Impact of Mission Modules on Naval Ship Design

A thesis submitted for the degree of Masters of Science in

Naval Architecture

by

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I, Felipe Teixeira Silva Bezerra, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been specified in the thesis.

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Abstract

This project identifies the impact of adopting the mission modules approach to naval ship designs. The work goes through the definition of the mission modules – analysing the most representative modules of the most used mission packages – the definition of the range of displacement and ship's size and type – analysing the most representative navies – and finally the definition of the ship design configuration – using generic hullforms and general arrangement.

The definition analyses reached three different naval ship designs a Patrol Vessel of 500ton, an Offshore Patrol Vessel of 2000ton, and a Frigate of 5000ton. Each vessel was designed with four configurations Traditional, ASW, ASuW, and MW, and an additional configuration without modules was also tested. All configurations were assessed by Stability, Survivability, Operability, and Cost analysis to understand the impact of each mission package on the naval ship design.

The performed analyses identified the impact of adopting the mission modules approach on the three tested naval ship designs, considering primary and secondary impacts. The Primary Impact refers to the hull changes being space/layout, structure, and stability. On the other hand, the secondary consists of the systems and logistics impact being auxiliary power, costs, and crew.

This work also confirmed that the impacts have different intensities when looking at ship's size, which is one of the main drivers of the mission modules approach.

Keywords: **Modularity**, **Mission Modules**, **Mission Packages**, **Ship Design**, **Stability**, **Survivability**, **Operability**, **Cost**.

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List of Symbols / Abbreviation / Nomenclature

Ships Definition

JSS	Joint Support Ship
LCS	Littoral Combatant Ship
MCMV	Mine Countermeasure Vessel
MEKO	Mehrzweck-Kombination
MSC	Medium Surface Combatant
OPV	Offshore Patrol Vessel
PV	Patrol Vessel
SSC	Small Surface Combatant

Warfare Definition

AAW	Anti-Air Warfare
ASW	Anti-Submarine Warfare
ASuW	Anti-Surface Warfare
MW	Mine Warfare

Modules Definition

MP	Mission Package
TAS	Towed Array Sonar
USV	Unmanned Surface Vehicles
UUV	Unmanned Underwater Vehicles
UAV	Unmanned Aerial (or Aircraft) Vehicle
VLS	Vertical Launching System

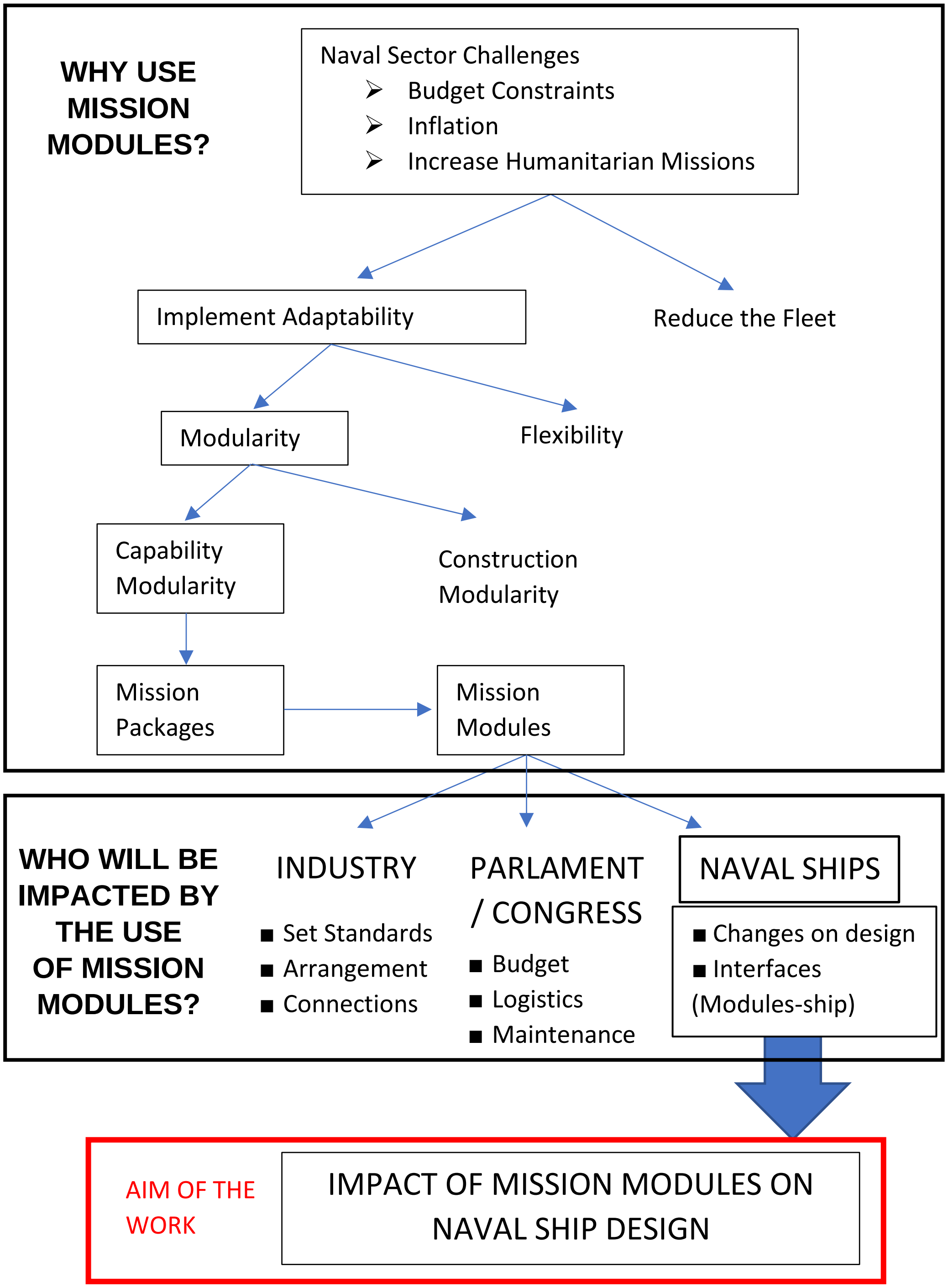
Stability Analysis

LCG	Longitudinal Centre of Gravity
TCG	Transverse Centre of Gravity
VCG	Vertical Centre of Gravity
GM	Metacentric Height

Others Definition

ANEP	Allied Naval Engineering Publication
CBA	Cost-Benefit Analysis
DNV	Det Norske Veritas
ISO	International Standards Organization
NATO	North Atlantic Treaty Organization
NAVSEA	Naval Sea Systems Command
NES	Naval Engineering Standard
STANREC	Standardization Recommendation
STANAG	Standardization Agreement
SEAMOD	Sea Systems Modification and Modernization by Modularity

Thesis Motivation Flow



1. Introduction

1.1. Motivation

Naval Sector Challenges

It is commonly known that governments suffer from budget reduction aligned with the growth of inflation that increases the costs around the globe (Doerry, 2017), mainly in a world post-COVID-19 pandemic.

In this scenario, navies will be even more affected since the cost of building, maintaining, and operating ships are incredibly high (sometimes reaching a total cost of 1 billion dollars), and the public sector will need to be more efficient and deliver more with less (Schank, 2016).

In addition to these two previous challenges, most of the navies deal with an increase in humanitarian missions instead of real war conflicts, leading to a necessity of implementing adaptability in the new ship designs in order to extend the ship's life utility during the future generations (Manley, 2018).

Adaptability

Two ways of achieving the necessary adaptability in a ship's operation perspective are by adopting modularity or flexibility. All these three terms seem to be synonyms and represent the same, but they have different definitions, as follows:

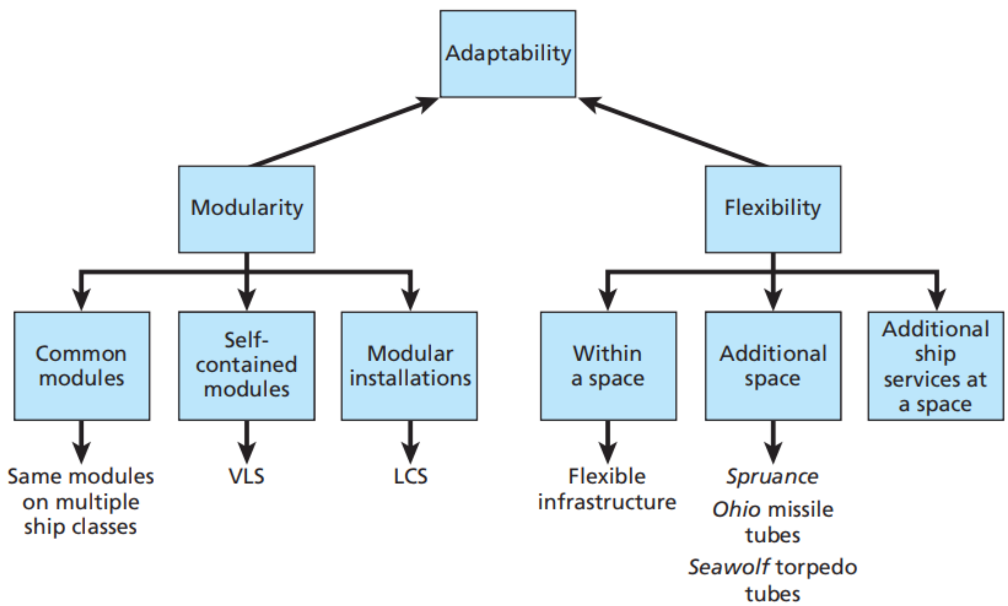


Figure 1 – Adaptability – Modularity x Flexibility – (Schank, 2016)

The adaptability of a ship is a combination of the modularity and flexibility of its systems and compartments, and according to Schank (2016), "modularity sets defined interfaces within rigidly defined boundaries, and flexibility allows both to change".

Hence, since it is hard to deal with changes in boundaries and interfaces on a ship, the modularity solution is the most applicable solution in the naval sector to achieve the required adaptability in ship design (Manley, 2018).

Modularity

Modularity is a vast subject, and considering a ship's perspective, it could be subdivided into modularity on construction (blocks/hullform) and modularity of capability (equipment/systems).

Construction Modularity

The first one is connected to the modular construction for the hull, where using the same block reduces the costs and time of building ships. On the other hand, this concept didn't provide the necessary adaptability for ship's operation to deal with the new challenges that emerge in actual times, as previously mentioned (Schank, 2016).

It is worth mentioning that some companies work with the concept of family customisable modular hullforms, where implementing new blocks to the same "generic" hull raises the displacement and changes from a smaller to a bigger ship. One example is the Blohm + Voss with the MEKO family ships, which have already delivered more than 60 naval ships for more than 11 navies (Schank, 2016).

Capability Modularity

The scope of work of this thesis is the second modularity concept, which is connected to raising the capability of the ships by implementing modules of equipment. Making a capability as a module is a challenge that needs to deal with self-contained systems that match the ship's interfaces in order to be quickly installed when the mission is defined (Pudduck, 2020).

Additionally, the self-contained modules provide an excellent solution for upgrades during the ship's life to insert new technologies quicker and cheaper than the modernizations of a traditional design which takes long shipyard dockage and has an enormous cost in a way that could be easier and cheaper to disposable it than modernizing it (Schank, 2016).

Mission Packages

Since it is impossible to substitute one main capability as Anti-Submarine Warfare in only one self-container system, the idea of mission packages was developed. Mission packages consist of a group of small systems and capabilities called mission modules that provide the required capability for the mission (Schank, 2016).

NATO studies (Logtmeijer, 2020) have already identified a few mission packages that could be developed and implemented in a naval ship design:

- ASW Anti-Submarine Warfare.
- ASuW Anti-Surface Warfare.
- MW Mine Warfare.
- CP Counterpiracy.
- Medic Medical.
- HP Harbour Protection
- HADR Humanitarian Aid and Disaster Relief.

Mission Modules

Mission Modules consist in a mounted capability/system that performs independent functions and could be tested separately to the full capability (Schank, 2016).

Even though the module can perform a task and be tested alone, it needs interfaces/connections with the other systems to achieve the desired capability.

This means the modules have strong interdependencies among their components but limited external interfaces (Schank, 2016).

The list below presents some systems that US LCS used as modules (FY LCS, 2015):

- Gun Modules.
- Aviation Modules.
- Missile Modules.
- Boat Modules.
- Torpedo Modules.
- TAS Modules.

Finally, it is worth mentioning that to be considered a module, it needs to fit inside a standard dimension in order to be quickly transported, installed, and managed in a ship.

Arrangement/Size

Thinking globally, the major purpose of modularity is to have the capability that could be embarked on any ship. Therefore, it is crucial to define the modules' size and format due to several possible ways to modularise one system. Recently, the US Navy with the Littoral Combatant Ship based mostly of their module in a 20 feet ISO Container size (Manley, 2018).

20' Dry Container

Dimensions*	Length	Width	Height
External	6096 mm	2362 mm	2590 mm
Internal	5944 mm	2337 mm	2388 mm
Door Openings		2337 mm	2286 mm
Weights*			Capacity*
Max. Gross	Tare	Max. Payload	
24000 kg	2080 kg	21920 kg	33.9 cub.m

Figure 2 – ISO Container dimensions[1]

Using an ISO Container provides a good logistical supply moving the modules quickly from the homeport to the interested area or ship since the existing transportation infrastructure is already done (Manley, 2018).

However, it is worth mentioning that some systems and capabilities didn't fit into a container size. Therefore, there are other formats and sizes for more specific modules.

[1] https://a-rt-marine.com/media/CONTAINER_TYPES_&_SPECIFICATIONS.pdf

Interfaces (Module-ship)

NATO has realised several studies to identify the interfaces between the modules and the ships, and the result was the development of STANREC & ANEP91, and STANAG4834 & ANEP99 (Pudduck, 2020).

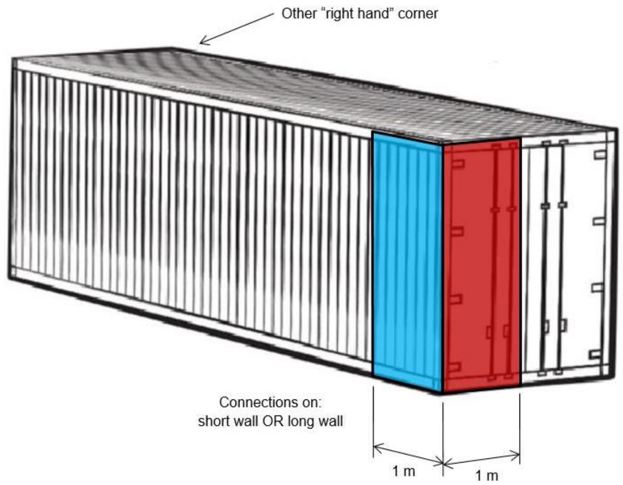


Figure 3 – Interface area on "right hand" corner of module – (ANEP-99)

An example of the physical interfaces between a Humanitarian Aid and Disaster Relief mission package and the ship's systems is represented in Figure 4 below.

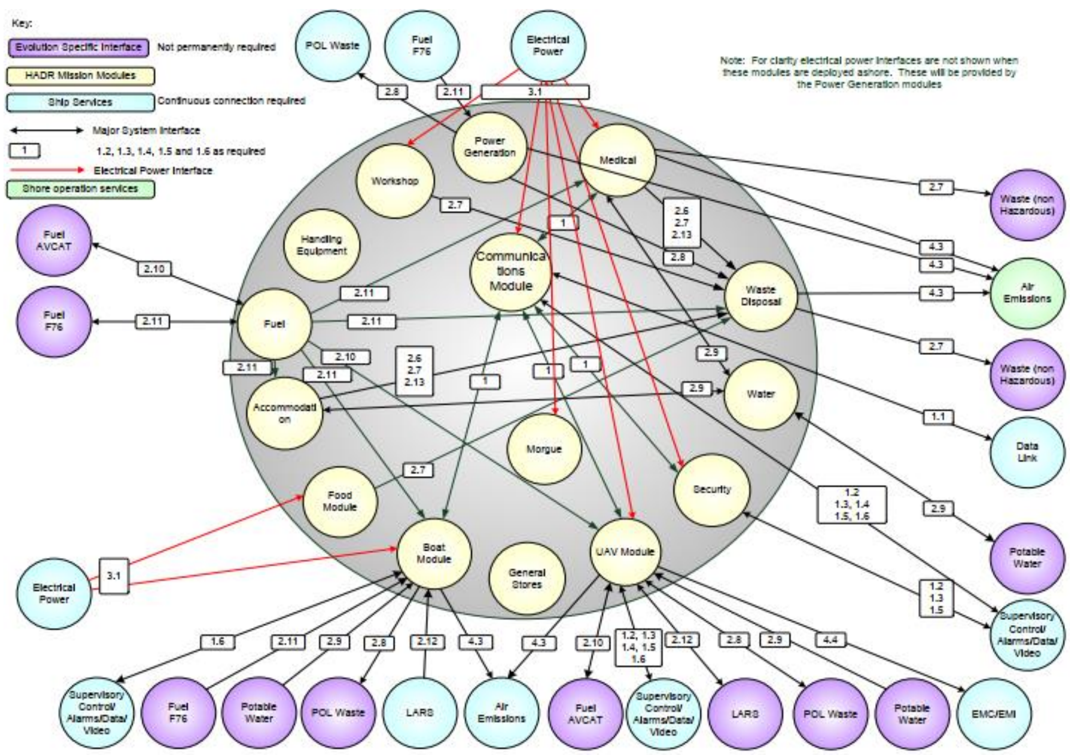


Figure 4 – Interface Diagram for HADR mission – (ANEP-91)

Many interfaces between modules and the ship mean the ship must be designed/prepared to receive the mission modules. Therefore, it is crucial to understand the impact of the mission module on a ship design, which will be the focus of this work.

1.2. Historically Background

The concept of modularity applied to ships dated from 1975 when the US Navy, via the SEAMOD Program in concomitant with the NAVSEA started to realise that the modernizations time and costs become too high and also the advance of the technology did not permit the older ship to support the new equipment. These issues were the beginning of the concept of separating the ship's systems into modules in order to simplify the installation, replacement, and updating, using the philosophy of the "Design for Change" (Schank, 2016).

1.3. Previous Work

Since the first idealisation of the design for change in 1975, several ships have been built, and studies made on modularity. The most recent and remarkable studies are presented below.

Drive to Modularity (Manley, 2018)

NATO specialists had discussed that one solution to deliver flexibility to the ships in order to achieve the desired capability is using modular systems.

Additionally, the concept of NATO operations leads to an increased scope of interoperability and switching modules and capabilities among navies and ships or using the modules positioned in different places along the globe to achieve the necessary capability for the mission.

This means defining standards and guidance, tests, trials, and other activities to ensure the modules fit and perform the capability in every installed ship.

Additionally, it considers the 20' ISO container as a basis for a modular system due to the container logistic environment already implemented worldwide.

Cost-Benefit Analysis (Logtmeijer, 2020)

NATO specialists had realised several studies about the cost of ships, modules, and the integration between both. The most recent study about CBA using modules has compared a traditional and modular fleet.

The analysis compares different scenarios of the fleet application, from low to high intense conflicts/warfighting. Hence, since different capabilities are required depending on the scenarios, not only cost was compared but also capabilities.

In total, 28 modular fleets were analysed against the traditional fleets and concluded that for highly intense conflicts/warfighting, both fleets have similar costs and performance.

On the other hand, for all other scenarios tested, the modular fleet is more cost-effective, being cheaper and achieving the requirements easier and faster due to the use of mission modules.

Future of Modularity (Knutsen, 2019)[2]

The modularity benefits apply not only to naval ship designs but also to the maritime industry, which has already started to understand and apply modularity concepts.

For civilian/merchant ships, a recent study published by DNV recognised that using modular systems is also a great idea to improve how owners deal with maintenance and surveys.

Modularity allows them to have a standard on all ships from the same class, and further, for the classification society, which will perform the surveys of the same system for several ships, being easier to identify the main risks and problems.

Norwegian Coastal Administration started the MIDAS project, which tested propulsion and communications modules on two ships in order to collect data and understand the benefits of modularity.

Hence, the future of modularity is beyond naval ships and will also apply to all types of ships and configurations.

Solutions to Support Modules

A few companies provide solutions to support the application of modules inside ships, and some examples are presented below.

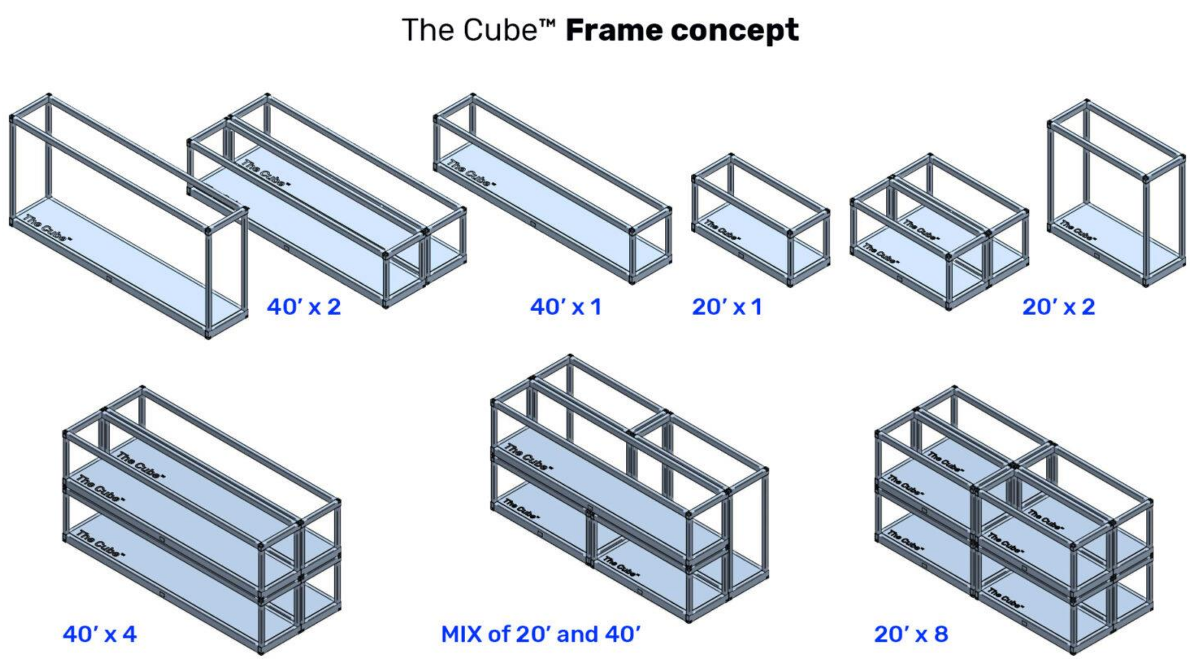


Figure 5 – The Cube Frame Concept [3] – SH Defence

[2] https://www.dnv.com/expert-story/maritime-impact/MIDAS-The-future-of-modularization.html

[3] https://shdefence.com/the-cube/

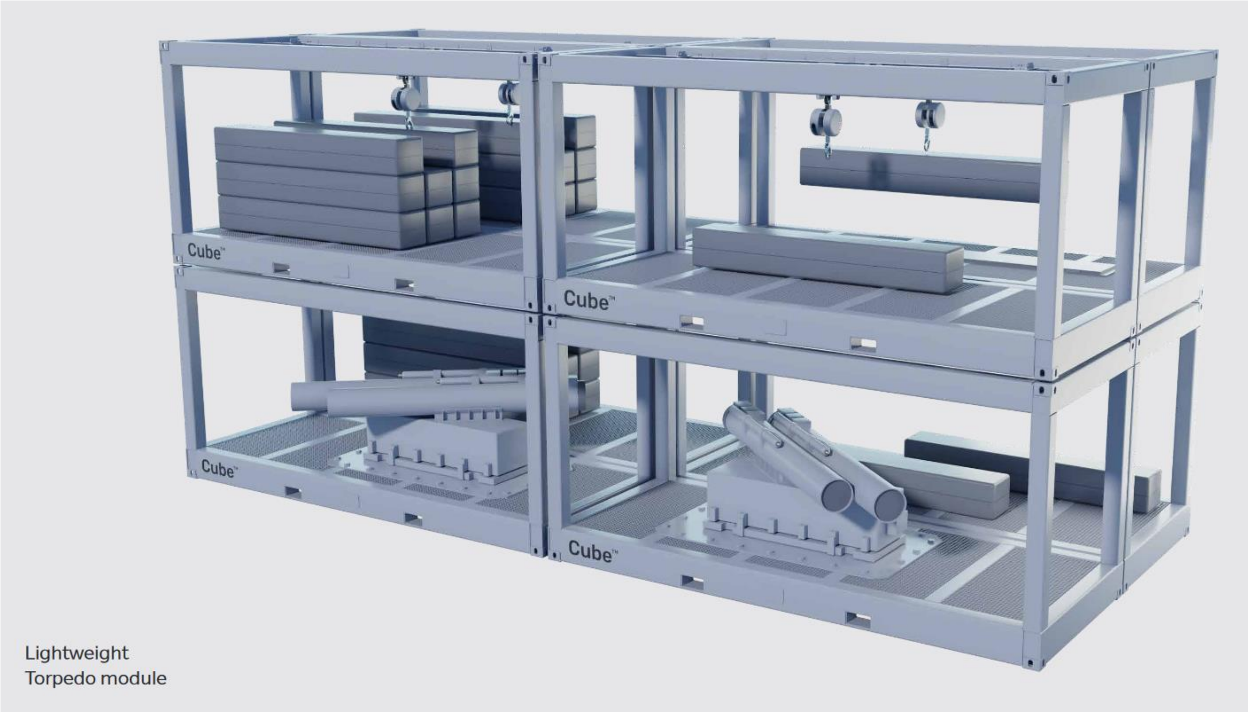


Figure 6 – 8 x 20' Container Lightweight Torpedo Module – SH Defence[4]

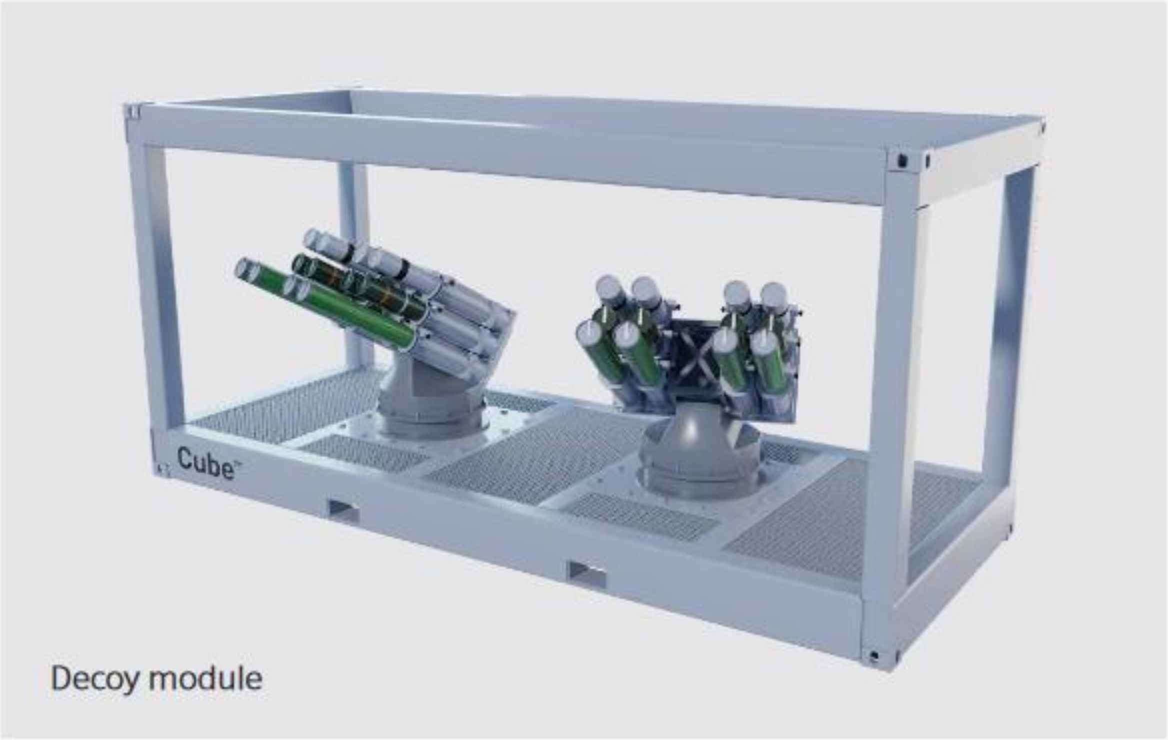


Figure 7 – 20' Container Decoy Module – SH Defence[4]

[4] https://shdefence.com/wp-content/uploads/2022/06/SH-Defence_Brochure_The-Cube_06_2022_Low.pdf

1.4. Aim and Objectives

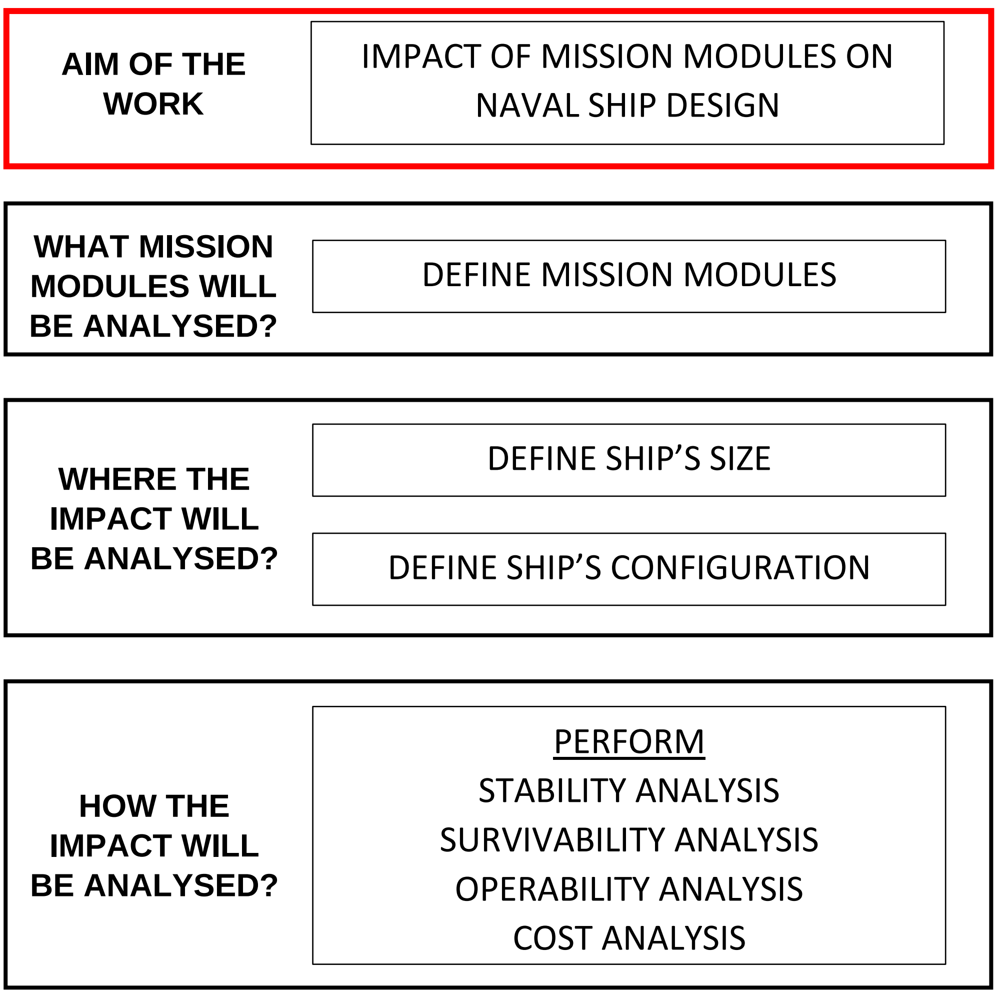
Aim

This study aims to understand the impact of implementing the flexibility of mission module on the naval ship design instead of using fixed systems. as used in the actual designs.

Objectives

In order to fulfil the aim of this study it was defined the following objectives:

1) Define Mission Modules.
2) Define Ship's Size.
3) Define Ship's Configuration.
4) Perform Stability, Survivability, Operability and Cost Analysis.
5) Evaluate and validate results.



2. Methodology

As previously exposed, modularity is a vast subject with several implicants and possible impacts on the ship design. Therefore, it is necessary to set some boundaries for this thesis to focus on a more specific point for a better and deeper analysis.

Hence, to have a better flow of the work, the methodology below was developed to be followed to achieve each objective.

The literature sustains that the design process needs a logical flow to reach a solution for a problem. This decision sequence should have analysis, synthesis, and evaluation to provide the correct background before the final decision. (Lawson, 1990).

The following definition could simplify these three steps of the decision sequence:

- **Analysis**: The understanding of the problem and the possible solutions that could be applied.
- **Synthesis**: Applying one of the possible solutions and trying to reach the final decision for the problem.
- **Evaluation**: Evaluate the proposed solutions against the objectives previously identified to reach the final solution.

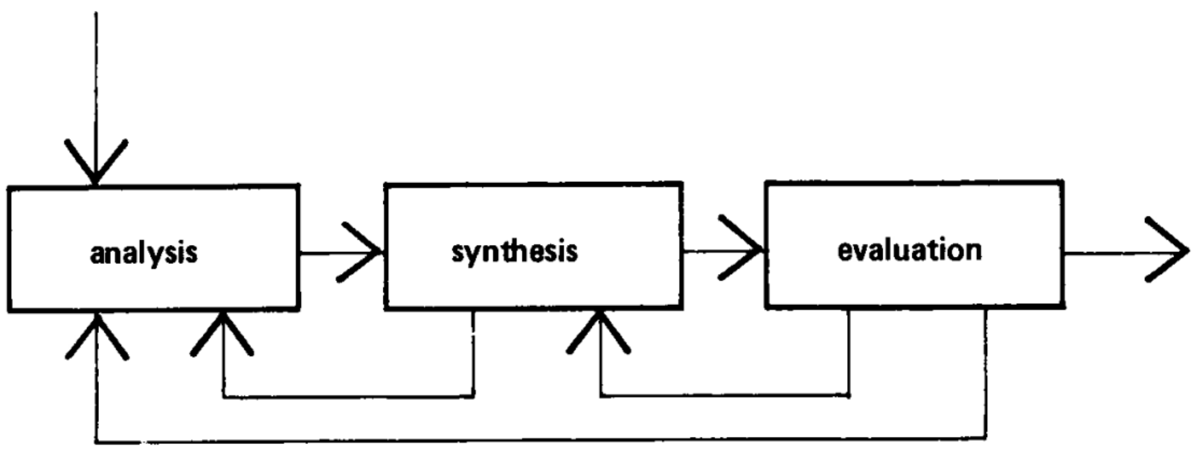
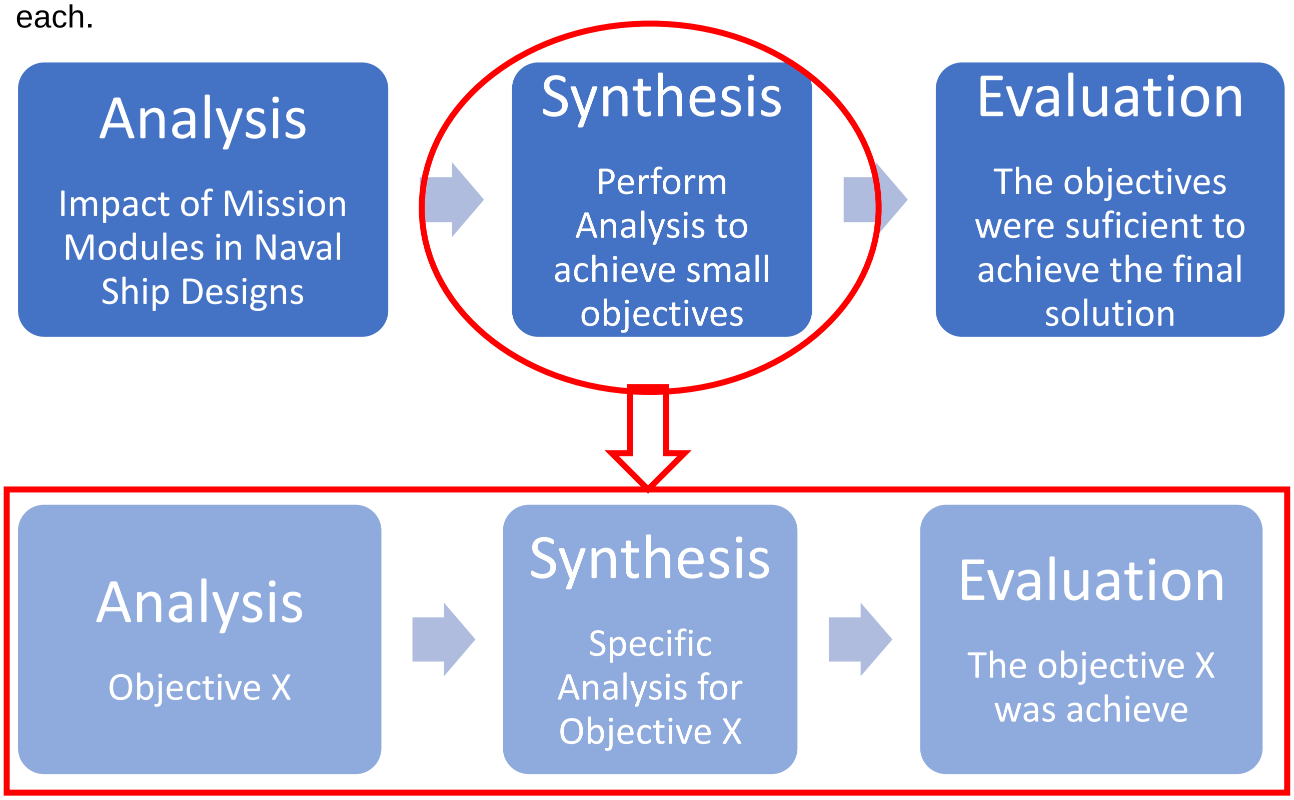


Figure 8 – Design Process – (Lawson, 1990)

It is clear to see in Figure 8 shows that this is an interactive process, and each step affects and updates the previous one. For example, when developing one of the possible solutions in the synthesis step, the understanding of the problem starts to be more deeply. Therefore, other solutions will be noticed and realised that could be necessary to make other analyses.

In the same way, the evaluation could identify another necessary synthesis on the same analysis or verify that the whole analysis is wrong and needs to get back to the beginning of the process.

Therefore, to achieve this thesis's final objective (solution), the decision process flow will pass through the minor objectives and try to reach the final conclusion as one single line. However, each of the objectives of this design process flows and is interactive inside of each.



Therefore, it is crucial to realise the correct analysis for each objective in order to achieve the final solution of the work. The following topics will explain how each of these objectives will be achieved.

2.1. Mission Modules

Analysis:

Several solutions for equipment, capability, and systems could be implemented in container size, making this a modular system. However, a few of them are mostly used in naval ship design.

Synthesis:

It is essential to analyse the main roles/mission of naval ships and what mission modules are most used on each of them. The mission modules analysis will focus on researching the most common mission modules used in the modular naval ships in operation.

Evaluation:

The criteria will be selecting the most representative mission modules in order to analyse the impact of implementing them in the naval ship design. Additionally, it is worth mentioning that for a naval ship, attack, defence, and related systems are more important than others, and therefore, should be considered.

2.2. Ship's Size

Analysis:

The impact of any change in a ship design depends on the size of the ship, and it will not be different for the mission modules.

In order to define the ship's size to be analysed it is crucial to understand the most representative ship's size in navies. Hence, an analysis of the average displacement of navies and the range of displacement where there are more ships in operation will be the best analysis to define the ship's size in this study.

Synthesis:

The way to achieve this objective will be to select the most representative navies and verify the distribution of their ships per displacement and type. Using the data, one histogram will be generated with the distribution of displacement and type per number of ships, defining where the specific navy has more ships and what the displacement and type of ships most represent that navy.

Evaluation:

Analysing more than one navy to achieve aligned results and comparing them to each other, verifying the average value and if the assumptions made are reasonable and valid to use in this work.

2.3. Ship's Configuration

Analysis:

Once the ship's sizes are defined, it is necessary to define the hullform and general arrangement in order to deal with the configuration of each ship design. It is worth mentioning that the different sizes will lead to a different layout/arrangement.

Synthesis:

The configuration analysis will start using a generic hullform, considering a traditional ship design without modularity for each ship size and type. Hence, it will be developed generic arrangement where it will be verified the available space for implementing the mission modules at the stern and forward on each specific ship in order to achieve the required level of modularity.

Evaluation:

Considering the space on each ship, the mission roles previously defined as the most representative will be designed and fit the mission modules inside a mission bay (if possible) or positioned in the weather deck. Therefore, obtaining the necessary number of mission modules to achieve each mission's desired capability on each ship's size and type.

2.4. Stability, Survivability, Operability/Capability and Cost

Analysis:

The calculations of the ship design configurations will start with a Stability simulation, and the configurations approved will be assessed by Survivability, and consequently, Operability. After all these three initials are considered satisfactory, a Cost analysis will be realised to give another measuring parameter for comparison on each configuration.

Figure 9 – Flow of Analysis – (Seon-kyung, 2017)

Synthesis:

The stability analysis will be performed using the MAXSURF software, considering intact and damaged cases for each ship and configuration, achieving the safe condition for operation, and defining the limitations of the modularity or hull changes.

The Survivability analysis will be verified by the standard firefighting regulations, compartment's size, and emergency exits.

The Operability/Capability analysis will be assessed by the extra capability generated for the ship and the time saved in the changes between one mission to another instead of the fixed ship switching the whole compartment taking more than six months in a shipyard.

The Cost analysis will be assessed by defining the module's and ship's cost. These two defined costs will be combined in the Fleet Cost Analysis in order to compare a Traditional and a Modular Fleet.

Evaluation:

The Stability results will be assessed by the Royal Navy standards (NES109).

The Survivability and Operability results will be discussed in the final topic.

The cost results will be compared with NATO CBA to verify whether they are reasonable.

2.5. Evaluate and Validate Results

Evaluation:

The results and conclusions of the work will be compared with the references of modularity to check if they are reasonable and acceptable.

3. Results

3.1. Mission Modules

One of the most recent NATO CBA research studies realises that the most commonly used configurations of mission packages in the future will be the Anti-Surface (ASuW), Anti-Submarine (ASW), and Mine Warfare (MW) (NATO unpublished study).

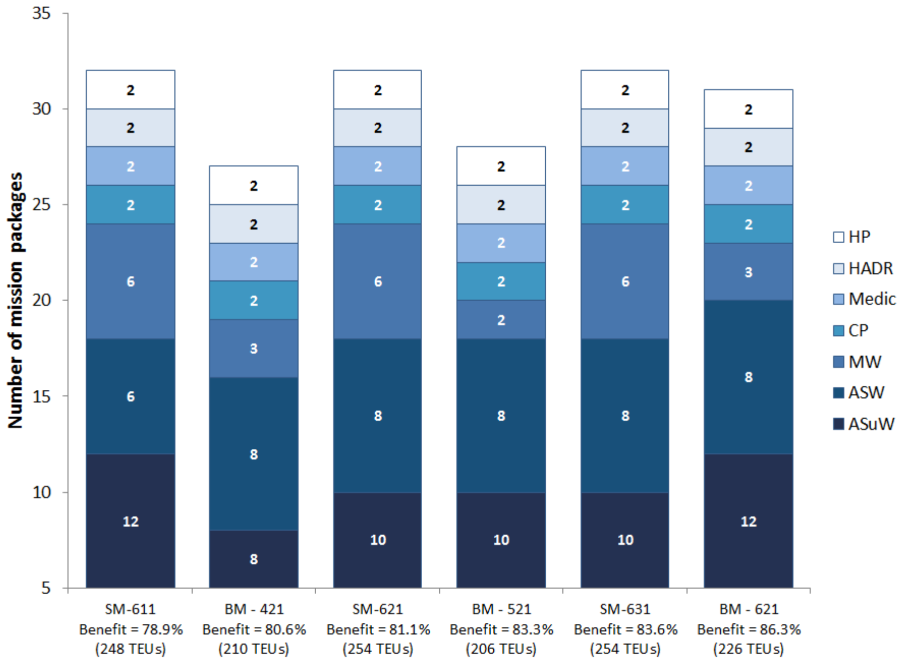


Figure 10 – Number of Mission Packages (MP) per Task Group (TG) – (NATO unpublished study)

The MP is constituted of several modules and equipment having different sizes and impact on the ship design. Hence it is crucial to identify the main mission modules of each configuration desired.

Table 1 – List of Mission Packages – (Logtmeijer, 2020)

Number	Name	Full Name	Size (TEU)
M01	ASW	Anti-Submarine Warfare	7
M02	ASuW	Anti-Surface Warfare	4
M03	MW	Mine Warfare	12
M04	CP	Counterpiracy	7
M05	Medic	Medical	2
M06	HP	Harbour Protection	14
M07	HADR	Humanitarian Aid and Disaster Relief	20

The modules that most represent the three main future MP previously mentioned are defined by (FY LCS, 2015):

- ASW: Torpedo and Towed Array Sonar (TAS).
- ASuW: Gun, VLS, and Small Boats.
- MW: UXVs (USV, UUV and/or UAV).

Therefore, these six mission modules are the most representative module for the analysis of the impact of the mission modules on a naval ship design.

There are a few industry solutions for modularity and taking advantage of those state-of-the-art technologies for the following roles and modules.

ASW Modules

Torpedo

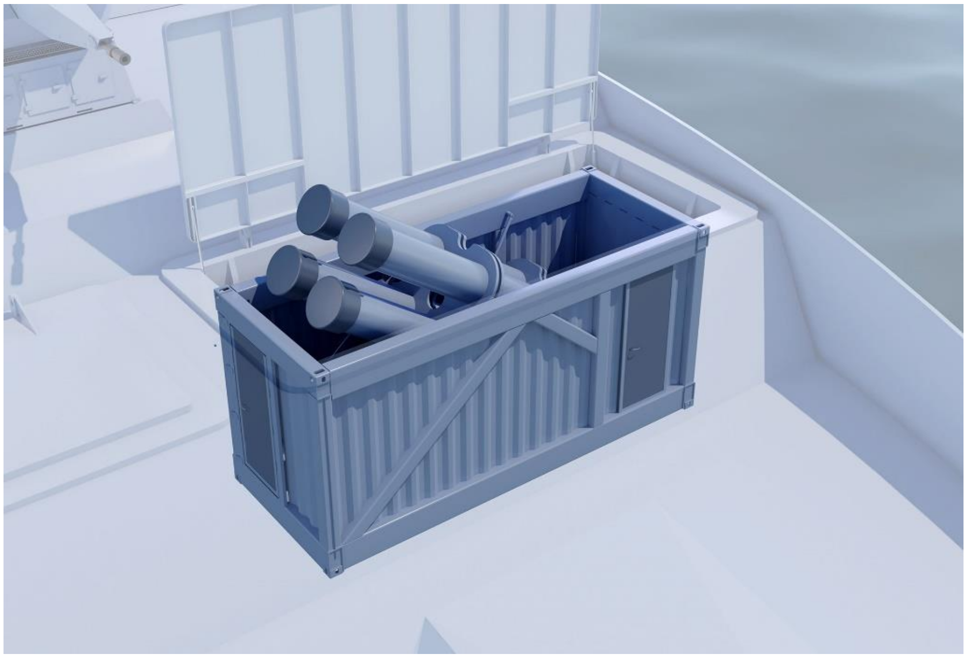


Figure 11 – Missile Containerized System – The Cube SH Defence[5]

Towed Array Sonar

Figure 12 – Towed Sonar – Sea Lancer ULTRA[6]

[5] https://shdefence.com/project/missile-containerized-system/

[6] https://www.ultra.group/gb/our-business-units/maritime/sonar-systems/towed-sonar/#acc-sealancermissionmodule

ASuW Modules

Gun 40mm

Figure 13 – Bofors 40 Mk4 – BAE Systems[7]

Gun 76mm

Figure 14 – OTO 76/62 SR – Leonardo Electronics Solutions[8]

[7] https://www.baesystems.com/en-media/uploadFile/20210404054312/1434555371622.pdf&usg=AOvVaw3ONEuKxqUuc47gllOwNhWL
[8] https://electronics.leonardo.com/en/products/76-62-super-rapid

VLS

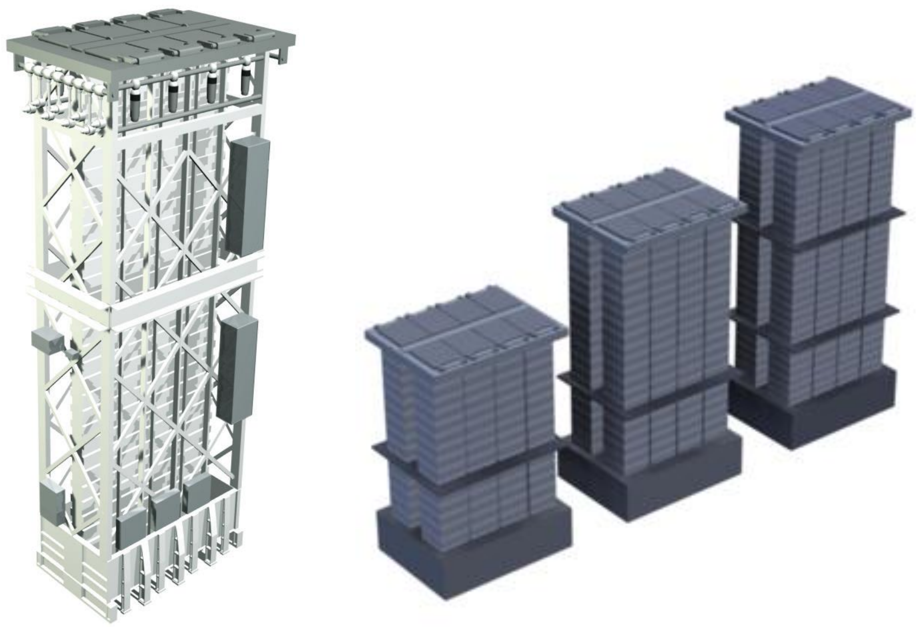


Figure 15 – Vertical Launching System (VLS) Mk 41 – BAE Systems[9]

Small Boats

Figure 16 – Fast Rescue Boat System – The Cube SH Defence[10]

[9] www.baesystems.com/en-media/uploadFile/20210404050242/1434555676119.pdf&usg=AOvVaw3EotvUr6s27V8vwFjackpn
[10] https://shdefence.com/project/fast-rescue-boat-system/

MW Modules

UUV

Figure 17 – Remote UUV at Side Probe Tow – The Cube SH Defence[11]

UAV

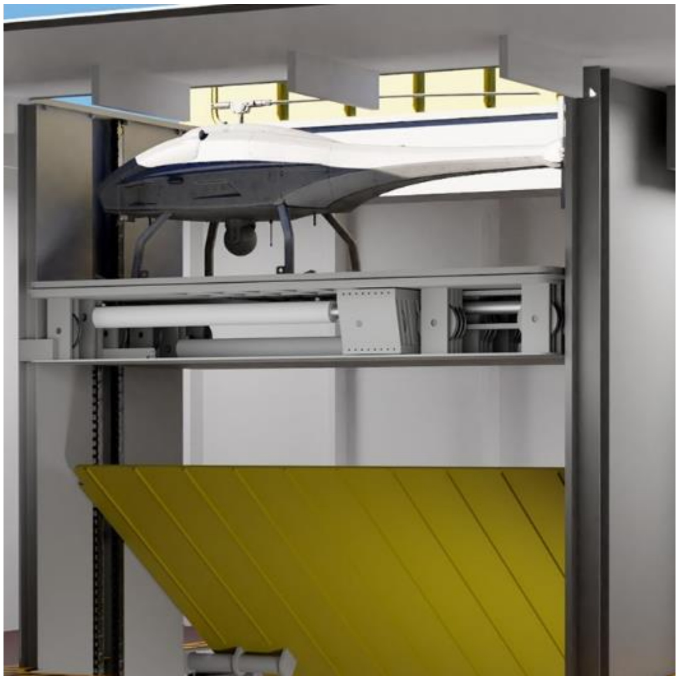


Figure 18 – UAV in a cargo lift system – The Cube SH Defence[12]

[11] https://shdefence.com/project/side-probe-tow/

[12] https://shdefence.com/project/1278/

3.2. Ship's Size

The world's most recognised and reliable source for naval ship's data is Janes's book. However, considering this source was not available at the moment of this work, the solution agreed upon in a conversation between the student, supervisor, and Dr. Rachel Pawling was to use the Wikipedia source. It is worth mentioning that for a thesis study, Wikipedia is considered by UCL as accurate as Janes's book.

Royal Navy

Considering the Royal Navy as one of the most representative navies, there are 73 commissioned ships, whose 63 are Surface Ships (Wikipedia, 2022). The range of displacement of the surface ships is shown below:

Table 2 – Displacement Range Royal Navy Surface Ships

Royal Navy Surface Ships			
Displacement [ton]	Number of Ships	% of total	% accumulate
<500t	19	30.16%	30.16%
500t< x <1000t	11	17.46%	47.62%
1000t< x <2000t	8	12.70%	60.32%
2000t< x <5000t	14	22.22%	82.54%
5000t< x <10000t	6	9.52%	92.06%
>10000t	5	7.94%	100.00%
Total Ships	63	100%	100%

French Navy

Considering the French Navy, there are 108 commissioned ships, whose 98 are Surface Ships (Wikipedia, 2022). The range of displacement is given by:

Table 3 – Displacement Range French Navy Surface Ships

French Navy Surface Ships			
Displacement [ton]	Number of Ships	% of total	% accumulate
<500t	25	25.51%	25.51%
500t< x <1000t	17	17.35%	42.86%
1000t< x <2000t	9	9.18%	52.04%
2000t< x <5000t	30	30.61%	82.65%
5000t< x <10000t	10	10.20%	92.86%
>10000t	7	7.14%	100.00%
Total Ships	98	100%	100%

Assumptions

The Royal and French Navy are ranked in the top 10 most powerful navies – 4th and 6th in the world, respectively[13] – and using them as a reference to select the range of the size of ships is a reasonable and valid assumption.

Histogram

Combining both Tables is possible to reach a histogram of the displacement of naval ships, as shown below.

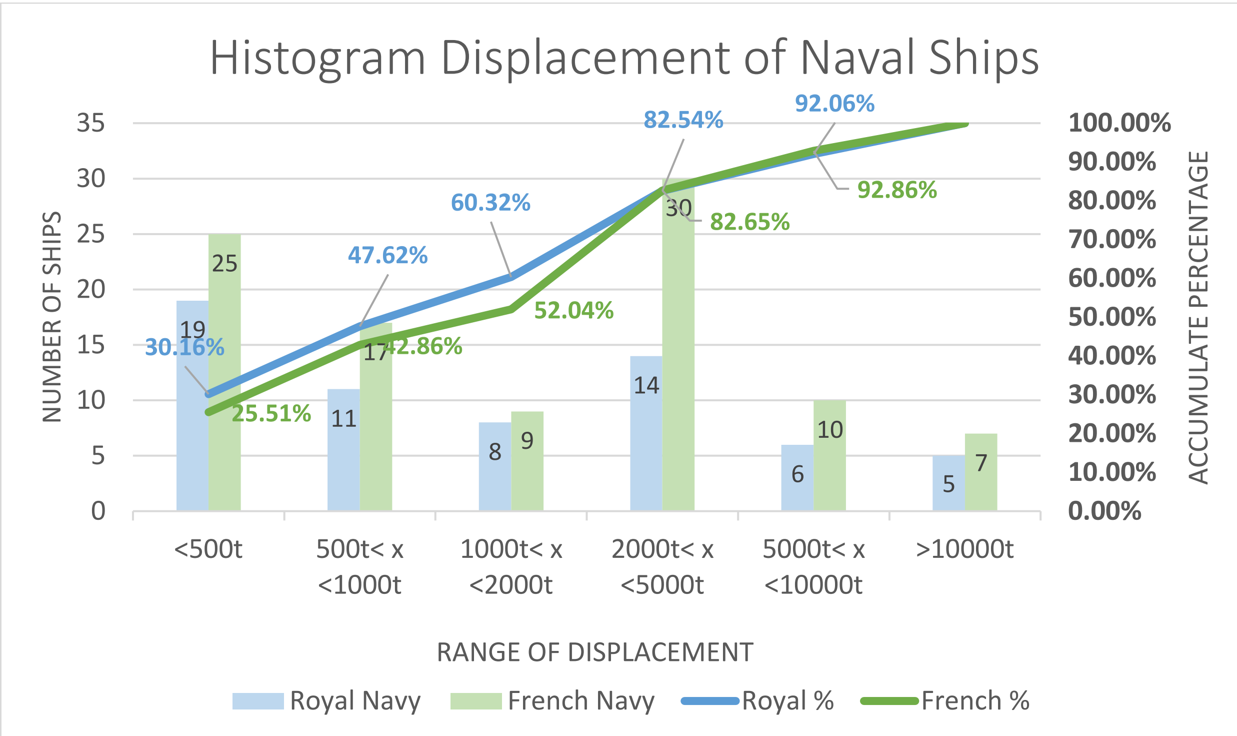


Figure 19 – Histogram Displacement of Naval Ships

It is possible to conclude that both navies have a similar distribution of displacement of naval ships. Therefore, considering the displacement range, ships with less than 5,000ton represent more than 80% of all naval ships.

Additionally, analysing the data, the classes of ships that operate below this displacement are Patrol Vessels, Offshore Patrol Vessels, Corvettes, and Frigates (Wikipedia, 2022).

Hence, in order to represent not only the size of ships but also the type, three of them were chosen to be analysed, as shown below:

- Frigate 5,000 ton.
- Offshore Patrol Vessel (OPV) 2,000 ton.
- Patrol Vessel 500 ton.

The complete ship's size analysis is presented in Appendix I.

[13] https://www.edudwar.com/top-10-strongest-navies-in-the-world/

3.3. Ship's Configuration

Since the aim of this work is not the ship design but only the impact of the mission modules on the design, it was assumed a generic hullform and general arrangement for the ships to be analysed.

Using the generic samples of MAXSURF Software, the hullform of the Frigate, Offshore Patrol Vessel, and Patrol Vessel were generated and are presented below.

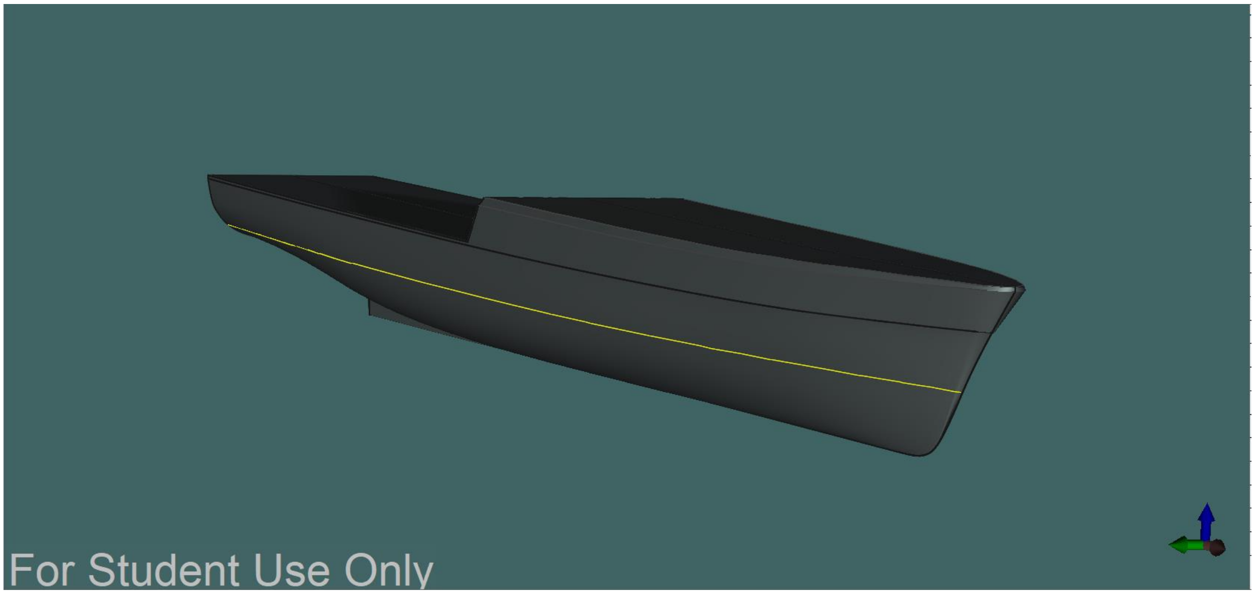


Figure 20 – Patrol Vessel Sample – MAXSURF

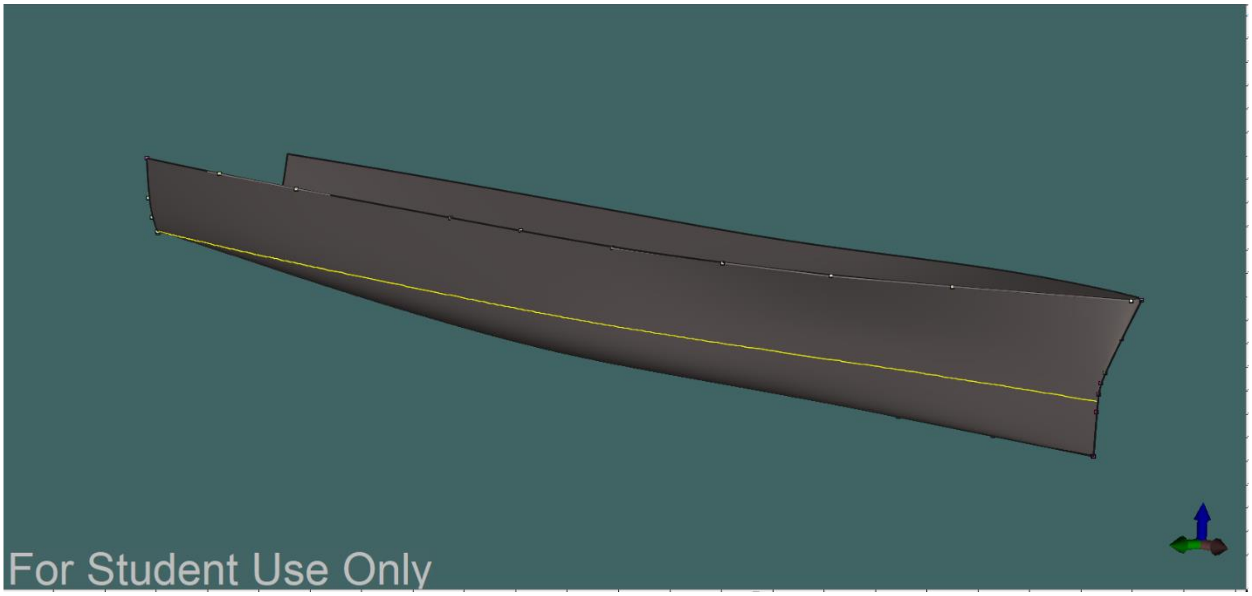


Figure 21 – Frigate Sample – MAXSURF

Assumptions

The most appropriate hullform for each displacement depends on the mission of each ship. It was assumed that for a larger ship, the Frigate Sample fits better for the hullform, and Patrol Vessel for the smaller ones.

Hydrostatics

Therefore, the hydrostatics characteristics for the hullforms using the MAXSURF Samples are presented below:

Table 4 – MAXSURF Models – Hydrostatics Characteristics

MAXSURF Models			
Hydrostatics Characteristics	500 ton	2000 ton	5000 ton
	Patrol Vessel	Patrol Vessel	Frigate
Displacement	**500**	**2000**	**5001**
Volume (displaced)	**488**	**1951**	**4879**
WL Length	**49.149**	**78.021**	**122.929**
Beam max on WL	**8.215**	**13.04**	**19.241**
Draft Amidships	**2.604**	**4.133**	**4.61**
Depth [main deck]	**4.386**	**6.946**	**11.555**
Prismatic coeff. (Cp)	**0.638**	**0.638**	**0.551**
Block coeff. (Cb)	**0.464**	**0.464**	**0.447**
Max Sect. area coeff. (Cm)	**0.738**	**0.738**	**0.827**
Waterpl. area coeff. (Cwp)	**0.775**	**0.775**	**0.718**

In order to achieve the aim of this work by understanding the impact of the mission modules, it is necessary to compare different types of configurations.

The Traditional Ship will be designed as an ASuW ship. On the other hand, the Modular ship will be designed for the three missions ASW, ASuW, and MW.

Therefore, this work will achieve a comparison between Traditional and Modular ASuW, further understanding the impact of changing the role from ASuW to ASW and MW mission ship.

Table 5 – Table of Ship's Configuration

	Patrol Vessel 500t		Offshore Patrol Vessel 2000t		Frigate 5000t	
Mission Package (MP)	Traditional	Modular	Traditional	Modular	Traditional	Modular
Anti-Submarine Warfare (ASW)		PVM1		OPVM1		FM1
Anti-Surface Warfare (ASuW)	PVT1	PVM2	OPVT1	OPVM2	FT1	FM2
Mine Warfare (MW)		PVM3		OPVM3		FM3

All the general arrangements of all designed ships are presented in Appendix II.

Propulsion x Auxiliary Power

Since this work considers generic designs, it is necessary to define the propulsion and auxiliary power, which will be crucial to analyse the impact of the mission modules.

Therefore, analysing a few similar designs with available data for both powers, it was possible to plot a graph of propulsion power and auxiliary ratio against the displacement.

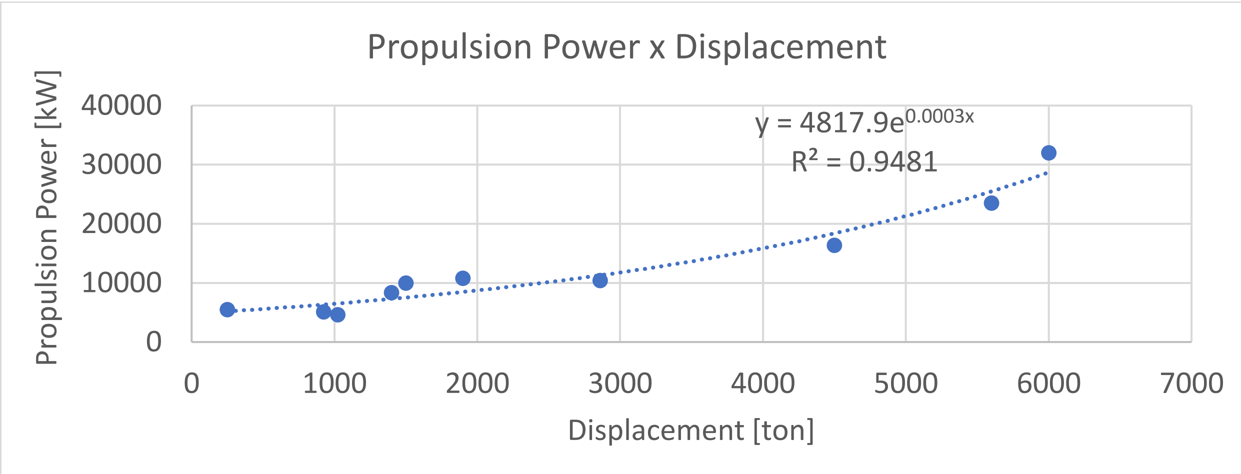


Figure 22 – Propulsion Power x Displacement Graph

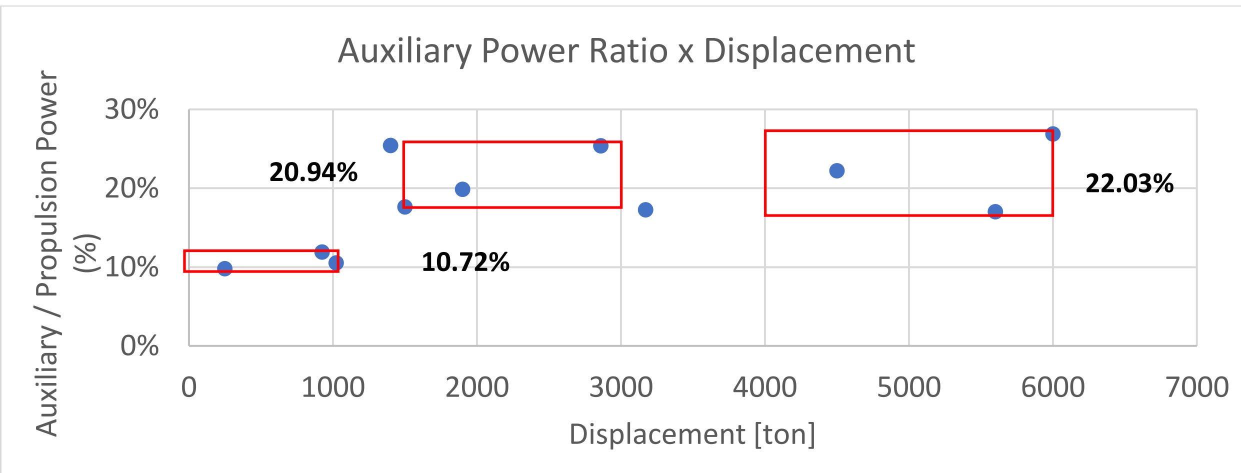


Figure 23 – Auxiliary Power Ratio x Displacement Graph

Hence, using the exponential regression of the propulsion power and using the average auxiliary power ratio on each displacement range, it was possible to define the values for the three designs.

Table 6 – Propulsion and Auxiliary Power definitions

Ship Design	Displacement [ton]	Propulsion Power [kW]	Displacement range	Average Auxiliary Power Ratio	Auxiliary Power [kW]
Patrol Vessel	500	5,597.60	0 < x < 1000t	10.72%	600.34
OPV	2000	8,778.79	1500 < x < 3000t	20.94%	1,838.49
Frigate	5000	21,592.33	4000 < x < 6000t	22.03%	4,756.89

The power analysis with ship's data and regressions are presented in Appendix II.

3.4. Perform Analysis

Stability Analysis

The stability analysis was made considering the traditional ship and the modular ship with three mission packages (ASW, ASuW, and MW). Additionally, an extra case of the modular ship without modules was analysed to verify the safety of the operation.

The damage stability case was considered only on the worst configuration case, which means the case with the lowest GM for the intact stability analysis.

Assumptions

The lightship was calculated considering the traditional ship configuration and the following assumptions:

- LCG was defined considering the level trim condition.
- TCG was assumed as centre line (zero).
- VCG was assumed to be 2/3 of the main deck height.
- Weight was defined considering the total displacement less the consumables tanks and 10% of the displacement for payload.

The lightship was calculated for each ship, and the same value was used for all configurations.

Simulations Results

Table 7 – Summary Stability Cases Patrol Vessel 500ton

Stability Configurations Patrol Vessel 500ton					
Configuration	Displacement [ton]	LCG [m]	TCG [m]	VCG [m]	GM [m]
Patrol Vessel 500ton_Traditional	500.00	23.443	0.000	3.049	1.351
Patrol Vessel 500ton_Modular_ASW	500.66	23.501	0.000	2.968	1.430
Patrol Vessel 500ton_Modular_ASuW	485.71	22.861	0.000	2.950	1.481
Patrol Vessel 500ton_Modular_MW	465.86	22.942	0.000	2.879	1.559
Patrol Vessel 500ton_Modular_No_Modules	450.00	23.418	0.000	2.776	1.648

Table 8 – Summary Stability Cases Offshore Patrol Vessel 2000ton

Stability Configurations Offshore Patrol Vessel 2000ton					
Configuration	Displacement [ton]	LCG [m]	TCG [m]	VCG [m]	GM [m]
Offshore Patrol Vessel 2000ton_Traditional	2000.00	37.223	0.000	4.661	2.323
Offshore Patrol Vessel 2000ton_Modular_ASW	1850.66	37.215	0.000	4.391	2.621
Offshore Patrol Vessel 2000ton_Modular_ASuW	1845.35	37.637	0.000	4.381	2.610
Offshore Patrol Vessel 2000ton_Modular_MW	1815.86	37.060	0.000	4.331	2.695
Offshore Patrol Vessel 2000ton_Modular_No_Modules	1800.00	37.130	0.000	4.296	2.729

Table 9 – Summary Stability Cases Frigate 5000ton

Stability Configurations Frigate 5000ton					
Configuration	Displacement [ton]	LCG [m]	TCG [m]	VCG [m]	GM [m]
Frigate 5000ton_Traditional	5000.00	58.005	0.000	7.022	3.989
Frigate 5000ton_Modular_ASW	4576.66	58.074	0.000	6.483	4.903
Frigate 5000ton_Modular_ASuW	4576.86	58.414	0.000	6.478	4.879
Frigate 5000ton_Modular_MW	4515.86	57.647	0.000	6.430	5.046
Frigate 5000ton_Modular_No_Modules	4500.00	57.823	0.000	6.407	5.073

All simulation cases were approved, and the results are presented in Appendix III.

Survivability Analysis

Survivability is one of the most important ship's design criteria and should consider susceptibility, vulnerability, and recoverability (SOLAS, 2022). For naval ships, survivability is even harder since it is necessary to take into account damage due to hits of missiles.

<u>Assumptions</u>

It is worth mentioning that survivability is not the main focus of this thesis. Therefore, this work will assume that the Traditional ship has already been approved for all survivability requirements and the modular ship did not change the position of any bulkhead. Hence, the main survivability analysis will be addressed by the modules and the changes made on the ship to receive them.

Figure 24 – Stern[14], Midship[15] and Forward[16] Modules Slots Location

Two locations were considered for the modules of this thesis, being at the stern or midship on the main deck and at a slot on forward.

[14] https://www.navalnews.com/naval-news/2020/08/russian-navy-to-begin-trials-of-modular-systems-for-surface-vessels/
[15] https://www.marinelink.com/news/multimission-designing429950
[16] https://dsiac.org/articles/a-promising-future-for-us-navy-vertical-launching-systems/

Stern and Midship Modules

At the stern and midship modules, the survivability concerns are linked with fire and explosion of the modules caused by a problem or a hit. Considering these locations are on the main deck outside the ship so the fire will not affect accommodations or offices inside the ship.

Therefore, the most effective countermeasure should be providing a firefighting system that covers the main deck, as done in cargo, containers, and commercial vessels.

Figure 25 – Fire Fighting Systems covering the main deck[17]

Forward Slot Modules

For the forward modules slot, the concern with survivability is fire, explosion, and flooding. Different from the open deck concerns, these modules are located inside the ship and close to accommodation areas. Hence, an automatic fire extinguishing system must be equipped in the adjacent compartments of these slots. Additionally, the forward slots are close to the bridge and ops rooms, and according to regulations, these compartments already have the extra protection of fire-retardant materials and fire extinguishing systems.

Due to flooding concerns, the forward slots must have watertight enclosures for the compartments in order to not affect any other location in case of embarked of water by the top. This concern is also valid for structural strength and will be mentioned further in this study.

Therefore, considering the modules, the impact of it on survivability is not the most significant, and the concerns are already normal for a naval ship operation.

[17] https://stock.adobe.com/uk/images/closeup-view-of-vessel-fire-fighting-system-which-covers-main-deck-of-offshore-supply-vessel-at-sea-cargo-containers-are-on-background/204700970

Operability Analysis

The Operability analysis is linked with the capability of using the MP without affecting the operational tasks of the naval ship.

One example of MP that affects the operability of the ship is the ASW, the installed equipment must complain with requirements of low noise signature.

Additionally, the TAS module must be installed on the transom or positioned at the stern of the main deck. Considering the ship designs analysed on this thesis, these requirements affect the flight deck operation on the Offshore Patrol Vessel 2000ton. Hence, the conclusion is that if the ASW MP was installed in this specific ship, it could not operate with helicopters losing one of the main operational capabilities of the ship.

Extra Power and Weight Analysis

According to module data, the powering and weight requirements can be summarised in Table 10 below.

Table 10 – Modules Power and Weight Requirements

Module	Power Required [kW]	Total Weight [ton]
Gun 40mm	9.60	9.35
Gun 76mm	9.60	14.86
VLS (tactical)	51.00	26.00
TAS	54.20	14.00
Torpedo	1.00	5.33
Missile	10.00	8.18
UAV	5.00	3.58
UUV	1.00	2.93
7m RIB	20.00	5.00

Hence, considering the modules required for each MP it is possible to reach the ship's power and weight requirements for each mission.

Table 11 – Ship's MP Power and Weight Requirements

Ship	Mod SPV 500t			Mod OPV 2000t			Mod Frigate 5000t		
Requirement \ Mission	ASW	ASuW	MW	ASW	ASuW	MW	ASW	ASuW	MW
Modules Required Power [kW]	107.20	69.60	42.00	107.20	100.60	42.00	158.20	151.60	42.00
Auxiliary Power [kW]	600.34	600.34	600.34	1838.49	1838.49	1838.49	4756.89	4756.89	4756.89
% Auxiliary Power Demand	17.86%	11.59%	7.00%	5.83%	5.47%	2.28%	3.33%	3.19%	0.88%
Modules Weight [ton]	50.66	35.71	15.86	50.66	45.35	15.86	76.66	76.86	15.86
Displacement [ton]	500	500	500	2000	2000	2000	5000	5000	5000
% Weight Demand	10.13%	7.14%	3.17%	2.53%	2.27%	0.79%	1.53%	1.54%	0.32%

It is clear to see in Table 11 the different impacts on power and weight that the modules have considering the size of the ship. In other words, the most impactful configuration for mission modules is the smaller ship, which is reasonable due to the lower displacement.

All operability analysis data are presented in Appendix IV.

Cost Analysis

Modules Cost

Two sources of module cost data were used for Cost Analysis. The first one was a NATO unpublished study (dated 2020) which has a few module cost data, and the other was UCL Zenith Cost Data (dated 2008) with several module cost data for reference since this source is used for Ship Design Exercise. However, the cost data have a difference of 12 years from one to another.

Therefore, using the available NATO study Cost data, a correction for the UCL Zenith Cost Data was proposed.

