M.SC. MARINE ENGINEERING SHIP DESIGN EXERCISE 2006

BY

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Table 1 Index

No.	Design	Students
1	RO – PAX FERRY (MONOHULL)	Mr J Thomas, ME(M) Mr V Mukundan, NA Mr D O'Driscoll, NA
2	SINGLE CLASS SURFACE COMBATANT (MONOHULL)	Lt N R Brooks, RN, ME(E) Lt G A Mac Quarrie, RN, ME(E) Lt (N) I C Flannagan, CF, NA Mr R D Lewis, MoD, NA
3	GENERAL PURPOSE FRIGATE (MONOHULL)	Lt P J Buckenham RN, ME(E) Lt R Onyiaorah NN, ME(E) Lt D MacCarthy RN, NA Lt A Hussain PN,NA
4	UNMANNED VEHICLE CARRIER (MONOHULL)	Lt G Nicklin RN, ME(E) Lt R Satterly RN, ME(E) Lt MPearce RN, NA Mr D Tan SingN, NA

The Ship designs are a group effort with teams of between two and four students comprising of Naval Architects and Marine Engineers. The students were issued outline requirement of their ships early in the New Year, but they did not start working on their design full time until 27th March. The Marine Engineers had to submit their reports on 8th June 2006.

Dr A Greig 8th June 2006 Dr R Bucknall 8th June 2006

RO – PAX FERRY, MONO HULL

GROUP 1: 2006

Mr Jacob Thomas, MSc Marine Engineering (Mechanical option)

Mr Vishnu Mukundan, MSc Naval Architecture

Mr David O'Driscoll, MSc Naval Architecture

The Ro – Pax ferry is to operate between untapped Cork - Bilbao route at a cruising speed of 27 knots with the duration of the voyage being 21 hours, the ferry provides the comforts of a mini cruise vessel at a cheaper price compared to other similar ferries. The pay load of the ferry is 1500 passengers, 400 cars and 50 trucks. The vessel was designed to have two tier simultaneous loading and unloading. Engine casing is situated in the sides giving a clear car and truck lane, a hoistable deck was also incorporated between deck 3 & 5 giving an option to change the payload.

The key design features include the speed of the vessel which is driven by the four 11250 KW main engines (Wartsila 9L46F), top speed of about 30 knots is predicted with design of bulbous bow which makes the vessel a fast Ro – Pax ferry, the main machinery space is split into two with 2 engines in each space, even if one of the engine rooms is not accessible as in case of an emergency 22500 KW can be generated giving a speed of 22 knots which is an added advantage, the propulsor is CPP and 27 to 30 knots is the ideal speed for maximum efficiency. Two bow and one stern thruster gives the vessel great manoeuvrability decreasing the turn around time.

The auxiliary machinery was designed with giving a stand by mode to all the equipments, a combination of 3 diesel generators and 2 engine driven alternators were selected; Loss of either one shaft generator or a diesel engine wouldn't hamper the vessel's performance. Options for shafting with solid and hollow shaft are worked out; different types of machinery discussed and compared for with the overall cost and the best ones suited for the Ro – Pax were chosen. The air conditioning and the fire system is divided in three zones and independent operation made possible in the design allowing for flexibility.

Alternate source of fuel like LNG/CNG, hydrogen, Biomass to liquid (BTL) and di-methy-ether (DME) was also studied and was later rejected because of the lack of infrastructure support, availability and safety reasons. The complement of the ship was calculated as per ILO regulations. The terrorist threat is also addressed and counter measures are taken as per the risk. The Ro - Pax is designed to give maximum comfort to the passengers, minimising the cost and incorporating equipments needed for the ship to function smoothly keeping the future in mind.

