Aalto University
School of Engineering

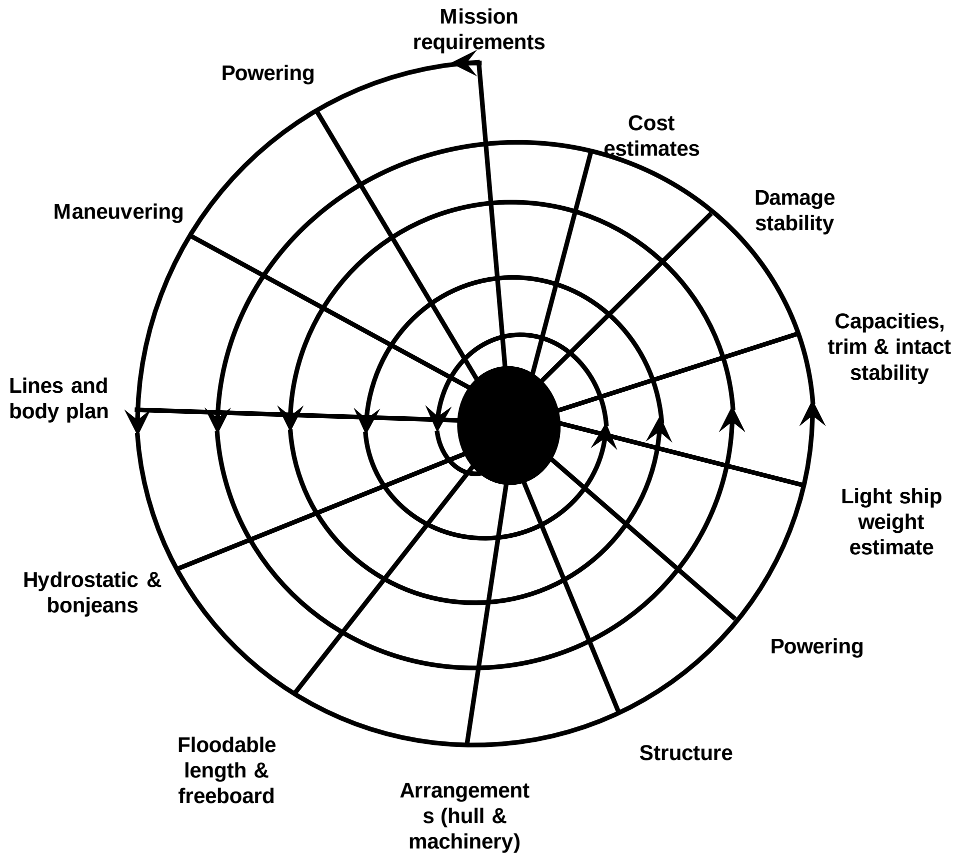
MEC-E2000 - Marine and Ship Systems Engineering

replaces (MEC-E2005 Ship Systems)

