplitudes are possible by other means as well. Stabilization systems can be broadly classified into:

- Passive Systems: In which no separate source of power is required and no special control system like the bilge keel, anti-rolling tanks (passive), fixed fins & passive moving weight system.
- Active Systems: In which the moment opposing roll is produced by moving masses or control surfaces by means of power like the active fins, Anti – rolling tanks (active), active moving weight & the gyroscope.

Passive systems

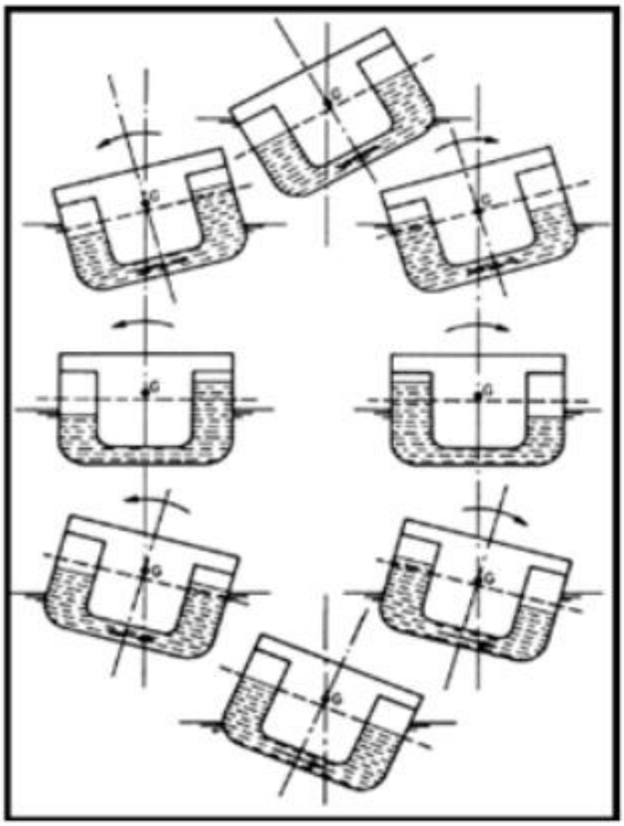
Bilge Keels

Bilge Keels are the most popular and fitted to the great majority of ships. They are plates projecting from the turn of the bilge and extending over the middle half to two-thirds of the ship's length. To avoid the damage, they do not normally protrude beyond the ship's side or keel lines, but they need to penetrate the boundary layer around the hull. They cause a body of water to move with the ship and create turbulence thus dampening the motion and causing an increase in period and reduction in amplitude. Although relatively small in dimension, they have large levers about the rolling axis and the forces on them produce a large moment opposing the rolling. Their effect is generally enhanced by ahead speed. They are aligned with the flow of water past the hull in still water to reduce their drag in that state. When the ship is rolling the drag will increase and slow the ship a little.



Passive anti–rolling tanks

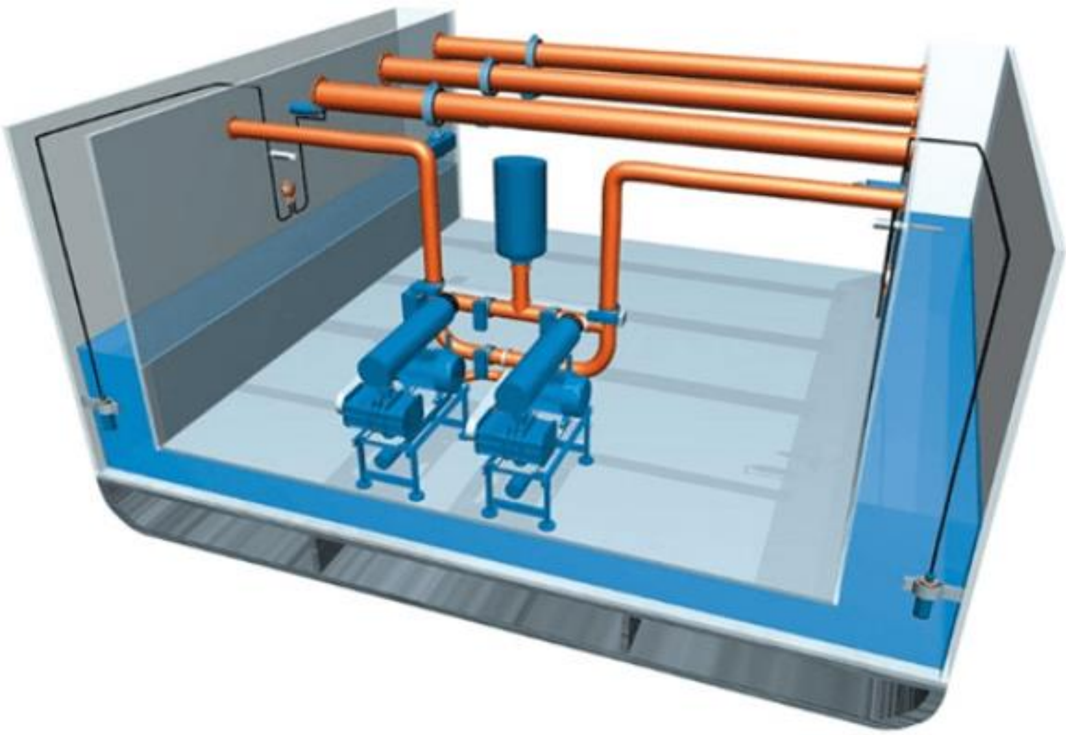
The U-tube anti-rolling tanks used as stabilizers are called passive when they are left alone on board except for the infrequent tuning needed for a change in the loading conditions. And the tanks are called active when they use additional power such as air-blower to move water from one wing tank to the other using developed automatic control algorithm. The effect of the passive ART decreases when the roll period of the vessel does not match the designed oscillating period of the fluid in the tank. In order to improve the effect of the passive ART, the damping plates are installed in the lower duct of the ART to adjust the oscillating period of the fluid. The optimum damping due to the U-tube tank is possible when there is a phase difference of 90o between the motion of the vessel and that of the water in the tank. Passive U-tube tanks with optimum damping show the best stabilizing effect near the resonance frequency with the minimum adverse effect at the high and low frequency ranges. The internal structural members of the passive tanks should be carefully designed to have the optimum tank damping moments.



Active Systems

Active anti-rolling tanks

They are like the principle of passive tank system, but the movement of water is controlled by pumps or by the air pressure above the water surface. The tanks either side of the ship may be connected by a lower limb or two separate tanks can be used. The air duct contains valves operated by a roll-sensing device. This concept uses an axial flow pump to force the water in the tank from one side of the ship to the other, rather than to have it slosh under the natural roll, sway and yaw forces, as happens in a passive tank.

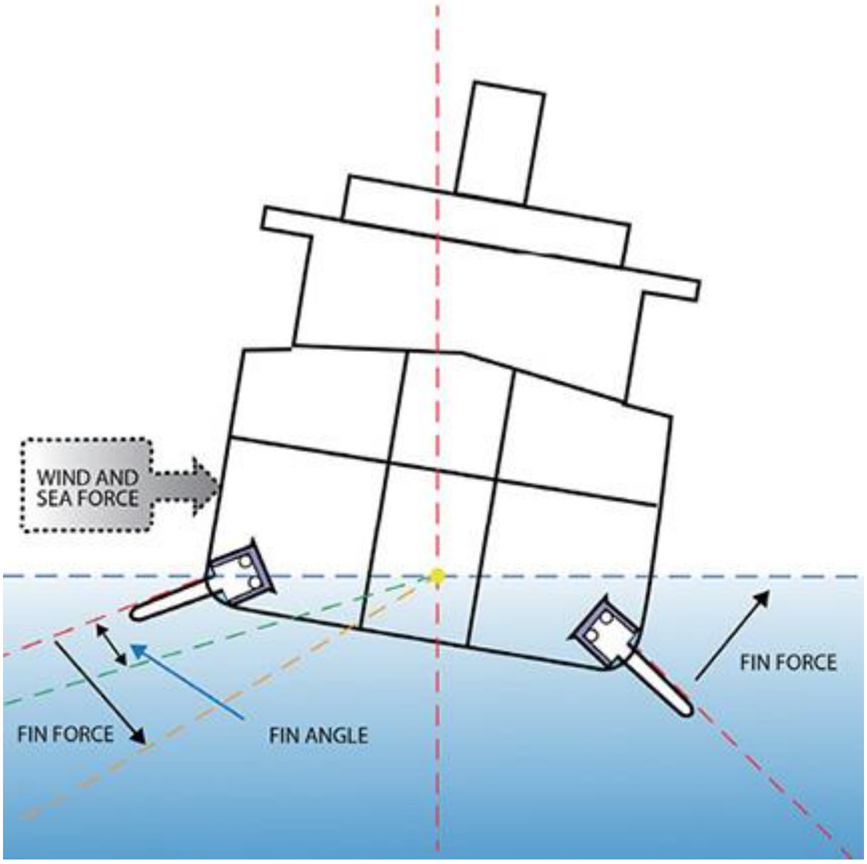


In a simplified version of an active system, an accelerometer senses the rolling motions, and signals are sent from this roll-sensing device to a variable pitch pump, which controls the liquid flow between the tanks.

The device can be either a simple accelerometer or a complicated gyroscopic sensing system that detects even a small angle of the roll by the gyroscopic precession. Thus, the device can be used to control ship motion due to every single wave. Depending on the sophistication of the system active tank stabilizers have been found to leave an efficiency of 80% or more in motion stabilization.

Active Fins

With active fins, a sensitive gyro system senses the rolling motion of the ship and sends a signal to the actuating system which, in turn, causes the fins to move in a direction such as to cause forces opposing the roll. The actuating gear is usually electrohydraulic. The fins, which may be capable of retraction into the hull, are placed about the turn of bilge in order to secure maximum leverage for the forces acting upon them. A flap from the trailing edge may be used to enhance the lift force generated. The capacity of a fin system is usually expressed in terms of the steady angle of heel it can cause with the ship moving ahead in still water at a given speed.



The force on a fin varies in proportion to the square of the ship speed, whereas the GZ curve for the ship is independent of speed. However, a fin system is not likely to be very effective at speeds below about 10 knots.

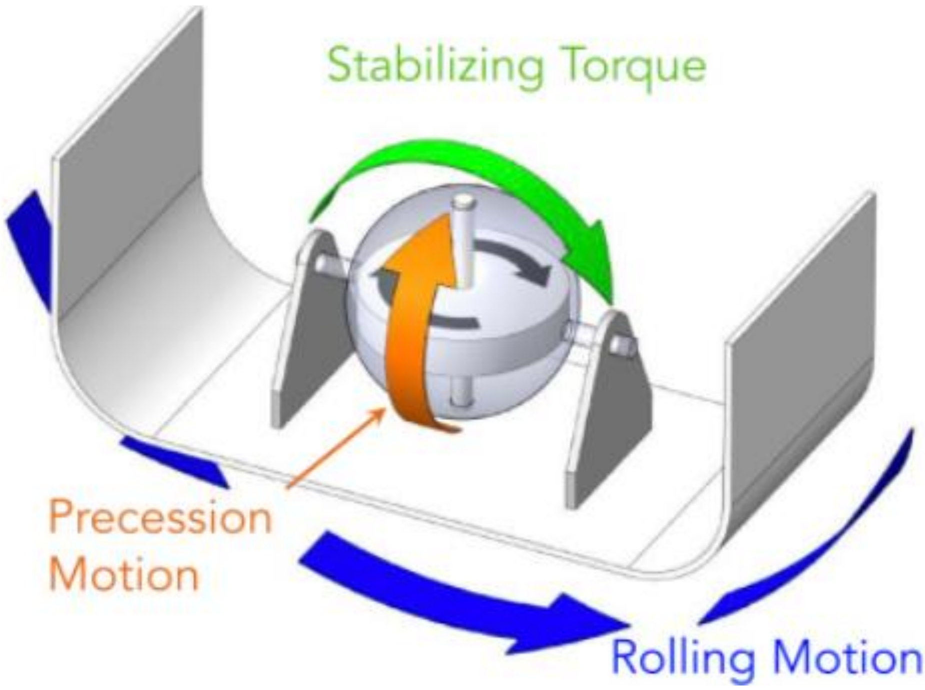
The Table 50. Roll stabilizers highlights some of the major aspects among the roll stabilizers as discussed above:

Table 50. Roll stabilizers

Type	Active fins	Passive tanks	Active tanks	Bilge keel
Percentage roll reduction	90%	60 – 70%	No data	35%
Effective at very low speeds	No	Yes	Yes	Yes
Increase in ship resistance	When in operation	No	No	No
Auxiliary power requirement	Small	Nil	Large	Nil
Vulnerable to damage	Not when retracted	No	No	Yes
First cost	High	Moderate	High	Low
Maintenance	Normal mechanical	Low	Normal mechanical	Often high

Gyrostabilizer

Other solution is the gyrostabilizer, a marine gyrostabilizer comprises a spinning flywheel mounted in a gimbal frame allowing two of the three possible rotational degrees of freedom. The frame is then rigidly mounted to a location on the vessel. Most often the device is in the engine room of the vessel but can be mounted at any location.



The specific way in which the flywheel is constrained in rotational motion allows the angular momentum of the spinning flywheel to combine with the flywheel's precession oscillation to generate large torques which vary with time to directly oppose the dynamic rolling motion caused by waves.

Without any intervention, the vessel rolling motion combines with the flywheel angular momentum to cause oscillating process motion. This then combines with the angular momentum to create stabilizing torque, which directly opposes the wave-induced rolling motion of the vessel. All this happens in the same instant and is perfectly synchronized. By arranging the gimbals in a specific way, a roll stabilizing device is created using the naturally occurring physics of gyro-dynamics, which requires no further intervention in order to function.

It can be concluded that each and every stabilization system has got its own advantages & disadvantages.

VEEM Marine Gyro stabilizers give us the solution to put different configurations options to consider, pending performance modelling, are likely to include:

4 x VG70SD (2,85 tonnes each)

2 x VG140SD (6,54 tonnes each)

1 x VG520SD (23,00 tonnes)

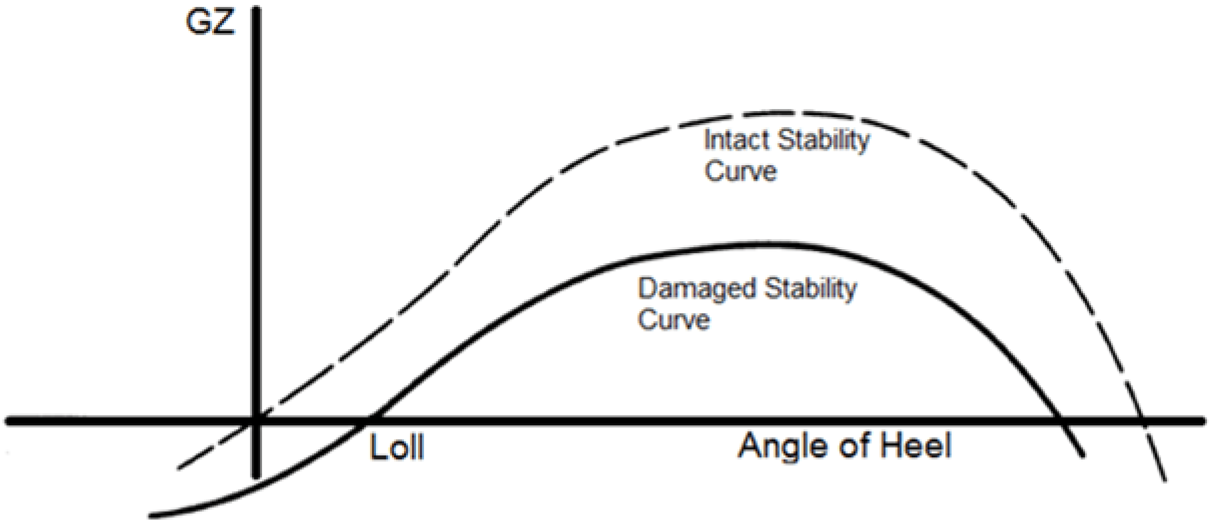
Conclusion

As we can see, this solution would increase the displacement of the vessel but considering that the ships of the data base have this systems and the margins of the weight prediction method, we conclude that this would not vary the final displacement predicted before, and it would solve the stability problems that the project presents by having such a large windage area exposed to the wind.

12. DAMAGE STABILITY

The study of damaged stability of a surface ship comes of use when the ship's watertight hull is affected in a way that allows water to flood any compartment within the ship's hull. Since this changes the stability parameters of the ship, the extent of which depends on the extent of damage and flooding, it is studied separately from intact stability.

The load conditions are shown in Appendix C.



The ship should be able to survive the breach (flooding) of anyone (two or three) compartment. The damage is assumed to extend vertically without any limit. The transverse penetration of damage is assumed to reach to the center line of the vessel but leaving any center line bulkhead intact.

Vessels with 30 m < L ≤ 90 m, the longitudinal extent of damage is given by:

$$l_d = 0{,}15 \cdot L - 2{,}6 \tag{44}$$

Table 51. Extent of damage.

Length at waterline	L	62,00	m
Length of damage	**l_d**	**6,70**	**m**

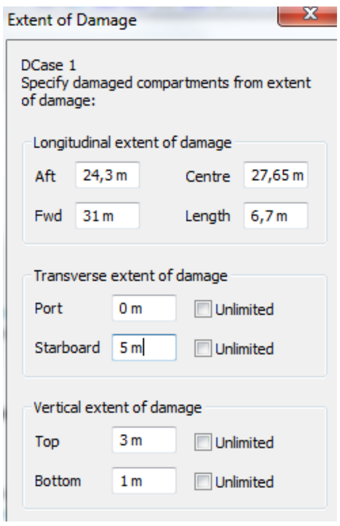


Figure 13. Damaged tanks

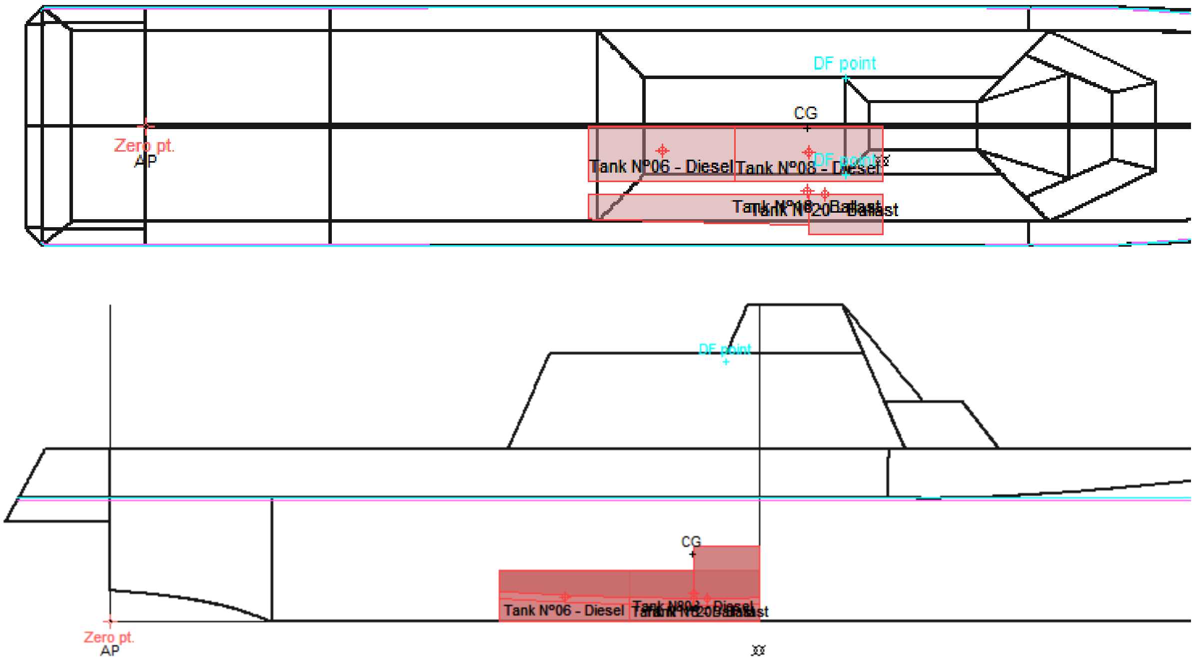
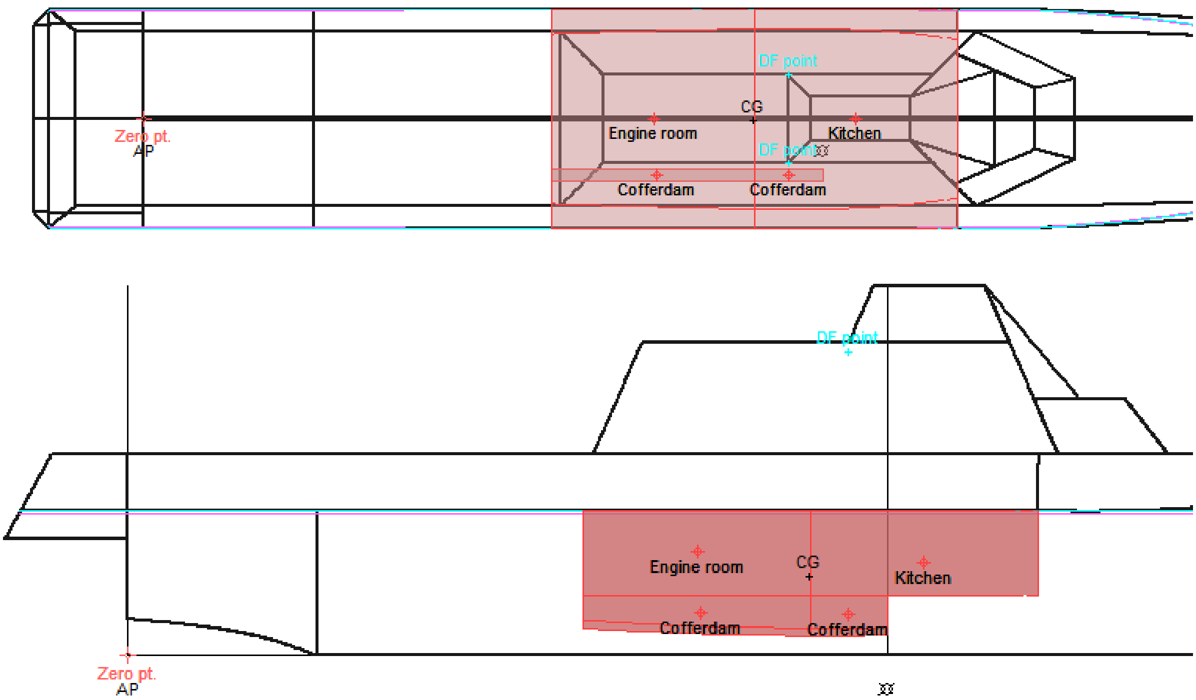


Figure 14. Damaged compartments



SURVIVAL CRITERIA AFTER DAMAGE

Restrictions to limit flooding:

a) The final waterline after flooding, taking into account sinkage, heel, and trim shall be at least 0,30 m below the lower edge of any opening through which progressive flooding may take place.

b) Openings, the lower edge of which shall not be submerged, include such as air pipes and ventilators, with weathertight closing, and weathertight hatches and doors.

c) Openings, which may be submerged, include manholes, watertight hatches, watertight doors, and side scuttles of the non-opening type.