Table 12 – Cost Data – CBA NATO and Zenith

	CBA NATO Cost Data							
	Name	**Unit Costs [£]**	**Acq. Cost [£]**	**Acq. Low [£]**	**Acq. Likely [£]**	**Acq. High [£]**	**Int. Cost [£]**	**Int. % Acq.**
Weapons	Gun (Small Calibre)	7,400,000	4,000,000	1,500,000	4,000,000	7,000,000	400,000	10.0%
	Gun (Medium Calibre)	10,700,000	7,000,000	4,000,000	7,000,000	10,000,000	700,000	10.0%
	Gun (Large Calibre)	15,000,000	10,000,000	8,500,000	10,000,000	14,000,000	1,000,000	10.0%
	VLS	17,560,000	13,000,000	8,000,000	13,000,000	16,000,000	1,560,000	12.0%
Sensors	3D Radar	7,500,000	5,000,000	3,000,000	5,000,000	7,000,000	500,000	10.0%
	Hull Mounted Sonar	14,640,000	8,000,000	4,000,000	8,000,000	14,000,000	640,000	8.0%
Boats	11m RIB	1,100,000	800,000	600,000	800,000	1,000,000	100,000	12.5%
	7m RIB	381,250	250,000	175,000	250,000	350,000	31,250	12.5%

	Zenith Cost Data		Cost % Raise			
	Item	**Cost [£ 2008 UCL]**	**Acq. Likely [£]**	**Acq. Likely % Raise**	**Unit Costs [£]**	**Unit Costs % Raise**
Weapons	30mm Gun	1,000,000	4,000,000	400%	7,400,000	740%
	76mm Gun	3,000,000	7,000,000	233%	10,700,000	357%
	127mm Gun	7,500,000	10,000,000	133%	15,000,000	200%
	Strike VLS	5,100,000	13,000,000	255%	17,560,000	344%
Sensors	3D Radar	4,500,000	5,000,000	111%	7,500,000	167%
	Hull Mounted Sonar	5,000,000	8,000,000	160%	14,640,000	293%
Boats	11m RIB	250,000	800,000	320%	1,100,000	440%
	7m RIB	125,000	250,000	200%	381,250	305%

Considering the Unit Costs raise, the following values will be used to normalise the costs:

Average ($\bar{X}$)	356%

Standard Deviation (σ)	166%
Number of Data (n)	8

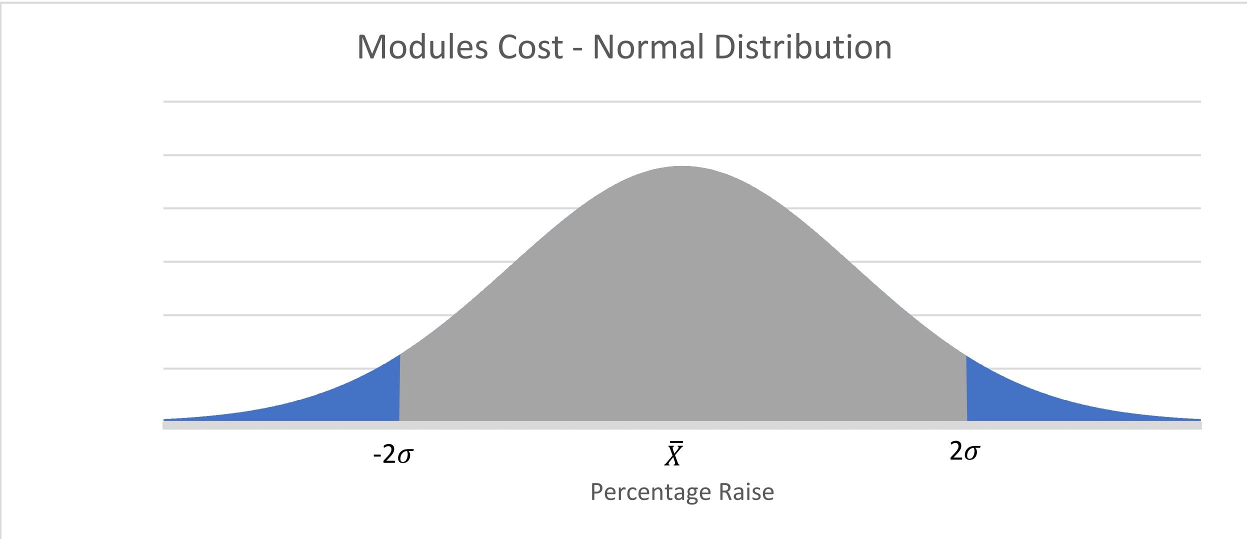


Figure 26 – Modules Cost – Normal Distribution

Hence, normalising the percentage raise and applying a 95% Confidence Interval (CI), it is possible to define the normalised curve with the lower and upper boundaries.

$$CI = \bar{X} \pm Z \cdot \frac{\sigma}{\sqrt{n}} = 241\% \text{ and } 471\%$$

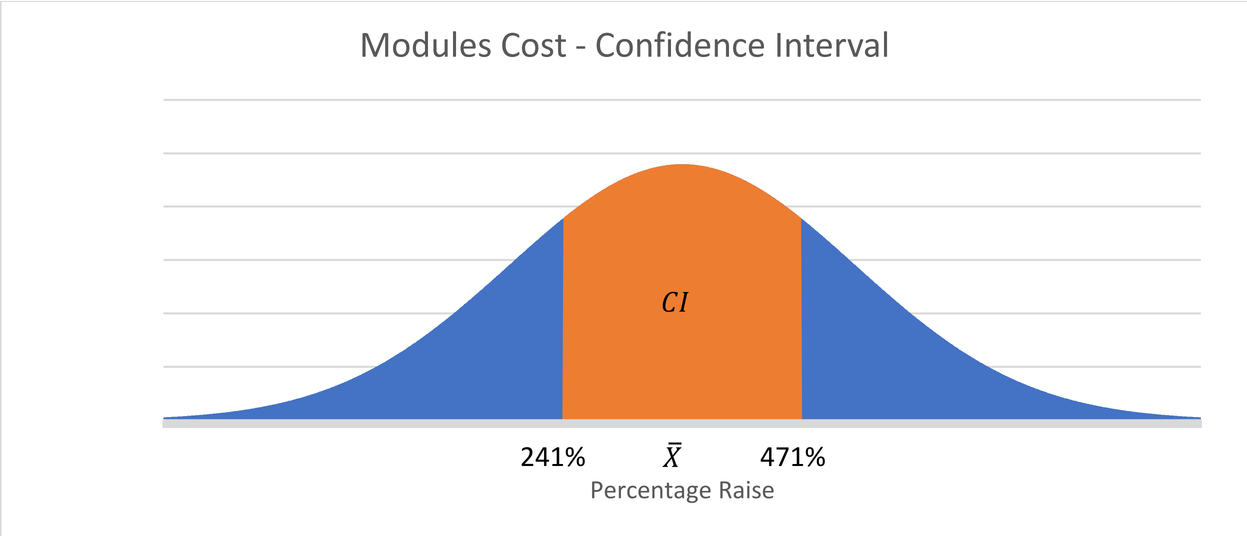


Figure 27 – Modules Cost – Confidence Interval

Considering NATO study dates from 2020 and the expected inflation in the UK for 2022 is higher than 10%, the proposed UCL Zenith Cost correction was the upper boundary of the confidence interval, which is 471%.

Additionally, to conclude the module cost analysis, it is necessary to consider an extra value to make the modularisation (make it modular) of the system. The value of 10% as an extra cost was added regarding modularization. Finally, the cost of each module considered in this study is presented below.

Table 13 – Modules Cost

Modules Cost	
Module	Cost [£M]
Gun 40mm	6.22
Gun 76mm	15.54
VLS (tactical)	17.62
TAS	25.91
Torpedo	2.59
Missile	14.40
UAV	62.17
UUV	5.44
7m RIB	2.46

All definitions for Modules Cost analysis are presented in Appendix V.

Ships Cost

Frigate and OPV

The data cost for different types of ship is provided by a NATO unpublished study and is presented in the table below.

Table 14 – Estimated cost per ship – NATO unpublished study

Ship Class	Cost per Ship [Mio. €]	90% Pred. Interval Lower Bound [Mio. €]	90% Pred. Interval Upper Bound [Mio. €]
Destroyer	1,024	985	1,100
Frigate	701	650	755
MCMV	249	228	270
OPV	233	232	270
JSS	968	870	1000
MSC	549	500	600
SSC	472	452	495
OPV small	318	297	340
OPV AAW	242	222	264

Hence, the Frigate and OPV Costs were associated with the Traditional Ships, and the MSC and OPV small were considered Modular Ships. Additionally, it is worth mentioning that the upper bound costs were considered due to military inflation and rising costs in the actual world scenario.

Patrol Vessel

However, the ship's costs for the Patrol Vessel were not provided in the cost data. Therefore, for the Traditional ship, it was made a linear regression assuming the costs reduces in a linear pattern with the displacement.

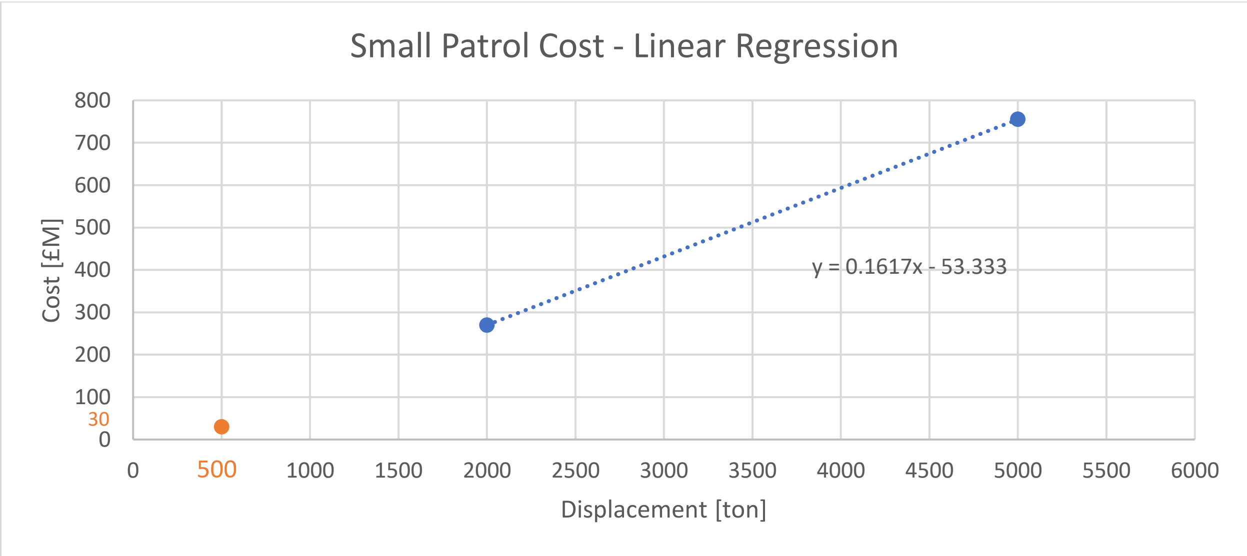


Figure 28 – Patrol Vessel Cost – Linear Regression

Table 15 – Traditional Patrol Vessel Cost

Traditional Ship		
Ship	Displacement [ton]	Cost [£M]
Frigate	5000	755
OPV	2000	270

Linear Regression (y = 0.1617x - 53.333)		
Ship	Displacement [ton]	Cost [£M]
Patrol Vessel	500	27.5
Assumed Patrol Vessel Cost		**30**

Considering the linear regression, the cost of a Patrol Vessel should be £27.5M. However, adding a margin, the value considered was £30M.

For the Modular ship, the cost was obtained by comparing the percentage of Traditional and Modular ship costs in the range of displacement.

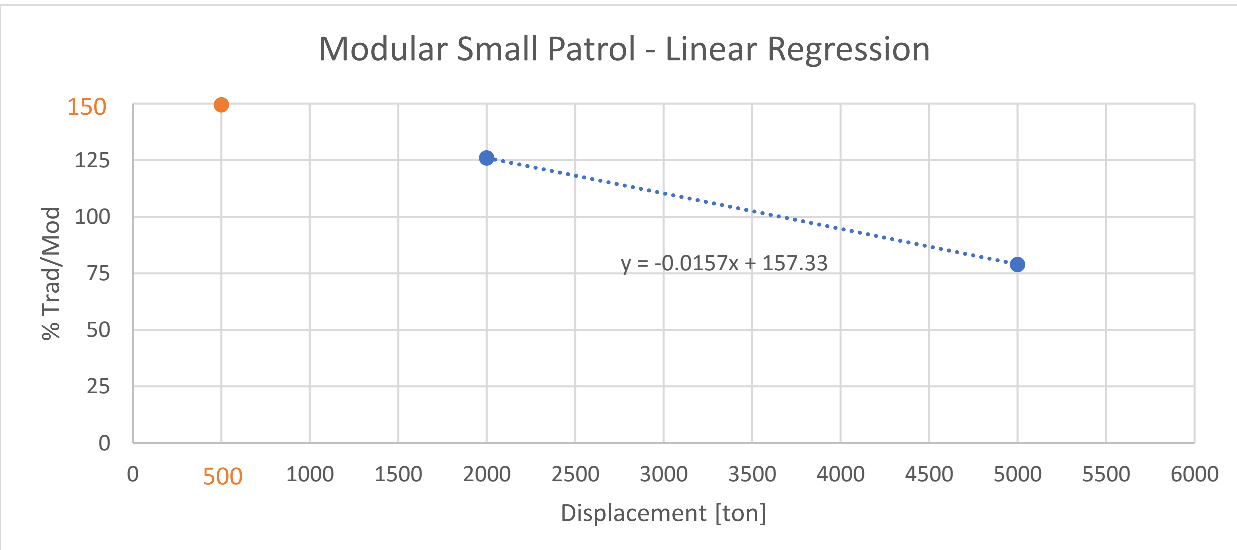


Figure 29 – Modular Patrol Vessel – Linear Regression

Table 16 – Modular Patrol Vessel Cost

Traditional Patrol Vessel 500t			
Ship	Displacement [ton]	Cost [£M]	% Trad/Mod
Frigate	5000	755	79%
MSC Frigate	5000	600	
OPV	2000	270	126%
OPV small	2000	340	

Linear Regression (y = -0.0157x + 157.33)			
Ship	Displacement [ton]	Cost [£M]	% Trad/Mod
Patrol Vessel	500	30	149%
Modular Patrol Vessel	500	44.8	
Assumed Modular Patrol Vessel Cost		**45**	

Considering the linear regression, the Modular Patrol Vessel should cost £44.8M. However, it was rounded to £45M.

All Ship Cost analyses are presented in Appendix V.

Fleet Cost

The Fleet Cost analysis was made considering three scenarios, explained below.

- First, analysing the same number of vessels for the modular and traditional fleet (Analysis 1). Additionally, for this scenario, the modular fleet was considered with the exact same number of mission packages as the number of ships. (Ex. 3 Ships – 3 Mission Packages)

Table 17 – Fleet Cost Analysis 1 – Same number of Modular and Traditional Ships

Analysis 1 - 1 Modular and 1 Traditional (Module for each specific ship)

Modular Fleet

Modular Ships				Ship Cost		
Ship	ASW	ASuW	MW	Total	Ship Cost [£M]	Total Cost [£M]
Mod SPV 500t	1	1	1	3	45	135
Mod OPV 2000t	1	1	1	3	340	1020
Mod Frigate 5000t	1	1	1	3	600	1800
				Total Modular Ship Cost		2955

Mission and Modules										Module Cost		
Ship	Mod SPV 500t			Mod OPV 2000t			Mod Frigate 5000t					
Module \ Mission	ASW	ASuW	MW	ASW	ASuW	MW	ASW	ASuW	MW	Total	Unit Cost [£M]	Total Cost [£M]
Gun 40mm		1			1					2	6.22	12.43
Gun 76mm								1		1	15.54	15.54
VLS (tactical)	1			1	1		2	2		7	17.62	123.31
TAS	1			1			1			3	25.91	77.72
Torpedo	2			2			2			6	2.59	15.54
Missile		2								2	14.40	28.80
UAV										0	62.17	0.00
UUV			2			2			2	6	5.44	32.64
7m RIB		2	2		2	2		2	2	12	2.46	29.53
										Total Modules Cost		335.52
										Modular Fleet Cost		3291

Traditional Fleet

Traditional Ships				Ship Cost		
Ship	ASW	ASuW	MW	Total	Ship Cost [£M]	Total Cost [£M]
SPV 500t	1	1	1	3	30	90
OPV 2000t	1	1	1	3	270	810
Frigate 5000t	1	1	1	3	755	2265
				Total Traditional Ship Cost		3165
				Traditional Fleet Cost		3165

Summary

Analysis 1 - Summary	
Fleet	Cost [£M]
Modular Fleet Cost	3291
Traditional Fleet Cost	3165
Cheapest Solution	Traditional Fleet Cost

- Second, considering the modular fleet with fewer ships than the traditional (Analysis 2-7). Furthermore, for this scenario, each modular ship was considered with all three mission packages (ASW, ASuW, MW) available for changing the role of the ship. (Ex. 3 Ships – 9 Mission Packages)

- Third, finding the break-even point (Break-even analysis). Finally, for this last scenario, the number of traditional ships was fixed at 100, and the number of modular ships was varied until it reached the exact same cost for both fleets. It is worth mentioning that each modular ship was considered with all mission packages. (Ex. X Ships – 3X Mission Packages)

Assumptions

- Traditional Ship has the same cost independently of the role ASW, ASuW, or MW.
- Modular Ship has the same performance with modules as the Traditional Ships. In other words, Modules have the same performance as fixed systems.
- The Mission Packages/Modules defined for each ship are enough to meet all the mission requirements without any loss compared with the Traditional Ship.
- Only Acquisition fleet costs were considered.

Hence, all the fleet cost analyses made are summarised in Table 18 below.

Table 18 – Fleet Cost Analysis Summary

Fleet Cost Analysis							
Analysis	Number of Ships		Fleet Cost			Cheapest Solution	% Mod/Trad
	Mod Ship	Trad Ship	Mod Fleet [£M]	Trad Fleet [£M]	Diff [£M]		
Analysis 1	3	3	3291	3165	126	Traditional Fleet	100%
Analysis 2	2	3	2506	3165	-659	Modular Fleet	67%
Analysis 3	3	4	3759	4220	-461	Modular Fleet	75%
Analysis 4	4	5	5012	5275	-263	Modular Fleet	80%
Analysis 5	5	6	6265	6330	-65	Modular Fleet	83%
Analysis 6	6	7	7517	7385	132	Traditional Fleet	86%
Analysis 7	7	8	8770	8440	330	Traditional Fleet	88%
Break-even Analysis	84.20	100	105500	105500	0	Break-even point	84.20%

All Fleet Cost analyses are presented in Appendix V.

4. Discussion

The discussion was subdivided into two parts the first Evaluation of Results and the second on the Impact of Mission Modules.

4.1. Evaluation of Results

Modules Capability

The ASW MP allows the ships to find and attack submarines. However, it is worth mentioning that to be an ASW ship, it is also necessary to have a low noise signature.

Therefore, only adding the ASW MP is not enough for a ship to become a submarine fighter, and then these modules should be used carefully in order to prevent the ship from becoming an easy target for a submarine.

Ship's Size

The Ship's size analysis was made only with Royal and French navies instead of using all the global navies. This was due to the different approaches and strategies adopted for each country. The navies's size in the numbers of ships and displacement depends directly on the country's position and aspirations on global actuation.

For example, the Japanese Navy has bigger ships due to the location of the country and the threats of defence linked with that region. On the other hand, the Chilean Navy has smaller ships due to the location being closer to the other countries and threats of the region acting more in coastal protection.

Hence, the analysis using the Royal and French Navies tries to take out the extremes and represents all navies on average to have a better and more valid assumption.

Ship's Configuration

The Operability analysis shows that the Patrol Vessel 500ton didn't have available power to receive the ASW modules, which require 107.2kW, representing 17.86% of the total available power. Considering the generator operating envelope cannot exceed 90% of the total power, it will be necessary to install extra power to receive the ASW mission package.

One solution is using one of the available container modules for a generator module to sustain the required power of the installed modules. This solution works perfectly and is widely used in other ships where the power requirements exceed the available power generated by the installed generators on board.

Stability

All cases analysed passed into the stability criteria selected (NES109). However, it is important to point out that for some configurations, the value of GM is excessively high (GM>3.0), and even though this is good for stability and safety purposes, this situation leads to terrible operation and seakeeping performance of the ship.

One good solution to solve the high GM problem is adopting a “ballast” module that could help elevate the centre of gravity of the ship in order to reduce the strong response caused by a high GM and return to an acceptable value.

Therefore, this aspect should be addressed in more detail in future works to understand the seakeeping response for each mission module.

Cost

The fleet cost analysis revealed that the break-even point for the modular fleet size is less than 84.2% of the traditional fleet to be cost-benefit to implement the mission modularity. This means that the modular fleet needs to be more efficient than the traditional.

Actually, this is true and was confirmed by several NATO Studies that concluded that the modular fleet is not only more cost-benefit than a traditional fleet but also more efficient in doing the same job with less cost and fewer ships.

Even though the results achieved by this cost analysis are aligned with NATO Studies and could be considered reasonable and acceptable, the fleet cost analysis was based on a few strong assumptions that should be verified in order to have more confidence in the results shown in this work.

4.2. Impact of Mission Modules

The impact of the mission modules was subdivided into Primary and Secondary Impacts in order to have a deep-seated look at each part of the impact. These two sections of impact will be discussed below.

The Primary Impact refers to the hull changes being space/layout, structure, and stability. On the other hand, the secondary consists of the systems and logistics impact being auxiliary power, costs, and crew.

a) Primary Impact

Space/Layout

Operations Room

The required number of consoles for each module is different. Hence, the impact of receiving the mission modules is directly connected with the Ops Room size and capability of receiving more consoles.

Change/Lost Compartments

The general arrangement is impacted by the necessity of reconfiguring some compartments to receive the modules. An example is the forward module slots that impact the accommodations area on the Frigate and Offshore Patrol Vessel analysed. The impact on accommodations is another crucial point discussed further in this work.

Stability

Free Module Slots

One main concern and impact of modules occurs when they are not installed on board. For example, the forward spaces destined for modules (Gun and VLS) are big openings on the ship throw more than one deck. Therefore, having completely empty space is a terrible use of the available capacity, and space is a master concern in naval ship design.

Additionally, even though stability is not a concern, having openings in decks could lead to not desirable conditions from an operational and maintenance perspective. Hence, one approach to consider when the ship is not carrying any capability on the aft or forward slot is using these to provide additional offices, accommodation, or storage for the ship by using specific modules build to fit on that space.

This approach solves not only the efficient use of space on board but also operational and maintenance concerns of having flooded spaces due to openings on the decks.

Structures/Vibration

From a structural perspective, modularity has two essential points to grab the attention: modules positioned on the main deck and the roles/openings on decks or side shells.

The structural concern for the modules on the main deck is a localized load in the deck plating. Therefore, it is advisable to verify if this local load will affect the total deck strength due to buckling a plate and losing the effectiveness of one of the most critical components of ship's beam.

For the modules which need roles and openings throw decks or side shells, the structural concern is losing the deck strength or structural continuity for the longitudinal stiffeners. Therefore, extra attention should be taken to the reinforced structure around the roles of openings to guarantee the correct response for the structure.

b) Secondary Impact

Auxiliary Power

As analysed in this work, the power requirement of the modules could be significant in a way that might be necessary for an extra module of generators to comply with the module's power requirement. Additionally, extra care should be taken in not considering only the installed power due to emergency and zone power requirements due to survivability impacts.

Cost

The cost impacts positively on naval ship design due to reaching a reduction in fleet cost when considering modularity below 84.2% of the traditional fleet size. However, it is worth mentioning that the cost of the initial implementation of a modular fleet could be higher than the Traditional, and this economy of the budget will only be justifiable in the long term considering the 30-year life cycle of the ships.

Crew

The modules require a specialist operator that is not always available in the crew. Hence, it is not uncommon for the specialist to embark on the ship at the same time as the module. Therefore, the requirement for accommodations also rises, which is usually a silent impact of receiving modules.

5. Conclusions and Future Works

5.1. Conclusions

It is not arguably the efficiency and capability generated by the modules. Modularity is not a new concept, but its impact of it on the naval ship design has not already been completely tested and identified.

Therefore, this thesis has identified the impacts of adopting the mission modules approach to naval ship designs. Due to the vast subject, some assumptions were made during the study in order to enable a broader analysis.

The boundaries of this work were the ASW, ASuW, and MW MP to define the analysed mission modules and the Royal and French Navies ships in order to obtain a definition of the analysed ship's size.

The impacts recognised in this work were the results of these previous assumptions/boundaries. However, it is clear that a different approach will not lead to different results, which could be considered a valid assumption for this work.

These impacts were subdivided into primary and secondary depending on the deepness/intensity of it. The primary impacts were layout, stability, and structure. On the other hand, the secondary impacts were auxiliary power, cost, and crew.

Determining these impacts provides new suggestions for deeper study in order to have a better understanding and knowledge of the impact and ways to mitigate it.

It is worth mentioning that the impacts have different intensities when looking at ship's size, which is one of the main drivers of adopting of mission modules. Receiving modules in a smaller ship is more challenging due to layout, auxiliary power, and crew impact but provides a huge upgrade on its capability. For example, a Patrol Vessel of 500ton carrying a VLS module and a TAS module is a surprise effect for this type and size of ship.

For a bigger ship, the impacts are the same, but their intensity is smaller or insignificant. The main concerns for bigger ships should be the structure and cost impacts of adopting modules. For example, due to larger lengths, Frigate's structures should be more complex, and therefore the forward openings for VLS and Gun modules generate higher loads in a 5000ton Frigate than in a smaller ship.

Finally, it is important to emphasise that other impacts may surge when the investigation/future studies go deeper into each area, and that is why this kind of study is so crucial for a start on the impact investigation.

5.2. Future Works

Due to available time and data limitations, some assumptions were made to finish this work. Therefore, for future work, these assumptions must be verified. Confirming or correcting the assumptions made in this work will help the naval industry better understand the impact of mission modules on ship design.

Even though NATO has already realised several CBA studies, it did not cover the smaller size of ships as the Patrol Vessel 500ton used in this work. Therefore, a specific study of modularity's implementation cost should be realised in this class and size to confirm the assumptions made.

The module's impact was analysed, but its capability was assumed to be the same as fixed systems. Hence, studies and tests should be addressed to compare the module's performance with fixed systems performance in order to understand the gaps and attention points that must be given to the modular approach.

Additionally, a seakeeping analysis should be addressed for the performance analysis to understand the best location to install mission modules on the ships and how the modules impact the ship's response and accelerations for operation security and crew comfort.

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Appendix I – Ship's Size Data

Royal Navy Active Ships[18]

Royal Navy Active Ships							
Ceremonial/Historic ship							
Flagship of the First Sea Lord							
Class	Ship	No.	Commissioned	Displacement	Type	Homeport	Note
Ship of the line	HMS Victory	—	1778[N 1]	3,556 tonnes	First-rate ship of the line	Portsmouth	[5]

Submarine service							
Strategic							
Class	Boat	No.	Commissioned	Displacement	Type	Homeport	Note
Vanguard class	HMS Vanguard	S28	1993	15,900 tonnes	Ballistic missile submarine	Clyde	[6]
	HMS Victorious	S29	1995				[7]
	HMS Vigilant	S30	1996				[8]
	HMS Vengeance	S31	1999				[9]
Fleet							
Class	Boat	Pennant No.	Commissioned	Displacement	Type	Homeport	Note
Astute class	HMS Astute	S119	2010	7,400 tonnes	Fleet submarine	Clyde	[10]
	HMS Ambush	S120	2013				[11]
	HMS Artful	S121	2016				[12]
	HMS Audacious	S122	2021				[13][14]
Trafalgar class	HMS Triumph	S93	1991	5,300 tonnes		Devonport	[15]

18 https://en.wikipedia.org/wiki/List_of_active_Royal_Navy_ships

Surface fleet							
Aircraft carriers							
Class	Ship	No.	Commissioned	Displacement	Type	Homeport	Note
Queen Elizabeth class	HMS Queen Elizabeth	R08	2017	65,000 tonnes	Aircraft carrier	Portsmouth	[16][17][N 2]
	HMS Prince of Wales	R09	2019	65,000 tonnes			[18]
Amphibious warfare							
Class	Ship	No.	Commissioned	Displacement	Type	Homeport	Note
Albion class	HMS Albion	L14	2003	19,560 tonnes	Amphibious transport dock	Devonport	[19]
	HMS Bulwark	L15	2004	19,560 tonnes			[20][N 3]
Destroyers							
Class	Ship	No.	Commissioned	Displacement	Type	Homeport	Note
Type 45 (Daring class)	HMS Daring	D32	2009	8,500 tonnes	Anti Air Guided Missile Destroyer	Portsmouth	[21][22]
	HMS Dauntless	D33	2010	8,500 tonnes			[23]
	HMS Diamond	D34	2011	8,500 tonnes			[24]
	HMS Dragon	D35	2012	8,500 tonnes			[25]
	HMS Defender	D36	2013	8,500 tonnes			[26]
	HMS Duncan	D37	2013	8,500 tonnes			[27]
Frigates							
Class	Ship	No.	Commissioned	Displacement	Type	Homeport	Note
Type 23 (Duke class)	HMS Argyll	F231	1991	4,900 tonnes	Guided missile frigate	Devonport	[28]
	HMS Lancaster	F229	1992	4,900 tonnes		Portsmouth	[29]
	HMS Iron Duke	F234	1993	4,900 tonnes		Portsmouth	[30]
	HMS Montrose	F236	1994	4,900 tonnes		Devonport	[31][N 4]
	HMS Westminster	F237	1994	4,900 tonnes		Portsmouth	[32]
	HMS Northumberland	F238	1994	4,900 tonnes		Devonport	[33]
	HMS Richmond	F239	1995	4,900 tonnes		Devonport	[34]
	HMS Somerset	F82	1996	4,900 tonnes		Devonport	[35]
	HMS Sutherland	F81	1997	4,900 tonnes		Devonport	[36]
	HMS Kent	F78	2000	4,900 tonnes		Portsmouth	[37]
	HMS Portland	F79	2001	4,900 tonnes		Devonport	[38]
	HMS St Albans	F83	2002	4,900 tonnes		Devonport	[39]

Offshore patrol							
Class	Ship	No.	Commissioned	Displacement	Type	Homeport	Note
River class	HMS Tyne	P281	2003	1,700 tonnes	Offshore patrol vessel	Portsmouth	[40]
	HMS Severn	P282	2003 and 2021	1,700 tonnes			[41]
	HMS Mersey	P283	2003	1,700 tonnes			[42]
	HMS Forth	P222	2018	2,000 tonnes			[43][N 5]
	HMS Medway	P223	2019	2,000 tonnes			[44][N 6]
	HMS Trent	P224	2020	2,000 tonnes			[45][N 7]
	HMS Tamar	P233	2020	2,000 tonnes			[46][N 8]
	HMS Spey	P234	2021	2,000 tonnes			[47][N 9]
Mine countermeasures							
Class	Ship	No.	Commissioned	Displacement	Type	Homeport	Note
Hunt class	HMS Ledbury	M30	1981	750 tonnes	Minehunter	Portsmouth	[48]
	HMS Cattistock	M31	1982	750 tonnes			[49]
	HMS Brocklesby	M33	1983	750 tonnes			[50]
	HMS Middleton	M34	1984	750 tonnes			[51][N 10]
	HMS Chiddingfold	M37	1984	750 tonnes			[52][N 11]
	HMS Hurworth	M39	1985	750 tonnes			[53]
Sandown class	HMS Penzance	M106	1998	600 tonnes		Clyde	[54][N 12]
	HMS Pembroke	M107	1998	600 tonnes			[55]
	HMS Grimsby	M108	1999	600 tonnes			[56]
	HMS Bangor	M109	2000	600 tonnes			[57][N 13]
	HMS Shoreham	M112	2001	600 tonnes			[58]

Coastal & Fast patrol							
Class	Ship	No.	Commissioned	Displacement	Type	Homeport	Note
P2000 or Archer class	HMS Archer	P264	1985	54 tonnes	Patrol boat, URNU	Edinburgh	[59]
	HMS Biter	P270	1986	54 tonnes		Eaglet	[60]
	HMS Smiter	P272	1988	54 tonnes		Portsmouth	[61]
	HMS Pursuer	P273	1988	54 tonnes		TBD[62]	[63][N 14]
	HMS Blazer	P279	1988	54 tonnes		Portsmouth	[64]
	HMS Dasher	P280	1988	54 tonnes		TBD[65]	[66][N 15]
	HMS Puncher	P291	1988	54 tonnes		Portsmouth	[67]
	HMS Charger	P292	1988	54 tonnes		Eaglet	[68]
	HMS Ranger	P293	1988	54 tonnes		Portsmouth	[69]
	HMS Trumpeter	P294	1988	54 tonnes		Ipswich	[70]
	HMS Express	P163	1988	54 tonnes		Cardiff	[71]
	HMS Example	P165	1985	54 tonnes		Gateshead	[72]
	HMS Explorer	P164	1986	54 tonnes		Hull	[73]
	HMS Exploit	P167	1988	54 tonnes		Portsmouth	[74]
	HMS Tracker	P274	1998	54 tonnes	Patrol boat	Clyde	[75][N 16]
	HMS Raider	P275	1998	54 tonnes			[76][N 17]
Cutlass class	HMS Cutlass	P295	2022	35 tonnes	Patrol boat	Gibraltar	[77][N 18]
	HMS Dagger	P296	2022	35 tonnes			[78][79][N 19]

Auxiliary fleet							
Survey							
Class	Ship	No.	Commissioned	Displacement	Type	Homeport	Note
Echo class	HMS Enterprise	H88	2003	3,740 tonnes	Multi-purpose survey	Devonport	[80]
—	HMS Scott	H131	1997	13,500 tonnes	Ocean survey		[81]
—	HMS Protector	A173	2011	5,000 tonnes	Icebreaker & survey		[82]
—	HMS Magpie	H130	2018	37 tonnes	Survey motor launch		[83]

Royal Navy Surface Ships			
Displacement [ton]	Number of Ships	% of total	% accumulate
<500t	19	30.16%	30.16%
500t< x <1000t	11	17.46%	47.62%
1000t< x <2000t	8	12.70%	60.32%
2000t< x <5000t	14	22.22%	82.54%
5000t< x <10000t	6	9.52%	92.06%
>10000t	5	7.94%	100.00%
Total Ships	63	100%	100%

French Navy Active Ships[19]

French Navy Active Ships						
Submarine fleet (*Forces sous-marines*)						
Ballistic missile submarines						
Class	**Boat**	No.	Comm	**Displacement**	**Type**	**Note**
Triomphant class	Triomphant	S616	1997	14,335 tonnes	Ballistic missile submarine	
	Téméraire	S617	1999			
	Vigilant	S618	2004			
	Terrible	S619	2010			

Nuclear attack submarines						
Class	**Boat**	No.	Comm	**Displacement**	**Type**	**Note**
Barracuda class	Suffren	Q284	2020	5,300 tonnes	Nuclear attack submarine	6 planned in total
Rubis class	Rubis	S601	1983	2,660 tonnes		Being phased out and replaced by the Barracuda class.
	Casabianca	S603	1987			
	Émeraude	S604	1988			
	Améthyste	S605	1992			
	Perle	S606	1993			

Surface fleet (*Bâtiments de combat*)						
Aircraft carrier						
Class	**Ship**	No.	Comm	**Displacement**	**Type**	**Note**
—	Charles de Gaulle	R91	2001	42,500 tonnes	Aircraft carrier	

[19] https://en.wikipedia.org/wiki/List_of_active_French_Navy_ships

Amphibious warfare						
Class	**Ship**	**No.**	**Comm**	**Displacement**	**Type**	**Note**
Mistral class	Mistral	L9013	2006	21,500 tonnes	Landing helicopter dock	
	Tonnerre	L9014				
	Dixmude	L9015	2012			

Major surface combatants						
Class	**Ship**	**No.**	**Comm**	**Displacement**	**Type**	**Note**
Horizon class	Forbin	D620	2008	7,050 tonnes	Air-defence destroyer	
	Chevalier Paul	D621	2009			
Aquitaine class	Aquitaine	D650	2012	6,040 tonnes	Anti-Submarine Warfare (ASW) destroyer	*Lorraine* (D657) to be commissioned in late 2022[5][6]
	Normandie	D651	2020			
	Provence	D652	2015			
	Languedoc	D653	2017			
	Auvergne	D654	2018			
	Bretagne	D655	2019			
	Alsace	D656	2021		Air defence/ASW destroyer	
La Fayette class	La Fayette	F710	1996	3,800 tonnes	General-purpose frigate	To be complemented and eventually replaced in first rank roles by future Frégate de Défense et d'Intervention (FDI) from 2024[7]
	Surcouf	F711	1997			
	Courbet	F712				
	Aconit	F713	1999			
	Guépratte	F714	2001			
Floréal class	Floréal	F730	1992	2,950 tonnes	Surveillance frigate	Class has anti-ship missiles removed and functions in a second-rank "surveillance frigate" role for French overseas territories.
	Prairial	F731	1992			
	Nivôse	F732				
	Ventôse	F733	1993			
	Vendémiaire	F734				
	Germinal	F735	1994			

Patrol						
Class	**Ship**	**No.**	**Comm**	**Displacement**	**Type**	**Note**
—	L'Astrolabe	P800	2017	4,000 tonnes	Icebreaker/support vessel/offshore patrol	Based in Réunion; co-operated by the French Southern and Antarctic Lands (TAAF) Administration and the French Navy.
D'Entrecasteaux class	*D'Entrecasteaux*	A621	2016	2,300 tonnes	Offshore patrol/support vessel	Based in Noumea
	Bougainville	A622				Based in Papeete
	Champlain	A623	2017			Based in Réunion
	Dumont d'Urville	A624	2020			Based in Fort-de-France[8]
D'Estienne d'Orves class	Premier-Maître L'Her	F792	1981	1,250 tonnes	Offshore patrol vessel	Originally entered service as avisos (sloops / light corvettes), reclassified as OPVs in 2012.[9] To be replaced from 2025 as part of the acquisition of a new class of ocean-going patrol vessels ("Patrouilleurs Océanique" - PO).[10]
	Commandant Blaison	F793	1982			
	Enseigne de Vaisseau Jacoubet	F794				
	Commandant Ducuing	F795	1983			
	Commandant Birot	F796	1984			
	Commandant Bouan	F797				
***La Confiance* class**	*La Confiance*	P733	2017	700 tonnes		Based in Guiana
	La Résolue	P734				
	La Combattante	P735	2020			Based in Fort-de-France
L'Audacieuse class	La Glorieuse	P686	1985	480 tonnes		Based in Noumea, to be decommissioned by 2023;[11][12] Class to be replaced in 2023-2025 period by 6 POM-type (*Patrouilleur d'Outre-Mer*) patrol vessels.[13][14][15]

Mine countermeasures						
Class	**Boat**	No.	Comm	**Displacement**	**Type**	**Note**
Éridan class	*Andromède*	M643	1984	615 tonnes	Minehunter	To be replaced by Système de lutte anti-mines futur (SLAM-F) starting in 2023[16]
	Pégase	M644	1985			
	Orion	M645	1986			
	Croix du Sud	M646				
	Aigle	M647	1987			
	Lyre	M648				
	Céphée	M652				
	Capricorne	M653				
	Sagittaire	M650	1996			
***Vulcain* class**	Vulcain	M611	1986	490 tonnes	Clearance diving	To be replaced by SLAM-F
	Pluton	M622	1986			
	Styx	M614	1987			
	Achéron	A613				
***Antarès* class**	*Antarès*	M770	1993	340 tonnes	Sonar towing vessel	To be replaced by SLAM-F
	Altaïr	M771				
	Aldébaran	M772	1994			

Coastguard						
Class	**Boat**	No.	Comm	**Displacement**	**Type**	**Note**
—	*Le Malin*	P701	1997	1,300 tonnes	Coastal patrol vessel	An ex-trawler based in La Reunion. To be replaced by a *Patrouilleur d'Outre-Mer* (POM)-class patrol vessel[13][14][15]
***Lapérouse* class**	*Arago*	P675	1988	980 tonnes		An ex-hydrographic survey vessel. Extension of role in French Polynesia until 2024 pending arrival of POM-class OPVs.[17]
—	*Fulmar*	P740	1991	550 tonnes		An ex-trawler based in Saint Pierre
Flamant class	*Flamant*	P676	1997	390 tonnes	Patrol boat	To be replaced from 2025 as part of the acquisition of new class of "PO" ocean-going patrol vessels.
	Cormoran	P677				
	Pluvier	P678				

Auxiliary fleet (*Bâtiments de soutien*)						
Replenishment						
Class	**Ship**	**No.**	**Comm**	**Displacement**	**Type**	**Note**
Durance class	Marne	A630	1987	17,900 tonnes	Replenishment oiler	To be replaced by 4 Bâtiments ravitailleur de forces between 2023 and 2029[18] (*Jacques Chevallier*-class), which will be 50% larger than the *Durance*-class ships.[19]
	Somme	A631	1990			

Intelligence, research and experimentation						
Class	**Boat**	**No.**	**Comm**	**Displacement**	**Type**	**Note**
—	Monge	A601	1992	21,040 tonnes	Tracking ship	
—	Dupuy de Lôme	A759	2006	3,600 tonnes	SIGINT	
—	*Alizé*	A645	2005	1,600 tonnes	DGSE diving support	Also used to test new equipment and diving procedures
***Lapérouse* class**	*Thétis*	A785	1988	1,050 tonnes	Mine-warfare experimentation	To be replaced by SLAM-F

Survey						
Class	**Boat**	**No.**	**Comm**	**Displacement**	**Type**	**Note**
—	Pourquoi Pas?	—	2005	6,600 tonnes	Oceanographic survey	Operated by IFREMER (55%) and the French Navy (45%) with civilian crew.[20]
—	Beautemps-Beaupré	A758	2003	3,600 tonnes		
***Lapérouse* class**	*Lapérouse*	A791	1988	980 tonnes	Hydrographic survey	To be replaced from 2025 to 2027 by 2 new hydro-oceanographic vessels.
	Borda	A792				
	Laplace	A793	1989			

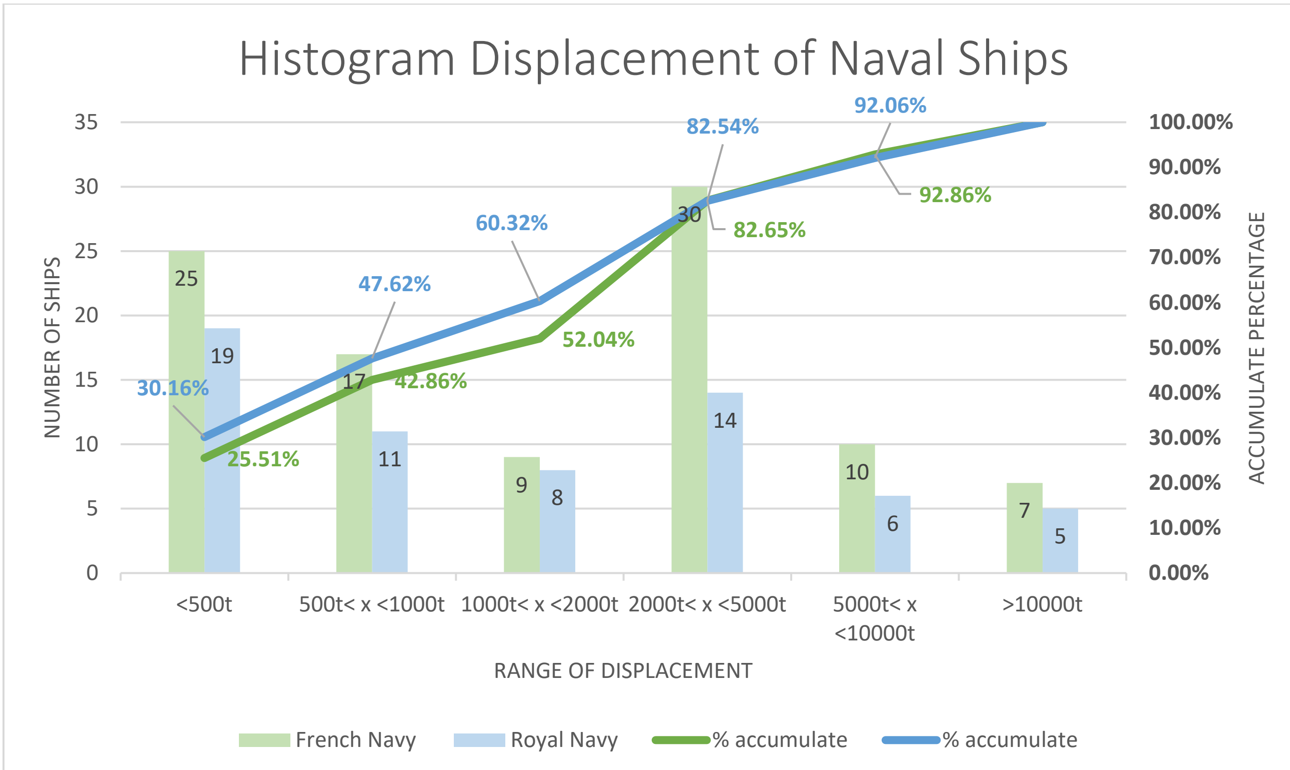
Tugboats						
Class	**Boat**	**No.**	**Comm**	**Displacement**	**Type**	**Note**
UT515	Abeille Bourbon	-	2005	4,600 tonnes	Oceangoing tug	Operated under charter
	Abeille Liberté	-				
VS-491 CD	*Abeille Normandie*	-	2010	3,978 tonnes		
	Abeille Méditerrannée	-				

Support						
Class	**Boat**	**No.**	**Comm**	**Displacement**	**Type**	**Note**
—	*Argonaute*	—	—	~4,000 tonnes	Support and pollution control	Operated under charter
	Jason	—				
	Pionnier	—				
	Sapeur	—				
***Loire* class**	*Loire*	A602	2018	2,960 tonnes	Offshore support and assistance	
	Rhône	A603	2019			
	Seine	A604				
	Garonne	A605	2020			

Training						
Class	**Boat**	No.	Comm	**Displacement**	**Type**	**Note**
UT712 class	*Rebel*	—	—	2,900 tonnes	Training ship	Operated under charter
UT745 class	*Partisan*	—	—	2,340 tonnes		
Léopard class	*Léopard*	A748	1982	470 tonnes		
	Panthère	A749				
	Jaguar	A750				
	Lynx	A751				
	Guépard	A752	1983			
	Chacal	A753				
	Tigre	A754				
	Lion	A755				
***Glycine* class**	*Glycine*	A770	1992	295 tonnes	Navigation training	
	Églantine	A771				
***Paimpolaise* class**	Étoile	A649	1932	275 tonnes	Sail training	Schooner
	Belle Poule	A650				

French Navy Surface Ships			
Displacement [ton]	Number of Ships	% of total	% accumulate
<500t	25	25.51%	25.51%
500t< x <1000t	17	17.35%	42.86%
1000t< x <2000t	9	9.18%	52.04%
2000t< x <5000t	30	30.61%	82.65%
5000t< x <10000t	10	10.20%	92.86%
>10000t	7	7.14%	100.00%
Total Ships	98	100%	100%

Histogram


Histogram Displacement of Naval Ships
NUMBER OF SHIPS
ACCUMULATE PERCENTAGE
RANGE OF DISPLACEMENT
<500t
500t< x <1000t
1000t< x <2000t
2000t< x <5000t
5000t< x <10000t
>10000t
25
19
17
11
9
8
30
14
10
6
7
5
30.16%
25.51%
47.62%
42.86%
60.32%
52.04%
82.54%
82.65%
92.06%
92.86%
French Navy
Royal Navy
% accumulate
% accumulate

Appendix II – Ship's Configuration Data

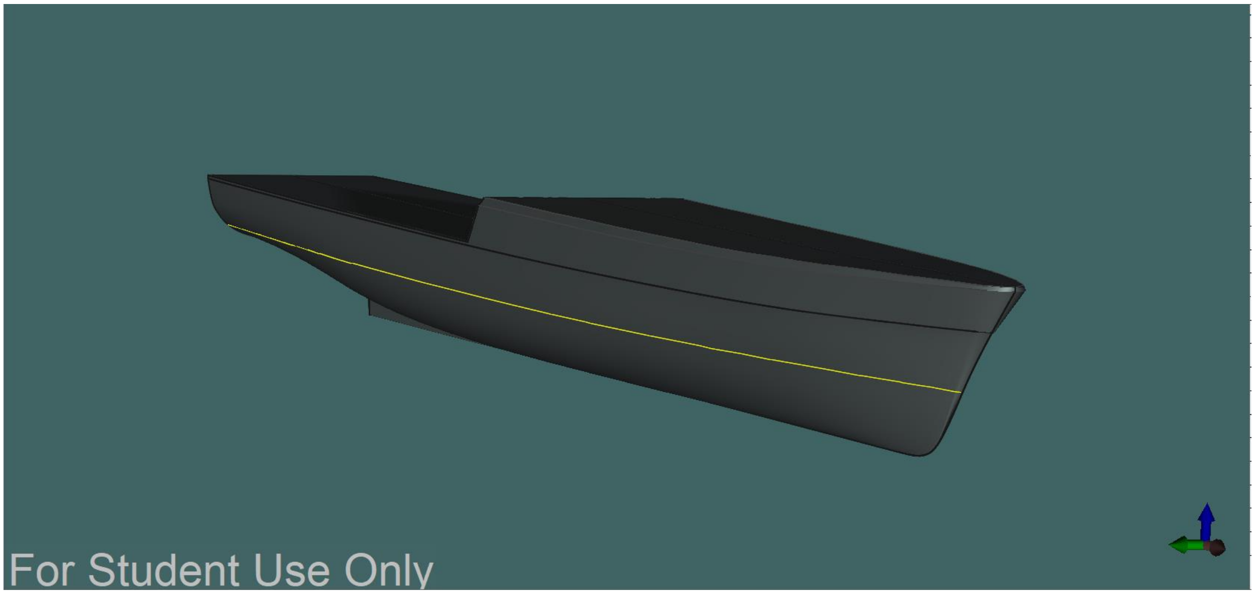
MAXSURF Models

MAXSURF Models - All						
Hydrostatics Characteristics	500 ton		2000 ton		5000 ton	
	Patrol Vessel	Frigate	Patrol Vessel	Frigate	Patrol Vessel	Frigate
Displacement	**500.2**	**500.2**	**2000**	**2001**	**5000**	**5001**
Volume (displaced)	**487.977**	**488.008**	**1951.364**	**1952.028**	**4878.084**	**4879.209**
Draft Amidships	**2.604**	**2.14**	**4.133**	**3.397**	**5.609**	**4.61**
Immersed depth	2.604	2.14	4.133	3.397	5.609	4.61
Immersed depth of station with max area	2.571	2.116	4.08	3.359	5.538	4.558
Immersed depth amidships	2.56	2.122	4.062	3.369	5.513	4.572
WL Length	**49.149**	**57.06**	**78.021**	**90.576**	**105.888**	**122.929**
Beam max extents on WL	**8.215**	**8.931**	**13.04**	**14.177**	**17.697**	**19.241**
Beam max on WL	**8.215**	**8.931**	**13.04**	**14.177**	**17.697**	**19.241**
Depth [main deck]	4.386		6.946			11.555
Beam extents on WL of station with max area	8.21	8.876	13.033	14.09	17.688	19.122
Beam on WL of station with max area	8.21	8.876	13.033	14.09	17.688	19.122
Beam extents on WL amidships	8.13	8.844	12.906	14.039	17.515	19.053
Beam on WL amidships	8.13	8.844	12.906	14.039	17.515	19.053
Wetted Area	416.878	469.721	1050.366	1183.617	1934.694	2180.057
Max sect. area	15.571	15.523	39.23	39.116	72.254	72.043
Sect. area amidships	15.289	15.512	38.52	39.088	70.945	71.992
Waterpl. Area	312.847	366.115	788.295	922.554	1451.983	1699.259
Waterpl. Itrans	1340.894	1843.665	8513.213	11706.696	28882.812	39716.284
Waterpl. Ilong	46070.755	64519.313	292513.829	409670.333	992414.509	1389857.757

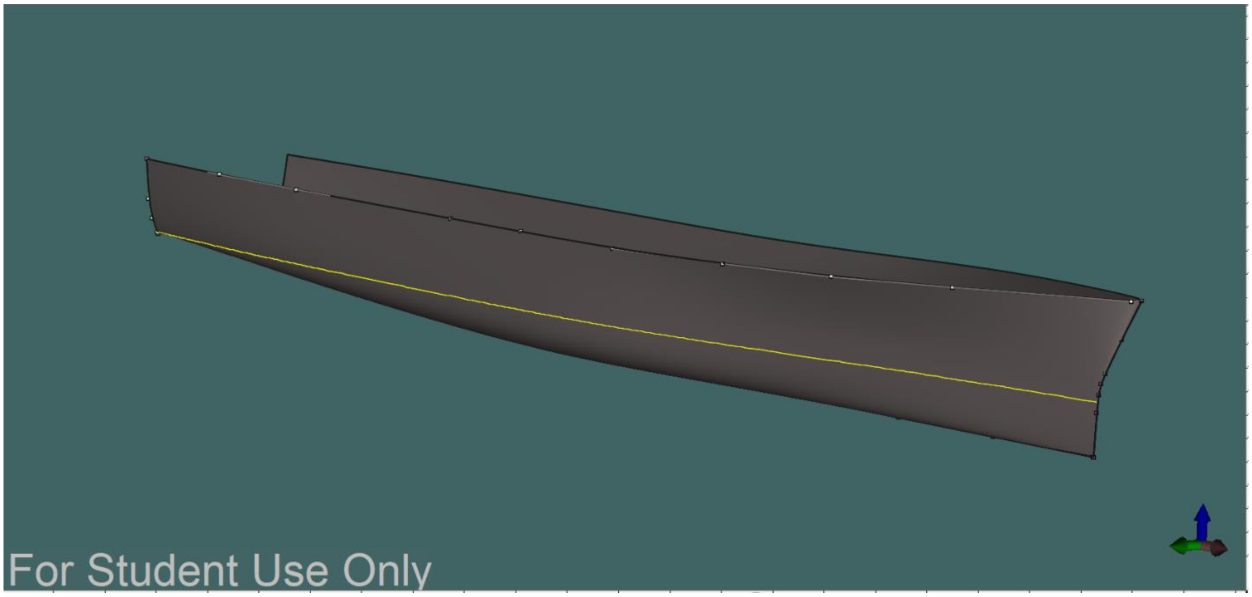
Prismatic coeff. (Cp)	**0.638**	**0.551**		**0.638**	**0.551**		**0.638**	**0.551**
Block coeff. (Cb)	**0.464**	**0.448**		**0.464**	**0.447**		**0.464**	**0.447**
Max Sect. area coeff. (Cm)	**0.738**	**0.827**		**0.738**	**0.827**		**0.738**	**0.827**
Waterpl. area coeff. (Cwp)	**0.775**	**0.718**		**0.775**	**0.718**		**0.775**	**0.718**
LCB length	23.445	26.918		37.221	42.73		50.513	57.994
LCF length	21.862	23.28		34.706	36.955		47.102	50.155
LCB %	47.702	47.176		47.706	47.176		47.704	47.177
LCF %	44.482	40.8		44.483	40.8		44.482	40.8
VCB	1.652	1.333		2.622	2.115		3.558	2.871
KB	1.652	1.333		2.622	2.115		3.558	2.871
Length:Beam ratio	5.983	6.389		5.983	6.389		5.983	6.389
Beam:Draft ratio	3.155	4.173		3.155	4.173		3.155	4.174
Length:Vol^0.333 ratio	6.243	7.247		6.244	7.247		6.244	7.248
Precision	Medium	Highest		Medium	Highest		Medium	Highest

MAXSURF Models - Used			
Hydrostatics Characteristics	500 ton	2000 ton	5000 ton
	Patrol Vessel	Patrol Vessel	Frigate
Displacement	**500**	**2000**	**5001**
Volume (displaced)	**488**	**1951**	**4879**
Draft Amidships	**2.604**	**4.133**	**4.61**
WL Length	**49.149**	**78.021**	**122.929**
Beam max extents on WL	**8.215**	**13.04**	**19.241**
Beam max on WL	**8.215**	**13.04**	**19.241**
Depth [main deck]	**4.386**	**6.946**	**11.555**
Wetted Area	417	1050	2180
Waterpl. Area	313	788	1699
Waterpl. Itrans	1341	8513	39716
Waterpl. Ilong	46071	292514	1389858
Prismatic coeff. (Cp)	**0.638**	**0.638**	**0.551**
Block coeff. (Cb)	**0.464**	**0.464**	**0.447**
Max Sect. area coeff. (Cm)	**0.738**	**0.738**	**0.827**
Waterpl. area coeff. (Cwp)	**0.775**	**0.775**	**0.718**
LCB length	23.445	37.221	57.994
LCF length	21.862	34.706	50.155
VCB	1.652	2.622	2.871
KB	1.652	2.622	2.871
BMt	2.748	4.363	8.14
BML	94.412	149.902	284.853
Immersion (TPc)	3.207	8.08	17.417
MTc	9.918	39.067	117.375

Patrol Vessel Model (500 ton, 2,000 ton)



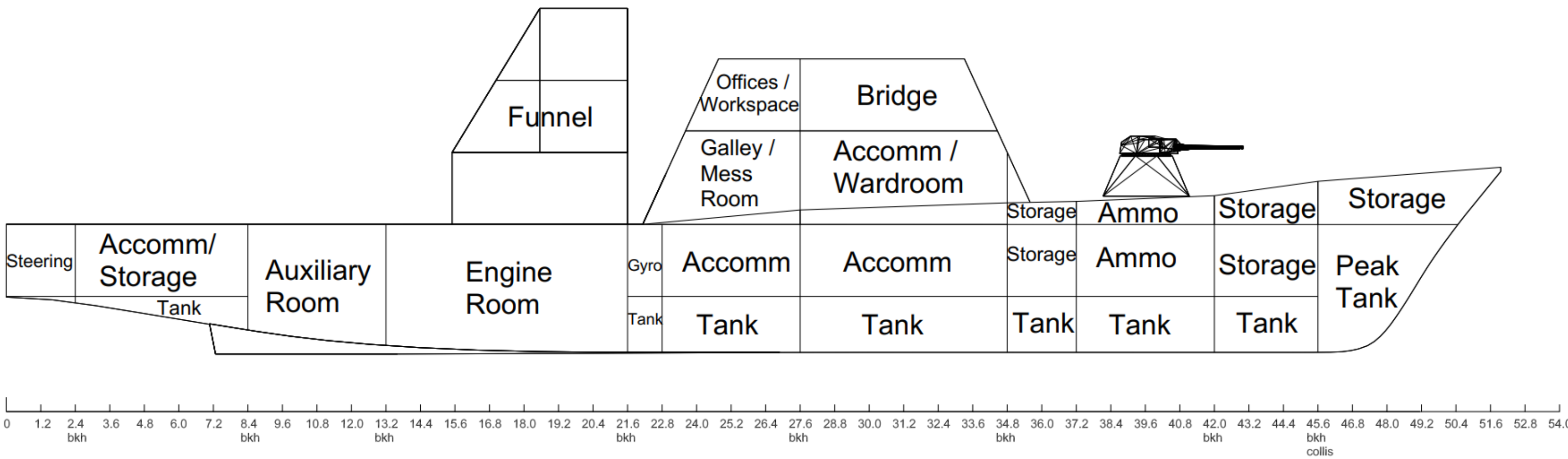
Frigate Model (5,000 ton)



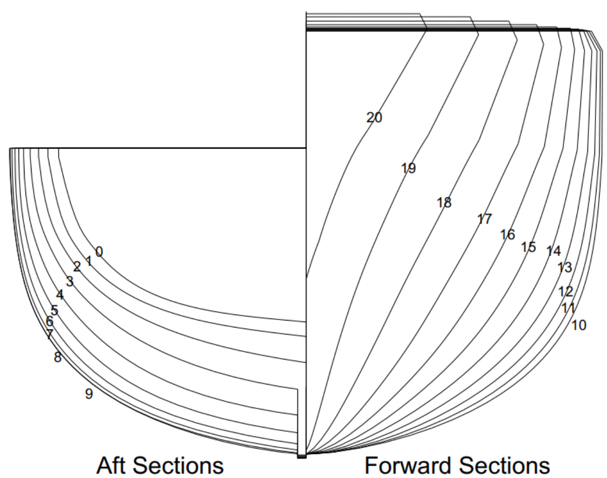
General Arrangement

<u>Patrol Vessel 500ton – Traditional</u>

Profile View



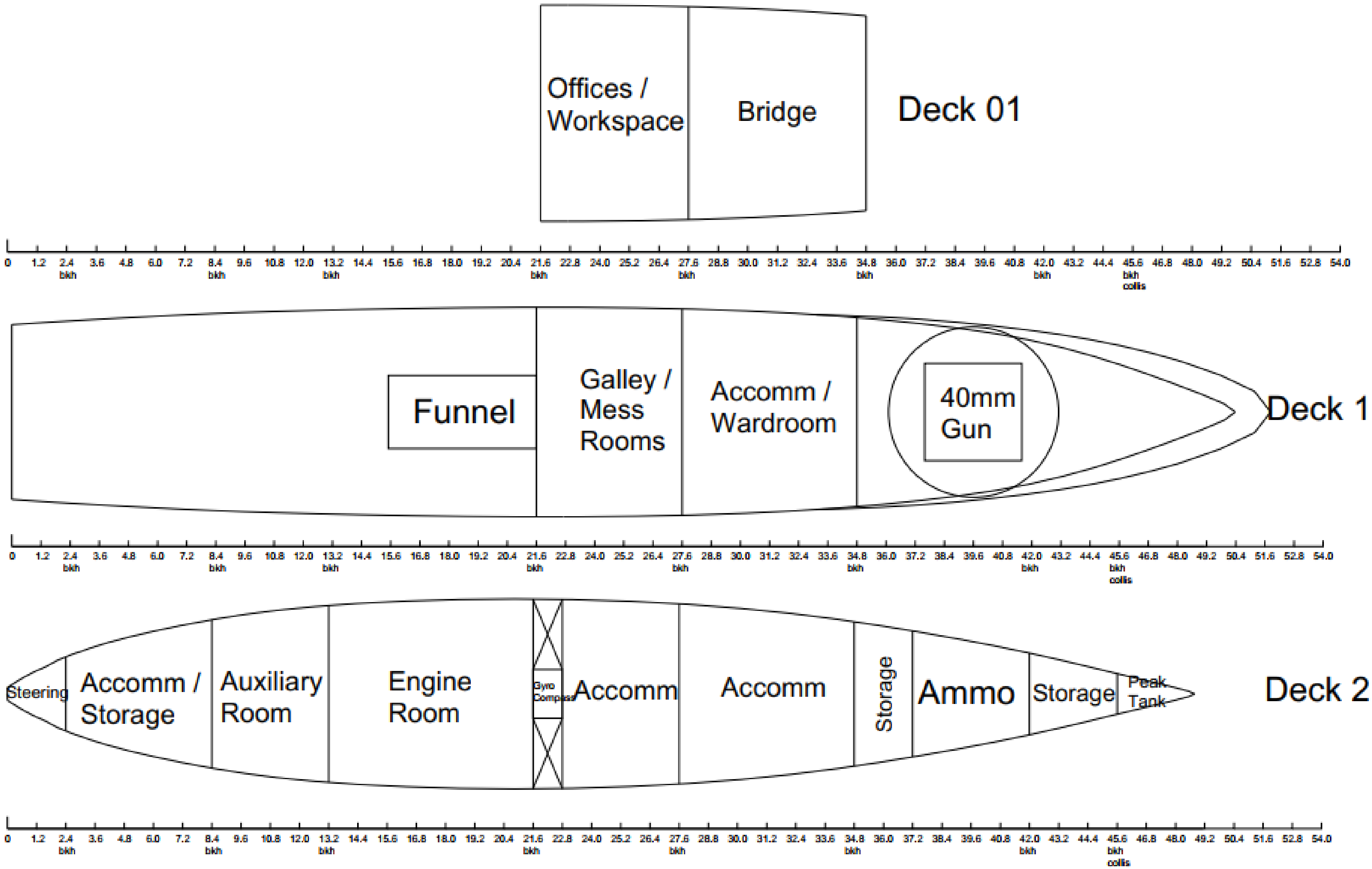
Body Plan



PRINCIPAL DIMENSIONS

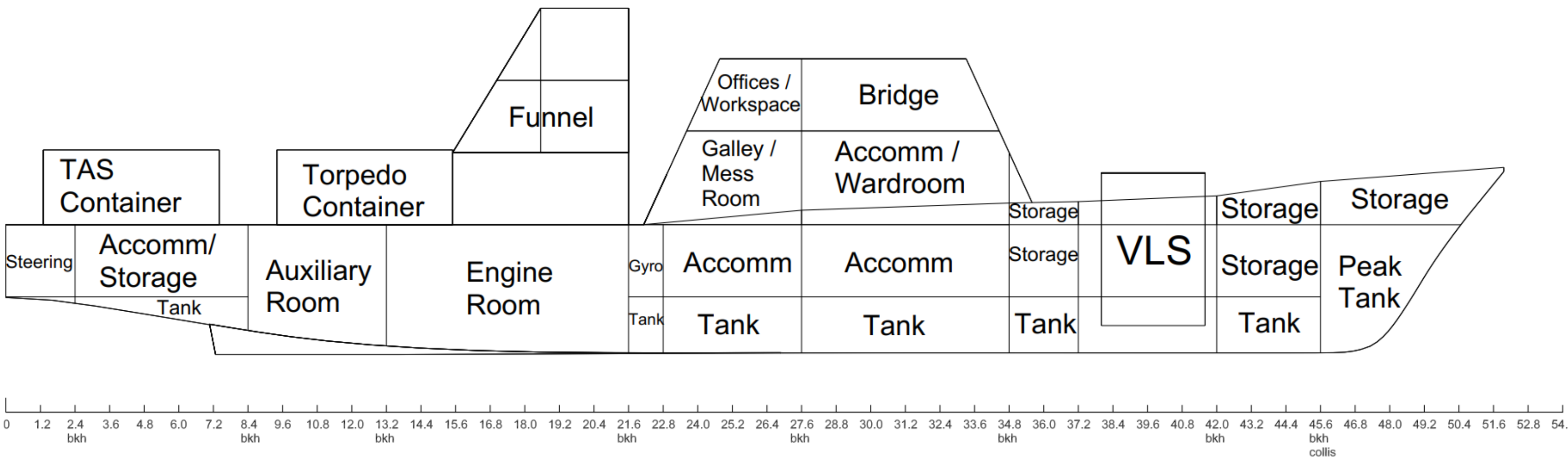
Length over all (LOA)	51.91 m
Length between perpendiculars (LBP)	49.15 m
Maximum Beam (B)	8.22 m
Depth (D)	4.50 m
Draught (T)	2.60 m
Displacement (Δ)	500 ton

Lower and Upper Decks

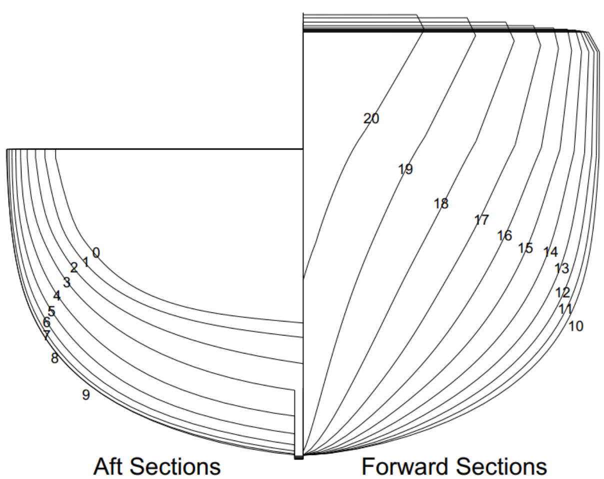


Patrol Vessel 500ton – Modular ASW

Profile View

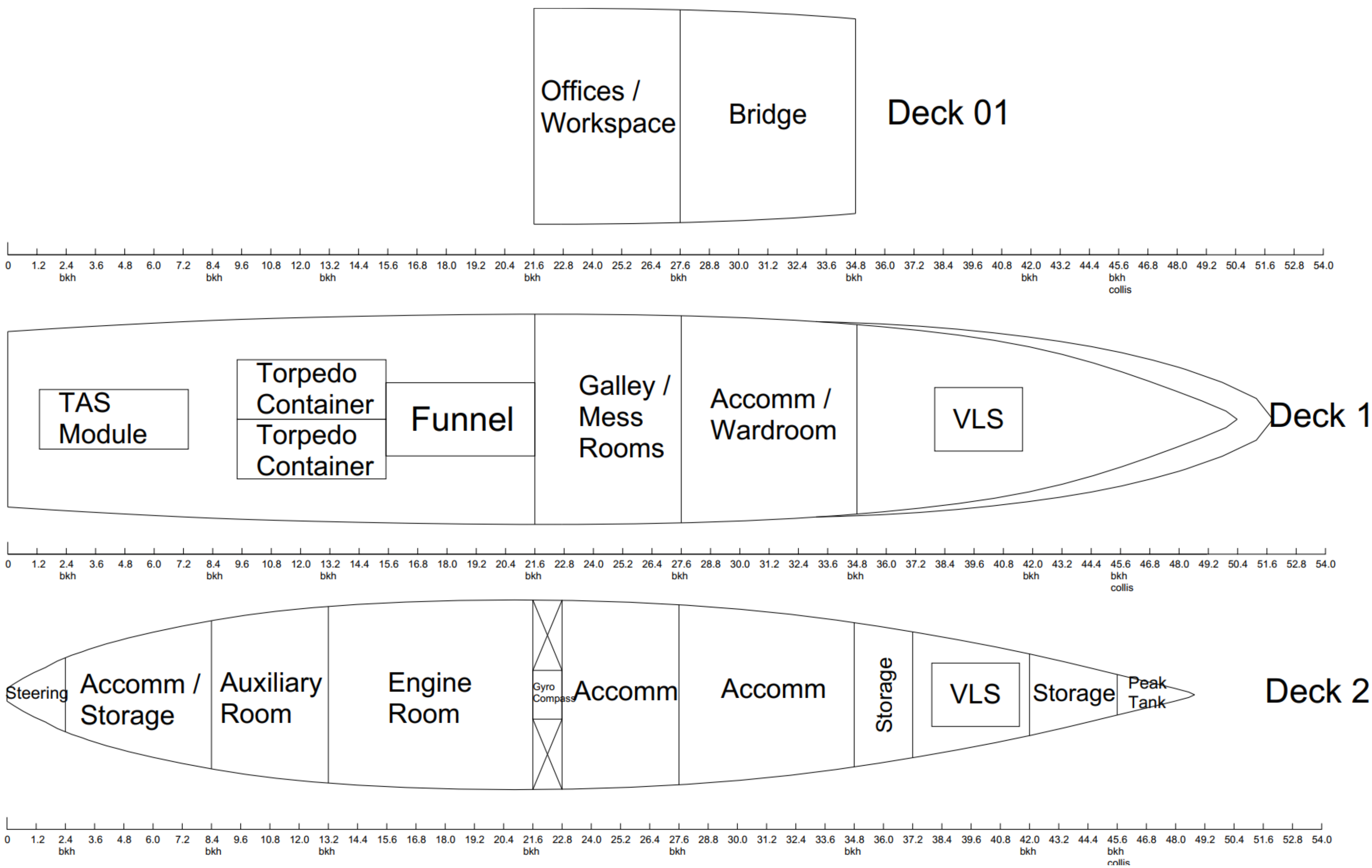


Body Plan



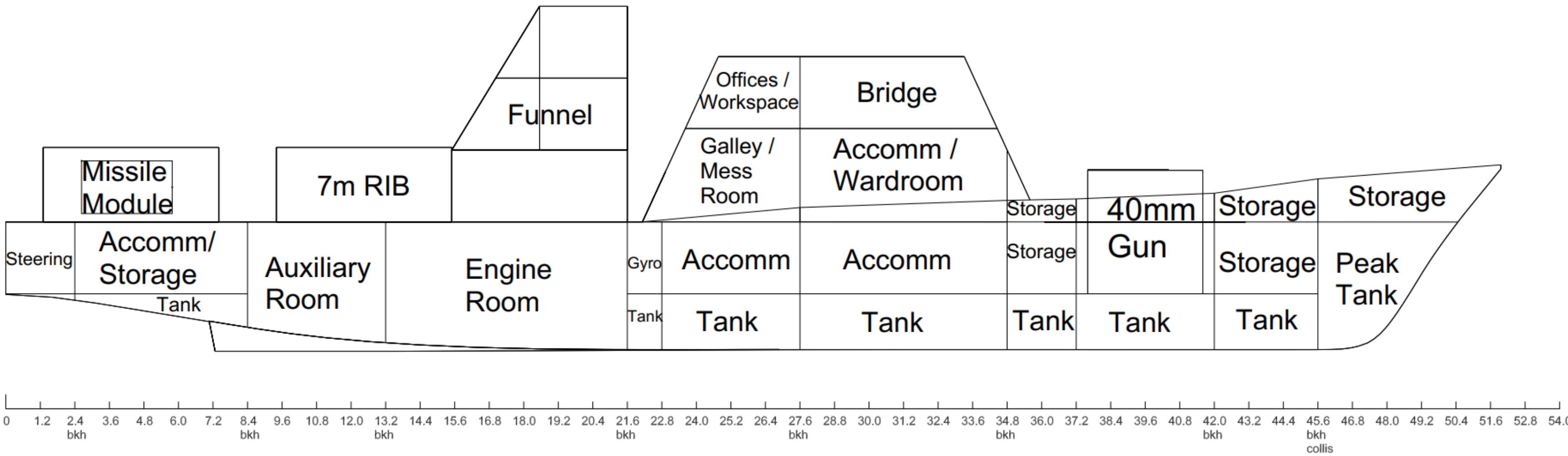
PRINCIPAL DIMENSIONS	
Length over all (LOA)	51.91 m
Length between perpendiculars (LBP)	49.15 m
Maximum Beam (B)	8.22 m
Depth (D)	4.50 m
Draught (T)	2.60 m
Displacement (Δ)	500 ton

Lower and Upper Decks

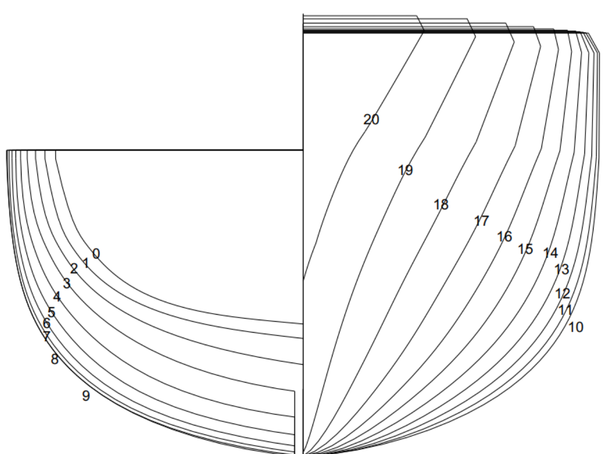


Patrol Vessel 500ton – Modular ASuW

Profile View

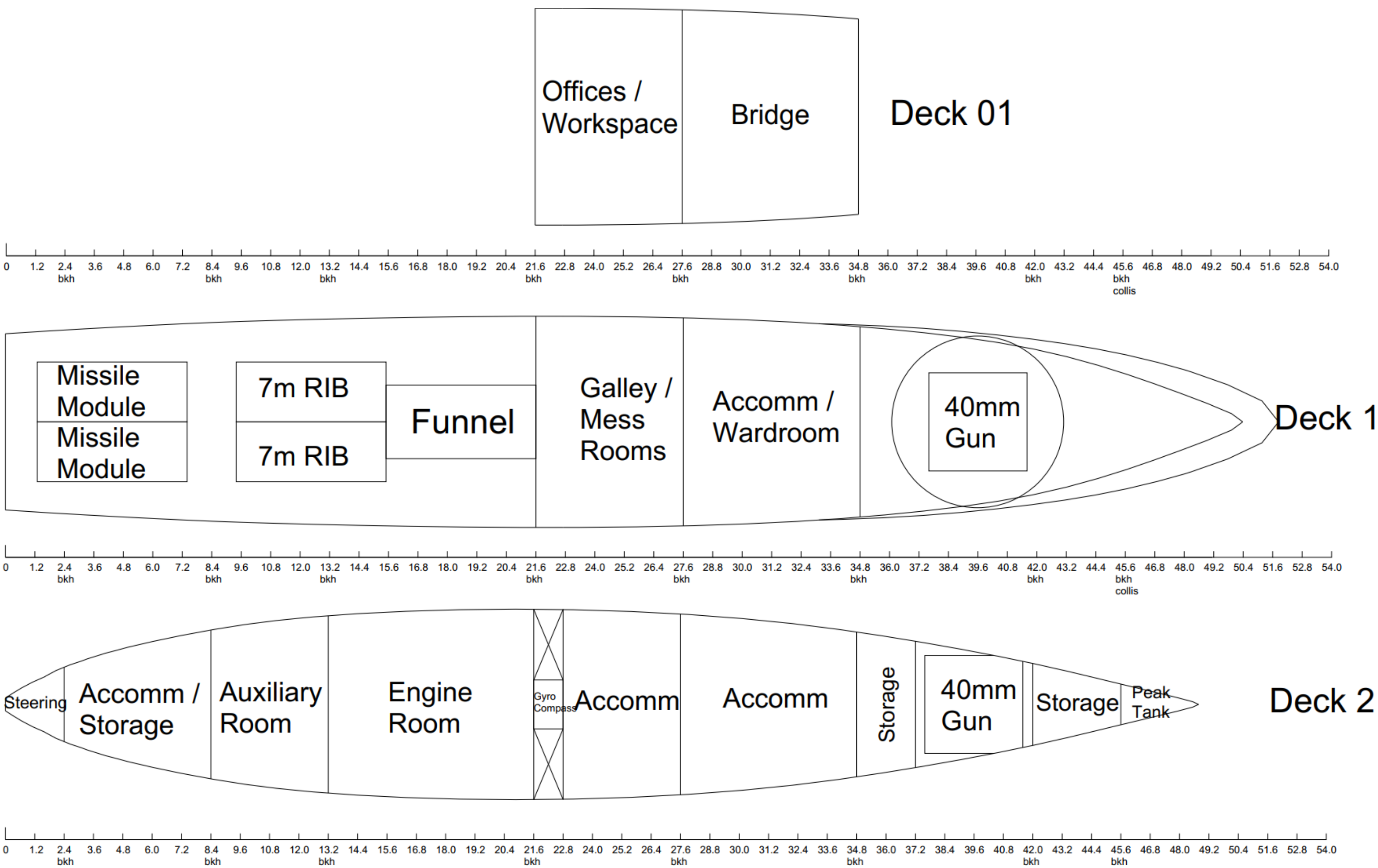


Body Plan



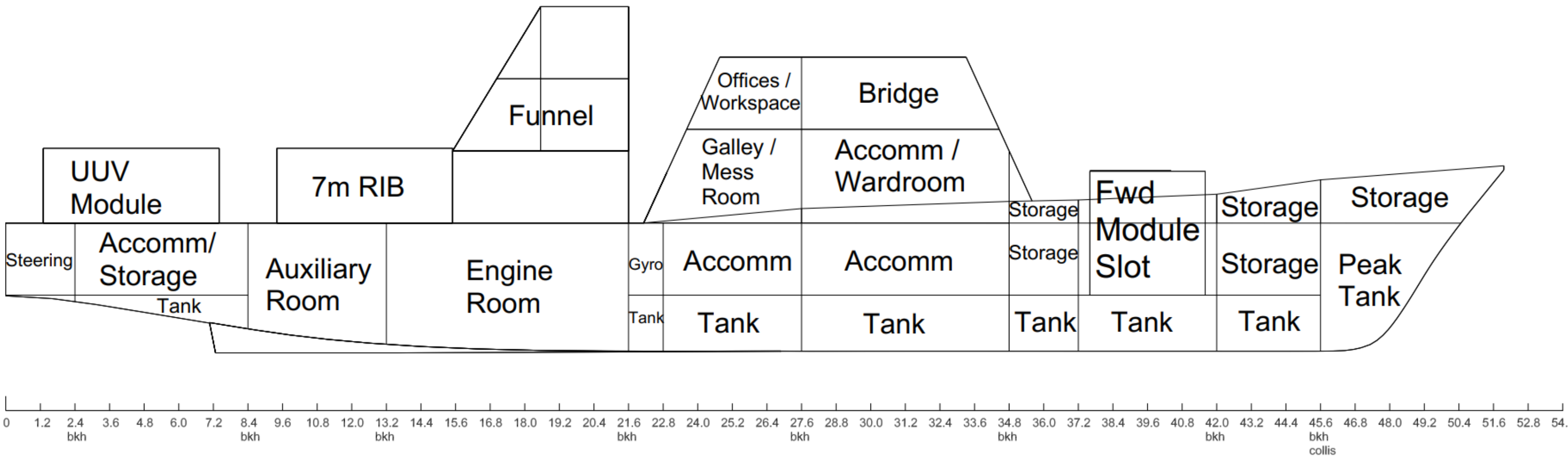
PRINCIPAL DIMENSIONS	
Length over all (LOA)	51.91 m
Length between perpendiculars (LBP)	49.15 m
Maximum Beam (B)	8.22 m
Depth (D)	4.50 m
Draught (T)	2.60 m
Displacement (Δ)	500 ton