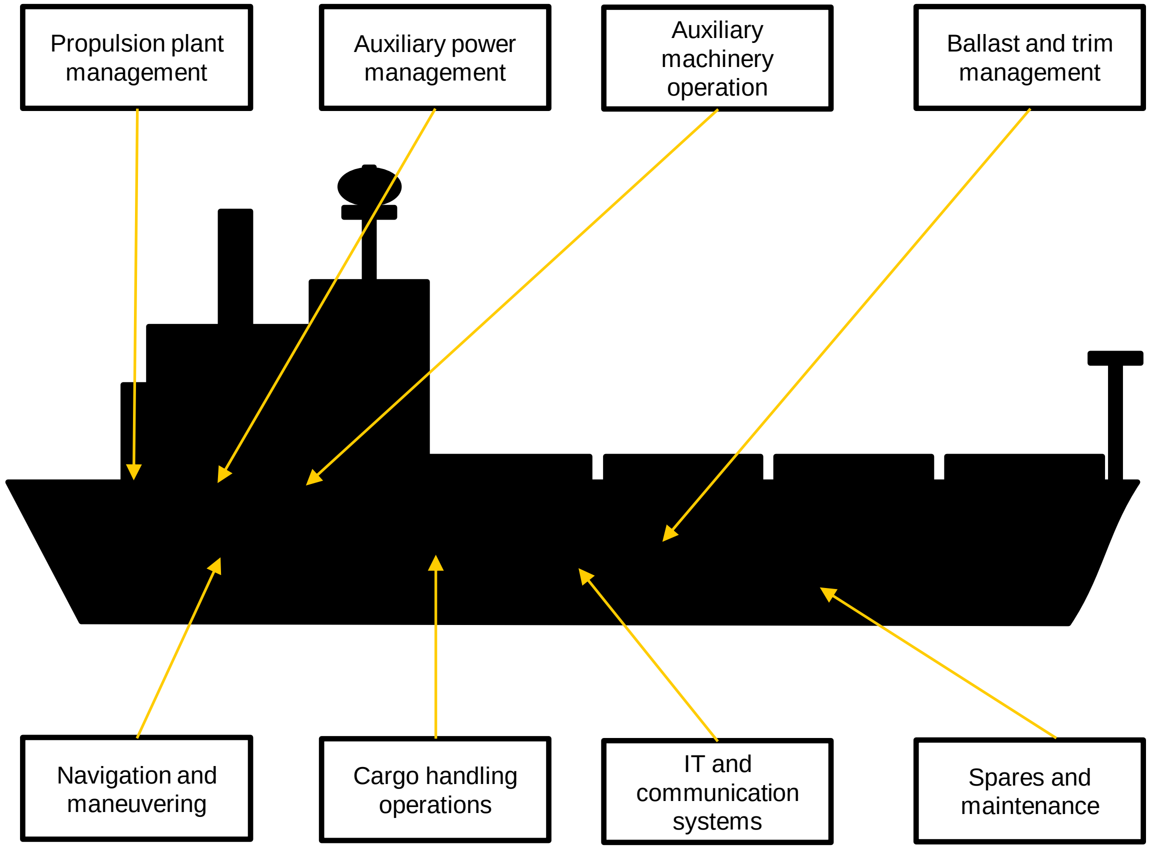
Lecture 1: Course content and aims

Assistant Professor Osiris A. Valdez Banda

The perspective and evolution of ship systems in ship design

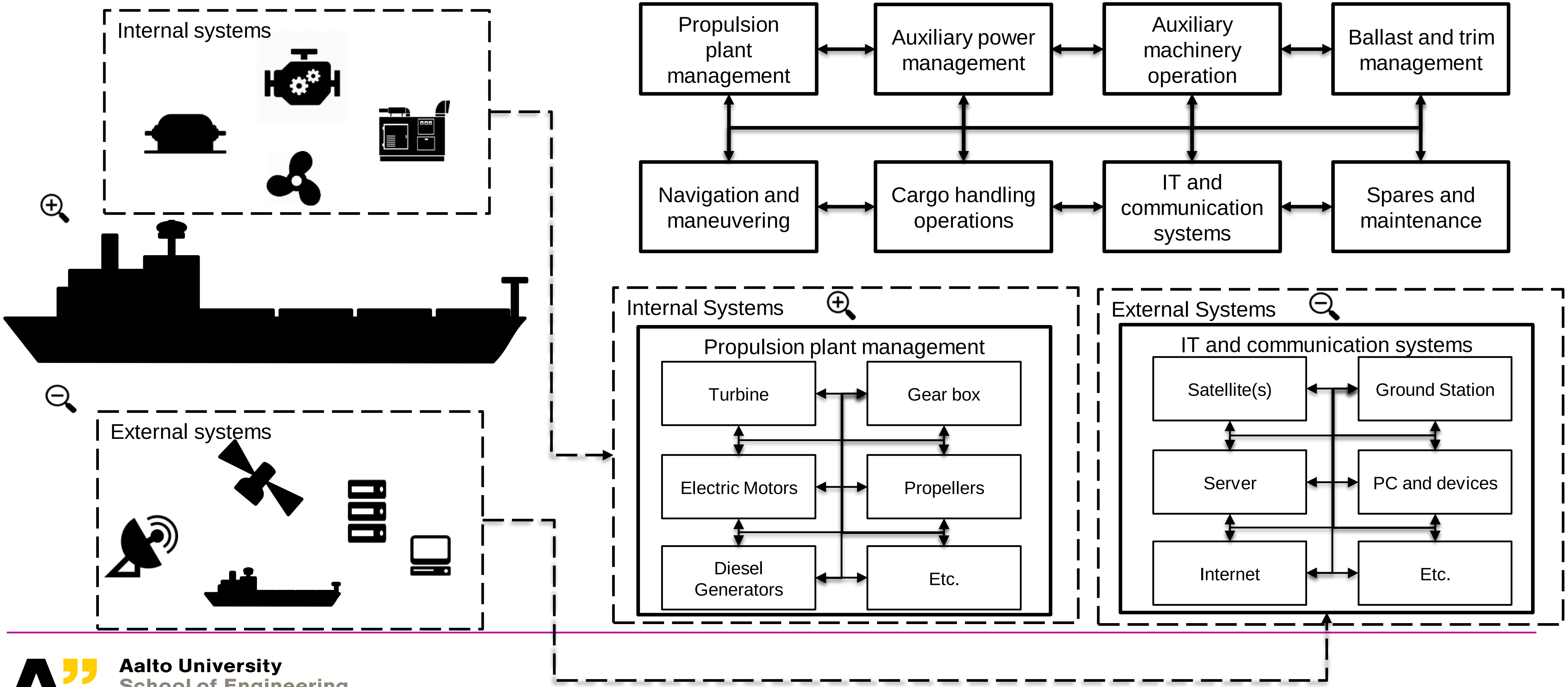


The traditional ship design spiral by Evans 1959



The design of the next generation of digital ships by Martin Stopford 2018

The ship as a system of systems



Lectures

- Propulsion plant management
- Auxiliary power management
- Auxiliary machinery operation
- Navigation and maneuvering
- IT and comm. systems
- Ballast and trim management
- Cargo handling operations
- Spares and maintenance

Topic	Time	Lecturer	Affiliation
Introductory lecture	24/10/22	Osiris Valdez Banda	Aalto University
System Engineering	31/10/22	Osiris Valdez Banda	Aalto University
Ship Energy sources	7/11/22	Mia Elg	Deltamarin
Machinery auxiliary systems	14/11/22	Antero Apajalahti	Helsinki Shipyard
HVAC and ballast water treatment systems	21/11/22	Vesa Heikkilä/ Konstantin Tchetchine	Meyer Turku/ Wärtsilä
Safety Systems	28/11/22	Victor Bolbot	Aalto University
Propulsion Systems	09/01/23	Ari Rakkola	Meyer Turku
Deck Machinery and Cargo Handling Systems	16/01/23	Osiris Valdez Banda	Aalto University
Electricity consumption and Power Management System	24/01/23	Mia Elg	Deltamarin
Integrated Bridge and IT systems	31/01/23	Kalevi Tervo	ABB

Learning outcomes

After the course, the student:

- Can describe the main requirements of ship systems
- Can define and justify an approach to fulfil systems requirements
- Can create a concept design of a machinery system by selecting appropriate components, guided by principles of energy efficient design
- Can apply current regulatory requirements for ship systems and understands what it takes to go beyond them
- Knows the utilization of automation systems in contemporary ship designs
- Can describe how adverse environmental effects of ships can be minimized, below the current and known future requirements

Course learning approach

The course utilizes guided problem-based learning concept. Ship system requirements are identified in the beginning and the lectures evolve around them. The course project is to select, describe and **justify** the choice of certain equipment.

Each lecture introduces certain type of system or equipment, and students afterwards consider that topic for their projects. Some topics are introduced or strengthened by visiting lecturers from industry.

Course workload

Projects are carried out in groups of 3-4 students, preferably the same as in PNA/ Ship Design Portfolio Project – course.