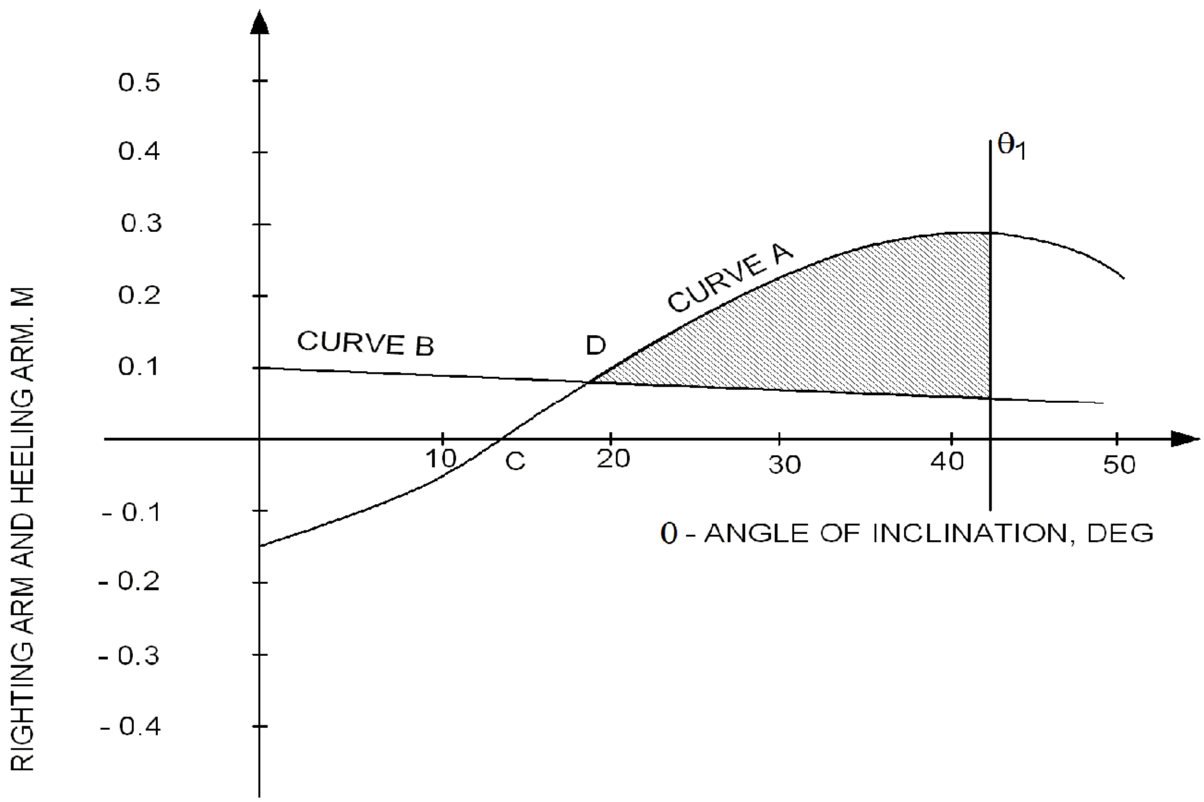
d) If pipes, ducts or tunnels are situated within the assumed extent of penetration of damage as defined above, arrangements shall be made so that flooding cannot thereby extend beyond the limits assumed for the calculation of the damaged condition in question.

e) No unprotected openings shall be located within a distance of 1,5 m measured from the equilibrium waterline.

The angle of heel (Point C in Figure 15) shall not exceed 15° in the final condition of equilibrium. When the damaged vessel is subject to a wind force calculated as intact stability, assuming a nominal wind speed of 40 knots, the following criteria shall be met:

The available dynamic stability beyond point D in Figure 15 up to the angle θ1, i.e. the shaded area shall not be less than 0,025 m.rad. The angle θ1 shall be taken as 45° or the angle at which progressive flooding (submersion of unprotected opening) would occur, whichever is less.

Figure 15. Stability criteria



HEELING ARM

$$t_W = \frac{0{,}02 \cdot \cos^2(\theta)}{1000 \cdot \Delta} \cdot \sum_{i=1}^{n} V_i^{\,2} \cdot A_i \cdot l_i = A \cdot \cos^2(\theta) \tag{45}$$

Table 52. Full load condition

Wind lateral projected area vertical center	VCA_W	7,095	m
Underwater lateral projected area vertical center	VCA_U	1,792	m
$VCA_W - VCA_U$	l_i	5,303	m
Wind speed	V_i	40	knots
Displacement	Δ	692,7	tonnes
Wind lateral projected area	A_i	431,8	m^2
Coefficient	**A**	0,106	m

Table 53. Minimum operating condition

Wind lateral projected area vertical center	VCA_W	7,114	m
Underwater lateral projected area vertical center	VCA_U	1,818	m
$VCA_W - VCA_U$	l_i	5,296	m
Wind speed	V_i	40	knots
Displacement	Δ	590,6	tonnes
Wind lateral projected area	A_i	454,7	m^2
Coefficient	**A**	0,130	m

Full load condition

Figure 16. Full load condition – damage stability curve

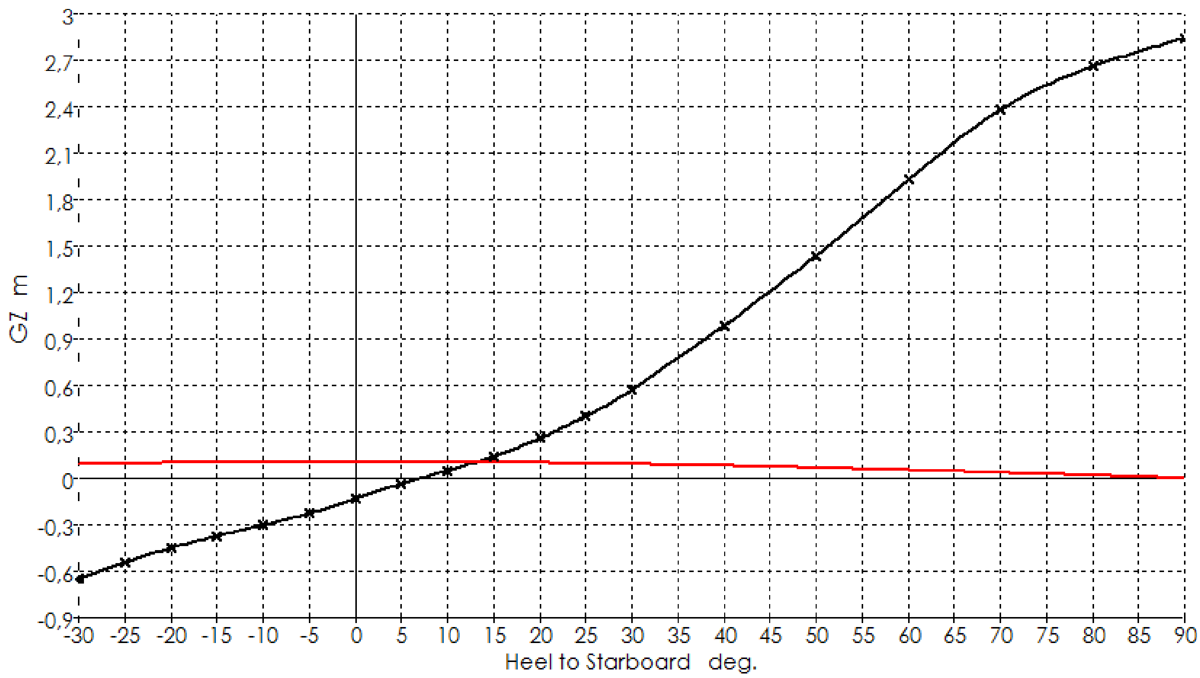


Table 54. Full load condition results

Criteria	Value		Actual	Status	Margin
Dynamic stability >0.025m.rad	1,432	m.deg	15,5769	Pass	+987,77 %

Minimum operating condition

Figure 17. Minimum operating condition – damage stability curve

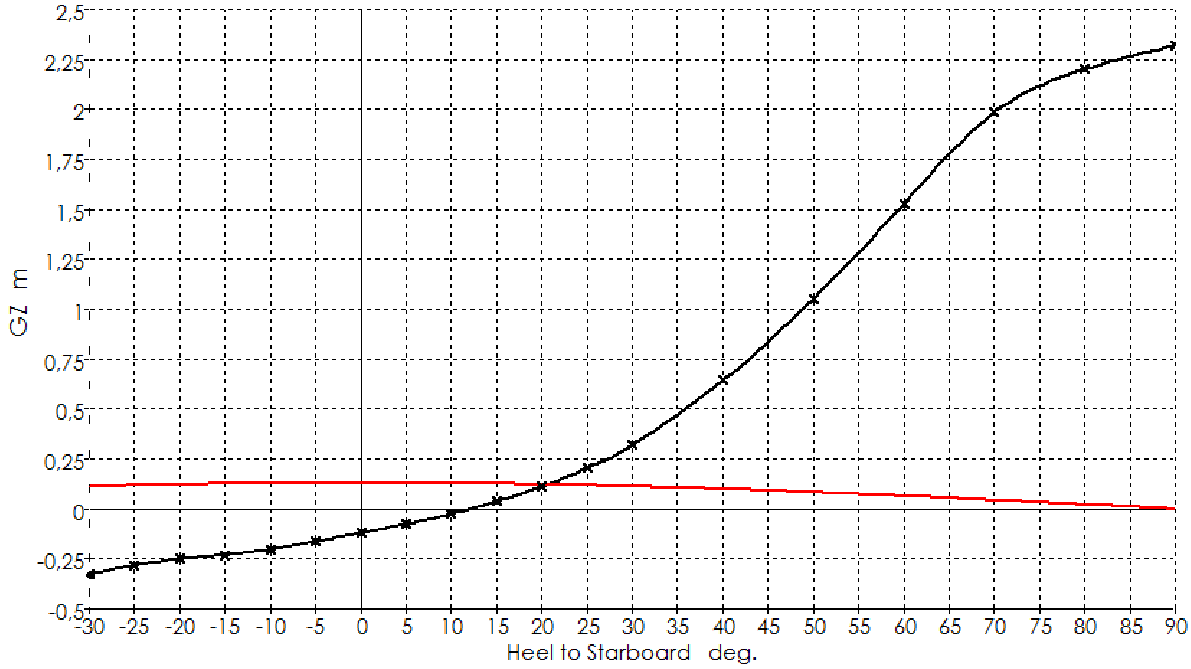


Table 55. Minimum operating condition results

Criteria	Value		Actual	Status	Margin
Dynamic stability >0.025m.rad	1,432	m.deg	7,7976	Pass	+444,52 %

13. SEAKEEPING

Seakeeping alludes to the performance and response of the vessel in various ensuing seagoing conditions. Also known as seaworthiness is thus a yardstick to estimate the vessel's behavioral efficacy during sea conditions underway its voyage.

In considering the performance of the ship at sea, the designer is primarily concerned with three qualities: habitability, operability and survivability.

Habitability deals with human comfort and performance on board of ships. The requirements depend on the ship type and its mission. For example, a much higher degree of habitability is required for a passenger ship than for ordinary merchant vessels.

Operability is concerned with the ability of the ship, with all mechanical equipment and instrumentation systems on board, and its crew to carry out the assigned tasks at sea.

Survivability is concerned with the safety of the ship, its crew and cargo when sea conditions become so rough that the ship, its crew and cargo, are in danger of damage or destruction.

SHIP CARACTERISTICS

From seakeeping point of view the following ship characteristics are important:

- Ship dimensions (like length, beam and draft) and their proportions
- Displacement and weight distribution
- Longitudinal position of the center of buoyancy (LCB) and of floatation (LCF)
- Shape of sections (U or V) below water
- Freeboard and flare
- Ship speed
- Bulbous bow
- Anti-rolling devices such as bilge keels, anti-rolling tanks and fins
- Anti-pitching devices such as anti-pitching fins

SEA CONDITIONS

The second element is concerned with the required information on the prevailing sea environment in which a ship is expected to operate such as:
Wind speed and direction

- Significant wave height
- Average wave period
- Wave spectra
- Dominant wave direction
- Angular spreading function (short-crestedness)

Wave spectra

The spectrum selected for the analysis in the software Maxsurf Motions is the Pierson Moskowitz, this spectrum is the one that best represents the state of the sea in our geographical area. Is based on wind speed, the other spectral parameters will be estimated from the wind speed entered.

Wave height

The analysis is based in the Beaufort scale, this is an empirical measure that relates wind speed to observed conditions at sea or on landing wave periods. As mentioned above, we need to introduce in the software only the wind speed.

Table 56. Sea state

Beaufort Nº	Wave height	Wind speed	Description
0	0	0	Calm
1	0,0 – 0,3	1 – 3	Light air
2	0,3 – 0,6	4 – 6	Light breeze
3	0,6 – 1,2	7 – 10	Gentle breeze
4	1,0 – 2,0	11 – 16	Moderate breeze
5	2,0 – 3,0	17 – 21	Fresh breeze
6	3,0 – 4,0	22 – 27	Strong breeze
7	4,0 – 5,5	28 – 33	High wind
8	5,5 – 7,5	34 – 40	Gale

SEAKEEPING CRITERIA

Recommendations of Nordforsk 1987 for general ship operability

Table 57. General operability limiting criteria for ships

Description	Navy vessels	
RMS of vertical acc. at FP	0,275 g =	2,697 m/s^2
RMS of vertical acc. at Bridge	0,200 g =	1,961 m/s^2
RMS of lateral acc. at Bridge	0,100 g =	0,981 m/s^2
RMS of Roll	4,0 deg	-
Probability of Slamming	0,03	-
Probability of Deck Wetness	0,05	-

Table 58. Criteria for accelerations and roll

Description	RMS Vertical acc.	RMS Lateral acc.	RMS Roll motion
Light manual work	0,200	0,010	6,0
Heavy manual work	0,150	0,07	4,0
Intellectual work	0,100	0,05	3,0
Transit passengers	0,050	0,04	2,5
Cruise liner	0,020	0,03	2,0

SEAKEEPING ANALYSIS

Locations

Motions may be used to calculate the motions at the center of gravity of the vessel and also at specified positions on the hull away from the center of gravity. These positions are known as remote locations. This may be useful for determining if a slam is likely to occur; what accelerations are likely to be experienced in the bridge or accommodation areas, etc.

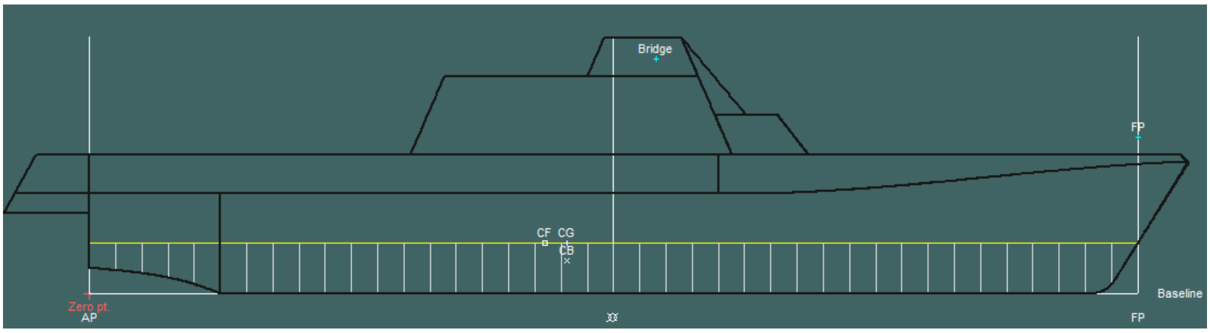
Motions will calculate the absolute and relative (to wave surface) vertical motion, velocity and acceleration and MSI at the specified remote locations.

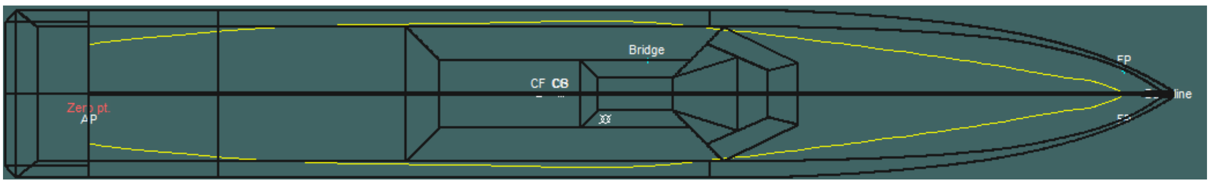
You may specify as many remote locations as you like, and they are referred to by name. Remote specified locations:

Table 59. Remote locations

Name	Long. pos. (m)	Offset (m)	Height (m)	Long. pos. from CG (m)	Offset from CG (m)	Height from CG (m)	MII slide friction coeff.	MII tip fore/aft stance coeff.	MII tip side/side stance coeff.	Exposure time for MSI (min)
Bridge	33,50	2,00	13,80	5,25	2,00	10,80	0,70	0,17	0,25	120
FP	62,00	1,40	9,20	33,75	1,40	6,20	0,70	0,17	0,25	120

Figure 18. Remote locations





Speeds, headings and spectra

The inputs window allows you to define multiple speeds, headings and spectra for analysis. Headings are given in terms of the relative heading of the waves compared with that of the vessel track (head seas = 180°; following seas = 0°; starboard beam seas = 90°, port beam = 270° etc…).