Lower and Upper Decks

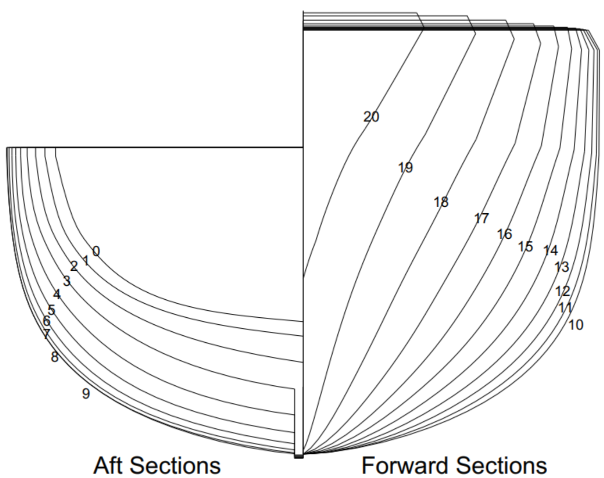


Patrol Vessel 500ton – Modular MW

Profile View

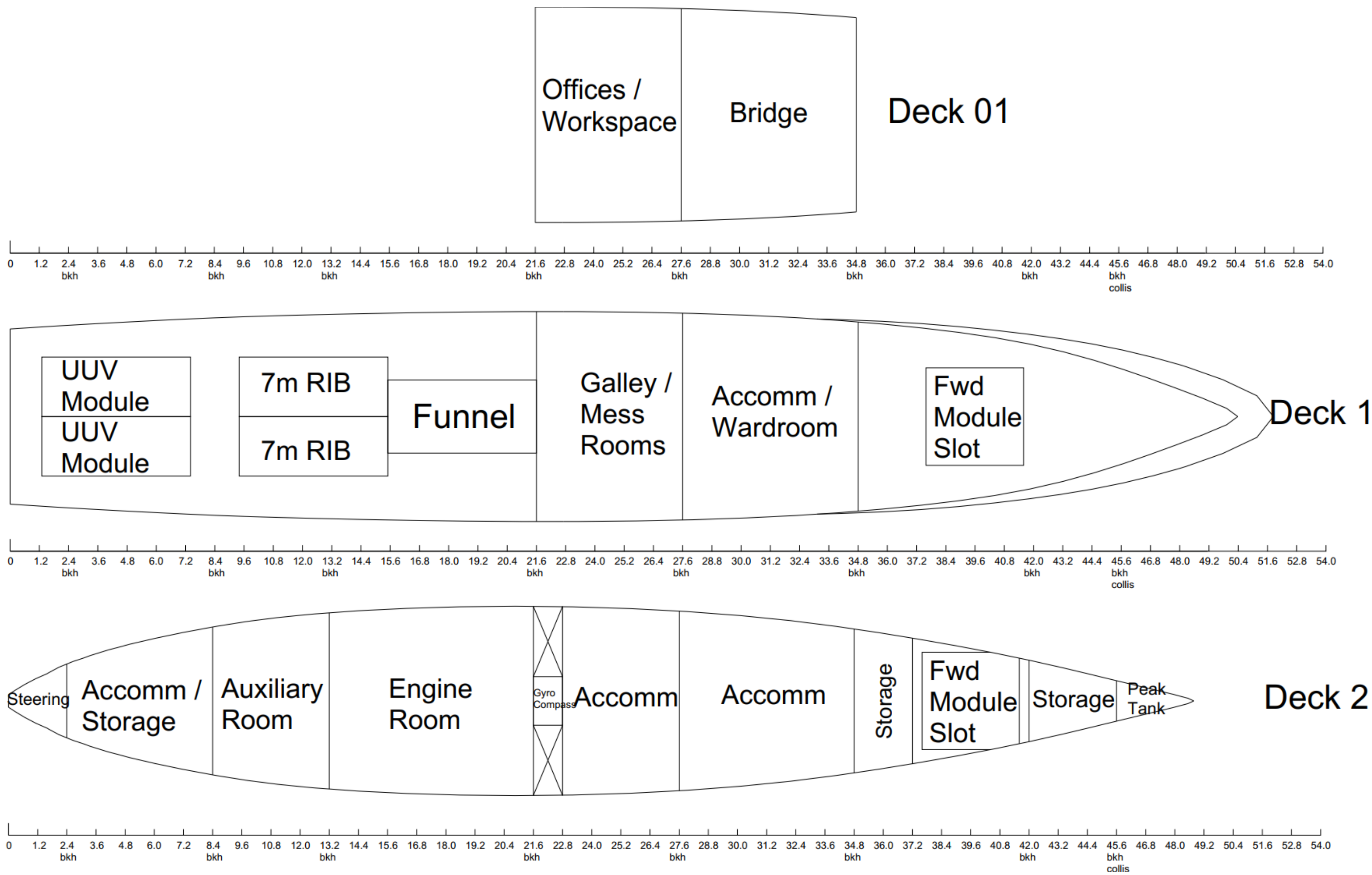


Body Plan



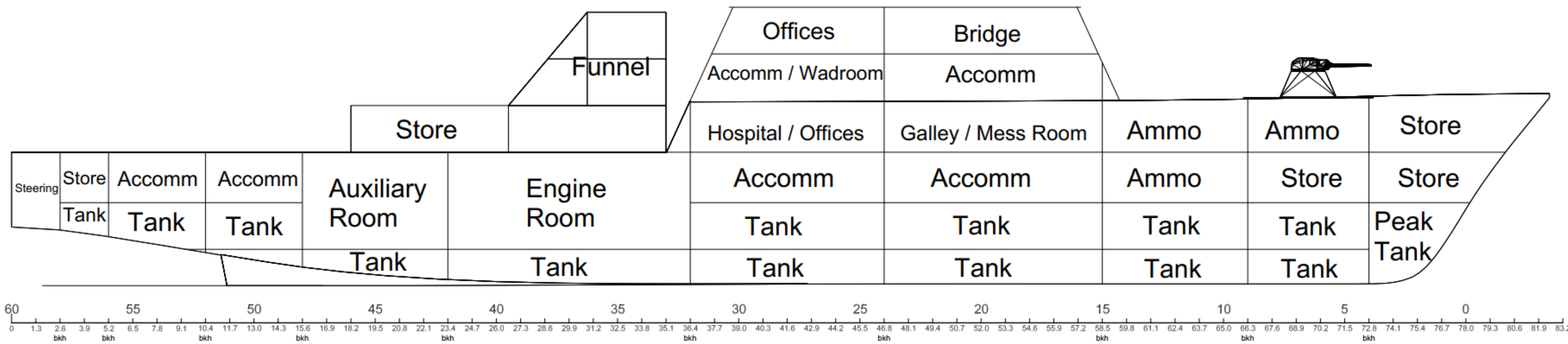
PRINCIPAL DIMENSIONS	
Length over all (LOA)	51.91 m
Length between perpendiculars (LBP)	49.15 m
Maximum Beam (B)	8.22 m
Depth (D)	4.50 m
Draught (T)	2.60 m
Displacement (Δ)	500 ton

Lower and Upper Decks

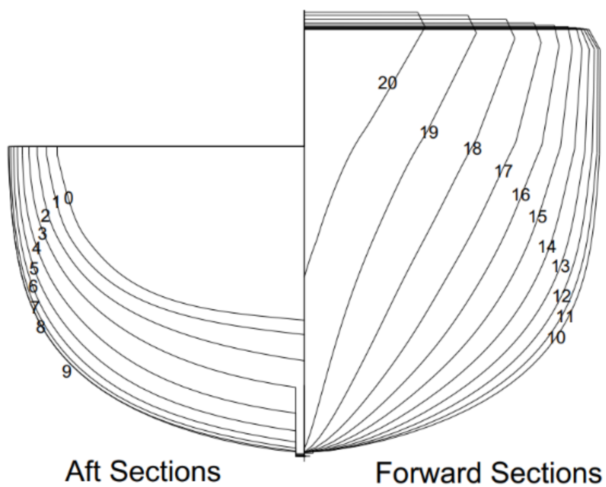


Offshore Patrol Vessel 2000ton – Traditional

Profile View

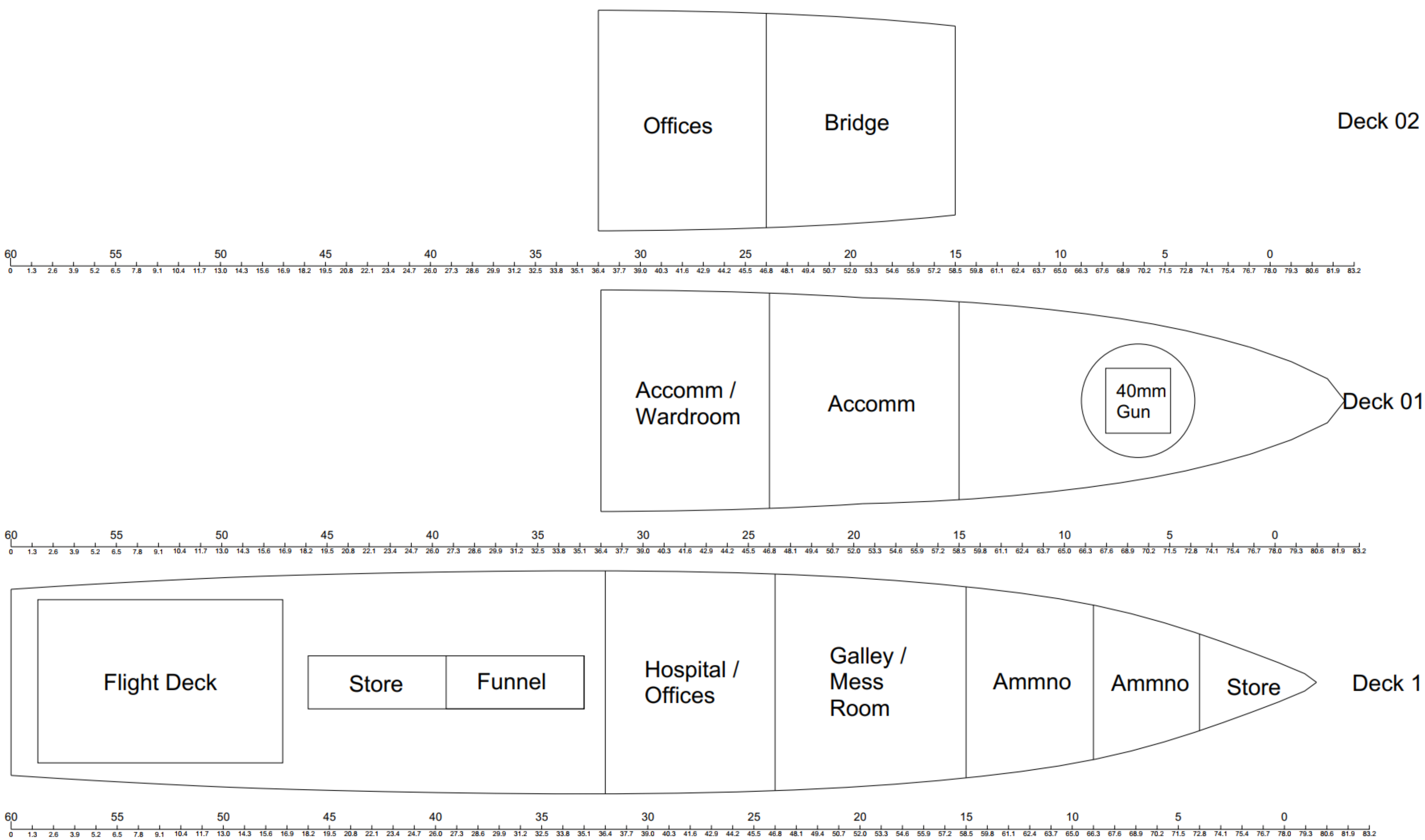


Body Plan

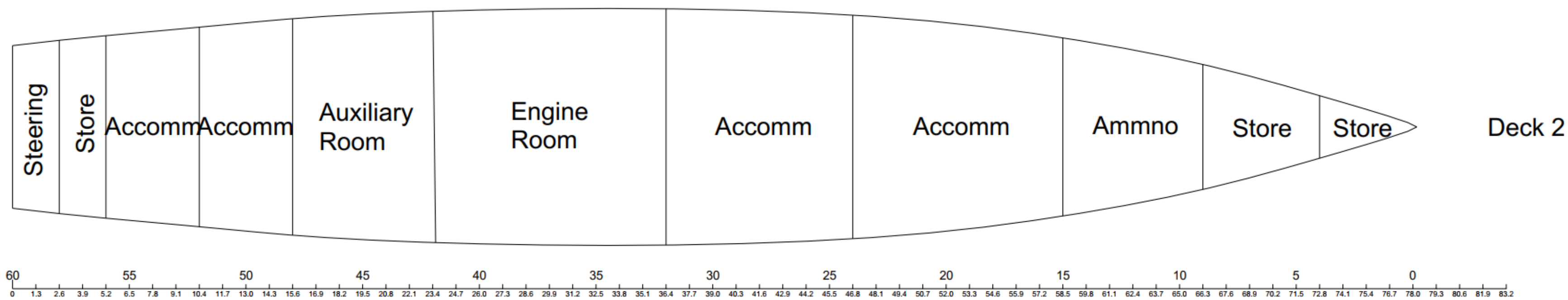


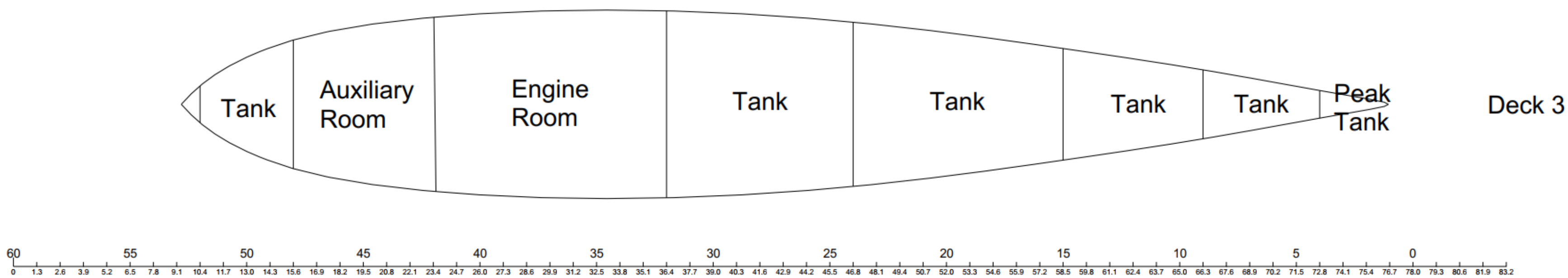
PRINCIPAL DIMENSIONS	
Length over all (LOA)	82.48 m
Length between perpendiculars (LBP)	78.02 m
Maximum Beam (B)	13.04 m
Depth (D)	6.95 m
Draught (T)	4.13 m
Displacement (Δ)	2000 ton

Upper Decks


Offices
Bridge
Deck 02
Accomm / Wardroom
Accomm
40mm Gun
Deck 01
Flight Deck
Store
Funnel
Hospital / Offices
Galley / Mess Room
Ammno
Ammno
Store
Deck 1

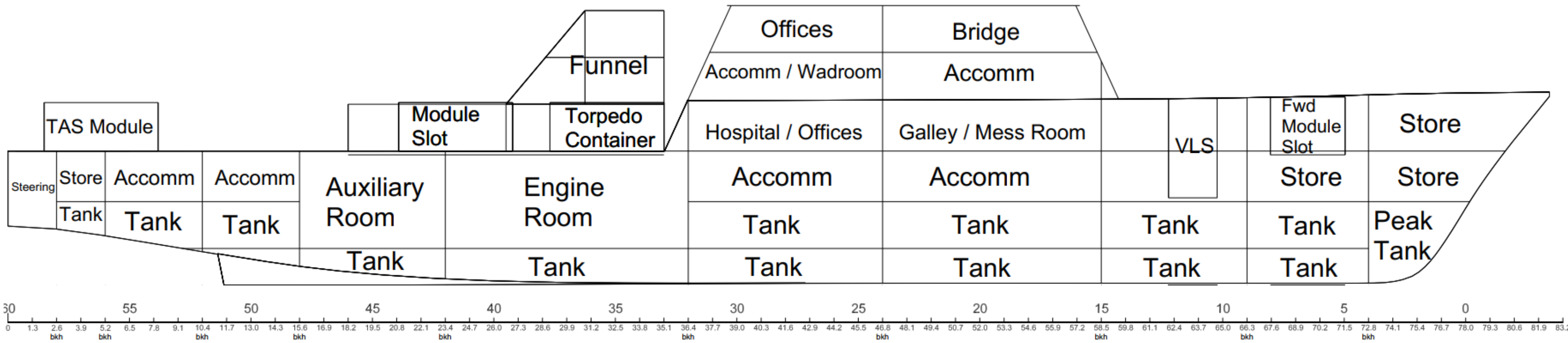
Lower Decks


Steering
Store
Accomm
Accomm
Auxiliary Room
Engine Room
Accomm
Accomm
Ammno
Store
Store
Deck 2

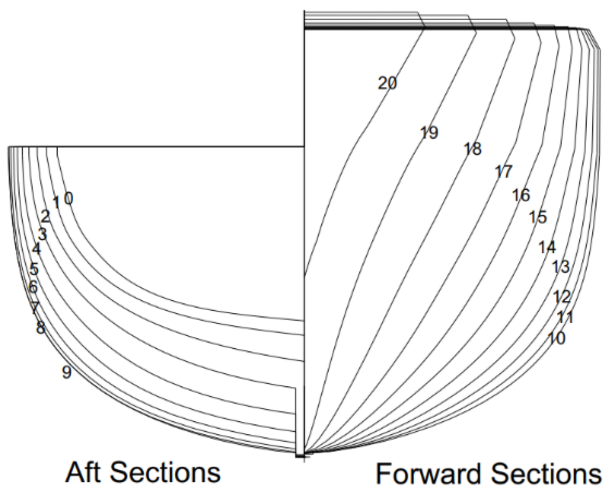

Tank
Auxiliary Room
Engine Room
Tank
Tank
Tank
Tank
Peak Tank
Deck 3

Offshore Patrol Vessel 2000ton – Modular ASW

Profile View

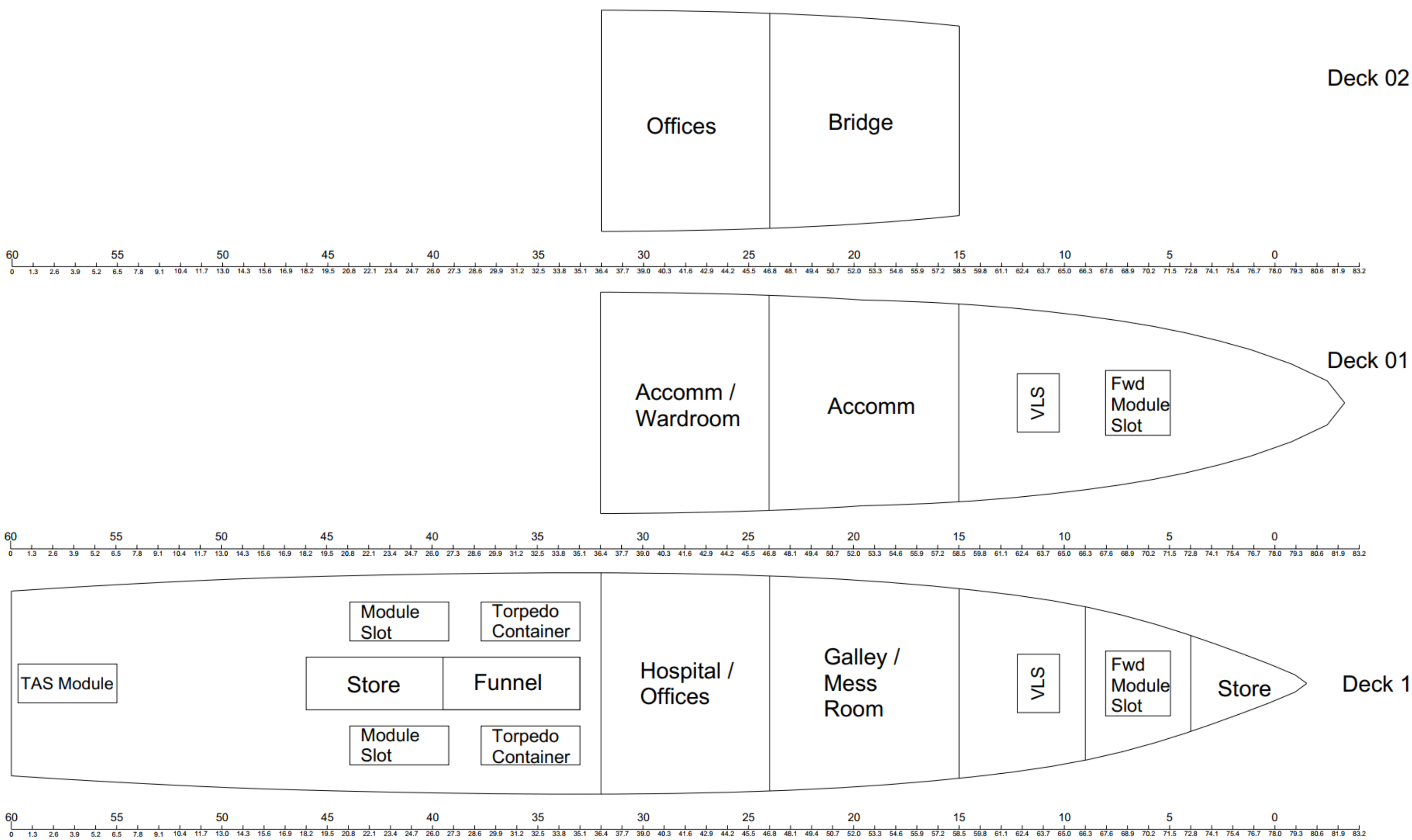


Body Plan

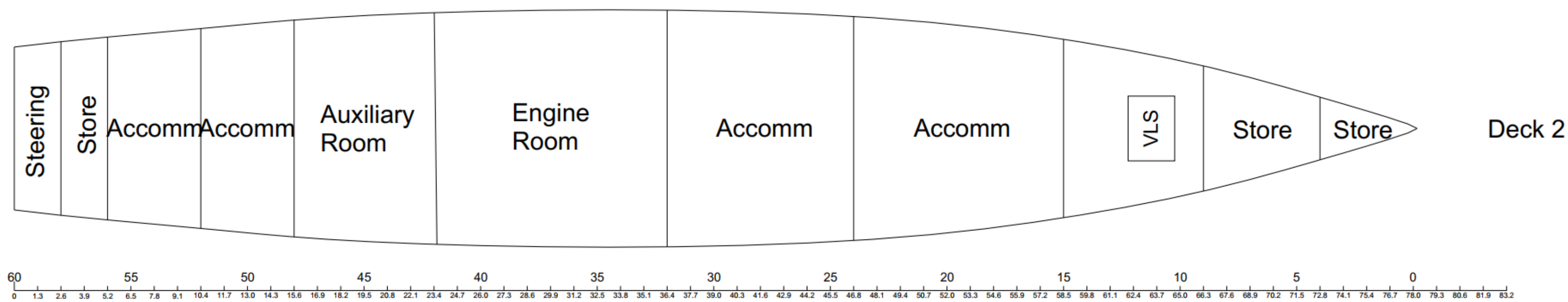


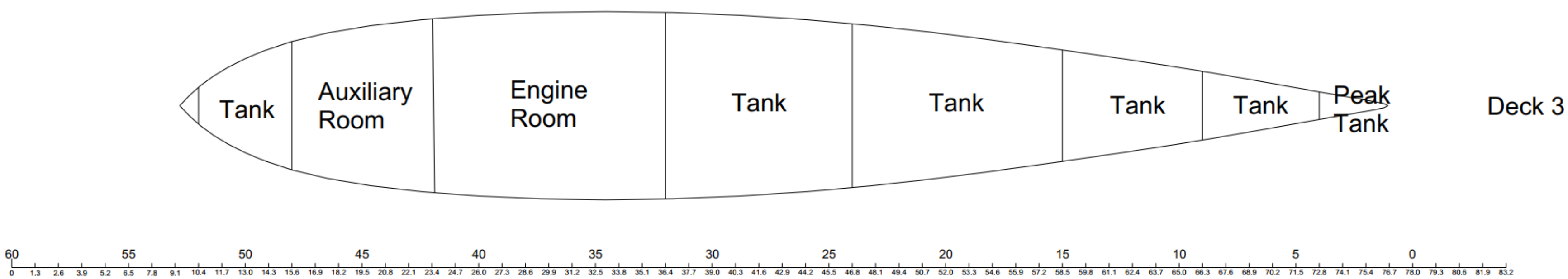
PRINCIPAL DIMENSIONS	
Length over all (LOA)	82.48 m
Length between perpendiculars (LBP)	78.02 m
Maximum Beam (B)	13.04 m
Depth (D)	6.95 m
Draught (T)	4.13 m
Displacement (Δ)	2000 ton

Upper Decks


Offices
Bridge
Deck 02
Accomm / Wardroom
Accomm
VLS
Fwd Module Slot
Deck 01
TAS Module
Module Slot
Torpedo Container
Store
Funnel
Module Slot
Torpedo Container
Hospital / Offices
Galley / Mess Room
VLS
Fwd Module Slot
Store
Deck 1

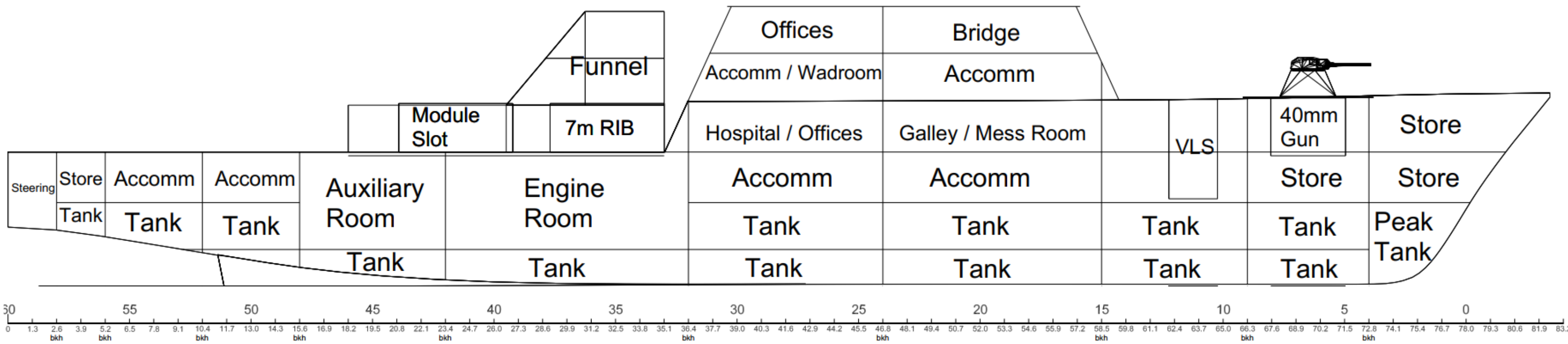
Lower Decks


Steering
Store
Accomm
Accomm
Auxiliary Room
Engine Room
Accomm
Accomm
VLS
Store
Store
Deck 2
60
55
50
45
40
35
30
25
20
15
10
5
0

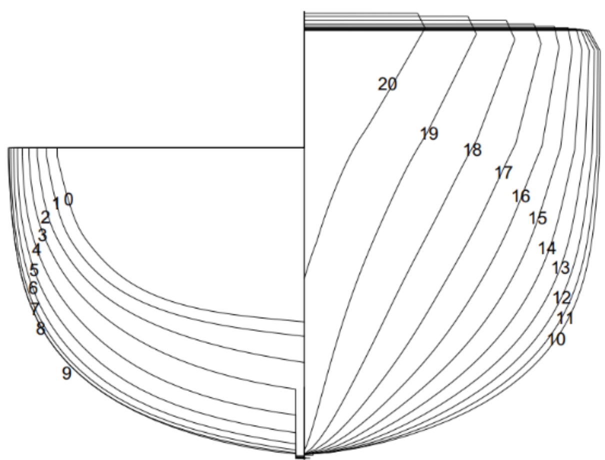

Tank
Auxiliary Room
Engine Room
Tank
Tank
Tank
Tank
Peak Tank
Deck 3
60
55
50
45
40
35
30
25
20
15
10
5
0

Offshore Patrol Vessel 2000ton – Modular ASuW

Profile View

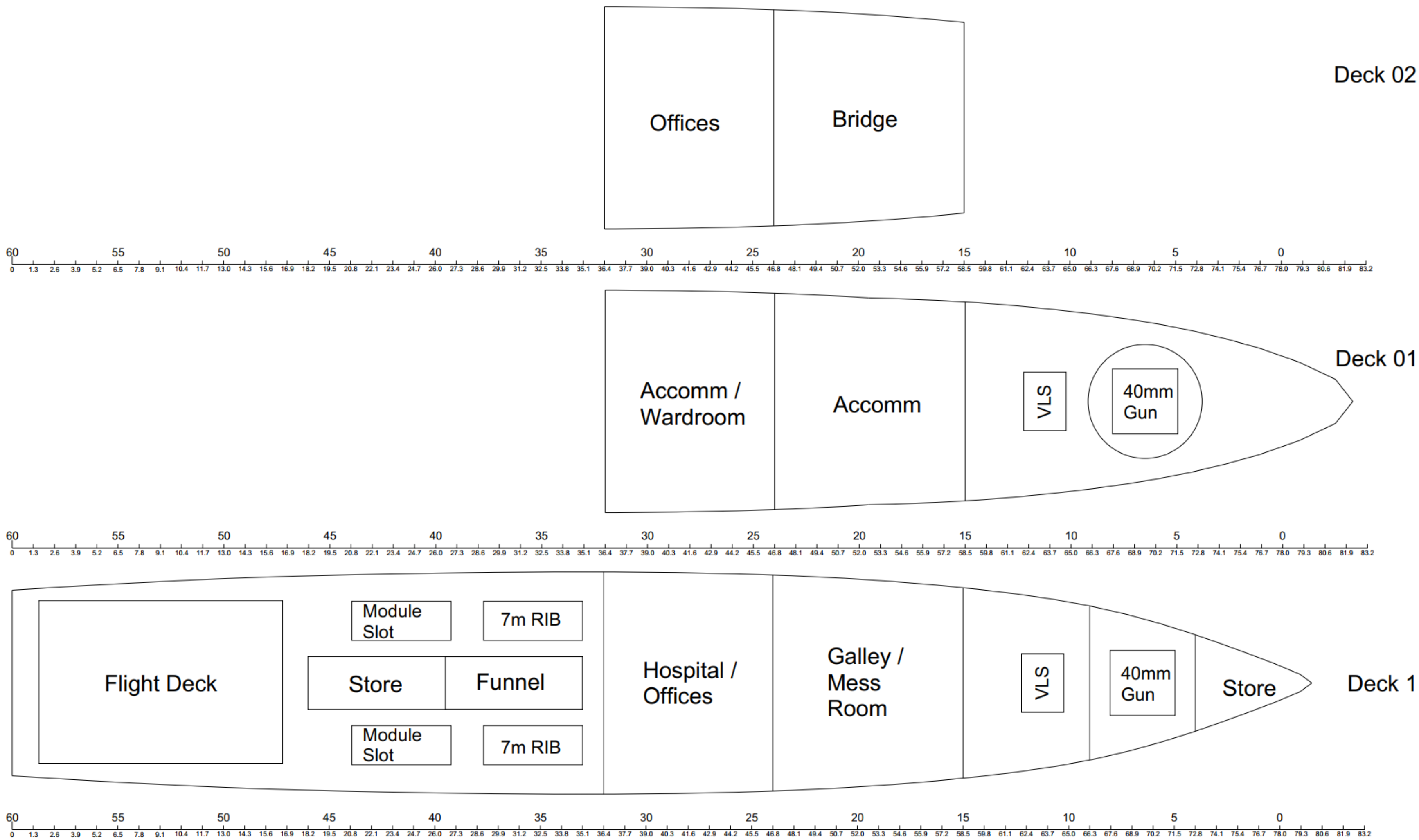


Body Plan

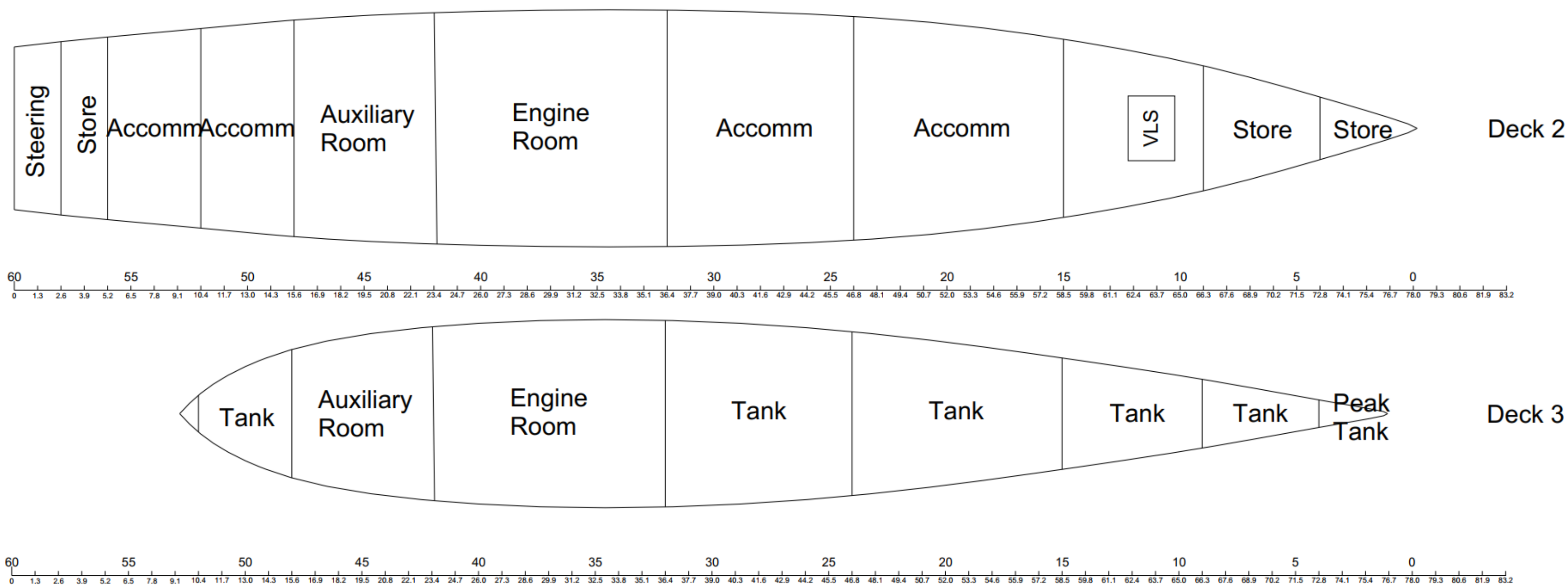


PRINCIPAL DIMENSIONS	
Length over all (LOA)	82.48 m
Length between perpendiculars (LBP)	78.02 m
Maximum Beam (B)	13.04 m
Depth (D)	6.95 m
Draught (T)	4.13 m
Displacement (Δ)	2000 ton

Upper Decks

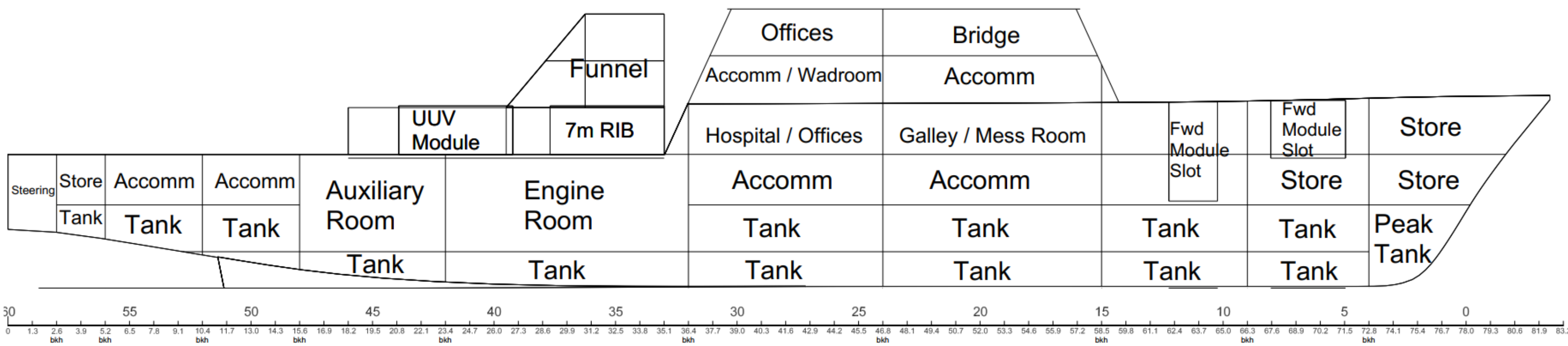

Deck 02
Offices
Bridge
Deck 01
Accomm / Wardroom
Accomm
VLS
40mm Gun
Deck 1
Flight Deck
Module Slot
7m RIB
Store
Funnel
Module Slot
7m RIB
Hospital / Offices
Galley / Mess Room
VLS
40mm Gun
Store
60 55 50 45 40 35 30 25 20 15 10 5 0

Lower Decks

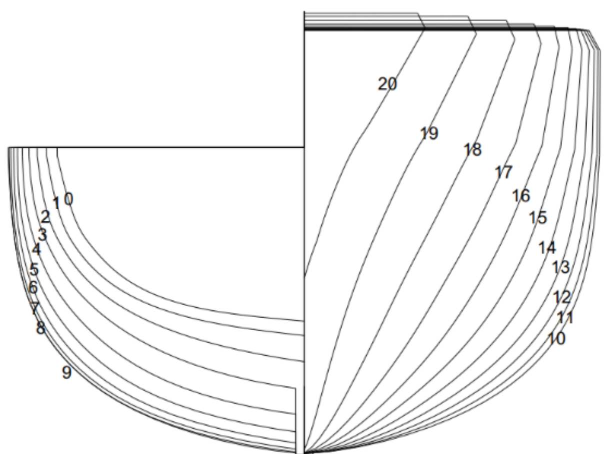

Steering
Store
Accomm
Accomm
Auxiliary Room
Engine Room
Accomm
Accomm
VLS
Store
Store
Deck 2
Tank
Auxiliary Room
Engine Room
Tank
Tank
Tank
Tank
Peak Tank
Deck 3

Offshore Patrol Vessel 2000ton – Modular MW

Profile View



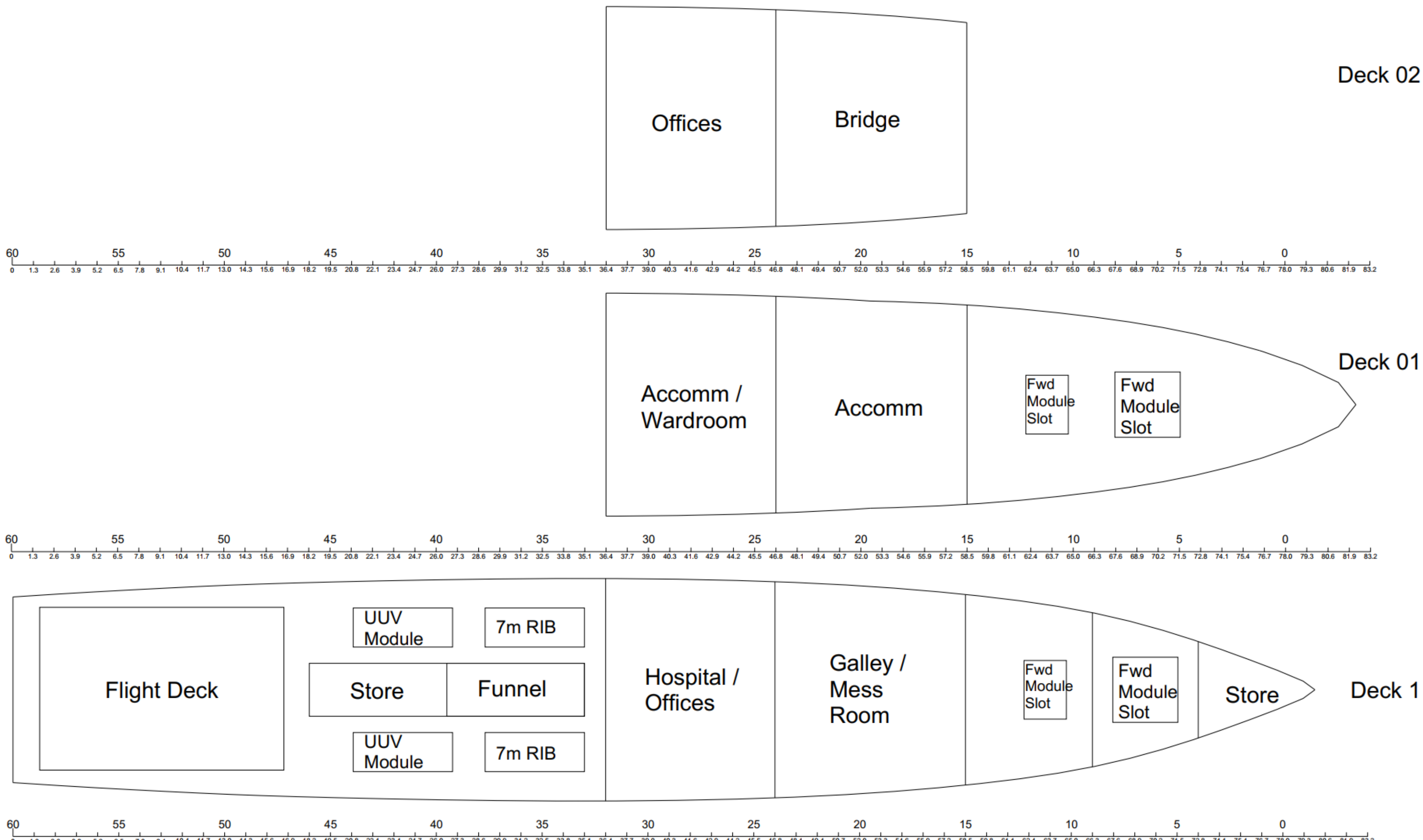
Body Plan



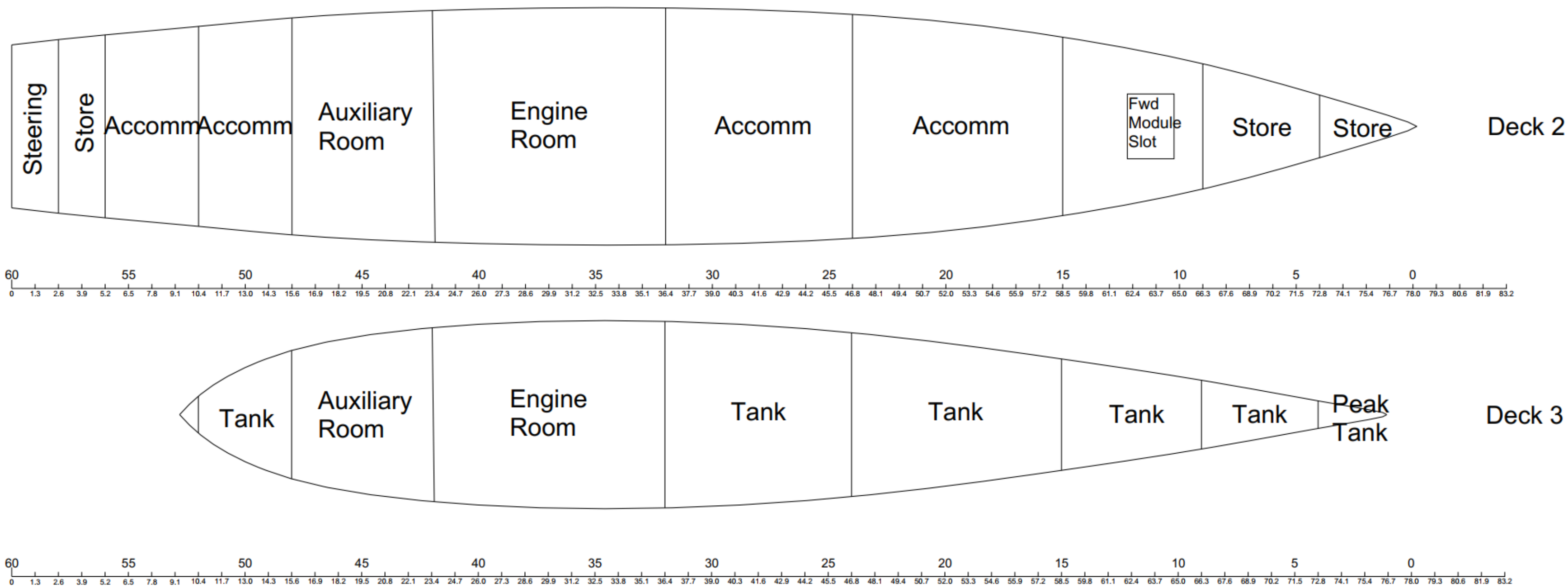
PRINCIPAL DIMENSIONS

Length over all (LOA)	82.48 m
Length between perpendiculars (LBP)	78.02 m
Maximum Beam (B)	13.04 m
Depth (D)	6.95 m
Draught (T)	4.13 m
Displacement (Δ)	2000 ton

Upper Decks

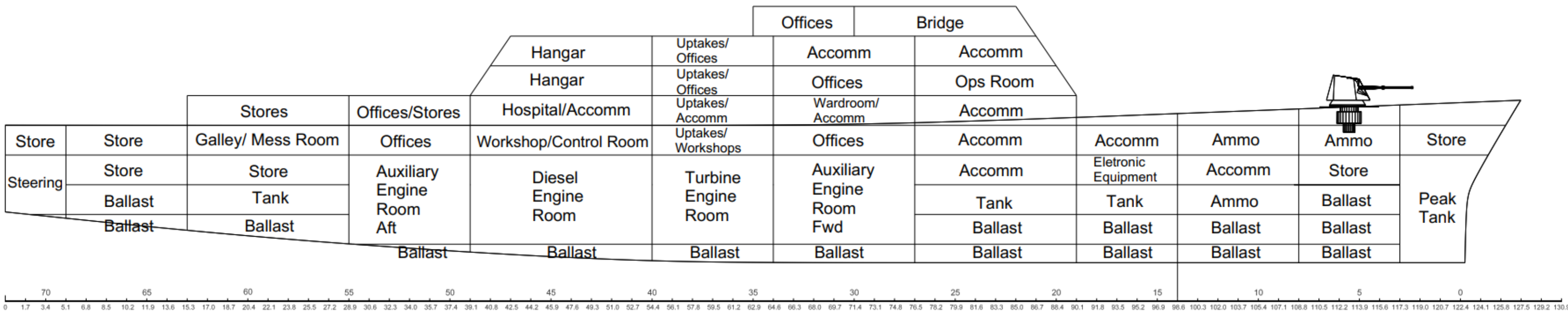

Deck 02
Offices
Bridge
Deck 01
Accomm / Wardroom
Accomm
Fwd Module Slot
Fwd Module Slot
Deck 1
Flight Deck
UUV Module
7m RIB
Store
Funnel
UUV Module
7m RIB
Hospital / Offices
Galley / Mess Room
Fwd Module Slot
Fwd Module Slot
Store

Lower Decks

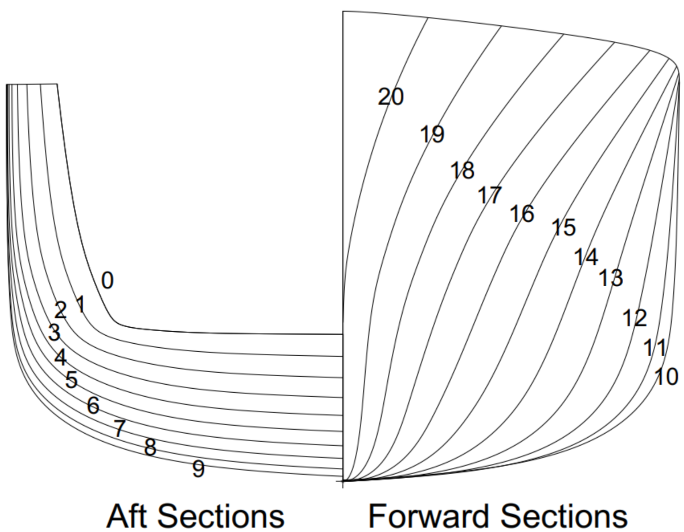

Steering
Store
Accomm
Accomm
Auxiliary Room
Engine Room
Accomm
Accomm
Fwd Module Slot
Store
Store
Deck 2
Tank
Auxiliary Room
Engine Room
Tank
Tank
Tank
Tank
Peak Tank
Deck 3

Frigate 5000ton – Traditional

Profile View

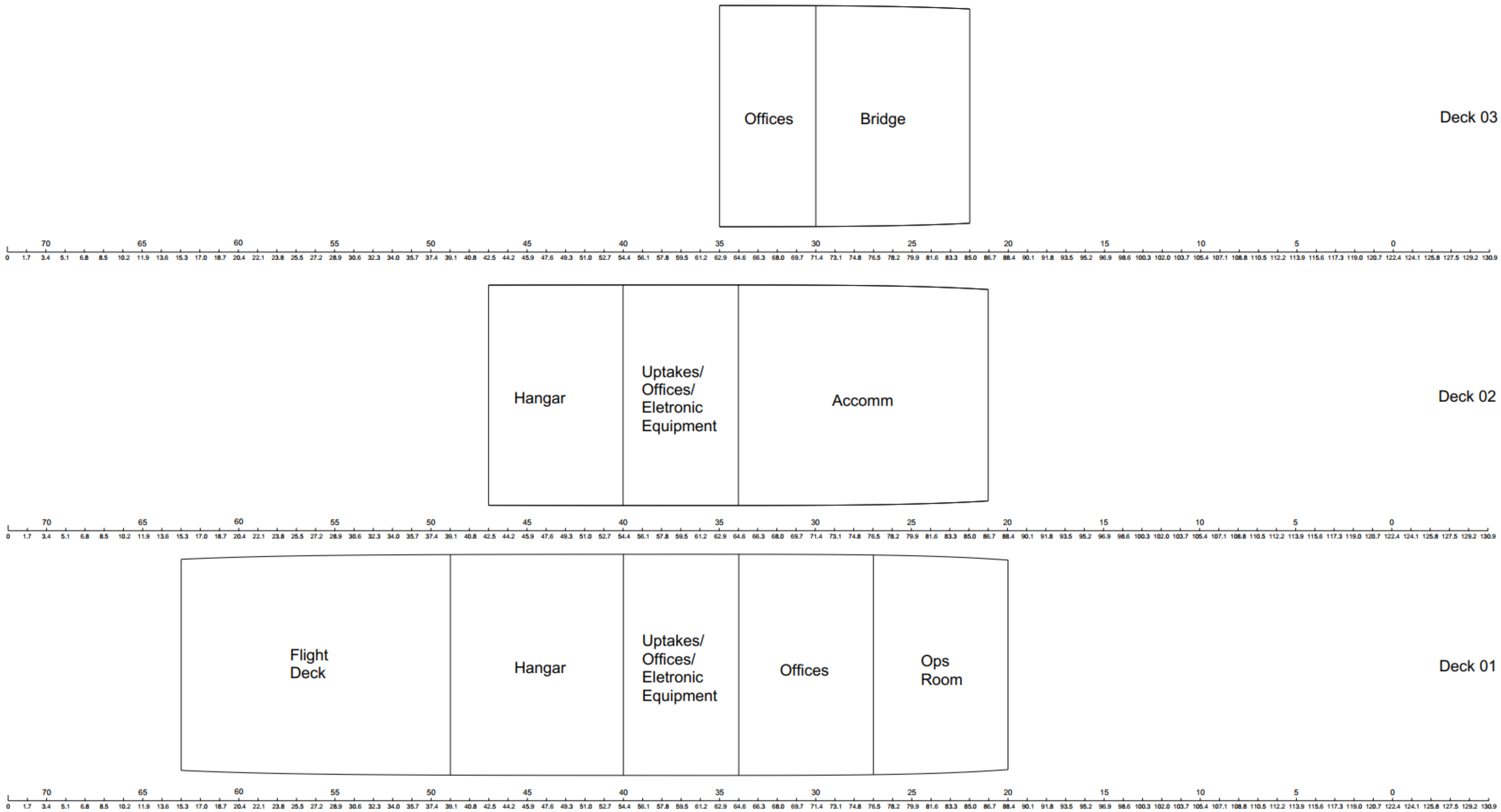


Body Plan

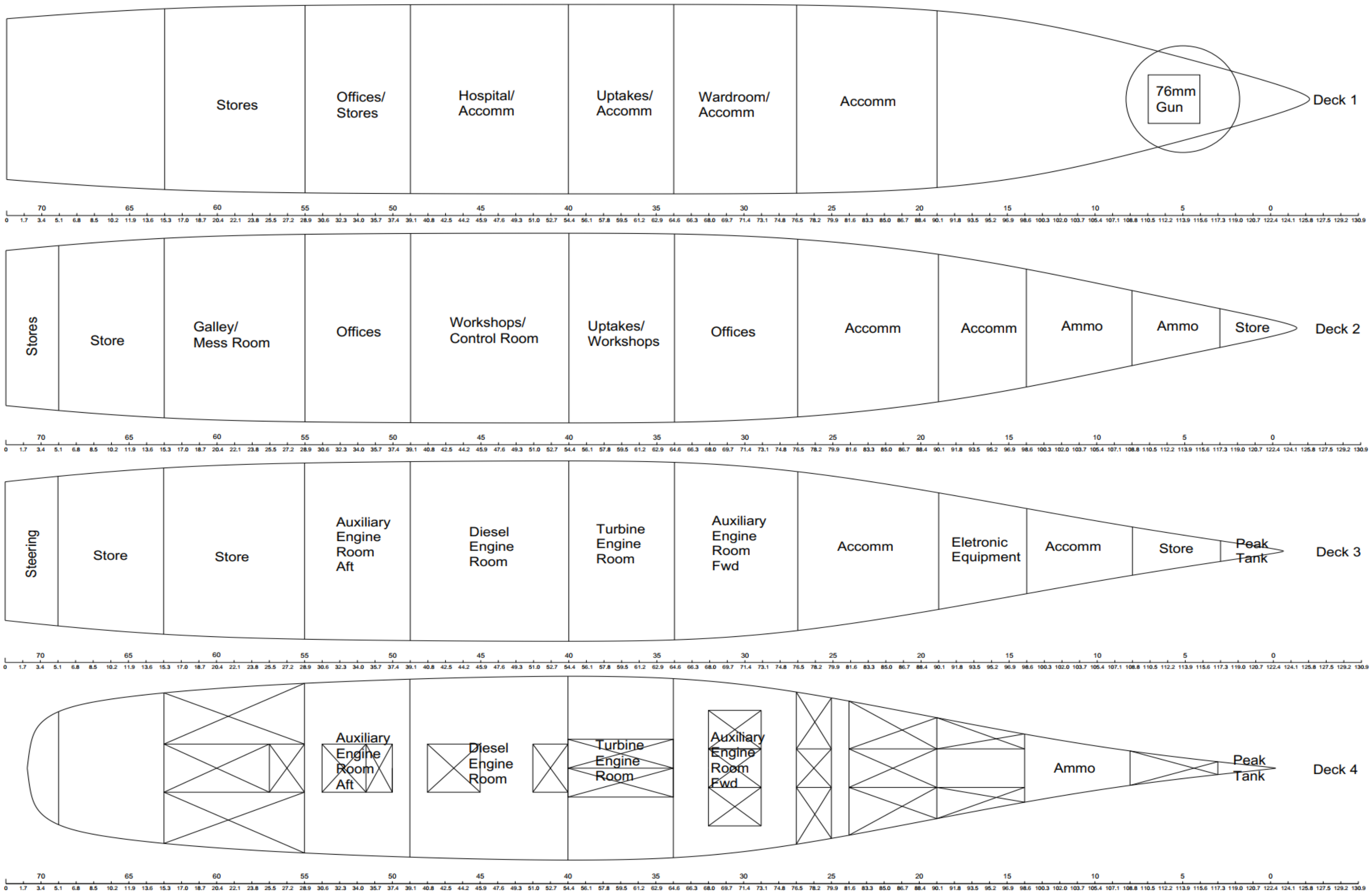


PRINCIPAL DIMENSIONS	
Length over all (LOA)	127.49 m
Length between perpendiculars (LBP)	122.93 m
Maximum Beam (B)	19.24 m
Depth (D)	11.56 m
Draught (T)	4.61 m
Displacement (Δ)	5000 ton

Upper Decks

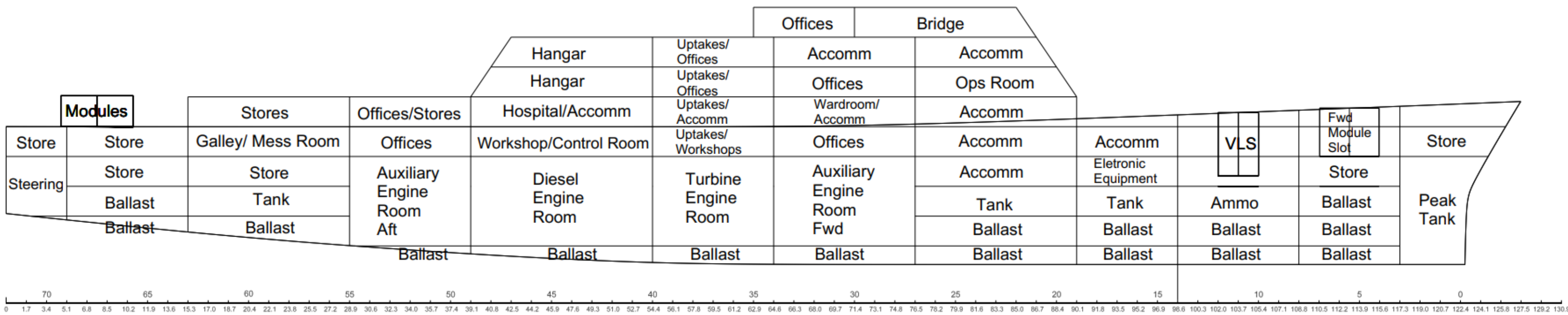

Offices
Bridge
Deck 03
Hangar
Uptakes/
Offices/
Eletronic
Equipment
Accomm
Deck 02
Flight
Deck
Hangar
Uptakes/
Offices/
Eletronic
Equipment
Offices
Ops
Room
Deck 01

Main and Lower Decks

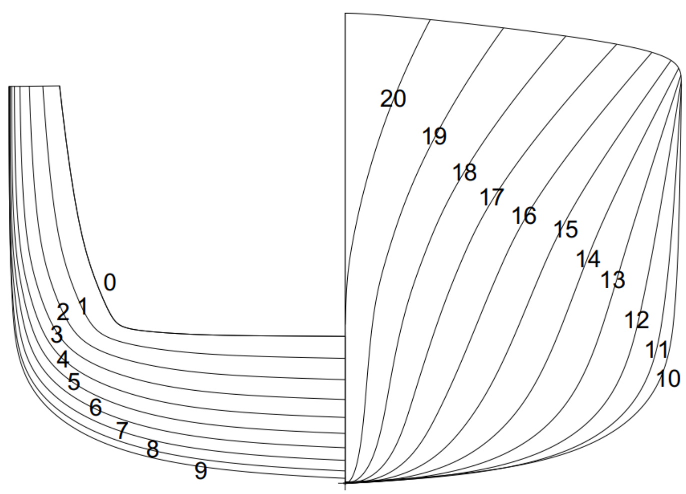


Frigate 5000ton – Modular ASW

Profile View



Body Plan



Aft Sections Forward Sections

PRINCIPAL DIMENSIONS	
Length over all (LOA)	127.49 m
Length between perpendiculars (LBP)	122.93 m
Maximum Beam (B)	19.24 m
Depth (D)	11.56 m
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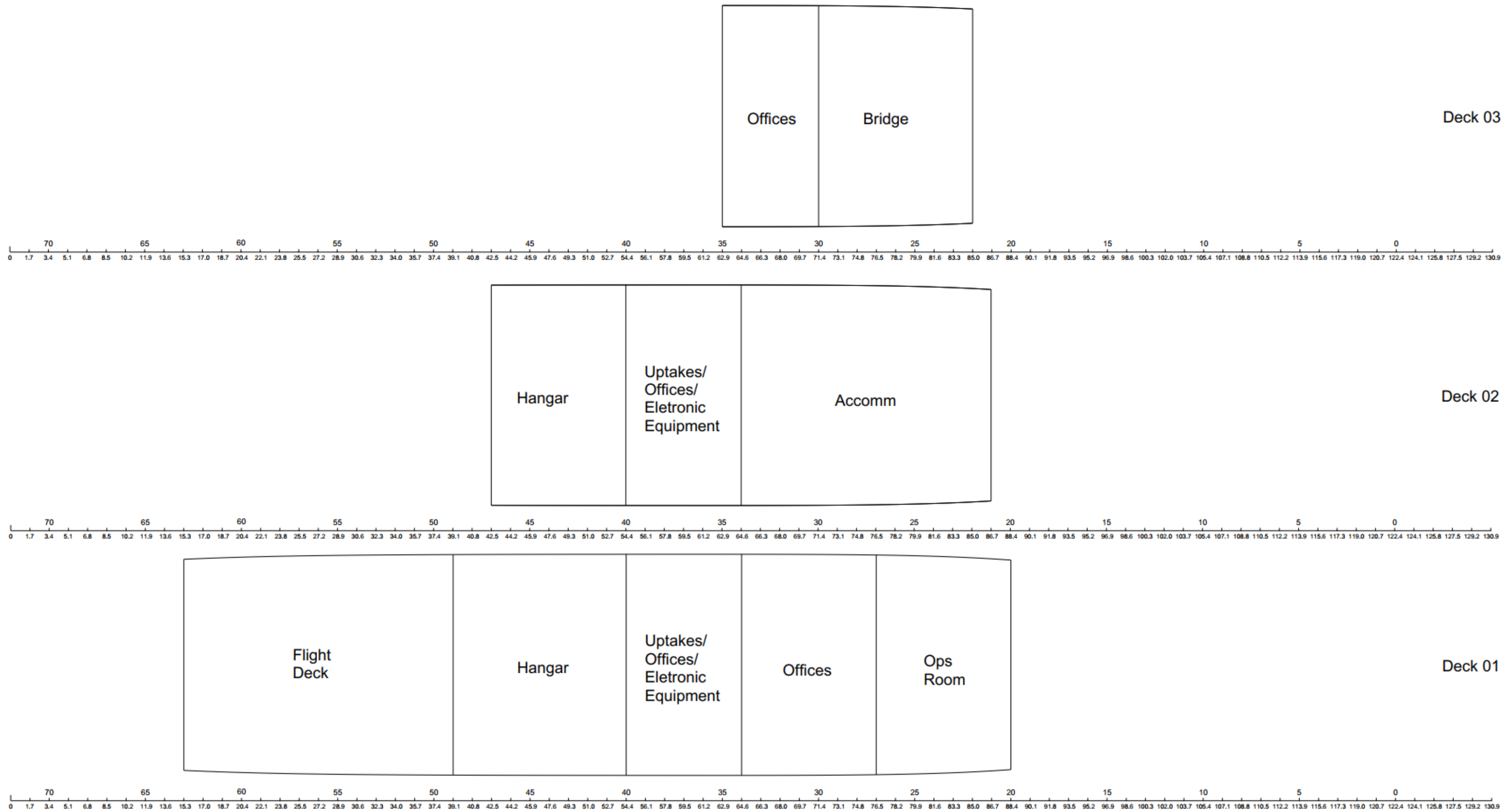
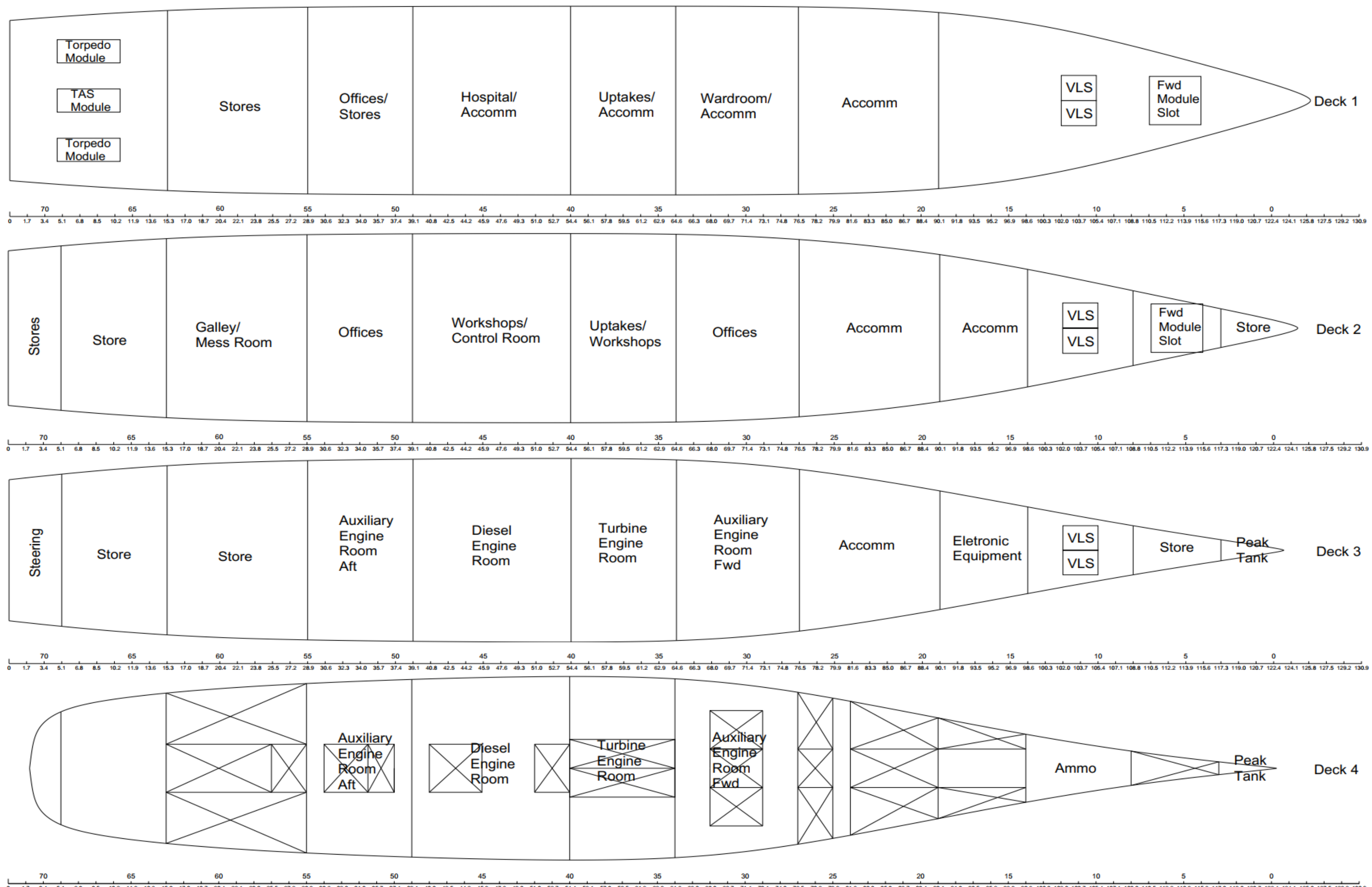
Upper Decks

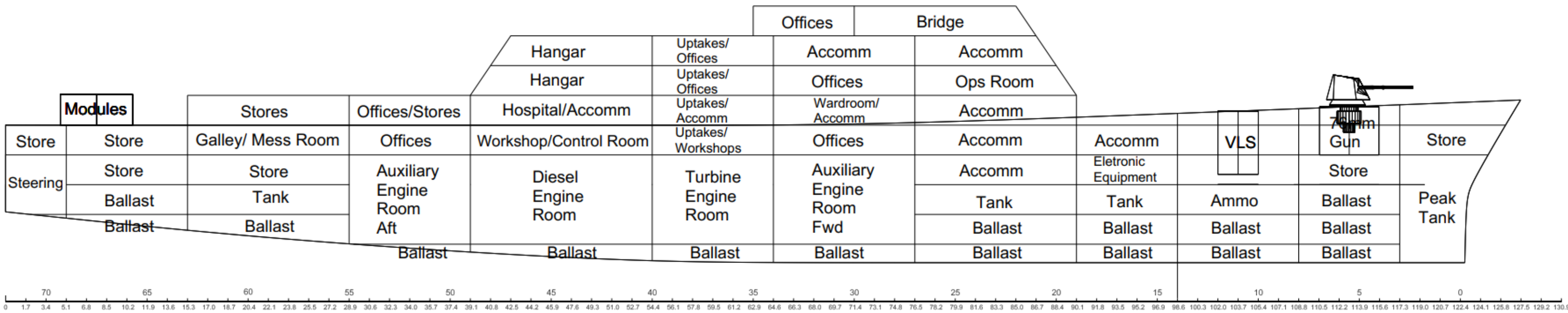

Offices
Bridge
Deck 03
Hangar
Uptakes/
Offices/
Eletronic
Equipment
Accomm
Deck 02
Flight
Deck
Hangar
Uptakes/
Offices/
Eletronic
Equipment
Offices
Ops
Room
Deck 01

Main and Lower Decks

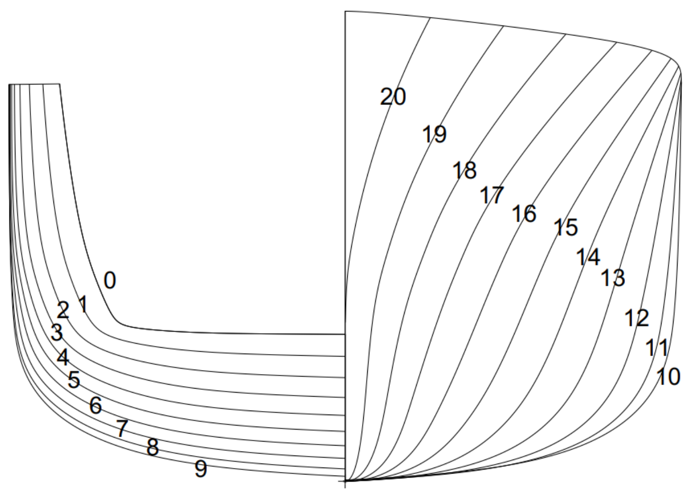


Frigate 5000ton – Modular ASuW

Profile View



Body Plan



Aft Sections Forward Sections

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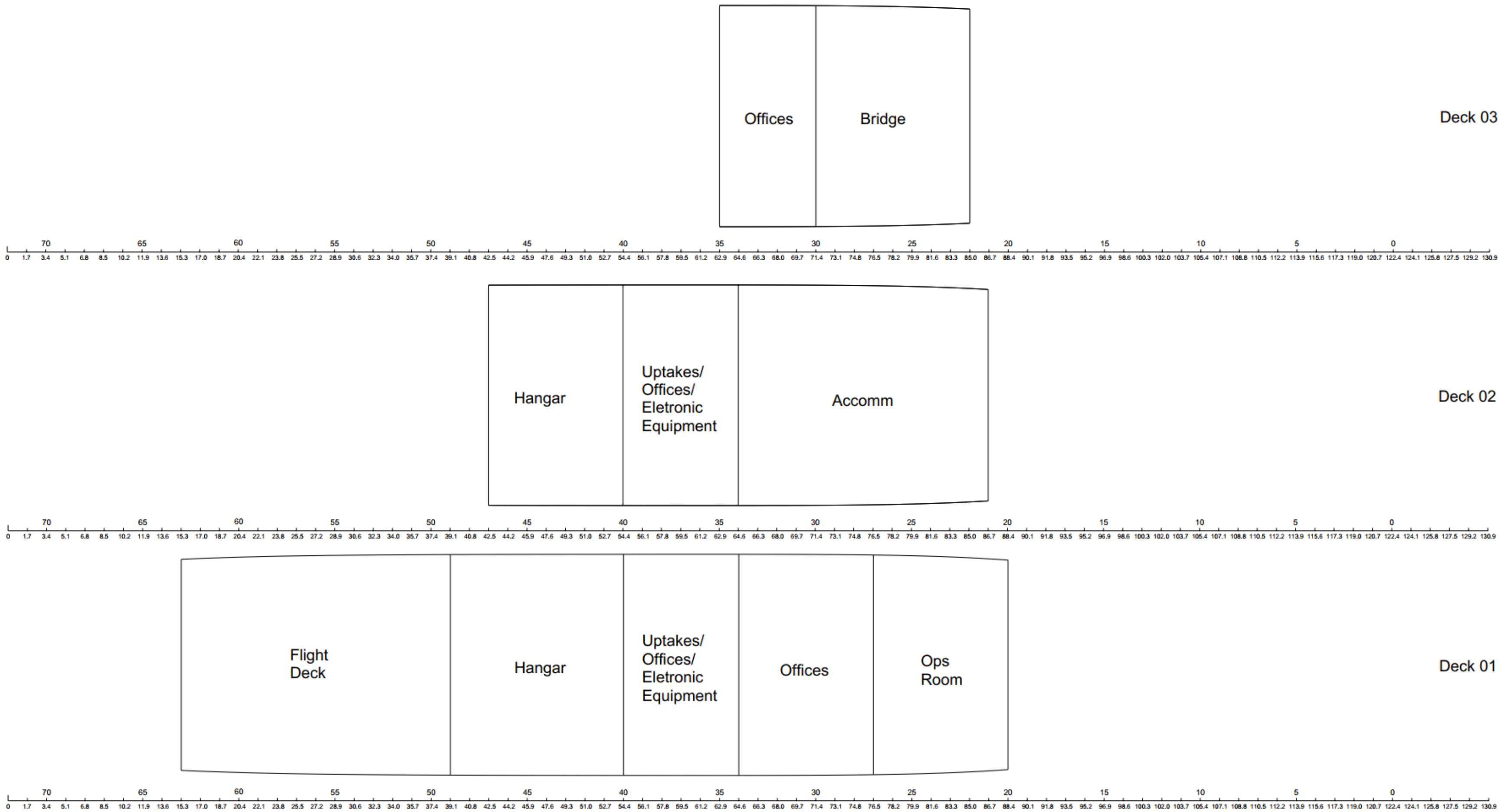
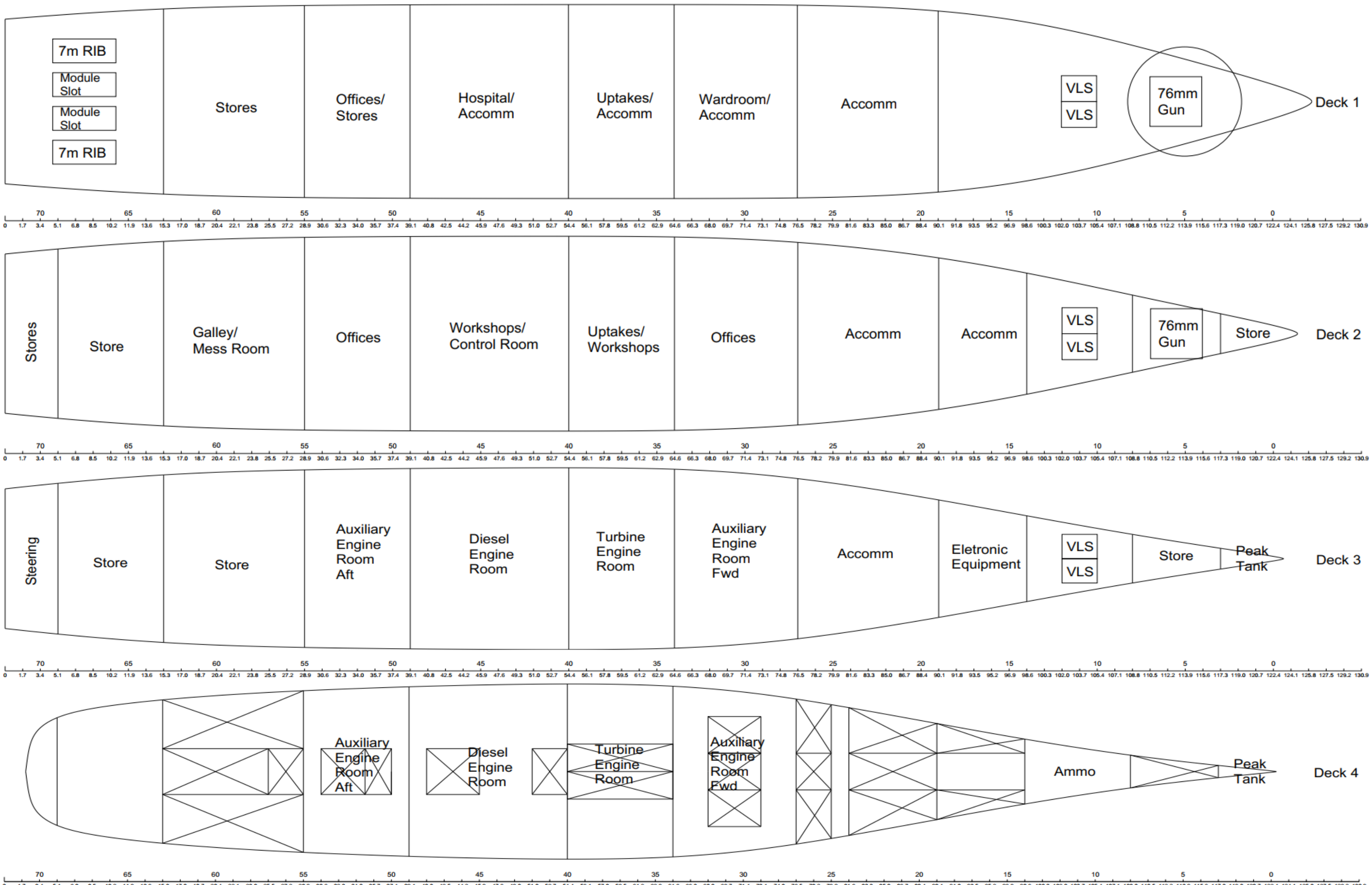
Upper Decks

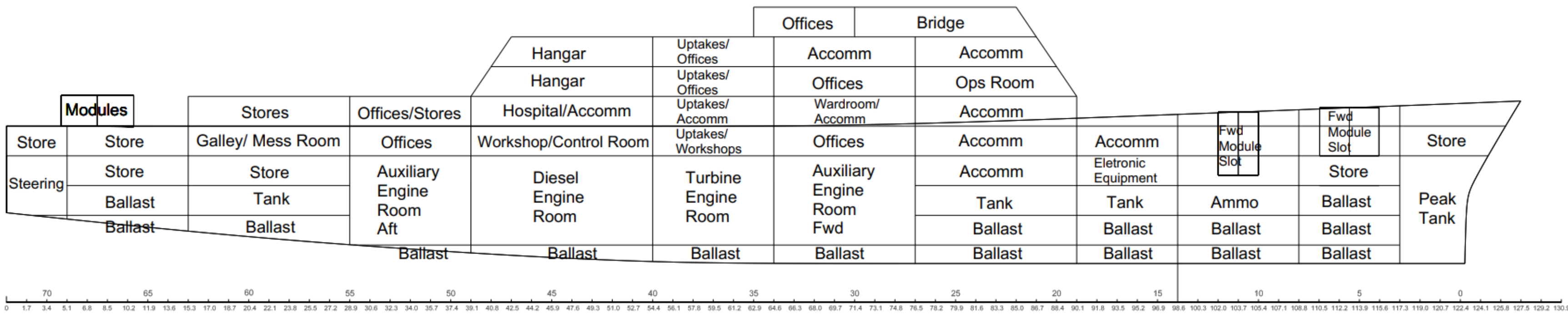

Offices
Bridge
Deck 03
Hangar
Uptakes/ Offices/ Eletronic Equipment
Accomm
Deck 02
Flight Deck
Hangar
Uptakes/ Offices/ Eletronic Equipment
Offices
Ops Room
Deck 01