Load:

- Interactive lectures: 20h (2h/week, 10 weeks)
- Instructed workshops: 4h (2h/week, 2 weeks)
- Group work: 30h (3 hours/week, 10 weeks)
- Studying materials: 60h (5 hours/week, 12 weeks)
- Preparing for Conference: 20h

Conference:

February 2023

Study Material

- The study material is updated weekly and it is linked to the Lectures (topics covered)

Osiris Valdez Banda, D.Sc. (Tech)
Assistant Professor

Teaching

- Main course responsible
- Lecturing L1, L2, and L8
- Assignment and conference
- Contact
  - Present at each lecture*
  - osiris.valdez.banda@aalto.fi

Research interests

- Marine and ship systems engineering
- Safety and resilience engineering
- Safety management and modelling
- Autonomous shipping safety
- Winter navigation

Victor Bolbot
Postdoctoral researcher

Contact

- Responsible for the assignment
- Questions and instructions for the assignment and conference
- Any other practicality about the course
- Contact:
    - victor.bolbot@aalto.fi

Research interests

- Safety and security aspects in ship design and operation
- Autonomous shipping safety
- Ship systems engineering
- Cyber-security

Organizing some course practicalities

- The course assignment (descriptions) start next week
- How many of you are taking part in PNA?
- Working in the assignment must be similar to the project you are doing in PNA (and later in Ship design portfolio)
- Please discuss and inform Victor about the organization of the groups for the course assignment
- Course assessment criteria
  - *Course assignment 55%*
  - *Conference contribution 35%*
  - *Weekly learning logs 10%*

Learning logs

- Instructions for the elaboration of the learning logs will be posted today in my courses
- The first learning log to be returned no later than Su. 06.11.2022 at 23:59 (The learning log 1 includes Lecture 1-2)
- Please submit your learning log to MyCourses

Aalto University
School of Engineering

Marine and Arctic Technology

MEC-E2000 - Marine and Ship Systems Engineering

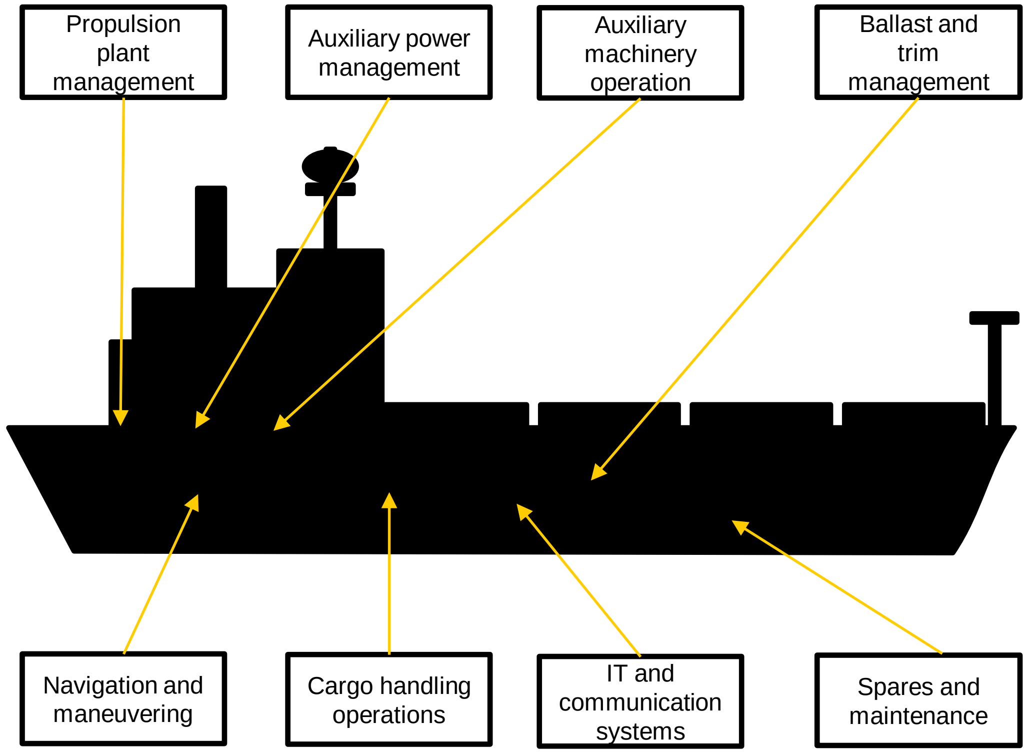
Lecture 1: Marine and Ship systems in ship design

Intended Learning Outcome

- Reflect and understand the importance of systemic thinking for design and operation of Ship and Marine Systems
- The students reflects on systemic applications for the analysis of complex ship designs

Content

- System of systems (SoS) Engineering
- The importance of the systemic view in ship design
- The ship as system of systems
- Overall view of main ship systems
- Analysing complex ship systems (example of a case study)



The design of the next generation of digital ships by Martin Stopford 2018

Systems of systems (SoS) Engineering

The **SoS** engineering focuses on systems taken as a whole, not on their parts taken separately. Such an approach is concerned with total-system performance even when a change in only one or a few of its parts is contemplated because there are some properties of systems that can only be treated adequately from a holistic point of view (1).