Speeds: 0 – 35 knots

Headings: 0 – 360 °

Spectra: Pierson Moskowitz

– Wind speed: 16 knots

RESULTS

Figure 19. RMS of vertical acc. at FP

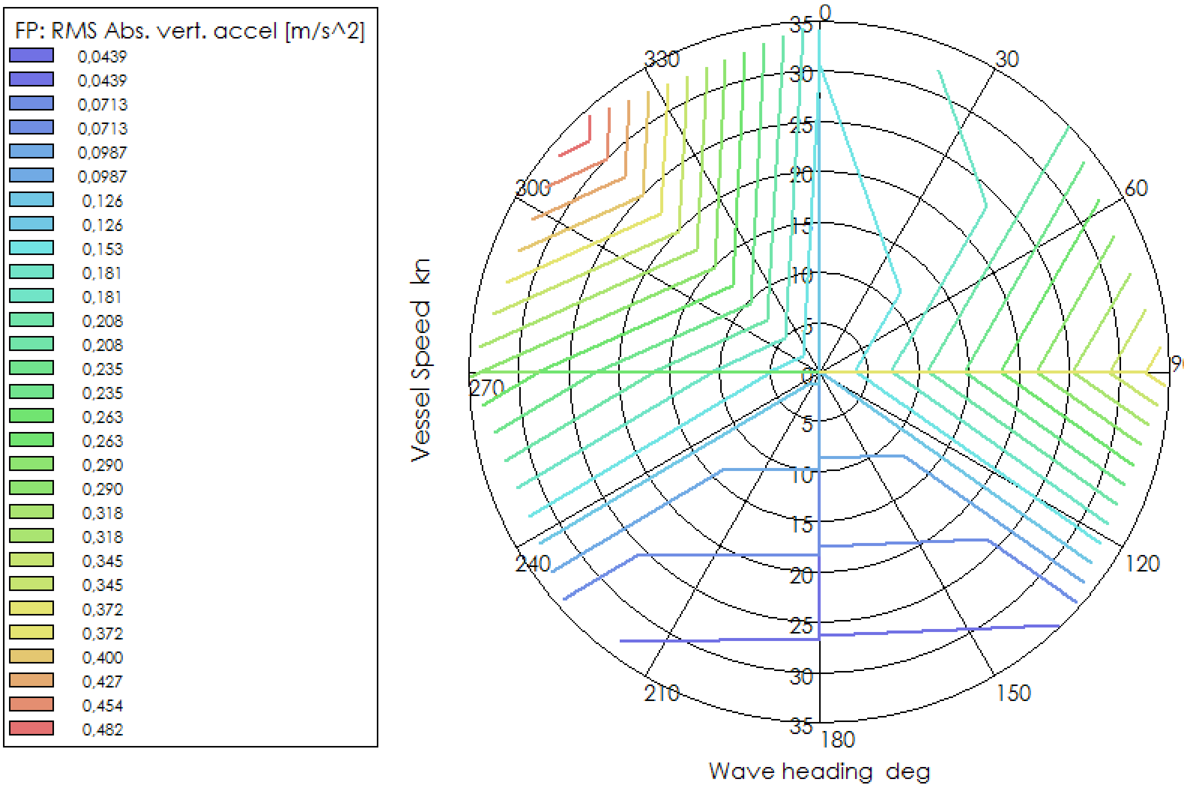


Figure 20. RMS of vertical acc. at bridge

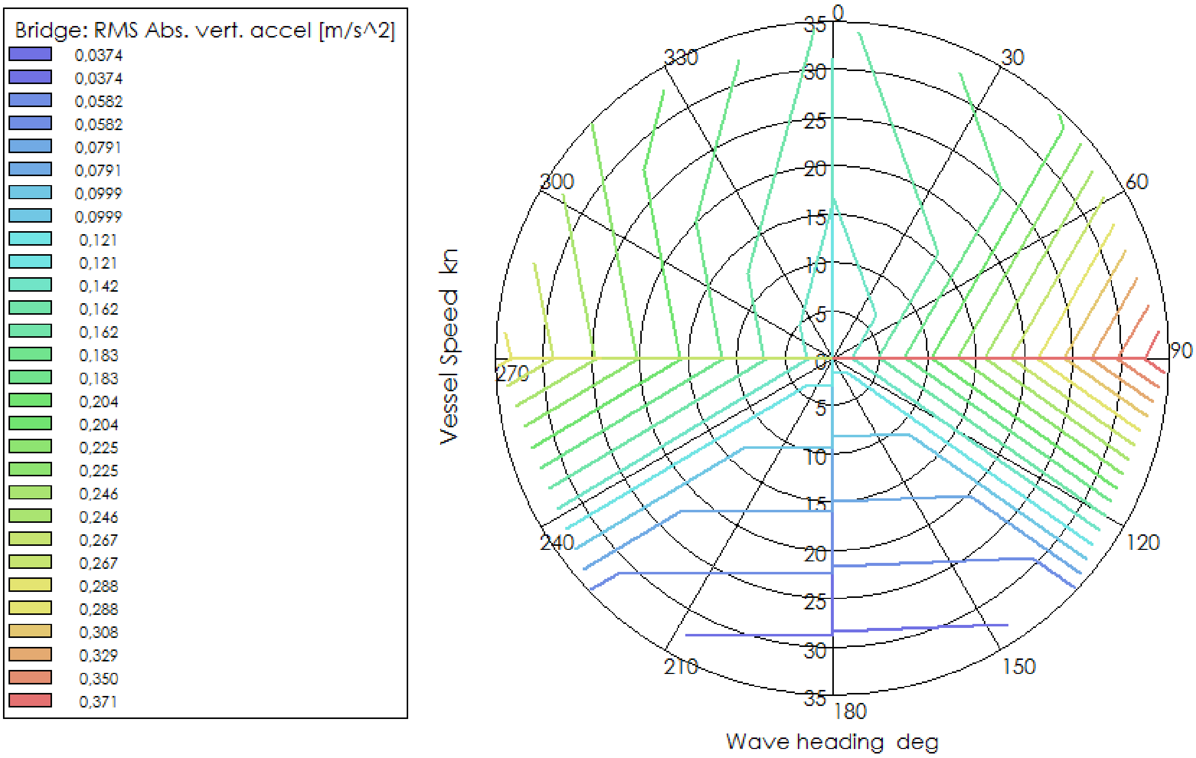


Figure 21. RMS of lateral acc. at bridge

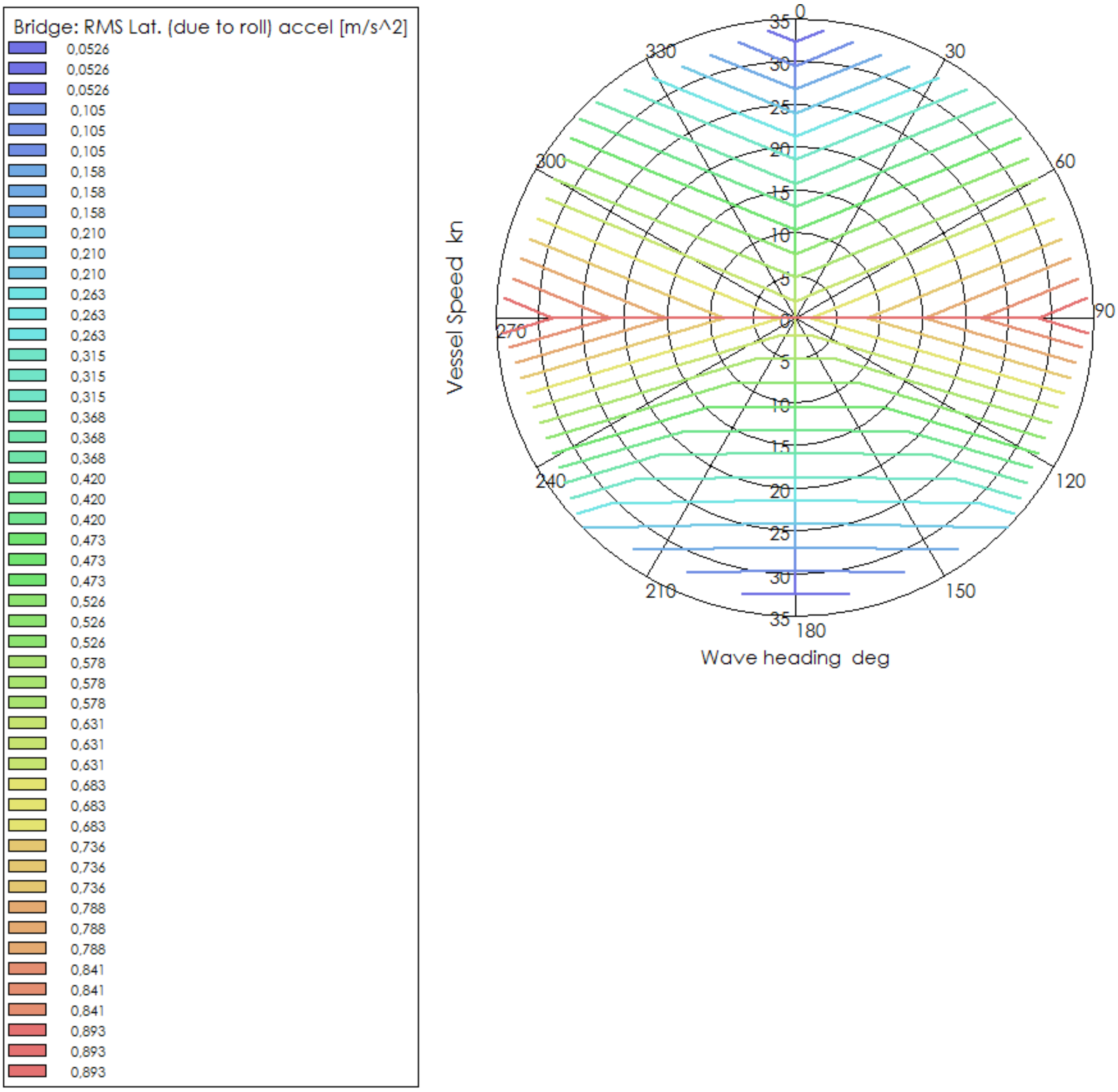


Figure 22. RMS of Roll

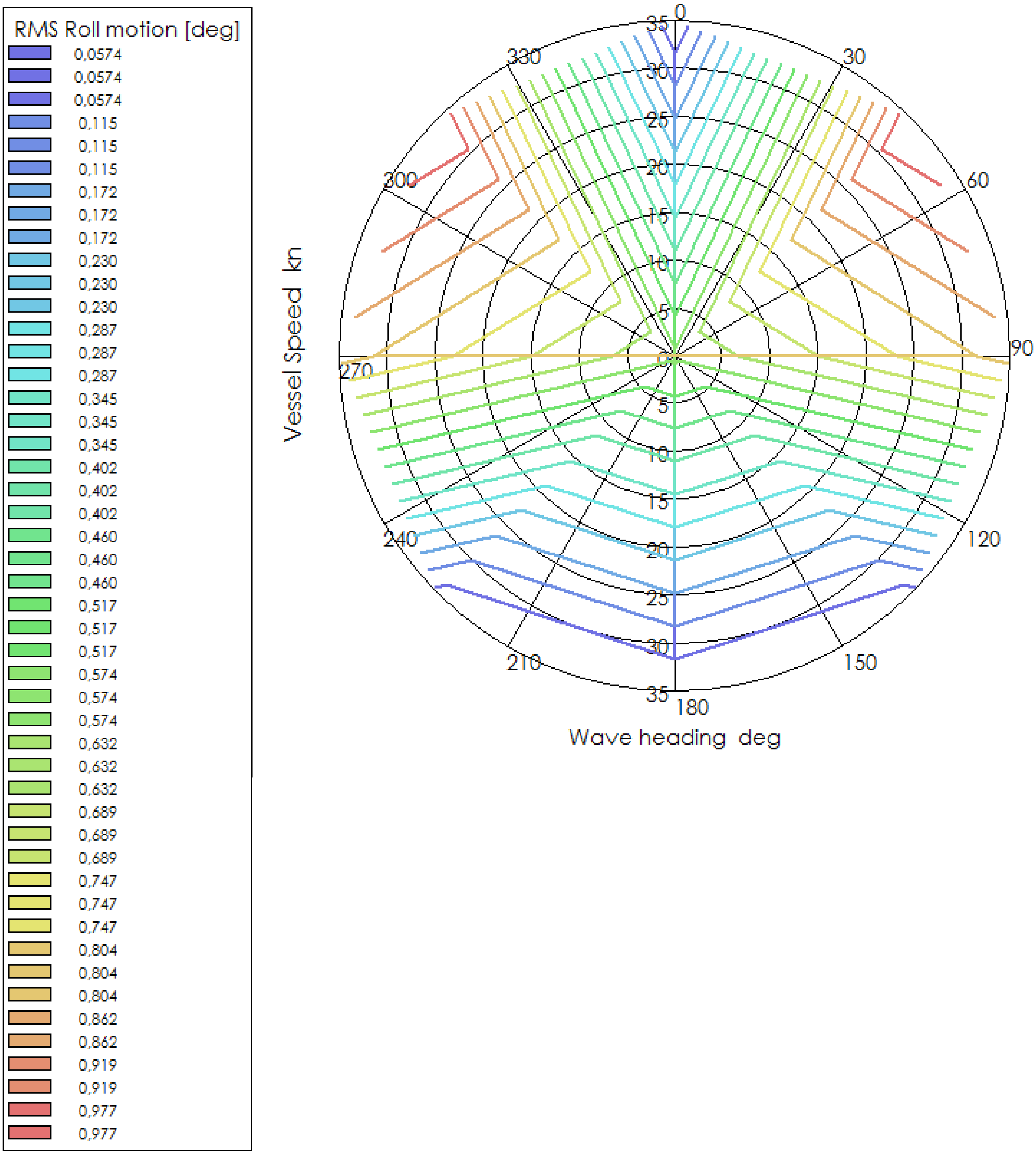


Table 60. Result vs. criteria

Description	Results	Criteria	Status
RMS of vertical acc. at FP	0,482 m/s²	2,697 m/s²	Pass
RMS of vertical acc. at Bridge	0,371 m/s²	1,961 m/s²	Pass
RMS of lateral acc. at Bridge	0,893 m/s²	0,981 m/s²	Pass
RMS of Roll	0,977 deg	4,0 deg	Pass
Probability of Slamming	0,00	0,03	Pass
Probability of Deck Wetness	0,00	0,05	Pass

14. AREA/VOLUME SUMMARY

The areas and volumes were obtained from Maxsurf Modeler and Maxsurf Stability modules.

Table 61. Total

Item	**Area (m^2)**	**Volume (m^3)**
Double bottom	239,393	446,469
Lower deck	709,452	1.561,266
Main deck	408,405	1.107,374
Upper deck	178,326	511,282
Bridge deck	29,579	40,185
Total	**1.565,155**	**3.666,576**

Table 62. Double bottom

Item	**Area (m^2)**	**Volume (m^3)**
Lube oil tanks	5,704	10,147
MDO tanks	142,279	267,294
Fresh water tanks	20,900	28,157
Ballast tanks	33,802	99,952
Cofferdams	36,708	40,919
Total	**239,393**	**446,469**

Table 63. Lower deck

Item	**Area (m^2)**	**Volume (m^3)**
Steering gear room	15,378	93,895
Gas turbine room	106,788	493,958
Engine room	74,808	249,652
Mess rooms	72,375	113,960
Accommodations	94,871	312,148
Aisles	32,085	101,263
Ammo rack	9,096	35,214
Double bottom	304,051	161,176
Total	**709,452**	**1.561,266**

Table 64. Main deck

Item	Area (m^2)	Volume (m^3)
Special forces area	15,378	481,802
Jet A-1 tanks	4,340	5,416
Special forces room	27,435	53,171
Sick bay	27,435	53,171
Recreation rooms	54,870	106,344
Kitchen	27,435	53,171
Mess room	27,435	53,171
Accommodations	158,750	326,704
Fore peak	18,982	36,513
Aisles	46,345	101,263
Total	**408,405**	**1.107,374**

Table 65. Lower deck

Item	Area (m^2)	Volume (m^3)
Hangar	120,800	372,302
Combat systems	57,526	138,980
Total	**178,326**	**511,282**

15. MANNING ESTIMATE

The required manning for the vessel is according to requirements of the Argentine Navy.

Table 66. Officers

Nº	Position	Naval rank
01	1st Commander	Commander
02	2nd Commander	Lieutenant commander
03	Chief of department of operations	Lieutenant
04	Chief of department of armament	Lieutenant
05	Chief of department of machinery	Lieutenant
06	Chief of navigation charge	Lieutenant (junior grade)
07	Chief of electricity charge	Lieutenant (junior grade)
08	Chief of artillery charge	Lieutenant (junior grade)
09	Chief of sourcing	Sub-lieutenant
10	Chief of general detall	Midshipman

Table 67. Non-commissioned officers & seamen

Nº	Position	Naval rank	Specialty
11	Unit petty officer	Senior chief petty officer	Machinery
12	Boatswain	Chief petty officer	Deck
13	Artillery manager	Chief petty officer	Gun mechanic
14	Non-commissioned officer of electricity	Chief petty officer	Electricity
15	Non-commissioned officer of machinery	Chief petty officer	Machinery
16	Supply manager	Chief petty officer	General support
17	Non-commissioned assistant of electricity	Petty officer second class	Electricity
18	Operations department manager	Petty officer second class	Operations
19	Non-commissioned assistant of machinery	Petty officer second class	Machinery
20	Communications manager	Petty officer second class	Communications
21	Boatswain assistant	Petty officer second class	Deck
22	Non-commissioned assistant of machinery	Petty officer second class	Machinery
23	Artillery assistant	Petty officer second class	Gun mechanic
24	General detall manager	Petty officer third class	Administrative furriel
25	Supply assistant	Petty officer third class	General support
26	Health manager	Petty officer third class	Nursing
27	Electronic repair manager	Petty officer third class	Gun mechanic
28	IT manager	Petty officer third class	Gun mechanic
29	Operations department assistant	Petty officer third class	Operations
30	Supply assistant	Petty officer third class	General support
31	Non-commissioned assistant of machinery	Petty officer third class	Machinery
32	Non-commissioned assistant of machinery	Petty officer third class	Machinery
33	Boatswain assistant	Petty officer third class	Deck
34	Boatswain assistant	Petty officer third class	Deck
35	Electronic repair assistant	Petty officer third class	Gun mechanic
36	Operations assistant	Petty officer third class	Operations
37	Communications assistant	Seaman	Communications
38	Machinery assistant	Seaman	Machinery
39	Electricity assistant	Seaman	Electricity
40	IT assistant	Seaman	Gun mechanic

16. PROPULSION TRADE-OFF STUDY

In this type of vessels where there are two speeds that vary greatly from each other, one being the cruising speed with the least fuel consumption and greater range, and the other being the maximum speed for pursuit or escape with greater fuel consumption, configurations traditionally with diesel engines for the first mentioned and gas turbines for the second are chosen.

These configurations are the CODG and CODAG. Generally, two shaft lines would be used, each consisting of a waterjet as the prime mover and connected to a gearbox clutched to one or more diesel engines plus one or more gas turbine per line, this increases consumption and gives us a very high amount of fuel, excessively increasing the ship's displacement due to the long range required compared to the vessels in the database, for which we did not find vessels of these dimensions with a range greater than 5.000 nautical miles (the project has to achieve 8.000 nautical miles).

Due to the low performance of the waterjet at cruise speeds, in this case a warp configuration was chosen, in which a single gas turbine drives a single shaft line connected to a waterjet system for high speeds, and two conventional propellers driven by two diesel engines, this allows that for low speeds with controllable pitch propellers to obtain the highest possible performance.

Then with the mentioned above, for cruising speed a single diesel engine would be used for propulsion at 12 knots, this one coupled to a shaft tail generator to cover basic navigation electrical needs, with the other engine idling. In the case of needing to increase the speed, the generator can be uncoupled and use all the power of the engine for propulsion and add the other engine that was idling.

SELECTED ENGINE (CRUISE SPEED)

	ABC Diesel Engine type 6DZC
Engine configuration	6-cylinder inline engine
Power range	Up to 1,326 kWm (continuous rating)
Power range	Up to 1,802 HP (continuous rating)
Nominal engine speed	Max. 1,000 rpm
Engine	Four-stroke
Sense of rotation	Anti-Clock or Clock
Fuel injection	Direct fuel injection
Turbo	Turbocharged
Charge-air	Water-cooled
Emission compliance	IMO Tier II, IMO Tier III compliant in combination with ABC aftertreatment system, CCNR 2, EU Stage V
Fuel flexibility	Diesel, Marine Diesel Oil (MDO), Gas Oil (GO), Heavy Fuel Oil (HFO), Dual Fuel (diesel + CNG or LNG), Biofuel, Vegetable Oil

Analysis of diesel engine configuration

A preliminary propeller performance is estimated as 0,6 because the performance of the controllable pitch propeller is not known.

Table 68. Propeller and shaft line efficiency

Propeller performance	η	0,6	-
SKW	η	0,96	-

$$\mathrm{BKW} = 0{,}6 \cdot 0{,}96 \cdot \mathrm{EKW} \tag{46}$$

Table 69. Low speed engine configuration

Speed (knots)	EKW (KW)	Tail Generator (KW)	BKW (KW)	N° of engines	Power Required p/engine (KW)
0	0	500	0	1	500
1	0	500	0	1	500
2	2	500	3	1	503
3	5	500	9	1	509
4	12	500	21	1	521
5	23	500	40	1	540
6	38	500	66	1	566
7	59	500	102	1	602
8	87	500	151	1	651
9	122	500	212	1	712
10	168	500	292	1	792
11	226	500	392	1	892
12	299	500	519	1	1.019
13	395	500	686	1	1.186
14	514	0	892	1	892
15	636	0	1.104	1	1.104
16	767	0	1.332	1	1.332
17	933	0	1.620	2	810
18	1.167	0	2.026	2	1.013
19	1.499	0	2.602	2	1.301

As we can see in the Table 69, up to 13 knots it is possible to sail with a single engine and the coupled tail generator, from 14 to 16 knots it is possible to sail with a single engine and without a coupled tail generator (for the electrical generation is used one of the two auxiliary generators), and finally from 17 to 19 knots it is possible to sail with the two diesel engines dedicated exclusively to propulsion. At higher speeds (pre-planing speeds) the turbine begins to be used with the waterjet system.

SELECTED ENGINE (MAXIMUM SPEED)

Now we must select the elements to reach the maximum speed of 35 knots, the gas turbine and the waterjet system.

From the obtained effective power, that is the power required to overcome a vessel's total resistance at a given speed, from Savistky pre-planning whit Maxsurf Resistance, it can be estimated the brake power, that is the maximum power generated by an engine at a given rpm as determined by the engine manufacturer.

To do this we have to determine the water jet propulsion efficiency, this is divided in to:

- η_{mec}: is mechanical efficiency, due to mechanical losses in power transmission from the propulsion plant to the jet in gearbox, bearings, etc. ($\eta_{mec} \cong 0{,}97$);
- η_b: is jet pump efficiency (between 0,85 to 0,90);
- η_{rr}: is the relative rotational efficiency that takes into account the difference in the operation of the pump in laboratory conditions compared to those installed in the jet: difference in inlet flow, etc. (between 0,97 to 0,99);
- η_j: is the jet efficiency ($\eta_j \cong 0{,}65$);
- $(1-t)$: is the hull efficiency (t at high speeds is between 0,00 to 0,03).

$$\eta_{total} = EKW/BKW \tag{47}$$

$$\eta_{total} = \eta_{mec} \cdot \eta_b \cdot \eta_{rr} \cdot \eta_j \cdot (1-t) \tag{48}$$

Table 70. Propeller and shaft line performance

Speed	v	35	knots
Effective power	EKW	10.092	KW
Mechanical efficiency	η_{mec}	0,970	-
Jet pump efficiency	η_b	0,875	-
Rel. rotational efficiency	η_{rr}	0,980	-
Jet efficiency	η_j	0,650	-
Coefficient of trust	t	0,015	-
Total efficiency	$\boldsymbol{\eta_{total}}$	**0,533**	**-**
Brake power	**BKW**	**18.935**	**KW**

Waterjet selection

Size selection for a given engine power

The product selection method of Wärtsilä is used to select the proper waterjet size now that the needed power per jet is known. First a correction factor is determined with aid of Figure 23.