Main and Lower Decks

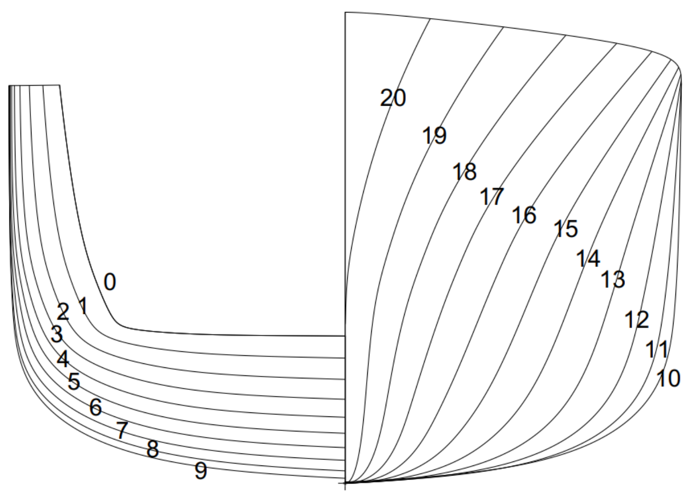


Frigate 5000ton – Modular MW

Profile View



Body Plan



Aft Sections Forward Sections

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Maximum Beam (B)	19.24 m
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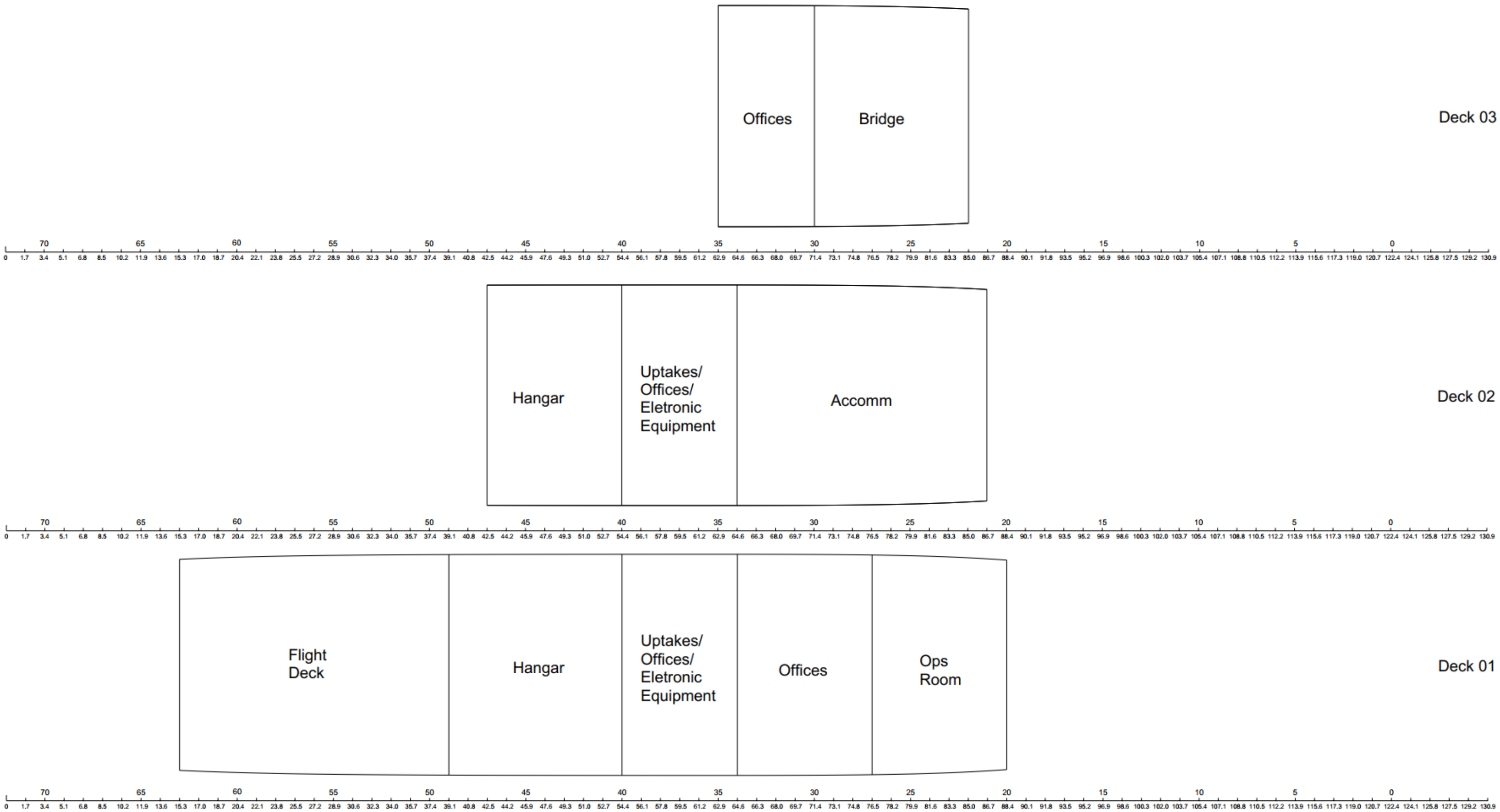
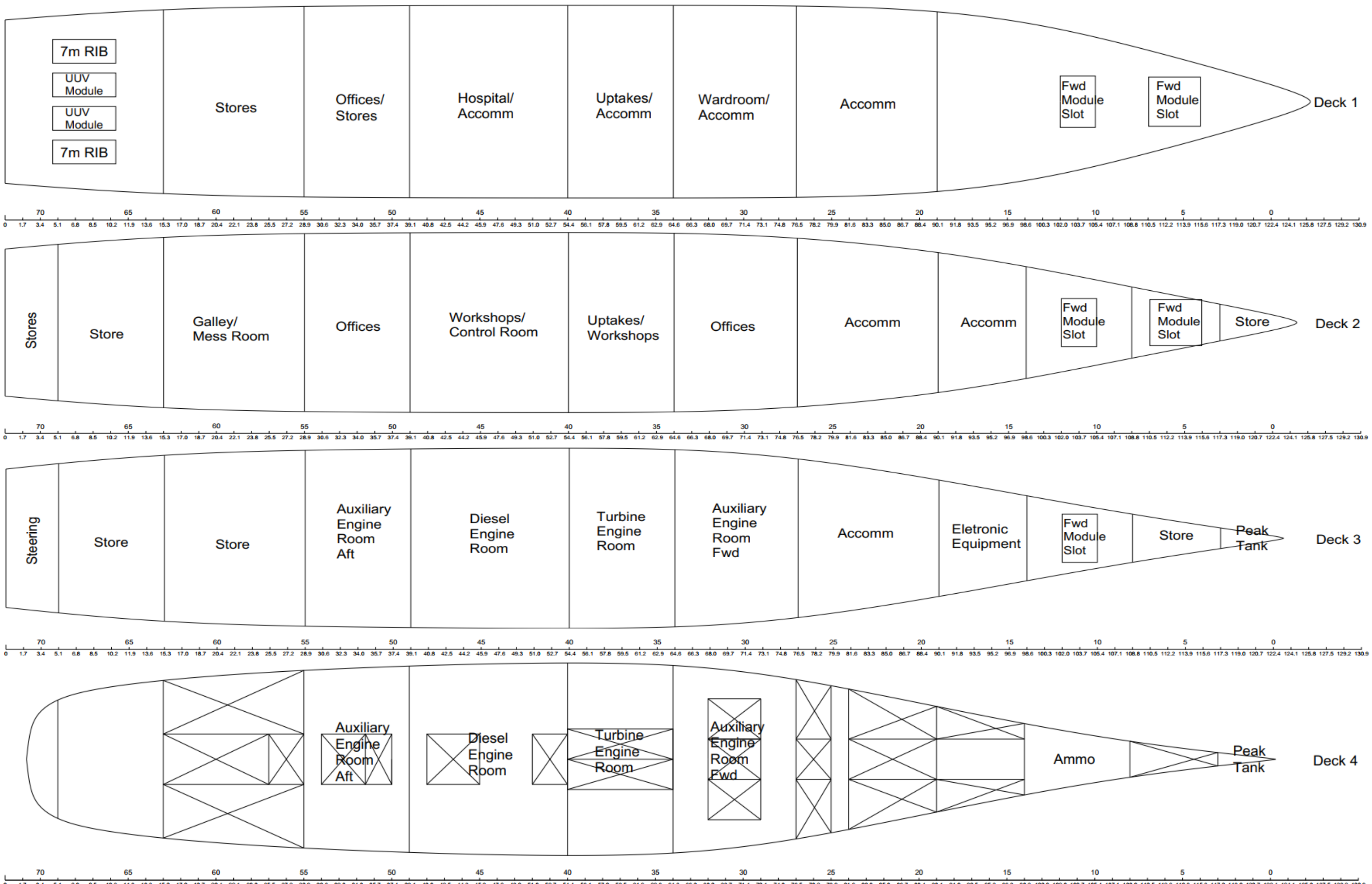
Upper Decks


Offices
Bridge
Deck 03
Hangar
Uptakes/
Offices/
Eletronic
Equipment
Accomm
Deck 02
Flight
Deck
Hangar
Uptakes/
Offices/
Eletronic
Equipment
Offices
Ops
Room
Deck 01

Main and Lower Decks



Power Definition

Ship's Data

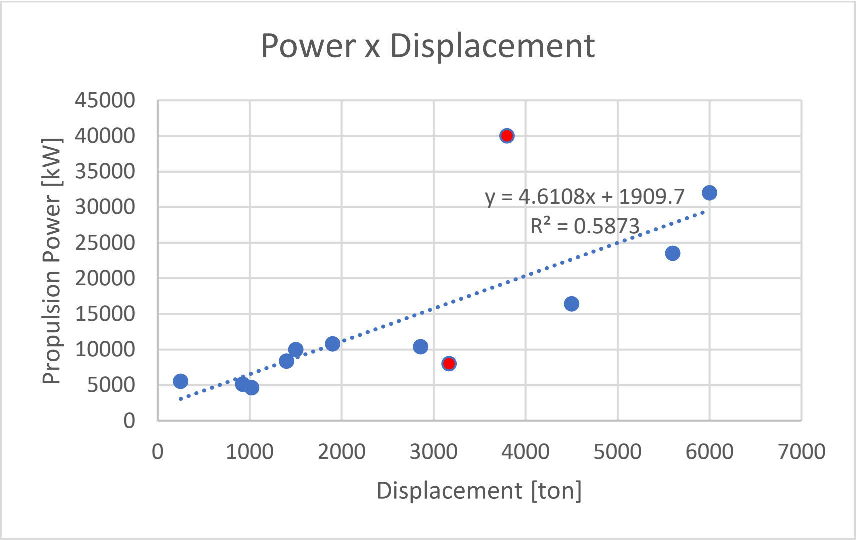
Ship Design	Length [m]	Beam [m]	Draft [m]	Displacement [ton]	Installed Power [kW]	Speed [knot]	Auxiliary Power [kW]	%
Aker PV50[20]	51.00	8.50	1.70	250	5520	30.0	540	9.78%
Damen OPV 950[21]	66.00	10.25	2.90	925	5120	20.6	608	11.88%
Damen OPV 1000[22]	61.94	9.70	3.25	1022	4640	18.0	488	10.52%
Aker PV75[23]	75.00	14.00	3.90	1400	8360	22.0	2125	25.42%
Aker PV80[24]	78.84	14.00	3.80	1500	10000	22.0	1760	17.60%
Aker PV85[25]	85.00	14.00	3.60	1900	10800	23.0	2143	19.84%
BAM Spain[26]	93.90	14.20	4.20	2860	10400	20.0	2640	25.38%
UT 512[27]	82.00	16.00	6.00	3171	8000	18.5	1380	17.25%
LF-4000[28]	113.20	15.60	4.70	3800	40000	30.0	3072	7.68%
Absalon Class[29]	137.00	19.50	6.30	4500	16400	24.0	3640	22.20%
FGS Hessen[30]	143.00	17.44	6.80	5600	23500	29.0	4000	17.02%
FREMM[31]	130.00	18.00	5.25	6000	32000	27.0	8600	26.88%

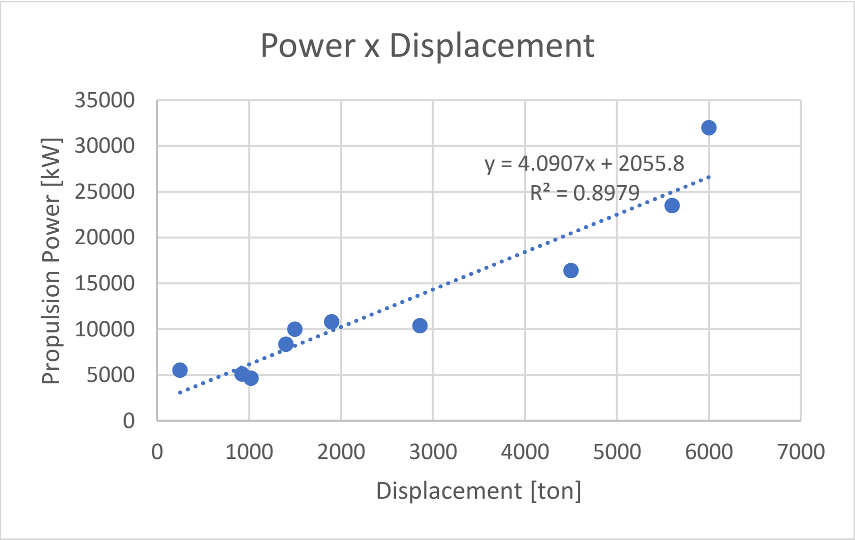
[20] https://en.wikipedia.org/wiki/Hamina-class_missile_boat
[21] https://products.damen.com/-/media/products/images/clusters-groups/naval/offshore-patrol-vessel/opv-950/documents/offshore_patrol_vessel_950_ds.pdf?rev=62ade1350dd34cc9aa143ba71b9fef7c
[22] https://products.damen.com/-/media/products/images/clusters-groups/naval/offshore-patrol-vessel/opv-1000/documents/offshore_patrol_vessel_1000_ds.pdf?rev=d667dbb43b744a759e7f2c60646f87ed
[23]
[24] https://en.wikipedia.org/wiki/R%C3%B3is%C3%ADn-class_patrol_vessel
[25] https://en.wikipedia.org/wiki/Protector-class_offshore_patrol_vessel
[26] https://en.wikipedia.org/wiki/Meteoro-class_offshore_patrol_vessel
[27] https://en.wikipedia.org/wiki/NoCGV_Harstad
[28]https://dokumen.tips/download/?url=effa0b6838d5a0a1554ed065b630ce64d7002b8b58417c784ef8c76bf266b533bb05131fb4ccef4cd5eec0c3158bbf85aff979a0650829932567e1fd025d08523CU1+RxTHt4G/1onM+uGaoNL5wb2I3G/YeuZRyPYhPP3kiVRPF7AB6aKiDwsyl6FWh5NkYNxoVVCbNm3m0vb1pRalMPcp4ZcIT3eDVSXoLZxVyOITqCY87jRNyClKg4QBqSRS+EdgesCwtlzpxzeCUBp5h3Hs60RNI148x+dAAA=&t=dl036
[29] https://en.wikipedia.org/wiki/Absalon-class_frigate
[30] https://en.wikipedia.org/wiki/German_frigate_Hessen
[31] https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=4581217

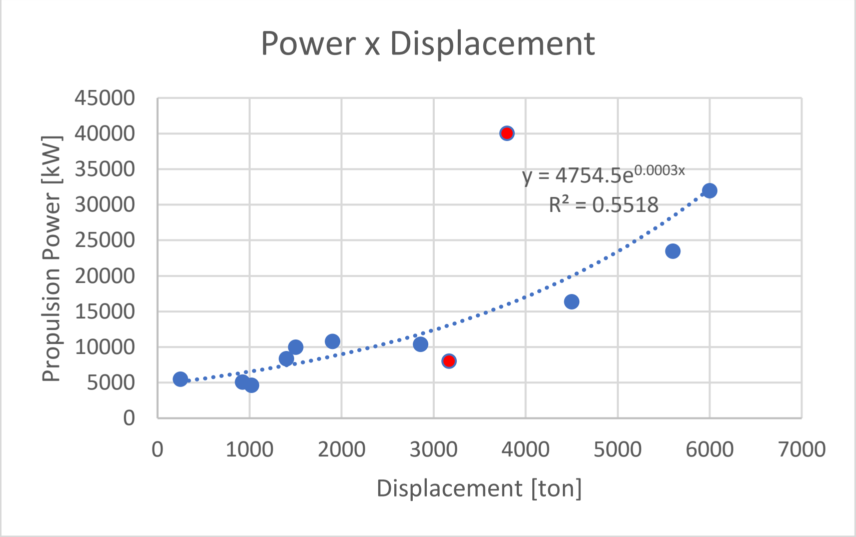
Propulsion Power (Regression Data)

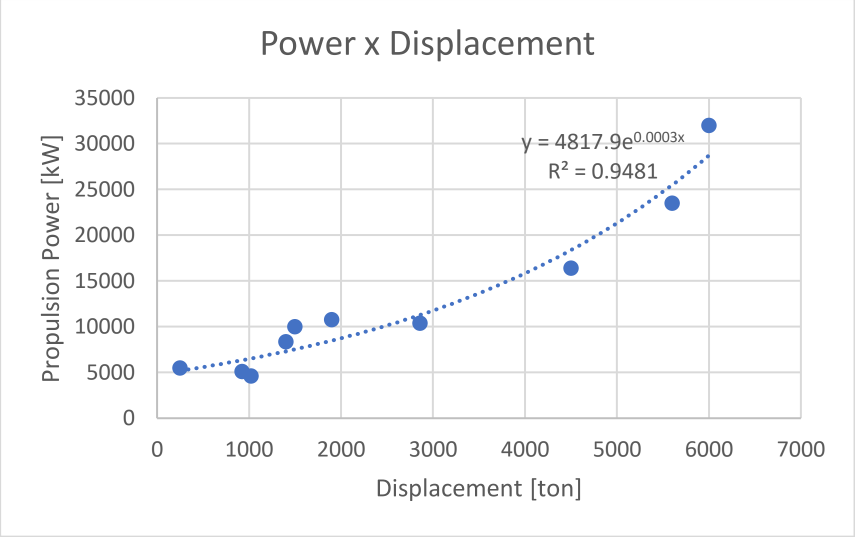
Original Data

Threated Data



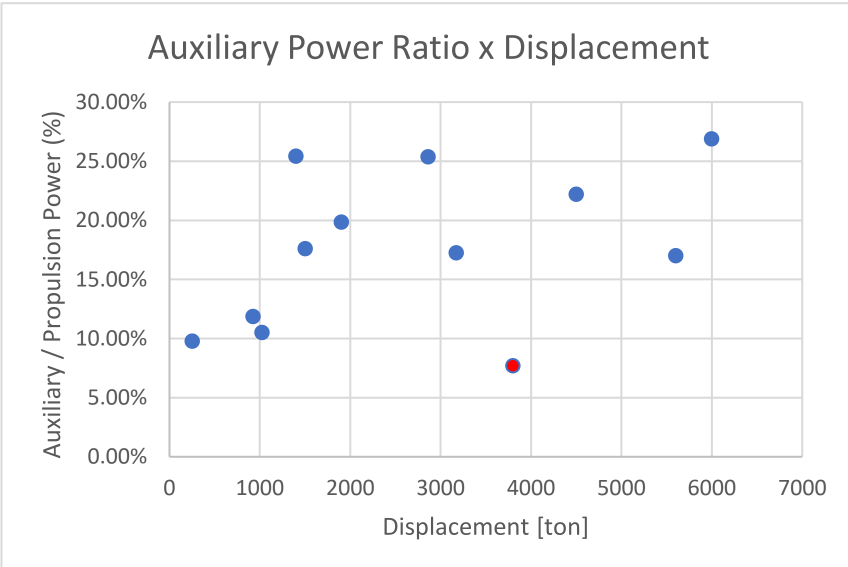




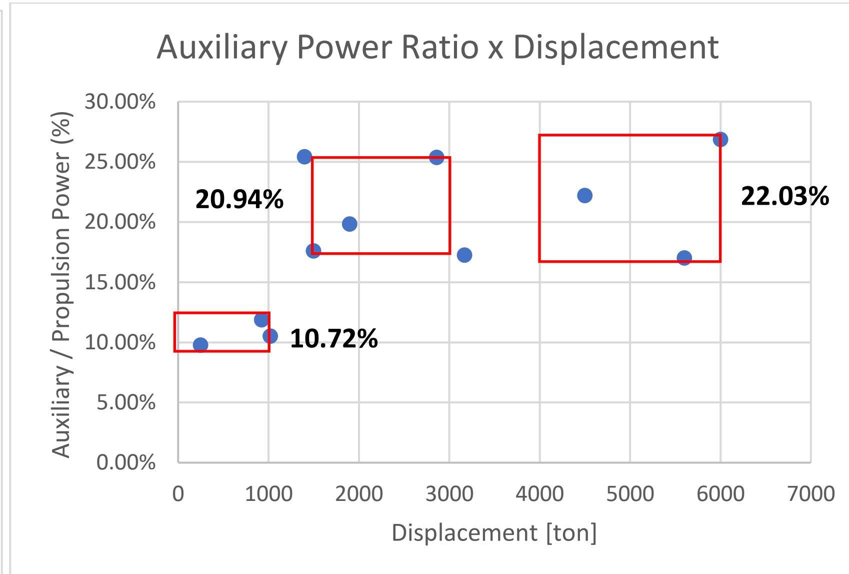


Auxiliary Power Ratio

Original Data



Threated Data



	Exponential regression y = 4817.9e^0.0003x				
Ship Design	Displacement [ton]	Propulsion Power [kW]	Displacement [ton]	Average Auxiliary Power Ratio	Auxiliary Power [kW]
Patrol Vessel	500	5,597.60	0 < x < 1000t	10.72%	600.34
OPV	2000	8,778.79	1500 < x < 3000t	20.94%	1,838.49
Frigate	5000	21,592.33	4000 < x < 6000t	22.03%	4,756.89

Appendix III – Stability Analysis

Patrol Vessel 500ton

Traditional – Equilibrium

Equilibrium calculation - PatrolVessel 500ton

Stability 23.04.00.76, build: 76

Model file: C:\Users\Felipe\OneDrive\Documentos\Felipe\UCL\MECH0070 - MSC Individual Project\Impact of Mission Modules on Naval Ship Design\Report\MAXSURF Models\PatrolVessel 500ton (Medium precision, 66 sections, Trimming on, Skin thickness not applied). Long. datum: AP; Vert. datum: Baseline. Analysis tolerance - ideal(worst case): Disp.%: 0.01000(0.100); Trim%(LCG-TCG): 0.01000(0.100); Heel%(LCG-TCG): 0.01000(0.100)

Loadcase - PatrolVessel 500ton_Traditional
Damage Case - Intact
Free to Trim
Specific gravity = 1.025; (Density = 1.025 tonne/m^3)
Fluid analysis method: Use corrected VCG

Item Name	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
Lightship	1	369.769	369.769			23.670	0.000	3.002	0.000	User Specified
Payload	1	50.000	50.000			23.670	0.000	5.503	0.000	User Specified
Aft Ballast Tank Port	0%	0.586	0.000	0.572	0.000	3.991	-0.001	1.535	0.000	Maximum
Aft Ballast Tank Starb	0%	0.586	0.000	0.572	0.000	3.991	0.001	1.535	0.000	Maximum
Aft Ballast Tank Port	0%	0.878	0.000	0.857	0.000	7.446	-0.113	1.000	0.000	Maximum
Aft Ballast Tank Starb	0%	0.878	0.000	0.857	0.000	7.446	0.113	1.000	0.000	Maximum
Aft Ballast Tank Port	0%	1.718	0.000	1.676	0.000	8.060	-0.378	1.000	0.000	Maximum
Aft Ballast Tank Starb	0%	1.718	0.000	1.676	0.000	8.060	0.378	1.000	0.000	Maximum
Aft Diesel Tank	100%	3.318	3.318	3.949	3.949	11.220	-2.516	1.618	0.000	Maximum
Aft Diesel Tank	100%	3.318	3.318	3.949	3.949	11.220	2.516	1.618	0.000	Maximum
Diesel Tank	100%	4.608	4.608	5.485	5.485	16.432	-2.973	1.562	0.000	Maximum
Diesel Tank	100%	4.608	4.608	5.485	5.485	16.432	2.973	1.562	0.000	Maximum
Lub Oil Tank	100%	2.121	2.121	2.305	2.305	19.800	0.000	1.039	0.000	Maximum
Dirty Oil Tank	0%	2.314	0.000	2.314	0.000	20.417	0.000	0.027	0.000	Maximum
Daily Diesel Tank	100%	13.708	13.708	16.320	16.320	22.200	-2.177	2.619	0.000	Maximum
Daily Diesel Tank	100%	13.708	13.708	16.320	16.320	22.200	2.177	2.619	0.000	Maximum
Fwd Diesel Tank	100%	10.665	10.665	12.696	12.696	23.994	-1.525	1.214	0.000	Maximum
Fwd Diesel Tank	100%	10.665	10.665	12.696	12.696	23.994	1.525	1.214	0.000	Maximum
Fresh Water Tank	100%	6.756	6.756	6.756	6.756	29.397	-0.492	1.061	0.000	Maximum
Fresh Water Tank	100%	6.756	6.756	6.756	6.756	29.397	0.492	1.061	0.000	Maximum
Black Water Tank	0%	12.870	0.000	12.556	0.000	34.513	0.000	0.058	0.000	Maximum
Ballast Tank Port	0%	6.306	0.000	6.152	0.000	40.815	0.000	0.057	0.000	Maximum
Ballast Tank Starb	0%	6.306	0.000	6.152	0.000	40.815	0.000	0.057	0.000	Maximum
Fwd Ballast Tank	0%	2.892	0.000	2.821	0.000	43.110	0.000	0.057	0.000	Maximum
Peak Tank	0%	18.609	0.000	18.155	0.000	45.653	0.000	0.059	0.000	Maximum
Total Loadcase			499.998	147.077	92.718	23.443	0.000	3.049	0.000	
FS correction								0.000		
VCG fluid								3.049		

Draft Amidships m	2.603
Displacement t	500.0
Heel deg	0.0
Draft at FP m	2.603
Draft at AP m	2.603
Draft at LCF m	2.603
Trim (+ve by stern) m	0.000
WL Length m	49.149
Beam max extents on WL m	8.214
Wetted Area m^2	417.434
Waterpl. Area m^2	312.820
Prismatic coeff. (Cp)	0.638
Block coeff. (Cb)	0.464
Max Sect. area coeff. (Cm)	0.738
Waterpl. area coeff. (Cwp)	0.775
LCB from zero pt. (+ve fwd) m	23.446
LCF from zero pt. (+ve fwd) m	21.863
KB m	1.651
KG fluid m	3.049
BMt m	2.748
BML m	94.431
GMt corrected m	1.351
GML m	93.033
KMt m	4.400
KML m	96.082
Immersion (TPc) tonne/cm	3.206
MTc tonne.m	9.464
RM at 1deg = GMt.Disp.sin(1) tonne.m	11.785
Max deck inclination deg	0.0000
Trim angle (+ve by stern) deg	0.0000

Key point	Type	Freeboard m
Margin Line (freeboard pos = 0 m)		1.822
Deck Edge (freeboard pos = 0 m)		1.898

Code	Criteria	Value	Units	Actual	Status	Margin %
Royal Navy, Damage Stability Criteria; DS 02-109(NES109) Part 1	1.3.5.a.(6) Longitudinal GM > 0	0.000	m	93.033	Pass	infinite

Traditional – Large Angle Stability

Stability calculation - PatrolVessel 500ton

Stability 23.04.00.76, build: 76
Model file: C:\Users\Felipe\OneDrive\Documentos\Felipe\UCL\MECH0070 - MSC Individual Project\Impact of Mission Modules on Naval Ship Design\Report\MAXSURF Models\PatrolVessel 500ton (Medium precision, 66 sections, Trimming on, Skin thickness not applied). Long. datum: AP; Vert. datum: Baseline. Analysis tolerance - ideal(worst case): Disp.%: 0.01000(0.100); Trim%(LCG-TCG): 0.01000(0.100); Heel%(LCG-TCG): 0.01000(0.100)

Loadcase - PatrolVessel 500ton_Traditional
Damage Case - Intact
Free to Trim
Specific gravity = 1.025; (Density = 1.025 tonne/m^3)
Fluid analysis method: Use corrected VCG

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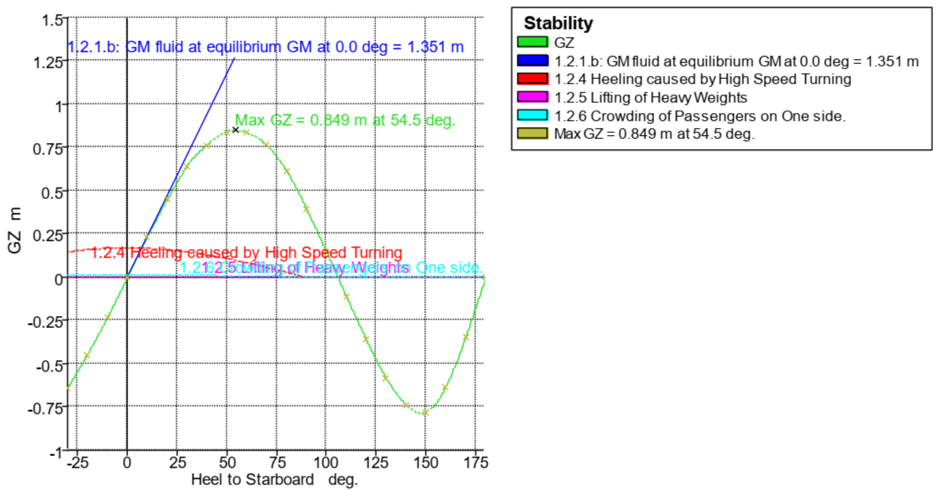
Diesel Tank	100%	4.608	4.608	5.485	5.485	16.432	2.973	1.562	0.000	Maximum
Lub Oil Tank	100%	2.121	2.121	2.305	2.305	19.800	0.000	1.039	0.000	Maximum
Dirty Oil Tank	0%	2.314	0.000	2.314	0.000	20.417	0.000	0.027	0.000	Maximum
Daily Diesel Tank	100%	13.708	13.708	16.320	16.320	22.200	-2.177	2.619	0.000	Maximum
Daily Diesel Tank	100%	13.708	13.708	16.320	16.320	22.200	2.177	2.619	0.000	Maximum
Fwd Diesel Tank	100%	10.665	10.665	12.696	12.696	23.994	-1.525	1.214	0.000	Maximum
Fwd Diesel Tank	100%	10.665	10.665	12.696	12.696	23.994	1.525	1.214	0.000	Maximum
Fresh Water Tank	100%	6.756	6.756	6.756	6.756	29.397	-0.492	1.061	0.000	Maximum
Fresh Water Tank	100%	6.756	6.756	6.756	6.756	29.397	0.492	1.061	0.000	Maximum
Black Water Tank	0%	12.870	0.000	12.556	0.000	34.513	0.000	0.058	0.000	Maximum
Ballast Tank Port	0%	6.306	0.000	6.152	0.000	40.815	0.000	0.057	0.000	Maximum
Ballast Tank Starb	0%	6.306	0.000	6.152	0.000	40.815	0.000	0.057	0.000	Maximum
Fwd Ballast Tank	0%	2.892	0.000	2.821	0.000	43.110	0.000	0.057	0.000	Maximum
Peak Tank	0%	18.609	0.000	18.155	0.000	45.653	0.000	0.059	0.000	Maximum
Total Loadcase			499.998	147.077	92.718	23.443	0.000	3.049	0.000	
FS correction								0.000		
VCG fluid								3.049		



Heel to Starboard deg	-30.0	-20.0	-10.0	0.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0	110.0
GZ m	-0.641	-0.449	-0.232	0.000	0.232	0.449	0.641	0.761	0.840	0.838	0.765	0.614	0.397	0.149	-0.111
Area under GZ curve from zero heel m.deg	10.0549	4.5939	1.1689	0.0000	1.1705	4.5875	10.0796	17.1384	25.1925	33.6497	41.7264	48.6863	53.7782	56.5253	56.7189
Displacement t	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0
Draft at FP m	2.483	2.563	2.594	2.603	2.594	2.562	2.483	2.289	1.878	1.199	-0.068	-4.024	n/a	-12.277	-8.256
Draft at AP m	2.209	2.438	2.564	2.604	2.565	2.438	2.210	1.936	1.626	1.202	0.466	-1.451	n/a	-5.774	-3.893
WL Length m	49.075	49.124	49.143	49.148	49.143	49.124	49.075	48.957	48.701	48.253	47.513	48.994	50.056	50.807	51.361
Beam max extents on WL m	8.045	8.120	8.190	8.214	8.190	8.120	8.045	8.164	7.769	7.027	6.668	6.198	6.008	5.972	6.080
Wetted Area m^2	419.196	415.678	416.733	417.432	416.735	415.679	419.212	428.902	435.205	439.703	436.198	426.311	426.008	427.390	430.269
Waterpl. Area m^2	305.187	309.957	311.637	312.821	311.638	309.958	305.190	289.665	278.784	262.511	253.035	228.161	216.810	212.127	213.399
Prismatic coeff. (Cp)	0.657	0.648	0.641	0.638	0.641	0.648	0.657	0.650	0.633	0.624	0.621	0.594	0.576	0.565	0.557
Block coeff. (Cb)	0.463	0.475	0.474	0.464	0.474	0.475	0.463	0.439	0.449	0.484	0.502	0.506	0.483	0.431	0.388
LCB from zero pt. (+ve fwd) m	23.451	23.448	23.444	23.443	23.444	23.447	23.451	23.452	23.450	23.443	23.435	23.423	23.406	23.388	23.375
LCF from zero pt. (+ve fwd) m	22.888	22.321	21.992	21.861	21.991	22.320	22.888	24.271	25.478	26.197	26.198	26.068	25.820	25.615	25.424
Max deck inclination deg	30.0012	20.0004	10.0001	0.0017	10.0001	20.0004	30.0012	40.0010	50.0003	60.0000	70.0001	80.0004	90.0000	99.9973	109.9904
Trim angle (+ve by stern) deg	-0.3190	-0.1456	-0.0351	0.0017	-0.0347	-0.1448	-0.3189	-0.4116	-0.2944	0.0033	0.6224	2.9968	n/a	7.5372	5.0723

Key point	Type	Immersion angle deg	Emergence angle deg	Freeboard at 0.0 deg m	Freeboard at 10.0 deg m	Freeboard at 20.0 deg m	Freeboard at 30.0 deg m	Freeboard at 40.0 deg m	Freeboard at 50.0 deg m	Freeboard at 60.0 deg m	Freeboard at 70.0 deg m	Freeboard at 80.0 deg m	Freeboard at 90.0 deg m	Freeboard at 100.0 deg m	Freeboard at 110.0 deg m	Freeboard at 120.0 deg m	Freeboard at 130.0 deg m	Freeboard at 140.0 deg m	Freeboard at 150.0 deg m	Freeboard at 160.0 deg m	Freeboard at 170.0 deg m	Freeboard at 180.0 deg m
Margin Line (immersion pos = 21.833 m)		25	n/a	1.822	1.073	0.344	-0.339	-0.981	-1.571	-2.117	-2.612	-3.031	-3.356	-3.713	-3.998	-4.142	-4.136	-3.970	-3.634	-3.113	-2.454	-1.726
Deck Edge (immersion pos = 21.833 m)		26	n/a	1.898	1.148	0.415	-0.273	-0.923	-1.522	-2.079	-2.586	-3.018	-3.356	-3.725	-4.024	-4.180	-4.184	-4.028	-3.700	-3.185	-2.529	-1.802

Code	Criteria	Value	Units	Actual	Status	Margin %
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 0 to 30	4.5840	m.deg	10.0796	Pass	+119.89
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 0 to 40	7.6200	m.deg	17.1384	Pass	+124.91
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 30 to 40	2.7500	m.deg	7.0588	Pass	+156.68
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Maximum GZ	0.300	m	0.840	Pass	+180.00
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Angle of maximum GZ	30.0	deg	54.5	Pass	+81.82
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: GM fluid at equilibrium	0.300	m	1.351	Pass	+350.33
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Range of positive stability	70.0	deg	105.7	Pass	+51.06
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Angle of vanishing stability	70.0	deg	105.7	Pass	+51.06
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.4 Heeling caused by High Speed Turning				Pass	
	Angle of steady heel shall be less than (<)	20.0	deg	7.2	Pass	+64.03
	Area1 / Area2 shall be greater than (>)	40.00	%	79.56	Pass	+98.90
	GZ(intersection) / GZ(max) shall be less than (<)	60.00	%	20.05	Pass	+66.58
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.5 Lifting of Heavy Weights				Pass	
	Angle of steady heel shall be less than (<)	15.0	deg	0.0	Pass	+99.94
	Area1 / Area2 shall be greater than (>)	50.00	%	99.93	Pass	+99.86
	GZ(intersection) / GZ(max) shall be less than (<)	50.00	%	0.03	Pass	+99.94
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.6 Crowding of Passengers on One side.				Pass	
	Angle of steady heel shall be less than (<)	10.0	deg	0.6	Pass	+93.63
	Area1 / Area2 shall be greater than (>)	40.00	%	98.08	Pass	+145.20
	GZ(intersection) / GZ(max) shall be less than (<)	60.00	%	1.79	Pass	+97.02

Traditional – Equilibrium (Damage)

Equilibrium calculation - PatrolVessel 500ton

Stability 23.04.00.76, build: 76
Model file: C:\Users\Felipe\OneDrive\Documentos\Felipe\UCL\MECH0070 - MSC Individual Project\Impact of Mission Modules on Naval Ship Design\Report\MAXSURF Models\PatrolVessel 500ton (Medium precision, 66 sections, Trimming on, Skin thickness not applied). Long. datum: AP; Vert. datum: Baseline. Analysis tolerance - ideal(worst case): Disp.%: 0.01000(0.100); Trim%(LCG-TCG): 0.01000(0.100); Heel%(LCG-TCG): 0.01000(0.100)

Loadcase - PatrolVessel 500ton_Traditional
Damage Case - Auxiliary+EngineRoom
Free to Trim
Specific gravity = 1.025; (Density = 1.025 tonne/m^3)
Compartments Damaged -

Compartment or Tank	Status	Perm.%	PartFlood.%	PartFlood.WL
Auxiliary Room[]	Fully flooded	100		
Engine Room[]	Fully flooded	100		

Fluid analysis method: Use corrected VCG

Item Name	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
Lightship	1	369.769	369.769			23.670	0.000	3.002	0.000	User Specified
Payload	1	50.000	50.000			23.670	0.000	5.503	0.000	User Specified
Aft Ballast Tank Port	0%	0.586	0.000	0.572	0.000	3.991	-0.001	1.535	0.000	Maximum
Aft Ballast Tank Starb	0%	0.586	0.000	0.572	0.000	3.991	0.001	1.535	0.000	Maximum
Aft Ballast Tank Port	0%	0.878	0.000	0.857	0.000	7.446	-0.113	1.000	0.000	Maximum
Aft Ballast Tank Starb	0%	0.878	0.000	0.857	0.000	7.446	0.113	1.000	0.000	Maximum
Aft Ballast Tank Port	0%	1.718	0.000	1.676	0.000	8.060	-0.378	1.000	0.000	Maximum
Aft Ballast Tank Starb	0%	1.718	0.000	1.676	0.000	8.060	0.378	1.000	0.000	Maximum
Aft Diesel Tank	100%	3.318	3.318	3.949	3.949	11.220	-2.516	1.618	0.000	Maximum
Aft Diesel Tank	100%	3.318	3.318	3.949	3.949	11.220	2.516	1.618	0.000	Maximum
Diesel Tank	100%	4.608	4.608	5.485	5.485	16.432	-2.973	1.562	0.000	Maximum
Diesel Tank	100%	4.608	4.608	5.485	5.485	16.432	2.973	1.562	0.000	Maximum
Lub Oil Tank	100%	2.121	2.121	2.305	2.305	19.800	0.000	1.039	0.000	Maximum
Dirty Oil Tank	0%	2.314	0.000	2.314	0.000	20.417	0.000	0.027	0.000	Maximum
Daily Diesel Tank	100%	13.708	13.708	16.320	16.320	22.200	-2.177	2.619	0.000	Maximum
Daily Diesel Tank	100%	13.708	13.708	16.320	16.320	22.200	2.177	2.619	0.000	Maximum
Fwd Diesel Tank	100%	10.665	10.665	12.696	12.696	23.994	-1.525	1.214	0.000	Maximum
Fwd Diesel Tank	100%	10.665	10.665	12.696	12.696	23.994	1.525	1.214	0.000	Maximum
Fresh Water Tank	100%	6.756	6.756	6.756	6.756	29.397	-0.492	1.061	0.000	Maximum
Fresh Water Tank	100%	6.756	6.756	6.756	6.756	29.397	0.492	1.061	0.000	Maximum
Black Water Tank	0%	12.870	0.000	12.556	0.000	34.513	0.000	0.058	0.000	Maximum
Ballast Tank Port	0%	6.306	0.000	6.152	0.000	40.815	0.000	0.057	0.000	Maximum
Ballast Tank Starb	0%	6.306	0.000	6.152	0.000	40.815	0.000	0.057	0.000	Maximum
Fwd Ballast Tank	0%	2.892	0.000	2.821	0.000	43.110	0.000	0.057	0.000	Maximum
Peak Tank	0%	18.609	0.000	18.155	0.000	45.653	0.000	0.059	0.000	Maximum
Total Loadcase			499.998	147.077	92.718	23.443	0.000	3.049	0.000	
FS correction								0.000		
VCG fluid								3.049		

Draft Amidships m	3.312
Displacement t	500.0
Heel deg	0.0
Draft at FP m	2.463
Draft at AP m	4.162
Draft at LCF m	3.323
Trim (+ve by stern) m	1.699
WL Length m	49.094
Beam max extents on WL m	8.496
Wetted Area m^2	502.174
Waterpl. Area m^2	225.884
Prismatic coeff. (Cp)	0.431
Block coeff. (Cb)	0.299
Max Sect. area coeff. (Cm)	0.766
Waterpl. area coeff. (Cwp)	0.542
LCB from zero pt. (+ve fwd) m	23.412
LCF from zero pt. (+ve fwd) m	24.276
KB m	2.121
KG fluid m	3.049
BMt m	2.062
BML m	88.455
GMt corrected m	1.134
GML m	87.526
KMt m	4.182
KML m	90.523
Immersion (TPc) tonne/cm	2.315
MTc tonne.m	8.905
RM at 1deg = GMt.Disp.sin(1) tonne.m	9.895
Max deck inclination deg	1.9798
Trim angle (+ve by stern) deg	1.9798

Key point	Type	Freeboard m
Margin Line (freeboard pos = 0 m)		0.264
Deck Edge (freeboard pos = 0 m)		0.34

Code	Criteria	Value	Units	Actual	Status	Margin %
Royal Navy, Damage Stability Criteria; DS 02-109(NES109) Part 1	1.3.5.a.(6) Longitudinal GM > 0	0.000	m	87.526	Pass	infinite
Royal Navy, Damage Stability Criteria; DS 02-109(NES109) Part 1	1.3.5.b.(1) Metacentric Height Greater than 0.15m	0.150	m	1.134	Pass	+656.00

Traditional – Large Angle Stability (Damage)

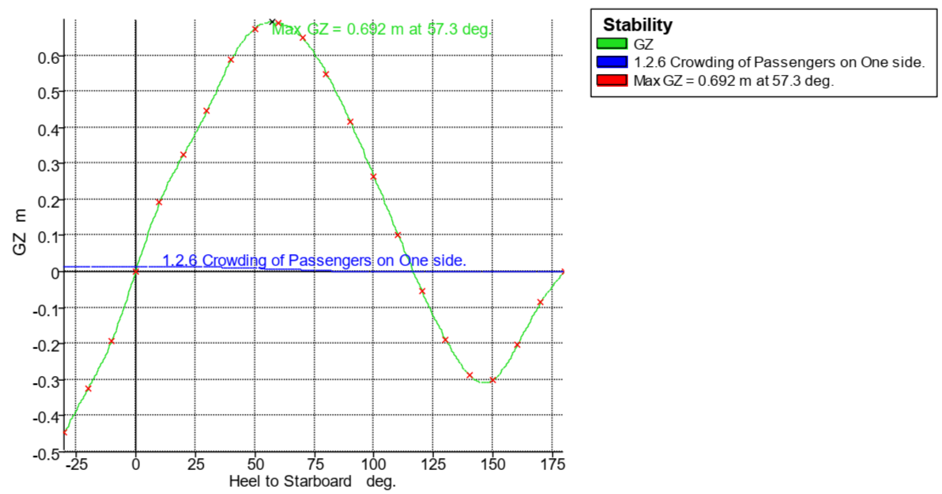
Stability calculation - PatrolVessel 500ton
Stability 23.04.00.76, build: 76
Model file: C:\Users\Felipe\OneDrive\Documentos\Felipe\UCL\MECH0070 - MSC Individual Project\Impact of Mission Modules on Naval Ship Design\Report\MAXSURF Models\PatrolVessel 500ton (Medium precision, 66 sections, Trimming on, Skin thickness not applied). Long. datum: AP; Vert. datum: Baseline. Analysis tolerance - ideal(worst case): Disp.%: 0.01000(0.100); Trim%(LCG-TCG): 0.01000(0.100); Heel%(LCG-TCG): 0.01000(0.100)

Loadcase - PatrolVessel 500ton_Traditional
Damage Case - Auxiliary+EngineRoom
Free to Trim
Specific gravity = 1.025; (Density = 1.025 tonne/m^3)
Compartments Damaged -

Compartment or Tank	Status	Perm.%	PartFlood.%	PartFlood.WL
Auxiliary Room[]	Fully flooded	100		
Engine Room[]	Fully flooded	100		

Fluid analysis method: Use corrected VCG

Item Name	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
Lightship	1	369.769	369.769			23.670	0.000	3.002	0.000	User Specified
Payload	1	50.000	50.000			23.670	0.000	5.503	0.000	User Specified
Aft Ballast Tank Port	0%	0.586	0.000	0.572	0.000	3.991	-0.001	1.535	0.000	Maximum
Aft Ballast Tank Starb	0%	0.586	0.000	0.572	0.000	3.991	0.001	1.535	0.000	Maximum
Aft Ballast Tank Port	0%	0.878	0.000	0.857	0.000	7.446	-0.113	1.000	0.000	Maximum
Aft Ballast Tank Starb	0%	0.878	0.000	0.857	0.000	7.446	0.113	1.000	0.000	Maximum
Aft Ballast Tank Port	0%	1.718	0.000	1.676	0.000	8.060	-0.378	1.000	0.000	Maximum
Aft Ballast Tank Starb	0%	1.718	0.000	1.676	0.000	8.060	0.378	1.000	0.000	Maximum
Aft Diesel Tank	100%	3.318	3.318	3.949	3.949	11.220	-2.516	1.618	0.000	Maximum
Aft Diesel Tank	100%	3.318	3.318	3.949	3.949	11.220	2.516	1.618	0.000	Maximum
Diesel Tank	100%	4.608	4.608	5.485	5.485	16.432	-2.973	1.562	0.000	Maximum
Diesel Tank	100%	4.608	4.608	5.485	5.485	16.432	2.973	1.562	0.000	Maximum
Lub Oil Tank	100%	2.121	2.121	2.305	2.305	19.800	0.000	1.039	0.000	Maximum
Dirty Oil Tank	0%	2.314	0.000	2.314	0.000	20.417	0.000	0.027	0.000	Maximum
Daily Diesel Tank	100%	13.708	13.708	16.320	16.320	22.200	-2.177	2.619	0.000	Maximum
Daily Diesel Tank	100%	13.708	13.708	16.320	16.320	22.200	2.177	2.619	0.000	Maximum
Fwd Diesel Tank	100%	10.665	10.665	12.696	12.696	23.994	-1.525	1.214	0.000	Maximum
Fwd Diesel Tank	100%	10.665	10.665	12.696	12.696	23.994	1.525	1.214	0.000	Maximum
Fresh Water Tank	100%	6.756	6.756	6.756	6.756	29.397	-0.492	1.061	0.000	Maximum
Fresh Water Tank	100%	6.756	6.756	6.756	6.756	29.397	0.492	1.061	0.000	Maximum
Black Water Tank	0%	12.870	0.000	12.556	0.000	34.513	0.000	0.058	0.000	Maximum
Ballast Tank Port	0%	6.306	0.000	6.152	0.000	40.815	0.000	0.057	0.000	Maximum
Ballast Tank Starb	0%	6.306	0.000	6.152	0.000	40.815	0.000	0.057	0.000	Maximum
Fwd Ballast Tank	0%	2.892	0.000	2.821	0.000	43.110	0.000	0.057	0.000	Maximum
Peak Tank	0%	18.609	0.000	18.155	0.000	45.653	0.000	0.059	0.000	Maximum
Total Loadcase			499.998	147.077	92.718	23.443	0.000	3.049	0.000	
FS correction								0.000		
VCG fluid								3.049		



Heel to Starboard deg	-30.0	-20.0	-10.0	0.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0	110.0
GZ m	-0.447	-0.324	-0.191	0.000	0.191	0.324	0.447	0.587	0.674	0.690	0.649	0.549	0.416	0.263	0.103
Area under GZ curve from zero heel m.deg	7.4579	3.6047	0.9929	0.0000	0.9924	3.6084	7.4480	12.6292	18.9959	25.8705	32.6134	38.6416	43.4863	46.8878	48.7190
Displacement t	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0
Draft at FP m	1.995	2.277	2.433	2.462	2.435	2.278	1.995	1.532	0.843	-0.215	-2.280	-8.465	n/a	-16.349	-10.122
Draft at AP m	4.650	4.349	4.173	4.162	4.172	4.348	4.650	5.124	5.865	7.054	9.423	16.402	n/a	11.375	4.311
WL Length m	48.841	48.993	49.077	49.093	49.077	48.993	48.841	48.586	48.172	46.932	45.839	47.262	48.388	49.321	50.173
Beam max extents on WL m	8.937	8.667	8.561	8.496	8.561	8.667	8.937	8.252	7.345	6.990	6.605	6.259	6.160	6.219	6.424
Wetted Area m^2	552.643	542.733	511.142	502.147	511.090	542.739	552.635	557.089	560.520	560.306	557.354	555.888	554.810	555.402	555.809
Waterpl. Area m^2	204.768	203.548	217.386	225.875	217.446	203.568	204.776	205.690	194.645	183.647	169.813	159.824	156.415	157.517	159.318
Prismatic coeff. (Cp)	0.438	0.431	0.431	0.431	0.431	0.431	0.438	0.424	0.419	0.426	0.434	0.420	0.412	0.405	0.400
Block coeff. (Cb)	0.292	0.299	0.300	0.299	0.300	0.300	0.292	0.296	0.313	0.316	0.312	0.294	0.273	0.254	0.238
LCB from zero pt. (+ve fwd) m	23.397	23.401	23.406	23.411	23.410	23.404	23.397	23.377	23.359	23.344	23.320	23.305	23.289	23.270	23.264
LCF from zero pt. (+ve fwd) m	27.778	26.996	25.247	24.275	25.243	26.996	27.778	28.320	29.012	29.445	29.434	29.390	29.072	28.715	28.551
Max deck inclination deg	30.1082	20.1230	10.1953	1.9807	10.1948	20.1228	30.1082	40.1066	50.1033	60.0900	70.0688	80.0388	90.0000	99.9519	109.8956
Trim angle (+ve by stern) deg	3.0920	2.4135	2.0270	1.9807	2.0242	2.4118	3.0912	4.1796	5.8338	8.4130	13.3940	26.8372	n/a	29.4269	16.3651

Key point	Type	Immersion angle deg	Emergence angle deg	Freeboard at 0.0 deg m	Freeboard at 10.0 deg m	Freeboard at 20.0 deg m	Freeboard at 30.0 deg m	Freeboard at 40.0 deg m	Freeboard at 50.0 deg m	Freeboard at 60.0 deg m	Freeboard at 70.0 deg m	Freeboard at 80.0 deg m	Freeboard at 90.0 deg m	Freeboard at 100.0 deg m	Freeboard at 110.0 deg m	Freeboard at 120.0 deg m	Freeboard at 130.0 deg m	Freeboard at 140.0 deg m	Freeboard at 150.0 deg m	Freeboard at 160.0 deg m	Freeboard at 170.0 deg m	Freeboard at 180.0 deg m
Margin Line (immersion pos = 0 m)		4.1	n/a	0.264	-0.373	-1.155	-1.988	-2.840	-3.669	-4.414	-5.069	-5.596	-5.990	-6.252	-6.333	-6.207	-5.901	-5.439	-4.878	-4.341	-3.850	-3.286
Deck Edge (immersion pos = 0 m)		5.3	n/a	0.340	-0.299	-1.084	-1.923	-2.782	-3.621	-4.376	-5.043	-5.584	-5.990	-6.266	-6.359	-6.246	-5.950	-5.498	-4.944	-4.413	-3.925	-3.362

Code	Criteria	Value	Units	Actual	Status	Margin %
Royal Navy, Damage Stability Criteria; DS 02-109(NES109) Part 1	1.3.5.a.(1): Angle of List or Loll.	20.0	deg	0.0	Pass	+100.00
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.6 Crowding of Passengers on One side.				Pass	
	Angle of steady heel shall be less than (<)	10.0	deg	0.7	Pass	+92.71
	Area1 / Area2 shall be greater than (>)	40.00	%	97.54	Pass	+143.85
	GZ(intersection) / GZ(max) shall be less than (<)	60.00	%	2.23	Pass	+96.28

Modular ASW – Equilibrium

Equilibrium calculation - PatrolVessel 500ton

Stability 23.04.00.76, build: 76
Model file: C:\Users\Felipe\OneDrive\Documentos\Felipe\UCL\MECH0070 - MSC Individual Project\Impact of Mission Modules on Naval Ship Design\Report\MAXSURF Models\PatrolVessel 500ton (Medium precision, 66 sections, Trimming on, Skin thickness not applied). Long. datum: AP; Vert. datum: Baseline. Analysis tolerance - ideal(worst case): Disp.%: 0.01000(0.100); Trim%(LCG-TCG): 0.01000(0.100); Heel%(LCG-TCG): 0.01000(0.100)

Loadcase - PatrolVessel 500ton_Modular_ASW
Damage Case - Intact
Free to Trim
Specific gravity = 1.025; (Density = 1.025 tonne/m^3)
Fluid analysis method: Use corrected VCG

Item Name	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
Lightship	1	369.769	369.769			23.670	0.000	3.002	0.000	User Specified
VLS fwd	1	26.000	26.000			39.790	0.000	3.590	0.000	User Specified
Torpedo Container	1	5.330	5.330			12.450	0.000	5.798	0.000	User Specified
Torpedo Container	1	5.330	5.330			12.450	0.000	5.798	0.000	User Specified
TAS Module	1	14.000	14.000			4.350	0.000	5.798	0.000	User Specified
Aft Ballast Tank Port	0%	0.586	0.000	0.572	0.000	3.991	-0.001	1.535	0.000	Maximum
Aft Ballast Tank Starb	0%	0.586	0.000	0.572	0.000	3.991	0.001	1.535	0.000	Maximum
Aft Ballast Tank Port	0%	0.878	0.000	0.857	0.000	7.446	-0.113	1.000	0.000	Maximum
Aft Ballast Tank Starb	0%	0.878	0.000	0.857	0.000	7.446	0.113	1.000	0.000	Maximum
Aft Ballast Tank Port	0%	1.718	0.000	1.676	0.000	8.060	-0.378	1.000	0.000	Maximum
Aft Ballast Tank Starb	0%	1.718	0.000	1.676	0.000	8.060	0.378	1.000	0.000	Maximum
Aft Diesel Tank	100%	3.318	3.318	3.949	3.949	11.220	-2.516	1.618	0.000	Maximum
Aft Diesel Tank	100%	3.318	3.318	3.949	3.949	11.220	2.516	1.618	0.000	Maximum
Diesel Tank	100%	4.608	4.608	5.485	5.485	16.432	-2.973	1.562	0.000	Maximum
Diesel Tank	100%	4.608	4.608	5.485	5.485	16.432	2.973	1.562	0.000	Maximum
Lub Oil Tank	100%	2.121	2.121	2.305	2.305	19.800	0.000	1.039	0.000	Maximum
Dirty Oil Tank	0%	2.314	0.000	2.314	0.000	20.417	0.000	0.027	0.000	Maximum
Daily Diesel Tank	100%	13.708	13.708	16.320	16.320	22.200	-2.177	2.619	0.000	Maximum
Daily Diesel Tank	100%	13.708	13.708	16.320	16.320	22.200	2.177	2.619	0.000	Maximum
Fwd Diesel Tank	100%	10.665	10.665	12.696	12.696	23.994	-1.525	1.214	0.000	Maximum
Fwd Diesel Tank	100%	10.665	10.665	12.696	12.696	23.994	1.525	1.214	0.000	Maximum
Fresh Water Tank	100%	6.756	6.756	6.756	6.756	29.397	-0.492	1.061	0.000	Maximum
Fresh Water Tank	100%	6.756	6.756	6.756	6.756	29.397	0.492	1.061	0.000	Maximum
Black Water Tank	0%	12.870	0.000	12.556	0.000	34.513	0.000	0.058	0.000	Maximum
Ballast Tank Port	0%	6.306	0.000	6.152	0.000	40.815	0.000	0.057	0.000	Maximum
Ballast Tank Starb	0%	6.306	0.000	6.152	0.000	40.815	0.000	0.057	0.000	Maximum
Fwd Ballast Tank	0%	2.892	0.000	2.821	0.000	43.110	0.000	0.057	0.000	Maximum
Peak Tank	0%	18.609	0.000	18.155	0.000	45.653	0.000	0.059	0.000	Maximum
Total Loadcase			500.658	147.077	92.718	23.501	0.000	2.968	0.000	
FS correction								0.000		
VCG fluid								2.968		

Draft Amidships m	2.607
Displacement t	500.7
Heel deg	0.0
Draft at FP m	2.622
Draft at AP m	2.592
Draft at LCF m	2.606
Trim (+ve by stern) m	-0.030
WL Length m	49.160
Beam max extents on WL m	8.215
Wetted Area m^2	417.722
Waterpl. Area m^2	312.890
Prismatic coeff. (Cp)	0.638
Block coeff. (Cb)	0.465
Max Sect. area coeff. (Cm)	0.738
Waterpl. area coeff. (Cwp)	0.775
LCB from zero pt. (+ve fwd) m	23.502
LCF from zero pt. (+ve fwd) m	21.888
KB m	1.653
KG fluid m	2.968
BMt m	2.744
BML m	94.365
GMt corrected m	1.430
GML m	93.050
KMt m	4.397
KML m	96.018
Immersion (TPc) tonne/cm	3.207
MTc tonne.m	9.479
RM at 1deg = GMt.Disp.sin(1) tonne.m	12.491
Max deck inclination deg	0.0354
Trim angle (+ve by stern) deg	-0.0354

Key point	Type	Freeboard m
Margin Line (freeboard pos = 21.833 m)		1.821
Deck Edge (freeboard pos = 21.833 m)		1.897

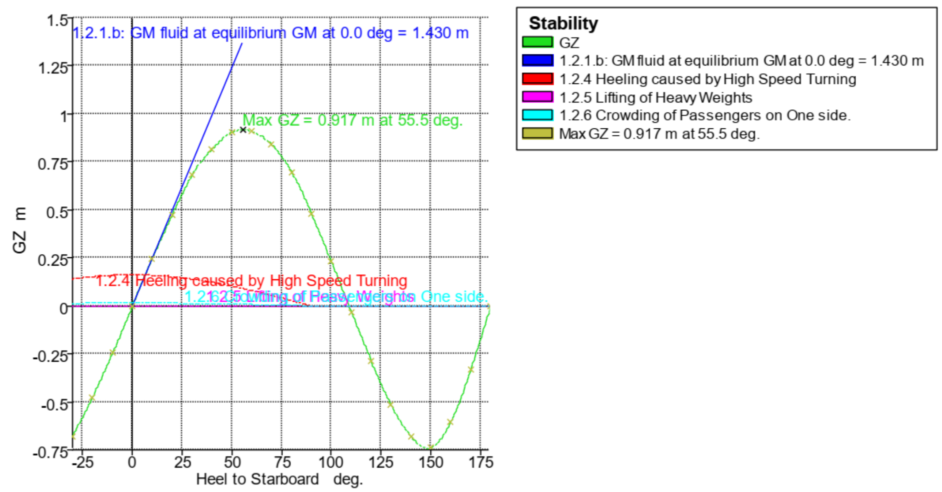
Code	Criteria	Value	Units	Actual	Status	Margin %
Royal Navy, Damage Stability Criteria; DS 02-109(NES109) Part 1	1.3.5.a.(6) Longitudinal GM > 0	0.000	m	93.050	Pass	infinite

Modular ASW – Large Angle Stability

Stability calculation - PatrolVessel 500ton
Stability 23.04.00.76, build: 76
Model file: C:\Users\Felipe\OneDrive\Documentos\Felipe\UCL\MECH0070 - MSC Individual Project\Impact of Mission Modules on Naval Ship Design\Report\MAXSURF Models\PatrolVessel 500ton (Medium precision, 66 sections, Trimming on, Skin thickness not applied). Long. datum: AP; Vert. datum: Baseline. Analysis tolerance - ideal(worst case): Disp.%: 0.01000(0.100); Trim%(LCG-TCG): 0.01000(0.100); Heel%(LCG-TCG): 0.01000(0.100)

Loadcase - PatrolVessel 500ton_Modular_ASW
Damage Case - Intact
Free to Trim
Specific gravity = 1.025; (Density = 1.025 tonne/m^3)
Fluid analysis method: Use corrected VCG

Item Name	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
Lightship	1	369.769	369.769			23.670	0.000	3.002	0.000	User Specified
VLS fwd	1	26.000	26.000			39.790	0.000	3.590	0.000	User Specified
Torpedo Container	1	5.330	5.330			12.450	0.000	5.798	0.000	User Specified
Torpedo Container	1	5.330	5.330			12.450	0.000	5.798	0.000	User Specified
TAS Module	1	14.000	14.000			4.350	0.000	5.798	0.000	User Specified
Aft Ballast Tank Port	0%	0.586	0.000	0.572	0.000	3.991	-0.001	1.535	0.000	Maximum
Aft Ballast Tank Starb	0%	0.586	0.000	0.572	0.000	3.991	0.001	1.535	0.000	Maximum
Aft Ballast Tank Port	0%	0.878	0.000	0.857	0.000	7.446	-0.113	1.000	0.000	Maximum
Aft Ballast Tank Starb	0%	0.878	0.000	0.857	0.000	7.446	0.113	1.000	0.000	Maximum
Aft Ballast Tank Port	0%	1.718	0.000	1.676	0.000	8.060	-0.378	1.000	0.000	Maximum
Aft Ballast Tank Starb	0%	1.718	0.000	1.676	0.000	8.060	0.378	1.000	0.000	Maximum
Aft Diesel Tank	100%	3.318	3.318	3.949	3.949	11.220	-2.516	1.618	0.000	Maximum
Aft Diesel Tank	100%	3.318	3.318	3.949	3.949	11.220	2.516	1.618	0.000	Maximum
Diesel Tank	100%	4.608	4.608	5.485	5.485	16.432	-2.973	1.562	0.000	Maximum
Diesel Tank	100%	4.608	4.608	5.485	5.485	16.432	2.973	1.562	0.000	Maximum
Lub Oil Tank	100%	2.121	2.121	2.305	2.305	19.800	0.000	1.039	0.000	Maximum
Dirty Oil Tank	0%	2.314	0.000	2.314	0.000	20.417	0.000	0.027	0.000	Maximum
Daily Diesel Tank	100%	13.708	13.708	16.320	16.320	22.200	-2.177	2.619	0.000	Maximum
Daily Diesel Tank	100%	13.708	13.708	16.320	16.320	22.200	2.177	2.619	0.000	Maximum
Fwd Diesel Tank	100%	10.665	10.665	12.696	12.696	23.994	-1.525	1.214	0.000	Maximum
Fwd Diesel Tank	100%	10.665	10.665	12.696	12.696	23.994	1.525	1.214	0.000	Maximum
Fresh Water Tank	100%	6.756	6.756	6.756	6.756	29.397	-0.492	1.061	0.000	Maximum
Fresh Water Tank	100%	6.756	6.756	6.756	6.756	29.397	0.492	1.061	0.000	Maximum
Black Water Tank	0%	12.870	0.000	12.556	0.000	34.513	0.000	0.058	0.000	Maximum
Ballast Tank Port	0%	6.306	0.000	6.152	0.000	40.815	0.000	0.057	0.000	Maximum
Ballast Tank Starb	0%	6.306	0.000	6.152	0.000	40.815	0.000	0.057	0.000	Maximum
Fwd Ballast Tank	0%	2.892	0.000	2.821	0.000	43.110	0.000	0.057	0.000	Maximum
Peak Tank	0%	18.609	0.000	18.155	0.000	45.653	0.000	0.059	0.000	Maximum
Total Loadcase			500.658	147.077	92.718	23.501	0.000	2.968	0.000	
FS correction								0.000		
VCG fluid								2.968		



Heel to Starboard deg	-30.0	-20.0	-10.0	0.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0	110.0
GZ m	-0.681	-0.476	-0.246	0.000	0.246	0.476	0.681	0.814	0.903	0.909	0.843	0.696	0.480	0.232	-0.032
Area under GZ curve from zero heel m.deg	10.6646	4.8673	1.2375	0.0000	1.2392	4.8609	10.6892	18.2120	26.8475	35.9786	44.7992	52.5563	58.4762	62.0556	63.0598
Displacement t	500.7	500.6	500.7	500.7	500.7	500.7	500.7	500.7	500.7	500.6	500.7	500.7	500.6	500.6	500.6
Draft at FP m	2.504	2.583	2.614	2.622	2.614	2.583	2.505	2.313	1.906	1.234	-0.015	-3.906	n/a	-12.148	-8.192
Draft at AP m	2.196	2.425	2.552	2.592	2.552	2.425	2.195	1.919	1.604	1.172	0.422	-1.551	n/a	-5.877	-3.944
WL Length m	49.089	49.137	49.155	49.160	49.155	49.136	49.089	48.971	48.719	48.276	47.571	49.054	50.104	50.857	51.379
Beam max extents on WL m	8.047	8.122	8.190	8.215	8.190	8.122	8.047	8.167	7.768	7.027	6.691	6.198	6.009	5.973	6.081
Wetted Area m^2	419.486	415.979	417.016	417.722	417.017	415.981	419.486	429.173	435.496	440.036	436.278	426.760	426.402	427.774	430.642
Waterpl. Area m^2	305.450	310.055	311.701	312.890	311.702	310.057	305.452	290.079	279.018	262.715	253.288	228.627	217.189	212.475	213.726
Prismatic coeff. (Cp)	0.656	0.648	0.641	0.638	0.641	0.648	0.656	0.650	0.633	0.624	0.621	0.593	0.576	0.565	0.557
Block coeff. (Cb)	0.463	0.475	0.476	0.465	0.476	0.475	0.463	0.440	0.449	0.485	0.500	0.507	0.484	0.431	0.388
LCB from zero pt. (+ve fwd) m	23.509	23.507	23.504	23.502	23.503	23.506	23.510	23.511	23.509	23.502	23.495	23.483	23.466	23.448	23.434
LCF from zero pt. (+ve fwd) m	22.911	22.349	22.019	21.888	22.019	22.348	22.911	24.288	25.494	26.211	26.217	26.112	25.858	25.652	25.459
Max deck inclination deg	30.0015	20.0007	10.0003	0.0355	10.0003	20.0007	30.0015	40.0013	50.0004	60.0000	70.0001	80.0003	90.0000	99.9975	109.9909
Trim angle (+ve by stern) deg	-0.3601	-0.1850	-0.0729	-0.0355	-0.0724	-0.1842	-0.3604	-0.4595	-0.3520	-0.0721	0.5100	2.7428	n/a	7.2712	4.9395

Key point	Type	Immersion angle deg	Emergence angle deg	Freeboard at 0.0 deg m	Freeboard at 10.0 deg m	Freeboard at 20.0 deg m	Freeboard at 30.0 deg m	Freeboard at 40.0 deg m	Freeboard at 50.0 deg m	Freeboard at 60.0 deg m	Freeboard at 70.0 deg m	Freeboard at 80.0 deg m	Freeboard at 90.0 deg m	Freeboard at 100.0 deg m	Freeboard at 110.0 deg m	Freeboard at 120.0 deg m	Freeboard at 130.0 deg m	Freeboard at 140.0 deg m	Freeboard at 150.0 deg m	Freeboard at 160.0 deg m	Freeboard at 170.0 deg m	Freeboard at 180.0 deg m
Margin Line (immersion pos = 21.833 m)		25	n/a	1.821	1.071	0.342	-0.340	-0.981	-1.571	-2.116	-2.611	-3.029	-3.352	-3.714	-3.999	-4.144	-4.137	-3.972	-3.636	-3.115	-2.456	-1.724
Deck Edge (immersion pos = 21.833 m)		26	n/a	1.897	1.146	0.413	-0.274	-0.923	-1.522	-2.079	-2.585	-3.016	-3.352	-3.727	-4.025	-4.181	-4.186	-4.030	-3.701	-3.186	-2.530	-1.800

Code	Criteria	Value	Units	Actual	Status	Margin %
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 0 to 30	4.5840	m.deg	10.6892	Pass	+133.19
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 0 to 40	7.6200	m.deg	18.2120	Pass	+139.00
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 30 to 40	2.7500	m.deg	7.5228	Pass	+173.55
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Maximum GZ	0.300	m	0.903	Pass	+201.00
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Angle of maximum GZ	30.0	deg	55.5	Pass	+84.85
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: GM fluid at equilibrium	0.300	m	1.430	Pass	+376.67
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Range of positive stability	70.0	deg	108.8	Pass	+55.42
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Angle of vanishing stability	70.0	deg	108.8	Pass	+55.42
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.4 Heeling caused by High Speed Turning				Pass	
	Angle of steady heel shall be less than (<)	20.0	deg	6.5	Pass	+67.64
	Area1 / Area2 shall be greater than (>)	40.00	%	81.74	Pass	+104.35
	GZ(intersection) / GZ(max) shall be less than (<)	60.00	%	17.79	Pass	+70.35
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.5 Lifting of Heavy Weights				Pass	
	Angle of steady heel shall be less than (<)	15.0	deg	0.0	Pass	+99.94
	Area1 / Area2 shall be greater than (>)	50.00	%	99.94	Pass	+99.88
	GZ(intersection) / GZ(max) shall be less than (<)	50.00	%	0.02	Pass	+99.96
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.6 Crowding of Passengers on One side.				Pass	
	Angle of steady heel shall be less than (<)	10.0	deg	0.6	Pass	+93.99
	Area1 / Area2 shall be greater than (>)	40.00	%	98.21	Pass	+145.52
	GZ(intersection) / GZ(max) shall be less than (<)	60.00	%	1.66	Pass	+97.23

Modular ASuW – Equilibrium

Equilibrium calculation - PatrolVessel 500ton

Stability 23.04.00.76, build: 76
Model file: C:\Users\Felipe\OneDrive\Documentos\Felipe\UCL\MECH0070 - MSC Individual Project\Impact of Mission Modules on Naval Ship Design\Report\MAXSURF Models\PatrolVessel 500ton (Medium precision, 66 sections, Trimming on, Skin thickness not applied). Long. datum: AP; Vert. datum: Baseline. Analysis tolerance - ideal(worst case): Disp.%: 0.01000(0.100); Trim%(LCG-TCG): 0.01000(0.100); Heel%(LCG-TCG): 0.01000(0.100)

Loadcase - PatrolVessel 500ton_Modular_ASuW
Damage Case - Intact
Free to Trim
Specific gravity = 1.025; (Density = 1.025 tonne/m^3)
Fluid analysis method: Use corrected VCG

Item Name	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
Lightship	1	369.769	369.769			23.670	0.000	3.002	0.000	User Specified
Gun 40mm	1	9.350	9.350			39.600	0.000	3.253	0.000	User Specified
7m RIB	1	5.000	5.000			12.450	0.000	5.798	0.000	User Specified
7m RIB	1	5.000	5.000			12.450	0.000	5.798	0.000	User Specified
Missile Container	1	8.180	8.180			4.350	0.000	5.798	0.000	User Specified
Missile Container	1	8.180	8.180			4.350	0.000	5.798	0.000	User Specified
Aft Ballast Tank Port	0%	0.586	0.000	0.572	0.000	3.991	-0.001	1.535	0.000	Maximum
Aft Ballast Tank Starb	0%	0.586	0.000	0.572	0.000	3.991	0.001	1.535	0.000	Maximum
Aft Ballast Tank Port	0%	0.878	0.000	0.857	0.000	7.446	-0.113	1.000	0.000	Maximum
Aft Ballast Tank Starb	0%	0.878	0.000	0.857	0.000	7.446	0.113	1.000	0.000	Maximum
Aft Ballast Tank Port	0%	1.718	0.000	1.676	0.000	8.060	-0.378	1.000	0.000	Maximum
Aft Ballast Tank Starb	0%	1.718	0.000	1.676	0.000	8.060	0.378	1.000	0.000	Maximum
Aft Diesel Tank	100%	3.318	3.318	3.949	3.949	11.220	-2.516	1.618	0.000	Maximum
Aft Diesel Tank	100%	3.318	3.318	3.949	3.949	11.220	2.516	1.618	0.000	Maximum
Diesel Tank	100%	4.608	4.608	5.485	5.485	16.432	-2.973	1.562	0.000	Maximum
Diesel Tank	100%	4.608	4.608	5.485	5.485	16.432	2.973	1.562	0.000	Maximum
Lub Oil Tank	100%	2.121	2.121	2.305	2.305	19.800	0.000	1.039	0.000	Maximum
Dirty Oil Tank	0%	2.314	0.000	2.314	0.000	20.417	0.000	0.027	0.000	Maximum
Daily Diesel Tank	100%	13.708	13.708	16.320	16.320	22.200	-2.177	2.619	0.000	Maximum
Daily Diesel Tank	100%	13.708	13.708	16.320	16.320	22.200	2.177	2.619	0.000	Maximum
Fwd Diesel Tank	100%	10.665	10.665	12.696	12.696	23.994	-1.525	1.214	0.000	Maximum
Fwd Diesel Tank	100%	10.665	10.665	12.696	12.696	23.994	1.525	1.214	0.000	Maximum
Fresh Water Tank	100%	6.756	6.756	6.756	6.756	29.397	-0.492	1.061	0.000	Maximum
Fresh Water Tank	100%	6.756	6.756	6.756	6.756	29.397	0.492	1.061	0.000	Maximum
Black Water Tank	0%	12.870	0.000	12.556	0.000	34.513	0.000	0.058	0.000	Maximum
Ballast Tank Port	0%	6.306	0.000	6.152	0.000	40.815	0.000	0.057	0.000	Maximum
Ballast Tank Starb	0%	6.306	0.000	6.152	0.000	40.815	0.000	0.057	0.000	Maximum
Fwd Ballast Tank	0%	2.892	0.000	2.821	0.000	43.110	0.000	0.057	0.000	Maximum
Peak Tank	0%	18.609	0.000	18.155	0.000	45.653	0.000	0.059	0.000	Maximum
Total Loadcase			485.708	147.077	92.718	22.861	0.000	2.950	0.000	
FS correction								0.000		
VCG fluid								2.950		

Draft Amidships m	2.540
Displacement t	485.7
Heel deg	0.0
Draft at FP m	2.376
Draft at AP m	2.704
Draft at LCF m	2.560
Trim (+ve by stern) m	0.328
WL Length m	49.011
Beam max extents on WL m	8.196
Wetted Area m^2	411.532
Waterpl. Area m^2	310.770
Prismatic coeff. (Cp)	0.634
Block coeff. (Cb)	0.444
Max Sect. area coeff. (Cm)	0.732
Waterpl. area coeff. (Cwp)	0.774
LCB from zero pt. (+ve fwd) m	22.852
LCF from zero pt. (+ve fwd) m	21.601
KB m	1.626
KG fluid m	2.950
BMt m	2.805
BML m	95.875
GMt corrected m	1.481
GML m	94.552
KMt m	4.431
KML m	97.499
Immersion (TPc) tonne/cm	3.185
MTc tonne.m	9.344
RM at 1deg = GMt.Disp.sin(1) tonne.m	12.555
Max deck inclination deg	0.3826
Trim angle (+ve by stern) deg	0.3826

Key point	Type	Freeboard m
Margin Line (freeboard pos = 0 m)		1.722
Deck Edge (freeboard pos = 0 m)		1.798

Code	Criteria	Value	Units	Actual	Status	Margin %
Royal Navy, Damage Stability Criteria; DS 02-109(NES109) Part 1	1.3.5.a.(6) Longitudinal GM > 0	0.000	m	94.552	Pass	infinite

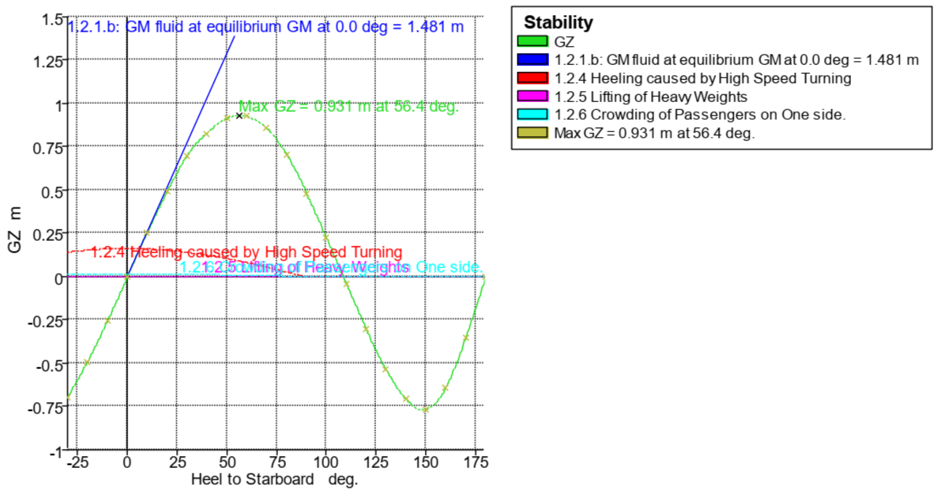
Modular ASuW – Large Angle Stability

Stability calculation - PatrolVessel 500ton

Stability 23.04.00.76, build: 76
Model file: C:\Users\Felipe\OneDrive\Documentos\Felipe\UCL\MECH0070 - MSC Individual Project\Impact of Mission Modules on Naval Ship Design\Report\MAXSURF Models\PatrolVessel 500ton (Medium precision, 66 sections, Trimming on, Skin thickness not applied). Long. datum: AP; Vert. datum: Baseline. Analysis tolerance - ideal(worst case): Disp.%: 0.01000(0.100); Trim%(LCG-TCG): 0.01000(0.100); Heel%(LCG-TCG): 0.01000(0.100)

Loadcase - PatrolVessel 500ton_Modular_ASuW
Damage Case - Intact
Free to Trim
Specific gravity = 1.025; (Density = 1.025 tonne/m^3)
Fluid analysis method: Use corrected VCG

Item Name	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
Lightship	1	369.769	369.769			23.670	0.000	3.002	0.000	User Specified
Gun_40mm	1	9.350	9.350			39.600	0.000	3.253	0.000	User Specified
7m RIB	1	5.000	5.000			12.450	0.000	5.798	0.000	User Specified
7m RIB	1	5.000	5.000			12.450	0.000	5.798	0.000	User Specified
Missile Container	1	8.180	8.180			4.350	0.000	5.798	0.000	User Specified
Missile Container	1	8.180	8.180			4.350	0.000	5.798	0.000	User Specified
Aft Ballast Tank Port	0%	0.586	0.000	0.572	0.000	3.991	-0.001	1.535	0.000	Maximum
Aft Ballast Tank Starb	0%	0.586	0.000	0.572	0.000	3.991	0.001	1.535	0.000	Maximum
Aft Ballast Tank Port	0%	0.878	0.000	0.857	0.000	7.446	-0.113	1.000	0.000	Maximum
Aft Ballast Tank Starb	0%	0.878	0.000	0.857	0.000	7.446	0.113	1.000	0.000	Maximum
Aft Ballast Tank Port	0%	1.718	0.000	1.676	0.000	8.060	-0.378	1.000	0.000	Maximum
Aft Ballast Tank Starb	0%	1.718	0.000	1.676	0.000	8.060	0.378	1.000	0.000	Maximum
Aft Diesel Tank	100%	3.318	3.318	3.949	3.949	11.220	-2.516	1.618	0.000	Maximum
Aft Diesel Tank	100%	3.318	3.318	3.949	3.949	11.220	2.516	1.618	0.000	Maximum
Diesel Tank	100%	4.608	4.608	5.485	5.485	16.432	-2.973	1.562	0.000	Maximum
Diesel Tank	100%	4.608	4.608	5.485	5.485	16.432	2.973	1.562	0.000	Maximum
Lub Oil Tank	100%	2.121	2.121	2.305	2.305	19.800	0.000	1.039	0.000	Maximum
Dirty Oil Tank	0%	2.314	0.000	2.314	0.000	20.417	0.000	0.027	0.000	Maximum
Daily Diesel Tank	100%	13.708	13.708	16.320	16.320	22.200	-2.177	2.619	0.000	Maximum
Daily Diesel Tank	100%	13.708	13.708	16.320	16.320	22.200	2.177	2.619	0.000	Maximum
Fwd Diesel Tank	100%	10.665	10.665	12.696	12.696	23.994	-1.525	1.214	0.000	Maximum
Fwd Diesel Tank	100%	10.665	10.665	12.696	12.696	23.994	1.525	1.214	0.000	Maximum
Fresh Water Tank	100%	6.756	6.756	6.756	6.756	29.397	-0.492	1.061	0.000	Maximum
Fresh Water Tank	100%	6.756	6.756	6.756	6.756	29.397	0.492	1.061	0.000	Maximum
Black Water Tank	0%	12.870	0.000	12.556	0.000	34.513	0.000	0.058	0.000	Maximum
Ballast Tank Port	0%	6.306	0.000	6.152	0.000	40.815	0.000	0.057	0.000	Maximum
Ballast Tank Starb	0%	6.306	0.000	6.152	0.000	40.815	0.000	0.057	0.000	Maximum
Fwd Ballast Tank	0%	2.892	0.000	2.821	0.000	43.110	0.000	0.057	0.000	Maximum
Peak Tank	0%	18.609	0.000	18.155	0.000	45.653	0.000	0.059	0.000	Maximum
Total Loadcase			485.708	147.077	92.718	22.861	0.000	2.950	0.000	
FS correction								0.000		
VCG fluid								2.950		