The system properties derive from the relationships between parts of systems: how the parts interact and fit together.

SoS engineering focuses on choosing the right system(s) and their interactions to satisfy the requirements.

Why we need SoS engineering

- Rapid technological changes
- Development of advanced technologies
- Constant changes in the operational environment

Effect:

- Embedded software in components (software errors)
- Increased component interactions (errors/risks due to wrong/unsafe interactions)
- Increased complexity (design and operational errors)
- Higher number of components. (large and disrupted models)

Amerigo Vespucci (Italian Navy)

Symphony of the Seas (Royal Caribbean)

Autonomous Ship Concept (Rolls-Royce)

Relevancy of SoS engineering in ship design (1)

Many system designers use traditional System Engineering tools and techniques, such as

- Requirements derivation and rationale,
- Functional allocation and decomposition
- Trade studies
- Technical performance measurements
- Risk analyses
- **Spiral development**, etc.

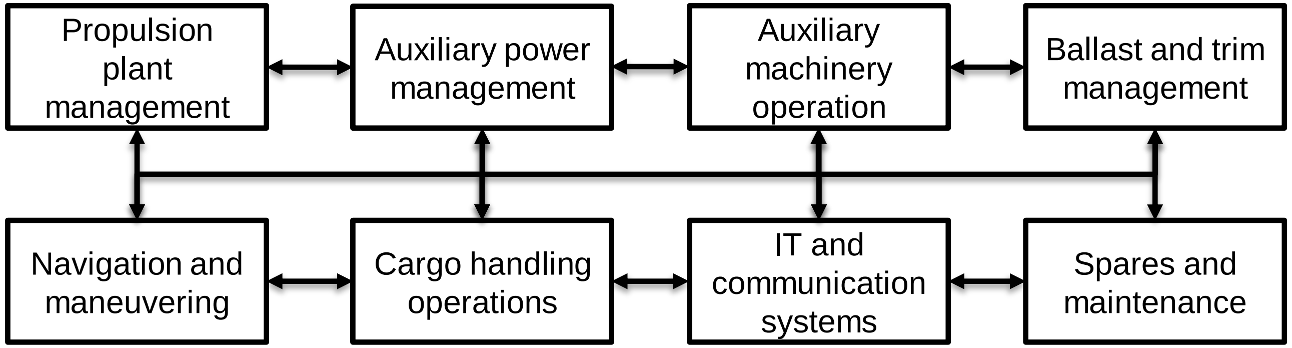
The key question is how to achieve the simple-yet-elegant, almost-beautiful system designs when faced with extremely complex system design problems (2).

Oasis of the Seas (Royal Caribbean)

Relevancy of SoS engineering in ship design (2)