Figure 23. Power factor

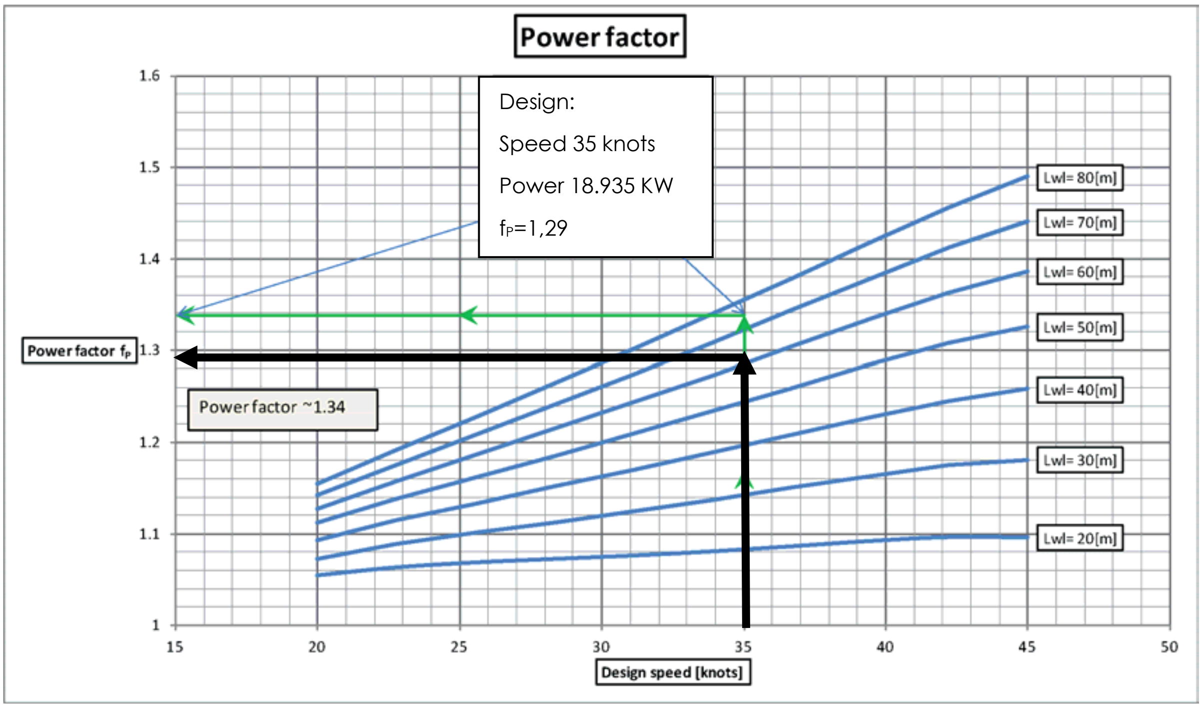
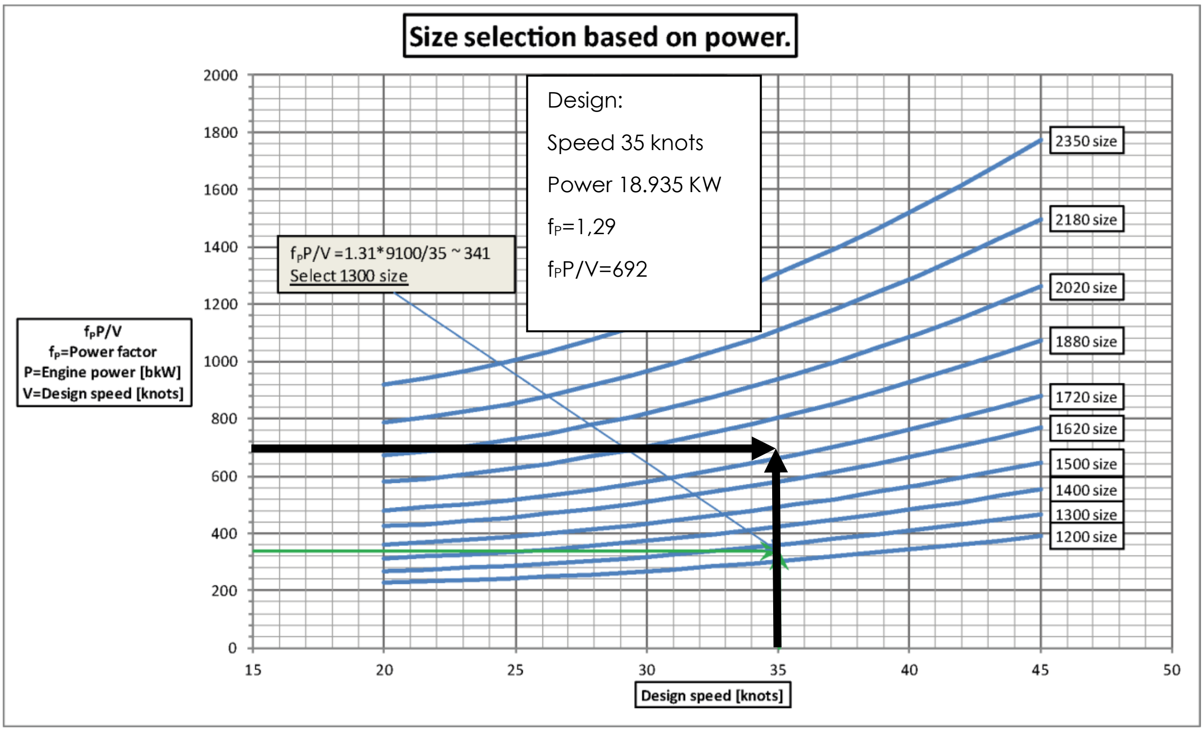


Figure 24.Waterjet size (power)



The proper size would be 1880 size Wärtsilä waterjet for a given power.

Size selection for a given resistance

The product selection method of Wärtsilä is used to select the proper waterjet size when the resistance of the ship is known. First a correction factor is determined with aid of

Figure 25. Resistance factor

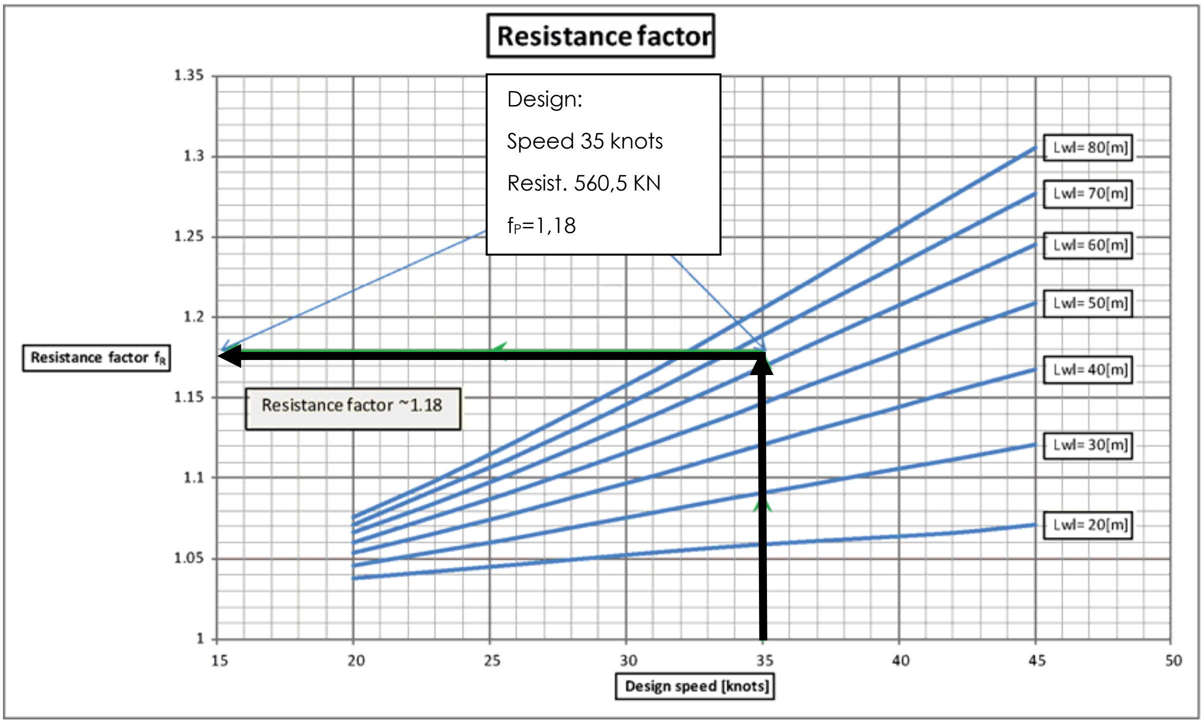
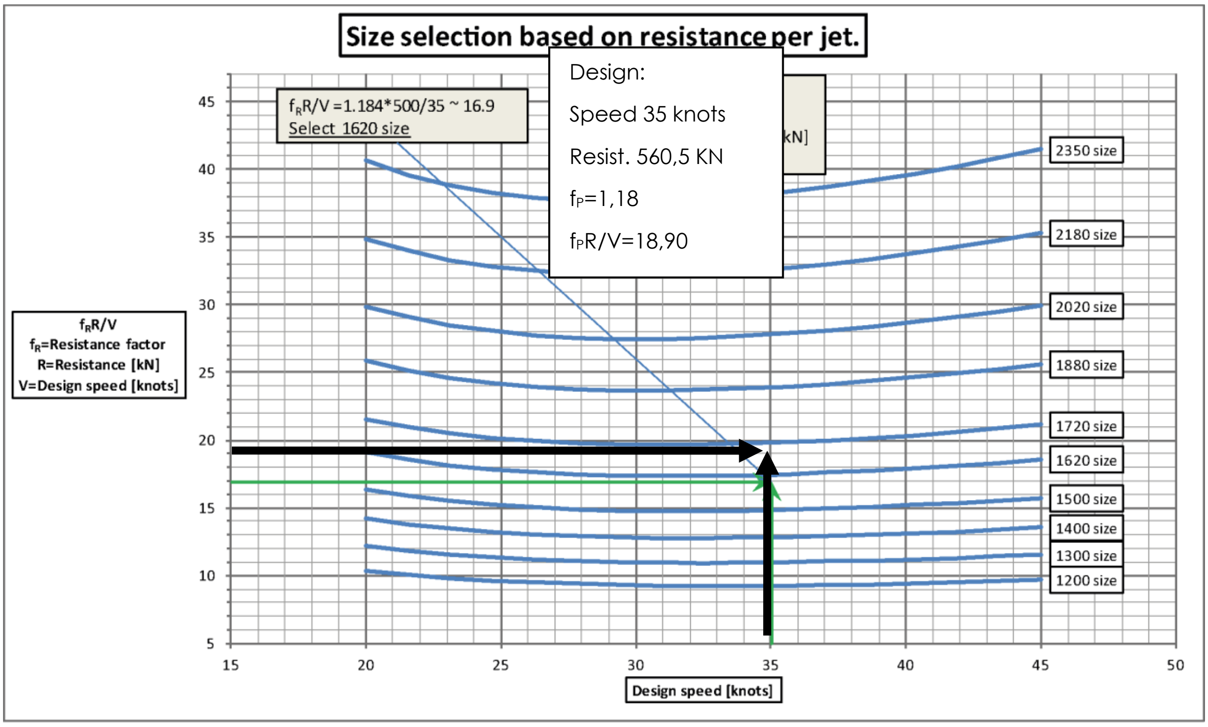


Figure 26. Waterjet size (resistance)



The proper size would be 1720 size Wärtsilä waterjet for a given resistance.

This selection needs a deeper analysis by the company supplying the product, the system can be evaluated from both points of view and assess which would be the most suitable for the needs of the ship.

Gas turbine

Originally, the turbines evaluated for the preliminary design of the ship were from the Ukrainian brand Zorya-Mashproekt, this was considered long before the war between the country that manufactures the product and Russia broke out.

Zorya-Mashproekt Type UGT 15000+

Type	Marine gas turbine
Power	20.000 kWm
Efficiency	36 %
Nominal speed	35.000 rpm
Dimensions (L x W x H)	6,1 x 2,2 x 2,5 m
Weight	11,5 tonnes
Mass flow	76,5 kg/s
Temperature	450 °C

Due to the current Ukraine's situation, an alternative to the originally established power plant is selected, this is a General Electric marine gas turbine.

General Electric LM25000

Type	Marine gas turbine
Power	19.800 to 25.100 kWm (depending on model)
Efficiency	36 %
Nominal speed	3.600 rpm
Dimensions (L x W x H)	8,0 x 2,6 x 2,4 m
Weight	18,4 tonnes
Mass flow	70,3 kg/s
Temperature	566 °C

Conclusion

Comparing the two turbines, the General Electric model is heavier, larger, and works at a higher temperature, which generates higher temperatures in the turbine room of a ship when taking into account ventilation and cooling, and dissipation of this temperature to reduce the thermal signature but working at lower rpm requires a smaller gearbox.

17. MISSION SYSTEMS AND EQUIPMENT

The ship is equipped with different systems and equipment that will allow it to carry out different missions for the Argentine Navy.

To begin with, I would like to clarify that in order to learn about the ship's systems, we had the opportunity to visit two OPVs, one is the Colombian ARC 20 De Julio, used mainly for the fight against drug trafficking, and the other is the Argentine ARA Storni, used mainly against illegal fishing.

Objectives

- Control and protection of natural resources renewable and non-renewable
- Control and protection of maritime and river trade
- Support and protection of smaller units
- Transport of special forces
- Helicopter scout operations
- Humanitarian aid operations
- Maritime and river search and rescue operations (SAR)
- Supplying of Antarctic bases
- Naval presence

FIN STABILIZERS

Argentina's Economic Exclusion Zone is very extensive, added to the fact that the ship must be able to participate in the Antarctic campaign, it not only has to have a long range but also the capacity to face severe sea conditions.

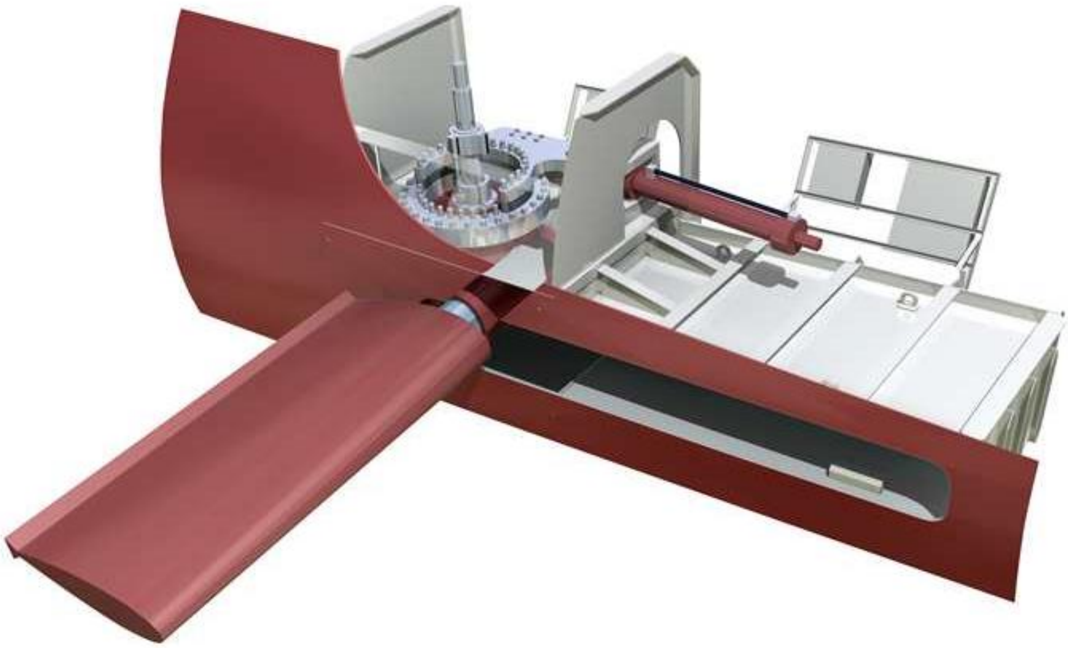
Considering the characteristics of the Drake Passage, known worldwide for its hostility and difficulty to navigate, which must cross to reach the Antarctic bases, the stability in the ship is not a minor issue.

Large amplitude rolling motion is one of the dangerous phenomena leading to capsizing of a ship in moderate and rough beam seas so it should be reduced by passive controllers such as bilge keels and active controllers such as fins, anti-roll tanks, etc. The effectiveness of bilge keels is limited so active fins are used when a more effective control action is needed to reduce rolling motion.

The crew of the ARA Storni vessel told us that this system is vital, especially to operate against illegal fishing vessels, because a group of them tends to rush and try to hit the patrol vessel to defend the illegal mother vessel which is the main objective.

The system chosen is the Kongsberg Aquarius Retractable-fin stabilizer, it must be retractable due to the ice that may be in the vicinity of the Antarctic bases.

The Aquarius retractable-fin stabilizer is suitable for a range of vessels including large motor yachts, smaller commercial vessels such as small cruise ships and passenger ferries, as well as naval, coastguard and fisheries protection vessels.



TECHNICAL DATA

MODEL	FIN AREA (M2)	A	B MIN	C	D	E MIN	F	G MIN	H	J	K	APPROX WEIGHT /SHIP SET (TONNES)
						SIZES (METRES)						
25	1.06	1.26	1.08	0.64	1.17	2.59	1.77	3.19	0.3	2.04	0.53	9.7
	1.41	1.68				3.01		3.61		2.44		10.0
	1.76	2.1				3.43		4.03		2.84		10.3
	2.05	2.44				3.77		4.37		3.14		10.8
50	1.82	1.65	1.41	0.845	1.41	3.4	2.2	4	0.4	3.09	0.68	19.3
	2.42	2.2				3.95		4.55		3.55		19.8
	3.03	2.75				4.5		5.1		4.18		20.3
	3.51	3.19				4.94		5.54		4.66		20.8
100	4.21	2.9		1.2	1.83	5.09	2.7	5.69	0.56	3.92	0.85	35.5
	4.73	3.26				5.45		6.05		4.28		37.0
	5.26	3.63				5.82		6.42		4.65		39.0
	5.78	3.99				6.18		6.78		5		40.2

HELICOPTER

The helicopter is used for two main missions, one is the tracking of illegal fishing vessels and the other is Search and rescue (SAR), the search for and provision of aid to people who are in distress or imminent danger at the sea.

Several helicopters from the Argentine Navy and Naval Prefecture can land on the ship, but the ship must be able to transport its own helicopter sheltered from the elements in the hangar. This is the Aérospatiale AS555 SN Fennec 2 as an embarked helicopter, for search and rescue, and for attack. The Argentine Navy has 4 Fennecs.

General characteristics

- Crew: 2
- Capacity: 4 passengers
- Length: 10,93 m (fuselage length), 12,94 m (overall length, rotors turning).
- Height: 3,34 m
- Empty weight: 1.220 kg
- Max takeoff weight: 2.250 kg
- Fuel capacity: 540 Liters
- Powerplant: 1 × Turbomeca Arriel 2B turboshaft, 632 kW (limited to 500 kW for take-off)
- Main rotor diameter: 10,69 m
- Main rotor area: 89,75 m2

The helicopter must be capable of making 10 trips, the fuel used is Jet A-1, the tanks for this fuel are surrounded by cofferdams (ceiling, deck, and sides) filled with inert gas (N_2O).

RIB BOATS

The boats are used to board tactical divers for interdiction operations, getting on an illegal fishing boat and Visit, Record and Capture (VRC) personnel, which is the same but with a lower level of intensity and violence, they generally differ in that the first ones mentioned above act when there is no cooperation on the part of the illegal vessel.

The ship has two ramps with winches on the aft main deck capable of embarking and disembarking quickly. Again, as mentioned above, the Argentine patrol boat and mainly the Colombian patrol boat were visited to see and compare the embarkation and disembarkation system to develop in a more advanced design stage.

The two RIBs are Zodiac Hurricane H930/935 MACH II Multi–Mission Platform

General characteristics

- Overall Length: 9,39 m
- Overall Width: 3,10 m
- Trailer Width: 2,60 m
- Lightship Weight: 4.500 kg
- Payload (Crew, Gear & Fuel): 3.000 kg
- Maximum Weight: 7.500 kg
- Crew Capacity: 16 people
- Propulsion: Twin Diesel Outdrives
- Max Rated Power: 900 hp
- Max Rated Speed: 55 knots
- Fuel: Minimum 550 liters (141 US gal)
- Range: Minimum 200 NM @ 40 knots

MAIN ARMAMENT

Due to the fact that the main "enemy" that this vessel will face is illegal fishing vessels, the cannon is mainly a deterrent weapon, which in extreme cases will fire warning shots or will be used to disable the enemy ship, always trying to shoot above the waterline and without causing casualties, always warning the opposing crew.

The gun selected is the 40 mm Marlin cannon, navalized by Leonardo. As established by the Argentine Navy a larger gun would be excessive and would cause too much damage.

The MARLIN 40 features light weight and compact dimensions such to make it installable on a wide variety of surface vessels as primary or secondary armament and allow ease of integration with existing Combat Management Systems and equipment.

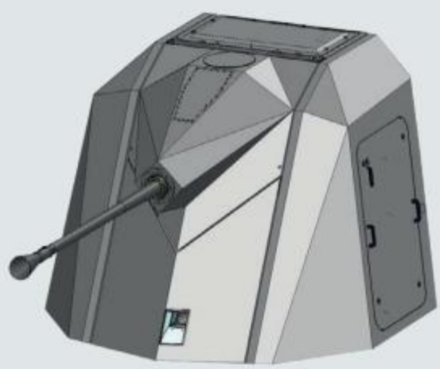
The MARLIN 40 uses a recoil-actuated machine gun, fed by an automatic system able to manage two different types of rounds selectable as a function of the specific threat.