Heel to Starboard deg	-30.0	-20.0	-10.0	0.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0	110.0
GZ m	-0.699	-0.491	-0.255	0.000	0.255	0.491	0.699	0.827	0.913	0.926	0.860	0.705	0.482	0.228	-0.042
Area under GZ curve from zero heel m.deg	11.0012	5.0343	1.2822	0.0000	1.2840	5.0270	11.0291	18.7110	27.4494	36.7121	45.7133	53.6071	59.5836	63.1526	64.0845
Displacement t	485.7	485.7	485.7	485.7	485.7	485.7	485.7	485.7	485.7	485.7	485.7	485.7	485.7	485.7	485.7
Draft at FP m	2.237	2.327	2.365	2.376	2.365	2.326	2.238	2.023	1.577	0.816	-0.658	-5.339	n/a	-13.704	-8.981
Draft at AP m	2.323	2.544	2.666	2.704	2.666	2.545	2.323	2.069	1.785	1.408	0.778	-0.744	n/a	-5.033	-3.522
WL Length m	48.925	48.981	49.005	49.011	49.004	48.980	48.926	48.793	48.511	47.970	46.865	48.347	49.444	50.261	50.934
Beam max extents on WL m	7.984	8.088	8.168	8.196	8.168	8.088	7.984	8.103	7.784	7.042	6.562	6.190	5.998	5.957	6.060
Wetted Area m^2	412.912	409.564	410.850	411.532	410.851	409.566	412.913	422.511	428.672	431.678	427.127	418.036	417.980	419.504	422.435
Waterpl. Area m^2	301.595	307.458	309.556	310.770	309.557	307.460	301.601	284.912	275.915	259.564	245.522	223.097	212.175	207.745	209.068
Prismatic coeff. (Cp)	0.656	0.645	0.637	0.634	0.637	0.645	0.656	0.649	0.629	0.620	0.621	0.594	0.577	0.565	0.556
Block coeff. (Cb)	0.460	0.472	0.455	0.444	0.455	0.472	0.460	0.436	0.440	0.475	0.505	0.501	0.474	0.431	0.387
LCB from zero pt. (+ve fwd) m	22.859	22.857	22.854	22.852	22.853	22.856	22.860	22.859	22.857	22.849	22.844	22.824	22.806	22.792	22.773
LCF from zero pt. (+ve fwd) m	22.635	22.043	21.722	21.601	21.722	22.042	22.635	24.053	25.268	25.940	25.669	25.636	25.406	25.216	25.031
Max deck inclination deg	30.0001	20.0014	10.0059	0.3823	10.0059	20.0014	30.0001	40.0000	50.0002	60.0006	70.0010	80.0013	90.0000	99.9953	109.9850
Trim angle (+ve by stern) deg	0.0998	0.2539	0.3506	0.3823	0.3509	0.2545	0.0990	0.0542	0.2423	0.6906	1.6726	5.3422	n/a	10.0050	6.3384

Key point	Type	Immersion angle deg	Emergence angle deg	Freeboard at 0.0 deg m	Freeboard at 10.0 deg m	Freeboard at 20.0 deg m	Freeboard at 30.0 deg m	Freeboard at 40.0 deg m	Freeboard at 50.0 deg m	Freeboard at 60.0 deg m	Freeboard at 70.0 deg m	Freeboard at 80.0 deg m	Freeboard at 90.0 deg m	Freeboard at 100.0 deg m	Freeboard at 110.0 deg m	Freeboard at 120.0 deg m	Freeboard at 130.0 deg m	Freeboard at 140.0 deg m	Freeboard at 150.0 deg m	Freeboard at 160.0 deg m	Freeboard at 170.0 deg m	Freeboard at 180.0 deg m
Margin Line (immersion pos = 20.198 m)		25.6	n/a	1.722	1.080	0.380	-0.299	-0.947	-1.542	-2.093	-2.594	-3.026	-3.371	-3.661	-3.945	-4.089	-4.084	-3.922	-3.591	-3.076	-2.418	-1.788
Deck Edge (immersion pos = 20.198 m)		26.6	n/a	1.798	1.155	0.451	-0.233	-0.889	-1.493	-2.055	-2.568	-3.013	-3.371	-3.673	-3.970	-4.127	-4.133	-3.980	-3.657	-3.148	-2.493	-1.864

Code	Criteria	Value	Units	Actual	Status	Margin %
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 0 to 30	4.5840	m.deg	11.0291	Pass	+140.60
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 0 to 40	7.6200	m.deg	18.7110	Pass	+145.55
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 30 to 40	2.7500	m.deg	7.6819	Pass	+179.34
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Maximum GZ	0.300	m	0.913	Pass	+204.33
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Angle of maximum GZ	30.0	deg	56.4	Pass	+87.88
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: GM fluid at equilibrium	0.300	m	1.481	Pass	+393.67
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Range of positive stability	70.0	deg	108.4	Pass	+54.92
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Angle of vanishing stability	70.0	deg	108.4	Pass	+54.92
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.4 Heeling caused by High Speed Turning				Pass	
	Angle of steady heel shall be less than (<)	20.0	deg	6.3	Pass	+68.47
	Area1 / Area2 shall be greater than (>)	40.00	%	81.90	Pass	+104.75
	GZ(intersection) / GZ(max) shall be less than (<)	60.00	%	17.77	Pass	+70.38
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.5 Lifting of Heavy Weights				Pass	
	Angle of steady heel shall be less than (<)	15.0	deg	0.0	Pass	+99.94
	Area1 / Area2 shall be greater than (>)	50.00	%	99.94	Pass	+99.88
	GZ(intersection) / GZ(max) shall be less than (<)	50.00	%	0.02	Pass	+99.96
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.6 Crowding of Passengers on One side.				Pass	
	Angle of steady heel shall be less than (<)	10.0	deg	0.6	Pass	+94.03
	Area1 / Area2 shall be greater than (>)	40.00	%	98.19	Pass	+145.47
	GZ(intersection) / GZ(max) shall be less than (<)	60.00	%	1.69	Pass	+97.18

Modular MW – Equilibrium

Equilibrium calculation - PatrolVessel 500ton

Stability 23.04.00.76, build: 76
Model file: C:\Users\Felipe\OneDrive\Documentos\Felipe\UCL\MECH0070 - MSC Individual Project\Impact of Mission Modules on Naval Ship Design\Report\MAXSURF Models\PatrolVessel 500ton (Medium precision, 66 sections, Trimming on, Skin thickness not applied). Long. datum: AP; Vert. datum: Baseline. Analysis tolerance - ideal(worst case): Disp.%: 0.01000(0.100); Trim%(LCG-TCG): 0.01000(0.100); Heel%(LCG-TCG): 0.01000(0.100)

Loadcase - PatrolVessel 500ton_Modular_MW
Damage Case - Intact
Free to Trim
Specific gravity = 1.025; (Density = 1.025 tonne/m^3)
Fluid analysis method: Use corrected VCG

Item Name	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
Lightship	1	369.769	369.769			23.670	0.000	3.002	0.000	User Specified
7m RIB	1	5.000	5.000			12.450	0.000	5.798	0.000	User Specified
7m RIB	1	5.000	5.000			12.450	0.000	5.798	0.000	User Specified
UUV Module	1	2.930	2.930			4.350	0.000	5.798	0.000	User Specified
UUV Module	1	2.930	2.930			4.350	0.000	5.798	0.000	User Specified
Aft Ballast Tank Port	0%	0.586	0.000	0.572	0.000	3.991	-0.001	1.535	0.000	Maximum
Aft Ballast Tank Starb	0%	0.586	0.000	0.572	0.000	3.991	0.001	1.535	0.000	Maximum
Aft Ballast Tank Port	0%	0.878	0.000	0.857	0.000	7.446	-0.113	1.000	0.000	Maximum
Aft Ballast Tank Starb	0%	0.878	0.000	0.857	0.000	7.446	0.113	1.000	0.000	Maximum
Aft Ballast Tank Port	0%	1.718	0.000	1.676	0.000	8.060	-0.378	1.000	0.000	Maximum
Aft Ballast Tank Starb	0%	1.718	0.000	1.676	0.000	8.060	0.378	1.000	0.000	Maximum
Aft Diesel Tank	100%	3.318	3.318	3.949	3.949	11.220	-2.516	1.618	0.000	Maximum
Aft Diesel Tank	100%	3.318	3.318	3.949	3.949	11.220	2.516	1.618	0.000	Maximum
Diesel Tank	100%	4.608	4.608	5.485	5.485	16.432	-2.973	1.562	0.000	Maximum
Diesel Tank	100%	4.608	4.608	5.485	5.485	16.432	2.973	1.562	0.000	Maximum
Lub Oil Tank	100%	2.121	2.121	2.305	2.305	19.800	0.000	1.039	0.000	Maximum
Dirty Oil Tank	0%	2.314	0.000	2.314	0.000	20.417	0.000	0.027	0.000	Maximum
Daily Diesel Tank	100%	13.708	13.708	16.320	16.320	22.200	-2.177	2.619	0.000	Maximum
Daily Diesel Tank	100%	13.708	13.708	16.320	16.320	22.200	2.177	2.619	0.000	Maximum
Fwd Diesel Tank	100%	10.665	10.665	12.696	12.696	23.994	-1.525	1.214	0.000	Maximum
Fwd Diesel Tank	100%	10.665	10.665	12.696	12.696	23.994	1.525	1.214	0.000	Maximum
Fresh Water Tank	100%	6.756	6.756	6.756	6.756	29.397	-0.492	1.061	0.000	Maximum
Fresh Water Tank	100%	6.756	6.756	6.756	6.756	29.397	0.492	1.061	0.000	Maximum
Black Water Tank	0%	12.870	0.000	12.556	0.000	34.513	0.000	0.058	0.000	Maximum
Ballast Tank Port	0%	6.306	0.000	6.152	0.000	40.815	0.000	0.057	0.000	Maximum
Ballast Tank Starb	0%	6.306	0.000	6.152	0.000	40.815	0.000	0.057	0.000	Maximum
Fwd Ballast Tank	0%	2.892	0.000	2.821	0.000	43.110	0.000	0.057	0.000	Maximum
Peak Tank	0%	18.609	0.000	18.155	0.000	45.653	0.000	0.059	0.000	Maximum
Total Loadcase			465.858	147.077	92.718	22.942	0.000	2.879	0.000	
FS correction								0.000		
VCG fluid								2.879		

Draft Amidships m	2.478
Displacement t	465.9
Heel deg	0.0
Draft at FP m	2.321
Draft at AP m	2.635
Draft at LCF m	2.497
Trim (+ve by stern) m	0.314
WL Length m	48.978
Beam max extents on WL m	8.161
Wetted Area m^2	404.194
Waterpl. Area m^2	307.582
Prismatic coeff. (Cp)	0.629
Block coeff. (Cb)	0.439
Max Sect. area coeff. (Cm)	0.729
Waterpl. area coeff. (Cwp)	0.770
LCB from zero pt. (+ve fwd) m	22.934
LCF from zero pt. (+ve fwd) m	21.615
KB m	1.587
KG fluid m	2.879
BMt m	2.851
BML m	98.261
GMt corrected m	1.559
GML m	96.969
KMt m	4.439
KML m	99.846
Immersion (TPc) tonne/cm	3.153
MTc tonne.m	9.191
RM at 1deg = GMt.Disp.sin(1) tonne.m	12.678
Max deck inclination deg	0.3659
Trim angle (+ve by stern) deg	0.3659

Key point	Type	Freeboard m
Margin Line (freeboard pos = 0 m)		1.791
Deck Edge (freeboard pos = 0 m)		1.867

Code	Criteria	Value	Units	Actual	Status	Margin %
Royal Navy, Damage Stability Criteria; DS 02-109(NES109) Part 1	1.3.5.a.(6) Longitudinal GM > 0	0.000	m	96.969	Pass	infinite

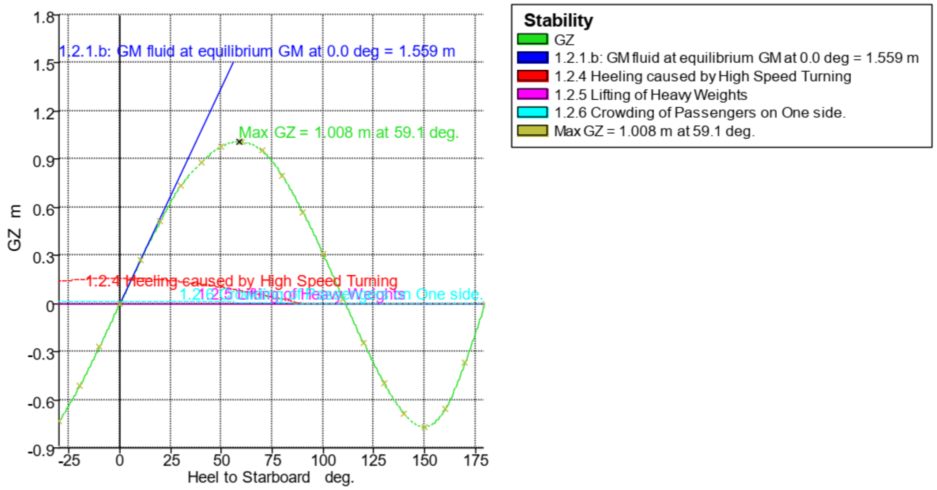
Modular MW – Large Angle Stability

Stability calculation - PatrolVessel 500ton

Stability 23.04.00.76, build: 76
Model file: C:\Users\Felipe\OneDrive\Documentos\Felipe\UCL\MECH0070 - MSC Individual Project\Impact of Mission Modules on Naval Ship Design\Report\MAXSURF Models\PatrolVessel 500ton (Medium precision, 66 sections, Trimming on, Skin thickness not applied). Long. datum: AP; Vert. datum: Baseline. Analysis tolerance - ideal(worst case): Disp.%: 0.01000(0.100); Trim%(LCG-TCG): 0.01000(0.100); Heel%(LCG-TCG): 0.01000(0.100)

Loadcase - PatrolVessel 500ton_Modular_MW
Damage Case - Intact
Free to Trim
Specific gravity = 1.025; (Density = 1.025 tonne/m^3)
Fluid analysis method: Use corrected VCG

Item Name	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
Lightship	1	369.769	369.769			23.670	0.000	3.002	0.000	User Specified
7m RIB	1	5.000	5.000			12.450	0.000	5.798	0.000	User Specified
7m RIB	1	5.000	5.000			12.450	0.000	5.798	0.000	User Specified
UUV Module	1	2.930	2.930			4.350	0.000	5.798	0.000	User Specified
UUV Module	1	2.930	2.930			4.350	0.000	5.798	0.000	User Specified
Aft Ballast Tank Port	0%	0.586	0.000	0.572	0.000	3.991	-0.001	1.535	0.000	Maximum
Aft Ballast Tank Starb	0%	0.586	0.000	0.572	0.000	3.991	0.001	1.535	0.000	Maximum
Aft Ballast Tank Port	0%	0.878	0.000	0.857	0.000	7.446	-0.113	1.000	0.000	Maximum
Aft Ballast Tank Starb	0%	0.878	0.000	0.857	0.000	7.446	0.113	1.000	0.000	Maximum
Aft Ballast Tank Port	0%	1.718	0.000	1.676	0.000	8.060	-0.378	1.000	0.000	Maximum
Aft Ballast Tank Starb	0%	1.718	0.000	1.676	0.000	8.060	0.378	1.000	0.000	Maximum
Aft Diesel Tank	100%	3.318	3.318	3.949	3.949	11.220	-2.516	1.618	0.000	Maximum
Aft Diesel Tank	100%	3.318	3.318	3.949	3.949	11.220	2.516	1.618	0.000	Maximum
Diesel Tank	100%	4.608	4.608	5.485	5.485	16.432	-2.973	1.562	0.000	Maximum
Diesel Tank	100%	4.608	4.608	5.485	5.485	16.432	2.973	1.562	0.000	Maximum
Lub Oil Tank	100%	2.121	2.121	2.305	2.305	19.800	0.000	1.039	0.000	Maximum
Dirty Oil Tank	0%	2.314	0.000	2.314	0.000	20.417	0.000	0.027	0.000	Maximum
Daily Diesel Tank	100%	13.708	13.708	16.320	16.320	22.200	-2.177	2.619	0.000	Maximum
Daily Diesel Tank	100%	13.708	13.708	16.320	16.320	22.200	2.177	2.619	0.000	Maximum
Fwd Diesel Tank	100%	10.665	10.665	12.696	12.696	23.994	-1.525	1.214	0.000	Maximum
Fwd Diesel Tank	100%	10.665	10.665	12.696	12.696	23.994	1.525	1.214	0.000	Maximum
Fresh Water Tank	100%	6.756	6.756	6.756	6.756	29.397	-0.492	1.061	0.000	Maximum
Fresh Water Tank	100%	6.756	6.756	6.756	6.756	29.397	0.492	1.061	0.000	Maximum
Black Water Tank	0%	12.870	0.000	12.556	0.000	34.513	0.000	0.058	0.000	Maximum
Ballast Tank Port	0%	6.306	0.000	6.152	0.000	40.815	0.000	0.057	0.000	Maximum
Ballast Tank Starb	0%	6.306	0.000	6.152	0.000	40.815	0.000	0.057	0.000	Maximum
Fwd Ballast Tank	0%	2.892	0.000	2.821	0.000	43.110	0.000	0.057	0.000	Maximum
Peak Tank	0%	18.609	0.000	18.155	0.000	45.653	0.000	0.059	0.000	Maximum
Total Loadcase			465.858	147.077	92.718	22.942	0.000	2.879	0.000	
FS correction								0.000		
VCG fluid								2.879		



Heel to Starboard deg	-30.0	-20.0	-10.0	0.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0	110.0
GZ m	-0.735	-0.515	-0.268	0.000	0.268	0.515	0.735	0.878	0.978	1.008	0.954	0.797	0.570	0.308	0.027
Area under GZ curve from zero heel m.deg	11.5530	5.2885	1.3489	0.0000	1.3506	5.2819	11.5785	19.6945	29.0173	39.0117	48.9008	57.7325	64.6100	69.0218	70.7002
Displacement t	465.9	465.8	465.9	465.9	465.9	465.9	465.9	465.9	465.9	465.8	465.8	465.8	465.8	465.8	465.9
Draft at FP m	2.185	2.273	2.311	2.321	2.311	2.273	2.185	1.980	1.544	0.781	-0.722	-5.465	n/a	-13.883	-9.080
Draft at AP m	2.230	2.466	2.594	2.635	2.595	2.466	2.230	1.936	1.596	1.131	0.365	-1.654	n/a	-5.952	-3.974
WL Length m	48.893	48.948	48.971	48.978	48.971	48.948	48.893	48.766	48.488	47.934	46.758	48.273	49.369	50.196	50.864
Beam max extents on WL m	7.907	8.027	8.123	8.161	8.123	8.028	7.907	8.005	7.809	7.057	6.559	6.174	5.977	5.926	6.022
Wetted Area m^2	403.808	401.869	403.349	404.194	403.351	401.871	403.808	413.090	419.267	422.068	415.411	407.863	407.757	409.218	412.108
Waterpl. Area m^2	300.399	303.703	306.113	307.582	306.114	303.705	300.404	283.889	275.981	259.732	244.230	221.421	210.377	205.773	206.872
Prismatic coeff. (Cp)	0.651	0.641	0.633	0.629	0.633	0.641	0.651	0.647	0.627	0.617	0.618	0.591	0.574	0.562	0.553
Block coeff. (Cb)	0.458	0.468	0.451	0.439	0.451	0.468	0.458	0.435	0.433	0.469	0.501	0.499	0.474	0.427	0.383
LCB from zero pt. (+ve fwd) m	22.941	22.939	22.936	22.934	22.935	22.938	22.942	22.943	22.941	22.935	22.926	22.911	22.893	22.873	22.853
LCF from zero pt. (+ve fwd) m	22.569	22.065	21.743	21.615	21.743	22.065	22.570	23.945	25.206	25.894	25.614	25.594	25.368	25.176	24.996
Max deck inclination deg	30.0000	20.0011	10.0052	0.3656	10.0053	20.0011	30.0000	40.0000	50.0000	60.0002	70.0006	80.0009	90.0000	99.9960	109.9868
Trim angle (+ve by stern) deg	0.0524	0.2240	0.3304	0.3656	0.3308	0.2248	0.0516	-0.0511	0.0606	0.4081	1.2667	4.4335	n/a	9.1667	5.9312

Key point	Type	Immersion angle deg	Emergence angle deg	Freeboard at 0.0 deg m	Freeboard at 10.0 deg m	Freeboard at 20.0 deg m	Freeboard at 30.0 deg m	Freeboard at 40.0 deg m	Freeboard at 50.0 deg m	Freeboard at 60.0 deg m	Freeboard at 70.0 deg m	Freeboard at 80.0 deg m	Freeboard at 90.0 deg m	Freeboard at 100.0 deg m	Freeboard at 110.0 deg m	Freeboard at 120.0 deg m	Freeboard at 130.0 deg m	Freeboard at 140.0 deg m	Freeboard at 150.0 deg m	Freeboard at 160.0 deg m	Freeboard at 170.0 deg m	Freeboard at 180.0 deg m
Margin Line (immersion pos = 20.198 m)		26.6	n/a	1.791	1.147	0.445	-0.234	-0.876	-1.465	-2.005	-2.499	-2.915	-3.248	-3.563	-3.848	-3.996	-3.998	-3.844	-3.523	-3.019	-2.365	-1.714
Deck Edge (immersion pos = 21.833 m)		27.6	n/a	1.867	1.222	0.516	-0.168	-0.817	-1.416	-1.967	-2.473	-2.902	-3.248	-3.576	-3.874	-4.034	-4.046	-3.902	-3.589	-3.090	-2.439	-1.790

Code	Criteria	Value	Units	Actual	Status	Margin %
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 0 to 30	4.5840	m.deg	11.5785	Pass	+152.58
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 0 to 40	7.6200	m.deg	19.6945	Pass	+158.46
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 30 to 40	2.7500	m.deg	8.1160	Pass	+195.13
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Maximum GZ	0.300	m	0.978	Pass	+226.00
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Angle of maximum GZ	30.0	deg	59.1	Pass	+96.97
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: GM fluid at equilibrium	0.300	m	1.559	Pass	+419.67
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Range of positive stability	70.0	deg	111.0	Pass	+58.52
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Angle of vanishing stability	70.0	deg	111.0	Pass	+58.52
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.4 Heeling caused by High Speed Turning				Pass	
	Angle of steady heel shall be less than (<)	20.0	deg	5.9	Pass	+70.73
	Area1 / Area2 shall be greater than (>)	40.00	%	83.41	Pass	+108.52
	GZ(intersection) / GZ(max) shall be less than (<)	60.00	%	16.21	Pass	+72.98
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.5 Lifting of Heavy Weights				Pass	
	Angle of steady heel shall be less than (<)	15.0	deg	0.0	Pass	+99.94
	Area1 / Area2 shall be greater than (>)	50.00	%	99.94	Pass	+99.88
	GZ(intersection) / GZ(max) shall be less than (<)	50.00	%	0.02	Pass	+99.96
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.6 Crowding of Passengers on One side.				Pass	
	Angle of steady heel shall be less than (<)	10.0	deg	0.6	Pass	+94.08
	Area1 / Area2 shall be greater than (>)	40.00	%	98.24	Pass	+145.60
	GZ(intersection) / GZ(max) shall be less than (<)	60.00	%	1.65	Pass	+97.25

Modular No Modules – Equilibrium

Equilibrium calculation - PatrolVessel 500ton

Stability 23.04.00.76, build: 76
Model file: C:\Users\Felipe\OneDrive\Documentos\Felipe\UCL\MECH0070 - MSC Individual Project\Impact of Mission Modules on Naval Ship Design\Report\MAXSURF Models\PatrolVessel 500ton (Medium precision, 66 sections, Trimming on, Skin thickness not applied). Long. datum: AP; Vert. datum: Baseline. Analysis tolerance - ideal(worst case): Disp.%: 0.01000(0.100); Trim%(LCG-TCG): 0.01000(0.100); Heel%(LCG-TCG): 0.01000(0.100)

Loadcase - PatrolVessel 500ton_Modular_No_Modules
Damage Case - Intact
Free to Trim
Specific gravity = 1.025; (Density = 1.025 tonne/m^3)
Fluid analysis method: Use corrected VCG

Item Name	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
Lightship	1	369.769	369.769			23.670	0.000	3.002	0.000	User Specified
Aft Ballast Tank Port	0%	0.586	0.000	0.572	0.000	3.991	-0.001	1.535	0.000	Maximum
Aft Ballast Tank Starb	0%	0.586	0.000	0.572	0.000	3.991	0.001	1.535	0.000	Maximum
Aft Ballast Tank Port	0%	0.878	0.000	0.857	0.000	7.446	-0.113	1.000	0.000	Maximum
Aft Ballast Tank Starb	0%	0.878	0.000	0.857	0.000	7.446	0.113	1.000	0.000	Maximum
Aft Ballast Tank Port	0%	1.718	0.000	1.676	0.000	8.060	-0.378	1.000	0.000	Maximum
Aft Ballast Tank Starb	0%	1.718	0.000	1.676	0.000	8.060	0.378	1.000	0.000	Maximum
Aft Diesel Tank	100%	3.318	3.318	3.949	3.949	11.220	-2.516	1.618	0.000	Maximum
Aft Diesel Tank	100%	3.318	3.318	3.949	3.949	11.220	2.516	1.618	0.000	Maximum
Diesel Tank	100%	4.608	4.608	5.485	5.485	16.432	-2.973	1.562	0.000	Maximum
Diesel Tank	100%	4.608	4.608	5.485	5.485	16.432	2.973	1.562	0.000	Maximum
Lub Oil Tank	100%	2.121	2.121	2.305	2.305	19.800	0.000	1.039	0.000	Maximum
Dirty Oil Tank	0%	2.314	0.000	2.314	0.000	20.417	0.000	0.027	0.000	Maximum
Daily Diesel Tank	100%	13.708	13.708	16.320	16.320	22.200	-2.177	2.619	0.000	Maximum
Daily Diesel Tank	100%	13.708	13.708	16.320	16.320	22.200	2.177	2.619	0.000	Maximum
Fwd Diesel Tank	100%	10.665	10.665	12.696	12.696	23.994	-1.525	1.214	0.000	Maximum
Fwd Diesel Tank	100%	10.665	10.665	12.696	12.696	23.994	1.525	1.214	0.000	Maximum
Fresh Water Tank	100%	6.756	6.756	6.756	6.756	29.397	-0.492	1.061	0.000	Maximum
Fresh Water Tank	100%	6.756	6.756	6.756	6.756	29.397	0.492	1.061	0.000	Maximum
Black Water Tank	0%	12.870	0.000	12.556	0.000	34.513	0.000	0.058	0.000	Maximum
Ballast Tank Port	0%	6.306	0.000	6.152	0.000	40.815	0.000	0.057	0.000	Maximum
Ballast Tank Starb	0%	6.306	0.000	6.152	0.000	40.815	0.000	0.057	0.000	Maximum
Fwd Ballast Tank	0%	2.892	0.000	2.821	0.000	43.110	0.000	0.057	0.000	Maximum
Peak Tank	0%	18.609	0.000	18.155	0.000	45.653	0.000	0.059	0.000	Maximum
Total Loadcase			449.998	147.077	92.718	23.418	0.000	2.777	0.000	
FS correction								0.000		
VCG fluid								2.777		

Draft Amidships m	2.440
Displacement t	450.0
Heel deg	0.0
Draft at FP m	2.390
Draft at AP m	2.490
Draft at LCF m	2.446
Trim (+ve by stern) m	0.099
WL Length m	49.019
Beam max extents on WL m	8.128
Wetted Area m^2	398.446
Waterpl. Area m^2	304.524
Prismatic coeff. (Cp)	0.627
Block coeff. (Cb)	0.445
Max Sect. area coeff. (Cm)	0.729
Waterpl. area coeff. (Cwp)	0.764
LCB from zero pt. (+ve fwd) m	23.418
LCF from zero pt. (+ve fwd) m	21.817
KB m	1.555
KG fluid m	2.777
BMt m	2.869
BML m	100.154
GMt corrected m	1.647
GML m	98.932
KMt m	4.424
KML m	101.709
Immersion (TPc) tonne/cm	3.121
MTc tonne.m	9.058
RM at 1deg = GMt.Disp.sin(1) tonne.m	12.938
Max deck inclination deg	0.1155
Trim angle (+ve by stern) deg	0.1155

Key point	Type	Freeboard m
Margin Line (freeboard pos = 0 m)		1.936
Deck Edge (freeboard pos = 0 m)		2.012

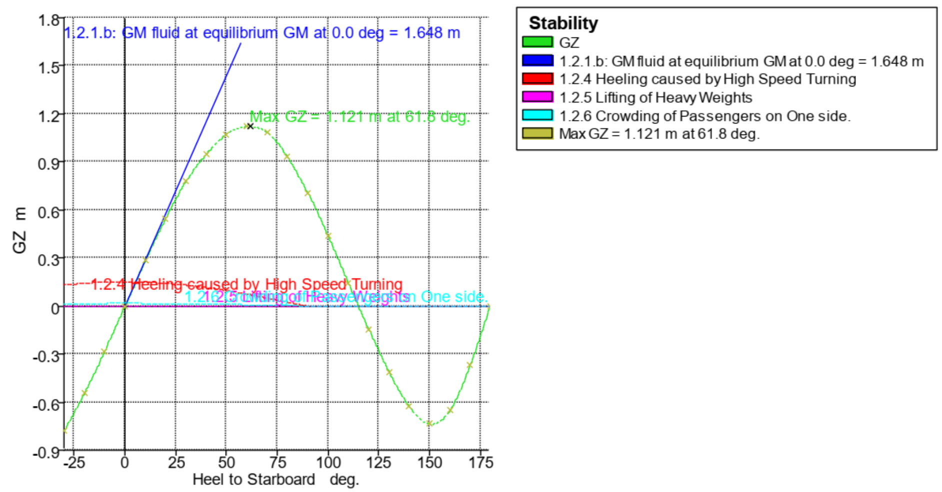
Code	Criteria	Value	Units	Actual	Status	Margin %
Royal Navy, Damage Stability Criteria; DS 02-109(NES109) Part 1	1.3.5.a.(6) Longitudinal GM > 0	0.000	m	98.932	Pass	infinite

Modular No Modules – Large Angle Stability

Stability calculation - PatrolVessel 500ton
Stability 23.04.00.76, build: 76
Model file: C:\Users\Felipe\OneDrive\Documentos\Felipe\UCL\MECH0070 - MSC Individual Project\Impact of Mission Modules on Naval Ship Design\Report\MAXSURF Models\PatrolVessel 500ton (Medium precision, 66 sections, Trimming on, Skin thickness not applied). Long. datum: AP; Vert. datum: Baseline. Analysis tolerance - ideal(worst case): Disp.%: 0.01000(0.100); Trim%(LCG-TCG): 0.01000(0.100); Heel%(LCG-TCG): 0.01000(0.100)

Loadcase - PatrolVessel 500ton_Modular_No_Modules
Damage Case - Intact
Free to Trim
Specific gravity = 1.025; (Density = 1.025 tonne/m^3)
Fluid analysis method: Use corrected VCG

Item Name	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
Lightship	1	369.769	369.769			23.670	0.000	3.002	0.000	User Specified
Aft Ballast Tank Port	0%	0.586	0.000	0.572	0.000	3.991	-0.001	1.535	0.000	Maximum
Aft Ballast Tank Starb	0%	0.586	0.000	0.572	0.000	3.991	0.001	1.535	0.000	Maximum
Aft Ballast Tank Port	0%	0.878	0.000	0.857	0.000	7.446	-0.113	1.000	0.000	Maximum
Aft Ballast Tank Starb	0%	0.878	0.000	0.857	0.000	7.446	0.113	1.000	0.000	Maximum
Aft Ballast Tank Port	0%	1.718	0.000	1.676	0.000	8.060	-0.378	1.000	0.000	Maximum
Aft Ballast Tank Starb	0%	1.718	0.000	1.676	0.000	8.060	0.378	1.000	0.000	Maximum
Aft Diesel Tank	100%	3.318	3.318	3.949	3.949	11.220	-2.516	1.618	0.000	Maximum
Aft Diesel Tank	100%	3.318	3.318	3.949	3.949	11.220	2.516	1.618	0.000	Maximum
Diesel Tank	100%	4.608	4.608	5.485	5.485	16.432	-2.973	1.562	0.000	Maximum
Diesel Tank	100%	4.608	4.608	5.485	5.485	16.432	2.973	1.562	0.000	Maximum
Lub Oil Tank	100%	2.121	2.121	2.305	2.305	19.800	0.000	1.039	0.000	Maximum
Dirty Oil Tank	0%	2.314	0.000	2.314	0.000	20.417	0.000	0.027	0.000	Maximum
Daily Diesel Tank	100%	13.708	13.708	16.320	16.320	22.200	-2.177	2.619	0.000	Maximum
Daily Diesel Tank	100%	13.708	13.708	16.320	16.320	22.200	2.177	2.619	0.000	Maximum
Fwd Diesel Tank	100%	10.665	10.665	12.696	12.696	23.994	-1.525	1.214	0.000	Maximum
Fwd Diesel Tank	100%	10.665	10.665	12.696	12.696	23.994	1.525	1.214	0.000	Maximum
Fresh Water Tank	100%	6.756	6.756	6.756	6.756	29.397	-0.492	1.061	0.000	Maximum
Fresh Water Tank	100%	6.756	6.756	6.756	6.756	29.397	0.492	1.061	0.000	Maximum
Black Water Tank	0%	12.870	0.000	12.556	0.000	34.513	0.000	0.058	0.000	Maximum
Ballast Tank Port	0%	6.306	0.000	6.152	0.000	40.815	0.000	0.057	0.000	Maximum
Ballast Tank Starb	0%	6.306	0.000	6.152	0.000	40.815	0.000	0.057	0.000	Maximum
Fwd Ballast Tank	0%	2.892	0.000	2.821	0.000	43.110	0.000	0.057	0.000	Maximum
Peak Tank	0%	18.609	0.000	18.155	0.000	45.653	0.000	0.059	0.000	Maximum
Total Loadcase			449.998	147.077	92.718	23.418	0.000	2.777	0.000	
FS correction								0.000		
VCG fluid								2.777		



Heel to Starboard deg	-30.0	-20.0	-10.0	0.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0	110.0	
GZ m	-0.778	-0.544	-0.283	0.000	0.283	0.544	0.778	0.947	1.070	1.120	1.083	0.932	0.705	0.436	0.145	
Area under GZ curve from zero heel m.deg	12.2106	5.5854	1.4247	0.0000	1.4261	5.5802	12.2310	20.9038	31.0352	42.0516	53.1585	63.3190	71.5481	77.2818	80.1944	8
Displacement t	450.0	450.0	450.0	450.0	450.0	450.0	450.0	450.0	450.0	450.0	450.0	450.0	450.0	450.0	450.0	
Draft at FP m	2.268	2.349	2.382	2.390	2.381	2.349	2.268	2.084	1.679	0.963	-0.432	-4.832	n/a	-13.230	-8.762	
Draft at AP m	2.049	2.304	2.445	2.490	2.445	2.304	2.049	1.699	1.275	0.677	-0.350	-3.191	n/a	-7.539	-4.756	
WL Length m	48.943	48.993	49.013	49.018	49.013	48.993	48.943	48.830	48.573	48.072	47.064	48.576	49.704	50.452	51.129	
Beam max extents on WL m	7.850	7.967	8.082	8.128	8.082	7.967	7.850	7.922	7.829	7.065	6.556	6.160	5.954	5.897	5.984	
Wetted Area m^2	396.825	395.930	397.409	398.440	397.412	395.933	396.823	405.393	411.874	414.465	402.741	400.264	399.980	401.317	404.083	4
Waterpl. Area m^2	299.652	300.400	302.814	304.524	302.817	300.403	299.651	285.302	277.798	262.262	241.413	222.321	210.901	205.934	206.671	2
Prismatic coeff. (Cp)	0.647	0.638	0.630	0.627	0.630	0.638	0.647	0.644	0.626	0.615	0.614	0.587	0.570	0.559	0.550	
Block coeff. (Cb)	0.455	0.466	0.458	0.445	0.458	0.466	0.455	0.435	0.429	0.467	0.498	0.500	0.478	0.423	0.379	
LCB from zero pt. (+ve fwd) m	23.424	23.421	23.417	23.415	23.416	23.419	23.424	23.427	23.427	23.425	23.416	23.404	23.392	23.366	23.345	
LCF from zero pt. (+ve fwd) m	22.723	22.279	21.957	21.816	21.957	22.279	22.723	23.965	25.278	25.953	26.087	25.807	25.582	25.387	25.203	
Max deck inclination deg	30.0007	20.0001	10.0003	0.1168	10.0003	20.0001	30.0007	40.0012	50.0007	60.0001	70.0000	80.0002	90.0000	99.9980	109.9919	11
Trim angle (+ve by stern) deg	-0.2550	-0.0529	0.0738	0.1168	0.0742	-0.0521	-0.2551	-0.4489	-0.4716	-0.3337	0.0958	1.9126	n/a	6.6048	4.6592	

Key point	Type	Immersion angle deg	Emergence angle deg	Freeboard at 0.0 deg m	Freeboard at 10.0 deg m	Freeboard at 20.0 deg m	Freeboard at 30.0 deg m	Freeboard at 40.0 deg m	Freeboard at 50.0 deg m	Freeboard at 60.0 deg m	Freeboard at 70.0 deg m	Freeboard at 80.0 deg m	Freeboard at 90.0 deg m	Freeboard at 100.0 deg m	Freeboard at 110.0 deg m	Freeboard at 120.0 deg m	Freeboard at 130.0 deg m	Freeboard at 140.0 deg m	Freeboard at 150.0 deg m	Freeboard at 160.0 deg m	Freeboard at 170.0 deg m	Freeboard at 180.0 deg m
Margin Line (immersion pos = 21.833 m)		27.4	n/a	1.936	1.230	0.503	-0.178	-0.810	-1.389	-1.919	-2.401	-2.795	-3.101	-3.474	-3.762	-3.914	-3.922	-3.776	-3.465	-2.970	-2.321	-1.592
Deck Edge (immersion pos = 21.833 m)		28.4	n/a	2.012	1.305	0.574	-0.113	-0.752	-1.340	-1.881	-2.375	-2.782	-3.101	-3.487	-3.787	-3.952	-3.971	-3.834	-3.531	-3.041	-2.395	-1.668

Code	Criteria	Value	Units	Actual	Status	Margin %
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 0 to 30	4.5840	m.deg	12.2310	Pass	+166.82
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 0 to 40	7.6200	m.deg	20.9038	Pass	+174.33
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 30 to 40	2.7500	m.deg	8.6728	Pass	+215.38
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Maximum GZ	0.300	m	1.070	Pass	+256.67
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Angle of maximum GZ	30.0	deg	61.8	Pass	+106.06
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: GM fluid at equilibrium	0.300	m	1.648	Pass	+449.33
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Range of positive stability	70.0	deg	115.0	Pass	+64.21
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Angle of vanishing stability	70.0	deg	115.0	Pass	+64.21
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.4 Heeling caused by High Speed Turning				Pass	
	Angle of steady heel shall be less than (<)	20.0	deg	5.3	Pass	+73.70
	Area1 / Area2 shall be greater than (>)	40.00	%	85.43	Pass	+113.57
	GZ(intersection) / GZ(max) shall be less than (<)	60.00	%	14.08	Pass	+76.53
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.5 Lifting of Heavy Weights				Pass	
	Angle of steady heel shall be less than (<)	15.0	deg	0.0	Pass	+99.94
	Area1 / Area2 shall be greater than (>)	50.00	%	99.94	Pass	+99.88
	GZ(intersection) / GZ(max) shall be less than (<)	50.00	%	0.02	Pass	+99.96
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.6 Crowding of Passengers on One side.				Pass	
	Angle of steady heel shall be less than (<)	10.0	deg	0.6	Pass	+94.20
	Area1 / Area2 shall be greater than (>)	40.00	%	98.32	Pass	+145.80
	GZ(intersection) / GZ(max) shall be less than (<)	60.00	%	1.56	Pass	+97.40

Offshore Patrol Vessel 2000ton

Traditional – Equilibrium

Equilibrium calculation - OffshorePatrolVessel 2000ton

Stability 23.04.00.76, build: 76

Model file: C:\Users\Felipe\OneDrive\Documentos\Felipe\UCL\MECH0070 - MSC Individual Project\Impact of Mission Modules on Naval Ship Design\Report\MAXSURF Models\OffshorePatrolVessel 2000ton (Medium precision, 65 sections, Trimming on, Skin thickness not applied). Long. datum: AP; Vert. datum: Baseline. Analysis tolerance - ideal(worst case): Disp.%: 0.01000(0.100); Trim%(LCG-TCG): 0.01000(0.100); Heel%(LCG-TCG): 0.01000(0.100)

Loadcase - OffshorePatrolVessel 2000ton_Traditional
Damage Case - Intact
Free to Trim
Specific gravity = 1.025; (Density = 1.025 tonne/m^3)
Fluid analysis method: Use corrected VCG

Item Name	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
Lightship	1	1560.253	1560.253			38.060	0.000	4.631	0.000	User Specified
Payload	1	200.000	200.000			38.060	0.000	7.946	0.000	User Specified
Aft Grey Water Tank	0%	15.877	0.000	15.490	0.000	5.185	0.000	2.623	0.000	Maximum
Aft Fuel Tank Starb	100%	19.344	19.344	23.029	23.029	9.149	-2.124	3.487	0.000	Maximum
Aft Fuel Tank Port	100%	19.344	19.344	23.029	23.029	9.149	2.124	3.487	0.000	Maximum
Aft Fuel Wing Tank Starb	100%	17.487	17.487	20.818	20.818	13.244	-4.052	3.563	0.000	Maximum
Aft Fuel Wing Tank Port	100%	17.487	17.487	20.818	20.818	13.244	4.052	3.563	0.000	Maximum
Aft Ballast Tank	0%	68.488	0.000	66.817	0.000	13.654	0.000	1.000	0.000	Maximum
Dirty Aviation Fuel Tank	0%	22.075	0.000	26.911	0.000	17.287	0.000	0.800	0.000	Maximum
Aviation Fuel Tank	100%	35.941	35.941	43.814	43.814	20.171	0.000	2.538	0.000	Maximum
Dirty Water Tank	0%	2.120	0.000	2.068	0.000	27.315	0.000	0.022	0.000	Maximum
Dirty Lub Oil Tank	0%	1.959	0.000	2.129	0.000	28.615	0.000	0.028	0.000	Maximum
Dirty Water Tank	0%	2.217	0.000	2.163	0.000	29.915	0.000	0.033	0.000	Maximum
Lub Oil Tank	100%	4.053	4.053	4.406	4.406	32.504	0.000	0.566	0.000	Maximum
Dirty Water Tank	0%	2.278	0.000	2.222	0.000	33.815	0.000	0.049	0.000	Maximum
Fuel Tank Starb	100%	14.254	14.254	16.969	16.969	37.695	-1.987	1.246	0.000	Maximum
Fuel Tank Port	100%	14.254	14.254	16.969	16.969	37.695	1.987	1.246	0.000	Maximum
Fuel Tank Central	100%	32.011	32.011	38.109	38.109	40.945	0.000	1.157	0.000	Maximum
Grey Water Starb	0%	8.035	0.000	7.839	0.000	42.940	-0.001	0.086	0.000	Maximum
Grey Water Port	0%	8.035	0.000	7.839	0.000	42.940	0.001	0.086	0.000	Maximum
Dirty Water Tank	0%	12.591	0.000	12.284	0.000	45.577	0.000	0.089	0.000	Maximum
Fwd Fuel Tank Starb	100%	22.771	22.771	27.108	27.108	49.331	-1.611	1.258	0.000	Maximum
Fwd Fuel Tank Port	100%	22.771	22.771	27.108	27.108	49.331	1.611	1.258	0.000	Maximum
Fwd Grey Water Tank	0%	21.812	0.000	23.709	0.000	54.209	0.000	0.091	0.000	Maximum
Fresh Water Tank Starb	100%	10.015	10.015	10.015	10.015	57.173	-1.209	1.272	0.000	Maximum
Fresh Water Tank Port	100%	10.015	10.015	10.015	10.015	57.173	1.209	1.272	0.000	Maximum
Fwd Ballast Tank	0%	16.696	0.000	16.289	0.000	61.993	0.000	0.091	0.000	Maximum
Fwd Ballast Tank	0%	56.929	0.000	55.541	0.000	64.173	0.000	0.091	0.000	Maximum
Peak Tank	0%	19.388	0.000	18.916	0.000	73.297	0.000	0.097	0.000	Maximum
Total Loadcase			2000.000	542.424	282.206	37.223	0.000	4.661	0.000	
FS correction								0.000		
VCG fluid								4.661		

Draft Amidships m	4.133
Displacement t	2000
Heel deg	0.0
Draft at FP m	4.133
Draft at AP m	4.133
Draft at LCF m	4.133
Trim (+ve by stern) m	0.000
WL Length m	78.021
Beam max extents on WL m	13.040
Wetted Area m^2	1051.953
Waterpl. Area m^2	788.295
Prismatic coeff. (Cp)	0.638
Block coeff. (Cb)	0.464
Max Sect. area coeff. (Cm)	0.738
Waterpl. area coeff. (Cwp)	0.775
LCB from zero pt. (+ve fwd) m	37.221
LCF from zero pt. (+ve fwd) m	34.706
KB m	2.622
KG fluid m	4.661
BMt m	4.363
BML m	149.902
GMt corrected m	2.323
GML m	147.863
KMt m	6.984
KML m	152.524
Immersion (TPc) tonne/cm	8.080
MTc tonne.m	37.906
RM at 1deg = GMt.Disp.sin(1) tonne.m	81.092
Max deck inclination deg	0.0000
Trim angle (+ve by stern) deg	0.0000

Key point	Type	Freeboard m
Margin Line (freeboard pos = 0 m)		2.937
Deck Edge (freeboard pos = 0 m)		3.013

Code	Criteria	Value	Units	Actual	Status	Margin %
Royal Navy, Damage Stability Criteria; DS 02-109(NES109) Part 1	1.3.5.a.(6) Longitudinal GM > 0	0.000	m	147.863	Pass	infinite

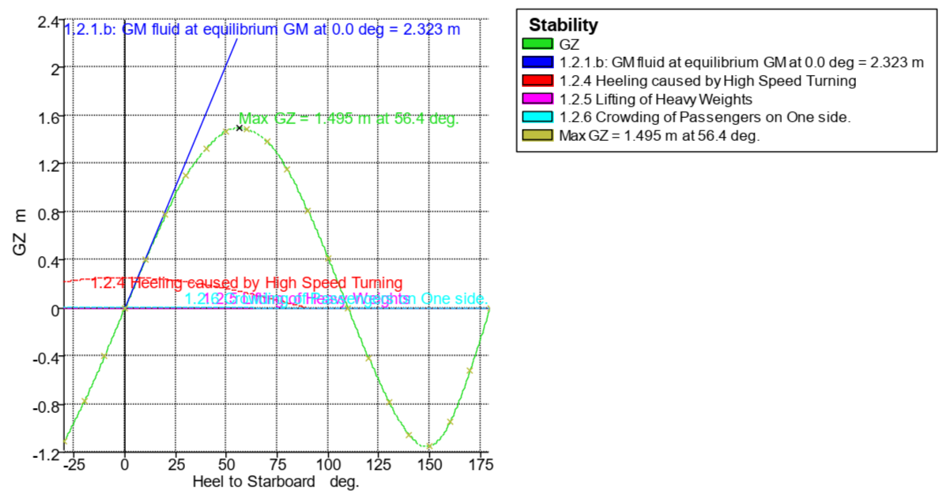
Traditional – Large Angle Stability

Stability calculation - OffshorePatrolVessel 2000ton

Stability 23.04.00.76, build: 76
Model file: C:\Users\Felipe\OneDrive\Documentos\Felipe\UCL\MECH0070 - MSC Individual Project\Impact of Mission Modules on Naval Ship Design\Report\MAXSURF Models\OffshorePatrolVessel 2000ton (Medium precision, 65 sections, Trimming on, Skin thickness not applied). Long. datum: AP; Vert. datum: Baseline. Analysis tolerance - ideal(worst case): Disp.%: 0.01000(0.100); Trim%(LCG-TCG): 0.01000(0.100); Heel%(LCG-TCG): 0.01000(0.100)

Loadcase - OffshorePatrolVessel 2000ton_Traditional
Damage Case - Intact
Free to Trim
Specific gravity = 1.025; (Density = 1.025 tonne/m^3)
Fluid analysis method: Use corrected VCG

Item Name	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
Lightship	1	1560.253	1560.253			38.060	0.000	4.631	0.000	User Specified
Payload	1	200.000	200.000			38.060	0.000	7.946	0.000	User Specified
Aft Grey Water Tank	0%	15.877	0.000	15.490	0.000	5.185	0.000	2.623	0.000	Maximum
Aft Fuel Tank Starb	100%	19.344	19.344	23.029	23.029	9.149	-2.124	3.487	0.000	Maximum
Aft Fuel Tank Port	100%	19.344	19.344	23.029	23.029	9.149	2.124	3.487	0.000	Maximum
Aft Fuel Wing Tank Starb	100%	17.487	17.487	20.818	20.818	13.244	-4.052	3.563	0.000	Maximum
Aft Fuel Wing Tank Port	100%	17.487	17.487	20.818	20.818	13.244	4.052	3.563	0.000	Maximum
Aft Ballast Tank	0%	68.488	0.000	66.817	0.000	13.654	0.000	1.000	0.000	Maximum
Dirty Aviation Fuel Tank	0%	22.075	0.000	26.911	0.000	17.287	0.000	0.800	0.000	Maximum
Aviation Fuel Tank	100%	35.941	35.941	43.814	43.814	20.171	0.000	2.538	0.000	Maximum
Dirty Water Tank	0%	2.120	0.000	2.068	0.000	27.315	0.000	0.022	0.000	Maximum
Dirty Lub Oil Tank	0%	1.959	0.000	2.129	0.000	28.615	0.000	0.028	0.000	Maximum
Dirty Water Tank	0%	2.217	0.000	2.163	0.000	29.915	0.000	0.033	0.000	Maximum
Lub Oil Tank	100%	4.053	4.053	4.406	4.406	32.504	0.000	0.566	0.000	Maximum
Dirty Water Tank	0%	2.278	0.000	2.222	0.000	33.815	0.000	0.049	0.000	Maximum
Fuel Tank Starb	100%	14.254	14.254	16.969	16.969	37.695	-1.987	1.246	0.000	Maximum
Fuel Tank Port	100%	14.254	14.254	16.969	16.969	37.695	1.987	1.246	0.000	Maximum
Fuel Tank Central	100%	32.011	32.011	38.109	38.109	40.945	0.000	1.157	0.000	Maximum
Grey Water Starb	0%	8.035	0.000	7.839	0.000	42.940	-0.001	0.086	0.000	Maximum
Grey Water Port	0%	8.035	0.000	7.839	0.000	42.940	0.001	0.086	0.000	Maximum
Dirty Water Tank	0%	12.591	0.000	12.284	0.000	45.577	0.000	0.089	0.000	Maximum
Fwd Fuel Tank Starb	100%	22.771	22.771	27.108	27.108	49.331	-1.611	1.258	0.000	Maximum
Fwd Fuel Tank Port	100%	22.771	22.771	27.108	27.108	49.331	1.611	1.258	0.000	Maximum
Fwd Grey Water Tank	0%	21.812	0.000	23.709	0.000	54.209	0.000	0.091	0.000	Maximum
Fresh Water Tank Starb	100%	10.015	10.015	10.015	10.015	57.173	-1.209	1.272	0.000	Maximum
Fresh Water Tank Port	100%	10.015	10.015	10.015	10.015	57.173	1.209	1.272	0.000	Maximum
Fwd Ballast Tank	0%	16.696	0.000	16.289	0.000	61.993	0.000	0.091	0.000	Maximum
Fwd Ballast Tank	0%	56.929	0.000	55.541	0.000	64.173	0.000	0.091	0.000	Maximum
Peak Tank	0%	19.388	0.000	18.916	0.000	73.297	0.000	0.097	0.000	Maximum
Total Loadcase			2000.000	542.424	282.206	37.223	0.000	4.661	0.000	
FS correction								0.000		
VCG fluid								4.661		



Heel to Starboard deg	-30.0	-20.0	-10.0	0.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0
GZ m	-1.107	-0.774	-0.400	0.000	0.400	0.774	1.107	1.324	1.471	1.486	1.383	1.151	0.809	0.41
Area under GZ curve from zero heel m.deg	17.3351	7.9112	2.0112	0.0000	2.0139	7.9009	17.3749	29.6068	43.6587	58.5516	72.9967	85.7766	95.6456	101.792
Displacement t	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	200
Draft at FP m	3.944	4.070	4.120	4.133	4.120	4.070	3.944	3.636	2.984	1.908	-0.101	-6.374	n/a	-19.47
Draft at AP m	3.505	3.868	4.069	4.132	4.069	3.869	3.506	3.071	2.577	1.903	0.732	-2.322	n/a	-9.18
WL Length m	77.906	77.983	78.014	78.021	78.013	77.983	77.906	77.718	77.312	76.601	75.432	77.783	79.468	80.66
Beam max extents on WL m	12.770	12.890	13.001	13.040	13.001	12.890	12.771	12.961	12.333	11.155	10.588	9.838	9.538	9.48
Wetted Area m^2	1056.333	1047.494	1050.156	1051.921	1050.160	1047.497	1056.383	1080.794	1096.679	1108.017	1099.130	1074.267	1073.668	1076.97
Waterpl. Area m^2	769.077	781.056	785.290	788.279	785.294	781.060	769.085	729.987	702.548	661.544	637.716	575.017	546.598	534.58
Prismatic coeff. (Cp)	0.657	0.648	0.640	0.638	0.640	0.648	0.657	0.650	0.633	0.624	0.621	0.593	0.576	0.56
Block coeff. (Cb)	0.462	0.475	0.474	0.464	0.474	0.475	0.462	0.439	0.449	0.484	0.501	0.506	0.483	0.43
LCB from zero pt. (+ve fwd) m	37.236	37.231	37.225	37.223	37.224	37.229	37.235	37.237	37.234	37.223	37.211	37.191	37.165	37.13
LCF from zero pt. (+ve fwd) m	36.336	35.437	34.914	34.707	34.914	35.436	36.336	38.531	40.447	41.588	41.592	41.388	41.007	40.66
Max deck inclination deg	30.0012	20.0005	10.0001	0.0009	10.0001	20.0005	30.0012	40.0011	50.0003	60.0000	70.0001	80.0004	90.0000	99.997
Trim angle (+ve by stern) deg	-0.3218	-0.1483	-0.0377	-0.0009	-0.0372	-0.1474	-0.3217	-0.4150	-0.2991	-0.0034	0.6121	2.9732	n/a	7.515

Key point	Type	Immersion angle deg	Emergence angle deg	Freeboard at 0.0 deg m	Freeboard at 10.0 deg m	Freeboard at 20.0 deg m	Freeboard at 30.0 deg m	Freeboard at 40.0 deg m	Freeboard at 50.0 deg m	Freeboard at 60.0 deg m	Freeboard at 70.0 deg m	Freeboard at 80.0 deg m	Freeboard at 90.0 deg m	Freeboard at 100.0 deg m	Freeboard at 110.0 deg m	Freeboard at 120.0 deg m	Freeboard at 130.0 deg m	Freeboard at 140.0 deg m	Freeboard at 150.0 deg m	Freeboard at 160.0 deg m	Freeboard at 170.0 deg m	Freeboard at 180.0 deg m
Margin Line (immersion pos = 34.659 m)		25.4	n/a	2.938	1.747	0.588	-0.499	-1.522	-2.465	-3.338	-4.130	-4.803	-5.326	-5.901	-6.362	-6.597	-6.593	-6.336	-5.808	-4.984	-3.940	-2.784
Deck Edge (immersion pos = 34.659 m)		26	n/a	3.014	1.822	0.659	-0.433	-1.464	-2.416	-3.300	-4.104	-4.790	-5.326	-5.914	-6.387	-6.635	-6.642	-6.394	-5.873	-5.055	-4.014	-2.860

Code	Criteria	Value	Units	Actual	Status	Margin %
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 0 to 30	4.5840	m.deg	17.3749	Pass	+279.03
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 0 to 40	7.6200	m.deg	29.6068	Pass	+288.54
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 30 to 40	2.7500	m.deg	12.2318	Pass	+344.79
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Maximum GZ	0.300	m	1.471	Pass	+390.33
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Angle of maximum GZ	30.0	deg	56.4	Pass	+87.88
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: GM fluid at equilibrium	0.300	m	2.323	Pass	+674.33
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Range of positive stability	70.0	deg	109.8	Pass	+56.90
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Angle of vanishing stability	70.0	deg	109.8	Pass	+56.90
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.4 Heeling caused by High Speed Turning				Pass	
	Angle of steady heel shall be less than (<)	20.0	deg	6.2	Pass	+68.94
	Area1 / Area2 shall be greater than (>)	40.00	%	82.48	Pass	+106.20
	GZ(intersection) / GZ(max) shall be less than (<)	60.00	%	17.04	Pass	+71.60
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.5 Lifting of Heavy Weights				Pass	
	Angle of steady heel shall be less than (<)	15.0	deg	0.0	Pass	+99.99
	Area1 / Area2 shall be greater than (>)	50.00	%	99.99	Pass	+99.98
	GZ(intersection) / GZ(max) shall be less than (<)	50.00	%	0.00	Pass	+100.00
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.6 Crowding of Passengers on One side.				Pass	
	Angle of steady heel shall be less than (<)	10.0	deg	0.1	Pass	+99.07
	Area1 / Area2 shall be greater than (>)	40.00	%	99.72	Pass	+149.30
	GZ(intersection) / GZ(max) shall be less than (<)	60.00	%	0.25	Pass	+99.58

Traditional – Equilibrium (Damage)

Equilibrium calculation - OffshorePatrolVessel 2000ton

Stability 23.04.00.76, build: 76
Model file: C:\Users\Felipe\OneDrive\Documentos\Felipe\UCL\MECH0070 - MSC Individual Project\Impact of Mission Modules on Naval Ship Design\Report\MAXSURF Models\OffshorePatrolVessel 2000ton (Medium precision, 65 sections, Trimming on, Skin thickness not applied). Long. datum: AP; Vert. datum: Baseline. Analysis tolerance - ideal(worst case): Disp.%: 0.01000(0.100); Trim%(LCG-TCG): 0.01000(0.100); Heel%(LCG-TCG): 0.01000(0.100)

Loadcase - OffshorePatrolVessel 2000ton_Traditional
Damage Case - Auxiliary+EngineRoom
Free to Trim
Specific gravity = 1.025; (Density = 1.025 tonne/m^3)
Compartments Damaged -

Compartment or Tank	Status	Perm.%	PartFlood.%	PartFlood.WL
Auxiliary Room[]	Fully flooded	85		
Engine Room[]	Fully flooded	85		

Fluid analysis method: Use corrected VCG

Item Name	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
Lightship	1	1560.253	1560.253			38.060	0.000	4.631	0.000	User Specified
Payload	1	200.000	200.000			38.060	0.000	7.946	0.000	User Specified
Aft Grey Water Tank	0%	15.877	0.000	15.490	0.000	5.185	0.000	2.623	0.000	Maximum
Aft Fuel Tank Starb	100%	19.344	19.344	23.029	23.029	9.149	-2.124	3.487	0.000	Maximum
Aft Fuel Tank Port	100%	19.344	19.344	23.029	23.029	9.149	2.124	3.487	0.000	Maximum
Aft Fuel Wing Tank Starb	100%	17.487	17.487	20.818	20.818	13.244	-4.052	3.563	0.000	Maximum
Aft Fuel Wing Tank Port	100%	17.487	17.487	20.818	20.818	13.244	4.052	3.563	0.000	Maximum
Aft Ballast Tank	0%	68.488	0.000	66.817	0.000	13.654	0.000	1.000	0.000	Maximum
Dirty Aviation Fuel Tank	0%	22.075	0.000	26.911	0.000	17.287	0.000	0.800	0.000	Maximum
Aviation Fuel Tank	100%	35.941	35.941	43.814	43.814	20.171	0.000	2.538	0.000	Maximum
Dirty Water Tank	0%	2.120	0.000	2.068	0.000	27.315	0.000	0.022	0.000	Maximum
Dirty Lub Oil Tank	0%	1.959	0.000	2.129	0.000	28.615	0.000	0.028	0.000	Maximum
Dirty Water Tank	0%	2.217	0.000	2.163	0.000	29.915	0.000	0.033	0.000	Maximum
Lub Oil Tank	100%	4.053	4.053	4.406	4.406	32.504	0.000	0.566	0.000	Maximum
Dirty Water Tank	0%	2.278	0.000	2.222	0.000	33.815	0.000	0.049	0.000	Maximum
Fuel Tank Starb	100%	14.254	14.254	16.969	16.969	37.695	-1.987	1.246	0.000	Maximum
Fuel Tank Port	100%	14.254	14.254	16.969	16.969	37.695	1.987	1.246	0.000	Maximum
Fuel Tank Central	100%	32.011	32.011	38.109	38.109	40.945	0.000	1.157	0.000	Maximum
Grey Water Starb	0%	8.035	0.000	7.839	0.000	42.940	-0.001	0.086	0.000	Maximum
Grey Water Port	0%	8.035	0.000	7.839	0.000	42.940	0.001	0.086	0.000	Maximum
Dirty Water Tank	0%	12.591	0.000	12.284	0.000	45.577	0.000	0.089	0.000	Maximum
Fwd Fuel Tank Starb	100%	22.771	22.771	27.108	27.108	49.331	-1.611	1.258	0.000	Maximum
Fwd Fuel Tank Port	100%	22.771	22.771	27.108	27.108	49.331	1.611	1.258	0.000	Maximum
Fwd Grey Water Tank	0%	21.812	0.000	23.709	0.000	54.209	0.000	0.091	0.000	Maximum
Fresh Water Tank Starb	100%	10.015	10.015	10.015	10.015	57.173	-1.209	1.272	0.000	Maximum
Fresh Water Tank Port	100%	10.015	10.015	10.015	10.015	57.173	1.209	1.272	0.000	Maximum
Fwd Ballast Tank	0%	16.696	0.000	16.289	0.000	61.993	0.000	0.091	0.000	Maximum

Item Name	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
Fwd Ballast Tank	0%	56.929	0.000	55.541	0.000	64.173	0.000	0.091	0.000	Maximum
Peak Tank	0%	19.388	0.000	18.916	0.000	73.297	0.000	0.097	0.000	Maximum
Total Loadcase			2000.000	542.424	282.206	37.223	0.000	4.661	0.000	
FS correction								0.000		
VCG fluid								4.661		

Draft Amidships m	5.048
Displacement t	2000
Heel deg	0.0
Draft at FP m	4.260
Draft at AP m	5.837
Draft at LCF m	5.087
Trim (+ve by stern) m	1.577
WL Length m	78.114
Beam max extents on WL m	13.418
Wetted Area m^2	1224.346
Waterpl. Area m^2	609.544
Prismatic coeff. (Cp)	0.468
Block coeff. (Cb)	0.332
Max Sect. area coeff. (Cm)	0.765
Waterpl. area coeff. (Cwp)	0.582
LCB from zero pt. (+ve fwd) m	37.198
LCF from zero pt. (+ve fwd) m	37.104
KB m	3.232
KG fluid m	4.661
BMt m	3.488
BML m	181.153
GMt corrected m	2.059
GML m	179.724
KMt m	6.720
KML m	184.349
Immersion (TPc) tonne/cm	6.248
MTc tonne.m	46.074
RM at 1deg = GMt.Disp.sin(1) tonne.m	71.879
Max deck inclination deg	1.1582
Trim angle (+ve by stern) deg	1.1582

Key point	Type	Freeboard m
Margin Line (freeboard pos = 0 m)		1.233
Deck Edge (freeboard pos = 0 m)		1.309

Code	Criteria	Value	Units	Actual	Status	Margin %
Royal Navy, Damage Stability Criteria; DS 02-109(NES109) Part 1	1.3.5.a.(6) Longitudinal GM > 0	0.000	m	179.724	Pass	infinite
Royal Navy, Damage Stability Criteria; DS 02-109(NES109) Part 1	1.3.5.b.(1) Metacentric Height Greater than 0.15m	0.150	m	2.059	Pass	+1272.67

Traditional – Large Angle Stability (Damage)

Stability calculation - OffshorePatrolVessel 2000ton

Stability 23.04.00.76, build: 76
Model file: C:\Users\Felipe\OneDrive\Documentos\Felipe\UCL\MECH0070 - MSC Individual Project\Impact of Mission Modules on Naval Ship Design\Report\MAXSURF Models\OffshorePatrolVessel 2000ton (Medium precision, 65 sections, Trimming on, Skin thickness not applied). Long. datum: AP; Vert. datum: Baseline. Analysis tolerance - ideal(worst case): Disp.%: 0.01000(0.100); Trim%(LCG-TCG): 0.01000(0.100); Heel%(LCG-TCG): 0.01000(0.100)

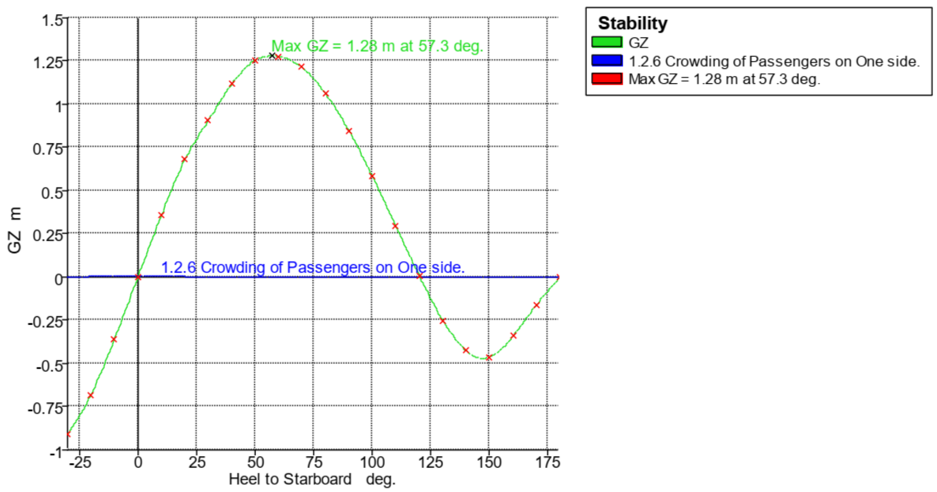
Loadcase - OffshorePatrolVessel 2000ton_Traditional
Damage Case - Auxiliary+EngineRoom
Free to Trim
Specific gravity = 1.025; (Density = 1.025 tonne/m^3)
Compartments Damaged -

Compartment or Tank	Status	Perm.%	PartFlood.%	PartFlood.WL
Auxiliary Room[]	Fully flooded	85		
Engine Room[]	Fully flooded	85		

Fluid analysis method: Use corrected VCG

Item Name	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
Lightship	1	1560.253	1560.253			38.060	0.000	4.631	0.000	User Specified
Payload	1	200.000	200.000			38.060	0.000	7.946	0.000	User Specified
Aft Grey Water Tank	0%	15.877	0.000	15.490	0.000	5.185	0.000	2.623	0.000	Maximum
Aft Fuel Tank Starb	100%	19.344	19.344	23.029	23.029	9.149	-2.124	3.487	0.000	Maximum
Aft Fuel Tank Port	100%	19.344	19.344	23.029	23.029	9.149	2.124	3.487	0.000	Maximum
Aft Fuel Wing Tank Starb	100%	17.487	17.487	20.818	20.818	13.244	-4.052	3.563	0.000	Maximum
Aft Fuel Wing Tank Port	100%	17.487	17.487	20.818	20.818	13.244	4.052	3.563	0.000	Maximum
Aft Ballast Tank	0%	68.488	0.000	66.817	0.000	13.654	0.000	1.000	0.000	Maximum
Dirty Aviation Fuel Tank	0%	22.075	0.000	26.911	0.000	17.287	0.000	0.800	0.000	Maximum
Aviation Fuel Tank	100%	35.941	35.941	43.814	43.814	20.171	0.000	2.538	0.000	Maximum
Dirty Water Tank	0%	2.120	0.000	2.068	0.000	27.315	0.000	0.022	0.000	Maximum
Dirty Lub Oil Tank	0%	1.959	0.000	2.129	0.000	28.615	0.000	0.028	0.000	Maximum
Dirty Water Tank	0%	2.217	0.000	2.163	0.000	29.915	0.000	0.033	0.000	Maximum
Lub Oil Tank	100%	4.053	4.053	4.406	4.406	32.504	0.000	0.566	0.000	Maximum
Dirty Water Tank	0%	2.278	0.000	2.222	0.000	33.815	0.000	0.049	0.000	Maximum
Fuel Tank Starb	100%	14.254	14.254	16.969	16.969	37.695	-1.987	1.246	0.000	Maximum
Fuel Tank Port	100%	14.254	14.254	16.969	16.969	37.695	1.987	1.246	0.000	Maximum
Fuel Tank Central	100%	32.011	32.011	38.109	38.109	40.945	0.000	1.157	0.000	Maximum
Grey Water Starb	0%	8.035	0.000	7.839	0.000	42.940	-0.001	0.086	0.000	Maximum
Grey Water Port	0%	8.035	0.000	7.839	0.000	42.940	0.001	0.086	0.000	Maximum
Dirty Water Tank	0%	12.591	0.000	12.284	0.000	45.577	0.000	0.089	0.000	Maximum
Fwd Fuel Tank Starb	100%	22.771	22.771	27.108	27.108	49.331	-1.611	1.258	0.000	Maximum
Fwd Fuel Tank Port	100%	22.771	22.771	27.108	27.108	49.331	1.611	1.258	0.000	Maximum
Fwd Grey Water Tank	0%	21.812	0.000	23.709	0.000	54.209	0.000	0.091	0.000	Maximum
Fresh Water Tank Starb	100%	10.015	10.015	10.015	10.015	57.173	-1.209	1.272	0.000	Maximum
Fresh Water Tank Port	100%	10.015	10.015	10.015	10.015	57.173	1.209	1.272	0.000	Maximum
Fwd Ballast Tank	0%	16.696	0.000	16.289	0.000	61.993	0.000	0.091	0.000	Maximum

Item Name	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
Fwd Ballast Tank	0%	56.929	0.000	55.541	0.000	64.173	0.000	0.091	0.000	Maximum
Peak Tank	0%	19.388	0.000	18.916	0.000	73.297	0.000	0.097	0.000	Maximum
Total Loadcase			2000.000	542.424	282.206	37.223	0.000	4.661	0.000	
FS correction								0.000		
VCG fluid								4.661		



Heel to Starboard deg	-30.0	-20.0	-10.0	0.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0
GZ m	-0.908	-0.680	-0.358	0.000	0.358	0.680	0.908	1.117	1.253	1.277	1.215	1.061	0.847	0.58
Area under GZ curve from zero heel m.deg	15.0529	7.0567	1.7994	0.0000	1.7988	7.0592	15.0465	25.1944	37.1352	49.8660	62.3987	73.8463	83.4337	90.608
Displacement t	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	200
Draft at FP m	3.796	4.114	4.230	4.260	4.230	4.116	3.796	3.226	2.351	1.020	-1.474	-9.098	n/a	-21.95
Draft at AP m	5.960	5.798	5.816	5.836	5.816	5.796	5.961	6.243	6.723	7.572	9.308	14.847	n/a	7.88
WL Length m	77.841	78.026	78.096	78.115	78.096	78.027	77.841	77.512	76.994	76.097	74.435	76.682	78.383	79.73

Heel to Starboard deg	-30.0	-20.0	-10.0	0.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0
Beam max extents on WL m	13.856	13.582	13.498	13.418	13.498	13.582	13.856	13.361	11.833	10.875	10.549	9.933	9.747	9.78
Wetted Area m^2	1303.340	1268.300	1224.724	1224.312	1224.723	1268.174	1303.353	1312.494	1320.241	1319.431	1311.931	1308.348	1308.341	1306.26
Waterpl. Area m^2	558.376	580.667	611.313	609.542	611.318	580.779	558.362	553.129	528.730	506.230	484.630	471.898	455.796	449.66
Prismatic coeff. (Cp)	0.481	0.473	0.469	0.468	0.469	0.473	0.481	0.470	0.466	0.468	0.475	0.459	0.447	0.43
Block coeff. (Cb)	0.331	0.349	0.335	0.332	0.335	0.349	0.331	0.327	0.355	0.372	0.374	0.363	0.332	0.30
LCB from zero pt. (+ve fwd) m	37.188	37.189	37.186	37.199	37.188	37.197	37.187	37.169	37.150	37.128	37.105	37.085	37.056	37.02
LCF from zero pt. (+ve fwd) m	41.784	39.417	37.234	37.104	37.235	39.415	41.785	43.501	44.736	45.389	45.169	44.064	43.494	43.04
Max deck inclination deg	30.0286	20.0324	10.0649	1.1575	10.0648	20.0322	30.0286	40.0299	50.0312	60.0291	70.0233	80.0143	90.0000	99.977
Trim angle (+ve by stern) deg	1.5890	1.2368	1.1650	1.1575	1.1642	1.2333	1.5896	2.2147	3.2078	4.7997	7.8684	17.0611	n/a	20.929

Key point	Type	Immersion angle deg	Emergence angle deg	Freeboard at 0.0 deg m	Freeboard at 10.0 deg m	Freeboard at 20.0 deg m	Freeboard at 30.0 deg m	Freeboard at 40.0 deg m	Freeboard at 50.0 deg m	Freeboard at 60.0 deg m	Freeboard at 70.0 deg m	Freeboard at 80.0 deg m	Freeboard at 90.0 deg m	Freeboard at 100.0 deg m	Freeboard at 110.0 deg m	Freeboard at 120.0 deg m	Freeboard at 130.0 deg m	Freeboard at 140.0 deg m	Freeboard at 150.0 deg m	Freeboard at 160.0 deg m	Freeboard at 170.0 deg m	Freeboard at 180.0 deg m
Margin Line (immersion pos = 0 m)		12.5	n/a	1.233	0.245	-0.758	-1.936	-3.105	-4.223	-5.262	-6.184	-6.997	-7.689	-8.197	-8.482	-8.501	-8.235	-7.679	-6.875	-5.938	-4.959	-3.958
Deck Edge (immersion pos = 0 m)		13.2	n/a	1.309	0.320	-0.687	-1.870	-3.047	-4.174	-5.224	-6.158	-6.984	-7.690	-8.210	-8.509	-8.539	-8.284	-7.738	-6.941	-6.010	-5.033	-4.034

Code	Criteria	Value	Units	Actual	Status	Margin %
Royal Navy, Damage Stability Criteria; DS 02-109(NES109) Part 1	1.3.5.a.(1): Angle of List or Loll.	20.0	deg	0.0	Pass	+100.00
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.6 Crowding of Passengers on One side.				Pass	
	Angle of steady heel shall be less than (<)	10.0	deg	0.1	Pass	+98.96
	Area1 / Area2 shall be greater than (>)	40.00	%	99.68	Pass	+149.20
	GZ(intersection) / GZ(max) shall be less than (<)	60.00	%	0.30	Pass	+99.50

Modular ASW – Equilibrium

Equilibrium calculation - OffshorePatrolVessel 2000ton

Stability 23.04.00.76, build: 76

Model file: C:\Users\Felipe\OneDrive\Documentos\Felipe\UCL\MECH0070 - MSC Individual Project\Impact of Mission Modules on Naval Ship Design\Report\MAXSURF Models\OffshorePatrolVessel 2000ton (Medium precision, 65 sections, Trimming on, Skin thickness not applied). Long. datum: AP; Vert. datum: Baseline. Analysis tolerance - ideal(worst case): Disp.%: 0.01000(0.100); Trim%(LCG-TCG): 0.01000(0.100); Heel%(LCG-TCG): 0.01000(0.100)

Loadcase - OffshorePatrolVessel 2000ton_Modular_ASW

Damage Case - Intact

Free to Trim / Specific gravity = 1.025; (Density = 1.025 tonne/m^3) / Fluid analysis method: Use corrected VCG

Item Name	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
Lightship	1	1560.253	1560.253			38.060	0.000	4.631	0.000	User Specified
VLS	1	26.000	26.000			63.400	0.000	7.300	0.000	User Specified
Torpedo Container	1	5.330	5.330			32.050	0.000	8.241	0.000	User Specified
Torpedo Container	1	5.330	5.330			32.050	0.000	8.241	0.000	User Specified
TAS Module	1	14.000	14.000			3.470	0.000	8.241	0.000	User Specified
Aft Grey Water Tank	0%	15.877	0.000	15.490	0.000	5.185	0.000	2.623	0.000	Maximum
Aft Fuel Tank Starb	100%	19.344	19.344	23.029	23.029	9.149	-2.124	3.487	0.000	Maximum
Aft Fuel Tank Port	100%	19.344	19.344	23.029	23.029	9.149	2.124	3.487	0.000	Maximum
Aft Fuel Wing Tank Starb	100%	17.487	17.487	20.818	20.818	13.244	-4.052	3.563	0.000	Maximum
Aft Fuel Wing Tank Port	100%	17.487	17.487	20.818	20.818	13.244	4.052	3.563	0.000	Maximum
Aft Ballast Tank	0%	68.488	0.000	66.817	0.000	13.654	0.000	1.000	0.000	Maximum
Dirty Aviation Fuel Tank	0%	22.075	0.000	26.911	0.000	17.287	0.000	0.800	0.000	Maximum
Aviation Fuel Tank	100%	35.941	35.941	43.814	43.814	20.171	0.000	2.538	0.000	Maximum
Dirty Water Tank	0%	2.120	0.000	2.068	0.000	27.315	0.000	0.022	0.000	Maximum
Dirty Lub Oil Tank	0%	1.959	0.000	2.129	0.000	28.615	0.000	0.028	0.000	Maximum
Dirty Water Tank	0%	2.217	0.000	2.163	0.000	29.915	0.000	0.033	0.000	Maximum
Lub Oil Tank	100%	4.053	4.053	4.406	4.406	32.504	0.000	0.566	0.000	Maximum
Dirty Water Tank	0%	2.278	0.000	2.222	0.000	33.815	0.000	0.049	0.000	Maximum
Fuel Tank Starb	100%	14.254	14.254	16.969	16.969	37.695	-1.987	1.246	0.000	Maximum
Fuel Tank Port	100%	14.254	14.254	16.969	16.969	37.695	1.987	1.246	0.000	Maximum
Fuel Tank Central	100%	32.011	32.011	38.109	38.109	40.945	0.000	1.157	0.000	Maximum
Grey Water Starb	0%	8.035	0.000	7.839	0.000	42.940	-0.001	0.086	0.000	Maximum
Grey Water Port	0%	8.035	0.000	7.839	0.000	42.940	0.001	0.086	0.000	Maximum
Dirty Water Tank	0%	12.591	0.000	12.284	0.000	45.577	0.000	0.089	0.000	Maximum
Fwd Fuel Tank Starb	100%	22.771	22.771	27.108	27.108	49.331	-1.611	1.258	0.000	Maximum
Fwd Fuel Tank Port	100%	22.771	22.771	27.108	27.108	49.331	1.611	1.258	0.000	Maximum
Fwd Grey Water Tank	0%	21.812	0.000	23.709	0.000	54.209	0.000	0.091	0.000	Maximum
Fresh Water Tank Starb	100%	10.015	10.015	10.015	10.015	57.173	-1.209	1.272	0.000	Maximum
Fresh Water Tank Port	100%	10.015	10.015	10.015	10.015	57.173	1.209	1.272	0.000	Maximum
Fwd Ballast Tank	0%	16.696	0.000	16.289	0.000	61.993	0.000	0.091	0.000	Maximum
Fwd Ballast Tank	0%	56.929	0.000	55.541	0.000	64.173	0.000	0.091	0.000	Maximum
Peak Tank	0%	19.388	0.000	18.916	0.000	73.297	0.000	0.097	0.000	Maximum
Total Loadcase			1850.660	542.424	282.206	37.215	0.000	4.391	0.000	
FS correction								0.000		
VCG fluid								4.391		