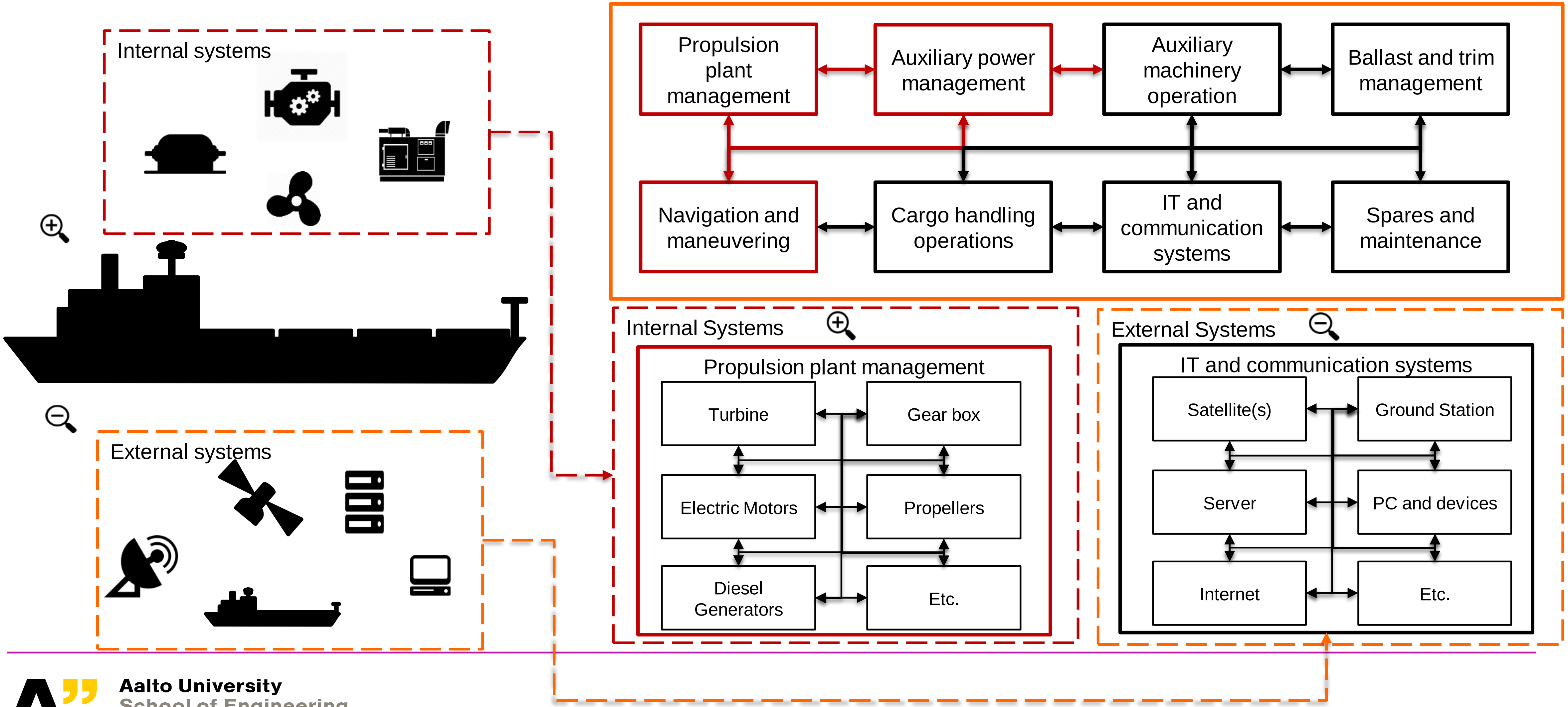
SoS engineering seeks to optimize network of various interacting systems brought together to satisfy multiple objectives in functional program or operation.

The **SoS** engineering enables the decision-makers to understand the implications of various choices on technical performance, costs, extensibility and flexibility over time.

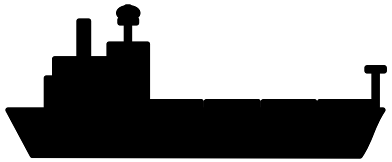


SoS engineering prepare decision-makers to design informed architectural solutions for System-of-Systems problems.

The ship as a system of systems



Ship systems



- Propulsion plant management
- Auxiliary power management
- Auxiliary machinery operation
- Navigation and maneuvering
- IT and comm. systems
- Ballast and trim management
- Cargo handling operations
- Spares and maintenance

Propulsion plant management (1)

Most modern ships use a reciprocating diesel engine as their prime mover

Why?

Operating simplicity,

Robustness

Fuel economy

Functionality:

The rotating crankshaft can be directly coupled to the propeller with slow speed engines, via a reduction gearbox for medium and high speed engines, or via an alternator and electric motor in diesel-electric vessels.