Table 2 Platform Data

Principle Dimensions		**Propulsion power required**	**44.5 MW**
Length Overall	190.9mts	Prime movers	
Length between perpendiculars	179.7mts	Main engine	4 x Wartsila 9L46F @11,250 KW
Beam	25.13mts	Propulsor	2 x CPP (5.3 mts dia)
Maximum draught	6.1mts	Gear box	Single reduction, double input, double out put
Displacement	16296 t	Maximum electrical load	6859 KVA (manoeuvring)
Complement	110	Minimum electrical load	2167 KVA (cruising - night)
Endurance	2 days	Electrical power plant	3 x Wartsila1400W9L20 @ 1400 KW/1750 KVA 2 x Leroy Somer LSA53M85/4P @ 1600 KW/2000KVA
Cost of the vessel	€103M		
Cruising speed	27 knots	Thrusters	2 x Lips CT/FT200M @ 1515 KW - Bow thrusters 1 x Lips CT/FT200M @ 1515 KW - Stern thruster
Maximum Speed	27.5 knots		
Payload		Fuel oil consumption	H.F.O - 686.36 tonnes for 100hrs
Passengers	1500	Main auxiliaries	Air conditioning, ventilation, ballast, bilge, fire, sewage, compressed air, fuel, sprinkler, fresh water systems, Fire detection, Stabilizers, anchor and cable & cathodic protection.
Cars	400		
Trucks	50		
Distance for the route	540nm		
In service date	2008		

SINGLE CLASS SURFACE COMBATANT (MONOHULL)

GROUP 2: 2006

Lt N R Brooks, RN. MSc Marine Engineering (Electrical option)

Lt G A Mac Quarrie, RN. MSc Marine Engineering (Electrical option)

Lt (N) I C Flannagan, Canadian Navy, MSc Naval Architecture

Mr R D Lewis, MoD. MSc Naval Architecture

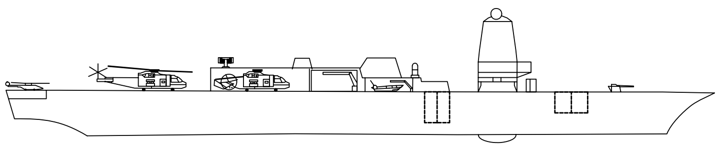

Fig. 1 Single Class Surface Combatant

Introduction

The Canadian Navy is to incrementally replace its current surface fleet capability through the sustained building of a new Single Class Surface Combatant (SCSC). Given the ever changing nature of global politics and threats facing Canada, this new class of ship is to be capable of operating effectively in a range of environments, both at home and abroad. The ship is to replace the IROQUOIS and HALIFAX Classes, the first of which will be paying off from 2014. The SCSC will be introduced in 4 batches, each consisting of 4 ships. Each batch will possess a common baseline capability that will enable core roles to be assumed. In addition, the SCSC will have the facility to undertake specific missions by embarking modular mission packages.

Roles

All SCSC vessels have the core capability to undertake detection, tracking, identification and engagement for self-defence against ASuW, AAW and ASW threats. They will also have the ability to carry out Naval Gunfire Support (NGS), Maritime Interdiction Operations (MIO) and Air Operations. In addition to the baseline capability, Batch 1 vessels are to fulfil Task Group AAW and C2 roles, which will be lost when the IROQUOIS Class is decommissioned. Modular mission packages will enhance the core capabilities to provide capacity for Task Group defence and attack operations in the ASuW, AAW and ASW roles. They will also permit the undertaking of Mine Counter Measures (MCM) and Special Forces (SF) operations.

Design Requirements

Each vessel is to have the capability to undertake baseline tasking requirements and embark modular packages. This is to be achieved whilst minimising the personnel requirement onboard. The SCSC is to be globally deployable and capable of operating in littoral, tropical and arctic theatres. As such it is to have the capacity to break through first year ice. The minimum performance requirements of the vessel are a 28 knot top speed and transit capacity of 6000nm at 15 knots. The normal deployment length is to be 180 days, with sufficient stores capacity onboard to allow for 60 days of continuous operation between replenishment. The hull life will be at least 25 years. The ship stability requirements of the design are based on the 3 compartment damage stability standard. Of particular importance to the marine engineering design of the vessel, the loss of any one machinery space, along with its adjacent compartment, is to result in a reduction in propulsion of no more than 50%.

Payload

The payload for the SCSC is detailed below. The Mk41 VLS launcher comprises a self-contained magazine and launcher, capable of discharging an array of weapons. This is the integral weapon system that will primarily afford modularity of the vessel. The modular mission packages and payload will be accommodated in a dedicated hangar forward of the aircraft hangar. Area Support Defence Missiles are to be fitted to Batch 1 vessels to facilitate the area AAW role. All batches are to incorporate the Harpoon for long range ASuW attack, 5”62 Gun for NGS and ASROC for rocket launched ASW torpedo attacks. The embarked helicopter will provide a significant capability for all vessels while the UAV will enable surveillance and over-the-horizon targeting tasking to be achieved.