Draft Amidships m	3.940
Displacement t	1851
Heel deg	0.0
Draft at FP m	3.889
Draft at AP m	3.992
Draft at LCF m	3.946
Trim (+ve by stern) m	0.103
WL Length m	77.872
Beam max extents on WL m	12.940
Wetted Area m^2	1016.438
Waterpl. Area m^2	772.927
Prismatic coeff. (Cp)	0.630
Block coeff. (Cb)	0.451
Max Sect. area coeff. (Cm)	0.731
Waterpl. area coeff. (Cwp)	0.767
LCB from zero pt. (+ve fwd) m	37.215
LCF from zero pt. (+ve fwd) m	34.663
KB m	2.507
KG fluid m	4.391
BMt m	4.504
BML m	156.589
GMt corrected m	2.620
GML m	154.705
KMt m	7.012
KML m	159.096
Immersion (TPc) tonne/cm	7.923
MTc tonne.m	36.696
RM at 1deg = GMt.Disp.sin(1) tonne.m	84.638
Max deck inclination deg	0.0759
Trim angle (+ve by stern) deg	0.0759

Key point	Type	Freeboard m
Margin Line (freeboard pos = 0 m)		3.078
Deck Edge (freeboard pos = 0 m)		3.154

Code	Criteria	Value	Units	Actual	Status	Margin %
Royal Navy, Damage Stability Criteria; DS 02-109(NES109) Part 1	1.3.5.a.(6) Longitudinal GM > 0	0.000	m	154.705	Pass	infinite

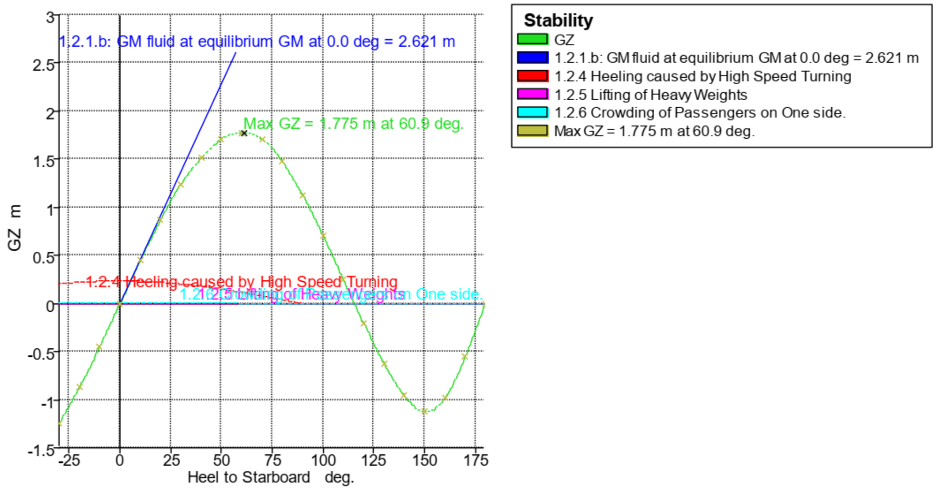
Modular ASW – Large Angle Stability

Stability calculation - OffshorePatrolVessel 2000ton

Stability 23.04.00.76, build: 76
Model file: C:\Users\Felipe\OneDrive\Documentos\Felipe\UCL\MECH0070 - MSC Individual Project\Impact of Mission Modules on Naval Ship Design\Report\MAXSURF Models\OffshorePatrolVessel 2000ton (Medium precision, 65 sections, Trimming on, Skin thickness not applied). Long. datum: AP; Vert. datum: Baseline. Analysis tolerance - ideal(worst case): Disp.%: 0.01000(0.100); Trim%(LCG-TCG): 0.01000(0.100); Heel%(LCG-TCG): 0.01000(0.100)

Loadcase - OffshorePatrolVessel 2000ton_Modular_ASW
Damage Case - Intact
Free to Trim / Specific gravity = 1.025; (Density = 1.025 tonne/m^3) / Fluid analysis method: Use corrected VCG

Item Name	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
Lightship	1	1560.253	1560.253			38.060	0.000	4.631	0.000	User Specified
VLS	1	26.000	26.000			63.400	0.000	7.300	0.000	User Specified
Torpedo Container	1	5.330	5.330			32.050	0.000	8.241	0.000	User Specified
Torpedo Container	1	5.330	5.330			32.050	0.000	8.241	0.000	User Specified
TAS Module	1	14.000	14.000			3.470	0.000	8.241	0.000	User Specified
Aft Grey Water Tank	0%	15.877	0.000	15.490	0.000	5.185	0.000	2.623	0.000	Maximum
Aft Fuel Tank Starb	100%	19.344	19.344	23.029	23.029	9.149	-2.124	3.487	0.000	Maximum
Aft Fuel Tank Port	100%	19.344	19.344	23.029	23.029	9.149	2.124	3.487	0.000	Maximum
Aft Fuel Wing Tank Starb	100%	17.487	17.487	20.818	20.818	13.244	-4.052	3.563	0.000	Maximum
Aft Fuel Wing Tank Port	100%	17.487	17.487	20.818	20.818	13.244	4.052	3.563	0.000	Maximum
Aft Ballast Tank	0%	68.488	0.000	66.817	0.000	13.654	0.000	1.000	0.000	Maximum
Dirty Aviation Fuel Tank	0%	22.075	0.000	26.911	0.000	17.287	0.000	0.800	0.000	Maximum
Aviation Fuel Tank	100%	35.941	35.941	43.814	43.814	20.171	0.000	2.538	0.000	Maximum
Dirty Water Tank	0%	2.120	0.000	2.068	0.000	27.315	0.000	0.022	0.000	Maximum
Dirty Lub Oil Tank	0%	1.959	0.000	2.129	0.000	28.615	0.000	0.028	0.000	Maximum
Dirty Water Tank	0%	2.217	0.000	2.163	0.000	29.915	0.000	0.033	0.000	Maximum
Lub Oil Tank	100%	4.053	4.053	4.406	4.406	32.504	0.000	0.566	0.000	Maximum
Dirty Water Tank	0%	2.278	0.000	2.222	0.000	33.815	0.000	0.049	0.000	Maximum
Fuel Tank Starb	100%	14.254	14.254	16.969	16.969	37.695	-1.987	1.246	0.000	Maximum
Fuel Tank Port	100%	14.254	14.254	16.969	16.969	37.695	1.987	1.246	0.000	Maximum
Fuel Tank Central	100%	32.011	32.011	38.109	38.109	40.945	0.000	1.157	0.000	Maximum
Grey Water Starb	0%	8.035	0.000	7.839	0.000	42.940	-0.001	0.086	0.000	Maximum
Grey Water Port	0%	8.035	0.000	7.839	0.000	42.940	0.001	0.086	0.000	Maximum
Dirty Water Tank	0%	12.591	0.000	12.284	0.000	45.577	0.000	0.089	0.000	Maximum
Fwd Fuel Tank Starb	100%	22.771	22.771	27.108	27.108	49.331	-1.611	1.258	0.000	Maximum
Fwd Fuel Tank Port	100%	22.771	22.771	27.108	27.108	49.331	1.611	1.258	0.000	Maximum
Fwd Grey Water Tank	0%	21.812	0.000	23.709	0.000	54.209	0.000	0.091	0.000	Maximum
Fresh Water Tank Starb	100%	10.015	10.015	10.015	10.015	57.173	-1.209	1.272	0.000	Maximum
Fresh Water Tank Port	100%	10.015	10.015	10.015	10.015	57.173	1.209	1.272	0.000	Maximum
Fwd Ballast Tank	0%	16.696	0.000	16.289	0.000	61.993	0.000	0.091	0.000	Maximum
Fwd Ballast Tank	0%	56.929	0.000	55.541	0.000	64.173	0.000	0.091	0.000	Maximum
Peak Tank	0%	19.388	0.000	18.916	0.000	73.297	0.000	0.097	0.000	Maximum
Total Loadcase			1850.660	542.424	282.206	37.215	0.000	4.391	0.000	
FS correction								0.000		
VCG fluid								4.391		



Heel to Starboard deg	-30.0	-20.0	-10.0	0.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0
GZ m	-1.243	-0.868	-0.450	0.000	0.450	0.868	1.243	1.511	1.703	1.775	1.712	1.476	1.122	0.70
Area under GZ curve from zero heel m.deg	19.4771	8.8982	2.2672	0.0000	2.2696	8.8893	19.5118	33.3551	49.5014	66.9980	84.5627	100.6358	113.6981	122.861
Displacement t	1851	1851	1851	1851	1851	1851	1851	1851	1851	1851	1851	1851	1851	185
Draft at FP m	3.695	3.825	3.875	3.888	3.875	3.824	3.697	3.403	2.758	1.642	-0.513	-7.286	n/a	-20.55
Draft at AP m	3.311	3.705	3.923	3.993	3.923	3.705	3.309	2.782	2.151	1.265	-0.248	-4.427	n/a	-11.31
WL Length m	77.754	77.833	77.864	77.872	77.864	77.832	77.754	77.574	77.167	76.401	74.922	77.312	79.096	80.26
Beam max extents on WL m	12.541	12.714	12.874	12.940	12.874	12.714	12.541	12.676	12.407	11.200	10.438	9.794	9.477	9.39
Wetted Area m^2	1014.238	1010.570	1014.038	1016.430	1014.044	1010.576	1014.236	1036.693	1053.211	1060.711	1037.626	1025.305	1024.772	1028.09
Waterpl. Area m^2	759.414	763.290	768.943	772.928	768.948	763.296	759.425	722.150	701.268	660.944	616.977	564.103	535.605	523.18
Prismatic coeff. (Cp)	0.650	0.641	0.633	0.630	0.633	0.641	0.650	0.646	0.628	0.618	0.615	0.589	0.571	0.56
Block coeff. (Cb)	0.457	0.468	0.463	0.451	0.463	0.468	0.457	0.436	0.434	0.472	0.500	0.502	0.480	0.42
LCB from zero pt. (+ve fwd) m	37.221	37.221	37.215	37.213	37.214	37.219	37.226	37.230	37.229	37.226	37.211	37.192	37.165	37.13
LCF from zero pt. (+ve fwd) m	36.135	35.398	34.883	34.662	34.883	35.397	36.137	38.175	40.223	41.303	41.374	41.079	40.730	40.41
Max deck inclination deg	30.0009	20.0002	10.0001	0.0766	10.0001	20.0002	30.0009	40.0013	50.0006	60.0001	70.0000	80.0002	90.0000	99.997
Trim angle (+ve by stern) deg	-0.2823	-0.0881	0.0350	0.0766	0.0354	-0.0873	-0.2843	-0.4557	-0.4457	-0.2768	0.1950	2.0984	n/a	6.751

Key point	Type	Immersion angle deg	Emergence angle deg	Freeboard at 0.0 deg m	Freeboard at 10.0 deg m	Freeboard at 20.0 deg m	Freeboard at 30.0 deg m	Freeboard at 40.0 deg m	Freeboard at 50.0 deg m	Freeboard at 60.0 deg m	Freeboard at 70.0 deg m	Freeboard at 80.0 deg m	Freeboard at 90.0 deg m	Freeboard at 100.0 deg m	Freeboard at 110.0 deg m	Freeboard at 120.0 deg m	Freeboard at 130.0 deg m	Freeboard at 140.0 deg m	Freeboard at 150.0 deg m	Freeboard at 160.0 deg m	Freeboard at 170.0 deg m	Freeboard at 180.0 deg m
Margin Line (immersion pos = 34.659 m)		27.1	n/a	3.078	1.934	0.775	-0.309	-1.320	-2.248	-3.101	-3.881	-4.522	-5.022	-5.618	-6.082	-6.328	-6.341	-6.108	-5.608	-4.815	-3.781	-2.623
Deck Edge (immersion pos = 34.659 m)		27.8	n/a	3.154	2.009	0.847	-0.243	-1.262	-2.199	-3.063	-3.855	-4.509	-5.022	-5.631	-6.107	-6.365	-6.389	-6.165	-5.674	-4.886	-3.856	-2.698

Code	Criteria	Value	Units	Actual	Status	Margin %
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 0 to 30	4.5840	m.deg	19.5118	Pass	+325.65
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 0 to 40	7.6200	m.deg	33.3551	Pass	+337.73
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 30 to 40	2.7500	m.deg	13.8433	Pass	+403.39
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Maximum GZ	0.300	m	1.703	Pass	+467.67
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Angle of maximum GZ	30.0	deg	60.9	Pass	+103.03
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: GM fluid at equilibrium	0.300	m	2.621	Pass	+773.67
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Range of positive stability	70.0	deg	115.4	Pass	+64.84
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Angle of vanishing stability	70.0	deg	115.4	Pass	+64.84
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.4 Heeling caused by High Speed Turning				Pass	
	Angle of steady heel shall be less than (<)	20.0	deg	5.1	Pass	+74.29
	Area1 / Area2 shall be greater than (>)	40.00	%	85.74	Pass	+114.35
	GZ(intersection) / GZ(max) shall be less than (<)	60.00	%	13.75	Pass	+77.08
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.5 Lifting of Heavy Weights				Pass	
	Angle of steady heel shall be less than (<)	15.0	deg	0.0	Pass	+99.99
	Area1 / Area2 shall be greater than (>)	50.00	%	99.99	Pass	+99.98
	GZ(intersection) / GZ(max) shall be less than (<)	50.00	%	0.00	Pass	+100.00
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.6 Crowding of Passengers on One side.				Pass	
	Angle of steady heel shall be less than (<)	10.0	deg	0.1	Pass	+99.11
	Area1 / Area2 shall be greater than (>)	40.00	%	99.74	Pass	+149.35
	GZ(intersection) / GZ(max) shall be less than (<)	60.00	%	0.24	Pass	+99.60

Modular ASuW – Equilibrium

Equilibrium calculation - OffshorePatrolVessel 2000ton

Stability 23.04.00.76, build: 76
Model file: C:\Users\Felipe\OneDrive\Documentos\Felipe\UCL\MECH0070 - MSC Individual Project\Impact of Mission Modules on Naval Ship Design\Report\MAXSURF Models\OffshorePatrolVessel 2000ton (Medium precision, 65 sections, Trimming on, Skin thickness not applied). Long. datum: AP; Vert. datum: Baseline. Analysis tolerance - ideal(worst case): Disp.%: 0.01000(0.100); Trim%(LCG-TCG): 0.01000(0.100); Heel%(LCG-TCG): 0.01000(0.100)

Loadcase - OffshorePatrolVessel 2000ton_Modular_ASuW
Damage Case - Intact
Free to Trim / Specific gravity = 1.025; (Density = 1.025 tonne/m^3) / Fluid analysis method: Use corrected VCG

Item Name	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
Lightship	1	1560.253	1560.253			38.060	0.000	4.631	0.000	User Specified
Gun 40mm	1	9.350	9.350			69.550	0.000	8.495	0.000	User Specified
VLS	1	26.000	26.000			63.400	0.000	7.300	0.000	User Specified
7m RIB	1	5.000	5.000			32.050	0.000	8.241	0.000	User Specified
7m RIB	1	5.000	5.000			32.050	0.000	8.241	0.000	User Specified
Aft Grey Water Tank	0%	15.877	0.000	15.490	0.000	5.185	0.000	2.623	0.000	Maximum
Aft Fuel Tank Starb	100%	19.344	19.344	23.029	23.029	9.149	-2.124	3.487	0.000	Maximum
Aft Fuel Tank Port	100%	19.344	19.344	23.029	23.029	9.149	2.124	3.487	0.000	Maximum
Aft Fuel Wing Tank Starb	100%	17.487	17.487	20.818	20.818	13.244	-4.052	3.563	0.000	Maximum
Aft Fuel Wing Tank Port	100%	17.487	17.487	20.818	20.818	13.244	4.052	3.563	0.000	Maximum
Aft Ballast Tank	0%	68.488	0.000	66.817	0.000	13.654	0.000	1.000	0.000	Maximum
Dirty Aviation Fuel Tank	0%	22.075	0.000	26.911	0.000	17.287	0.000	0.800	0.000	Maximum
Aviation Fuel Tank	100%	35.941	35.941	43.814	43.814	20.171	0.000	2.538	0.000	Maximum
Dirty Water Tank	0%	2.120	0.000	2.068	0.000	27.315	0.000	0.022	0.000	Maximum
Dirty Lub Oil Tank	0%	1.959	0.000	2.129	0.000	28.615	0.000	0.028	0.000	Maximum
Dirty Water Tank	0%	2.217	0.000	2.163	0.000	29.915	0.000	0.033	0.000	Maximum
Lub Oil Tank	100%	4.053	4.053	4.406	4.406	32.504	0.000	0.566	0.000	Maximum
Dirty Water Tank	0%	2.278	0.000	2.222	0.000	33.815	0.000	0.049	0.000	Maximum
Fuel Tank Starb	100%	14.254	14.254	16.969	16.969	37.695	-1.987	1.246	0.000	Maximum
Fuel Tank Port	100%	14.254	14.254	16.969	16.969	37.695	1.987	1.246	0.000	Maximum
Fuel Tank Central	100%	32.011	32.011	38.109	38.109	40.945	0.000	1.157	0.000	Maximum
Grey Water Starb	0%	8.035	0.000	7.839	0.000	42.940	-0.001	0.086	0.000	Maximum
Grey Water Port	0%	8.035	0.000	7.839	0.000	42.940	0.001	0.086	0.000	Maximum
Dirty Water Tank	0%	12.591	0.000	12.284	0.000	45.577	0.000	0.089	0.000	Maximum
Fwd Fuel Tank Starb	100%	22.771	22.771	27.108	27.108	49.331	-1.611	1.258	0.000	Maximum
Fwd Fuel Tank Port	100%	22.771	22.771	27.108	27.108	49.331	1.611	1.258	0.000	Maximum
Fwd Grey Water Tank	0%	21.812	0.000	23.709	0.000	54.209	0.000	0.091	0.000	Maximum
Fresh Water Tank Starb	100%	10.015	10.015	10.015	10.015	57.173	-1.209	1.272	0.000	Maximum
Fresh Water Tank Port	100%	10.015	10.015	10.015	10.015	57.173	1.209	1.272	0.000	Maximum
Fwd Ballast Tank	0%	16.696	0.000	16.289	0.000	61.993	0.000	0.091	0.000	Maximum
Fwd Ballast Tank	0%	56.929	0.000	55.541	0.000	64.173	0.000	0.091	0.000	Maximum
Peak Tank	0%	19.388	0.000	18.916	0.000	73.297	0.000	0.097	0.000	Maximum
Total Loadcase			1845.350	542.424	282.206	37.637	0.000	4.381	0.000	
FS correction								0.000		
VCG fluid								4.381		

Draft Amidships m	3.945
Displacement t	1846
Heel deg	0.0
Draft at FP m	3.996
Draft at AP m	3.895
Draft at LCF m	3.940
Trim (+ve by stern) m	-0.101
WL Length m	77.937
Beam max extents on WL m	12.932
Wetted Area m^2	1015.349
Waterpl. Area m^2	771.567
Prismatic coeff. (Cp)	0.629
Block coeff. (Cb)	0.456
Max Sect. area coeff. (Cm)	0.731
Waterpl. area coeff. (Cwp)	0.766
LCB from zero pt. (+ve fwd) m	37.632
LCF from zero pt. (+ve fwd) m	34.857
KB m	2.503
KG fluid m	4.381
BMt m	4.489
BML m	156.621
GMt corrected m	2.611
GML m	154.743
KMt m	6.992
KML m	159.124
Immersion (TPc) tonne/cm	7.909
MTc tonne.m	36.603
RM at 1deg = GMt.Disp.sin(1) tonne.m	84.086
Max deck inclination deg	0.0742
Trim angle (+ve by stern) deg	-0.0742

Key point	Type	Freeboard m
Margin Line (freeboard pos = 34.659 m)		3.132
Deck Edge (freeboard pos = 34.659 m)		3.208

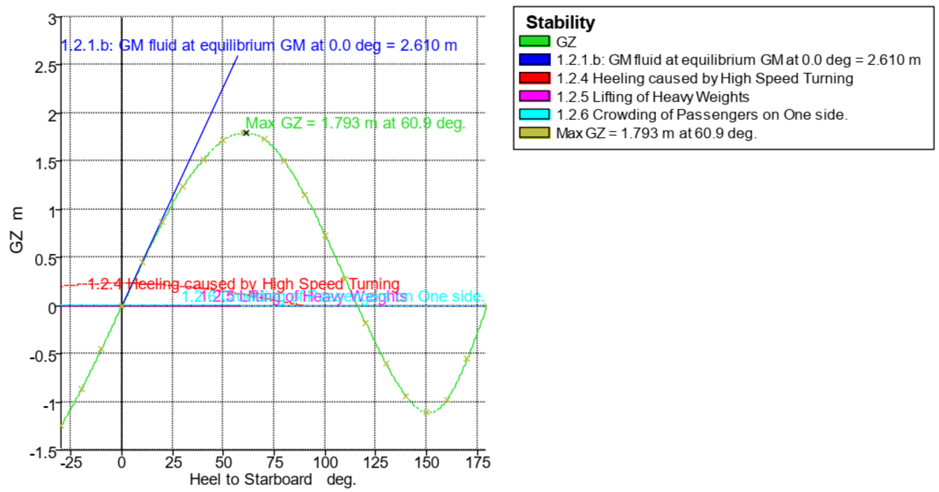
Code	Criteria	Value	Units	Actual	Status	Margin %
Royal Navy, Damage Stability Criteria; DS 02-109(NES109) Part 1	1.3.5.a.(6) Longitudinal GM > 0	0.000	m	154.743	Pass	infinite

Modular ASuW – Large Angle Stability

Stability calculation - OffshorePatrolVessel 2000ton
Stability 23.04.00.76, build: 76
Model file: C:\Users\Felipe\OneDrive\Documentos\Felipe\UCL\MECH0070 - MSC Individual Project\Impact of Mission Modules on Naval Ship Design\Report\MAXSURF Models\OffshorePatrolVessel 2000ton (Medium precision, 65 sections, Trimming on, Skin thickness not applied). Long. datum: AP; Vert. datum: Baseline. Analysis tolerance - ideal(worst case): Disp.%: 0.01000(0.100); Trim%(LCG-TCG): 0.01000(0.100); Heel%(LCG-TCG): 0.01000(0.100)

Loadcase - OffshorePatrolVessel 2000ton_Modular_ASuW
Damage Case - Intact
Free to Trim / Specific gravity = 1.025; (Density = 1.025 tonne/m^3) / Fluid analysis method: Use corrected VCG

Item Name	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
Lightship	1	1560.253	1560.253			38.060	0.000	4.631	0.000	User Specified
Gun 40mm	1	9.350	9.350			69.550	0.000	8.495	0.000	User Specified
VLS	1	26.000	26.000			63.400	0.000	7.300	0.000	User Specified
7m RIB	1	5.000	5.000			32.050	0.000	8.241	0.000	User Specified
7m RIB	1	5.000	5.000			32.050	0.000	8.241	0.000	User Specified
Aft Grey Water Tank	0%	15.877	0.000	15.490	0.000	5.185	0.000	2.623	0.000	Maximum
Aft Fuel Tank Starb	100%	19.344	19.344	23.029	23.029	9.149	-2.124	3.487	0.000	Maximum
Aft Fuel Tank Port	100%	19.344	19.344	23.029	23.029	9.149	2.124	3.487	0.000	Maximum
Aft Fuel Wing Tank Starb	100%	17.487	17.487	20.818	20.818	13.244	-4.052	3.563	0.000	Maximum
Aft Fuel Wing Tank Port	100%	17.487	17.487	20.818	20.818	13.244	4.052	3.563	0.000	Maximum
Aft Ballast Tank	0%	68.488	0.000	66.817	0.000	13.654	0.000	1.000	0.000	Maximum
Dirty Aviation Fuel Tank	0%	22.075	0.000	26.911	0.000	17.287	0.000	0.800	0.000	Maximum
Aviation Fuel Tank	100%	35.941	35.941	43.814	43.814	20.171	0.000	2.538	0.000	Maximum
Dirty Water Tank	0%	2.120	0.000	2.068	0.000	27.315	0.000	0.022	0.000	Maximum
Dirty Lub Oil Tank	0%	1.959	0.000	2.129	0.000	28.615	0.000	0.028	0.000	Maximum
Dirty Water Tank	0%	2.217	0.000	2.163	0.000	29.915	0.000	0.033	0.000	Maximum
Lub Oil Tank	100%	4.053	4.053	4.406	4.406	32.504	0.000	0.566	0.000	Maximum
Dirty Water Tank	0%	2.278	0.000	2.222	0.000	33.815	0.000	0.049	0.000	Maximum
Fuel Tank Starb	100%	14.254	14.254	16.969	16.969	37.695	-1.987	1.246	0.000	Maximum
Fuel Tank Port	100%	14.254	14.254	16.969	16.969	37.695	1.987	1.246	0.000	Maximum
Fuel Tank Central	100%	32.011	32.011	38.109	38.109	40.945	0.000	1.157	0.000	Maximum
Grey Water Starb	0%	8.035	0.000	7.839	0.000	42.940	-0.001	0.086	0.000	Maximum
Grey Water Port	0%	8.035	0.000	7.839	0.000	42.940	0.001	0.086	0.000	Maximum
Dirty Water Tank	0%	12.591	0.000	12.284	0.000	45.577	0.000	0.089	0.000	Maximum
Fwd Fuel Tank Starb	100%	22.771	22.771	27.108	27.108	49.331	-1.611	1.258	0.000	Maximum
Fwd Fuel Tank Port	100%	22.771	22.771	27.108	27.108	49.331	1.611	1.258	0.000	Maximum
Fwd Grey Water Tank	0%	21.812	0.000	23.709	0.000	54.209	0.000	0.091	0.000	Maximum
Fresh Water Tank Starb	100%	10.015	10.015	10.015	10.015	57.173	-1.209	1.272	0.000	Maximum
Fresh Water Tank Port	100%	10.015	10.015	10.015	10.015	57.173	1.209	1.272	0.000	Maximum
Fwd Ballast Tank	0%	16.696	0.000	16.289	0.000	61.993	0.000	0.091	0.000	Maximum
Fwd Ballast Tank	0%	56.929	0.000	55.541	0.000	64.173	0.000	0.091	0.000	Maximum
Peak Tank	0%	19.388	0.000	18.916	0.000	73.297	0.000	0.097	0.000	Maximum
Total Loadcase			1845.350	542.424	282.206	37.637	0.000	4.381	0.000	
FS correction								0.000		
VCG fluid								4.381		



Heel to Starboard deg	-30.0	-20.0	-10.0	0.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0
GZ m	-1.241	-0.866	-0.449	0.000	0.449	0.866	1.240	1.516	1.717	1.792	1.734	1.503	1.151	0.73
Area under GZ curve from zero heel m.deg	19.4201	8.8668	2.2586	0.0000	2.2607	8.8587	19.4519	33.3080	49.5554	67.2097	84.9670	101.2788	114.6171	124.070
Displacement t	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	184
Draft at FP m	3.816	3.940	3.986	3.997	3.986	3.940	3.818	3.539	2.919	1.849	-0.186	-6.566	n/a	-19.78
Draft at AP m	3.191	3.595	3.820	3.893	3.821	3.596	3.189	2.633	1.956	0.998	-0.674	-5.345	n/a	-12.27
WL Length m	77.828	77.904	77.931	77.938	77.931	77.903	77.830	77.659	77.269	76.548	75.278	77.676	79.387	80.56
Beam max extents on WL m	12.536	12.704	12.864	12.932	12.864	12.704	12.536	12.662	12.412	11.200	10.496	9.792	9.471	9.38
Wetted Area m^2	1012.991	1009.618	1012.829	1015.309	1012.835	1009.624	1012.988	1034.695	1050.799	1060.272	1035.901	1024.604	1023.782	1026.85
Waterpl. Area m^2	759.990	762.181	767.461	771.532	767.467	762.188	759.999	725.551	704.156	665.334	620.935	567.667	538.529	525.66
Prismatic coeff. (Cp)	0.648	0.640	0.632	0.629	0.632	0.640	0.648	0.646	0.629	0.618	0.615	0.588	0.571	0.56
Block coeff. (Cb)	0.457	0.467	0.468	0.456	0.468	0.467	0.457	0.437	0.435	0.472	0.498	0.503	0.482	0.42
LCB from zero pt. (+ve fwd) m	37.647	37.648	37.642	37.640	37.641	37.646	37.653	37.659	37.659	37.656	37.644	37.627	37.601	37.56
LCF from zero pt. (+ve fwd) m	36.320	35.600	35.089	34.861	35.088	35.599	36.322	38.263	40.338	41.453	42.002	41.335	40.973	40.64
Max deck inclination deg	30.0024	20.0014	10.0007	0.0768	10.0007	20.0014	30.0024	40.0027	50.0015	60.0005	70.0000	80.0000	90.0000	99.998
Trim angle (+ve by stern) deg	-0.4591	-0.2536	-0.1219	-0.0768	-0.1214	-0.2527	-0.4616	-0.6653	-0.7075	-0.6247	-0.3585	0.8972	n/a	5.496

Key point	Type	Immersion angle deg	Emergence angle deg	Freeboard at 0.0 deg m	Freeboard at 10.0 deg m	Freeboard at 20.0 deg m	Freeboard at 30.0 deg m	Freeboard at 40.0 deg m	Freeboard at 50.0 deg m	Freeboard at 60.0 deg m	Freeboard at 70.0 deg m	Freeboard at 80.0 deg m	Freeboard at 90.0 deg m	Freeboard at 100.0 deg m	Freeboard at 110.0 deg m	Freeboard at 120.0 deg m	Freeboard at 130.0 deg m	Freeboard at 140.0 deg m	Freeboard at 150.0 deg m	Freeboard at 160.0 deg m	Freeboard at 170.0 deg m	Freeboard at 180.0 deg m
Margin Line (immersion pos = 34.659 m)		27.2	n/a	3.132	1.942	0.784	-0.298	-1.303	-2.224	-3.073	-3.850	-4.483	-4.970	-5.596	-6.061	-6.309	-6.325	-6.094	-5.597	-4.806	-3.774	-2.616
Deck Edge (immersion pos = 34.659 m)		27.9	n/a	3.208	2.017	0.856	-0.232	-1.244	-2.175	-3.035	-3.824	-4.470	-4.970	-5.609	-6.087	-6.347	-6.373	-6.151	-5.662	-4.877	-3.849	-2.692

Code	Criteria	Value	Units	Actual	Status	Margin %
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 0 to 30	4.5840	m.deg	19.4519	Pass	+324.34
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 0 to 40	7.6200	m.deg	33.3080	Pass	+337.11
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 30 to 40	2.7500	m.deg	13.8562	Pass	+403.86
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Maximum GZ	0.300	m	1.717	Pass	+472.33
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Angle of maximum GZ	30.0	deg	60.9	Pass	+103.03
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: GM fluid at equilibrium	0.300	m	2.610	Pass	+770.00
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Range of positive stability	70.0	deg	116.0	Pass	+65.68
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Angle of vanishing stability	70.0	deg	116.0	Pass	+65.68
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.4 Heeling caused by High Speed Turning				Pass	
	Angle of steady heel shall be less than (<)	20.0	deg	5.1	Pass	+74.32
	Area1 / Area2 shall be greater than (>)	40.00	%	85.88	Pass	+114.70
	GZ(intersection) / GZ(max) shall be less than (<)	60.00	%	13.57	Pass	+77.38
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.5 Lifting of Heavy Weights				Pass	
	Angle of steady heel shall be less than (<)	15.0	deg	0.0	Pass	+99.99
	Area1 / Area2 shall be greater than (>)	50.00	%	99.99	Pass	+99.98
	GZ(intersection) / GZ(max) shall be less than (<)	50.00	%	0.00	Pass	+100.00
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.6 Crowding of Passengers on One side.				Pass	
	Angle of steady heel shall be less than (<)	10.0	deg	0.1	Pass	+99.11
	Area1 / Area2 shall be greater than (>)	40.00	%	99.74	Pass	+149.35
	GZ(intersection) / GZ(max) shall be less than (<)	60.00	%	0.24	Pass	+99.60

Modular MW – Equilibrium

Equilibrium calculation - OffshorePatrolVessel 2000ton
Stability 23.04.00.76, build: 76
Model file: C:\Users\Felipe\OneDrive\Documentos\Felipe\UCL\MECH0070 - MSC Individual Project\Impact of Mission Modules on Naval Ship Design\Report\MAXSURF Models\OffshorePatrolVessel 2000ton (Medium precision, 65 sections, Trimming on, Skin thickness not applied). Long. datum: AP; Vert. datum: Baseline. Analysis tolerance - ideal(worst case): Disp.%: 0.01000(0.100); Trim%(LCG-TCG): 0.01000(0.100); Heel%(LCG-TCG): 0.01000(0.100)

Loadcase - OffshorePatrolVessel 2000ton_Modular_MW
Damage Case - Intact
Free to Trim / Specific gravity = 1.025; (Density = 1.025 tonne/m^3) / Fluid analysis method: Use corrected VCG

Item Name	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
Lightship	1	1560.253	1560.253			38.060	0.000	4.631	0.000	User Specified
7m RIB	1	5.000	5.000			32.050	0.000	8.241	0.000	User Specified
7m RIB	1	5.000	5.000			32.050	0.000	8.241	0.000	User Specified
UUV Module	1	2.930	2.930			23.950	0.000	8.241	0.000	User Specified
UUV Module	1	2.930	2.930			23.950	0.000	8.241	0.000	User Specified
Aft Grey Water Tank	0%	15.877	0.000	15.490	0.000	5.185	0.000	2.623	0.000	Maximum
Aft Fuel Tank Starb	100%	19.344	19.344	23.029	23.029	9.149	-2.124	3.487	0.000	Maximum
Aft Fuel Tank Port	100%	19.344	19.344	23.029	23.029	9.149	2.124	3.487	0.000	Maximum
Aft Fuel Wing Tank Starb	100%	17.487	17.487	20.818	20.818	13.244	-4.052	3.563	0.000	Maximum
Aft Fuel Wing Tank Port	100%	17.487	17.487	20.818	20.818	13.244	4.052	3.563	0.000	Maximum
Aft Ballast Tank	0%	68.488	0.000	66.817	0.000	13.654	0.000	1.000	0.000	Maximum
Dirty Aviation Fuel Tank	0%	22.075	0.000	26.911	0.000	17.287	0.000	0.800	0.000	Maximum
Aviation Fuel Tank	100%	35.941	35.941	43.814	43.814	20.171	0.000	2.538	0.000	Maximum
Dirty Water Tank	0%	2.120	0.000	2.068	0.000	27.315	0.000	0.022	0.000	Maximum
Dirty Lub Oil Tank	0%	1.959	0.000	2.129	0.000	28.615	0.000	0.028	0.000	Maximum
Dirty Water Tank	0%	2.217	0.000	2.163	0.000	29.915	0.000	0.033	0.000	Maximum
Lub Oil Tank	100%	4.053	4.053	4.406	4.406	32.504	0.000	0.566	0.000	Maximum
Dirty Water Tank	0%	2.278	0.000	2.222	0.000	33.815	0.000	0.049	0.000	Maximum
Fuel Tank Starb	100%	14.254	14.254	16.969	16.969	37.695	-1.987	1.246	0.000	Maximum
Fuel Tank Port	100%	14.254	14.254	16.969	16.969	37.695	1.987	1.246	0.000	Maximum
Fuel Tank Central	100%	32.011	32.011	38.109	38.109	40.945	0.000	1.157	0.000	Maximum
Grey Water Starb	0%	8.035	0.000	7.839	0.000	42.940	-0.001	0.086	0.000	Maximum
Grey Water Port	0%	8.035	0.000	7.839	0.000	42.940	0.001	0.086	0.000	Maximum
Dirty Water Tank	0%	12.591	0.000	12.284	0.000	45.577	0.000	0.089	0.000	Maximum
Fwd Fuel Tank Starb	100%	22.771	22.771	27.108	27.108	49.331	-1.611	1.258	0.000	Maximum
Fwd Fuel Tank Port	100%	22.771	22.771	27.108	27.108	49.331	1.611	1.258	0.000	Maximum
Fwd Grey Water Tank	0%	21.812	0.000	23.709	0.000	54.209	0.000	0.091	0.000	Maximum
Fresh Water Tank Starb	100%	10.015	10.015	10.015	10.015	57.173	-1.209	1.272	0.000	Maximum
Fresh Water Tank Port	100%	10.015	10.015	10.015	10.015	57.173	1.209	1.272	0.000	Maximum
Fwd Ballast Tank	0%	16.696	0.000	16.289	0.000	61.993	0.000	0.091	0.000	Maximum
Fwd Ballast Tank	0%	56.929	0.000	55.541	0.000	64.173	0.000	0.091	0.000	Maximum
Peak Tank	0%	19.388	0.000	18.916	0.000	73.297	0.000	0.097	0.000	Maximum
Total Loadcase			1815.860	542.424	282.206	37.060	0.000	4.331	0.000	
FS correction								0.000		
VCG fluid								4.331		

Draft Amidships m	3.891
Displacement t	1816
Heel deg	0.0
Draft at FP m	3.787
Draft at AP m	3.994
Draft at LCF m	3.902
Trim (+ve by stern) m	0.207
WL Length m	77.811
Beam max extents on WL m	12.916
Wetted Area m^2	1007.865
Waterpl. Area m^2	769.356
Prismatic coeff. (Cp)	0.628
Block coeff. (Cb)	0.445
Max Sect. area coeff. (Cm)	0.726
Waterpl. area coeff. (Cwp)	0.766
LCB from zero pt. (+ve fwd) m	37.054
LCF from zero pt. (+ve fwd) m	34.582
KB m	2.480
KG fluid m	4.331
BMt m	4.546
BML m	158.281
GMt corrected m	2.695
GML m	156.431
KMt m	7.026
KML m	160.761
Immersion (TPc) tonne/cm	7.886
MTc tonne.m	36.408
RM at 1deg = GMt.Disp.sin(1) tonne.m	85.422
Max deck inclination deg	0.1517
Trim angle (+ve by stern) deg	0.1517

Key point	Type	Freeboard m
Margin Line (freeboard pos = 0 m)		3.076
Deck Edge (freeboard pos = 0 m)		3.152

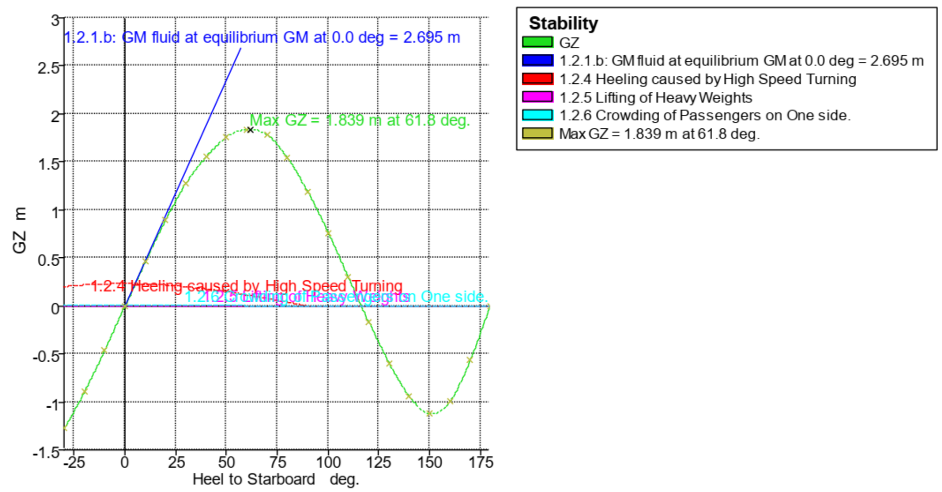
Code	Criteria	Value	Units	Actual	Status	Margin %
Royal Navy, Damage Stability Criteria; DS 02-109(NES109) Part 1	1.3.5.a.(6) Longitudinal GM > 0	0.000	m	156.431	Pass	infinite

Modular MW – Large Angle Stability

Stability calculation - OffshorePatrolVessel 2000ton
Stability 23.04.00.76, build: 76
Model file: C:\Users\Felipe\OneDrive\Documentos\Felipe\UCL\MECH0070 - MSC Individual Project\Impact of Mission Modules on Naval Ship Design\Report\MAXSURF Models\OffshorePatrolVessel 2000ton (Medium precision, 65 sections, Trimming on, Skin thickness not applied). Long. datum: AP; Vert. datum: Baseline. Analysis tolerance - ideal(worst case): Disp.%: 0.01000(0.100); Trim%(LCG-TCG): 0.01000(0.100); Heel%(LCG-TCG): 0.01000(0.100)

Loadcase - OffshorePatrolVessel 2000ton_Modular_MW
Damage Case - Intact
Free to Trim / Specific gravity = 1.025; (Density = 1.025 tonne/m^3) / Fluid analysis method: Use corrected VCG

Item Name	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
Lightship	1	1560.253	1560.253			38.060	0.000	4.631	0.000	User Specified
7m RIB	1	5.000	5.000			32.050	0.000	8.241	0.000	User Specified
7m RIB	1	5.000	5.000			32.050	0.000	8.241	0.000	User Specified
UUV Module	1	2.930	2.930			23.950	0.000	8.241	0.000	User Specified
UUV Module	1	2.930	2.930			23.950	0.000	8.241	0.000	User Specified
Aft Grey Water Tank	0%	15.877	0.000	15.490	0.000	5.185	0.000	2.623	0.000	Maximum
Aft Fuel Tank Starb	100%	19.344	19.344	23.029	23.029	9.149	-2.124	3.487	0.000	Maximum
Aft Fuel Tank Port	100%	19.344	19.344	23.029	23.029	9.149	2.124	3.487	0.000	Maximum
Aft Fuel Wing Tank Starb	100%	17.487	17.487	20.818	20.818	13.244	-4.052	3.563	0.000	Maximum
Aft Fuel Wing Tank Port	100%	17.487	17.487	20.818	20.818	13.244	4.052	3.563	0.000	Maximum
Aft Ballast Tank	0%	68.488	0.000	66.817	0.000	13.654	0.000	1.000	0.000	Maximum
Dirty Aviation Fuel Tank	0%	22.075	0.000	26.911	0.000	17.287	0.000	0.800	0.000	Maximum
Aviation Fuel Tank	100%	35.941	35.941	43.814	43.814	20.171	0.000	2.538	0.000	Maximum
Dirty Water Tank	0%	2.120	0.000	2.068	0.000	27.315	0.000	0.022	0.000	Maximum
Dirty Lub Oil Tank	0%	1.959	0.000	2.129	0.000	28.615	0.000	0.028	0.000	Maximum
Dirty Water Tank	0%	2.217	0.000	2.163	0.000	29.915	0.000	0.033	0.000	Maximum
Lub Oil Tank	100%	4.053	4.053	4.406	4.406	32.504	0.000	0.566	0.000	Maximum
Dirty Water Tank	0%	2.278	0.000	2.222	0.000	33.815	0.000	0.049	0.000	Maximum
Fuel Tank Starb	100%	14.254	14.254	16.969	16.969	37.695	-1.987	1.246	0.000	Maximum
Fuel Tank Port	100%	14.254	14.254	16.969	16.969	37.695	1.987	1.246	0.000	Maximum
Fuel Tank Central	100%	32.011	32.011	38.109	38.109	40.945	0.000	1.157	0.000	Maximum
Grey Water Starb	0%	8.035	0.000	7.839	0.000	42.940	-0.001	0.086	0.000	Maximum
Grey Water Port	0%	8.035	0.000	7.839	0.000	42.940	0.001	0.086	0.000	Maximum
Dirty Water Tank	0%	12.591	0.000	12.284	0.000	45.577	0.000	0.089	0.000	Maximum
Fwd Fuel Tank Starb	100%	22.771	22.771	27.108	27.108	49.331	-1.611	1.258	0.000	Maximum
Fwd Fuel Tank Port	100%	22.771	22.771	27.108	27.108	49.331	1.611	1.258	0.000	Maximum
Fwd Grey Water Tank	0%	21.812	0.000	23.709	0.000	54.209	0.000	0.091	0.000	Maximum
Fresh Water Tank Starb	100%	10.015	10.015	10.015	10.015	57.173	-1.209	1.272	0.000	Maximum
Fresh Water Tank Port	100%	10.015	10.015	10.015	10.015	57.173	1.209	1.272	0.000	Maximum
Fwd Ballast Tank	0%	16.696	0.000	16.289	0.000	61.993	0.000	0.091	0.000	Maximum
Fwd Ballast Tank	0%	56.929	0.000	55.541	0.000	64.173	0.000	0.091	0.000	Maximum
Peak Tank	0%	19.388	0.000	18.916	0.000	73.297	0.000	0.097	0.000	Maximum
Total Loadcase			1815.860	542.424	282.206	37.060	0.000	4.331	0.000	
FS correction								0.000		
VCG fluid								4.331		



Heel to Starboard deg	-30.0	-20.0	-10.0	0.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0
GZ m	-1.275	-0.892	-0.463	0.000	0.463	0.892	1.275	1.553	1.753	1.837	1.782	1.544	1.186	0.76
Area under GZ curve from zero heel m.deg	20.0055	9.1453	2.3314	0.0000	2.3336	9.1365	20.0399	34.2571	50.8602	68.9186	87.1532	103.9192	117.6440	127.421
Displacement t	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	181
Draft at FP m	3.590	3.721	3.774	3.787	3.774	3.721	3.590	3.294	2.643	1.498	-0.738	-7.781	n/a	-21.11
Draft at AP m	3.304	3.704	3.924	3.994	3.924	3.704	3.304	2.766	2.118	1.209	-0.339	-4.611	n/a	-11.49
WL Length m	77.689	77.770	77.802	77.811	77.802	77.769	77.689	77.506	77.092	76.288	74.664	77.061	78.837	80.04
Beam max extents on WL m	12.485	12.670	12.845	12.916	12.845	12.670	12.485	12.608	12.421	11.211	10.407	9.784	9.460	9.37
Wetted Area m^2	1004.339	1001.627	1005.346	1007.864	1005.352	1001.634	1004.335	1026.398	1042.608	1049.666	1022.099	1013.587	1012.954	1016.37
Waterpl. Area m^2	756.178	759.093	765.148	769.355	765.153	759.099	756.177	718.798	699.481	660.028	610.117	560.360	531.709	519.38
Prismatic coeff. (Cp)	0.648	0.639	0.631	0.628	0.631	0.639	0.648	0.645	0.627	0.616	0.615	0.588	0.571	0.55
Block coeff. (Cb)	0.456	0.466	0.457	0.445	0.457	0.466	0.456	0.436	0.430	0.468	0.499	0.500	0.478	0.42
LCB from zero pt. (+ve fwd) m	37.067	37.063	37.057	37.055	37.056	37.060	37.067	37.072	37.071	37.067	37.053	37.033	37.006	36.97
LCF from zero pt. (+ve fwd) m	36.033	35.315	34.803	34.582	34.802	35.314	36.033	38.052	40.120	41.197	41.300	40.929	40.568	40.26
Max deck inclination deg	30.0005	20.0000	10.0006	0.1515	10.0006	20.0000	30.0005	40.0009	50.0005	60.0001	70.0000	80.0003	90.0000	99.997
Trim angle (+ve by stern) deg	-0.2100	-0.0131	0.1100	0.1515	0.1104	-0.0123	-0.2100	-0.3877	-0.3858	-0.2124	0.2929	2.3261	n/a	7.023

Key point	Type	Immersion angle deg	Emergence angle deg	Freeboard at 0.0 deg m	Freeboard at 10.0 deg m	Freeboard at 20.0 deg m	Freeboard at 30.0 deg m	Freeboard at 40.0 deg m	Freeboard at 50.0 deg m	Freeboard at 60.0 deg m	Freeboard at 70.0 deg m	Freeboard at 80.0 deg m	Freeboard at 90.0 deg m	Freeboard at 100.0 deg m	Freeboard at 110.0 deg m	Freeboard at 120.0 deg m	Freeboard at 130.0 deg m	Freeboard at 140.0 deg m	Freeboard at 150.0 deg m	Freeboard at 160.0 deg m	Freeboard at 170.0 deg m	Freeboard at 180.0 deg m
Margin Line (immersion pos = 34.659 m)		27.5	n/a	3.077	1.974	0.819	-0.266	-1.276	-2.203	-3.054	-3.829	-4.468	-4.969	-5.556	-6.020	-6.267	-6.284	-6.055	-5.562	-4.775	-3.745	-2.608
Deck Edge (immersion pos = 34.659 m)		28.2	n/a	3.153	2.049	0.891	-0.200	-1.218	-2.154	-3.016	-3.803	-4.455	-4.969	-5.568	-6.045	-6.305	-6.332	-6.113	-5.627	-4.846	-3.819	-2.684

Code	Criteria	Value	Units	Actual	Status	Margin %
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 0 to 30	4.5840	m.deg	20.0399	Pass	+337.17
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 0 to 40	7.6200	m.deg	34.2571	Pass	+349.57
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 30 to 40	2.7500	m.deg	14.2172	Pass	+416.99
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Maximum GZ	0.300	m	1.753	Pass	+484.33
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Angle of maximum GZ	30.0	deg	61.8	Pass	+106.06
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: GM fluid at equilibrium	0.300	m	2.695	Pass	+798.33
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Range of positive stability	70.0	deg	116.4	Pass	+66.24
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Angle of vanishing stability	70.0	deg	116.4	Pass	+66.24
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.4 Heeling caused by High Speed Turning				Pass	
	Angle of steady heel shall be less than (<)	20.0	deg	4.9	Pass	+75.36
	Area1 / Area2 shall be greater than (>)	40.00	%	86.34	Pass	+115.85
	GZ(intersection) / GZ(max) shall be less than (<)	60.00	%	13.17	Pass	+78.05
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.5 Lifting of Heavy Weights				Pass	
	Angle of steady heel shall be less than (<)	15.0	deg	0.0	Pass	+99.99
	Area1 / Area2 shall be greater than (>)	50.00	%	99.99	Pass	+99.98
	GZ(intersection) / GZ(max) shall be less than (<)	50.00	%	0.00	Pass	+100.00
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.6 Crowding of Passengers on One side.				Pass	
	Angle of steady heel shall be less than (<)	10.0	deg	0.1	Pass	+99.12
	Area1 / Area2 shall be greater than (>)	40.00	%	99.75	Pass	+149.38
	GZ(intersection) / GZ(max) shall be less than (<)	60.00	%	0.24	Pass	+99.60

Modular No Modules – Equilibrium

Equilibrium calculation - OffshorePatrolVessel 2000ton

Stability 23.04.00.76, build: 76

Model file: C:\Users\Felipe\OneDrive\Documentos\Felipe\UCL\MECH0070 - MSC Individual Project\Impact of Mission Modules on Naval Ship Design\Report\MAXSURF Models\OffshorePatrolVessel 2000ton (Medium precision, 65 sections, Trimming on, Skin thickness not applied). Long. datum: AP; Vert. datum: Baseline. Analysis tolerance - ideal(worst case): Disp.%: 0.01000(0.100); Trim%(LCG-TCG): 0.01000(0.100); Heel%(LCG-TCG): 0.01000(0.100)

Loadcase - OffshorePatrolVessel 2000ton_Modular_No_Modules
Damage Case - Intact
Free to Trim / Specific gravity = 1.025; (Density = 1.025 tonne/m^3) / Fluid analysis method: Use corrected VCG

Item Name	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
Lightship	1	1560.253	1560.253			38.060	0.000	4.631	0.000	User Specified
Aft Grey Water Tank	0%	15.877	0.000	15.490	0.000	5.185	0.000	2.623	0.000	Maximum
Aft Fuel Tank Starb	100%	19.344	19.344	23.029	23.029	9.149	-2.124	3.487	0.000	Maximum
Aft Fuel Tank Port	100%	19.344	19.344	23.029	23.029	9.149	2.124	3.487	0.000	Maximum
Aft Fuel Wing Tank Starb	100%	17.487	17.487	20.818	20.818	13.244	-4.052	3.563	0.000	Maximum
Aft Fuel Wing Tank Port	100%	17.487	17.487	20.818	20.818	13.244	4.052	3.563	0.000	Maximum
Aft Ballast Tank	0%	68.488	0.000	66.817	0.000	13.654	0.000	1.000	0.000	Maximum
Dirty Aviation Fuel Tank	0%	22.075	0.000	26.911	0.000	17.287	0.000	0.800	0.000	Maximum
Aviation Fuel Tank	100%	35.941	35.941	43.814	43.814	20.171	0.000	2.538	0.000	Maximum
Dirty Water Tank	0%	2.120	0.000	2.068	0.000	27.315	0.000	0.022	0.000	Maximum
Dirty Lub Oil Tank	0%	1.959	0.000	2.129	0.000	28.615	0.000	0.028	0.000	Maximum
Dirty Water Tank	0%	2.217	0.000	2.163	0.000	29.915	0.000	0.033	0.000	Maximum
Lub Oil Tank	100%	4.053	4.053	4.406	4.406	32.504	0.000	0.566	0.000	Maximum
Dirty Water Tank	0%	2.278	0.000	2.222	0.000	33.815	0.000	0.049	0.000	Maximum
Fuel Tank Starb	100%	14.254	14.254	16.969	16.969	37.695	-1.987	1.246	0.000	Maximum
Fuel Tank Port	100%	14.254	14.254	16.969	16.969	37.695	1.987	1.246	0.000	Maximum
Fuel Tank Central	100%	32.011	32.011	38.109	38.109	40.945	0.000	1.157	0.000	Maximum
Grey Water Starb	0%	8.035	0.000	7.839	0.000	42.940	-0.001	0.086	0.000	Maximum
Grey Water Port	0%	8.035	0.000	7.839	0.000	42.940	0.001	0.086	0.000	Maximum
Dirty Water Tank	0%	12.591	0.000	12.284	0.000	45.577	0.000	0.089	0.000	Maximum
Fwd Fuel Tank Starb	100%	22.771	22.771	27.108	27.108	49.331	-1.611	1.258	0.000	Maximum
Fwd Fuel Tank Port	100%	22.771	22.771	27.108	27.108	49.331	1.611	1.258	0.000	Maximum
Fwd Grey Water Tank	0%	21.812	0.000	23.709	0.000	54.209	0.000	0.091	0.000	Maximum
Fresh Water Tank Starb	100%	10.015	10.015	10.015	10.015	57.173	-1.209	1.272	0.000	Maximum
Fresh Water Tank Port	100%	10.015	10.015	10.015	10.015	57.173	1.209	1.272	0.000	Maximum
Fwd Ballast Tank	0%	16.696	0.000	16.289	0.000	61.993	0.000	0.091	0.000	Maximum
Fwd Ballast Tank	0%	56.929	0.000	55.541	0.000	64.173	0.000	0.091	0.000	Maximum
Peak Tank	0%	19.388	0.000	18.916	0.000	73.297	0.000	0.097	0.000	Maximum
Total Loadcase			1800.000	542.424	282.206	37.130	0.000	4.296	0.000	
FS correction								0.000		
VCG fluid								4.296		

Draft Amidships m	3.872
Displacement t	1800
Heel deg	0.0
Draft at FP m	3.782
Draft at AP m	3.962
Draft at LCF m	3.882
Trim (+ve by stern) m	0.180
WL Length m	77.807
Beam max extents on WL m	12.903
Wetted Area m^2	1004.044
Waterpl. Area m^2	767.457
Prismatic coeff. (Cp)	0.627
Block coeff. (Cb)	0.445
Max Sect. area coeff. (Cm)	0.725
Waterpl. area coeff. (Cwp)	0.764
LCB from zero pt. (+ve fwd) m	37.129
LCF from zero pt. (+ve fwd) m	34.613
KB m	2.468
KG fluid m	4.296
BMt m	4.557
BML m	159.013
GMt corrected m	2.729
GML m	157.185
KMt m	7.025
KML m	161.481
Immersion (TPc) tonne/cm	7.866
MTc tonne.m	36.265
RM at 1deg = GMt.Disp.sin(1) tonne.m	85.732
Max deck inclination deg	0.1324
Trim angle (+ve by stern) deg	0.1324

Key point	Type	Freeboard m
Margin Line (freeboard pos = 0 m)		3.108
Deck Edge (freeboard pos = 0 m)		3.184

Code	Criteria	Value	Units	Actual	Status	Margin %
Royal Navy, Damage Stability Criteria; DS 02-109(NES109) Part 1	1.3.5.a.(6) Longitudinal GM > 0	0.000	m	157.185	Pass	infinite

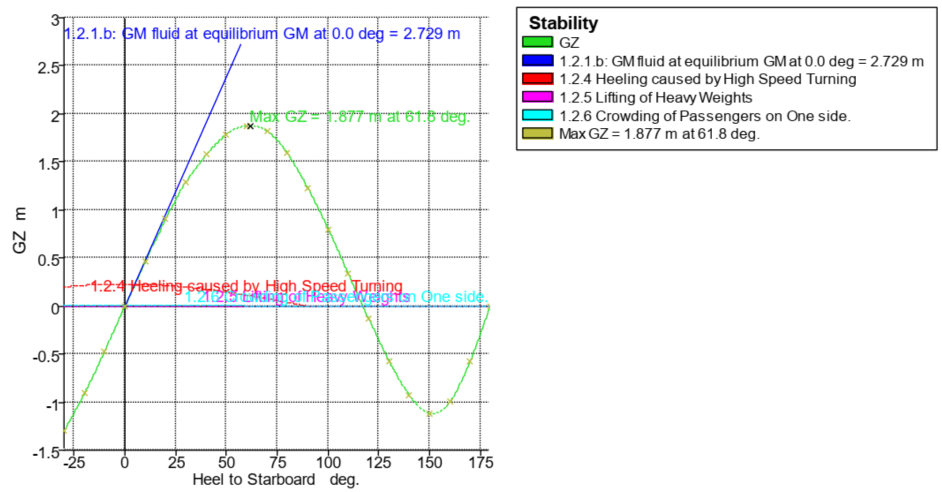
Modular No Modules – Large Angle Stability

Stability calculation - OffshorePatrolVessel 2000ton

Stability 23.04.00.76, build: 76
Model file: C:\Users\Felipe\OneDrive\Documentos\Felipe\UCL\MECH0070 - MSC Individual Project\Impact of Mission Modules on Naval Ship Design\Report\MAXSURF Models\OffshorePatrolVessel 2000ton (Medium precision, 65 sections, Trimming on, Skin thickness not applied). Long. datum: AP; Vert. datum: Baseline. Analysis tolerance - ideal(worst case): Disp.%: 0.01000(0.100); Trim%(LCG-TCG): 0.01000(0.100); Heel%(LCG-TCG): 0.01000(0.100)

Loadcase - OffshorePatrolVessel 2000ton_Modular_No_Modules
Damage Case - Intact
Free to Trim / Specific gravity = 1.025; (Density = 1.025 tonne/m^3) / Fluid analysis method: Use corrected VCG

Item Name	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
Lightship	1	1560.253	1560.253			38.060	0.000	4.631	0.000	User Specified
Aft Grey Water Tank	0%	15.877	0.000	15.490	0.000	5.185	0.000	2.623	0.000	Maximum
Aft Fuel Tank Starb	100%	19.344	19.344	23.029	23.029	9.149	-2.124	3.487	0.000	Maximum
Aft Fuel Tank Port	100%	19.344	19.344	23.029	23.029	9.149	2.124	3.487	0.000	Maximum
Aft Fuel Wing Tank Starb	100%	17.487	17.487	20.818	20.818	13.244	-4.052	3.563	0.000	Maximum
Aft Fuel Wing Tank Port	100%	17.487	17.487	20.818	20.818	13.244	4.052	3.563	0.000	Maximum
Aft Ballast Tank	0%	68.488	0.000	66.817	0.000	13.654	0.000	1.000	0.000	Maximum
Dirty Aviation Fuel Tank	0%	22.075	0.000	26.911	0.000	17.287	0.000	0.800	0.000	Maximum
Aviation Fuel Tank	100%	35.941	35.941	43.814	43.814	20.171	0.000	2.538	0.000	Maximum
Dirty Water Tank	0%	2.120	0.000	2.068	0.000	27.315	0.000	0.022	0.000	Maximum
Dirty Lub Oil Tank	0%	1.959	0.000	2.129	0.000	28.615	0.000	0.028	0.000	Maximum
Dirty Water Tank	0%	2.217	0.000	2.163	0.000	29.915	0.000	0.033	0.000	Maximum
Lub Oil Tank	100%	4.053	4.053	4.406	4.406	32.504	0.000	0.566	0.000	Maximum
Dirty Water Tank	0%	2.278	0.000	2.222	0.000	33.815	0.000	0.049	0.000	Maximum
Fuel Tank Starb	100%	14.254	14.254	16.969	16.969	37.695	-1.987	1.246	0.000	Maximum
Fuel Tank Port	100%	14.254	14.254	16.969	16.969	37.695	1.987	1.246	0.000	Maximum
Fuel Tank Central	100%	32.011	32.011	38.109	38.109	40.945	0.000	1.157	0.000	Maximum
Grey Water Starb	0%	8.035	0.000	7.839	0.000	42.940	-0.001	0.086	0.000	Maximum
Grey Water Port	0%	8.035	0.000	7.839	0.000	42.940	0.001	0.086	0.000	Maximum
Dirty Water Tank	0%	12.591	0.000	12.284	0.000	45.577	0.000	0.089	0.000	Maximum
Fwd Fuel Tank Starb	100%	22.771	22.771	27.108	27.108	49.331	-1.611	1.258	0.000	Maximum
Fwd Fuel Tank Port	100%	22.771	22.771	27.108	27.108	49.331	1.611	1.258	0.000	Maximum
Fwd Grey Water Tank	0%	21.812	0.000	23.709	0.000	54.209	0.000	0.091	0.000	Maximum
Fresh Water Tank Starb	100%	10.015	10.015	10.015	10.015	57.173	-1.209	1.272	0.000	Maximum
Fresh Water Tank Port	100%	10.015	10.015	10.015	10.015	57.173	1.209	1.272	0.000	Maximum
Fwd Ballast Tank	0%	16.696	0.000	16.289	0.000	61.993	0.000	0.091	0.000	Maximum
Fwd Ballast Tank	0%	56.929	0.000	55.541	0.000	64.173	0.000	0.091	0.000	Maximum
Peak Tank	0%	19.388	0.000	18.916	0.000	73.297	0.000	0.097	0.000	Maximum
Total Loadcase			1800.000	542.424	282.206	37.130	0.000	4.296	0.000	
FS correction								0.000		
VCG fluid								4.296		



Heel to Starboard deg	-30.0	-20.0	-10.0	0.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0
GZ m	-1.291	-0.903	-0.469	0.000	0.469	0.903	1.291	1.576	1.783	1.874	1.823	1.587	1.228	0.800
Area under GZ curve from zero heel m.deg	20.2538	9.2593	2.3606	0.0000	2.3628	9.2508	20.2869	34.6981	51.5657	69.9580	88.5888	105.7794	119.9310	130.1194
Displacement t	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
Draft at FP m	3.586	3.716	3.768	3.781	3.767	3.715	3.586	3.293	2.647	1.506	-0.723	-7.752	n/a	-21.090
Draft at AP m	3.265	3.668	3.892	3.963	3.892	3.669	3.265	2.712	2.043	1.101	-0.513	-4.977	n/a	-11.875
WL Length m	77.686	77.766	77.798	77.806	77.798	77.766	77.686	77.506	77.095	76.293	74.671	77.072	78.851	80.057
Beam max extents on WL m	12.461	12.648	12.830	12.903	12.830	12.648	12.461	12.576	12.429	11.216	10.404	9.780	9.452	9.361
Wetted Area m^2	999.931	997.678	1001.436	1004.029	1001.442	997.685	999.926	1021.587	1037.864	1044.457	1014.733	1008.507	1007.828	1011.207
Waterpl. Area m^2	754.991	757.024	763.152	767.457	763.157	757.031	754.990	718.515	699.693	660.560	607.880	559.817	531.058	518.617
Prismatic coeff. (Cp)	0.647	0.638	0.630	0.627	0.630	0.638	0.647	0.644	0.626	0.615	0.614	0.587	0.570	0.559
Block coeff. (Cb)	0.455	0.466	0.457	0.444	0.457	0.466	0.455	0.435	0.429	0.467	0.498	0.500	0.478	0.423
LCB from zero pt. (+ve fwd) m	37.138	37.134	37.128	37.126	37.127	37.132	37.139	37.144	37.143	37.140	37.127	37.107	37.079	37.046
LCF from zero pt. (+ve fwd) m	36.051	35.345	34.834	34.611	34.834	35.344	36.051	38.031	40.114	41.188	41.384	40.940	40.581	40.275
Max deck inclination deg	30.0006	20.0000	10.0004	0.1337	10.0004	20.0000	30.0006	40.0011	50.0006	60.0001	70.0000	80.0002	90.0000	99.9979
Trim angle (+ve by stern) deg	-0.2356	-0.0348	0.0911	0.1337	0.0915	-0.0339	-0.2356	-0.4263	-0.4441	-0.2974	0.1539	2.0367	n/a	6.7359

Key point	Type	Immersion angle deg	Emergence angle deg	Freeboard at 0.0 deg m	Freeboard at 10.0 deg m	Freeboard at 20.0 deg m	Freeboard at 30.0 deg m	Freeboard at 40.0 deg m	Freeboard at 50.0 deg m	Freeboard at 60.0 deg m	Freeboard at 70.0 deg m	Freeboard at 80.0 deg m	Freeboard at 90.0 deg m	Freeboard at 100.0 deg m	Freeboard at 110.0 deg m	Freeboard at 120.0 deg m	Freeboard at 130.0 deg m	Freeboard at 140.0 deg m	Freeboard at 150.0 deg m	Freeboard at 160.0 deg m	Freeboard at 170.0 deg m	Freeboard at 180.0 deg m
Margin Line (immersion pos = 34.659 m)		27.7	n/a	3.108	1.996	0.840	-0.245	-1.253	-2.177	-3.025	-3.798	-4.433	-4.928	-5.523	-5.988	-6.237	-6.255	-6.029	-5.540	-4.757	-3.728	-2.579
Deck Edge (immersion pos = 34.659 m)		28.4	n/a	3.184	2.071	0.911	-0.179	-1.194	-2.129	-2.987	-3.773	-4.420	-4.928	-5.536	-6.013	-6.274	-6.304	-6.087	-5.605	-4.828	-3.802	-2.655

Code	Criteria	Value	Units	Actual	Status	Margin %
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 0 to 30	4.5840	m.deg	20.2869	Pass	+342.56
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 0 to 40	7.6200	m.deg	34.6981	Pass	+355.36
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 30 to 40	2.7500	m.deg	14.4113	Pass	+424.05
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Maximum GZ	0.300	m	1.783	Pass	+494.33
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Angle of maximum GZ	30.0	deg	61.8	Pass	+106.06
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: GM fluid at equilibrium	0.300	m	2.729	Pass	+809.67
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Range of positive stability	70.0	deg	117.1	Pass	+67.24
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Angle of vanishing stability	70.0	deg	117.1	Pass	+67.24
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.4 Heeling caused by High Speed Turning				Pass	
	Angle of steady heel shall be less than (<)	20.0	deg	4.8	Pass	+75.92
	Area1 / Area2 shall be greater than (>)	40.00	%	86.69	Pass	+116.72
	GZ(intersection) / GZ(max) shall be less than (<)	60.00	%	12.82	Pass	+78.63
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.5 Lifting of Heavy Weights				Pass	
	Angle of steady heel shall be less than (<)	15.0	deg	0.0	Pass	+99.99
	Area1 / Area2 shall be greater than (>)	50.00	%	99.99	Pass	+99.98
	GZ(intersection) / GZ(max) shall be less than (<)	50.00	%	0.00	Pass	+100.00
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.6 Crowding of Passengers on One side.				Pass	
	Angle of steady heel shall be less than (<)	10.0	deg	0.1	Pass	+99.12
	Area1 / Area2 shall be greater than (>)	40.00	%	99.75	Pass	+149.38
	GZ(intersection) / GZ(max) shall be less than (<)	60.00	%	0.23	Pass	+99.62

Frigate 5000ton

Traditional – Equilibrium

Equilibrium calculation - Frigate 5000ton
Stability 23.04.00.76, build: 76
Model file: C:\Users\Felipe\OneDrive\Documentos\Felipe\UCL\MECH0070 - MSC Individual Project\Impact of Mission Modules on Naval Ship Design\Report\MAXSURF Models\Frigate 5000ton (Highest precision, 61 sections, Trimming off, Skin thickness not applied). Long. datum: AP; Vert. datum: Baseline. Analysis tolerance - ideal(worst case): Disp.%: 0.01000(0.100); Trim%(LCG-TCG): 0.01000(0.100); Heel%(LCG-TCG): 0.01000(0.100)

Loadcase - Frigate 5000ton_Traditional
Damage Case - Intact
Free to Trim
Specific gravity = 1.025; (Density = 1.025 tonne/m^3)
Fluid analysis method: Use corrected VCG

Item Name	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
Lightship	1	2931.885	2931.885			59.640	0.000	7.703	0.000	User Specified
Payload	1	500.000	500.000			59.640	0.000	12.555	0.000	User Specified
Aft Fuel Tank Starb	100%	214.155	214.155	254.946	254.946	22.408	4.895	4.524	0.000	Maximum
Aft Fuel Tank	100%	171.926	171.926	204.674	204.674	20.578	0.000	4.402	0.000	Maximum
Aft Aviation Fuel Tank	100%	63.381	63.381	77.265	77.265	27.215	0.000	4.132	0.000	Maximum
Aft Fuel Tank Port	100%	214.155	214.155	254.946	254.946	22.408	-4.895	4.524	0.000	Maximum
Fuel Tank	100%	25.663	25.663	30.551	30.551	32.728	0.000	2.251	0.000	Maximum
Overflow Tank	0%	5.141	0.000	6.120	0.000	35.275	0.000	1.500	0.000	Maximum
Aft Lub Oil Tank	100%	30.845	30.845	36.720	36.720	43.350	0.000	2.250	0.000	Maximum
Aft Drain Lub Oil Tank	0%	22.522	0.000	24.480	0.000	52.700	0.000	1.500	0.000	Maximum
Lub Oil Tank Port	100%	40.539	40.539	44.064	44.064	59.500	1.500	2.250	0.000	Maximum
Lub Oil Tank Port	100%	40.539	40.539	44.064	44.064	59.500	-1.500	2.250	0.000	Maximum
Fwd Fuel Tank Starb	100%	30.582	30.582	36.407	36.407	70.539	4.980	2.255	0.000	Maximum
Fwd Ballast Tank	0%	37.638	0.000	36.720	0.000	70.550	0.000	1.500	0.000	Maximum
Fwd Fuel Tank Port	100%	30.582	30.582	36.407	36.407	70.539	-4.980	2.255	0.000	Maximum
Fwd Fresh Water Tank Port	100%	76.926	76.926	76.926	76.926	78.182	4.877	4.108	0.000	Maximum
Fwd Fresh Water Tank	100%	81.600	81.600	81.600	81.600	78.200	0.000	4.000	0.000	Maximum
Fwd Fresh Water Tank Starb	100%	76.926	76.926	76.926	76.926	78.182	-4.877	4.108	0.000	Maximum
Fwd Fuel Tank Starb	100%	119.710	119.710	142.512	142.512	85.509	4.348	4.280	0.000	Maximum
Fwd Fuel Tank	100%	171.360	171.360	204.000	204.000	85.850	0.000	4.000	0.000	Maximum
Fwd Fuel Tank Port	100%	119.710	119.710	142.512	142.512	85.509	-4.348	4.280	0.000	Maximum
Fwd Fuel Tank Starb	100%	29.758	29.758	35.426	35.426	93.704	2.972	2.911	0.000	Maximum
Fwd Fuel Tank Port	100%	29.758	29.758	35.426	35.426	93.704	-2.972	2.911	0.000	Maximum
Fwd Ballast	0%	103.672	0.000	101.143	0.000	112.401	0.000	1.500	0.000	Maximum
Peak Tank	0%	50.874	0.000	49.634	0.000	119.129	0.000	0.000	0.000	Maximum
Total Loadcase			4999.998	2033.468	1815.372	58.005	0.000	7.022	0.000	
FS correction								0.000		
VCG fluid								7.022		

Draft Amidships m	4.611
Displacement t	5000
Heel deg	0.0
Draft at FP m	4.611
Draft at AP m	4.611
Draft at LCF m	4.611
Trim (+ve by stern) m	0.000
WL Length m	122.929
Beam max extents on WL m	19.238
Wetted Area m^2	2175.105
Waterpl. Area m^2	1698.746
Prismatic coeff. (Cp)	0.551
Block coeff. (Cb)	0.447
Max Sect. area coeff. (Cm)	0.827
Waterpl. area coeff. (Cwp)	0.718
LCB from zero pt. (+ve fwd) m	57.994
LCF from zero pt. (+ve fwd) m	50.154
KB m	2.872
KG fluid m	7.022
BMt m	8.139
BML m	284.941
GMt corrected m	3.990
GML m	280.791
KMt m	11.012
KML m	287.813
Immersion (TPc) tonne/cm	17.412
MTc tonne.m	114.209
RM at 1deg = GMt.Disp.sin(1) tonne.m	348.155
Max deck inclination deg	0.0000
Trim angle (+ve by stern) deg	0.0000

Key point	Type	Freeboard m
Margin Line (freeboard pos = 37.936 m)		6.852
Deck Edge (freeboard pos = 37.936 m)		6.928

Code	Criteria	Value	Units	Actual	Status	Margin %
Royal Navy, Damage Stability Criteria; DS 02-109(NES109) Part 1	1.3.5.a.(6) Longitudinal GM > 0	0.000	m	280.791	Pass	infinite

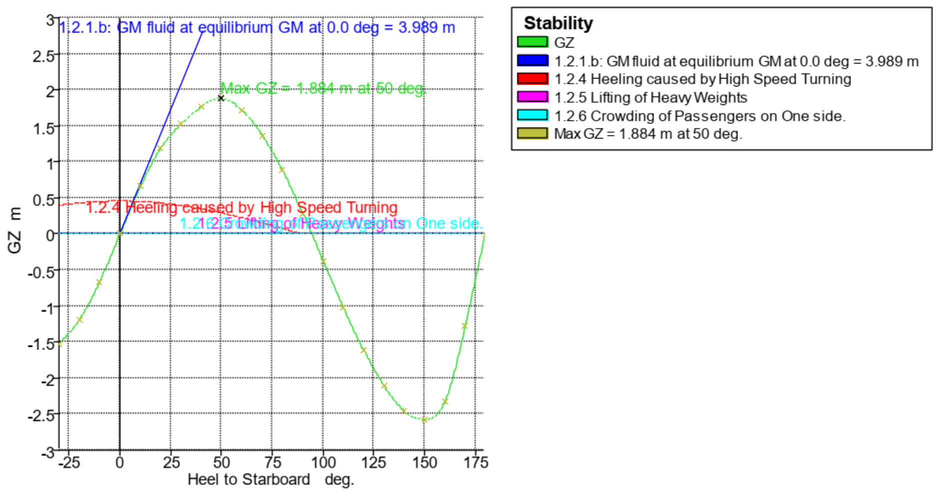
Traditional – Large Angle Stability

Stability calculation - Frigate 5000ton

Stability 23.04.00.76, build: 76
Model file: C:\Users\Felipe\OneDrive\Documentos\Felipe\UCL\MECH0070 - MSC Individual Project\Impact of Mission Modules on Naval Ship Design\Report\MAXSURF Models\Frigate 5000ton (Highest precision, 61 sections, Trimming off, Skin thickness not applied). Long. datum: AP; Vert. datum: Baseline. Analysis tolerance - ideal(worst case): Disp.%: 0.01000(0.100); Trim%(LCG-TCG): 0.01000(0.100); Heel%(LCG-TCG): 0.01000(0.100)

Loadcase - Frigate 5000ton_Traditional
Damage Case - Intact
Free to Trim
Specific gravity = 1.025; (Density = 1.025 tonne/m^3)
Fluid analysis method: Use corrected VCG

Item Name	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
Lightship	1	2931.885	2931.885			59.640	0.000	7.703	0.000	User Specified
Payload	1	500.000	500.000			59.640	0.000	12.555	0.000	User Specified
Aft Fuel Tank Starb	100%	214.155	214.155	254.946	254.946	22.408	4.895	4.524	0.000	Maximum
Aft Fuel Tank	100%	171.926	171.926	204.674	204.674	20.578	0.000	4.402	0.000	Maximum
Aft Aviation Fuel Tank	100%	63.381	63.381	77.265	77.265	27.215	0.000	4.132	0.000	Maximum
Aft Fuel Tank Port	100%	214.155	214.155	254.946	254.946	22.408	-4.895	4.524	0.000	Maximum
Fuel Tank	100%	25.663	25.663	30.551	30.551	32.728	0.000	2.251	0.000	Maximum
Overflow Tank	0%	5.141	0.000	6.120	0.000	35.275	0.000	1.500	0.000	Maximum
Aft Lub Oil Tank	100%	30.845	30.845	36.720	36.720	43.350	0.000	2.250	0.000	Maximum
Aft Drain Lub Oil Tank	0%	22.522	0.000	24.480	0.000	52.700	0.000	1.500	0.000	Maximum
Lub Oil Tank Port	100%	40.539	40.539	44.064	44.064	59.500	1.500	2.250	0.000	Maximum
Lub Oil Tank Port	100%	40.539	40.539	44.064	44.064	59.500	-1.500	2.250	0.000	Maximum
Fwd Fuel Tank Starb	100%	30.582	30.582	36.407	36.407	70.539	4.980	2.255	0.000	Maximum
Fwd Ballast Tank	0%	37.638	0.000	36.720	0.000	70.550	0.000	1.500	0.000	Maximum
Fwd Fuel Tank Port	100%	30.582	30.582	36.407	36.407	70.539	-4.980	2.255	0.000	Maximum
Fwd Fresh Water Tank Port	100%	76.926	76.926	76.926	76.926	78.182	4.877	4.108	0.000	Maximum
Fwd Fresh Water Tank	100%	81.600	81.600	81.600	81.600	78.200	0.000	4.000	0.000	Maximum
Fwd Fresh Water Tank Starb	100%	76.926	76.926	76.926	76.926	78.182	-4.877	4.108	0.000	Maximum
Fwd Fuel Tank Starb	100%	119.710	119.710	142.512	142.512	85.509	4.348	4.280	0.000	Maximum
Fwd Fuel Tank	100%	171.360	171.360	204.000	204.000	85.850	0.000	4.000	0.000	Maximum
Fwd Fuel Tank Port	100%	119.710	119.710	142.512	142.512	85.509	-4.348	4.280	0.000	Maximum
Fwd Fuel Tank Starb	100%	29.758	29.758	35.426	35.426	93.704	2.972	2.911	0.000	Maximum
Fwd Fuel Tank Port	100%	29.758	29.758	35.426	35.426	93.704	-2.972	2.911	0.000	Maximum
Fwd Ballast	0%	103.672	0.000	101.143	0.000	112.401	0.000	1.500	0.000	Maximum
Peak Tank	0%	50.874	0.000	49.634	0.000	119.129	0.000	0.000	0.000	Maximum
Total Loadcase			4999.998	2033.468	1815.372	58.005	0.000	7.022	0.000	
FS correction								0.000		
VCG fluid								7.022		