TECHNICAL DESCRIPTION

Caliber	40 mm
Rate of fire	single shot, 100 RPM, 300 RPM
Ready to fire rounds	Up to 80
Maximum effective range	4500 m
Training range (1)	Nx360°
Training speed and acceleration	120°/s, 200°/s²
Elevation range (1)	-20÷85°
Elev. speed and acceleration	75°/s, 200°/s2
Mass without ammunition	2100 Kg
Day Camera (2)	20 / 9 / 4.5 Km D / R / I
IR Camera (2)	15 / 6.8 / 3.5 Km D / R / I
LRF (2)	6.5 Km

(1): Mechanical limit stops can be installed, obstacle contouring data and no-firing zones settable via SW

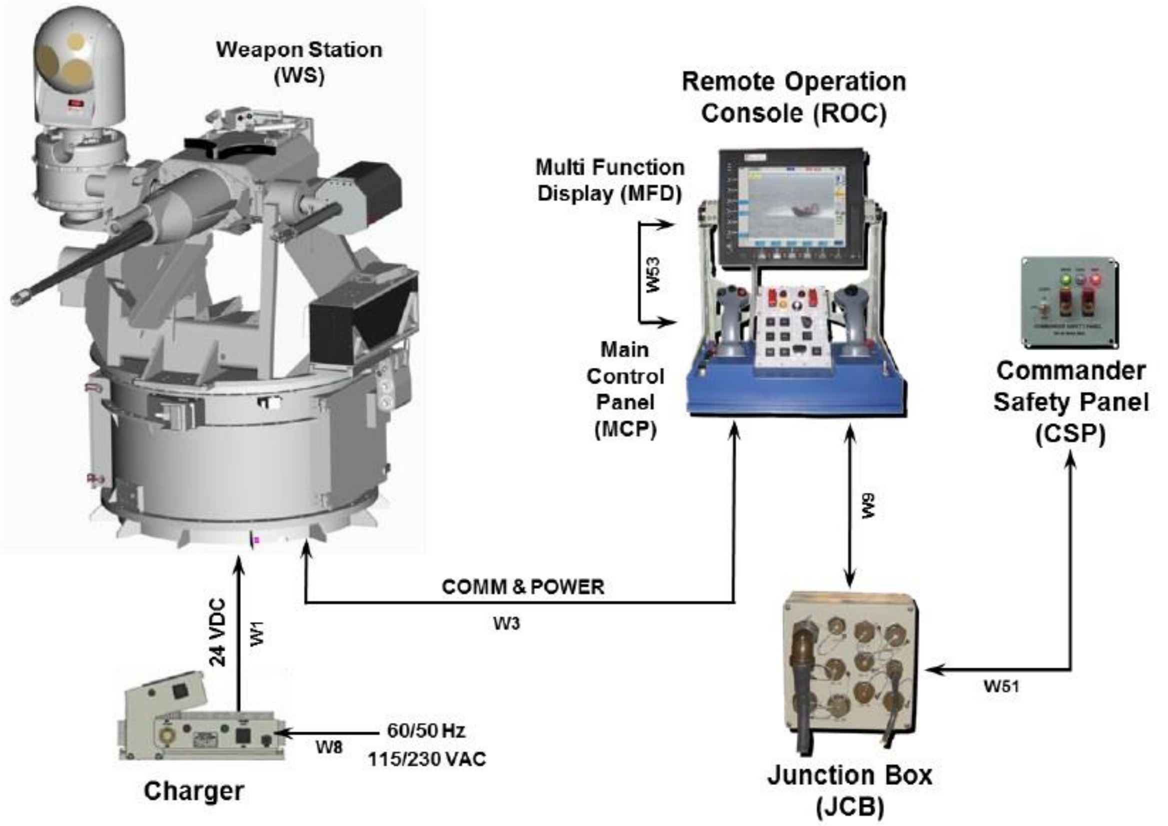
(2): Typical performances achieved with respect to a NATO standard target



Remotely Controlled

SECONDARY ARMAMENT

The secondary armament serves as support for the main one, it is composed by the Mk 38 Mod 3 Machine Gun System (MGS) from BAE Systems. The main weapon is the proven 25mm M242 Bushmaster cannon with 2.5-km range and selectable rates of fire. The co-axially mounted 7.62mm chain gun upgrade provides the capability to accurately engage threats while in port and/or close to port.



Specifications	
Weight (with gun, w/o ammo)	2,300 lbs/1,042 kg
Weapon station Train Elevation	± 15° to ± 165° adjustable to any value in range -20° to +40°
Electro-Optical Fire Control System (relative to mount) Train Elevation	 ± 165° 20° to +85°
Gun type	25-mm M242 Bushmaster, 7.62-mm Chain Gun Mk52 Mod 0
Ammunition feed	Dual feed for main gun, single feed for the 7.62-mm gun
Ammunition capacity	168 ready rounds main gun, 750 rounds for 7.62-mm gun
Rate of fire	5 rates from single to 180 rpm max for main gun and up to 570 rpm for 7.62-mm gun
Personnel requirements Remote Ammunition loading	 1 2
Operability tests and scheduled maintenance (average daily) Ammunition reloading time Availability (inherent/predicted)	 6 minutes 5 minutes 99.9%*

**Based on mission-critical MTBF of 1,441 hours and MTTR of 1.2 hours*

18. COST ANALYSIS

CONSTRUCTION COSTS

Product-oriented design and construction model (PODAC)

Originally, the estimated ship cost was wight-driven cost models, this approach is not sensitive to changes in production processes and advanced manufacturing techniques. The PODAC is an effort to develop a cost model which is sensitive to the way that shipyards build ships today, as well as being sensitive to how they may be built in the future.

The goal of the PODAC cost model is to utilize a product-oriented work breakdown structure and group technology, as well as to accommodate alternative work breakdown structures.

Strengths

- It is based on decades of historical data;
- It is defensible and reproducible;
- It is relatively simple (not overly burdensome with detail);
- It is tonnage based, requiring minimum design information to develop an estimate;
- It has been an accurate predictor of ship cost in the past; and
- It is adequate for budgeting and financial reporting.

Weaknesses

- It does not break down costs the way that ships are built;
- It is not useful in making design decisions;
- It does not relate to the design characteristics of a ship
- It cannot address the impact of new technologies or processes; and
- It provides no feedback for engineering or production.

Development of the PODAC cost model as a hybrid using features from the various concepts, which include:

- An existing commercial model to minimize development time and provide a commercial user base to help support future improvements and maintenance of the model;
- The capability for early stage parametric costing with a topdown approach;
- An underlying cost database that supports a top-down approach;
- Re-use modules for costing interim products; and
- A module to identify risk.

Because this model is the first of its kind in Argentina and it does not have a database of previous constructions, the parametric model is used, which is a driven-cost weight method. In a project spiral, the costs can be detailed in more depth.

Parametric module

The parametric module enables designers and estimators to develop reliable cost estimating relationships for ship design parameters available at the concept, preliminary, and contract design stages. The parametric module provides the mechanism for entering the parameters available at the various design levels for specified ship types, and their associated costs.
The PODAC cost model uses two types of cost estimating relationship (CER):

- Empirical CERs, which relate cost to system-level parameters like structural weight and propulsion prime mover/power output, or cost relationships for higher level interim products such as blocks or zones.
- Direct CERs, which relate cost to production-based parameters like weld length and pipe length.

The empirical is used.

Table 71. Preliminary labor & material equations

SWBS	Labor man-hours	Material dollars
100	$\mathrm{CF} \cdot 177 \cdot {\mathrm{W}_{100}}^{0,862}$	$800 \cdot \mathrm{W}_{100}$
200	$\mathrm{CF} \cdot 365 \cdot {\mathrm{W}_{200}}^{0,704}$	$15.000 + 20.000 \cdot \mathrm{W}_{200}$
300	$682 \cdot {\mathrm{W}_{300}}^{1,025}$	$25.000 \cdot \mathrm{W}_{300}$
400	$1.605 \cdot {\mathrm{W}_{400}}^{0,795}$	$40.000 \cdot \mathrm{W}_{400}$
500	$\mathrm{CF} \cdot 34,8 \cdot {\mathrm{W}_{500}}^{1,24}$	$10.000 + 10.000 \cdot \mathrm{W}_{500}$
600	$310 \cdot (\mathrm{W}_{600} + \mathrm{W}_{700})^{0,949}$	$5.000 + 10.000 \cdot (\mathrm{W}_{600} + \mathrm{W}_{700})$

The complexity factor (CF) derived from a size factor (SF) and ship type factor (TF):

$$\mathrm{SF} = 32,47 \cdot \Delta^{-0,3792} \tag{49}$$

$$\mathrm{CF} = \mathrm{SF} \cdot \mathrm{TF} \tag{50}$$

Table 72. Complexity factor

Displacement	Δ	750,6	tonnes
Size factor	SF	2,637	-
Type factor	TF	4	-
Complexity factor	**CF**	**10,548**	

Table 73. Ship cost estimate

Displacement	Δ	750,6	tonnes
Speed	v	35,0	knots
Labor rate	LR	15	$/h
Labor overhead rate	LOR	100,0	%
Material overhead rate	MOR	2,0	%
Profit	p	10,0	%

Table 74. Preliminary design cost estimate

Item		**Weight (tonnes)**	**Man-hours (hours)**	**Material (US$)**
Structural weight	W_{100}	165,3	152.501	132.226
Propulsion weight	W_{200}	109,5	104.997	2.204.624
Electrical power weight	W_{300}	32,6	24.273	815.508
Electronic equipment weight	W_{400}	4,8	5.616	193.308
Auxiliary machinery weight	W_{500}	58,2	56.670	592.089
Outfit weight	W_{600}	64,3		
Special system weight	W_{700}	32,1	23.667	968.743
Total	$\mathbf{W_{LS}}$	466,8	367.724	4.906.498

Labor total		367.724
Labor rate		15
Labor direct cost	$	5.515.860
Labor indirect cost	$	5.515.860
Material direct cost	$	4.906.498
Material indirect cost	$	98.130
Profit	$	1.603.635
Total	**$**	**17.639.983**

Conclusion

The paper used is from 1997 and the estimation method was designed long ago, so this final cost should be actualized to the actual inflation.

OPERATING AND SUPPORT COST

Crew expenses

The annual cost per crew member is around 5.500 dollars per month[2], whit this value we can estimate the annual crew cost, the ship has 40 stable crew members, this give as per year 2.640.000 dollars per year.

Consumables

The coefficient of annual expenditure on consumption, referred to the total propulsive power (TPP) is between 100 to 125 dollars year per kilowatt. Being the TPP 22.652 KW, the total cost of the consumption is 2.831.500 dollars per year.

Maintenance, repair, insurance and others

Maintenance & repair, insurance and miscellaneous expenses depend from total investment and some coefficients:

- Maintenance & repair   0,015 < gmi < 0,020
- Insurance   0,010 < gsi < 0,015
- Others   0,010 < gvi < 0,015

The total investment estimated above is 17.639.983 dollars, taking the more expensive approach of each coefficient the sum of all the give us 0,05, multiplied by the total investment give us 882.000 dollars per year.

Table 75. Operational cost per year

Crew	$	2.640.000
Consumables	$	2.831.500
Maintenance, repair, insurance & others	$	882.000
Total	**$**	**6.353.500**

Conclusion

Due to the fact that it is a ship designed for the Argentine Navy, the constant political and economic variations of our country that affect the normal operation of ships belonging to a state entity must be taken into account.

[2] Value obtained from an extrapolation from: CONCEPT DESIGN OF AN OFFSHORE PATROL VESSEL FOR THE CANADIAN COAST GUARD - NAVAL ARCHITECTURE AND MARINE ENGINEERING DEPARTMENT OF MECHANICAL ENGINEERING UNIVERSITY OF BRITISH COLUMBIA - NAME 591 – COMPUTER-AIDED SHIP DESIGN PROJECT

19. TECHNICAL RISK

Due that the design is for a naval ship, and because Argentina is primarily an importer of these ships rather than a builder, there is little access to updated specific information.

There are practically no manufacturers of military technology in our country, due to this we must resort to foreign companies that do not want to reveal data.

STABILITY

A deeper analysis should be carried out with the stability of the ship, taking into account the roll moment generated by the stabilizer fins and gyrostabilizer. In the case of fins, it can be done using the method found in the paper "Control design of fin roll stabilization in beam seas based on Lyapunov's direct method".

In this study, a fin controller based on Lyapunov's direct method is designed in order to reduce severe rolling motion of ship in steady beam seas under the influence of random wind force. The effectiveness of the controller is tested by comparing controlled and uncontrolled roll angle simulations for different initial conditions considering stall effect. In order to succeed this type of comparison, safe basin concept is used. In that method, the safe and capsizing initial conditions are represented by white and black points respectively and the effects of different initial conditions on the stability of the dynamic system (ship) can be shown by using just one graphic. From the comparisons of safe basins plots of controlled and uncontrolled roll motion, it is seen if the controller is successful.

COST ANALYSIS

The risk of using an estimation method from 1997 and not using real market prices generates that there is no value of what the ship may currently cost, the constant inflation that is not even over time, in the next project stage, it would be necessary to start communicating with suppliers and brands. It should also be taken into account due to the problems in Argentina for the long entry times of imported products, construction times are lengthened.

EPLA

In a more advanced stage of the project, it will be possible to obtain more detailed data of each element that depends on the electrical system, then the transformers will be selected and the single-line diagram will be developed with the dimensioning of the distribution components.

HULL FORM TO SPEED VS. POWER ANALISYS

The series used are developed from models analyzed in test channels, in a more advanced stage of the project scale models can be made to test them and compare the results with the values obtained by software.

PROJECT RISK MANAGEMENT

PRM describes the processes that they have to do with the identification, analysis and response to project risk. This consists of risk management planning, identification of risks, qualitative risk analysis, quantitative risk analysis, risk response planning; and risk monitoring and control. Is a systematic process that consists of identify, analyze and respond to project risk. This includes maximizing probability and consequences of positive events and minimizing the probability and consequences of adverse events for the project objectives.

Risk probability/impact weighting matrix

It can construct a matrix that assigns a weight to the risks (very low, low, moderate, high, and very high) to risks or conditions, based on to combine the probability and impact scales. risks with high probability and high impact, are likely to require further analysis, including quantification and aggressive risk management weighting of the risks is carried out using a matrix and the risk scales for each of these events or conditions.

Table 76. Risk matrix

Probability	Very low 0,050	Low 0,100	Moderate 0,200	High 0,400	Very high 0,800
0,1	0,005	0,010	0,020	0,040	0,080
0,3	0,015	0,030	0,060	0,120	0,240
0,5	0,025	0,050	0,100	0,200	0,400
0,7	0,035	0,070	0,140	0,280	0,560
0,9	0,045	0,090	0,180	0,360	0,720

Table 77. Risk summary

Project's objective	Probability	Impacts	Score
Dimensioning	0,5	0,200	0,100
Hull form	0,3	0,400	0,120
Weights estimate	0,5	0,200	0,100
Floodable length	0,1	0,050	0,005
Structural mid-ship section	0,1	0,100	0,010
Speed vs. Power analysis	0,3	0,200	0,060
Electrical load analysis	0,7	0,200	0,140
Intact/damage stability	0,3	0,400	0,120
Seakeeping	0,3	0,200	0,060
Manning estimate	0,1	0,050	0,005
Propulsion trade-off study	0,3	0,200	0,060
Mission systems & equipment	0,1	0,100	0,010
Cost analysis	0,9	0,800	0,720

Table 78. Observations

Project's objective	Description
Dimensioning	None OPV of this disp. come close to 8.000 nmi of range
Hull form	The most current hull series may be obsolete compared to the experience that a shipyard may have with this type of vessel
Weights estimate	In a later stage of the project, data from more equipment can be known
Floodable length	No major variations should show a later stage of the project
Structural mid-ship section	Classification rules usually give adequate safety margins, but a finite element analysis can be performed at a more advanced stage
Speed vs. Power analysis	Testing of models in test channels
Electrical load analysis	At this stage of the project, not all the equipment is known, nor is there all the information on those that are known.
Intact/damage stability	By varying the above data can vary the stability
Seakeeping	A deeper analysis can be carried out once the critical areas in the ship have been defined
Manning estimate	Obtained from the owner's requirements can vary 2 o 3 crew members
Propulsion trade-off study	Similar ships have similar systems incorporated in the Argentine navy, the CODOG warp combination may raise doubts
Mission systems & equipment	Obtained from the owner's requirements can vary some minor systems
Cost analysis	>20% increase of costs

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APPENDIX A
Reference vessels

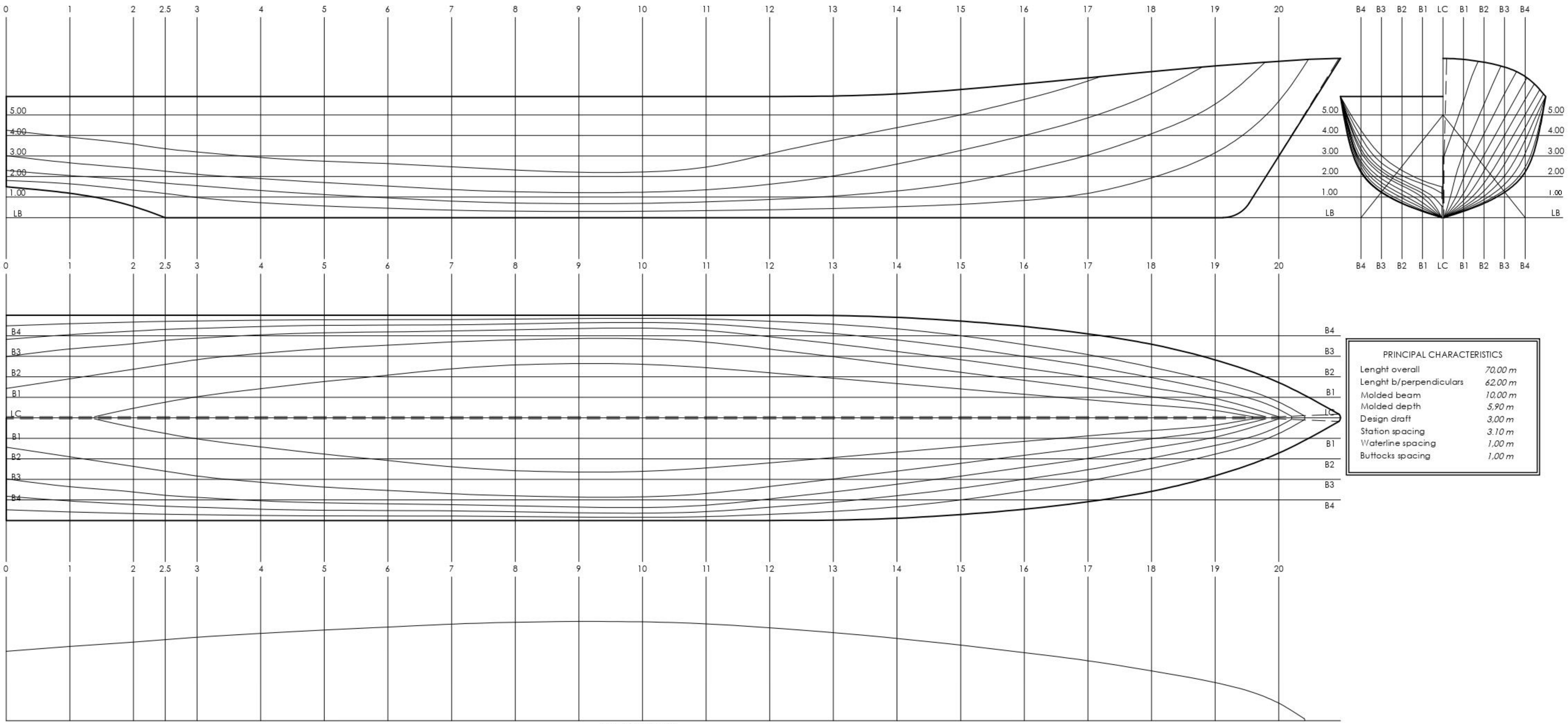
Table 79. Reference vessels principal characteristics