Propulsion

SCSC propulsion is provided by an Integrated Full Electric Propulsion system. Two Pielstick 12 PA6B diesel generators and two General Electric LM2500 gas turbine alternators are installed as the prime movers. Two Advanced Induction Motors, each controlled by their own IGBT based PWM converter, deliver the power to the water via two shafts and fixed pitch propellers. The selected propulsion system enables the vessel to achieve the desired top speed of 30 knots. The cruising speed has been set at 17knots to meet the operating profile requirement in the most efficient and economical manner. Auxiliary systems include 3 Chilled Water plants, 5 High Pressure Sea Water pumps, 2 High Pressure and 2 Low Pressure Air Compressors, 2 Reverse Osmosis plants, and 2 IMO approved Sewage Treatment Plants.

Principle Features

Table 3 Platform Data

Principle Characteristics		**Payload**
Displacement (Deep/Standard)	6603/6355 tonnes	10 x Mk41 VLS Launcher (8 Cell Modules)
LBP/LOA	139/148 metres	8 x Area Support Defence Missile/SM2 (Batch 1)
Beam (Extreme/Waterline)	19/18.3 metres	8 x VLS ASROC
Depth	10.8 metres	2 x 4 Cell Harpoon Launcher
Draught (Mean)	5.23 metres	32 x Evolved Sea Sparrow Missile (ESSM)
Speed (Maximum/Cruise)	30/17 knots	1 x 5”62 Gun
Endurance (Fuel with 20% Reserve)	10322nm @ 17 knots	1 x 21 Cell Rolling Airframe Missile CIWS Launcher
Endurance (Stores)	60 days	2 x Phalanx CIWS
Complement (Maximum)	192	4 x Fixed IR/Chaff Launchers
Cost	£400 million	2 x 30mm Gun
In Service Date	2014	1 x Helicopter (Sikorsky CH-148 Cyclone)
Number in Class	16 (4 Batches of 4)	2 x Fire Scout UAV
Design Hull Life	25 years	Modular Payload
Maximum Loads		Propulsion
Total Power	44.83MW	Integrated Full Electric Propulsion
Propulsion Power	41.48MW	2 x GE LM2500 GTA (21MW)
Service Load (Cruising/State 1)	2.33/3.35MW	2 x Pielstick 12 PA6B DG (4.08MW)
Propulsors		2 x Advanced Induction Motor (21MW)
2 x Shafts		2 x IGBT based PWM Converters
2 x Fixed Pitch Propellers		4.16kV 60Hz Propulsion Busbar
Auxiliaries		1 x Retractable Bow Thruster (900kW)
3x CW plant, 5x HPSW pp, 2x HPAC, 2x LPAC, 2x RO plant, 2x STP, 4x AFUs, 17x ATUs		1 x Pielstick 12 PA4 Harbour D G (1.65MW)

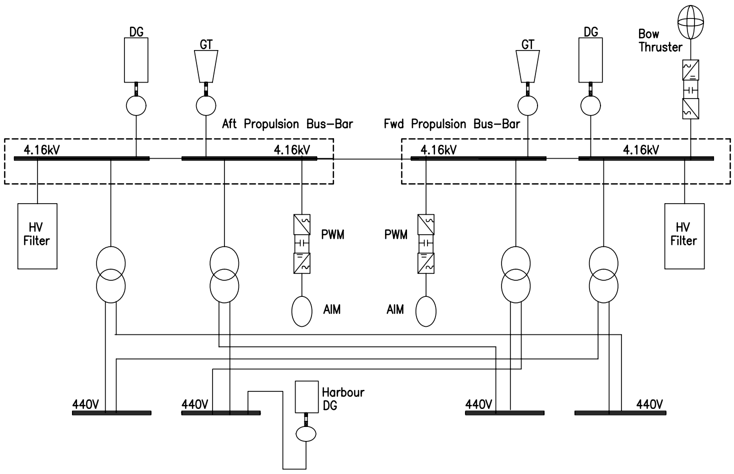

Fig. 2 IFEP Layout

GENERAL PURPOSE FRIGATE, MONOHULL

GROUP 3: 2006

Lt P J Buckenham RN. MSc Marine Engineering (Electrical option)

Lt R Onyiaorah NN. MSc Marine Engineering (Electrical option)