Heel to Starboard deg	-30.0	-20.0	-10.0	0.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0
GZ m	-1.521	-1.184	-0.664	0.000	0.664	1.184	1.522	1.762	1.884	1.721	1.367	0.884	0.280	-0.37
Area under GZ curve from zero heel m.deg	26.4108	12.7866	3.3848	0.0000	3.3865	12.7817	26.4292	42.9070	61.3167	79.5638	95.1202	106.4821	112.3822	111.927
Displacement t	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	500
Draft at FP m	4.770	4.724	4.645	4.613	4.643	4.725	4.767	4.614	4.188	3.555	2.338	-1.468	n/a	-16.17
Draft at AP m	3.334	4.107	4.503	4.610	4.504	4.106	3.336	2.075	0.122	-2.986	-8.842	-25.598	n/a	-38.21
WL Length m	122.948	122.939	122.931	122.929	122.931	122.939	122.947	122.944	122.929	122.915	122.891	122.536	125.547	127.37
Beam max extents on WL m	17.956	18.699	19.178	19.238	19.178	18.699	17.956	17.640	15.395	14.185	13.683	12.582	11.627	11.41
Wetted Area m^2	2074.001	2103.012	2144.582	2175.154	2144.583	2103.019	2073.966	2088.212	2142.526	2181.127	2195.791	2168.189	2163.046	2170.78
Waterpl. Area m^2	1556.040	1594.302	1656.714	1698.742	1656.761	1594.264	1556.079	1587.607	1503.517	1411.960	1342.263	1251.839	1192.076	1172.60
Prismatic coeff. (Cp)	0.569	0.561	0.554	0.551	0.554	0.561	0.569	0.573	0.583	0.593	0.604	0.616	0.618	0.62
Block coeff. (Cb)	0.362	0.384	0.424	0.447	0.424	0.384	0.362	0.349	0.393	0.426	0.450	0.506	0.480	0.43
LCB from zero pt. (+ve fwd) m	58.062	58.021	58.017	58.001	58.011	58.027	58.051	58.084	58.112	58.156	58.180	58.208	58.206	58.19
LCF from zero pt. (+ve fwd) m	55.270	53.349	51.453	50.156	51.450	53.352	55.264	57.456	58.964	60.907	62.754	62.115	61.363	60.91
Max deck inclination deg	30.0051	20.0017	10.0002	0.0015	10.0002	20.0018	30.0050	40.0085	50.0109	60.0117	70.0101	80.0059	90.0000	99.995
Trim angle (+ve by stern) deg	-0.6694	-0.2872	-0.0663	-0.0015	-0.0651	-0.2885	-0.6667	-1.1833	-1.8941	-3.0456	-5.1964	-11.1056	n/a	-10.162

Key point	Type	Immersion angle deg	Emergence angle deg	Freeboard at 0.0 deg m	Freeboard at 10.0 deg m	Freeboard at 20.0 deg m	Freeboard at 30.0 deg m	Freeboard at 40.0 deg m	Freeboard at 50.0 deg m	Freeboard at 60.0 deg m	Freeboard at 70.0 deg m	Freeboard at 80.0 deg m	Freeboard at 90.0 deg m	Freeboard at 100.0 deg m	Freeboard at 110.0 deg m	Freeboard at 120.0 deg m	Freeboard at 130.0 deg m	Freeboard at 140.0 deg m	Freeboard at 150.0 deg m	Freeboard at 160.0 deg m	Freeboard at 170.0 deg m	Freeboard at 180.0 deg m
Margin Line (immersion pos = 69.854 m)		39.3	n/a	6.852	5.098	3.295	1.529	-0.116	-1.651	-3.167	-4.614	-5.901	-6.918	-7.650	-8.087	-8.224	-8.051	-7.561	-6.747	-5.585	-4.154	-3.492
Deck Edge (immersion pos = 73.906 m)		39.6	n/a	6.928	5.173	3.366	1.594	-0.066	-1.617	-3.154	-4.625	-5.930	-6.966	-7.710	-8.158	-8.304	-8.136	-7.655	-6.841	-5.678	-4.241	-3.568

Code	Criteria	Value	Units	Actual	Status	Margin %
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 0 to 30	4.5840	m.deg	26.4292	Pass	+476.55
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 0 to 40	7.6200	m.deg	42.9070	Pass	+463.08
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 30 to 40	2.7500	m.deg	16.4777	Pass	+499.19
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Maximum GZ	0.300	m	1.884	Pass	+528.00
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Angle of maximum GZ	30.0	deg	50.0	Pass	+66.67
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: GM fluid at equilibrium	0.300	m	3.989	Pass	+1229.67
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Range of positive stability	70.0	deg	94.3	Pass	+34.74
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Angle of vanishing stability	70.0	deg	94.3	Pass	+34.74
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.4 Heeling caused by High Speed Turning				Pass	
	Angle of steady heel shall be less than (<)	20.0	deg	6.7	Pass	+66.47
	Area1 / Area2 shall be greater than (>)	40.00	%	75.67	Pass	+89.17
	GZ(intersection) / GZ(max) shall be less than (<)	60.00	%	24.15	Pass	+59.75
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.5 Lifting of Heavy Weights				Pass	
	Angle of steady heel shall be less than (<)	15.0	deg	0.0	Pass	+100.00
	Area1 / Area2 shall be greater than (>)	50.00	%	100.00	Pass	+100.00
	GZ(intersection) / GZ(max) shall be less than (<)	50.00	%	0.00	Pass	+100.00
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.6 Crowding of Passengers on One side.				Pass	
	Angle of steady heel shall be less than (<)	10.0	deg	0.0	Pass	+99.78
	Area1 / Area2 shall be greater than (>)	40.00	%	99.92	Pass	+149.80
	GZ(intersection) / GZ(max) shall be less than (<)	60.00	%	0.08	Pass	+99.87

Traditional – Equilibrium (Damage)

Equilibrium calculation - Frigate 5000ton

Stability 23.04.00.76, build: 76
Model file: C:\Users\Felipe\OneDrive\Documentos\Felipe\UCL\MECH0070 - MSC Individual Project\Impact of Mission Modules on Naval Ship Design\Report\MAXSURF Models\Frigate 5000ton\Frigate 5000ton (Highest precision, 61 sections, Trimming off, Skin thickness not applied). Long. datum: AP; Vert. datum: Baseline. Analysis tolerance - ideal(worst case): Disp.%: 0.01000(0.100); Trim%(LCG-TCG): 0.01000(0.100); Heel%(LCG-TCG): 0.01000(0.100)

Loadcase - Frigate 5000ton_Traditional
Damage Case - Aft_AuxiliaryRoom+DieselEngineRoom
Free to Trim
Specific gravity = 1.025; (Density = 1.025 tonne/m^3)
Compartments Damaged -

Compartment or Tank	Status	Perm.%	PartFlood.%	PartFlood.WL
Aft Auxiliary Room[]	Fully flooded	80		
Diesel Engine Room[]	Fully flooded	80		

Fluid analysis method: Use corrected VCG

Item Name	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
Lightship	1	2931.885	2931.885			59.640	0.000	7.703	0.000	User Specified
Payload	1	500.000	500.000			59.640	0.000	12.555	0.000	User Specified
Aft Fuel Tank Starb	100%	214.155	214.155	254.946	254.946	22.408	4.895	4.524	0.000	Maximum
Aft Fuel Tank	100%	171.926	171.926	204.673	204.673	20.578	0.000	4.402	0.000	Maximum
Aft Aviation Fuel Tank	100%	63.381	63.381	77.265	77.265	27.215	0.000	4.132	0.000	Maximum
Aft Fuel Tank Port	100%	214.155	214.155	254.946	254.946	22.408	-4.895	4.524	0.000	Maximum
Fuel Tank	100%	25.663	25.663	30.551	30.551	32.728	0.000	2.251	0.000	Maximum
Overflow Tank	0%	5.141	0.000	6.120	0.000	35.275	0.000	1.500	0.000	Maximum
Aft Lub Oil Tank	100%	30.845	30.845	36.720	36.720	43.350	0.000	2.250	0.000	Maximum
Aft Drain Lub Oil Tank	0%	22.522	0.000	24.480	0.000	52.700	0.000	1.500	0.000	Maximum
Lub Oil Tank Port	100%	40.539	40.539	44.064	44.064	59.500	1.500	2.250	0.000	Maximum
Lub Oil Tank Port	100%	40.539	40.539	44.064	44.064	59.500	-1.500	2.250	0.000	Maximum
Fwd Fuel Tank Starb	100%	30.582	30.582	36.407	36.407	70.539	4.980	2.255	0.000	Maximum
Fwd Ballast Tank	0%	37.638	0.000	36.720	0.000	70.550	0.000	1.500	0.000	Maximum
Fwd Fuel Tank Port	100%	30.582	30.582	36.407	36.407	70.539	-4.980	2.255	0.000	Maximum
Fwd Fresh Water Tank Port	100%	76.926	76.926	76.926	76.926	78.182	4.877	4.108	0.000	Maximum
Fwd Fresh Water Tank	100%	81.600	81.600	81.600	81.600	78.200	0.000	4.000	0.000	Maximum
Fwd Fresh Water Tank Starb	100%	76.926	76.926	76.926	76.926	78.182	-4.877	4.108	0.000	Maximum
Fwd Fuel Tank Starb	100%	119.710	119.710	142.512	142.512	85.509	4.348	4.280	0.000	Maximum
Fwd Fuel Tank	100%	171.360	171.360	204.000	204.000	85.850	0.000	4.000	0.000	Maximum
Fwd Fuel Tank Port	100%	119.710	119.710	142.512	142.512	85.509	-4.348	4.280	0.000	Maximum
Fwd Fuel Tank Starb	100%	29.758	29.758	35.426	35.426	93.704	2.972	2.911	0.000	Maximum
Fwd Fuel Tank Port	100%	29.758	29.758	35.426	35.426	93.704	-2.972	2.911	0.000	Maximum
Fwd Ballast	0%	103.672	0.000	101.143	0.000	112.401	0.000	1.500	0.000	Maximum
Peak Tank	0%	50.874	0.000	49.634	0.000	119.129	0.000	0.000	0.000	Maximum
Total Loadcase			4999.997	2033.468	1815.372	58.005	0.000	7.022	0.000	
FS correction								0.000		
VCG fluid								7.022		

Draft Amidships m	5.279
Displacement t	5000
Heel deg	0.0
Draft at FP m	4.825
Draft at AP m	5.733
Draft at LCF m	5.347
Trim (+ve by stern) m	0.908
WL Length m	122.950
Beam max extents on WL m	19.341
Wetted Area m^2	2363.216
Waterpl. Area m^2	1356.673
Prismatic coeff. (Cp)	0.466
Block coeff. (Cb)	0.391
Max Sect. area coeff. (Cm)	0.845
Waterpl. area coeff. (Cwp)	0.571
LCB from zero pt. (+ve fwd) m	57.986
LCF from zero pt. (+ve fwd) m	52.233
KB m	3.232
KG fluid m	7.022
BMt m	6.309
BML m	344.204
GMt corrected m	2.520
GML m	340.414
KMt m	9.541
KML m	347.427
Immersion (TPc) tonne/cm	13.906
MTc tonne.m	138.460
RM at 1deg = GMt.Disp.sin(1) tonne.m	219.872
Max deck inclination deg	0.4230
Trim angle (+ve by stern) deg	0.4230

Key point	Type	Freeboard m
Margin Line (freeboard pos = 0 m)		5.746
Deck Edge (freeboard pos = 0 m)		5.822

Code	Criteria	Value	Units	Actual	Status	Margin %
Royal Navy, Damage Stability Criteria; DS 02-109(NES109) Part 1	1.3.5.a.(6) Longitudinal GM > 0	0.000	m	340.414	Pass	infinite
Royal Navy, Damage Stability Criteria; DS 02-109(NES109) Part 1	1.3.5.b.(1) Metacentric Height Greater than 0.15m	0.150	m	2.520	Pass	+1580.00

Traditional – Large Angle Stability (Damage)

Stability calculation - Frigate 5000ton

Stability 23.04.00.76, build: 76

Model file: C:\Users\Felipe\OneDrive\Documentos\Felipe\UCL\MECH0070 - MSC Individual Project\Impact of Mission Modules on Naval Ship Design\Report\MAXSURF Models\Frigate 5000ton\Frigate 5000ton (Highest precision, 61 sections, Trimming off, Skin thickness not applied). Long. datum: AP; Vert. datum: Baseline. Analysis tolerance - ideal(worst case): Disp.%: 0.01000(0.100); Trim%(LCG-TCG): 0.01000(0.100); Heel%(LCG-TCG): 0.01000(0.100)

Loadcase - Frigate 5000ton_Traditional

Damage Case - Aft_AuxiliaryRoom+DieselEngineRoom

Free to Trim

Specific gravity = 1.025; (Density = 1.025 tonne/m^3)

Compartments Damaged -

Compartment or Tank	Status	Perm.%	PartFlood.%	PartFlood.WL
Aft Auxiliary Room[]	Fully flooded	80		
Diesel Engine Room[]	Fully flooded	80		

Fluid analysis method: Use corrected VCG

Item Name	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
Lightship	1	2931.885	2931.885			59.640	0.000	7.703	0.000	User Specified
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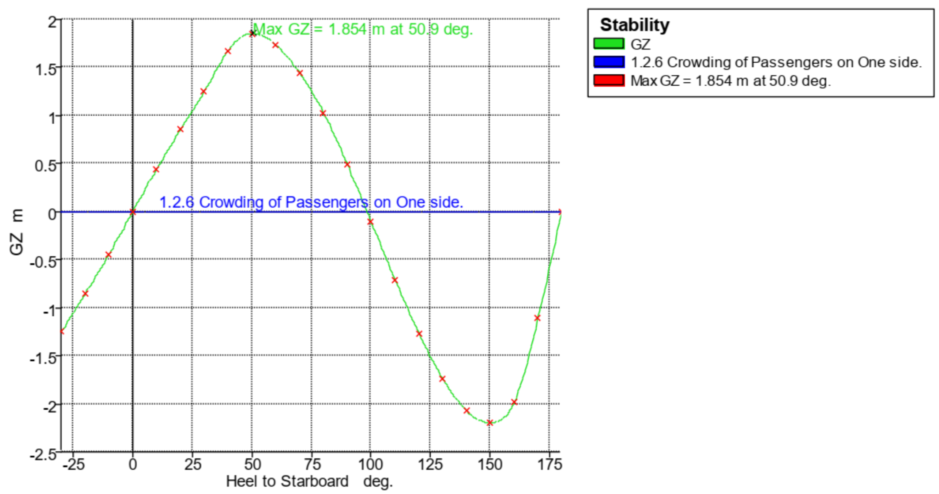
Aft Fuel Tank Starb	100%	214.155	214.155	254.946	254.946	22.408	4.895	4.524	0.000	Maximum
Aft Fuel Tank	100%	171.926	171.926	204.673	204.673	20.578	0.000	4.402	0.000	Maximum
Aft Aviation Fuel Tank	100%	63.381	63.381	77.265	77.265	27.215	0.000	4.132	0.000	Maximum
Aft Fuel Tank Port	100%	214.155	214.155	254.946	254.946	22.408	-4.895	4.524	0.000	Maximum
Fuel Tank	100%	25.663	25.663	30.551	30.551	32.728	0.000	2.251	0.000	Maximum
Overflow Tank	0%	5.141	0.000	6.120	0.000	35.275	0.000	1.500	0.000	Maximum
Aft Lub Oil Tank	100%	30.845	30.845	36.720	36.720	43.350	0.000	2.250	0.000	Maximum
Aft Drain Lub Oil Tank	0%	22.522	0.000	24.480	0.000	52.700	0.000	1.500	0.000	Maximum
Lub Oil Tank Port	100%	40.539	40.539	44.064	44.064	59.500	1.500	2.250	0.000	Maximum
Lub Oil Tank Port	100%	40.539	40.539	44.064	44.064	59.500	-1.500	2.250	0.000	Maximum
Fwd Fuel Tank Starb	100%	30.582	30.582	36.407	36.407	70.539	4.980	2.255	0.000	Maximum
Fwd Ballast Tank	0%	37.638	0.000	36.720	0.000	70.550	0.000	1.500	0.000	Maximum
Fwd Fuel Tank Port	100%	30.582	30.582	36.407	36.407	70.539	-4.980	2.255	0.000	Maximum
Fwd Fresh Water Tank Port	100%	76.926	76.926	76.926	76.926	78.182	4.877	4.108	0.000	Maximum
Fwd Fresh Water Tank	100%	81.600	81.600	81.600	81.600	78.200	0.000	4.000	0.000	Maximum
Fwd Fresh Water Tank Starb	100%	76.926	76.926	76.926	76.926	78.182	-4.877	4.108	0.000	Maximum
Fwd Fuel Tank Starb	100%	119.710	119.710	142.512	142.512	85.509	4.348	4.280	0.000	Maximum
Fwd Fuel Tank	100%	171.360	171.360	204.000	204.000	85.850	0.000	4.000	0.000	Maximum
Fwd Fuel Tank Port	100%	119.710	119.710	142.512	142.512	85.509	-4.348	4.280	0.000	Maximum
Fwd Fuel Tank Starb	100%	29.758	29.758	35.426	35.426	93.704	2.972	2.911	0.000	Maximum
Fwd Fuel Tank Port	100%	29.758	29.758	35.426	35.426	93.704	-2.972	2.911	0.000	Maximum
Fwd Ballast	0%	103.672	0.000	101.143	0.000	112.401	0.000	1.500	0.000	Maximum
Peak Tank	0%	50.874	0.000	49.634	0.000	119.129	0.000	0.000	0.000	Maximum
Total Loadcase			4999.997	2033.468	1815.372	58.005	0.000	7.022	0.000	
FS correction								0.000		
VCG fluid								7.022		



Heel to Starboard deg	-30.0	-20.0	-10.0	0.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0
GZ m	-1.250	-0.857	-0.443	0.000	0.443	0.857	1.250	1.676	1.854	1.738	1.444	1.029	0.488	-0.10
Area under GZ curve from zero heel m.deg	19.2955	8.7543	2.2306	0.0000	2.2286	8.7659	19.2653	33.9685	51.8837	70.0434	86.0639	98.5342	106.1997	108.111
Displacement t	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	500
Draft at FP m	4.727	4.789	4.812	4.825	4.808	4.785	4.726	4.495	4.038	3.312	1.948	-2.247	n/a	-16.64
Draft at AP m	4.888	5.475	5.689	5.733	5.691	5.479	4.889	3.797	2.304	0.062	-4.130	-16.094	n/a	-29.51
WL Length m	122.938	122.945	122.948	122.950	122.948	122.944	122.938	122.921	122.899	122.873	122.838	122.126	125.167	127.17
Beam max extents on WL m	18.951	19.429	19.481	19.341	19.481	19.428	18.951	17.427	15.234	14.072	13.649	12.722	11.787	11.55
Wetted Area m^2	2312.989	2342.954	2364.193	2363.204	2364.038	2342.932	2312.972	2324.306	2365.814	2393.126	2400.455	2375.092	2362.115	2360.99
Waterpl. Area m^2	1404.812	1347.063	1363.795	1356.669	1363.764	1347.117	1404.826	1449.022	1334.540	1253.851	1201.196	1120.918	1056.449	1039.43
Prismatic coeff. (Cp)	0.485	0.474	0.468	0.466	0.468	0.475	0.485	0.497	0.511	0.523	0.534	0.548	0.549	0.55
Block coeff. (Cb)	0.310	0.329	0.368	0.391	0.368	0.329	0.310	0.322	0.361	0.388	0.404	0.448	0.450	0.41
LCB from zero pt. (+ve fwd) m	57.999	57.996	57.985	57.984	57.972	57.979	57.994	58.022	58.041	58.070	58.092	58.111	58.115	58.11
LCF from zero pt. (+ve fwd) m	56.018	54.356	52.528	52.233	52.524	54.347	56.015	58.023	60.620	63.133	65.056	64.719	64.090	63.60
Max deck inclination deg	30.0001	20.0022	10.0080	0.4234	10.0081	20.0022	30.0001	40.0006	50.0020	60.0029	70.0030	80.0019	90.0000	99.998
Trim angle (+ve by stern) deg	0.0750	0.3197	0.4088	0.4234	0.4115	0.3235	0.0762	-0.3254	-0.8084	-1.5144	-2.8302	-6.4268	n/a	-5.974

Key point	Type	Immersion angle deg	Emergence angle deg	Freeboard at 0.0 deg m	Freeboard at 10.0 deg m	Freeboard at 20.0 deg m	Freeboard at 30.0 deg m	Freeboard at 40.0 deg m	Freeboard at 50.0 deg m	Freeboard at 60.0 deg m	Freeboard at 70.0 deg m	Freeboard at 80.0 deg m	Freeboard at 90.0 deg m	Freeboard at 100.0 deg m	Freeboard at 110.0 deg m	Freeboard at 120.0 deg m	Freeboard at 130.0 deg m	Freeboard at 140.0 deg m	Freeboard at 150.0 deg m	Freeboard at 160.0 deg m	Freeboard at 170.0 deg m	Freeboard at 180.0 deg m
Margin Line (immersion pos = 61.337 m)		35.7	n/a	5.746	4.176	2.469	0.868	-0.661	-2.162	-3.635	-5.042	-6.309	-7.313	-8.021	-8.424	-8.531	-8.317	-7.772	-6.889	-5.669	-4.176	-3.492
Deck Edge (immersion pos = 61.337 m)		36.1	n/a	5.822	4.251	2.541	0.934	-0.603	-2.118	-3.608	-5.043	-6.333	-7.352	-8.072	-8.495	-8.610	-8.403	-7.861	-6.983	-5.759	-4.263	-3.568

Code	Criteria	Value	Units	Actual	Status	Margin %
Royal Navy, Damage Stability Criteria; DS 02-109(NES109) Part 1	1.3.5.a.(1): Angle of List or Loll.	20.0	deg	0.0	Pass	+100.00
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.6 Crowding of Passengers on One side.				Pass	
	Angle of steady heel shall be less than (<)	10.0	deg	0.0	Pass	+99.67
	Area1 / Area2 shall be greater than (>)	40.00	%	99.91	Pass	+149.77
	GZ(intersection) / GZ(max) shall be less than (<)	60.00	%	0.08	Pass	+99.87

Modular ASW – Equilibrium

Equilibrium calculation - Frigate 5000ton

Stability 23.04.00.76, build: 76
Model file: C:\Users\Felipe\OneDrive\Documentos\Felipe\UCL\MECH0070 - MSC Individual Project\Impact of Mission Modules on Naval Ship Design\Report\MAXSURF Models\Frigate 5000ton (Highest precision, 61 sections, Trimming off, Skin thickness not applied). Long. datum: AP; Vert. datum: Baseline. Analysis tolerance - ideal(worst case): Disp.%: 0.01000(0.100); Trim%(LCG-TCG): 0.01000(0.100); Heel%(LCG-TCG): 0.01000(0.100)

Loadcase - Frigate 5000ton_Modular_ASW
Damage Case - Intact
Free to Trim
Specific gravity = 1.025; (Density = 1.025 tonne/m^3)
Fluid analysis method: Use corrected VCG

Item Name	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
Lightship	1	2931.885	2931.885			59.640	0.000	7.703	0.000	User Specified
2 x VLS	1	52.000	52.000			103.700	0.000	10.070	0.000	User Specified
TAS Module	1	14.000	14.000			7.650	0.000	12.850	0.000	User Specified
Torpedo Module	1	5.330	5.330			7.650	0.000	12.850	0.000	User Specified
Torpedo Module	1	5.330	5.330			7.650	0.000	12.850	0.000	User Specified
Aft Fuel Tank Starb	100%	214.155	214.155	254.946	254.946	22.408	4.895	4.524	0.000	Maximum
Aft Fuel Tank	100%	171.926	171.926	204.674	204.674	20.578	0.000	4.402	0.000	Maximum
Aft Aviation Fuel Tank	100%	63.381	63.381	77.265	77.265	27.215	0.000	4.132	0.000	Maximum
Aft Fuel Tank Port	100%	214.155	214.155	254.946	254.946	22.408	-4.895	4.524	0.000	Maximum
Fuel Tank	100%	25.663	25.663	30.551	30.551	32.728	0.000	2.251	0.000	Maximum
Overflow Tank	0%	5.141	0.000	6.120	0.000	35.275	0.000	1.500	0.000	Maximum
Aft Lub Oil Tank	100%	30.845	30.845	36.720	36.720	43.350	0.000	2.250	0.000	Maximum
Aft Drain Lub Oil Tank	0%	22.522	0.000	24.480	0.000	52.700	0.000	1.500	0.000	Maximum
Lub Oil Tank Port	100%	40.539	40.539	44.064	44.064	59.500	1.500	2.250	0.000	Maximum
Lub Oil Tank Port	100%	40.539	40.539	44.064	44.064	59.500	-1.500	2.250	0.000	Maximum
Fwd Fuel Tank Starb	100%	30.582	30.582	36.407	36.407	70.539	4.980	2.255	0.000	Maximum
Fwd Ballast Tank	0%	37.638	0.000	36.720	0.000	70.550	0.000	1.500	0.000	Maximum
Fwd Fuel Tank Port	100%	30.582	30.582	36.407	36.407	70.539	-4.980	2.255	0.000	Maximum
Fwd Fresh Water Tank Port	100%	76.926	76.926	76.926	76.926	78.182	4.877	4.108	0.000	Maximum
Fwd Fresh Water Tank	100%	81.600	81.600	81.600	81.600	78.200	0.000	4.000	0.000	Maximum
Fwd Fresh Water Tank Starb	100%	76.926	76.926	76.926	76.926	78.182	-4.877	4.108	0.000	Maximum
Fwd Fuel Tank Starb	100%	119.710	119.710	142.512	142.512	85.509	4.348	4.280	0.000	Maximum
Fwd Fuel Tank	100%	171.360	171.360	204.000	204.000	85.850	0.000	4.000	0.000	Maximum
Fwd Fuel Tank Port	100%	119.710	119.710	142.512	142.512	85.509	-4.348	4.280	0.000	Maximum
Fwd Fuel Tank Starb	100%	29.758	29.758	35.426	35.426	93.704	2.972	2.911	0.000	Maximum
Fwd Fuel Tank Port	100%	29.758	29.758	35.426	35.426	93.704	-2.972	2.911	0.000	Maximum
Fwd Ballast	0%	103.672	0.000	101.143	0.000	112.401	0.000	1.500	0.000	Maximum
Peak Tank	0%	50.874	0.000	49.634	0.000	119.129	0.000	0.000	0.000	Maximum
Total Loadcase			4576.658	2033.468	1815.372	58.074	0.000	6.483	0.000	
FS correction								0.000		
VCG fluid								6.483		

Draft Amidships m	4.343
Displacement t	4577
Heel deg	0.0
Draft at FP m	4.213
Draft at AP m	4.472
Draft at LCF m	4.367
Trim (+ve by stern) m	0.260
WL Length m	122.903
Beam max extents on WL m	19.183
Wetted Area m^2	2102.471
Waterpl. Area m^2	1677.470
Prismatic coeff. (Cp)	0.543
Block coeff. (Cb)	0.438
Max Sect. area coeff. (Cm)	0.819
Waterpl. area coeff. (Cwp)	0.712
LCB from zero pt. (+ve fwd) m	58.075
LCF from zero pt. (+ve fwd) m	50.052
KB m	2.723
KG fluid m	6.483
BMt m	8.662
BML m	303.703
GMt corrected m	4.902
GML m	299.942
KMt m	11.385
KML m	306.425
Immersion (TPc) tonne/cm	17.194
MTc tonne.m	111.669
RM at 1deg = GMt.Disp.sin(1) tonne.m	391.546
Max deck inclination deg	0.1210
Trim angle (+ve by stern) deg	0.1210

Key point	Type	Freeboard m
Margin Line (freeboard pos = 0 m)		7.006
Deck Edge (freeboard pos = 0 m)		7.082

Code	Criteria	Value	Units	Actual	Status	Margin %
Royal Navy, Damage Stability Criteria; DS 02-109(NES109) Part 1	1.3.5.a.(6) Longitudinal GM > 0	0.000	m	299.942	Pass	infinite

Modular ASW – Large Angle Stability

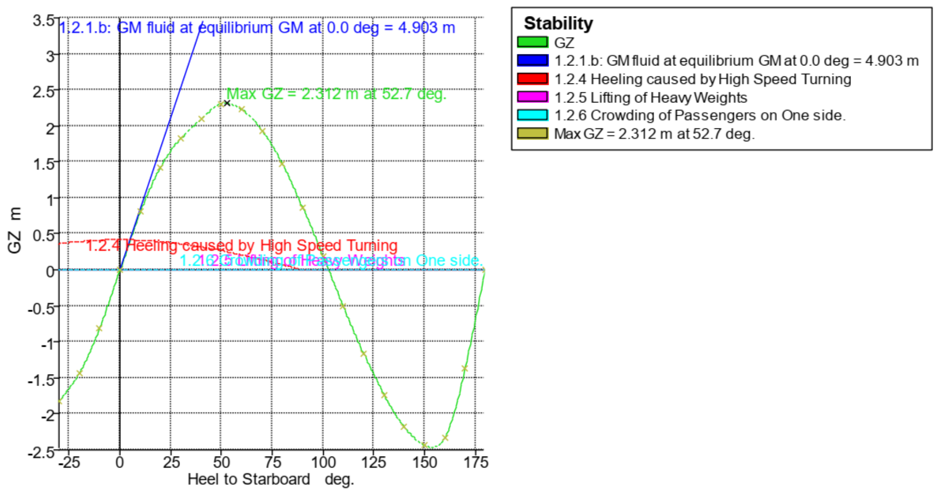
Stability calculation - Frigate 5000ton

Stability 23.04.00.76, build: 76

Model file: C:\Users\Felipe\OneDrive\Documentos\Felipe\UCL\MECH0070 - MSC Individual Project\Impact of Mission Modules on Naval Ship Design\Report\MAXSURF Models\Frigate 5000ton (Highest precision, 61 sections, Trimming off, Skin thickness not applied). Long. datum: AP; Vert. datum: Baseline. Analysis tolerance - ideal(worst case): Disp.%: 0.01000(0.100); Trim%(LCG-TCG): 0.01000(0.100); Heel%(LCG-TCG): 0.01000(0.100)

Loadcase - Frigate 5000ton_Modular_ASW
Damage Case - Intact
Free to Trim
Specific gravity = 1.025; (Density = 1.025 tonne/m^3)
Fluid analysis method: Use corrected VCG

Item Name	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
Lightship	1	2931.885	2931.885			59.640	0.000	7.703	0.000	User Specified
2 x VLS	1	52.000	52.000			103.700	0.000	10.070	0.000	User Specified
TAS Module	1	14.000	14.000			7.650	0.000	12.850	0.000	User Specified
Torpedo Module	1	5.330	5.330			7.650	0.000	12.850	0.000	User Specified
Torpedo Module	1	5.330	5.330			7.650	0.000	12.850	0.000	User Specified
Aft Fuel Tank Starb	100%	214.155	214.155	254.946	254.946	22.408	4.895	4.524	0.000	Maximum
Aft Fuel Tank	100%	171.926	171.926	204.674	204.674	20.578	0.000	4.402	0.000	Maximum
Aft Aviation Fuel Tank	100%	63.381	63.381	77.265	77.265	27.215	0.000	4.132	0.000	Maximum
Aft Fuel Tank Port	100%	214.155	214.155	254.946	254.946	22.408	-4.895	4.524	0.000	Maximum
Fuel Tank	100%	25.663	25.663	30.551	30.551	32.728	0.000	2.251	0.000	Maximum
Overflow Tank	0%	5.141	0.000	6.120	0.000	35.275	0.000	1.500	0.000	Maximum
Aft Lub Oil Tank	100%	30.845	30.845	36.720	36.720	43.350	0.000	2.250	0.000	Maximum
Aft Drain Lub Oil Tank	0%	22.522	0.000	24.480	0.000	52.700	0.000	1.500	0.000	Maximum
Lub Oil Tank Port	100%	40.539	40.539	44.064	44.064	59.500	1.500	2.250	0.000	Maximum
Lub Oil Tank Port	100%	40.539	40.539	44.064	44.064	59.500	-1.500	2.250	0.000	Maximum
Fwd Fuel Tank Starb	100%	30.582	30.582	36.407	36.407	70.539	4.980	2.255	0.000	Maximum
Fwd Ballast Tank	0%	37.638	0.000	36.720	0.000	70.550	0.000	1.500	0.000	Maximum
Fwd Fuel Tank Port	100%	30.582	30.582	36.407	36.407	70.539	-4.980	2.255	0.000	Maximum
Fwd Fresh Water Tank Port	100%	76.926	76.926	76.926	76.926	78.182	4.877	4.108	0.000	Maximum
Fwd Fresh Water Tank	100%	81.600	81.600	81.600	81.600	78.200	0.000	4.000	0.000	Maximum
Fwd Fresh Water Tank Starb	100%	76.926	76.926	76.926	76.926	78.182	-4.877	4.108	0.000	Maximum
Fwd Fuel Tank Starb	100%	119.710	119.710	142.512	142.512	85.509	4.348	4.280	0.000	Maximum
Fwd Fuel Tank	100%	171.360	171.360	204.000	204.000	85.850	0.000	4.000	0.000	Maximum
Fwd Fuel Tank Port	100%	119.710	119.710	142.512	142.512	85.509	-4.348	4.280	0.000	Maximum
Fwd Fuel Tank Starb	100%	29.758	29.758	35.426	35.426	93.704	2.972	2.911	0.000	Maximum
Fwd Fuel Tank Port	100%	29.758	29.758	35.426	35.426	93.704	-2.972	2.911	0.000	Maximum
Fwd Ballast	0%	103.672	0.000	101.143	0.000	112.401	0.000	1.500	0.000	Maximum
Peak Tank	0%	50.874	0.000	49.634	0.000	119.129	0.000	0.000	0.000	Maximum
Total Loadcase			4576.658	2033.468	1815.372	58.074	0.000	6.483	0.000	
FS correction								0.000		
VCG fluid								6.483		



Heel to Starboard deg	-30.0	-20.0	-10.0	0.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0
GZ m	-1.824	-1.427	-0.807	0.000	0.807	1.427	1.824	2.095	2.302	2.228	1.935	1.473	0.862	0.18
Area under GZ curve from zero heel m.deg	31.8683	15.4952	4.1221	0.0000	4.1249	15.4866	31.9002	51.5392	73.6703	96.5585	117.5194	134.6977	146.4693	151.723
Displacement t	4577	4577	4577	4577	4577	4577	4577	4577	4577	4577	4577	4577	4577	457
Draft at FP m	4.402	4.347	4.254	4.209	4.253	4.349	4.401	4.270	3.808	3.090	1.695	-2.903	n/a	-17.85
Draft at AP m	3.068	3.902	4.344	4.475	4.345	3.901	3.069	1.728	-0.353	-3.694	-10.020	-28.008	n/a	-40.63
WL Length m	122.920	122.911	122.905	122.903	122.905	122.912	122.919	122.921	122.912	122.902	122.879	121.800	124.892	127.00
Beam max extents on WL m	17.502	18.368	19.028	19.183	19.028	18.368	17.502	17.249	15.521	14.325	13.839	12.290	11.503	11.31
Wetted Area m^2	1978.883	2014.464	2062.405	2102.410	2062.413	2014.469	1978.873	1984.644	2038.679	2072.488	2084.291	2057.579	2056.455	2067.21
Waterpl. Area m^2	1501.101	1548.564	1621.304	1677.521	1621.364	1548.517	1501.110	1523.604	1483.952	1393.946	1319.836	1219.351	1162.516	1144.16
Prismatic coeff. (Cp)	0.560	0.553	0.546	0.543	0.546	0.553	0.560	0.562	0.567	0.577	0.586	0.603	0.606	0.61
Block coeff. (Cb)	0.356	0.377	0.415	0.438	0.415	0.376	0.356	0.341	0.372	0.405	0.428	0.504	0.467	0.42
LCB from zero pt. (+ve fwd) m	58.117	58.083	58.080	58.060	58.074	58.089	58.115	58.149	58.180	58.233	58.262	58.293	58.290	58.28
LCF from zero pt. (+ve fwd) m	55.336	53.481	51.583	50.047	51.579	53.484	55.335	57.402	59.021	60.542	62.054	61.057	60.481	60.17
Max deck inclination deg	30.0044	20.0009	10.0001	0.1238	10.0001	20.0009	30.0044	40.0086	50.0114	60.0126	70.0111	80.0063	90.0000	99.994
Trim angle (+ve by stern) deg	-0.6215	-0.2071	0.0418	0.1238	0.0431	-0.2086	-0.6209	-1.1845	-1.9389	-3.1587	-5.4438	-11.5424	n/a	-10.501

Key point	Type	Immersion angle deg	Emergence angle deg	Freeboard at 0.0 deg m	Freeboard at 10.0 deg m	Freeboard at 20.0 deg m	Freeboard at 30.0 deg m	Freeboard at 40.0 deg m	Freeboard at 50.0 deg m	Freeboard at 60.0 deg m	Freeboard at 70.0 deg m	Freeboard at 80.0 deg m	Freeboard at 90.0 deg m	Freeboard at 100.0 deg m	Freeboard at 110.0 deg m	Freeboard at 120.0 deg m	Freeboard at 130.0 deg m	Freeboard at 140.0 deg m	Freeboard at 150.0 deg m	Freeboard at 160.0 deg m	Freeboard at 170.0 deg m	Freeboard at 180.0 deg m
Margin Line (immersion pos = 73.906 m)		41	n/a	7.005	5.348	3.569	1.807	0.149	-1.385	-2.894	-4.339	-5.601	-6.601	-7.324	-7.761	-7.902	-7.738	-7.263	-6.470	-5.337	-3.928	-3.245
Deck Edge (immersion pos = 73.906 m)		41.3	n/a	7.081	5.423	3.640	1.871	0.199	-1.351	-2.882	-4.349	-5.635	-6.649	-7.385	-7.832	-7.981	-7.823	-7.358	-6.564	-5.430	-4.014	-3.321

Code	Criteria	Value	Units	Actual	Status	Margin %
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 0 to 30	4.5840	m.deg	31.9002	Pass	+595.90
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 0 to 40	7.6200	m.deg	51.5392	Pass	+576.37
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 30 to 40	2.7500	m.deg	19.6390	Pass	+614.15
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Maximum GZ	0.300	m	2.302	Pass	+667.33
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Angle of maximum GZ	30.0	deg	52.7	Pass	+75.76
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: GM fluid at equilibrium	0.300	m	4.903	Pass	+1534.33
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Range of positive stability	70.0	deg	102.6	Pass	+46.61
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Angle of vanishing stability	70.0	deg	102.6	Pass	+46.61
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.4 Heeling caused by High Speed Turning				Pass	
	Angle of steady heel shall be less than (<)	20.0	deg	5.0	Pass	+74.97
	Area1 / Area2 shall be greater than (>)	40.00	%	81.69	Pass	+104.22
	GZ(intersection) / GZ(max) shall be less than (<)	60.00	%	18.13	Pass	+69.78
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.5 Lifting of Heavy Weights				Pass	
	Angle of steady heel shall be less than (<)	15.0	deg	0.0	Pass	+100.00
	Area1 / Area2 shall be greater than (>)	50.00	%	100.00	Pass	+100.00
	GZ(intersection) / GZ(max) shall be less than (<)	50.00	%	0.00	Pass	+100.00
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.6 Crowding of Passengers on One side.				Pass	
	Angle of steady heel shall be less than (<)	10.0	deg	0.0	Pass	+99.81
	Area1 / Area2 shall be greater than (>)	40.00	%	99.92	Pass	+149.80
	GZ(intersection) / GZ(max) shall be less than (<)	60.00	%	0.07	Pass	+99.88

Modular ASuW – Equilibrium

Equilibrium calculation - Frigate 5000ton

Stability 23.04.00.76, build: 76
Model file: C:\Users\Felipe\OneDrive\Documentos\Felipe\UCL\MECH0070 - MSC Individual Project\Impact of Mission Modules on Naval Ship Design\Report\MAXSURF Models\Frigate 5000ton (Highest precision, 61 sections, Trimming off, Skin thickness not applied). Long. datum: AP; Vert. datum: Baseline. Analysis tolerance - ideal(worst case): Disp.%: 0.01000(0.100); Trim%(LCG-TCG): 0.01000(0.100); Heel%(LCG-TCG): 0.01000(0.100)

Loadcase - Frigate 5000ton_Modular_ASuW
Damage Case - Intact
Free to Trim
Specific gravity = 1.025; (Density = 1.025 tonne/m^3)
Fluid analysis method: Use corrected VCG

Item Name	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
Lightship	1	2931.885	2931.885			59.640	0.000	7.703	0.000	User Specified
Gun 76mm	1	14.860	14.860			113.050	0.000	11.080	0.000	User Specified
2 x VLS	1	52.000	52.000			103.700	0.000	10.070	0.000	User Specified
7m RIB	1	5.000	5.000			7.650	0.000	12.850	0.000	User Specified
7m RIB	1	5.000	5.000			7.650	0.000	12.850	0.000	User Specified
Aft Fuel Tank Starb	100%	214.155	214.155	254.946	254.946	22.408	4.895	4.524	0.000	Maximum
Aft Fuel Tank	100%	171.926	171.926	204.674	204.674	20.578	0.000	4.402	0.000	Maximum
Aft Aviation Fuel Tank	100%	63.381	63.381	77.265	77.265	27.215	0.000	4.132	0.000	Maximum
Aft Fuel Tank Port	100%	214.155	214.155	254.946	254.946	22.408	-4.895	4.524	0.000	Maximum
Fuel Tank	100%	25.663	25.663	30.551	30.551	32.728	0.000	2.251	0.000	Maximum
Overflow Tank	0%	5.141	0.000	6.120	0.000	35.275	0.000	1.500	0.000	Maximum
Aft Lub Oil Tank	100%	30.845	30.845	36.720	36.720	43.350	0.000	2.250	0.000	Maximum
Aft Drain Lub Oil Tank	0%	22.522	0.000	24.480	0.000	52.700	0.000	1.500	0.000	Maximum
Lub Oil Tank Port	100%	40.539	40.539	44.064	44.064	59.500	1.500	2.250	0.000	Maximum
Lub Oil Tank Port	100%	40.539	40.539	44.064	44.064	59.500	-1.500	2.250	0.000	Maximum
Fwd Fuel Tank Starb	100%	30.582	30.582	36.407	36.407	70.539	4.980	2.255	0.000	Maximum
Fwd Ballast Tank	0%	37.638	0.000	36.720	0.000	70.550	0.000	1.500	0.000	Maximum
Fwd Fuel Tank Port	100%	30.582	30.582	36.407	36.407	70.539	-4.980	2.255	0.000	Maximum
Fwd Fresh Water Tank Port	100%	76.926	76.926	76.926	76.926	78.182	4.877	4.108	0.000	Maximum
Fwd Fresh Water Tank	100%	81.600	81.600	81.600	81.600	78.200	0.000	4.000	0.000	Maximum
Fwd Fresh Water Tank Starb	100%	76.926	76.926	76.926	76.926	78.182	-4.877	4.108	0.000	Maximum
Fwd Fuel Tank Starb	100%	119.710	119.710	142.512	142.512	85.509	4.348	4.280	0.000	Maximum
Fwd Fuel Tank	100%	171.360	171.360	204.000	204.000	85.850	0.000	4.000	0.000	Maximum
Fwd Fuel Tank Port	100%	119.710	119.710	142.512	142.512	85.509	-4.348	4.280	0.000	Maximum
Fwd Fuel Tank Starb	100%	29.758	29.758	35.426	35.426	93.704	2.972	2.911	0.000	Maximum
Fwd Fuel Tank Port	100%	29.758	29.758	35.426	35.426	93.704	-2.972	2.911	0.000	Maximum
Fwd Ballast	0%	103.672	0.000	101.143	0.000	112.401	0.000	1.500	0.000	Maximum
Peak Tank	0%	50.874	0.000	49.634	0.000	119.129	0.000	0.000	0.000	Maximum
Total Loadcase			4576.858	2033.468	1815.372	58.414	0.000	6.478	0.000	
FS correction								0.000		
VCG fluid								6.478		

Draft Amidships m	4.355
Displacement t	4577
Heel deg	0.0
Draft at FP m	4.293
Draft at AP m	4.418
Draft at LCF m	4.367
Trim (+ve by stern) m	0.125
WL Length m	122.908
Beam max extents on WL m	19.184
Wetted Area m^2	2103.550
Waterpl. Area m^2	1676.025
Prismatic coeff. (Cp)	0.541
Block coeff. (Cb)	0.436
Max Sect. area coeff. (Cm)	0.819
Waterpl. area coeff. (Cwp)	0.711
LCB from zero pt. (+ve fwd) m	58.407
LCF from zero pt. (+ve fwd) m	50.168
KB m	2.723
KG fluid m	6.478
BMt m	8.635
BML m	303.230
GMt corrected m	4.880
GML m	299.475
KMt m	11.358
KML m	305.952
Immersion (TPc) tonne/cm	17.179
MTc tonne.m	111.500
RM at 1deg = GMt.Disp.sin(1) tonne.m	389.814
Max deck inclination deg	0.0583
Trim angle (+ve by stern) deg	0.0583

Key point	Type	Freeboard m
Margin Line (freeboard pos = 4.658 m)		7.061
Deck Edge (freeboard pos = 4.658 m)		7.137

Code	Criteria	Value	Units	Actual	Status	Margin %
Royal Navy, Damage Stability Criteria; DS 02-109(NES109) Part 1	1.3.5.a.(6) Longitudinal GM > 0	0.000	m	299.475	Pass	infinite

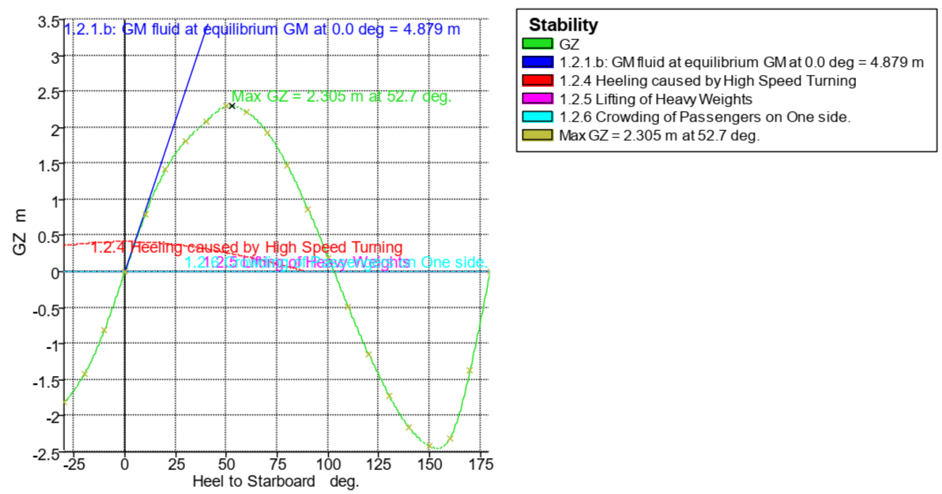
Modular ASuW – Large Angle Stability

Stability calculation - Frigate 5000ton

Stability 23.04.00.76, build: 76
Model file: C:\Users\Felipe\OneDrive\Documentos\Felipe\UCL\MECH0070 - MSC Individual Project\Impact of Mission Modules on Naval Ship Design\Report\MAXSURF Models\Frigate 5000ton (Highest precision, 61 sections, Trimming off, Skin thickness not applied). Long. datum: AP; Vert. datum: Baseline. Analysis tolerance - ideal(worst case): Disp.%: 0.01000(0.100); Trim%(LCG-TCG): 0.01000(0.100); Heel%(LCG-TCG): 0.01000(0.100)

Loadcase - Frigate 5000ton_Modular_ASuW
Damage Case - Intact
Free to Trim
Specific gravity = 1.025; (Density = 1.025 tonne/m^3)
Fluid analysis method: Use corrected VCG

Item Name	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
Lightship	1	2931.885	2931.885			59.640	0.000	7.703	0.000	User Specified
Gun_76mm	1	14.860	14.860			113.050	0.000	11.080	0.000	User Specified
2 x VLS	1	52.000	52.000			103.700	0.000	10.070	0.000	User Specified
7m RIB	1	5.000	5.000			7.650	0.000	12.850	0.000	User Specified
7m RIB	1	5.000	5.000			7.650	0.000	12.850	0.000	User Specified
Aft Fuel Tank Starb	100%	214.155	214.155	254.946	254.946	22.408	4.895	4.524	0.000	Maximum
Aft Fuel Tank	100%	171.926	171.926	204.674	204.674	20.578	0.000	4.402	0.000	Maximum
Aft Aviation Fuel Tank	100%	63.381	63.381	77.265	77.265	27.215	0.000	4.132	0.000	Maximum
Aft Fuel Tank Port	100%	214.155	214.155	254.946	254.946	22.408	-4.895	4.524	0.000	Maximum
Fuel Tank	100%	25.663	25.663	30.551	30.551	32.728	0.000	2.251	0.000	Maximum
Overflow Tank	0%	5.141	0.000	6.120	0.000	35.275	0.000	1.500	0.000	Maximum
Aft Lub Oil Tank	100%	30.845	30.845	36.720	36.720	43.350	0.000	2.250	0.000	Maximum
Aft Drain Lub Oil Tank	0%	22.522	0.000	24.480	0.000	52.700	0.000	1.500	0.000	Maximum
Lub Oil Tank Port	100%	40.539	40.539	44.064	44.064	59.500	1.500	2.250	0.000	Maximum
Lub Oil Tank Port	100%	40.539	40.539	44.064	44.064	59.500	-1.500	2.250	0.000	Maximum
Fwd Fuel Tank Starb	100%	30.582	30.582	36.407	36.407	70.539	4.980	2.255	0.000	Maximum
Fwd Ballast Tank	0%	37.638	0.000	36.720	0.000	70.550	0.000	1.500	0.000	Maximum
Fwd Fuel Tank Port	100%	30.582	30.582	36.407	36.407	70.539	-4.980	2.255	0.000	Maximum
Fwd Fresh Water Tank Port	100%	76.926	76.926	76.926	76.926	78.182	4.877	4.108	0.000	Maximum
Fwd Fresh Water Tank	100%	81.600	81.600	81.600	81.600	78.200	0.000	4.000	0.000	Maximum
Fwd Fresh Water Tank Starb	100%	76.926	76.926	76.926	76.926	78.182	-4.877	4.108	0.000	Maximum
Fwd Fuel Tank Starb	100%	119.710	119.710	142.512	142.512	85.509	4.348	4.280	0.000	Maximum
Fwd Fuel Tank	100%	171.360	171.360	204.000	204.000	85.850	0.000	4.000	0.000	Maximum
Fwd Fuel Tank Port	100%	119.710	119.710	142.512	142.512	85.509	-4.348	4.280	0.000	Maximum
Fwd Fuel Tank Starb	100%	29.758	29.758	35.426	35.426	93.704	2.972	2.911	0.000	Maximum
Fwd Fuel Tank Port	100%	29.758	29.758	35.426	35.426	93.704	-2.972	2.911	0.000	Maximum
Fwd Ballast	0%	103.672	0.000	101.143	0.000	112.401	0.000	1.500	0.000	Maximum
Peak Tank	0%	50.874	0.000	49.634	0.000	119.129	0.000	0.000	0.000	Maximum
Total Loadcase			4576.858	2033.468	1815.372	58.414	0.000	6.478	0.000	
FS correction								0.000		
VCG fluid								6.478		



Heel to Starboard deg	-30.0	-20.0	-10.0	0.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0
GZ m	-1.814	-1.419	-0.802	0.000	0.802	1.419	1.814	2.087	2.295	2.222	1.932	1.477	0.871	0.19
Area under GZ curve from zero heel m.deg	31.6852	15.4039	4.0982	0.0000	4.1009	15.3957	31.7156	51.2637	73.3186	96.1401	117.0498	134.2266	146.0615	151.424
Displacement t	4577	4577	4577	4577	4577	4577	4577	4577	4577	4577	4577	4577	4577	457
Draft at FP m	4.501	4.441	4.342	4.295	4.341	4.443	4.501	4.374	3.923	3.229	1.894	-2.457	n/a	-17.38
Draft at AP m	2.987	3.830	4.280	4.416	4.281	3.829	2.987	1.636	-0.459	-3.829	-10.222	-28.447	n/a	-41.08
WL Length m	122.928	122.918	122.910	122.908	122.910	122.918	122.928	122.930	122.920	122.910	122.889	122.034	125.105	127.14
Beam max extents on WL m	17.516	18.377	19.033	19.184	19.033	18.377	17.516	17.290	15.505	14.303	13.805	12.339	11.517	11.32
Wetted Area m^2	1979.968	2014.627	2061.939	2103.571	2061.950	2014.630	1979.968	1987.244	2047.180	2075.876	2089.311	2063.302	2059.894	2069.87
Waterpl. Area m^2	1499.761	1546.048	1617.957	1675.967	1618.021	1545.999	1499.761	1523.999	1489.533	1395.551	1323.833	1226.501	1167.175	1147.90
Prismatic coeff. (Cp)	0.558	0.552	0.544	0.541	0.544	0.552	0.558	0.561	0.566	0.576	0.585	0.601	0.604	0.61
Block coeff. (Cb)	0.355	0.376	0.413	0.436	0.413	0.376	0.355	0.340	0.372	0.405	0.429	0.501	0.463	0.41
LCB from zero pt. (+ve fwd) m	58.460	58.428	58.425	58.417	58.418	58.435	58.460	58.495	58.533	58.579	58.608	58.643	58.638	58.63
LCF from zero pt. (+ve fwd) m	55.528	53.662	51.760	50.172	51.757	53.665	55.528	57.625	59.361	60.688	62.231	61.375	60.718	60.39
Max deck inclination deg	30.0056	20.0017	10.0000	0.0563	10.0000	20.0017	30.0056	40.0099	50.0126	60.0136	70.0118	80.0068	90.0000	99.994
Trim angle (+ve by stern) deg	-0.7055	-0.2847	-0.0290	0.0563	-0.0277	-0.2862	-0.7056	-1.2758	-2.0415	-3.2859	-5.6290	-11.9379	n/a	-10.913

Key point	Type	Immersion angle deg	Emergence angle deg	Freeboard at 0.0 deg m	Freeboard at 10.0 deg m	Freeboard at 20.0 deg m	Freeboard at 30.0 deg m	Freeboard at 40.0 deg m	Freeboard at 50.0 deg m	Freeboard at 60.0 deg m	Freeboard at 70.0 deg m	Freeboard at 80.0 deg m	Freeboard at 90.0 deg m	Freeboard at 100.0 deg m	Freeboard at 110.0 deg m	Freeboard at 120.0 deg m	Freeboard at 130.0 deg m	Freeboard at 140.0 deg m	Freeboard at 150.0 deg m	Freeboard at 160.0 deg m	Freeboard at 170.0 deg m	Freeboard at 180.0 deg m
Margin Line (immersion pos = 73.906 m)		40.8	n/a	7.062	5.353	3.559	1.793	0.129	-1.406	-2.917	-4.366	-5.637	-6.639	-7.362	-7.798	-7.938	-7.773	-7.301	-6.505	-5.370	-3.963	-3.301
Deck Edge (immersion pos = 73.906 m)		41.2	n/a	7.138	5.428	3.630	1.858	0.179	-1.374	-2.910	-4.376	-5.671	-6.687	-7.422	-7.869	-8.018	-7.860	-7.396	-6.599	-5.463	-4.050	-3.377

Code	Criteria	Value	Units	Actual	Status	Margin %
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 0 to 30	4.5840	m.deg	31.7156	Pass	+591.88
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 0 to 40	7.6200	m.deg	51.2637	Pass	+572.75
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 30 to 40	2.7500	m.deg	19.5480	Pass	+610.84
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Maximum GZ	0.300	m	2.295	Pass	+665.00
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Angle of maximum GZ	30.0	deg	52.7	Pass	+75.76
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: GM fluid at equilibrium	0.300	m	4.879	Pass	+1526.33
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Range of positive stability	70.0	deg	102.8	Pass	+46.89
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Angle of vanishing stability	70.0	deg	102.8	Pass	+46.89
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.4 Heeling caused by High Speed Turning				Pass	
	Angle of steady heel shall be less than (<)	20.0	deg	5.0	Pass	+74.90
	Area1 / Area2 shall be greater than (>)	40.00	%	81.68	Pass	+104.20
	GZ(intersection) / GZ(max) shall be less than (<)	60.00	%	18.13	Pass	+69.78
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.5 Lifting of Heavy Weights				Pass	
	Angle of steady heel shall be less than (<)	15.0	deg	0.0	Pass	+100.00
	Area1 / Area2 shall be greater than (>)	50.00	%	100.00	Pass	+100.00
	GZ(intersection) / GZ(max) shall be less than (<)	50.00	%	0.00	Pass	+100.00
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.6 Crowding of Passengers on One side.				Pass	
	Angle of steady heel shall be less than (<)	10.0	deg	0.0	Pass	+99.80
	Area1 / Area2 shall be greater than (>)	40.00	%	99.92	Pass	+149.80
	GZ(intersection) / GZ(max) shall be less than (<)	60.00	%	0.07	Pass	+99.88

Modular MW – Equilibrium

Equilibrium calculation - Frigate 5000ton

Stability 23.04.00.76, build: 76
Model file: C:\Users\Felipe\OneDrive\Documentos\Felipe\UCL\MECH0070 - MSC Individual Project\Impact of Mission Modules on Naval Ship Design\Report\MAXSURF Models\Frigate 5000ton (Highest precision, 61 sections, Trimming off, Skin thickness not applied). Long. datum: AP; Vert. datum: Baseline. Analysis tolerance - ideal(worst case): Disp.%: 0.01000(0.100); Trim%(LCG-TCG): 0.01000(0.100); Heel%(LCG-TCG): 0.01000(0.100)

Loadcase - Frigate 5000ton_Modular_MW
Damage Case - Intact
Free to Trim
Specific gravity = 1.025; (Density = 1.025 tonne/m^3)
Fluid analysis method: Use corrected VCG

Item Name	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
Lightship	1	2931.885	2931.885			59.640	0.000	7.703	0.000	User Specified
7m RIB	1	5.000	5.000			7.650	0.000	12.850	0.000	User Specified
7m RIB	1	5.000	5.000			7.650	0.000	12.850	0.000	User Specified
UUV Module	1	2.930	2.930			7.650	0.000	12.850	0.000	User Specified
UUV Module	1	2.930	2.930			7.650	0.000	12.850	0.000	User Specified
Aft Fuel Tank Starb	100%	214.155	214.155	254.946	254.946	22.408	4.895	4.524	0.000	Maximum
Aft Fuel Tank	100%	171.926	171.926	204.674	204.674	20.578	0.000	4.402	0.000	Maximum
Aft Aviation Fuel Tank	100%	63.381	63.381	77.265	77.265	27.215	0.000	4.132	0.000	Maximum
Aft Fuel Tank Port	100%	214.155	214.155	254.946	254.946	22.408	-4.895	4.524	0.000	Maximum
Fuel Tank	100%	25.663	25.663	30.551	30.551	32.728	0.000	2.251	0.000	Maximum
Overflow Tank	0%	5.141	0.000	6.120	0.000	35.275	0.000	1.500	0.000	Maximum
Aft Lub Oil Tank	100%	30.845	30.845	36.720	36.720	43.350	0.000	2.250	0.000	Maximum
Aft Drain Lub Oil Tank	0%	22.522	0.000	24.480	0.000	52.700	0.000	1.500	0.000	Maximum
Lub Oil Tank Port	100%	40.539	40.539	44.064	44.064	59.500	1.500	2.250	0.000	Maximum
Lub Oil Tank Port	100%	40.539	40.539	44.064	44.064	59.500	-1.500	2.250	0.000	Maximum
Fwd Fuel Tank Starb	100%	30.582	30.582	36.407	36.407	70.539	4.980	2.255	0.000	Maximum
Fwd Ballast Tank	0%	37.638	0.000	36.720	0.000	70.550	0.000	1.500	0.000	Maximum
Fwd Fuel Tank Port	100%	30.582	30.582	36.407	36.407	70.539	-4.980	2.255	0.000	Maximum
Fwd Fresh Water Tank Port	100%	76.926	76.926	76.926	76.926	78.182	4.877	4.108	0.000	Maximum
Fwd Fresh Water Tank	100%	81.600	81.600	81.600	81.600	78.200	0.000	4.000	0.000	Maximum
Fwd Fresh Water Tank Starb	100%	76.926	76.926	76.926	76.926	78.182	-4.877	4.108	0.000	Maximum
Fwd Fuel Tank Starb	100%	119.710	119.710	142.512	142.512	85.509	4.348	4.280	0.000	Maximum
Fwd Fuel Tank	100%	171.360	171.360	204.000	204.000	85.850	0.000	4.000	0.000	Maximum
Fwd Fuel Tank Port	100%	119.710	119.710	142.512	142.512	85.509	-4.348	4.280	0.000	Maximum
Fwd Fuel Tank Starb	100%	29.758	29.758	35.426	35.426	93.704	2.972	2.911	0.000	Maximum
Fwd Fuel Tank Port	100%	29.758	29.758	35.426	35.426	93.704	-2.972	2.911	0.000	Maximum
Fwd Ballast	0%	103.672	0.000	101.143	0.000	112.401	0.000	1.500	0.000	Maximum
Peak Tank	0%	50.874	0.000	49.634	0.000	119.129	0.000	0.000	0.000	Maximum
Total Loadcase			4515.858	2033.468	1815.372	57.647	0.000	6.430	0.000	
FS correction								0.000		
VCG fluid								6.430		

Draft Amidships m	4.286
Displacement t	4516
Heel deg	0.0
Draft at FP m	4.045
Draft at AP m	4.527
Draft at LCF m	4.332
Trim (+ve by stern) m	0.482
WL Length m	122.895
Beam max extents on WL m	19.172
Wetted Area m^2	2089.683
Waterpl. Area m^2	1675.381
Prismatic coeff. (Cp)	0.544
Block coeff. (Cb)	0.439
Max Sect. area coeff. (Cm)	0.817
Waterpl. area coeff. (Cwp)	0.711
LCB from zero pt. (+ve fwd) m	57.629
LCF from zero pt. (+ve fwd) m	49.905
KB m	2.703
KG fluid m	6.430
BMt m	8.772
BML m	306.854
GMt corrected m	5.046
GML m	303.128
KMt m	11.475
KML m	309.555
Immersion (TPc) tonne/cm	17.173
MTc tonne.m	111.356
RM at 1deg = GMt.Disp.sin(1) tonne.m	397.669
Max deck inclination deg	0.2247
Trim angle (+ve by stern) deg	0.2247

Key point	Type	Freeboard m
Margin Line (freeboard pos = 0 m)		6.951
Deck Edge (freeboard pos = 0 m)		7.027

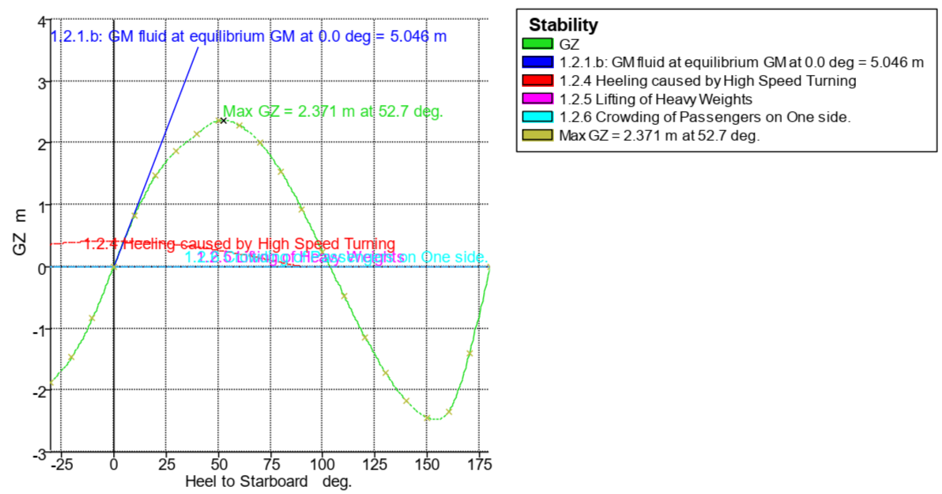
Code	Criteria	Value	Units	Actual	Status	Margin %
Royal Navy, Damage Stability Criteria; DS 02-109(NES109) Part 1	1.3.5.a.(6) Longitudinal GM > 0	0.000	m	303.128	Pass	infinite

Modular MW – Large Angle Stability

Stability calculation - Frigate 5000ton
Stability 23.04.00.76, build: 76
Model file: C:\Users\Felipe\OneDrive\Documentos\Felipe\UCL\MECH0070 - MSC Individual Project\Impact of Mission Modules on Naval Ship Design\Report\MAXSURF Models\Frigate 5000ton (Highest precision, 61 sections, Trimming off, Skin thickness not applied). Long. datum: AP; Vert. datum: Baseline. Analysis tolerance - ideal(worst case): Disp.%: 0.01000(0.100); Trim%(LCG-TCG): 0.01000(0.100); Heel%(LCG-TCG): 0.01000(0.100)

Loadcase - Frigate 5000ton_Modular_MW
Damage Case - Intact
Free to Trim
Specific gravity = 1.025; (Density = 1.025 tonne/m^3)
Fluid analysis method: Use corrected VCG

Item Name	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
Lightship	1	2931.885	2931.885			59.640	0.000	7.703	0.000	User Specified
7m RIB	1	5.000	5.000			7.650	0.000	12.850	0.000	User Specified
7m RIB	1	5.000	5.000			7.650	0.000	12.850	0.000	User Specified
UUV Module	1	2.930	2.930			7.650	0.000	12.850	0.000	User Specified
UUV Module	1	2.930	2.930			7.650	0.000	12.850	0.000	User Specified
Aft Fuel Tank Starb	100%	214.155	214.155	254.946	254.946	22.408	4.895	4.524	0.000	Maximum
Aft Fuel Tank	100%	171.926	171.926	204.674	204.674	20.578	0.000	4.402	0.000	Maximum
Aft Aviation Fuel Tank	100%	63.381	63.381	77.265	77.265	27.215	0.000	4.132	0.000	Maximum
Aft Fuel Tank Port	100%	214.155	214.155	254.946	254.946	22.408	-4.895	4.524	0.000	Maximum
Fuel Tank	100%	25.663	25.663	30.551	30.551	32.728	0.000	2.251	0.000	Maximum
Overflow Tank	0%	5.141	0.000	6.120	0.000	35.275	0.000	1.500	0.000	Maximum
Aft Lub Oil Tank	100%	30.845	30.845	36.720	36.720	43.350	0.000	2.250	0.000	Maximum
Aft Drain Lub Oil Tank	0%	22.522	0.000	24.480	0.000	52.700	0.000	1.500	0.000	Maximum
Lub Oil Tank Port	100%	40.539	40.539	44.064	44.064	59.500	1.500	2.250	0.000	Maximum
Lub Oil Tank Port	100%	40.539	40.539	44.064	44.064	59.500	-1.500	2.250	0.000	Maximum
Fwd Fuel Tank Starb	100%	30.582	30.582	36.407	36.407	70.539	4.980	2.255	0.000	Maximum
Fwd Ballast Tank	0%	37.638	0.000	36.720	0.000	70.550	0.000	1.500	0.000	Maximum
Fwd Fuel Tank Port	100%	30.582	30.582	36.407	36.407	70.539	-4.980	2.255	0.000	Maximum
Fwd Fresh Water Tank Port	100%	76.926	76.926	76.926	76.926	78.182	4.877	4.108	0.000	Maximum
Fwd Fresh Water Tank	100%	81.600	81.600	81.600	81.600	78.200	0.000	4.000	0.000	Maximum
Fwd Fresh Water Tank Starb	100%	76.926	76.926	76.926	76.926	78.182	-4.877	4.108	0.000	Maximum
Fwd Fuel Tank Starb	100%	119.710	119.710	142.512	142.512	85.509	4.348	4.280	0.000	Maximum
Fwd Fuel Tank	100%	171.360	171.360	204.000	204.000	85.850	0.000	4.000	0.000	Maximum
Fwd Fuel Tank Port	100%	119.710	119.710	142.512	142.512	85.509	-4.348	4.280	0.000	Maximum
Fwd Fuel Tank Starb	100%	29.758	29.758	35.426	35.426	93.704	2.972	2.911	0.000	Maximum
Fwd Fuel Tank Port	100%	29.758	29.758	35.426	35.426	93.704	-2.972	2.911	0.000	Maximum
Fwd Ballast	0%	103.672	0.000	101.143	0.000	112.401	0.000	1.500	0.000	Maximum
Peak Tank	0%	50.874	0.000	49.634	0.000	119.129	0.000	0.000	0.000	Maximum
Total Loadcase			4515.858	2033.468	1815.372	57.647	0.000	6.430	0.000	
FS correction								0.000		
VCG fluid								6.430		



Heel to Starboard deg	-30.0	-20.0	-10.0	0.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0
GZ m	-1.873	-1.468	-0.831	0.000	0.831	1.468	1.873	2.144	2.359	2.294	2.006	1.537	0.918	0.23
Area under GZ curve from zero heel m.deg	32.7788	15.9532	4.2470	0.0000	4.2500	15.9439	32.8128	52.9378	75.5899	99.0934	120.7468	138.6013	150.9676	156.739
Displacement t	4516	4516	4516	4516	4516	4516	4516	4516	4515	4516	4516	4516	4516	451
Draft at FP m	4.218	4.172	4.085	4.045	4.084	4.174	4.219	4.084	3.609	2.842	1.343	-3.701	n/a	-18.71
Draft at AP m	3.135	3.964	4.402	4.528	4.403	3.963	3.133	1.794	-0.291	-3.622	-9.928	-27.785	n/a	-40.40
WL Length m	122.907	122.901	122.896	122.895	122.896	122.901	122.907	122.908	122.900	122.889	122.866	121.379	124.505	126.73
Beam max extents on WL m	17.416	18.308	18.998	19.172	18.998	18.308	17.416	17.118	15.569	14.385	13.924	12.213	11.473	11.29
Wetted Area m^2	1963.490	2001.176	2050.830	2089.674	2050.835	2001.182	1963.502	1966.268	2014.752	2053.682	2063.504	2036.134	2036.719	2048.68
Waterpl. Area m^2	1494.745	1544.871	1620.090	1675.384	1620.147	1544.827	1494.726	1513.569	1475.338	1389.985	1312.679	1207.344	1152.328	1135.10
Prismatic coeff. (Cp)	0.560	0.554	0.547	0.544	0.547	0.554	0.560	0.561	0.566	0.575	0.584	0.603	0.606	0.61
Block coeff. (Cb)	0.356	0.377	0.415	0.439	0.415	0.377	0.356	0.341	0.369	0.400	0.422	0.507	0.471	0.42
LCB from zero pt. (+ve fwd) m	57.675	57.648	57.646	57.627	57.639	57.655	57.680	57.714	57.756	57.797	57.830	57.859	57.855	57.84
LCF from zero pt. (+ve fwd) m	55.102	53.275	51.382	49.905	51.379	53.278	55.104	57.113	58.662	60.361	61.773	60.572	60.052	59.79
Max deck inclination deg	30.0029	20.0002	10.0010	0.2250	10.0011	20.0002	30.0029	40.0070	50.0100	60.0114	70.0102	80.0058	90.0000	99.995
Trim angle (+ve by stern) deg	-0.5051	-0.0968	0.1474	0.2250	0.1487	-0.0982	-0.5062	-1.0675	-1.8171	-3.0103	-5.2387	-11.0851	n/a	-10.007

Key point	Type	Immersion angle deg	Emergence angle deg	Freeboard at 0.0 deg m	Freeboard at 10.0 deg m	Freeboard at 20.0 deg m	Freeboard at 30.0 deg m	Freeboard at 40.0 deg m	Freeboard at 50.0 deg m	Freeboard at 60.0 deg m	Freeboard at 70.0 deg m	Freeboard at 80.0 deg m	Freeboard at 90.0 deg m	Freeboard at 100.0 deg m	Freeboard at 110.0 deg m	Freeboard at 120.0 deg m	Freeboard at 130.0 deg m	Freeboard at 140.0 deg m	Freeboard at 150.0 deg m	Freeboard at 160.0 deg m	Freeboard at 170.0 deg m	Freeboard at 180.0 deg m
Margin Line (immersion pos = 69.854 m)		41.4	n/a	6.951	5.348	3.619	1.865	0.208	-1.318	-2.823	-4.265	-5.516	-6.505	-7.227	-7.664	-7.807	-7.646	-7.172	-6.385	-5.261	-3.853	-3.141
Deck Edge (immersion pos = 73.906 m)		41.7	n/a	7.027	5.423	3.691	1.929	0.262	-1.285	-2.810	-4.275	-5.545	-6.553	-7.287	-7.735	-7.886	-7.731	-7.266	-6.479	-5.351	-3.940	-3.217

Code	Criteria	Value	Units	Actual	Status	Margin %
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 0 to 30	4.5840	m.deg	32.8128	Pass	+615.81
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 0 to 40	7.6200	m.deg	52.9378	Pass	+594.72
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 30 to 40	2.7500	m.deg	20.1250	Pass	+631.82
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Maximum GZ	0.300	m	2.359	Pass	+686.33
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Angle of maximum GZ	30.0	deg	52.7	Pass	+75.76
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: GM fluid at equilibrium	0.300	m	5.046	Pass	+1582.00
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Range of positive stability	70.0	deg	103.3	Pass	+47.53
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Angle of vanishing stability	70.0	deg	103.3	Pass	+47.53
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.4 Heeling caused by High Speed Turning				Pass	
	Angle of steady heel shall be less than (<)	20.0	deg	4.8	Pass	+75.88
	Area1 / Area2 shall be greater than (>)	40.00	%	82.26	Pass	+105.65
	GZ(intersection) / GZ(max) shall be less than (<)	60.00	%	17.59	Pass	+70.68
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.5 Lifting of Heavy Weights				Pass	
	Angle of steady heel shall be less than (<)	15.0	deg	0.0	Pass	+100.00
	Area1 / Area2 shall be greater than (>)	50.00	%	100.00	Pass	+100.00
	GZ(intersection) / GZ(max) shall be less than (<)	50.00	%	0.00	Pass	+100.00
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.6 Crowding of Passengers on One side.				Pass	
	Angle of steady heel shall be less than (<)	10.0	deg	0.0	Pass	+99.81
	Area1 / Area2 shall be greater than (>)	40.00	%	99.93	Pass	+149.82
	GZ(intersection) / GZ(max) shall be less than (<)	60.00	%	0.07	Pass	+99.88

Modular No Modules – Equilibrium

Equilibrium calculation - Frigate 5000ton

Stability 23.04.00.76, build: 76
Model file: C:\Users\Felipe\OneDrive\Documentos\Felipe\UCL\MECH0070 - MSC Individual Project\Impact of Mission Modules on Naval Ship Design\Report\MAXSURF Models\Frigate 5000ton (Highest precision, 61 sections, Trimming off, Skin thickness not applied). Long. datum: AP; Vert. datum: Baseline. Analysis tolerance - ideal(worst case): Disp.%: 0.01000(0.100); Trim%(LCG-TCG): 0.01000(0.100); Heel%(LCG-TCG): 0.01000(0.100)

Loadcase - Frigate 5000ton_Modular_No_Modules
Damage Case - Intact
Free to Trim
Specific gravity = 1.025; (Density = 1.025 tonne/m^3)
Fluid analysis method: Use corrected VCG

Item Name	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
Lightship	1	2931.885	2931.885			59.640	0.000	7.703	0.000	User Specified
Aft Fuel Tank Starb	100%	214.155	214.155	254.946	254.946	22.408	4.895	4.524	0.000	Maximum
Aft Fuel Tank	100%	171.926	171.926	204.674	204.674	20.578	0.000	4.402	0.000	Maximum
Aft Aviation Fuel Tank	100%	63.381	63.381	77.265	77.265	27.215	0.000	4.132	0.000	Maximum
Aft Fuel Tank Port	100%	214.155	214.155	254.946	254.946	22.408	-4.895	4.524	0.000	Maximum
Fuel Tank	100%	25.663	25.663	30.551	30.551	32.728	0.000	2.251	0.000	Maximum
Overflow Tank	0%	5.141	0.000	6.120	0.000	35.275	0.000	1.500	0.000	Maximum
Aft Lub Oil Tank	100%	30.845	30.845	36.720	36.720	43.350	0.000	2.250	0.000	Maximum
Aft Drain Lub Oil Tank	0%	22.522	0.000	24.480	0.000	52.700	0.000	1.500	0.000	Maximum
Lub Oil Tank Port	100%	40.539	40.539	44.064	44.064	59.500	1.500	2.250	0.000	Maximum
Lub Oil Tank Port	100%	40.539	40.539	44.064	44.064	59.500	-1.500	2.250	0.000	Maximum
Fwd Fuel Tank Starb	100%	30.582	30.582	36.407	36.407	70.539	4.980	2.255	0.000	Maximum
Fwd Ballast Tank	0%	37.638	0.000	36.720	0.000	70.550	0.000	1.500	0.000	Maximum
Fwd Fuel Tank Port	100%	30.582	30.582	36.407	36.407	70.539	-4.980	2.255	0.000	Maximum
Fwd Fresh Water Tank Port	100%	76.926	76.926	76.926	76.926	78.182	4.877	4.108	0.000	Maximum
Fwd Fresh Water Tank	100%	81.600	81.600	81.600	81.600	78.200	0.000	4.000	0.000	Maximum
Fwd Fresh Water Tank Starb	100%	76.926	76.926	76.926	76.926	78.182	-4.877	4.108	0.000	Maximum
Fwd Fuel Tank Starb	100%	119.710	119.710	142.512	142.512	85.509	4.348	4.280	0.000	Maximum
Fwd Fuel Tank	100%	171.360	171.360	204.000	204.000	85.850	0.000	4.000	0.000	Maximum
Fwd Fuel Tank Port	100%	119.710	119.710	142.512	142.512	85.509	-4.348	4.280	0.000	Maximum
Fwd Fuel Tank Starb	100%	29.758	29.758	35.426	35.426	93.704	2.972	2.911	0.000	Maximum
Fwd Fuel Tank Port	100%	29.758	29.758	35.426	35.426	93.704	-2.972	2.911	0.000	Maximum
Fwd Ballast	0%	103.672	0.000	101.143	0.000	112.401	0.000	1.500	0.000	Maximum
Peak Tank	0%	50.874	0.000	49.634	0.000	119.129	0.000	0.000	0.000	Maximum
Total Loadcase			4499.998	2033.468	1815.372	57.823	0.000	6.407	0.000	
FS correction								0.000		
VCG fluid								6.407		

Draft Amidships m	4.283
Displacement t	4500
Heel deg	0.0
Draft at FP m	4.072
Draft at AP m	4.494
Draft at LCF m	4.322
Trim (+ve by stern) m	0.422
WL Length m	122.896
Beam max extents on WL m	19.170
Wetted Area m^2	2087.772
Waterpl. Area m^2	1674.110
Prismatic coeff. (Cp)	0.543
Block coeff. (Cb)	0.438
Max Sect. area coeff. (Cm)	0.817
Waterpl. area coeff. (Cwp)	0.711
LCB from zero pt. (+ve fwd) m	57.807
LCF from zero pt. (+ve fwd) m	49.953
KB m	2.697
KG fluid m	6.407
BMt m	8.783
BML m	307.568
GMt corrected m	5.072
GML m	303.857
KMt m	11.479
KML m	310.263
Immersion (TPc) tonne/cm	17.160
MTc tonne.m	111.232
RM at 1deg = GMt.Disp.sin(1) tonne.m	398.362
Max deck inclination deg	0.1965
Trim angle (+ve by stern) deg	0.1965

Key point	Type	Freeboard m
Margin Line (freeboard pos = 0 m)		6.985
Deck Edge (freeboard pos = 0 m)		7.061

Code	Criteria	Value	Units	Actual	Status	Margin %
Royal Navy, Damage Stability Criteria; DS 02-109(NES109) Part 1	1.3.5.a.(6) Longitudinal GM > 0	0.000	m	303.857	Pass	infinite

Modular No Modules – Large Angle Stability

Stability calculation - Frigate 5000ton

Stability 23.04.00.76, build: 76
Model file: C:\Users\Felipe\OneDrive\Documentos\Felipe\UCL\MECH0070 - MSC Individual Project\Impact of Mission Modules on Naval Ship Design\Report\MAXSURF Models\Frigate 5000ton (Highest precision, 61 sections, Trimming off, Skin thickness not applied). Long. datum: AP; Vert. datum: Baseline. Analysis tolerance - ideal(worst case): Disp.%: 0.01000(0.100); Trim%(LCG-TCG): 0.01000(0.100); Heel%(LCG-TCG): 0.01000(0.100)

Loadcase - Frigate 5000ton_Modular_No_Modules
Damage Case - Intact
Free to Trim
Specific gravity = 1.025; (Density = 1.025 tonne/m^3)
Fluid analysis method: Use corrected VCG