Nº	Name	Shipyard	Year	Δ	LOA	BOA	D	T	Propulsion	Cruise speed	Max. speed	Range	Complement
1	Visby-class	Kockums	2009	640 tonnes	72,7 m	10,4 m	-	2,4 m	16.000 kW	15 knots	35 knots	2.500 nmi	43
2	Baynunah-class	Abu Dhabi Ship Building	2009	915 tonnes	71,3 m	11,0 m	-	2,8 m	12.956 kW	15 knots	30 knots	2.400 nmi	37
3	LMV 60	Fassmer	2021	600 tonnes	60,2 m	10,0 m	-	2,5 m	-	12 knots	40 knots	3.000 nmi	50
4	Yoon Youngha-class	Hanjin Heavy Industries	2014	570 tonnes	63,0 m	9,0 m	-	3,0 m	9.140 kW	15 knots	44 knots	1.998 nmi	40
5	Musherib-class	Ficantieri	2017	745 tonnes	63,8 m	9,2 m	5,7 m	-	-	15 knots	30 knots	1.500 nmi	38
6	SA'AR S - 72	Israel Shipyards	2013	800 tonnes	72,0 m	10,3 m	-	-	11.840 kW	18 knots	30 knots	3.000 nmi	50
7	Serie 7 062	Vard Marine	2021	-	62,0 m	9,6 m	5,6 m	2,8 m	-	-	28 knots	-	47
8	Combattante BR71	CMN	2022	-	71,3 m	11,0 m	-	3,0 m	-	12 knots	30 knots	2.500 nmi	45
9	LMS3	Boustead Heavy Industries	2020	710 tonnes	68,0 m	9,2 m	5,1 m	-	7.200 kW	16 knots	22 knots	2.000 nmi	45
10	OPV 65	Kership	2021	870 tonnes	65,4 m	11,3 m	-	-	-	15 knots	-	3.000 nmi	-
11	70 FREYJA	Ares	2022	780 tonnes	70,8 m	9,8 m	-	2,3 m	-	-	-	-	50
12	OPV-70	STX France SA	2011	800 tonnes	70,0 m	11,3 m	-	3,3 m	8.160 kW	12 knots	22 knots	4.200 nmi	64
13	LARGE PATROL CRAFT	Khulna Shipyard	2011	648 tonnes	64,2 m	9,0 m	5,3 m	4,0 m	-	15 knots	28 knots	-	70
14	OPV 190 MkII	Ocea	2016	500 tonnes	58,0 m	9,4 m	-	2,3 m	5.120 kW	-	26 knots	-	35
15	Fast Attack Craft FAC 65	Dearsan	2021	600 tonnes	65,0 m	10,0 m	-	2,8 m	19.200 kW	-	45 knots	1.000 nmi	42
16	Keris-class	CSIC	2018	700 tonnes	69,0 m	9,0 m	-	2,8 m	-	15 knots	24 knots	2.000 nmi	45
17	SIGMA 7311	Damen	2021	900 tonnes	73,2 m	11,0 m	-	3,0 m	-	15 knots	30 knots	2.500 nmi	63
18	Bad Bramstedt-class	Abeking & Rasmussen	2002	880 tonnes	65,9 m	10,6 m	-	3,2 m	5.200 kW	12 knots	22 knots	-	14

Table 80. Reference vessels principal relations

Nº	Name	Shipyard	Year	Δ/LOA	BOA/LOA	D/LOA	LOA/T
1	Visby-class	Kockums	2009	8,803	0,1431	-	0,0330
2	Baynunah-class	Abu Dhabi Ship Building	2009	12,586	0,1543	-	0,0393
3	LMV 60	Fassmer	2021	8,253	0,1661	-	0,0415
4	Yoon Youngha-class	Hanjin Heavy Industries	2014	7,840	0,1429	-	0,0476
5	Musherib-class	Ficantieri	2017	10,248	0,1442	0,0886	-
6	SA'AR S - 72	Israel Shipyards	2013	11,004	0,1424	-	-
7	Serie 7 062	Vard Marine	2021	-	0,1548	0,0903	0,0452
8	Combattante BR71	CMN	2022	-	0,1543	-	0,0421
9	LMS3	Boustead Heavy Industries	2020	9,766	0,1353	0,0750	-
10	OPV 65	Kership	2021	11,967	0,1728	-	-
11	70 FREYJA	Ares	2022	10,729	0,1384	-	0,0325
12	OPV-70	STX France SA	2011	11,004	0,1614	-	0,0464
13	LARGE PATROL CRAFT	Khulna Shipyard	2011	8,913	0,1402	0,0818	0,0623
14	OPV 190 MkII	Ocea	2016	6,878	0,1621	-	0,0397
15	Fast Attack Craft FAC 65	Dearsan	2021	8,253	0,1538	-	0,0431
16	Keris-class	CSIC	2018	9,629	0,1304	-	0,0406
17	SIGMA 7311	Damen	2021	12,380	0,1505	-	0,0410
18	Bad Bramstedt-class	Abeking & Rasmussen	2002	12,105	0,1608	-	0,0486
				10,022	**0,1504**	**0,0839**	**0,0431**

APPENDIX B
Line plan



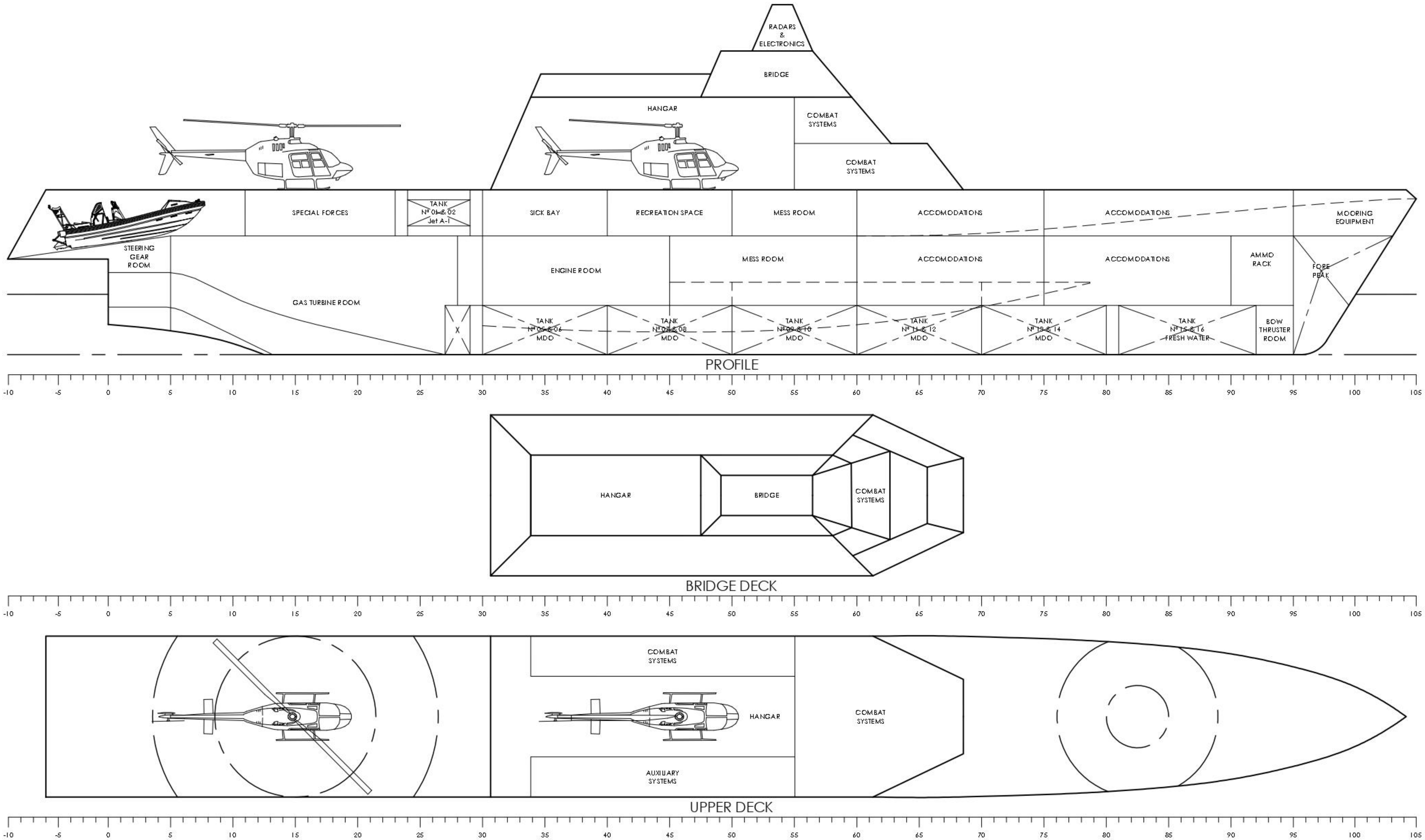
PRINCIPAL CHARACTERISTICS	
Lenght overall	70,00 m
Lenght b/perpendiculars	62,00 m
Molded beam	10,00 m
Molded depth	5,90 m
Design draft	3,00 m
Station spacing	3.10 m
Waterline spacing	1,00 m
Buttocks spacing	1,00 m

	Date	Name	Client:
Drawn	01/05/2022	P. Duhalde	Argentine Navy
Checked	31/05/2022	P. Duhalde	
Approved	31/05/2022	P. Duhalde	

Scale: 1:200	Vessel: 70 m Offshore Patrol Vessel	
1 of 1	Title: Line plan	DWG Nº: 01
2022	National Technological University	Mar del Plata

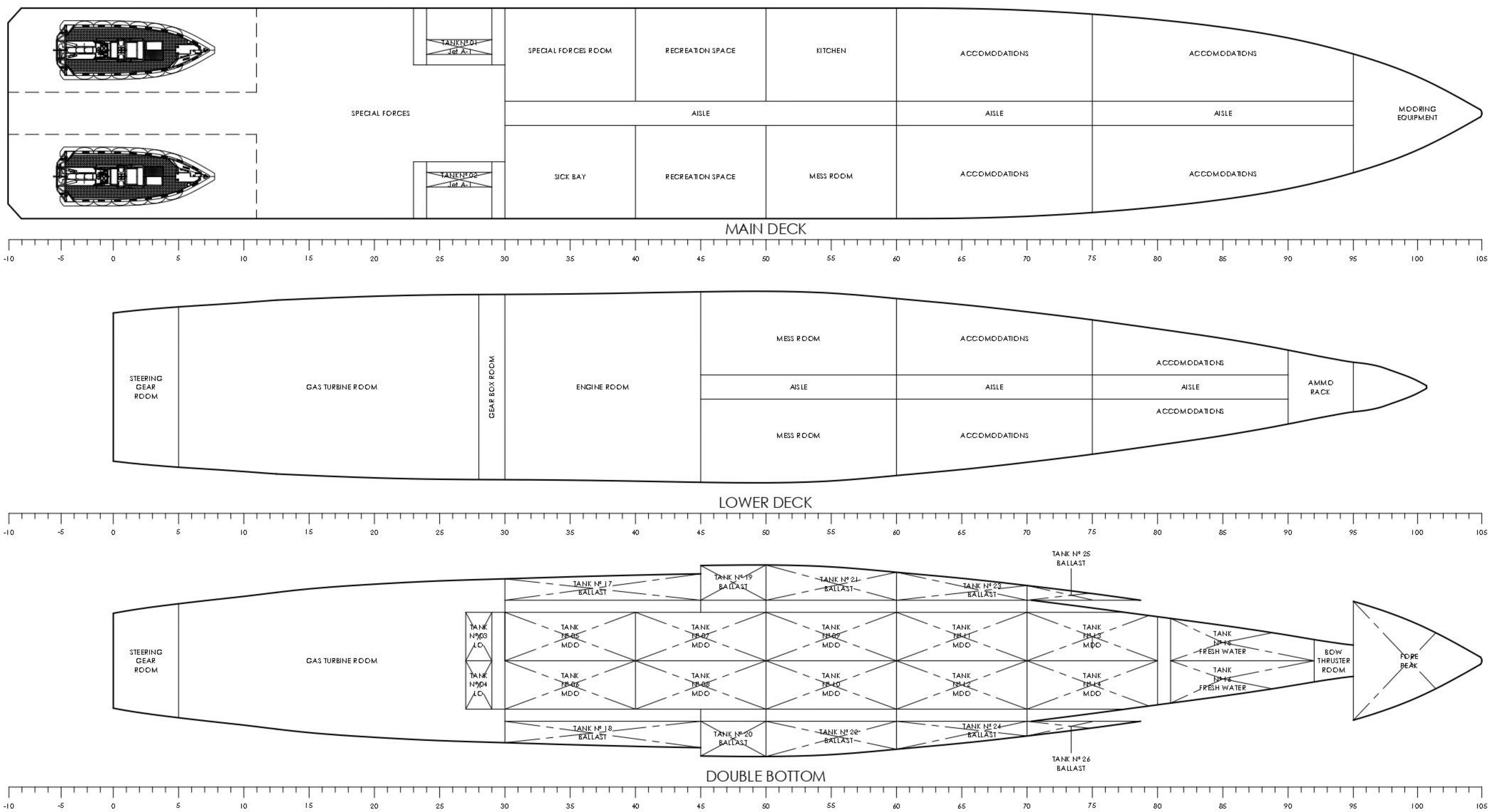
UTN MDP
Regional Mar del Plata

APPENDIX C
General arrangement



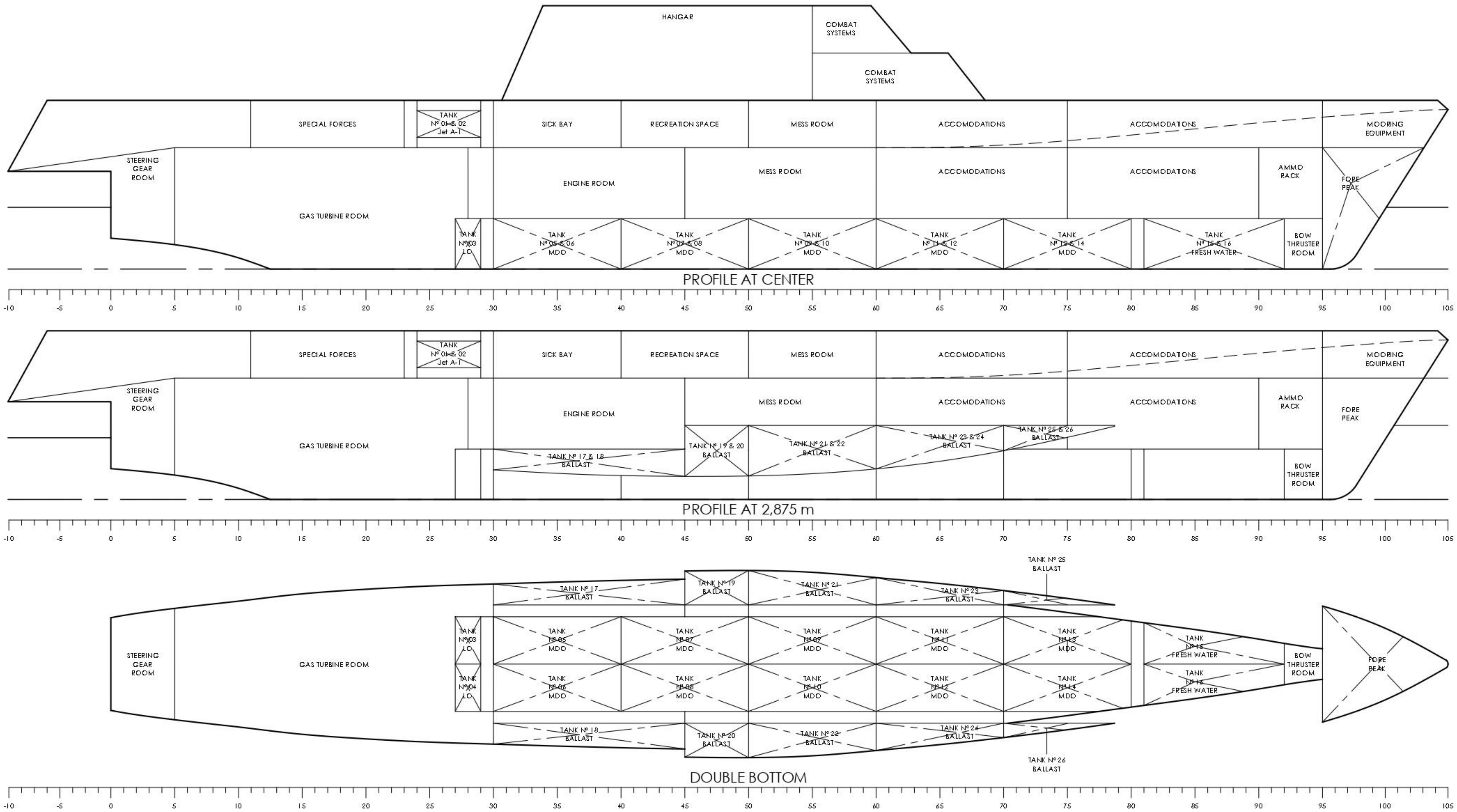
	Date	Name	Client:
Drawn	15/05/2022	P. Duhalde	Argentine Navy
Checked	31/05/2022	P. Duhalde	
Approved	31/05/2022	P. Duhalde	
Scale: 1:200	Vessel: 70 m Offshore Patrol Vessel		
1 of 2	Title: General arrangement		DWG Nº: 02
2022	National Technological University		Mar del Plata

UTN MDP
Regional Mar del Plata



	Date	Name	Client:	
Drawn	15/05/2022	P. Duhalde	Argentine Navy	UTN MDP Regional Mar del Plata
Checked	31/05/2022	P. Duhalde		
Approved	31/05/2022	P. Duhalde		
Scale: 1:200	Vessel: 70 m Offshore Patrol Vessel			
2 of 2	Title: General arrangement			DWG Nº: 02
2022	National Technological University			Mar del Plata

APPENDIX D
Capacity plan

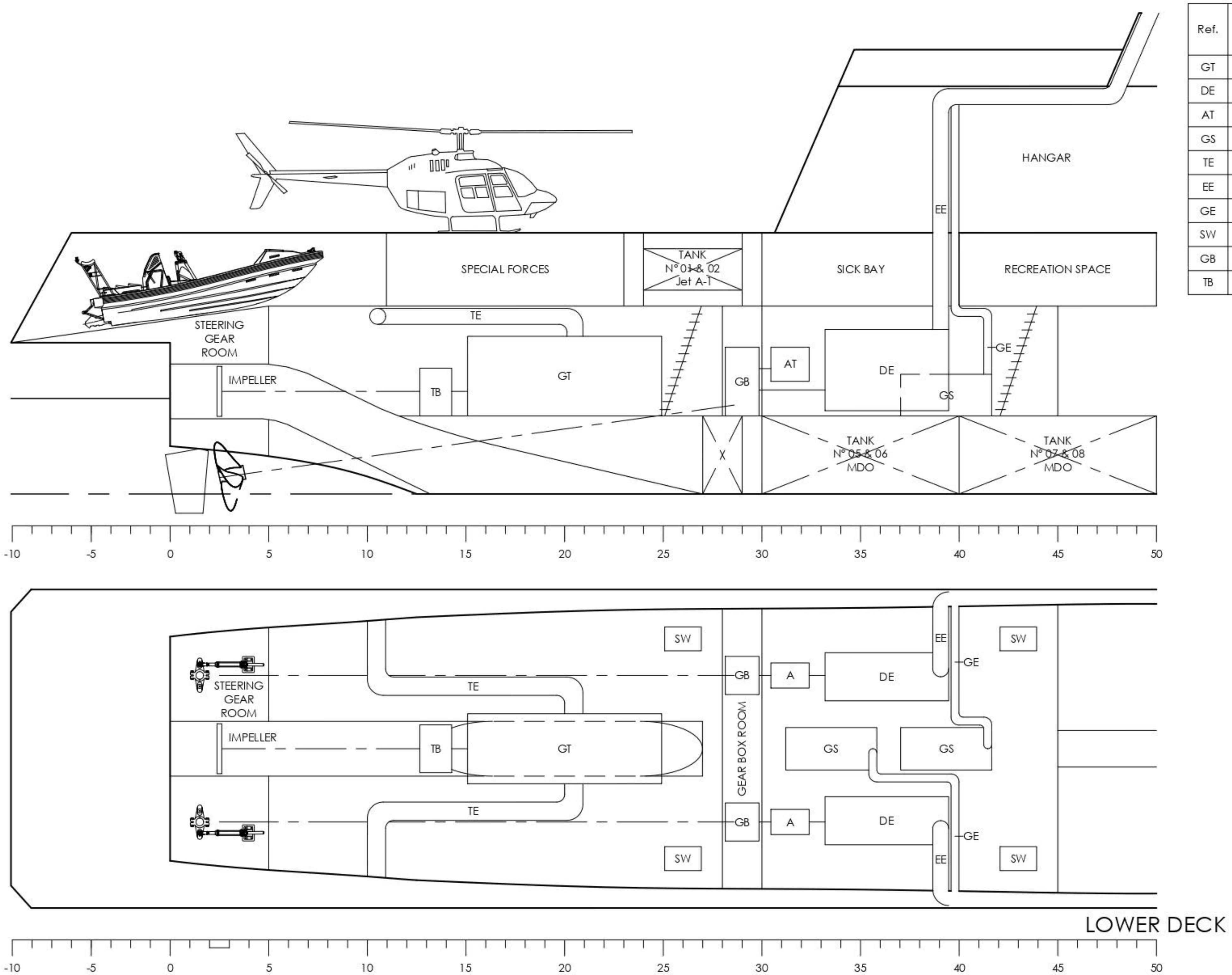


Item	B/Frame Nº	Specific gravity (tonne/m³)	Volume (m³)	Mass (tonne)	Long. arm (m)	Trans. arm (m)	Vert. arm (m)
Helicopter fuel							
TANK Nº 01 - Jet A1	24 - 29	0,840	2,708	2,275	16,430	-3,150	7,050
TANK Nº 02 - Jet A1	24 - 29	0,840	2,708	2,275	16,430	3,150	7,050
			5,416	4,550	16,430	0,000	7,050
Lube oil							
TANK Nº 03 - Lube Oil	27 - 29	0,920	5,073	4,667	17,362	-1,026	1,481
TANK Nº 04 - Lube Oil	27 - 29	0,920	5,073	4,667	17,362	1,026	1,481
			10,147	9,335	0,000	0,000	1,481
Fuel							
TANK Nº 05 - MDO	30 - 40	0,840	27,977	23,501	21,739	-1,057	1,429
TANK Nº 06 - MDO	30 - 40	0,840	27,977	23,501	21,739	1,057	1,429
TANK Nº 07 - MDO	40 - 50	0,840	29,016	24,373	27,902	-1,073	1,398
TANK Nº 08 - MDO	40 - 50	0,840	29,016	24,373	27,902	1,073	1,398
TANK Nº 09 - MDO	50 - 60	0,840	28,377	23,837	34,075	-1,062	1,417
TANK Nº 10 - MDO	50 - 60	0,840	28,377	23,837	34,075	1,062	1,417
TANK Nº 11 - MDO	60 - 70	0,840	26,342	22,127	40,245	-1,019	1,469
TANK Nº 12 - MDO	60 - 70	0,840	26,342	22,127	40,245	1,019	1,469
TANK Nº 13 - MDO	70 - 80	0,840	21,934	18,425	46,348	-0,892	1,536
TANK Nº 14 - MDO	70 - 80	0,840	21,934	18,425	46,348	0,892	1,536
Total	30 - 80	0,840	267,294	224,527	33,383	0,000	1,445