Lt D MacCarthy RN. MSc Naval Architecture

Lt A Hussain PN. MSc Naval Architecture

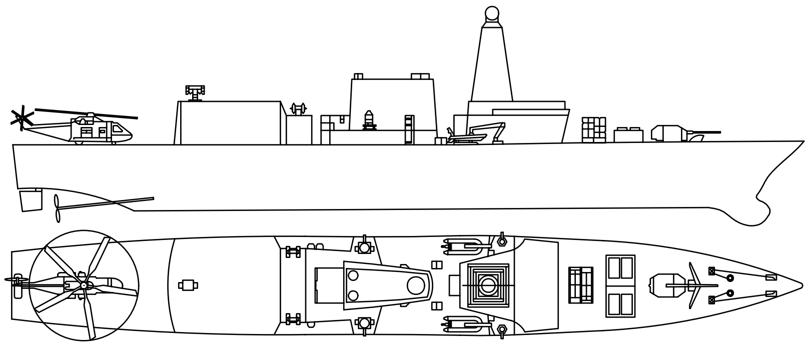

Fig. 3 General Purpose Frigate

The evolving nature of conflict and operations requires rapidly deployable and expeditionary forces. Such operations in both littoral and open water theatres have defined the requirement for adaptable general purpose naval vessels, requiring both offensive and defensive capabilities in multi threat environments. This requirement to provide a full range of capabilities has led to the design of the General Purpose Frigate whose primary roles are defined as;

Sea Control

Provision of air defence and ASW capability when operating in support of a multi-national Task Group or as escort to an Amphibious Task Force.

Projection of Power Ashore

Provision of aerial support and Naval Fire Support to tactical amphibious landings and in-land strike operations.

Naval Presence

Contribution to low-key operations worldwide through posturing and promotion of the United Kingdom's interests worldwide.

The General Purpose Frigate requires the capability to operate worldwide in open water and littoral theatres. The essence of the payload selection was to establish a balance between the requirements for ASW, AAW and ASuW roles whilst maintaining a minimum capability commensurate with self defence, effective offensive action and peacetime operations. The General Purpose Frigate carries a wide range of weapons and sensors and 2 Merlin size helicopters to enhance ASW, ASuW capabilities and general tasks.

The requirement for an Ultra Quiet mode of operation and a non-specific operating profile were influential in the propulsion selection process. Difficulties were encountered following the initial propulsion selection with respect to the size of the diesel generators and acoustic control. The consequent size of the machinery spaces led to decreasing ship density and the probability that intact stability criteria would not be achieved. Following a critical review of the propulsion a gas turbine alternator solution was considered as optimal.

Studies include on the sensitivity of gas turbines to changes in ambient air temperature and the impact on the range of the vessel. The design includes High Temperature Superconducting Motors which, although still in the developmental stage, were found to offer significant fuel savings.

Machinery

An Integrated Full Electric Propulsion system is fitted with 3 gas turbine alternators providing power for both propulsion and ship service load. Propulsion is transmitted to the Fixed Pitch Propellers using 2 x 20MW High Temperature Superconducting Motors driven by 6 x 6.6MW Pulse Width Modulated

Converters. A separate Diesel Generator permits efficient, low emission power generation in harbour and acts as an Emergency Generator

Auxiliary systems includes 3 High Pressure and 2 Low Pressure Air Compressors with 3 separate Breathing Air Compressors, 2 Reverse Osmosis plants, 3 Chilled Water plants, 5 HPSW pumps and 2 Membrane Bioreactors for grey and black water processing.

Key Features

Table 4 Platform Data

Principle Characteristics		**Payload**
Cost	£268 million	8 x Harpoon
Displacement (Deep/Light)	4713/3713 tonnes	16 x Aster 15
LBP/LOA	127.96 m/137.96 m	16 x Aster 30
Beam (extreme)	16.8 m	MTLS
Depth	11.2 m	Multi Function Radar
Draught (mean)	5.08 m	Composite Mast
Speed (Maximum)	30 knots	1 x 120mm Mk 2 Medium Calibre Gun
Endurance (Fuel)	7500 @ 18knots	2 x Phalanx CIWS
Endurance (Stores)	45 days	1 x SeaRAM
In Service Date	2014	2 x EH101, Single spot flightdeck
Design Hull Life	30 years	Variable Depth Sonar
Complement	199	Hull Mounted Active/Passive Sonar
Accommodation	222	
Propulsors		
2 x shafts		2 x Fixed Pitch Propellers
Propulsion		
Integrated Full Electric Propulsion		Integrated Platform Management System
1 x Rolls Royce MT30 GTA (36MW)		4160V, 60Hz Propulsion Busbar
2 x Solar Turbine Taurus 60 GTA (5.5MW)		Wartsila Auxpac 1400W9L20 Harbour/Emergency Diesel Generator (1.4MW)
2 x High Temperature Superconducting Motors (20MW)		6 x PWM Converters