Item Name	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
Lightship	1	2931.885	2931.885			59.640	0.000	7.703	0.000	User Specified
Aft Fuel Tank Starb	100%	214.155	214.155	254.946	254.946	22.408	4.895	4.524	0.000	Maximum
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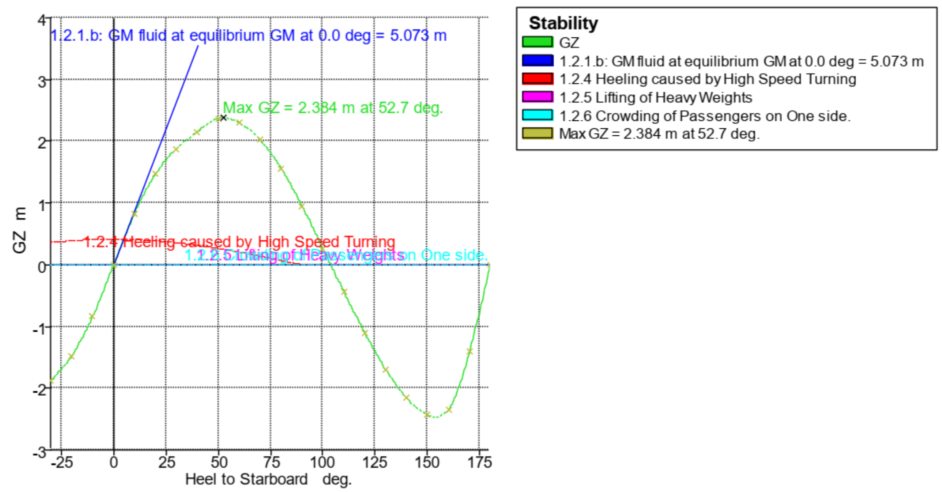
Overflow Tank	0%	5.141	0.000	6.120	0.000	35.275	0.000	1.500	0.000	Maximum
Aft Lub Oil Tank	100%	30.845	30.845	36.720	36.720	43.350	0.000	2.250	0.000	Maximum
Aft Drain Lub Oil Tank	0%	22.522	0.000	24.480	0.000	52.700	0.000	1.500	0.000	Maximum
Lub Oil Tank Port	100%	40.539	40.539	44.064	44.064	59.500	1.500	2.250	0.000	Maximum
Lub Oil Tank Port	100%	40.539	40.539	44.064	44.064	59.500	-1.500	2.250	0.000	Maximum
Fwd Fuel Tank Starb	100%	30.582	30.582	36.407	36.407	70.539	4.980	2.255	0.000	Maximum
Fwd Ballast Tank	0%	37.638	0.000	36.720	0.000	70.550	0.000	1.500	0.000	Maximum
Fwd Fuel Tank Port	100%	30.582	30.582	36.407	36.407	70.539	-4.980	2.255	0.000	Maximum
Fwd Fresh Water Tank Port	100%	76.926	76.926	76.926	76.926	78.182	4.877	4.108	0.000	Maximum
Fwd Fresh Water Tank	100%	81.600	81.600	81.600	81.600	78.200	0.000	4.000	0.000	Maximum
Fwd Fresh Water Tank Starb	100%	76.926	76.926	76.926	76.926	78.182	-4.877	4.108	0.000	Maximum
Fwd Fuel Tank Starb	100%	119.710	119.710	142.512	142.512	85.509	4.348	4.280	0.000	Maximum
Fwd Fuel Tank	100%	171.360	171.360	204.000	204.000	85.850	0.000	4.000	0.000	Maximum
Fwd Fuel Tank Port	100%	119.710	119.710	142.512	142.512	85.509	-4.348	4.280	0.000	Maximum
Fwd Fuel Tank Starb	100%	29.758	29.758	35.426	35.426	93.704	2.972	2.911	0.000	Maximum
Fwd Fuel Tank Port	100%	29.758	29.758	35.426	35.426	93.704	-2.972	2.911	0.000	Maximum
Fwd Ballast	0%	103.672	0.000	101.143	0.000	112.401	0.000	1.500	0.000	Maximum
Peak Tank	0%	50.874	0.000	49.634	0.000	119.129	0.000	0.000	0.000	Maximum
Total Loadcase			4499.998	2033.468	1815.372	57.823	0.000	6.407	0.000	
FS correction								0.000		
VCG fluid								6.407		



Heel to Starboard deg	-30.0	-20.0	-10.0	0.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0
GZ m	-1.879	-1.473	-0.834	0.000	0.834	1.473	1.879	2.152	2.370	2.310	2.025	1.560	0.944	0.25
Area under GZ curve from zero heel m.deg	32.8927	16.0111	4.2636	0.0000	4.2666	16.0017	32.9266	53.1217	75.8688	99.5066	121.3337	139.4033	152.0200	158.058
Displacement t	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	450
Draft at FP m	4.255	4.205	4.115	4.071	4.113	4.207	4.256	4.124	3.653	2.895	1.420	-3.527	n/a	-18.53
Draft at AP m	3.083	3.920	4.363	4.494	4.365	3.919	3.082	1.734	-0.362	-3.717	-10.075	-28.099	n/a	-40.72
WL Length m	122.909	122.903	122.898	122.896	122.898	122.903	122.910	122.912	122.903	122.893	122.870	121.471	124.590	126.80
Beam max extents on WL m	17.405	18.298	18.994	19.170	18.994	18.298	17.405	17.118	15.563	14.375	13.907	12.222	11.474	11.29
Wetted Area m^2	1960.406	1997.887	2047.498	2087.760	2047.505	1997.892	1960.425	1963.614	2012.073	2051.229	2061.494	2034.242	2034.397	2046.12
Waterpl. Area m^2	1491.948	1541.840	1617.057	1674.117	1617.117	1541.794	1491.925	1511.217	1474.359	1390.063	1313.651	1209.102	1153.512	1135.89
Prismatic coeff. (Cp)	0.559	0.553	0.546	0.543	0.546	0.553	0.559	0.561	0.565	0.574	0.583	0.602	0.605	0.61
Block coeff. (Cb)	0.356	0.376	0.414	0.438	0.414	0.376	0.356	0.341	0.368	0.400	0.422	0.505	0.468	0.42
LCB from zero pt. (+ve fwd) m	57.853	57.827	57.824	57.805	57.818	57.834	57.859	57.893	57.934	57.976	58.009	58.041	58.036	58.02
LCF from zero pt. (+ve fwd) m	55.201	53.371	51.476	49.952	51.472	53.374	55.204	57.223	58.749	60.416	61.828	60.668	60.137	59.87
Max deck inclination deg	30.0034	20.0004	10.0006	0.1969	10.0007	20.0004	30.0034	40.0076	50.0106	60.0120	70.0107	80.0061	90.0000	99.995
Trim angle (+ve by stern) deg	-0.5459	-0.1329	0.1158	0.1969	0.1171	-0.1344	-0.5473	-1.1139	-1.8703	-3.0789	-5.3421	-11.3039	n/a	-10.232

Key point	Type	Immersion angle deg	Emergence angle deg	Freeboard at 0.0 deg m	Freeboard at 10.0 deg m	Freeboard at 20.0 deg m	Freeboard at 30.0 deg m	Freeboard at 40.0 deg m	Freeboard at 50.0 deg m	Freeboard at 60.0 deg m	Freeboard at 70.0 deg m	Freeboard at 80.0 deg m	Freeboard at 90.0 deg m	Freeboard at 100.0 deg m	Freeboard at 110.0 deg m	Freeboard at 120.0 deg m	Freeboard at 130.0 deg m	Freeboard at 140.0 deg m	Freeboard at 150.0 deg m	Freeboard at 160.0 deg m	Freeboard at 170.0 deg m	Freeboard at 180.0 deg m
Margin Line (immersion pos = 73.906 m)		41.4	n/a	6.985	5.371	3.627	1.868	0.210	-1.319	-2.825	-4.268	-5.520	-6.513	-7.234	-7.671	-7.813	-7.652	-7.179	-6.392	-5.267	-3.862	-3.160
Deck Edge (immersion pos = 73.906 m)		41.7	n/a	7.061	5.446	3.698	1.933	0.264	-1.286	-2.812	-4.278	-5.552	-6.561	-7.294	-7.742	-7.893	-7.738	-7.274	-6.486	-5.358	-3.948	-3.236

Code	Criteria	Value	Units	Actual	Status	Margin %
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 0 to 30	4.5840	m.deg	32.9266	Pass	+618.29
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 0 to 40	7.6200	m.deg	53.1217	Pass	+597.14
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Area 30 to 40	2.7500	m.deg	20.1951	Pass	+634.37
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Maximum GZ	0.300	m	2.370	Pass	+690.00
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Angle of maximum GZ	30.0	deg	52.7	Pass	+75.76
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: GM fluid at equilibrium	0.300	m	5.073	Pass	+1591.00
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Range of positive stability	70.0	deg	103.7	Pass	+48.08
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.1.b: Angle of vanishing stability	70.0	deg	103.7	Pass	+48.08
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.4 Heeling caused by High Speed Turning				Pass	
	Angle of steady heel shall be less than (<)	20.0	deg	4.8	Pass	+76.09
	Area1 / Area2 shall be greater than (>)	40.00	%	82.42	Pass	+106.05
	GZ(intersection) / GZ(max) shall be less than (<)	60.00	%	17.42	Pass	+70.97
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.5 Lifting of Heavy Weights				Pass	
	Angle of steady heel shall be less than (<)	15.0	deg	0.0	Pass	+100.00
	Area1 / Area2 shall be greater than (>)	50.00	%	100.00	Pass	+100.00
	GZ(intersection) / GZ(max) shall be less than (<)	50.00	%	0.00	Pass	+100.00
Royal Navy, Intact Stability Criteria; DS 02-109(NES109) Part 1	1.2.6 Crowding of Passengers on One side.				Pass	
	Angle of steady heel shall be less than (<)	10.0	deg	0.0	Pass	+99.81
	Area1 / Area2 shall be greater than (>)	40.00	%	99.93	Pass	+149.82
	GZ(intersection) / GZ(max) shall be less than (<)	60.00	%	0.07	Pass	+99.88

Appendix IV – Operability Analysis

Extra Power and Weight Analysis

Modules Data

Module	Power Required [kW]	Total Weight [ton]	Cost [£M]
Gun 40mm	9.60	9.35	6.22
Gun 76mm	9.60	14.86	15.54
VLS (tactical)	51.00	26.00	17.62
TAS	54.20	14.00	25.91
Torpedo	1.00	5.33	2.59
Missile	10.00	8.18	14.40
UAV	5.00	3.58	62.17
UUV	1.00	2.93	5.44
7m RIB	20.00	5.00	2.46

Ship	Mod SPV 500t			Mod OPV 2000t			Mod Frigate 5000t		
Module \ Mission	ASW	ASuW	MW	ASW	ASuW	MW	ASW	ASuW	MW
Gun 40mm		1			1				
Gun 76mm								1	
VLS (tactical)	1			1	1		2	2	
TAS	1			1			1		
Torpedo	2			2			2		
Missile		2							
UAV									
UUV			2			2			2
7m RIB		2	2		2	2		2	2
	Power Required			Power Required			Power Required		
Gun 40mm		9.60			9.60				
Gun 76mm								9.60	
VLS (tactical)	51.00			51.00	51.00		102.00	102.00	
TAS	54.20			54.20			54.20		
Torpedo	2.00			2.00			2.00		
Missile		20.00							
UAV									
UUV			2.00			2.00			2.00
7m RIB		40.00	40.00		40.00	40.00		40.00	40.00
Modules Required Power [kW]	107.20	69.60	42.00	107.20	100.60	42.00	158.20	151.60	42.00

Module	Total Weight			Total Weight			Total Weight		
Gun 40mm		9.35			9.35				
Gun 76mm								14.86	
VLS (tactical)	26.00			26.00	26.00		52.00	52.00	
TAS	14.00			14.00			14.00		
Torpedo	10.66			10.66			10.66		
Missile		16.36							
UAV									
UUV			5.86			5.86			5.86
7m RIB		10.00	10.00		10.00	10.00		10.00	10.00
Modules Weight [ton]	50.66	35.71	15.86	50.66	45.35	15.86	76.66	76.86	15.86

Summary Extra Power and Weight Analysis

Ship	Mod SPV 500t			Mod OPV 2000t			Mod Frigate 5000t		
Requirement \ Mission	ASW	ASuW	MW	ASW	ASuW	MW	ASW	ASuW	MW
Modules Required Power [kW]	107.20	69.60	42.00	107.20	100.60	42.00	158.20	151.60	42.00
Auxiliary Power [kW]	600.34	600.34	600.34	1838.49	1838.49	1838.49	4756.89	4756.89	4756.89
% Auxiliary Power Demand	17.86%	11.59%	7.00%	5.83%	5.47%	2.28%	3.33%	3.19%	0.88%
Modules Weight [ton]	50.66	35.71	15.86	50.66	45.35	15.86	76.66	76.86	15.86
Displacement [ton]	500	500	500	2000	2000	2000	5000	5000	5000
% Weight Demand	10.13%	7.14%	3.17%	2.53%	2.27%	0.79%	1.53%	1.54%	0.32%

Appendix V – Cost Analysis

Modules Cost

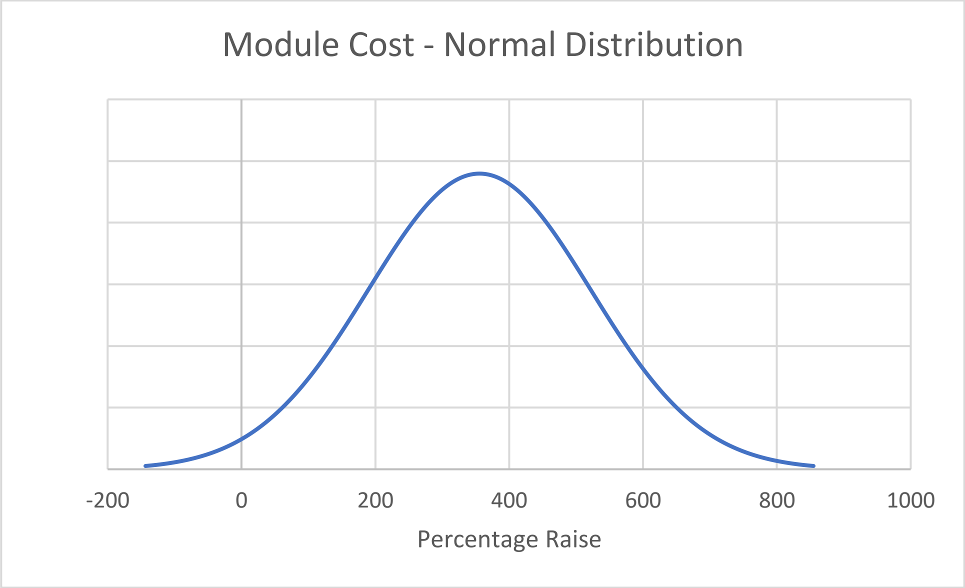
Cost Data

	CBA NATO Cost Data							
	Name	**Unit Costs [£]**	**Acq. Cost [£]**	**Acq. Low [£]**	**Acq. Likely [£]**	**Acq. High [£]**	**Int. Cost [£]**	**Int. % Acq.**
Weapons	Gun (Small Calibre)	7,400,000	4,000,000	1,500,000	4,000,000	7,000,000	400,000	10.0%
	Gun (Medium Calibre)	10,700,000	7,000,000	4,000,000	7,000,000	10,000,000	700,000	10.0%
	Gun (Large Calibre)	15,000,000	10,000,000	8,500,000	10,000,000	14,000,000	1,000,000	10.0%
	VLS	17,560,000	13,000,000	8,000,000	13,000,000	16,000,000	1,560,000	12.0%
Sensors	3D Radar	7,500,000	5,000,000	3,000,000	5,000,000	7,000,000	500,000	10.0%
	Hull Mounted Sonar	14,640,000	8,000,000	4,000,000	8,000,000	14,000,000	640,000	8.0%
Boats	11m RIB	1,100,000	800,000	600,000	800,000	1,000,000	100,000	12.5%
	7m RIB	381,250	250,000	175,000	250,000	350,000	31,250	12.5%

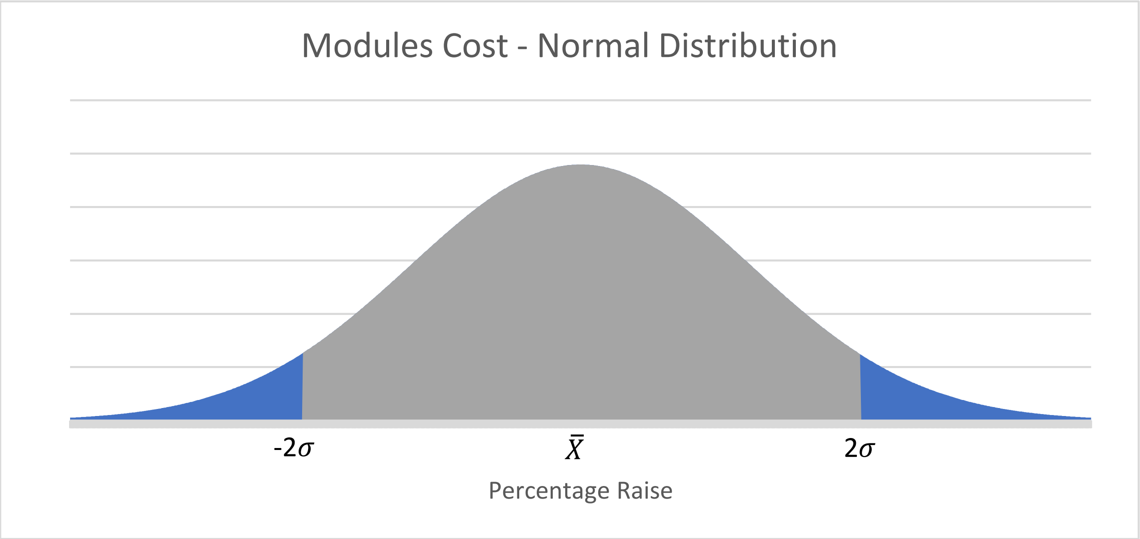
	Zenith Cost Data		Cost % Raise			
	Item	**Cost (£ 2008 UCL)**	**Acq. Likely**	**Likely % Raise**	**Acq. High**	**High % Raise**
Weapons	30mm Gun	1,000,000	4,000,000	400%	7,400,000	740%
	76mm Gun	3,000,000	7,000,000	233%	10,700,000	357%
	127mm Gun	7,500,000	10,000,000	133%	15,000,000	200%
	Strike VLS	5,100,000	13,000,000	255%	17,560,000	344%
Sensors	3D Radar	4,500,000	5,000,000	111%	7,500,000	167%
	Hull Mounted Sonar	5,000,000	8,000,000	160%	14,640,000	293%
Boats	11m RIB	250,000	800,000	320%	1,000,000	400%
	7m RIB	125,000	250,000	200%	350,000	280%

Cost Normalisation Curve

	Parameters	
Normalization	Average ($\bar{X}$)	355.68
	Standard Deviation (σ)	166.37
Confidence Interval	Number of Observations (n)	8
	Z_95%	1.96
	Min	240.39
	Max	470.97



Parameters	
Average ($\bar{X}$)	355.68
Standard Deviation (σ)	166.37
($\bar{X} - 2\sigma$)	22.94
($\bar{X} + 2\sigma$)	688.42

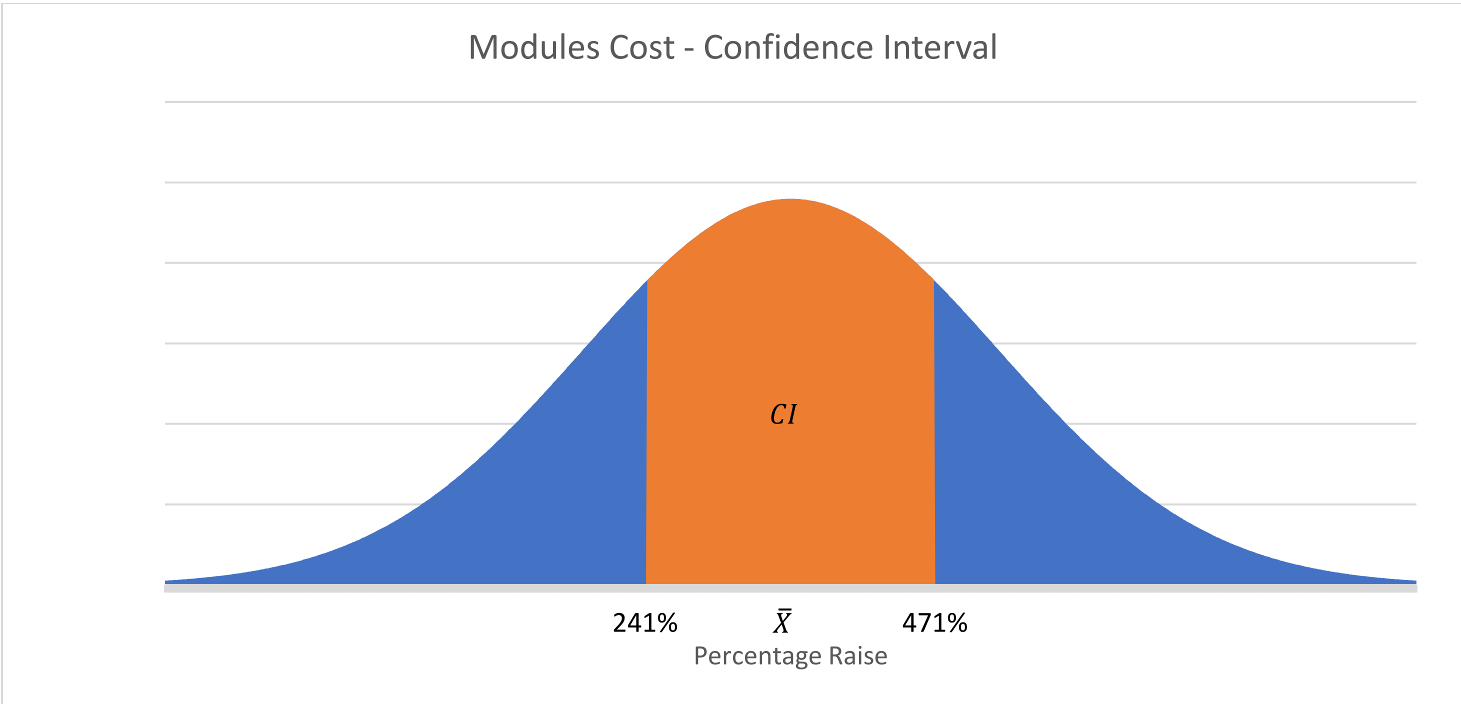


Proposed Zenith Cost Correction

Confidence Interval

$$CI = \bar{X} \pm Z \cdot \frac{\sigma}{\sqrt{n}}$$

$$CI = 356\% \pm 1.96 * \frac{166}{\sqrt{8}} = 356\% \pm 115\% = 241\% \text{ and } 471\%$$



Proposed Zenith Cost Correction	471%

Gun Modules

Guns Data - Zenith

30mm Gun	
Complement	2
Consoles	1
Power [kW]	10
Cooling [kW]	20
Cost [£M]	1
Correction	471%
Modularization	110%
40mm Correction	**120%**
Corrected Cost [£M]	**6.22**

http://128.40.55.189/mediawiki/index.php/30mm_Gun

76mm Gun	
Complement	4
Consoles	1
Power [kW]	10
Cooling [kW]	2
Cost [£M]	3
Correction	471%
Modularization	110%
Corrected Cost [£M]	15.54

http://128.40.55.189/mediawiki/index.php/76mm_Gun

Dimensions

Item	Weight [t]	Space
Gun Mount	2	3.5m radius
Gun Bay		9m²
Magazine	1	4m²
Ammunition	2	

Dimensions

Item	Weight [t]	Space
Gun Mount	6.5	5.5m radius
Gun Bay	2	5m²
Magazine	3	14m²
Ammunition	6	
Control Space	0.4	4m²

VLS Module

VLS Data - Zenith

Tactical VLS	
Complement	
Consoles	1
Power [kW]	50
Cooling [kW]	40
Cost [£M]	3.4
Correction	471%
Modularization	110%
Corrected Cost [£M]	**17.62**

http://128.40.55.189/mediawiki/index.php/Tactical_VLS

Strike-Length	
Complement	
Consoles	1
Power [kW]	45
Cooling [kW]	40
Cost [£M]	5.1

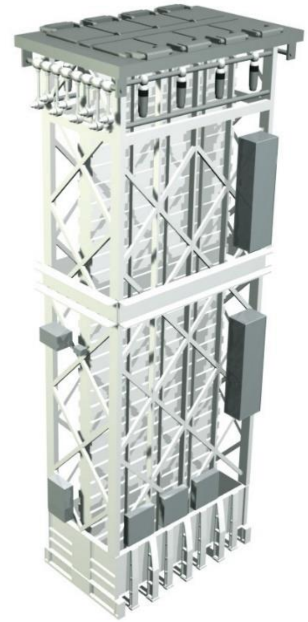
http://128.40.55.189/mediawiki/index.php/Strike-Length_VLS

Dimensions

Item	Weight [t]	Space
8-Cells VLS Unit	12	3.4x2.6x5.3m
Service Cabinet	0.7	4m²
Ammunition	12	

Dimensions

Item	Weight [t]	Space
8-Cells VLS Unit	12	3.4x2.6x7.7m
Service Cabinet	0.7	4m²
Ammunition	17.6	



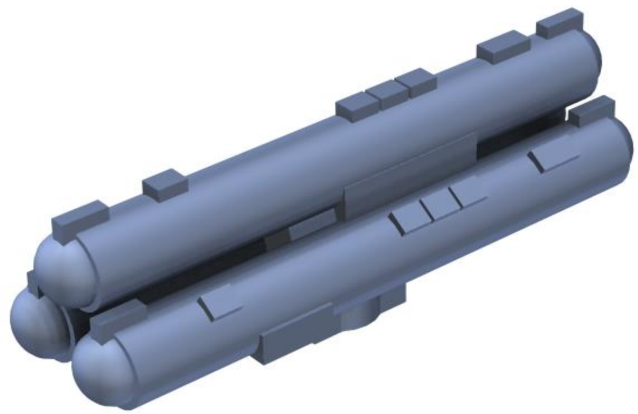
TAS Module

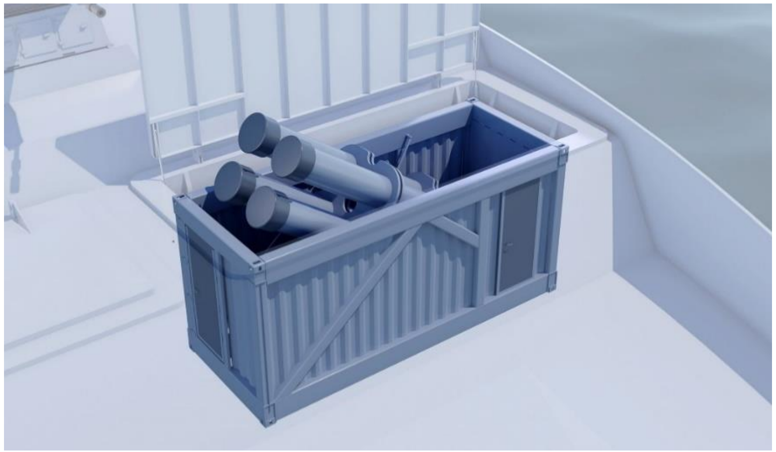
Towed Array Sonar Data - Zenith		
Small Towed Array Sonar		http://128.40.55.189/mediawiki/index.php/Small_Towed_Array_Sonar
Complement		
Consoles	1	
Power [kW]		
Cooling [kW]		
Cost [£M]	5	
Correction	471%	
Modularization	110%	
Corrected Cost [£M]	**25.91**	
Dimensions		
Item	Weight [t]	Space
Array handling system	6	4m x 2.5m x 2m
Equipment room	0.3	5m²

Torpedo Module

Torpedo Tubes - Zenith		
Torpedo Tubes		http://128.40.55.189/mediawiki/index.php/Torpedo_Tubes
Complement	2	
Consoles	1	
Power [kW]	1	
Cooling [kW]	0	
Cost [£M]	0.5	
Correction	471%	
Modularization	110%	
Corrected Cost [£M]	**2.59**	

Dimensions		
Item	Weight [t]	Space
Triple Launcher	1.5	3 x 1 x 1.2m
Service Cabinet	0.5	$3m^2$
Ammunition	0.75	Nil - in Launcher
Magazine (Optional)	2.6	$10m^2$
Reload Ammunition (Optional)	2.6	Nil - in Magazine

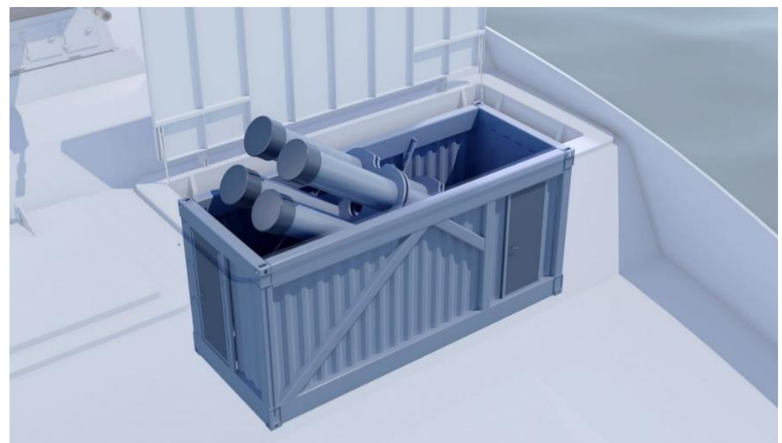




Missile Module

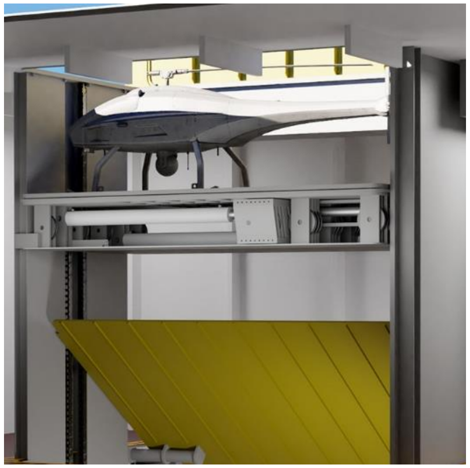
Point Defence Launcher - Zenith		
Point Defence Launcher		http://128.40.55.189/mediawiki/index.php/Point_Defence_Launcher
Complement	4	
Consoles	1	
Power [kW]	10	
Cooling [kW]	2	
Cost [£M]	3	
Corrected Cost [£M]	**14.4**	

Dimensions		
Item	Weight [t]	Space
Launcher	3.6	2.2m clear radius, 2.5m high.
Ammunition	1.5	Nil - in Launcher
Container	2.08	6.1 x 2.4 x 2.59
Elevation System	1	Nil - in container



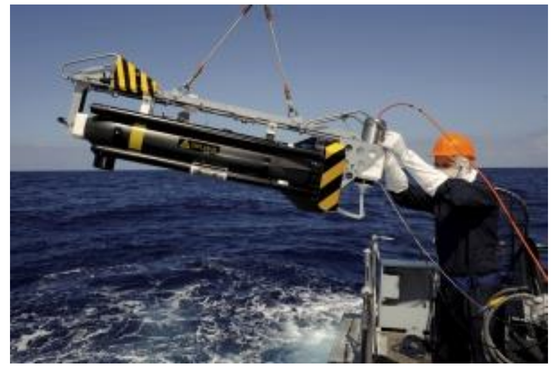
UAV Module

1.5-ton Rotary Wing UAV - Zenith		
Remote UAV		http://128.40.55.189/mediawiki/index.php/1.5-ton_Rotary_Wing_UAV
Complement	4	
Consoles	0	
Power [kW]	5	
Cooling [kW]	0	
Cost [£M]	12	
Correction	471%	
Modularization	110%	
Corrected Cost [£M]	**62.17**	
Dimensions		
Item	Weight [t]	Space
Helicopter	1.5	3.6 x 1.8 x 2.5m
Container	2.08	6.1 x 2.4 x 2.59m



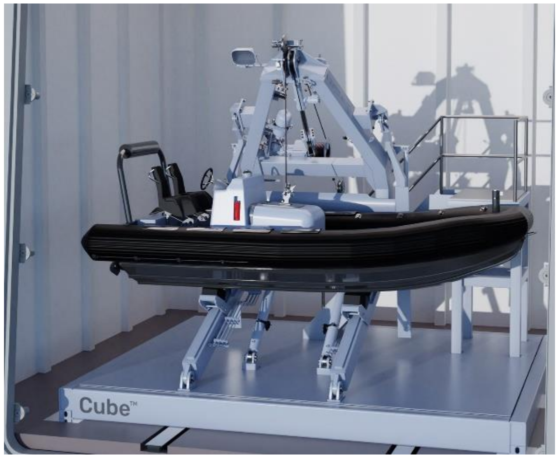
UUV Module

Remote Mine Destruction System - Zenith		
Remote UUV		http://128.40.55.189/mediawiki/index.php/Remote_Mine_Destruction_System
Complement	3	
Consoles	1	
Power [kW]	1	
Cooling [kW]	0	
Cost [£M]	1.05	
Correction	471%	
Modularization	110%	
Corrected Cost [£M]	**5.44**	
Dimensions		
Item	Weight [t]	Space
RMDS Vehicle	0.05	1.5 x 0.4 x 0.4m
Container	2.08	6.1 x 2.4 x 2.59m
Launch System	0.5	2 x 1 x 2m
Control Equipment	0.3	



RIB Module

RIB - Zenith		
7m RIB		http://128.40.55.189/mediawiki/index.php/7m_RIB
Complement	0	
Consoles	0	
Power [kW]	20	
Cooling [kW]	0	
Cost [£M]	0.475	
Correction	471%	
Modularization	110%	
Corrected Cost [£M]	**2.46**	
Dimensions		
Item	Weight [t]	Space
7m RIB	2.5	7 x 2.5m
Launch davits	2.5	10 x 2.5 x 4m



Summary of Modules Data

Module	Power Required [kW]	Total Weight [ton]	Cost [£M]
Gun 40mm	9.60	9.35	6.22
Gun 76mm	9.60	14.86	15.54
VLS (tactical)	51.00	26.00	17.62
TAS	54.20	14.00	25.91
Torpedo	1.00	5.33	2.59
Missile	10.00	8.18	14.40
UAV	5.00	3.58	62.17
UUV	1.00	2.93	5.44
7m RIB	20.00	5.00	2.46

Ships Cost

Frigate and OPV (Traditional and Modular)

Table 4-1: Estimated costs per ship.

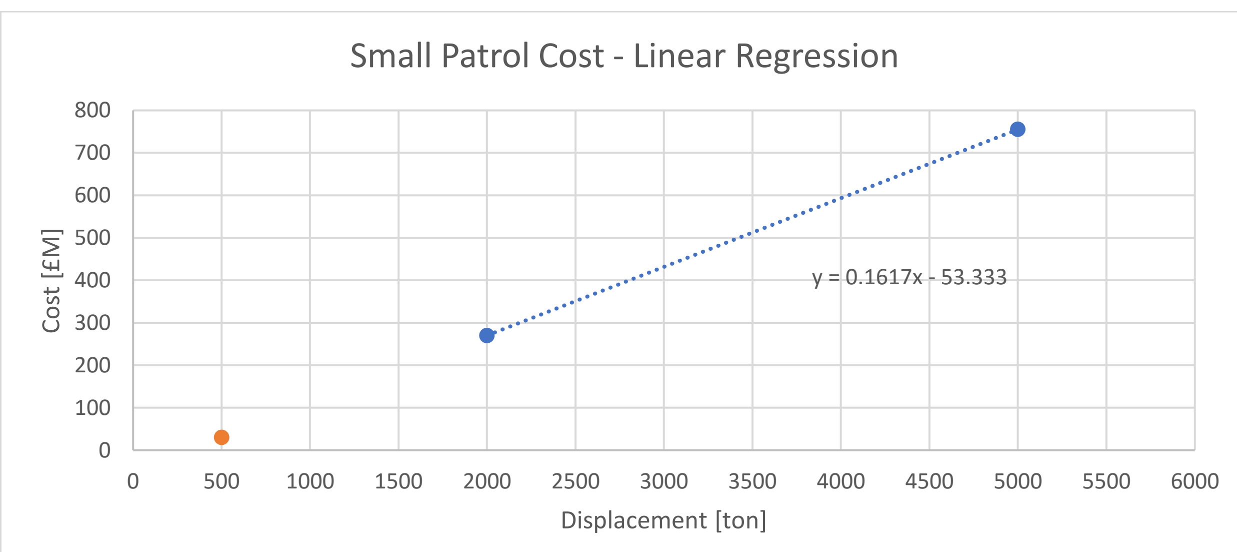
Ship Class	Cost per Ship [Mio. €]	90% Pred. Interval Lower Bound [Mio. €]	90% Pred. Interval Upper Bound [Mio. €]
Destroyer	1,024	985	1,100
Frigate	701	650	755
MCMV	249	228	270
OPV	233	232	270
JSS	968	870	1000
MSC	549	500	600
SSC	472	452	495
OPV small	318	297	340
OPV AAW	242	222	264

Reference: NATO Mission Modularity CBA v6

Traditional Patrol Vessel 500t

Traditional Patrol Vessel 500t		
Ship	Displacement [ton]	Cost [£M]
Frigate	5000	755
OPV	2000	270

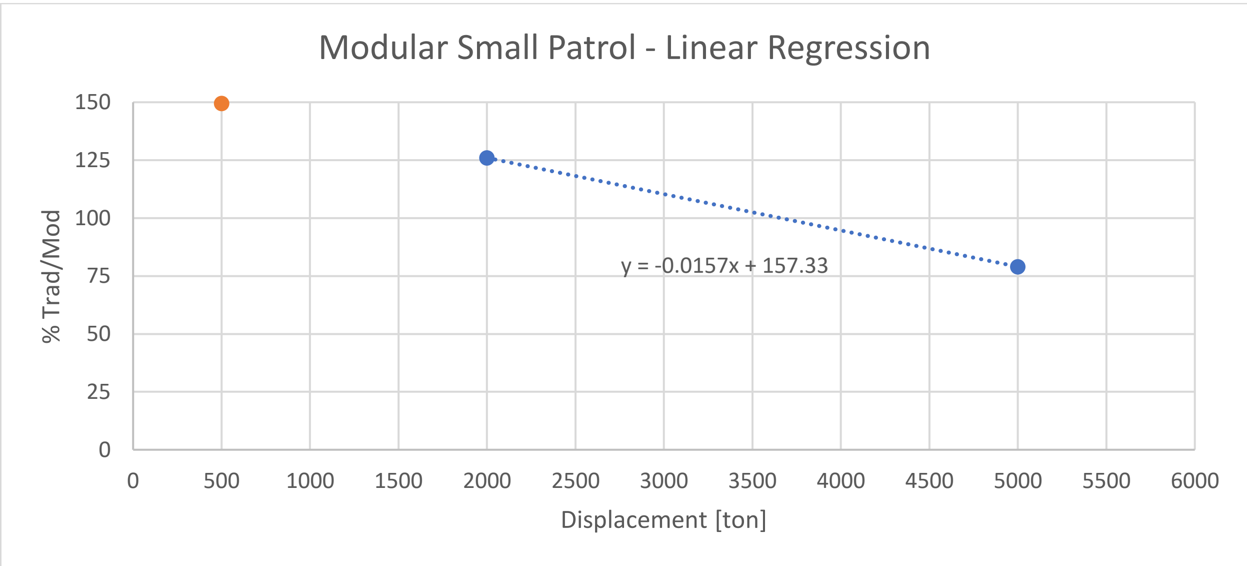
Linear Regression (y = 0.1617x - 53.333)		
Ship	Displacement [ton]	Cost [£M]
Patrol Vessel	500	27.5
Assumed Patrol Vessel Cost		**30**



Modular Patrol Vessel 500t

Modular Patrol Vessel 500t			
Ship	Displacement [ton]	Cost [£M]	% Trad/ Mod
Frigate	5000	755	79%
MSC Frigate	5000	600	
OPV	2000	270	126%
OPV small	2000	340	

Linear Regression (y = -0.0157x + 157.33)			
Ship	Displacement [ton]	Cost [£M]	% Trad/Mod
Patrol Vessel	500	30	149.48
Modular Patrol Vessel	500	44.84	
Assumed Modular Patrol Vessel Cost		45	



Fleet Cost

Analysis 1

Analysis 1 - 1 Modular and 1 Traditional (Module for each specific ship)

Modular Fleet

Modular Ships				Ship Cost		
Ship	ASW	ASuW	MW	Total	Ship Cost [£M]	Total Cost [£M]
Mod SPV 500t	1	1	1	3	45	135
Mod OPV 2000t	1	1	1	3	340	1020
Mod Frigate 5000t	1	1	1	3	600	1800
				Total Modular Ship Cost		2955

Mission and Modules										Module Cost		
Ship	Mod SPV 500t			Mod OPV 2000t			Mod Frigate 5000t					
Module \ Mission	ASW	ASuW	MW	ASW	ASuW	MW	ASW	ASuW	MW	Total	Unit Cost [£M]	Total Cost [£M]
Gun 40mm		1			1					2	6.22	12.43
Gun 76mm								1		1	15.54	15.54
VLS (tactical)	1			1	1		2	2		7	17.62	123.31
TAS	1			1			1			3	25.91	77.72
Torpedo	2			2			2			6	2.59	15.54
Missile		2								2	14.40	28.80
UAV										0	62.17	0.00
UUV			2			2			2	6	5.44	32.64
7m RIB		2	2		2	2		2	2	12	2.46	29.53
										Total Modules Cost		335.52
										Modular Fleet Cost		3291

Traditional Fleet

Traditional Ships				Ship Cost		
Ship	ASW	ASuW	MW	Total	Ship Cost [£M]	Total Cost [£M]
SPV 500t	1	1	1	3	30	90
OPV 2000t	1	1	1	3	270	810
Frigate 5000t	1	1	1	3	755	2265
				Total Traditional Ship Cost		3165
				Traditional Fleet Cost		3165

Summary

Analysis 1 - Summary	
Fleet	Cost [£M]
Modular Fleet Cost	3291
Traditional Fleet Cost	3165
Cheapest Solution	Traditional Fleet Cost

Analysis 2

Analysis 2 - 2 Modular for 3 Traditional (2 Modular doing the role of 3 traditional)

Modular Fleet

Modular Ships				Ship Cost		
Ship	ASW	ASuW	MW	Total	Ship Cost [£M]	Total Cost [£M]
Mod SPV 500t	1	1	0	2	45	90
Mod OPV 2000t	1	1	0	2	340	680
Mod Frigate 5000t	1	1	0	2	600	1200
				Total Modular Ship Cost		1970

Mission and Modules										Module Cost		
Ship	Mod SPV 500t			Mod OPV 2000t			Mod Frigate 5000t					
Module \ Mission	ASW	ASuW	MW	ASW	ASuW	MW	ASW	ASuW	MW	Total	Unit Cost [£M]	Total Cost [£M]
Gun 40mm		1			1					4	6.22	24.87
Gun 76mm								1		2	15.54	31.09
VLS (tactical)	1			1	1		2	2		8	17.62	140.92
TAS	1			1			1			6	25.91	155.43
Torpedo	2			2			2			12	2.59	31.09
Missile		2								4	14.40	57.60
UAV										0	62.17	0.00
UUV			2			2			2	12	5.44	65.28
7m RIB		2	2		2	2		2	2	12	2.46	29.53
										Total Modules Cost		535.81
										Modular Fleet Cost		2506

Traditional Fleet

Traditional Ships				Ship Cost		
Ship	ASW	ASuW	MW	Total	Ship Cost [£M]	Total Cost [£M]
SPV 500t	1	1	1	3	30	90
OPV 2000t	1	1	1	3	270	810
Frigate 5000t	1	1	1	3	755	2265
				Total Traditional Ship Cost		3165
				Traditional Fleet Cost		3165

Summary

Analysis 2 - Summary	
Fleet	Cost [£M]
Modular Fleet Cost	2506
Traditional Fleet Cost	3165
Cheapest Solution	Modular Fleet Cost

Analysis 3

Analysis 3 - 3 Modular for 4 Traditional (3 Modular doing the role of 4 traditional)

Modular Fleet

Modular Ships				Ship Cost		
Ship	ASW	ASuW	MW	Total	Ship Cost [£M]	Total Cost [£M]
Mod SPV 500t	2	1	0	3	45	135
Mod OPV 2000t	2	1	0	3	340	1020
Mod Frigate 5000t	2	1	0	3	600	1800
				Total Modular Ship Cost		2955

Mission and Modules										Module Cost		
Ship	Mod SPV 500t			Mod OPV 2000t			Mod Frigate 5000t					
Module \ Mission	ASW	ASuW	MW	ASW	ASuW	MW	ASW	ASuW	MW	Total	Unit Cost [£M]	Total Cost [£M]
Gun 40mm		1			1					6	6.22	37.30
Gun 76mm								1		3	15.54	46.63
VLS (tactical)	1			1	1		2	2		12	17.62	211.38
TAS	1			1			1			9	25.91	233.15
Torpedo	2			2			2			18	2.59	46.63
Missile		2								6	14.40	86.40
UAV										0	62.17	0.00
UUV			2			2			2	18	5.44	97.92
7m RIB		2	2		2	2		2	2	18	2.46	44.30
										Total Modules Cost		803.71
										Modular Fleet Cost		3759

Traditional Fleet

Traditional Ships				Ship Cost		
Ship	ASW	ASuW	MW	Total	Ship Cost [£M]	Total Cost [£M]
SPV 500t	2	1	1	4	30	120
OPV 2000t	2	1	1	4	270	1080
Frigate 5000t	2	2	0	4	755	3020
				Total Traditional Ship Cost		4220
				Traditional Fleet Cost		4220

Summary

Analysis 3 - Summary	
Fleet	Cost [£M]
Modular Fleet Cost	3759
Traditional Fleet Cost	4220
Cheapest Solution	Modular Fleet Cost

Analysis 4

Analysis 4 - 4 Modular for 5 Traditional (4 Modular doing the role of 5 traditional)

Modular Fleet

Modular Ships				Ship Cost		
Ship	ASW	ASuW	MW	Total	Ship Cost [£M]	Total Cost [£M]
Mod SPV 500t	2	1	1	4	45	180
Mod OPV 2000t	2	1	1	4	340	1360
Mod Frigate 5000t	2	1	1	4	600	2400
				Total Modular Ship Cost		3940

Mission and Modules										Module Cost		
Ship	Mod SPV 500t			Mod OPV 2000t			Mod Frigate 5000t					
Module \ Mission	ASW	ASuW	MW	ASW	ASuW	MW	ASW	ASuW	MW	Total	Unit Cost [£M]	Total Cost [£M]
Gun 40mm		1			1					8	6.22	49.74
Gun 76mm								1		4	15.54	62.17
VLS (tactical)	1			1	1		2	2		16	17.62	281.85
TAS	1			1			1			12	25.91	310.86
Torpedo	2			2			2			24	2.59	62.17
Missile		2								8	14.40	115.20
UAV										0	62.17	0.00
UUV			2			2			2	24	5.44	130.56
7m RIB		2	2		2	2		2	2	24	2.46	59.06
										Total Modules Cost		1071.61
										Modular Fleet Cost		5012

Traditional Fleet

Traditional Ships				Ship Cost		
Ship	ASW	ASuW	MW	Total	Ship Cost [£M]	Total Cost [£M]
SPV 500t	2	2	1	5	30	150
OPV 2000t	2	2	1	5	270	1350
Frigate 5000t	2	2	1	5	755	3775
				Total Traditional Ships Cost		5275
				Traditional Fleet Cost		5275

Summary

Analysis 4 - Summary	
Fleet	Cost [£M]
Modular Fleet Cost	5012
Traditional Fleet Cost	5275
Cheapest Solution	Modular Fleet Cost

Analysis 5

Analysis 5 - 5 Modular for 6 Traditional (5 Modular doing the role of 6 traditional)

Modular Fleet

Modular Ships				Ship Cost		
Ship	ASW	ASuW	MW	Total	Ship Cost [£M]	Total Cost [£M]
Mod SPV 500t	2	2	1	5	45	225
Mod OPV 2000t	2	2	1	5	340	1700
Mod Frigate 5000t	2	2	1	5	600	3000
				Total Modular Ship Cost		4925

Mission and Modules										Module Cost		
Ship	Mod SPV 500t			Mod OPV 2000t			Mod Frigate 5000t					
Module \ Mission	ASW	ASuW	MW	ASW	ASuW	MW	ASW	ASuW	MW	Total	Unit Cost [£M]	Total Cost [£M]
Gun 40mm		1			1					10	6.22	62.17
Gun 76mm								1		5	15.54	77.72
VLS (tactical)	1			1	1		2	2		20	17.62	352.31
TAS	1			1			1			15	25.91	388.58
Torpedo	2			2			2			30	2.59	77.72
Missile		2								10	14.40	144.00
UAV										0	62.17	0.00
UUV			2			2			2	30	5.44	163.20
7m RIB		2	2		2	2		2	2	30	2.46	73.83
										Total Modules Cost		1339.52
										Modular Fleet Cost		6265

Traditional Fleet

Traditional Ships				Ship Cost		
Ship	ASW	ASuW	MW	Total	Ship Cost [£M]	Total Cost [£M]
SPV 500t	2	2	2	6	30	180
OPV 2000t	2	2	2	6	270	1620
Frigate 5000t	2	2	2	6	755	4530
				Total Traditional Ships Cost		6330
				Traditional Fleet Cost		6330

Summary

Analysis 5 - Summary	
Fleet	Cost [£M]
Modular Fleet Cost	6265
Traditional Fleet Cost	6330
Cheapest Solution	Modular Fleet Cost

Analysis 6

Analysis 6 - 6 Modular for 7 Traditional (6 Modular doing the role of 7 traditional)

Modular Fleet

Modular Ships				Ship Cost		
Ship	ASW	ASuW	MW	Total	Ship Cost [£M]	Total Cost [£M]
Mod SPV 500t	2	2	2	6	45	270
Mod OPV 2000t	2	2	2	6	340	2040
Mod Frigate 5000t	2	2	2	6	600	3600
				Total Modular Ship Cost		5910

Mission and Modules										Module Cost		
Ship	Mod SPV 500t			Mod OPV 2000t			Mod Frigate 5000t					
Module \ Mission	ASW	ASuW	MW	ASW	ASuW	MW	ASW	ASuW	MW	Total	Unit Cost [£M]	Total Cost [£M]
Gun 40mm		1			1					12	6.22	74.61
Gun 76mm								1		6	15.54	93.26
VLS (tactical)	1			1	1		2	2		24	17.62	422.77
TAS	1			1			1			18	25.91	466.29
Torpedo	2			2			2			36	2.59	93.26
Missile		2								12	14.40	172.80
UAV										0	62.17	0.00
UUV			2			2			2	36	5.44	195.84
7m RIB		2	2		2	2		2	2	36	2.46	88.60
										Total Modules Cost		1607.42
										Modular Fleet Cost		7517

Traditional Fleet

Traditional Ships				Ship Cost		
Ship	ASW	ASuW	MW	Total	Ship Cost [£M]	Total Cost [£M]
SPV 500t	3	2	2	7	30	210
OPV 2000t	3	2	2	7	270	1890
Frigate 5000t	3	2	2	7	755	5285
				Total Traditional Ships Cost		7385
				Traditional Fleet Cost		7385

Summary

Analysis 6 - Summary	
Fleet	Cost [£M]
Modular Fleet Cost	7517
Traditional Fleet Cost	7385
Cheapest Solution	Traditional Fleet Cost

Analysis 7

Analysis 7 - 7 Modular for 8 Traditional (7 Modular doing the role of 8 traditional)

Modular Fleet

Ship	ASW	ASuW	MW	Total	Ship Cost [£M]	Total Cost [£M]
Mod SPV 500t	3	2	2	7	45	315
Mod OPV 2000t	3	2	2	7	340	2380
Mod Frigate 5000t	3	2	2	7	600	4200
				Total Modular Ship Cost		6895

Ship	Mod SPV 500t			Mod OPV 2000t			Mod Frigate 5000t			Module Cost		
Module \ Mission	ASW	ASuW	MW	ASW	ASuW	MW	ASW	ASuW	MW	Total	Unit Cost [£M]	Total Cost [£M]
Gun 40mm		1			1					14	6.22	87.04
Gun 76mm								1		7	15.54	108.80
VLS (tactical)	1			1	1		2	2		28	17.62	493.23
TAS	1			1			1			21	25.91	544.01
Torpedo	2			2			2			42	2.59	108.80
Missile		2								14	14.40	201.60
UAV										0	62.17	0.00
UUV			2			2			2	42	5.44	228.48
7m RIB		2	2		2	2		2	2	42	2.46	103.36
										Total Modules Cost		1875.32
										Modular Fleet Cost		8770

Traditional Fleet

Ship	ASW	ASuW	MW	Total	Ship Cost [£M]	Total Cost [£M]
SPV 500t	3	3	2	8	30	240
OPV 2000t	3	3	2	8	270	2160
Frigate 5000t	3	3	2	8	755	6040
				Total Traditional Ships Cost		8440
				Traditional Fleet Cost		8440

Summary

Analysis 7 - Summary

Fleet	Cost [£M]
Modular Fleet Cost	8770
Traditional Fleet Cost	8440
Cheapest Solution	Traditional Fleet Cost

Break-even Analysis

Break-even Analysis

Modular Fleet

Modular Ships				Ship Cost		
Ship	ASW	ASuW	MW	Total	Ship Cost [£M]	Total Cost [£M]
Mod SPV 500t	30	30	24.20	84.20	45	3789.20
Mod OPV 2000t	30	30	24.20	84.20	340	28629.51
Mod Frigate 5000t	30	30	24.20	84.20	600	50522.66
				Total Modular Ship Cost		82941.37

Mission and Modules										Module Cost		
Ship	Mod SPV 500t			Mod OPV 2000t			Mod Frigate 5000t					
Module \ Mission	ASW	ASuW	MW	ASW	ASuW	MW	ASW	ASuW	MW	Total	Unit Cost [£M]	Total Cost [£M]
Gun 40mm		1			1					168.41	6.22	1047.03
Gun 76mm								1		84.20	15.54	1308.79
VLS (tactical)	1			1	1		2	2		336.82	17.62	5933.18
TAS	1			1			1			252.61	25.91	6543.95
Torpedo	2			2			2			505.23	2.59	1308.79
Missile		2								168.41	14.40	2425.09
UAV										0.00	62.17	0.00
UUV			2			2			2	505.23	5.44	2748.46
7m RIB		2	2		2	2		2	2	505.23	2.46	1243.35
										Total Modules Cost		22558.63
										Modular Fleet Cost		105500

Traditional Fleet

Traditional Ships				Ship Cost		
Ship	ASW	ASuW	MW	Total	Ship Cost [£M]	Total Cost [£M]
SPV 500t	35	35	30	100	30	3000
OPV 2000t	35	35	30	100	270	27000
Frigate 5000t	35	35	30	100	755	75500
				Total Traditional Ships Cost		105500
				Traditional Fleet Cost		105500

Summary

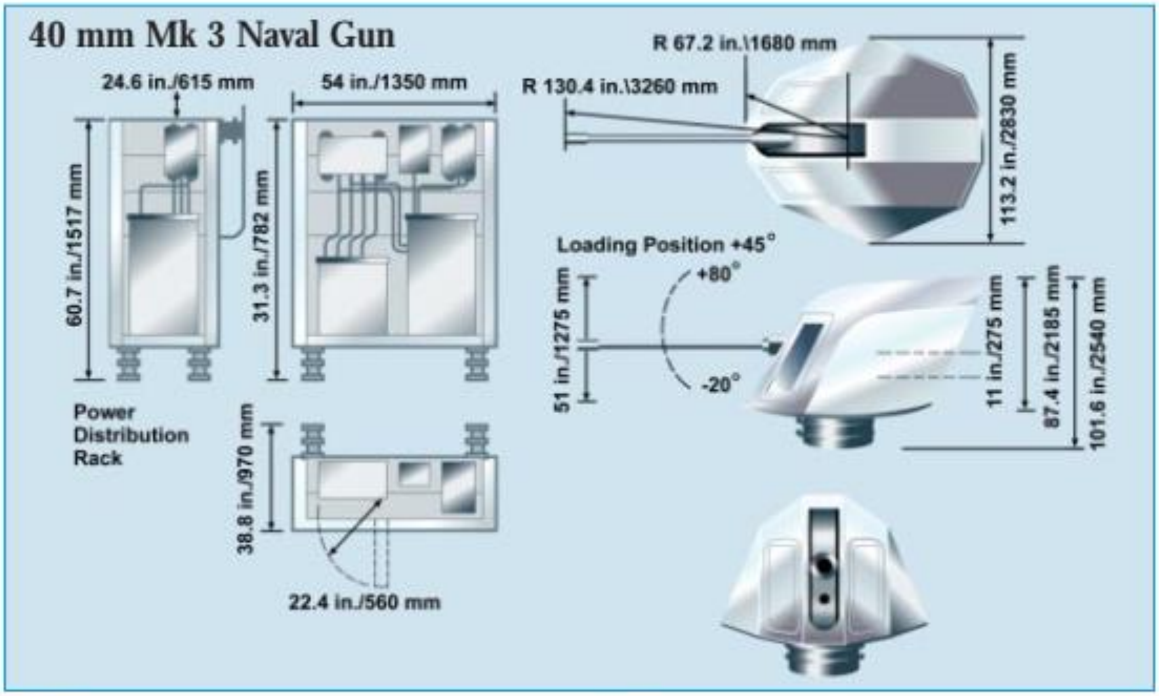
Break-even Analysis - Summary	
Fleet	Cost [£M]
Modular Fleet Cost	105500
Traditional Fleet Cost	105500
Cheapest Solution	Break-even Point

Summary of Fleet Cost Analysis

Fleet Cost Analysis							
Analysis	Number of Ships		Fleet Cost			Cheapest Solution	% Mod/Trad
	Mod Ship	Trad Ship	Mod Fleet [£M]	Trad Fleet [£M]	Diff [£M]		
Analysis 1	3	3	3291	3165	126	Traditional Fleet	100%
Analysis 2	2	3	2506	3165	-659	Modular Fleet	67%
Analysis 3	3	4	3759	4220	-461	Modular Fleet	75%
Analysis 4	4	5	5012	5275	-263	Modular Fleet	80%
Analysis 5	5	6	6265	6330	-65	Modular Fleet	83%
Analysis 6	6	7	7517	7385	132	Traditional Fleet	86%
Analysis 7	7	8	8770	8440	330	Traditional Fleet	88%
Break-even Analysis	84.20	100	105500	105500	0	Break-even point	84.20%

Annex A – Gun Modules Data

Gun 40mm



Gun Data

Rate of fire	330 rounds/min
Dispersion	<0.9 mrad polar (1 sigma)
Magazine capacity	101 rounds
Elevation	-20° to +80°
Elevation speed	57°/sec
Elevation acceleration	287°/sec²
Training	Unlimited
Training speed	92°/sec
Training acceleration	155°/sec²

Installation Data

Weight above deck (excluding ammunition)	7,700 lb (3,500 kg)
Weight below deck	770 lb (350 kg)
Electrical system	440 Vac 60 Hz 3 phase
Mean effective power	12 kVA
Peak power	41 kVA
Internal communication	MIL-STD-1553B Bus
External communication	MIL-STD-1553B Bus

3P Data

Round

Length	21.4 in. (534.4 mm)
Weight	5.5 lb (2.5 kg)

Shell

Weight complete	2.1 lb (975 g)
Explosive	4.2 oz (120 g) Octol
Tungsten pellets	0.12 in. (3 mm) diameter
Number of pellets	1,100
Muzzle velocity	3,319 ft/sec (1,012 m/sec)

Fuze

Type	Programmable proximity (PPX)
Function modes	6
Maximum triggering distance:	
Aircraft	>10 m
Missiles	5 m
Seaskimmers	3 m
Time accuracy	<0.5% of T1
Impact sensitivity	2 mm Dural
Impact delay	0.3 ms

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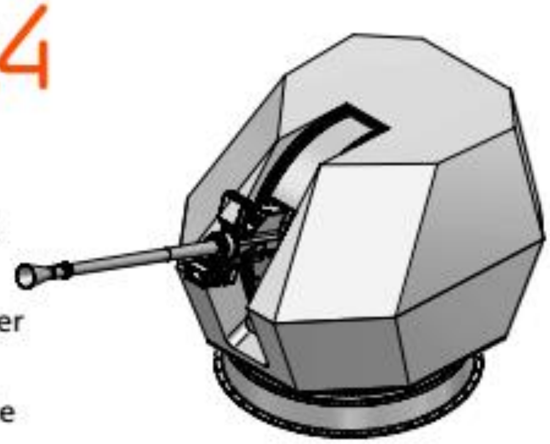
Bofors 40 Mk4

Naval Gun System

Today's naval assets need to swiftly adapt to an unprecedented range of roles and scenarios. When survival hangs on a matter of seconds, they must be equipped with agile, flexible weapon systems that enable a lightning-quick response.



When every second counts

The Bofors 40 Mk4 naval gun system is designed to meet that demand. Its low weight and compact dimensions combine with a long range and a high rate of fire. It has the capability to rapidly switch between optimised ammunition types, including programmable 40mm 3P all-target ammo. This delivers high tactical and operational flexibility alongside outstanding survivability, giving ships the advantage in conflicts of any kind.

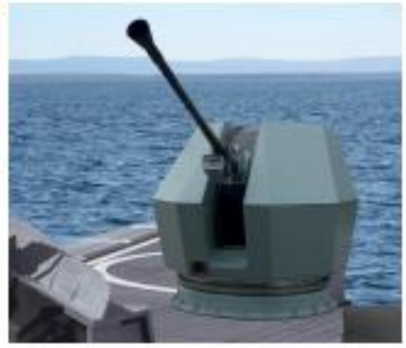
Typical Applications

Peacekeeping operations
The weapon system fulfils a preventative role, for example by firing warning shots.

Law enforcement missions
Threats such as pirates, smugglers and terrorists require the weapon to respond to multiple small, unpredictable targets.

Full war conditions
The system is vital for defence against hostile ships, attack aircraft, anti-ship missiles and shore targets.

Littoral scenarios
The weapon is equipped with a superior level of target capability, beyond the engagement ability of conventional gun systems.



SIMPLE INTEGRATION

The system's light weight and modest size are made possible by innovative features including its electric drive system. It also has a fully-digitised modular architecture, providing weapon synergies and future flexibility. Programmable 3P ammo means less round types are needed, reducing transport, storage, weight and space. These aspects combine to provide straightforward, cost-effective integration.

QUICK FLEXIBLE RESPONSE

The Bofors 40 Mk4 can go from warning to destruction in less than 0.5 seconds. The 3P ammo can be programmed for optimised effect against any target, including airburst patterns for new threats that were previously impossible to engage. The automatically loaded, remotely controlled weapon can also be locally controlled as a backup, equipping the operator for any scenario.

Key Features

Control

- Computer-controlled burst pattern
- On-mount muzzle velocity radar
- Remotely-operated with gyro-stabilised local control backup

Firing

- 6-mode programmable all-target ammunition
- Short firing sequences:
  300 rounds per minute
  Superb accuracy
- 100 rounds ready to fire with the possibility to shift between different types of ammunition
- Air burst capability for small boat defence and engagement of concealed targets

Technical Data

Standard specifications

- Calibre: 40 mm L/70
- Weight excl. ammunition: 2,300 kg
- Height: < 2.0 m
- Elevation limits: -20 to +80 degrees
- Training limits: unlimited (slip ring)
- Remote control with gyro-stabilised local control back-up

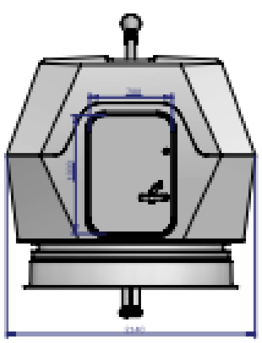
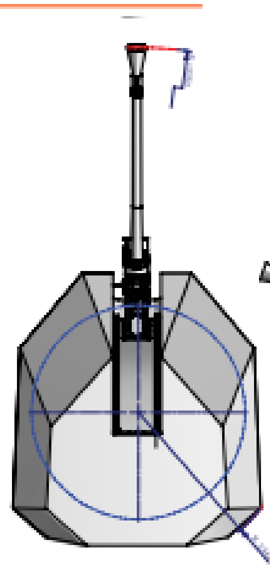
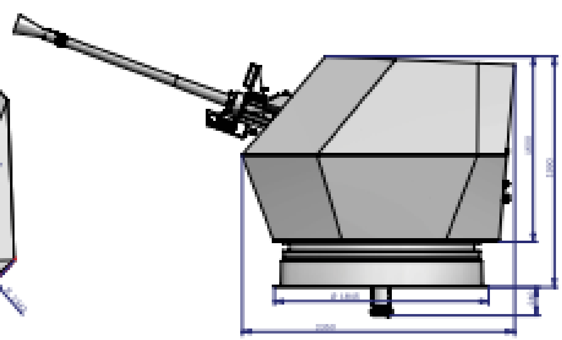
Performance

- Maximum range: 12,500 m
- Rate of fire: 300 rounds/min
- Muzzle velocity: 1012 m/s (3P)
- Number of rounds available in gun: ≥ 100
- Barrel life: up to 5,000 rounds

Options

- On-mount TV camera
- On-mount muzzle velocity radar
- Programmable 3P ammunition

Dimensions

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Gun 76mm

The OTO 76/62 Super Rapid (SR) Gun Mount is a light weight, rapid-fire naval gun providing unrivalled performance and flexibility in any air defence and antisurface role, particularly in anti-missile role.

Capability for very effective engagement of shore based targets is also provided for unique multirole performance. The OTO 76/62 SR is suitable for installation on ships of any type and class, including small naval units.

Interface to a large variety of ship's Combat Management System and/or FCS/EOS is provided, according to digital as well as analogical standard, including open architecture.

The Firing rate can be selected from single shot to 120 rds/min. In operational conditions the tactical time is less than 3 seconds and the standard deviation at firing is less than 0.3 mrad, thus providing excellent accuracy.

The OTO 76/62 SR (together with the OTO 76/62 Compact) is the only medium calibre naval gun available in the capable of sustained fire, which is a fundamental requirement in any scenario involving the simultaneous engagement of multiple manoeuvring targets, as requested by the emerging asymmetric warfare scenarios.

Automatic loading is provided through a revolving magazine and rapid reloading is easily undertaken even during firing action by two ammunition handlers. Standard supply includes the new Digital Control Console (DCC) capitalizing the digital technology to increase the functions available to the operator and to the maintainers.

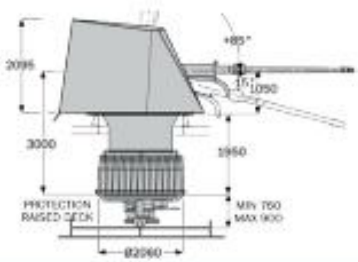
LEONARDO

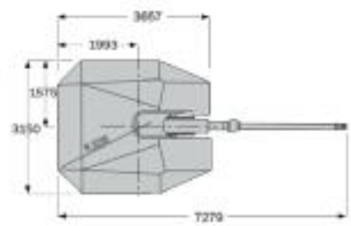
The OTO 76/62 SR is ready for operating the Leonardo Defence Systems OTO 3AP Multifunction Programmable Fuse. The in service and new 76/62 SR, have the necessary flexibility for being fitted with optional:

- Integral Stealth Shield to reduce the total RCS of the ship
- Muzzle Velocity Radar to update the FCS of eventual deviations from range table values
- Multi Feeding Device for the automatic handling, selection and feeding of any type of ammunition loaded
- OTO STRALES system - a guidance system for the OTO DART guided projectile

The Gun Mount capabilities included of a New Main Distribution Box/ Control Console, which provides:

- Basic functions
  - Gun Control algorithms/obstacle contouring
  - BITE on line
  - FCS Interfaces (digital, analogical, CORBA protocol etc.)
  - Control Panel Interfaces/Man Machine Interface
- Expanded functions
  - Maintenance
  - Troubleshooting
  - Documentation on line (Manuals on line and PMS)
  - Log Book (for management support)
  - Guideline
  - Black Box





MAIN CHARATERISTICS

Rate of fire	120 rds/min
Dry Weight (without a mmunition)	7900kg
Training arc (with slip ring)	unlimited
Elevation arc	-15° to +85°
Training speed/acceleration max	60°/sec (72°/sec²)
Elevation speed/acceleration	35°/sec (72°/sec²)
Ready-to-fire-rounds	80 (on gun mount)
Range (max)	16000m standard ammo 20000m with extended range OTO SAPOMER Ammunition 40000m with guided long range (GLR) OTO Vulcano 76 ammo (in development)
Cooling system	sea water - fresh water for flushing
Electrical power supply	440V, 3 -phase, 60Hz, main circuit 115V, 1 -phase, 400Hz, servo and synchro network

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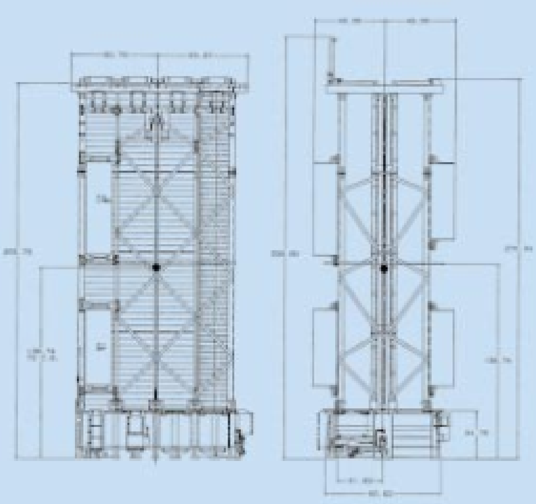
Annex B – VLS Module Data

Vertical Launch System (VLS) – Tactical Module

Vertical Launching System (VLS) Mk 41– Tactical-Length Module



Missiles	SM-2 BLK II	VLA ASROC	SEASPARROW VL/RIM-7
Type	AAW	ASW	AAW
Maximum weight (lb)	1,560	1,400	540
Maximum length (in)	184	200	152
Maximum diameter (in)	14	14	8

Quantity per launcher module – 8

System Size	1 Module	2 Module	4 Module
Length (Inches)	103 Inches	103 Inches	103 Inches
Width (Inches)	135	249	249
Height (Inches)	266	266	266

Launcher RM&A– 4-Module Launcher

Mean time between failure	3,872 hours
Mean time to repair	3.2 hours
Average scheduled maintenance time	0.5 hours per day
Intrinsic availability	0.978

Power Required by Single Module Variant

60 Hz, 440 Vac, 3 phase	29 kW
60 Hz, 115 Vac, 1 phase (Lightning)	2 kW
60 Hz, 115 Vac, 3 phase (Backup power for 440 Vac)	4 kW
60 Hz, 115 Vac, 1 phase (Launch control unit)	6 kW
400 Hz, 440 Vac , 3 phase	10 kW

Ship Services Required by Single Module Variant

Low-pressure air	225 psi
Freshwater	55 gallons (tank and lines)
Saltwater:	
Deluge	320 gal/min at 105 psi
Sprinkling	280 gal/min at 65 psi
Drainage	600 gal/min
Cooling	17,000 btu/hour
Heating	8,000 btuU/hour
Fresh air replenishment	75 ft³/min
Blow-out air exchange	15 min

Environmental Conditions

Internal launcher conditions range . . . .56 °F and 95% relative humidity to 85 °F and 55% relative humidity

System Weights–Single Module	Pounds	Long Ton
Launcher empty	32,000	14
Loaded with 8 SM-2 Blk II missiles	56,400	25
Loaded with 8 VLA ASROC missiles	57,800	26
Loaded with 8 SEASPARROW missiles	53,700	24

Canister Weights	Pounds
Mk 13 with SM-2 Blk II missile	3,050
Mk 22 with SEASPARROW (VL/RIM-7) missile	2,700
Mk 15 with VLA ASROC	3,200
with VLA ASROC (max growth)	3,450

Launch Control System Sizes and Weights

	Inches (L x W x H)*	Pounds
Status panel	11.5 x 18 x 24	100
Remote launch enable panel	8 x 10 x 13	30
Launch control unit	34 x 44 x 80	1,350

*Length x Width x Height

Strikedown Equipment Weights	Pounds
Strongback, horizontal transfer assembly	211
Vertical strongback	47
Cell guide assembly	51
Lift adapter, truck assembly (4)	284
Chock (4)	133
Other assemblies (13)	243
Total	969

Safety

Restrained Firing: . . . . . .Launcher capable of surviving a full motor burn of restrained missile

Warhead Deluge: . . . . . .Deluge provided to prevent warhead explosion (320 gpm at 105 psig)

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United Defense


VERTICAL LAUNCHING SYSTEM (VLS)
MK 41–STRIKE-LENGTH MODULE
LOCKHEED MARTIN
BAE SYSTEMS

Vertical Launching System (VLS)
Mk 41–Strike-Length Module

BAE Systems and Lockheed Martin are teamed to produce the Vertical Launching System (VLS) Mk 41 for current and future naval surface combatants. As the U.S. Navy's VLS Mk 41 mechanical design agent, BAE Systems has over 30 years of experience in the development, production, and support of this system for naval forces throughout the world.

8-Cell Module

Lethal–The VLS Mk 41 capability to simultaneously prepare two missiles in each 8-cell launcher module allows for fast reaction to multiple threats with concentrated, continuous firepower.

Multi-Mission–Multi-mode operation allows simultaneous interface and missile preparation for discrete anti-aircraft, anti-submarine warfare, strike, naval surface fire support, and ballistic missile defense missions.

Flexible–Any missile, any cell. The VLS Mk 41 is designed to allow for any missile to be fired out of any cell.

Survivable–The VLS Mk 41 is a highly survivable system with missiles and associated hardware located below the armored deck. Redundant fire control and launcher interface links also enhance system survivability in casualty situations.

Specifications

System size	
8-Cell (1 Module)	
Length	81.75 inches/2.1 m
Width	124.8 inches/3.2 m
Height	303 inches/7.7 m
64-Cell Launcher (8 Modules)	
Length	343 inches/8.7 m
Width	249 inches/6.3 m
Height	303 inches/7.7 m
Launcher RM&A–8-Cell Module Launcher	
Mean time between failure	1,936 hours
Mean time to repair	3.2 hours
Average scheduled maintenance time	0.5 hour per day
Intrinsic availability	0.978
Strikedown mean cycle between failures	200 cycles
Power required by 64-Cell Launcher	
440-Vac 60-Hz 3-phase	200 kW
115-Vac 60-Hz 1-phase (lighting)	8 kW
115-Vac 60-Hz 3-phase (backup power for 400 Vac)	10 kW
115-Vac 60-Hz 1-phase (launch control unit)	5 kW
115-Vac 400-Hz 3-phase	45 kW
Safety	
Restrained firing	Launcher capable of surviving a full motor burn of restrained missile
Warhead deluge	Deluge provided to prevent warhead explosion (320 gpm at 105 psig/723.9 kpa)

BAE Systems, Inc.
Land & Armaments
www.baesystems.com

For more information contact
Land.Armaments@baesystems.com


Vertical Launching System (VLS)
Mk 41 Missile Canisters
baesystems.com
BAE SYSTEMS

BAE Systems, Inc.
Platforms & Services
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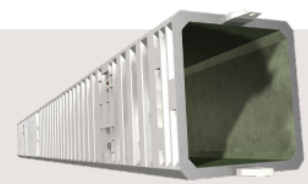
For more information contact
E: platforms.services@baesystems.com

Vertical Launching System (VLS) Mk 41 missile canisters provide a sealed storage, transportation, and launch container for the wide range of system-compatible weapons. The VLS Mk 41 canister envelope is common to system launcher module standards, while internal mechanical and electrical components are tailored to specific weapon shape and interface requirements.



BAE Systems is the U.S. Navy's exclusive design agent and worldwide supplier of VLS Mk 41 canisters. Since establishing canister and launcher module configuration nearly 25 years ago, BAE Systems' innovations to canister design and integration continue to expand VLS Mk 41 multi-mission capabilities.

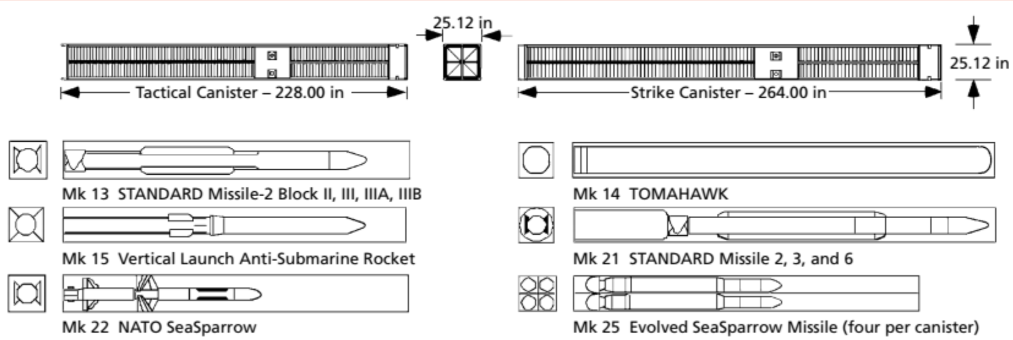
Systems Engineering – BAE Systems applies leading-edge modeling tools to optimize canister performance relative to shock, vibration, gas management, environmental, safety, reliability, and weapon density requirements.

Volume Manufacturing – To ensure high-quality and costeffective fabrication, BAE Systems operates a dedicated VLS Mk 41 canister production facility in Aberdeen, South Dakota.

Worldwide Logistic Support – BAE Systems Integrated Logistics Support Team supplies the services required throughout the entire life-cycle for reliable, maintainable canisters. Logistic services include service life documentation, damage assessment, and complete refurbishment for serviceable used VLS Mk 41 canisters.

Specifications

Canister	Mission
Mk 14	Strike
Mk 15	Anti-submarine
Mk 21	Ballistic/theater/area defense
Mk 22	Ship self-defense
Mk 25	Quad Pack Ship self-defense



Vertical Launching System (VLS) Mk 41 Missile Canisters

Annex C – TAS Module Data

Towed Array Sonar (TAS)

ULTRA

Key features

- A self-contained single 20 ft Mission Module
- Simple onboarding and off-boarding process
- Integrates seamlessly with Ultra's Sonar Suite
- Passive only or active-passive operations
- Configurable Sea Lancer™ acoustic payload(1)
- MIL-STD-810G Environmental and Shipboard Vibration qualified
- MIL-S-901D Shock qualified

Overview

As LFA-capable platforms become smaller and multi-role ships become more prevalent, Ultra's unique Sea Lancer™ addresses the problem of size and weight head-on. Any Sea Lancer™ configuration can be containerized in a single 20 ft Mission Module for maximum modularity and portability.

The Sea Lancer™ can be configured as passive only sonar with a suite of directional or omnidirectional sensor modules or as a Low Frequency Active sonar with an inline Horizontal Projector Array (HPA), which is an array of multiple in-line, independently driven projectors. The entire towed array is stored on, and deployed directly from, a single winch without needing the additional space and weight of a separate overboarding system. Consult Sea Lancer™ datasheets for more details on acoustic configurations.

ultra.group

ULTRA

Technical Specification

A Sea Lancer™ Mission Module consists of a single 20 ft container that holds a high performance Variable Depth Sonar. Everything that is required to deploy, recover, and operate the VDS is contained within the mission module.

The equipment space is configurable for both passive only and LFA operations in addition to housing Ultra's integrated sonar suite that can operate independently or pass information to the platform's combat management system.

Key benefits

- High Performance
- Single 20 ft Mission Module for easy onboarding and off-boarding of assets
- Low size and weight compared to active dual tow systems
- Modular acoustic payload configurations(1)
- < 30 kW Power Requirement

(1) Consult Ultra's Sea Lancer™ datasheets for more information.

Technical Specification	
Mission Module Mass	8,862 kg
Mission Module Mass (w. payload)	11500-14000 kg
Single Phase Power	3.2 kW 115 VAC; 60 Hz
Three Phase Power (winching)	21 kW 440 VAC 3Ø; 60 Hz
Three Phase Power (transmitting)	30 kW 440 VAC 3Ø; 60 Hz
Dimensions (WxDxH)	2.44 m x 6.06 m x 2.59 m (excl. maintenance area)
Acoustic Payload	Sea Lancer™ Variable Depth Sonar(1)
Environmental	
Operating Temperature	-2°C to +35°C
Storage Temperature	-30°C to +70°C
Deployment & Recovery Speed	4 kts to 12 kts
Survival Speed	Up to 27kts in Sea State 5

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