Item	B/Frame Nº	Specific gravity (tonne/m³)	Volume (m³)	Mass (tonne)	Long. arm (m)	Trans. arm (m)	Vert. arm (m)
Fresh water							
TANK Nº 15 - Fresh Water	81 - 92	1,000	14,078	14,078	53,227	-0,561	1,558
TANK Nº 16 - Fresh Water	81 - 92	1,000	14,078	14,078	53,227	0,561	1,558
			28,157	28,157	53,227	0,000	1,558
Ballast water							
TANK Nº 17 - Ballast	30 - 45	1,025	7,496	7,684	23,652	-3,299	2,009
TANK Nº 18 - Ballast	30 - 45	1,025	7,496	7,684	23,652	3,299	2,009
TANK Nº 19 - Ballast	45 - 50	1,025	8,199	8,404	29,450	-3,519	2,656
TANK Nº 20 - Ballast	45 - 50	1,025	8,199	8,404	29,450	3,519	2,656
TANK Nº 21 - Ballast	50 - 60	1,025	13,843	14,189	33,857	-3,468	2,725
TANK Nº 22 - Ballast	50 - 60	1,025	13,843	14,189	33,857	3,468	2,725
TANK Nº 23 - Ballast	60 - 70	1,025	6,043	6,194	39,663	-3,259	2,967
TANK Nº 24 - Ballast	60 - 70	1,025	6,043	6,194	39,663	3,259	2,967
TANK Nº 25 - Ballast	70 - 80	1,025	0,780	0,799	44,787	-3,053	3,297
TANK Nº 26 - Ballast	70 - 80	1,025	0,780	0,799	44,787	3,053	3,297
Fore peak	95 - 105	1,025	27,231	27,911	60,357	0,000	4,246
Subtotal			99,952	102,451	39,695	0,000	3,059

	Date	Name	Client:	
Drawn	15/05/2022	P. Duhalde	Argentine Navy	UTN MDP Regional Mar del Plata
Checked	31/05/2022	P. Duhalde		
Approved	31/05/2022	P. Duhalde		
Scale: 1:200	Vessel: 70 m Offshore Patrol Vessel			
1 of 1	Title: Capacity plan			DWG Nº: 03
2022	National Technological University			Mar del Plata

APPENDIX E
Machinery arrangement

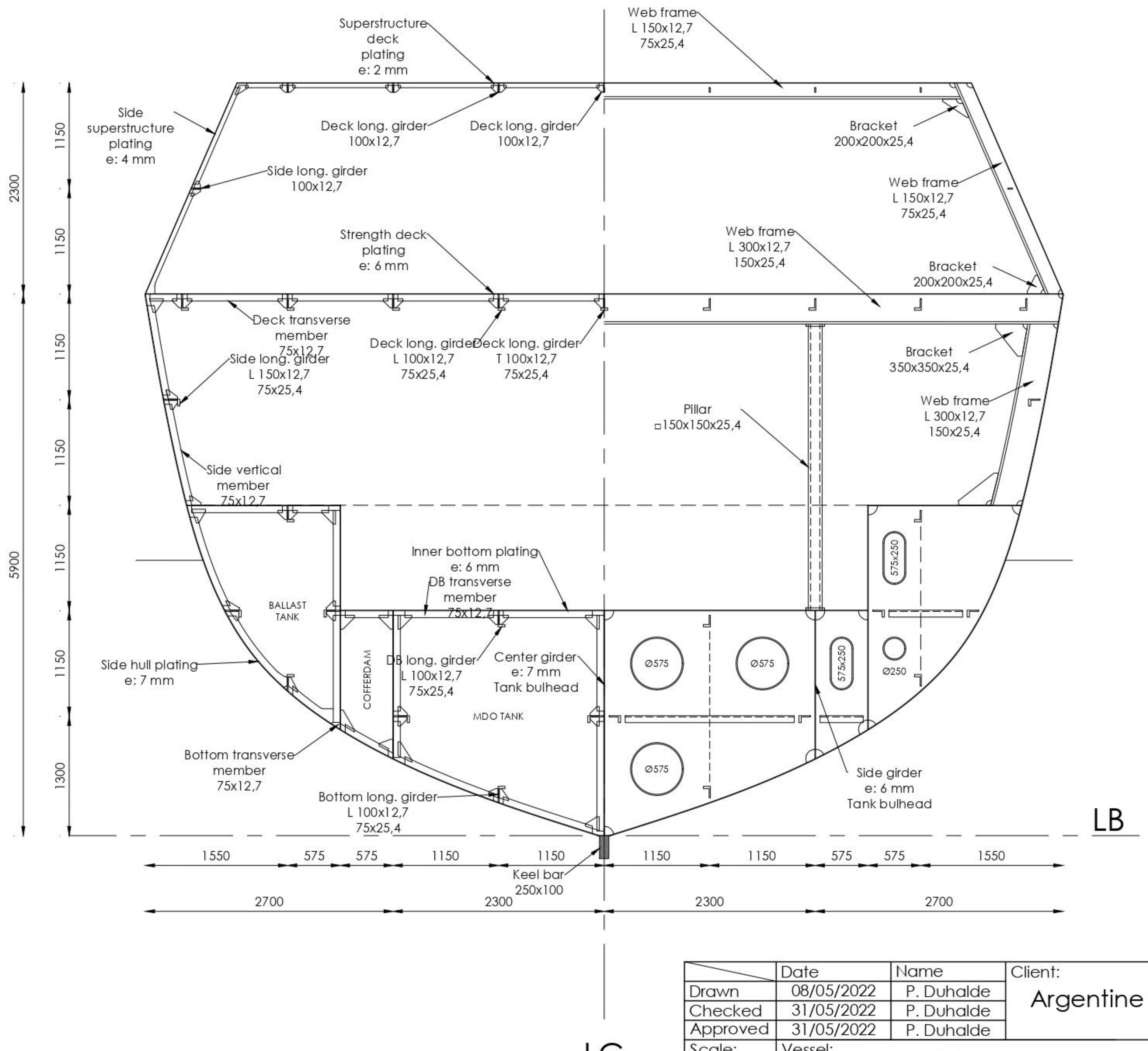


Ref.	Item	N°	Brand	Model	Capacity
GT	Gas turbine	1	Zorya-Mashproekt	Type UGT 15000+	20.000 kWm at 35.000 rpm
DE	Diesel engine	2	Anglo Belgian Co.	6DZC	1.326 kWm at 1000 rpm
AT	Alternator	2	Cramaco	G2R 400 SSA/4	520 kW50 Hz
GS	Genset	2	Volvo Penta	D16 - MG	525 kW 50 Hz
TE	Turbine exhaust pipe	2	-	-	-
EE	Diesel engine exhaust pipe	2	-	-	-
GE	Genset exhaust pipe	2	-	-	-
SW	Stairwell	4	-	-	-
GB	Diesel engine gearbox	2	ZF Friedrichshafen AG	9000 A	r: 2,958
TB	Turbine gearbox	2	Cincinnati Gear	Single imput	-

	Date	Name	Client:
Drawn	15/05/2022	P. Duhalde	Argentine Navy
Checked	31/05/2022	P. Duhalde	
Approved	31/05/2022	P. Duhalde	
Scale: 1:200	Vessel: 70 m Offshore Patrol Vessel		
1 of 1	Title: Machinery arrangement		DWG N°: 04
2022	National Technological University		Mar del Plata

UTN MDP Regional Mar del Plata

APPENDIX F
Structural mid-ship section



	Date	Name	Client:
Drawn	08/05/2022	P. Duhalde	Argentine Navy
Checked	31/05/2022	P. Duhalde	
Approved	31/05/2022	P. Duhalde	
Scale: 1:50	Vessel: 70 m Offshore Patrol Vessel		
1 of 1	Title: Midship section		DWG Nº: 04
2022	National Technological University		Mar del Plata

UTN MDP
Regional Mar del Plata

APPENDIX G
Electrical load analysis

Table 81. SWBS Group 1 - Propulsion Plant

System	Quantity	Rated power (kW)	Load (kW)	Simultaneity coefficient	Load factor					Load (kW)				
					Anchor	Shore	Cruising	Functional	Emergency	Anchor	Shore	Cruising	Functional	Emergency
Auxiliary seawater circulating pump	2	6	12	1						0	0	0	0	0
Blow in door heater, gas turbine	2	1,5	3	1	0	0	0	0,9	0	0	0	0	2,7	0
Controllable pitch propeller hydraulic oil heater	2	1	2	1	0,3	0,3	0,3	0,3	0	0,6	0,6	0,6	0,6	0
Controllable pitch propeller hydraulic oil pump	2	1,5	3	1	0	0	0,9	0,9	0	0	0	2,7	2,7	0
Controllable pitch propeller hydraulic oil purifier heater	2	1,5	3	1	0,1	0	0,1	0	0	0,3	0	0,3	0	0
Controllable pitch propeller hydraulic oil purifier	2	1,5	3	1	0,3	0	0,3	0,3	0	0,9	0	0,9	0,9	0
Emergency feed booster and transfer pump	2	-	-	0,5	0	0	0	0	0	-	-	-	-	-
Fuel service pump	2	10	20	1	0,4	0,1	0,9	0,9	0	8	2	18	18	0
Inlet louver heater, gas turbine	2	3	6	1	0	0	0	0,9	0	0	0	0	5,4	0
Lighting off forced draft blower	2	10	20	1	0,1	0	0	0	0	2	0	0	0	0
Lube oil purifier	2	7	14	0,5	0,9	0	0,3	0,3	0	6,3	0	2,1	2,1	0
Main circulating MO valve	2	-	-	1	0	0	0	0	0	-	-	-	-	-
Main circulating pump	2	6	12	1	0	0	0,9	0,9	0	0	0	10,8	10,8	0
Main condensate pump	2	1,5	3	1	0	0	0,9	0,9	0	0	0	2,7	2,7	0
Main engine cooling fan, gas turbine	2	50	100	1	0	0	0,9	0,9	0	0	0	90	90	0
Main engine prelube pump	2	-	-	1	0	0	0	0	0	-	-	-	-	-
Main feed booster pump	2	5	10	1	0,1	0	0,9	0,9	0,5	1	0	9	9	5
Main vacuum pump	2	15	30	1	0	0	0,9	0,9	0	0	0	27	27	0
Main feed lube pump	2	7,5	15	1	0,2	0	0,9	0,9	0	3	0	13,5	13,5	0
Module equipment, gas turbine	1	10	10	1	0,4	0,4	0,2	0,2	0	4	4	2	2	0
Port fuel service pump	1	2,5	2,5	1	0	0,1	0	0	0	0	0,25	0	0	0
Port-use forced draft blower	2	15	30	1	0,2	0	0	0	0	6	0	0	0	0
Propulsion control console	2	5	10	1	0,5	0,2	0,6	0,8	0	5	2	6	8	0
Propulsion motor lubricating oil pump	4	5	20	1	0	0	0,9	0,9	0	0	0	18	18	0
Propulsion motor ventilation fan	6	7,5	45	1	0	0	0,9	0,9	0	0	0	40,5	40,5	0
Reserve feed transfer pump	1	1,5	1,5	1	0,2	0,2	0,2	0	0	0,3	0,3	0,3	0	0
Seawater booster pump	2	10	20	0,5	0	0	0,3	0,9	0	0	0	3	9	0
Shaft turning gear	2	6,5	13	1	0,1	0,1	0	0	0,1	1,3	1,3	0	0	1,3
Standby reduction gear lubricating oil pump	2	2	4	1	0	0	0	0	0,2	0	0	0	0	0,8
Standby lubricating oil service pump	2	5	10	1	0	0	0	0	0,2	0	0	0	0	2
Total										**39**	**11**	**248**	**263**	**10**

Table 82. SWBS Group 2 - Electric Plant

System	Quantity	Rated power (kW)	Load (kW)	Simultaneity coefficient	Load factor					Load (kW)				
					Anchor	Shore	Cruising	Functional	Emergency	Anchor	Shore	Cruising	Functional	Emergency
Electric plant control console	2	2,5	5	1	0,2	0,2	0,2	0,2	0,2	1	1	1	1	1
Emergency gen saltwater booster pump	1	5,5	5,5	1	0	0	0	0	0,9	0	0	0	0	4,95
Forklift battery charger	2	20	40	1	0,2	0,2	0,3	0,3	0	8	8	12	12	0
Generator space heater	2	30	60	1	0,9	0,9	0	0	0	54	54	0	0	0
Lighting machinery spaces	1	20	20	1	0,9	0,9	0,9	0,9	0,9	18	18	18	18	18
Lighting outside machinery spaces	1	10	10	1	0,6	0,4	0,6	0,6	0,4	6	4	6	6	4
Ship battery charger	4	3	12	0,5	0,2	0,2	0,2	0,2	0	1,2	1,2	1,2	1,2	0
STGEN circulating pump	2	5	10	1	0,5	0	0,5	0,9	0	5	0	5	9	0
STGEN condensate pump	2	1,5	3	1	0,5	0	0,5	0,9	0	1,5	0	1,5	2,7	0
STGEN start-up lubricating oil pump	2	2,5	5	1	0	0	0	0	0,9	0	0	0	0	4,5
STGEN vacuum pump	2	5	10	1	0,5	0	0,5	0,9	0	5	0	5	9	0
Helicopter starting rectifier	1	-	-	1	0	0	0	0	0	-	-	-	-	-
Total										**100**	**87**	**50**	**59**	**33**

Table 83. SWBS Group 3 - Command and Surveillance

System	Quantity	Rated power (kW)	Load (kW)	Simultaneity coefficient	Load factor					Load (kW)				
					Anchor	Shore	Cruising	Functional	Emergency	Anchor	Shore	Cruising	Functional	Emergency
Combat information center	1	20	20	1	0,2	0	0,4	0,7	0	4	0	8	14	0
Electronic cooling system	1	10	10	1	0,4	0,2	0,7	0,7	0,5	4	2	7	7	5
Entertainment system	1	1	1	1	0,1	0,1	0,3	0	0	0,1	0,1	0,3	0	0
Lighting, navigation	1	5	5	1	0,6	0,4	0,6	0,4	0,2	3	2	3	2	1
Surface search radar	1	40	40	1	0,2	0	0,5	0,7	0,5	8	0	20	28	20
Air and surface search radar	1	30	30	1	0,2	0	0,5	0,7	0,5	6	0	15	21	15
Electro optical multisensor system	1	100	100	1	0,2	0	0,5	0,7	0,5	20	0	50	70	50
Inertial measurement unit	1	0,04	0,04	1	0,2	0	0,5	0,7	0,5	0,008	0	0,02	0,028	0,02
Helicopter visual landing aid system	1	15	15	1	0,2	0	0,5	0,7	0,5	3	0	7,5	10,5	7,5
Radio	2	3	6	1	0,2	0,1	0,4	0,7	0,4	1,2	0,6	2,4	4,2	2,4
Searchlight	4	2,5	10	1	0	0	0	0,2	0	0	0	0	2	0
Fire control	1	2,8	2,8	1	0,2	0,1	0,4	0,7	0,4	0,56	0,28	1,12	1,96	1,12
Total										**50**	**5**	**115**	**161**	**103**

Table 84. SWBS Group 4 - Auxiliary Systems

System	Quantity	Rated power (kW)	Load (kW)	Simultaneity coefficient	Load factor					Load (kW)				
					Anchor	Shore	Cruising	Functional	Emergency	Anchor	Shore	Cruising	Functional	Emergency
A/C chilled water pump (T)	2	6	12	1	0,7	0,5	0,7	0,7	0,4	8,4	6	8,4	8,4	4,8
A/C compressor (T)	2	25	50	1	0,7	0,5	0,7	0,7	0,4	35	25	35	35	20
A/C purge recovery unit (T)	2	1,5	3	1	0,3	0,3	0,3	0,3	0	0,9	0,9	0,9	0,9	0
A/C seawater circulating pump (T)	2	2,5	5	1	0,7	0,5	0,7	0,7	0,4	3,5	2,5	3,5	3,5	2
Anchor windlass	-	-	-	1	0	0	0	0	0	-	-	-	-	-
Bilge & fuel tank stripping	2	0,5	1	0,5	0,1	0,1	0,1	0	0	0,05	0,05	0,05	0	0
Bilge pump	2	1	2	0,5	0,1	0,1	0,1	0,1	0	0,1	0,1	0,1	0,1	0
Boat winch	2	2	4	1	0	0	0	0	0	0	0	0	0	0
Capstan	6	5	30	1	0	0	0	0	0	0	0	0	0	0
Cargo refrigerator compressor (T)	2	25	50	1	0,3	0,3	0,3	0,3	0	15	15	15	15	0
Cathodic protection	2	1	2	1	0,9	0,9	0,9	0	0	1,8	1,8	1,8	0	0
Control air compressor	1	25	25	1	0,2	0	0,6	0,6	0	5	0	15	15	0
Distiller plant	2	2,5	5	1	0,5	0	0,7	0,7	0	2,5	0	3,5	3,5	0
Fire pump	6	3,5	21	0,5	0,2	0,2	0,2	0,4	0,4	2,1	2,1	2,1	4,2	4,2
Fuel drain and transfer pump	1	2,5	2,5	1	0,3	0	0,3	0,3	0	0,75	0	0,75	0,75	0
Fuel transfer pump	2	2,5	5	0,5	0,1	0,1	0,1	0,1	0	0,25	0,25	0,25	0,25	0
Fuel transfer pump purifier	2	3	6	0,5	0,3	0	0,3	0	0	0,9	0	0,9	0	0
Fuel tank stripping pump	1	0,3	0,3	1	0	0	0	0	0	0	0	0	0	0
Flushing system	1	2,5	2,5	1	0	0	0,1	0,1	0	0	0	0,25	0,25	0
Fresh water drain tank pump	2	1	2	0,5	0,3	0,1	0,6	0	0	0,3	0,1	0,6	0	0
Gas turbine wash down pump	1	-	-	1	0	0	0	0	0	-	-	-	-	-
Gas turbine water wash tank heater	1	2	2	1	0,1	0,1	0,1	0,1	0	0,2	0,2	0,2	0,2	0
High pressure air compressor	1	5	5	1	0,1	0,1	0,1	0,1	0	0,5	0,5	0,5	0,5	0
Hot water circulating pump	2	2,5	5	0,5	0,3	0,3	0,6	0,6	0	0,75	0,75	1,5	1,5	0
HP air compressor air dryer	1	2,5	2,5	1	0,1	0,1	0,1	0,1	0	0,25	0,25	0,25	0,25	0
Lubricating oil transfer pump	1	1,5	1,5	1	0,1	0,1	0,1	0	0	0,15	0,15	0,15	0	0
Main steering gear pump	2	2,5	5	1	0	0	0,3	0,3	0,3	0	0	1,5	1,5	1,5
Potable water booster pump	2	2,5	5	0,5	0,3	0,2	0,3	0,3	0	0,75	0,5	0,75	0,75	0
Potable water priming pump	-	-	-	1	0	0	0	0	0	-	-	-	-	-
Potable water pump	2	2,5	5	0,5	0,3	0,2	0,3	0,3	0	0,75	0,5	0,75	0,75	0
Sewage macerator	1	1,5	1,5	1	0,1	0,1	0,1	0,1	0	0,15	0,15	0,15	0,15	0
Sewage pump	1	0,5	0,5	1	0	0	0,1	0,1	0	0	0	0,05	0,05	0
Ship service air compressor	1	40	40	1	0,1	0,1	0,1	0,1	0	4	4	4	4	0
Soluble fog foam	2	10	20	1	0	0	0	0	0	0	0	0	0	0
Steering gear control	4	3	12	1	0	0	0,5	0,5	0,5	0	0	6	6	6
Steering gear servo pump	2	2	4	1	0	0	0,5	0,5	0,1	0	0	2	2	0,4
Standby steering gear pump	2	1,5	3	1	0	0	0	0	0	0	0	0	0	0
Steering gear fill & drain pump	2	0,5	1	1	0	0	0	0	0	0	0	0	0	0
Helicopter winch	1	-	-	1	0	0	0	0	0	-	-	-	-	-
Jet A-1 purifier	1	1	1	1	0	0	0,1	0	0	0	0	0,1	0	0
Jet A-1 service pump	1	1,5	1,5	1	0	0	0,1	0	0	0	0	0,15	0	0
Jet A-1 transfer pump	1	1,5	1,5	1	0	0	0	0	0	0	0	0	0	0
Total										**85**	**61**	**107**	**105**	**39**