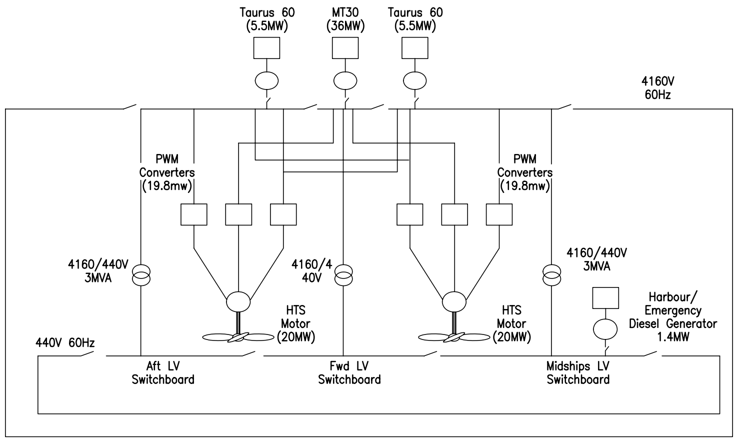

Fig. 4 Electric Propulsion System Configuration

UNMANNED VEHICLE CARRIER (MONOHULL)

GROUP 4: 2006

Lt Gareth J.E Nicklin RN. MSc Marine Engineering (Electrical option)

Lt Robert J Satterly RN. MSc Marine Engineering (Electrical option)

Lt Mark Pearce RN. MSc Naval Architecture

Mr D Tan SingN. MEng Naval Architecture

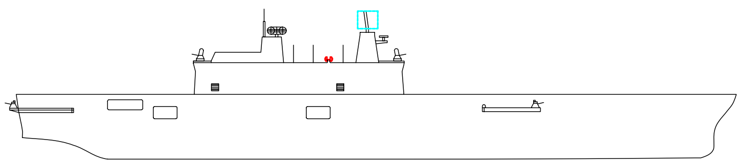

Fig. 5 Unmanned Vehicle Carrier

Introduction

In the 21st century, the fundamental component of maritime force projection remains the ability to sustain, deploy and recover military air assets. The ability to provide a launch and recovery system in the littoral, in a region with little or no host nation support, is a fundamental concept of NATO maritime doctrine. Recent advances in remotely controlled air and sea vehicles have brought additional flexibility and endurance to this component. Unmanned air and sea vehicles can be used in a variety of missions, from reconnaissance and target surveillance, to deep and precision strike using guided ordnance. UVX is a proposed batch of some 20-30 vessels for the United States Navy. A key design emphasis has therefore been placed on modularity, automation and interoperability, minimising where possible the through life cost burden. Whilst capable of acting independently in a low intensity environment, UVX has been designed with significant C3 capabilities, allowing her to take on the role of task force command ship during a high intensity littoral assault, where the bulk of the fire power and force protection would be provided collectively by the task group. With the ability to support manned STOVL and existing NATO helicopters, UVX can accommodate considerable organic air power. The addition of a floodable stern dock provides the capability to safely and covertly deploy unmanned surface and sub-surface vehicles for a multitude of missions.

UVX embodies the essential elements required for air and sea supremacy in the littoral environment. Extensive reach, sustainability, and a host of deployable weapons, combined with an inherent ability to co-ordinate the attack, will provide the tactical commander with a truly expeditionary capability.

Roles

Primary: Launch, control and recover rotary and fixed wing Unmanned Air Vehicles (UAV); Launch control and recover Unmanned Surface Vehicles (USV); Launch control and recover Unmanned Underwater Vehicles (UUV).

Secondary: Command & Control of Task Group and organic air assets; Recover, prepare and launch manned STOVL fixed and rotor wing aircraft; Recover, prepare and launch manned STOVL aircraft; Special Forces insertion; C4ISTAR; Logistics support to other vessels (including re-fuel); Humanitarian Operations, NEO and MACO.

Payload

The design of UVX has been driven by the deployable unmanned vehicles that it will carry; there is, however, rapid change in this area. Aviation systems, namely the hangar and the flight deck, have been designed to achieve operational tempo whilst deploying the latest development in fixed wing UAV: the Boeing X-47. Resultantly, UVX will be built capable of integrating a linear catapult and arrester. With aircraft on deck, UVX can accommodate 18 of these airframes. The envelope for UAV rotorcraft is, on the other hand, not expected to grow by the same volume, accordingly, the Northrop Grumman Firescout has been selected as the baseline rotorcraft for UVX; up to 18 folded airframes will be carried. Unmanned sea vehicles will be housed and prepared in a highly adaptable stern well-dock, carrying 3 Spartan surface vessels and 2 Marauder underwater vehicles. A Gemini manned rigid inflatable will be carried on davits on each waist. The flight deck, ammunitioning and fuelling systems have been designed to land on and prepare manned STOVL aircraft and rotorcraft (including Chinook). Force projection is conducted by deployable vehicles and through the co-ordination of other task group assets. Self protection against projectile and sea-skimming attack is provided by 3 Phalanx close in guns. Force protection from an asymmetric threat is provided by 20 mm guns.

Engineering

An Integrated Full Electric Propulsion solution has been selected for UVX, with 2 Wärtsilä 12V26 DGs and 2 Wärtsilä 16V26 DGs generating at 60 Hz onto a 4.16 kV HV busbar, providing both propulsion and ship service loads. Harbour and emergency sea power is provided by a single Wärtsilä 6L26 Diesel Generator located on the hangar deck, generating directly onto the 440V LV bus. Single generator operation is employed at DC State 3 cruising speeds in order to maximise fuel efficiency and minimise engine part load operation. With an increased probability of TLF In this configuration, emergency and essential equipment is supported by a series of UPS devices. Propulsive power is derived from 2 Alstom/Rolls-Royce podded azimuthing propellers, developing 7.82 MW at 125 rpm, equating to a vessel top speed of 20 kts. A 6-phase synchronous motor within each pod is fed with a diverse variable frequency supply from the HV busbar via phase shifting propulsion transformers and dual channel 12-pulse IGBT PWMs, with 4-quadrant design allowing significant dynamic pod breaking for improved crash stop and astern performance. A single, variable speed, 1100 kW Siemens Schottel transverse thruster is located in the bow. A high capacity variable speed ballast system supports rapid ballasting and de-ballasting of the stern well dock. Fixed automatic fire fighting and damage control systems have been employed extensively throughout the design, allowing a challenging core crew allowance of just 38 to be justified. High fire risk areas, including both engine rooms and the hangar, have been fitted with Hi-Fog™ automatic fire suppression systems, allowing the remote extinction of fire on the casualty unit without loss of function from other systems in the same compartment.

Key Features

Table 5 Platform Data

Principle Dimensions		**Payload**
Cost	£235m	Max. 18 Firescout unmanned rotor craft
No in class	20-30	Max. 18 UAV (based on X-47 growth envelope)
Displacement (Docked down)	10714 tonnes	3 Spartan USV
LBP/LOA	173 m/189 m	2 Marauder UUV
Beam (Extreme/ Waterline)	33.9 m/22.9 m	1 x Electromagnetic Catapult (FFBNW)
Depth	18.5 m	Flight Deck Arrestor Wire system (FFBNW)
Draught (mean)	5.2 m	Alenia Marconi S1850M C2/air search radar
Speed (Maximum/ Cruise)	20 kts/10 kts	Enhanced C4ISTAR communications fit
Propulsion Power Requirement	10.56 MW	2 x Phalanx CIWS
Endurance (Fuel)	12,000 nm at 18 kts	Full Authority Digital PMS
In Service Date	2015	**Propulsion**
Endurance	60 days	Integrated Full Electric Propulsion
Design Hull Life	30 yrs	2 x Wärtsilä 12V26 3745 kWe DG
Core Complement	38	2 x Wärtsilä 16V26 5615 kWe DG
Mission Crew (Maximum)	145	4.16 kV 60 Hz HV propulsion busbar
Max Ship Service Load	5 MVA (Dock Ops)	4 x 4.4 MW Phase Shifting Transformers
		4 x 4-quad 12 pulse IGBT PWM Converters
		2 x Alstom 7.82 MW Double Wound Azipods
		1 x Wärtsilä 6L26 1650 kWe Emer/Hbr DG