Table 85. SWBS Group 5 - Outfit and Furnishings

System	Quantity	Rated power (kW)	Load (kW)	Simultaneity coefficient	Load factor					Load (kW)				
					Anchor	Shore	Cruising	Functional	Emergency	Anchor	Shore	Cruising	Functional	Emergency
Arc welders AC/DC	2	7	14	1	0,1	0,1	0,1	0,1	0	1,4	1,4	1,4	1,4	0
Bake oven	4	2	8	1	0,2	0,2	0,2	0	0	1,6	1,6	1,6	0	0
Coffee maker	4	1	4	1	0,3	0,2	0,3	0,3	0	1,2	0,8	1,2	1,2	0
Coil winder	2	1,5	3	1	0,2	0,2	0,2	0	0	0,6	0,6	0,6	0	0
Deep fat fryer	2	6	12	1	0,4	0,4	0,4	0	0	4,8	4,8	4,8	0	0
Dishwasher	2	2	4	1	0,3	0,2	0,3	0,2	0	1,2	0,8	1,2	0,8	0
Drill press	1	5,5	5,5	1	0,1	0,1	0,1	0	0	0,55	0,55	0,55	0	0
Dryer	2	2	4	1	0,2	0,2	0,2	0	0	0,8	0,8	0,8	0	0
Flatwork ironer	1	40	40	1	0,2	0,2	0,2	0	0	8	8	8	0	0
Fry kettle	2	1,5	3	1	0,4	0,2	0,4	0,4	0	1,2	0,6	1,2	1,2	0
Garbage disposal	2	3	6	1	0,2	0,2	0,2	0	0	1,2	1,2	1,2	0	0
Garbage grinder	1	11	11	1	0,2	0,2	0,2	0	0	2,2	2,2	2,2	0	0
Generator test stand	1	350	350	1	0,1	0,1	0,1	0,1	0	35	35	35	35	0
Grinder	2	1	2	1	0,1	0,1	0,1	0	0	0,2	0,2	0,2	0	0
Hydraulic test stand	1	150	150	1	0,1	0,1	0,1	0,1	0	15	15	15	15	0
Ice maker	1	20	20	1	0,3	0,2	0,3	0,3	0	6	4	6	6	0
Milling machine	1	4	4	1	0,1	0,1	0,1	0	0	0,4	0,4	0,4	0	0
Mixer	2	0,45	0,9	1	0,2	0,2	0,2	0,2	0	0,18	0,18	0,18	0,18	0
Oven	2	30	60	1	0,4	0,2	0,4	0,4	0	24	12	24	24	0
Power saw	2	0,05	0,1	1	0,1	0,1	0,1	0	0	0,01	0,01	0,01	0	0
Refrigerator/freezer combination	2	5	10	1	0,5	0,5	0,5	0,5	0	5	5	5	5	0
Refrigerator - small	1	0,75	0,75	1	0,3	0,3	0,3	0,3	0	0,225	0,225	0,225	0,225	0
Sewing machine	2	0,25	0,5	1	0,2	0,2	0,2	0	0	0,1	0,1	0,1	0	0
Shearing machine	1	11	11	1	0,2	0,2	0,2	0	0	2,2	2,2	2,2	0	0
Toaster	2	2	4	1	0,3	0,2	0,3	0	0	1,2	0,8	1,2	0	0
Vegetable cutter	2	0,58	1,16	1	0,2	0,1	0,2	0	0	0,232	0,116	0,232	0	0
Vegetable peeler	2	0,58	1,16	1	0,2	0,1	0,2	0	0	0,232	0,116	0,232	0	0
Washer extractor	2	1,5	3	1	0,2	0,2	0,2	0	0	0,6	0,6	0,6	0	0
Water heater	4	6	24	1	0,1	0,1	0,5	0,5	0,1	2,4	2,4	12	12	2,4
Window wipers	20	0,2	4	1	0	0	0	0	0	0	0	0	0	0
X-ray machine	1	50	50	1	0,1	0,1	0,1	0,2	0,2	5	5	5	10	10
Total										**123**	**107**	**133**	**113**	**13**

Table 86. SWBS Group 6 - Armament

System	Quantity	Rated power (kW)	Load (kW)	Simultaneity coefficient	Load factor					Load (kW)				
					Anchor	Shore	Cruising	Functional	Emergency	Anchor	Shore	Cruising	Functional	Emergency
Gun mounts	1	50	50	1	0	0	0	0,6	0,6	0	0	0	30	30
Magazine bridge crane	1	2,5	2,5	1	0,2	0,2	0,1	0,1	0	0,5	0,5	0,25	0,25	0
Weapons elevator	1	2,5	2,5	1	0,2	0,2	0	0,7	0	0,5	0,5	0	1,75	0
Weapons handling hoist	1	1	1	1	0,2	0,2	0	0,7	0	0,2	0,2	0	0,7	0
Total										**2**	**2**	**1**	**33**	**30**

APPENDIX H
Intact stability load conditions

Table 87. Full load condition

Item	Qty.	Unit mass (tonnes)	Total mass (tonnes)	Unit volume (m3)	Total volume (m3)	LCG (m)	TCG (m)	VCG (m)	Total F.S.M. (tonnes.m)
Lightship	1	466,800	466,8			23,362	0	3,941	0
Helicopter fuel									
Tank N°01 - Jet A-1	95%	2,275	2,161	2,708	2,573	16,43	-3,150	7,017	0,074
Tank N°02 - Jet A-1	95%	2,275	2,161	2,708	2,573	16,43	3,150	7,017	0,074
Subsubtotal	95%	4,550	4,322	5,416	5,146	16,43	0,000	7,017	0,149
Lube oil									
Tank N°03 - Lube Oil	95%	4,667	4,434	5,073	4,820	17,362	-1,020	1,433	1,157
Tank N°04 - Lube Oil	95%	4,667	4,434	5,073	4,820	17,362	1,020	1,433	1,157
Subsubtotal	95%	9,335	8,868	10,147	9,639	17,362	0,000	1,433	2,313
Fuel									
Tank N°05 - Diesel	76,1%	23,501	17,884	27,977	21,291	21,752	-1,028	1,183	5,280
Tank N°06 - Diesel	76,1%	23,501	17,884	27,977	21,291	21,752	1,028	1,183	5,280
Tank N°07 - Diesel	100%	24,373	24,373	29,016	29,016	27,902	-1,073	1,398	0,000
Tank N°08 - Diesel	100%	24,373	24,373	29,016	29,016	27,902	1,073	1,398	0,000
Tank N°09 - Diesel	100%	23,837	23,837	28,377	28,377	34,075	-1,062	1,417	0,000
Tank N°10 - Diesel	100%	23,837	23,837	28,377	28,377	34,075	1,062	1,417	0,000
Tank N°11 - Diesel	100%	22,127	22,127	26,342	26,342	40,245	-1,019	1,469	0,000
Tank N°12 - Diesel	100%	22,127	22,127	26,342	26,342	40,245	1,019	1,469	0,000
Tank N°13 - Diesel	100%	18,425	18,425	21,934	21,934	46,348	-0,892	1,536	0,000
Tank N°14 - Diesel	100%	18,425	18,425	21,934	21,934	46,348	0,892	1,536	0,000
Subsubtotal	95%	224,527	213,293	267,294	253,921	33,998	0,000	1,405	10,561
Fresh water									
Tank N°15 - Fresh Water	95%	14,78	14,041	14,78	14,041	53,419	-0,538	1,514	2,392
Tank N°16 - Fresh Water	95%	14,78	14,041	14,78	14,041	53,419	0,538	1,514	2,392
Subsubtotal	95%	29,56	28,082	29,56	28,082	53,419	0,000	1,514	4,785
Crew & effects	40	0,160	6,400			28,429	0,000	5,900	0,000
Provisions	1	4,300	4,300			28,429	0,000	3,624	0,000
Ammunition	1	4,200	4,200			51,150	0,000	4,025	0,000
Ballast									
Tank N°17 - Ballast	0%	7,684	0,000	7,496	0,000	27,854	-2,689	1,137	0,000
Tank N°18 - Ballast	0%	7,684	0,000	7,496	0,000	27,854	2,689	1,137	0,000
Tank N°19 - Ballast	0%	8,404	0,000	8,199	0,000	28,555	-2,854	1,136	0,000
Tank N°20 - Ballast	0%	8,404	0,000	8,199	0,000	28,555	2,854	1,136	0,000
Tank N°21 - Ballast	0%	14,189	0,000	13,843	0,000	31,017	-1,917	1,158	0,000
Tank N°22 - Ballast	0%	14,189	0,000	13,843	0,000	31,017	1,917	1,158	0,000
Tank N°23 - Ballast	0%	6,194	0,000	6,043	0,000	37,208	-1,917	1,509	0,000
Tank N°24 - Ballast	0%	6,194	0,000	6,043	0,000	37,208	1,917	1,509	0,000
Tank N°25 - Ballast	0%	0,799	0,000	0,780	0,000	43,446	-1,917	2,409	0,000
Tank N°26 - Ballast	0%	0,799	0,000	0,780	0,000	43,446	1,917	2,409	0,000
Tank N°27 - Ballast	0%	27,911	0,000	27,231	0,000	59,111	0,000	0,000	0,000
Subtotal	0%	102,451	0,000	99,952	0,000	0,000	0,000	0,000	0,000
Total Loadcase			734,933	410,966	295,454	27,655	0,000	3,120	17,637
FS correction								0,024	
VCG fluid								3,144	

Table 88. Minimum operating condition

Item	Qty.	Unit mass (tonnes)	Total mass (tonnes)	Unit volume (m3)	Total volume (m3)	LCG (m)	TCG (m)	VCG (m)	Total F.S.M. (tonnes.m)
Lightship	1	466,800	466,8			23,362	0,000	3,941	0,000
Helicopter fuel									
Tank N°01 - Jet A-1	50%	2,275	1,137	2,708	1,354	16,430	-3,150	6,725	0,074
Tank N°02 - Jet A-1	50%	2,275	1,137	2,708	1,354	16,430	3,150	6,725	0,074
Subsubtotal	50%	4,550	2,275	5,416	2,708	16,430	0,000	6,725	0,149
Lube oil									
Tank N°03 - Lube Oil	66,7%	4,667	3,112	5,073	3,382	17,363	-0,965	1,153	1,157
Tank N°04 - Lube Oil	66,7%	4,667	3,112	5,073	3,382	17,363	0,965	1,153	1,157
Subsubtotal	66,7%	9,335	6,223	10,147	6,765	17,363	0,000	1,153	2,313
Fuel									
Tank N°05 - Diesel	23,9%	23,501	5,617	27,977	6,687	21,851	-0,767	0,602	4,643
Tank N°06 - Diesel	23,9%	23,501	5,617	27,977	6,687	21,851	0,767	0,602	4,643
Tank N°07 - Diesel	0%	24,373	0,000	29,016	0,000	27,900	-0,025	0,000	0,000
Tank N°08 - Diesel	0%	24,373	0,000	29,016	0,000	27,900	0,025	0,000	0,000
Tank N°09 - Diesel	0%	23,837	0,000	28,377	0,000	34,100	-0,025	0,000	0,000
Tank N°10 - Diesel	0%	23,837	0,000	28,377	0,000	34,100	0,025	0,000	0,000
Tank N°11 - Diesel	0%	22,127	0,000	26,342	0,000	40,300	-0,025	0,000	0,000
Tank N°12 - Diesel	0%	22,127	0,000	26,342	0,000	40,300	0,025	0,000	0,000
Tank N°13 - Diesel	0%	18,425	0,000	21,934	0,000	46,500	-0,025	0,000	0,000
Tank N°14 - Diesel	0%	18,425	0,000	21,934	0,000	46,500	0,025	0,000	0,000
Subsubtotal	5%	224,527	11,233	267,294	13,373	21,851	0,000	0,602	9,286
Fresh water									
Tank N°15 - Fresh Water	50%	14,078	7,039	14,078	7,039	53,219	-0,422	1,051	1,056
Tank N°16 - Fresh Water	50%	14,078	7,039	14,078	7,039	53,219	0,422	1,051	1,056
Subsubtotal	50%	28,157	14,078	28,157	14,078	53,219	0,000	1,051	2,112
Crew & effects	40	0,160	6,400			28,429	0,000	5,900	0,000
Provisions	0,333	4,300	1,433			28,429	0,000	3,624	0,000
Ammunition	0,333	4,200	1,400			51,150	0,000	4,025	0,000
Ballast									
Tank N°17 - Ballast	100%	7,684	7,684	7,496	7,496	23,652	-3,299	2,009	0,000
Tank N°18 - Ballast	100%	7,684	7,684	7,496	7,496	23,652	3,299	2,009	0,000
Tank N°19 - Ballast	100%	8,404	8,404	8,199	8,199	29,450	-3,519	2,656	0,000
Tank N°20 - Ballast	100%	8,404	8,404	8,199	8,199	29,450	3,519	2,656	0,000
Tank N°21 - Ballast	100%	14,189	14,189	13,843	13,843	33,857	-3,468	2,725	0,000
Tank N°22 - Ballast	100%	14,189	14,189	13,843	13,843	33,857	3,468	2,725	0,000
Tank N°23 - Ballast	100%	6,194	6,194	6,043	6,043	39,663	-3,259	2,967	0,000
Tank N°24 - Ballast	100%	6,194	6,194	6,043	6,043	39,663	3,259	2,967	0,000
Tank N°25 - Ballast	100%	0,799	0,799	0,780	0,780	44,787	-3,053	3,297	0,000
Tank N°26 - Ballast	100%	0,799	0,799	0,780	0,780	44,787	3,053	3,297	0,000
Tank N°27 - Ballast	100%	27,911	27,911	27,231	27,231	60,357	0,000	4,246	0,000
Subtotal	100%	102,451	102,451	99,952	99,952	39,695	0,000	3,059	0,000
			612,295	410,966	136,877	26,795	0,000	3,668	13,860
Total Loadcase								0,023	
FS correction								3,690	
VCG fluid			612,295	410,966	136,877	26,795	0,000	3,668	13,860

APPENDIX I

Damage stability load conditions

Table 89. Full load condition

Item	Qty.	Unit mass (tonnes)	Total mass (tonnes)	Unit volume (m3)	Total volume (m3)	LCG (m)	TCG (m)	VCG (m)	Total F.S.M. (tonnes.m)
Lightship	1	466,800	466,8			23,362	0,000	3,941	0,000
Helicopter fuel									
Tank N°01 - Jet A-1	95%	2,275	2,161	2,708	2,573	16,430	-3,150	7,017	0,074
Tank N°02 - Jet A-1	95%	2,275	2,161	2,708	2,573	16,430	3,150	7,017	0,074
Subsubtotal	95%	4,550	4,322	5,416	5,146	16,430	0,000	7,017	0,149
Lube oil									
Tank N°03 - Lube Oil	95%	4,667	4,434	5,073	4,820	17,362	-1,020	1,433	1,157
Tank N°04 - Lube Oil	95%	4,667	4,434	5,073	4,820	17,362	1,020	1,433	1,157
Subsubtotal	95%	9,335	8,868	10,147	9,639	17,362	0,000	1,433	2,313
Fuel									
Tank N°05 - Diesel	76,1%	23,501	17,884	27,977	21,291	21,752	-1,028	1,183	5,280
Tank N°06 - Diesel	Damaged								
Tank N°07 - Diesel	100%	24,373	24,373	29,016	29,016	27,902	-1,073	1,398	0,000
Tank N°08 - Diesel	Damaged								
Tank N°09 - Diesel	100%	23,837	23,837	28,377	28,377	34,075	-1,062	1,417	0,000
Tank N°10 - Diesel	100%	23,837	23,837	28,377	28,377	34,075	1,062	1,417	0,000
Tank N°11 - Diesel	100%	22,127	22,127	26,342	26,342	40,245	-1,019	1,469	0,000
Tank N°12 - Diesel	100%	22,127	22,127	26,342	26,342	40,245	1,019	1,469	0,000
Tank N°13 - Diesel	100%	18,425	18,425	21,934	21,934	46,348	-0,892	1,536	0,000
Tank N°14 - Diesel	100%	18,425	18,425	21,934	21,934	46,348	0,892	1,536	0,000
Subsubtotal	95%	224,527	213,293	267,294	253,921	33,998	0	1,405	10,561
Fresh water									
Tank N°15 - Fresh Water	95%	14,078	13,375	14,078	13,375	53,226	-0,549	1,513	2,307
Tank N°16 - Fresh Water	95%	14,078	13,375	14,078	13,375	53,226	0,549	1,513	2,307
Subsubtotal	95%	28,157	26,749	28,157	26,749	53,226	0,000	1,513	4,613
Crew & effects	40	0,160	6,400			28,429	0,000	5,900	0,000
Provisions	1	4,300	4,300			28,429	0,000	3,624	0,000
Ammunition	1	4,200	4,200			51,150	0,000	4,025	0,000
Ballast									
Tank N°17 - Ballast	0%	7,684	0,000	7,496	0,000	27,854	-2,689	1,137	0,000
Tank N°18 - Ballast	Damaged								
Tank N°19 - Ballast	0%	8,404	0,000	8,199	0,000	28,555	-2,854	1,136	0,000
Tank N°20 - Ballast	Damaged								
Tank N°21 - Ballast	0%	14,189	0,000	13,843	0,000	31,017	-1,917	1,158	0,000
Tank N°22 - Ballast	0%	14,189	0,000	13,843	0,000	31,017	1,917	1,158	0,000
Tank N°23 - Ballast	0%	6,194	0,000	6,043	0,000	37,208	-1,917	1,509	0,000
Tank N°24 - Ballast	0%	6,194	0,000	6,043	0,000	37,208	1,917	1,509	0,000
Tank N°25 - Ballast	0%	0,799	0,000	0,780	0,000	43,446	-1,917	2,409	0,000
Tank N°26 - Ballast	0%	0,799	0,000	0,780	0,000	43,446	1,917	2,409	0,000
Tank N°27 - Ballast	0%	27,911	0,000	27,231	0,000	59,111	0,000	0,000	0,000
Subtotal	0%	86,364	0,000	84,257	0,000	0,000	0,000	0,000	0,000
Total Loadcase			692,675	338,278	245,148	27,799	-0,064	3,231	12,356
FS correction								0,018	
VCG fluid								3,248	

Table 90. Minimum operating condition

Item	Qty.	Unit mass (tonnes)	Total mass (tonnes)	Unit volume (m3)	Total volume (m3)	LCG (m)	TCG (m)	VCG (m)	Total F.S.M. (tonnes.m)
Lightship	1	466,800	466,8			23,362	0	3,941	0
Helicopter fuel									
Tank N°01 - Jet A-1	50%	2,275	1,137	2,708	1,354	16,430	-3,150	6,725	0,074
Tank N°02 - Jet A-1	50%	2,275	1,137	2,708	1,354	16,430	3,150	6,725	0,074
Subsubtotal	50%	4,550	2,275	5,416	2,708	16,430	0,000	6,725	0,149
Lube oil									
Tank N°03 - Lube Oil	66,7%	4,667	3,112	5,073	3,382	17,363	-0,965	1,153	1,157
Tank N°04 - Lube Oil	66,7%	4,667	3,112	5,073	3,382	17,363	0,965	1,153	1,157
Subsubtotal	66,7%	9,335	6,223	10,147	6,765	17,363	0,000	1,153	2,313
Fuel									
Tank N°05 - Diesel	23,9%	23,501	5,617	27,977	6,687	21,851	-0,767	0,602	4,643
Tank N°06 - Diesel					Damaged				
Tank N°07 - Diesel	0%	24,373	0,000	29,016	0,000	27,900	-0,025	0,000	0,000
Tank N°08 - Diesel					Damaged				
Tank N°09 - Diesel	0%	23,837	0,000	28,377	0,000	34,100	-0,025	0,000	0,000
Tank N°10 - Diesel	0%	23,837	0,000	28,377	0,000	34,100	0,025	0,000	0,000
Tank N°11 - Diesel	0%	22,127	0,000	26,342	0,000	40,300	-0,025	0,000	0,000
Tank N°12 - Diesel	0%	22,127	0,000	26,342	0,000	40,300	0,025	0,000	0,000
Tank N°13 - Diesel	0%	18,425	0,000	21,934	0,000	46,500	-0,025	0,000	0,000
Tank N°14 - Diesel	0%	18,425	0,000	21,934	0,000	46,500	0,025	0,000	0,000
Subsubtotal	3,18%	176,652	5,617	210,301	6,687	21,851	-0,767	0,602	4,643
Fresh water									
Tank N°15 - Fresh Water	50%	14,078	7,039	14,078	7,039	53,219	-0,422	1,051	1,056
Tank N°16 - Fresh Water	50%	14,078	7,039	14,078	7,039	53,219	0,422	1,051	1,056
Subsubtotal	50%	28,157	14,078	28,157	14,078	53,219	0,000	1,051	2,112
Crew & effects	40	0,160	6,400			28,429	0,000	5,9	0,000
Provisions	0,333	4,300	1,433			28,429	0,000	3,624	0,000
Ammunition	0,333	4,200	1,400			51,150	0,000	4,025	0,000
Ballast									
Tank N°17 - Ballast	100%	7,684	7,684	7,496	7,496	23,652	-3,299	2,009	0,000
Tank N°18 - Ballast					Damaged				
Tank N°19 - Ballast	100%	8,404	8,404	8,199	8,199	29,450	-3,519	2,656	0,000
Tank N°20 - Ballast					Damaged				
Tank N°21 - Ballast	100%	14,189	14,189	13,843	13,843	33,857	-3,468	2,725	0,000
Tank N°22 - Ballast	100%	14,189	14,189	13,843	13,843	33,857	3,468	2,725	0,000
Tank N°23 - Ballast	100%	6,194	6,194	6,043	6,043	39,663	-3,259	2,967	0,000
Tank N°24 - Ballast	100%	6,194	6,194	6,043	6,043	39,663	3,259	2,967	0,000
Tank N°25 - Ballast	100%	0,799	0,799	0,780	0,780	44,787	-3,053	3,297	0,000
Tank N°26 - Ballast	100%	0,799	0,799	0,780	0,780	44,787	3,053	3,297	0,000
Tank N°27 - Ballast	100%	27,911	27,911	27,231	27,231	60,357	0,000	4,246	0,000
Subtotal	100%	86,364	86,364	84,257	84,257	42,120	-0,636	3,192	0,000
Total Loadcase			590,590	338,278	114,495	26,846	-0,100	3,733	9,217
FS correction								0,016	
VCG fluid								3,748	