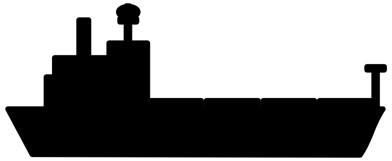
Classification by:

Operating cycle (two-stroke engine or four-stroke engine)

Construction (crosshead, trunk, or opposed piston)

Speed (Slow: 300rpm, Medium 300-1000 rpm, High (>1000 rpm)

Ship systems



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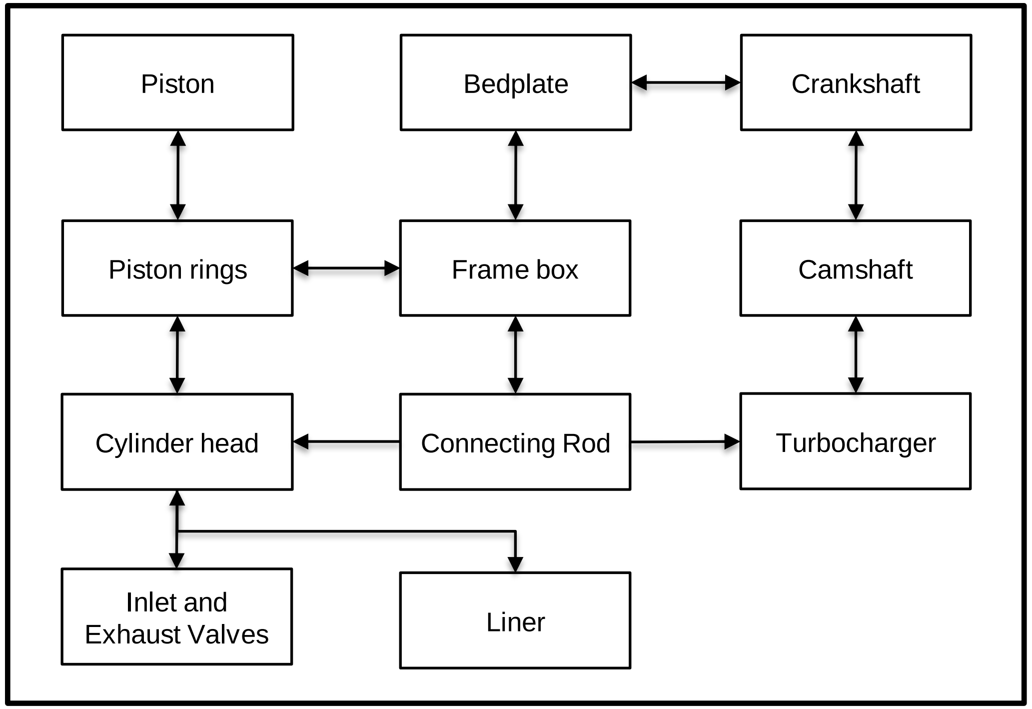
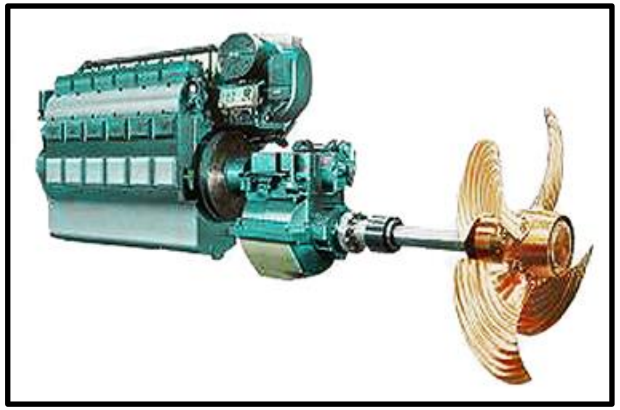
Propulsion and plant management (2)

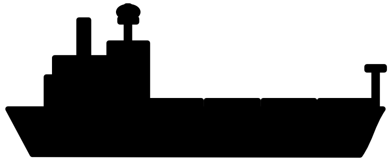
Marine Diesel Engine (Components):





4-Stroke Marine Diesel Engine System

Ship systems



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Auxiliary power management (1)

A power management system (PMS) decides which generators combination will be the best according to the load Consumptions.

PMS Functionality:

1. Cutting in and out of the generators according to increase and decrease of load.
2. Gradually loading and unloading of generator alternator sets, so as to minimise thermal and frictional stresses.
3. Performing load sharing operations among the generators symmetrically or asymmetrically (depending on auto/manually set parameters).

PMS Role:

Automatic Synchronizing; Automatic Load Sharing; Automatic Start/Stop/Stby Generators according to Load Demand; Large Motors Automatic Blocking; Load Analysis and Monitoring; Redundant Power Distribution; Frequency Control; Blackout Start; Selection of Generators Priority; Etc.

Ship systems

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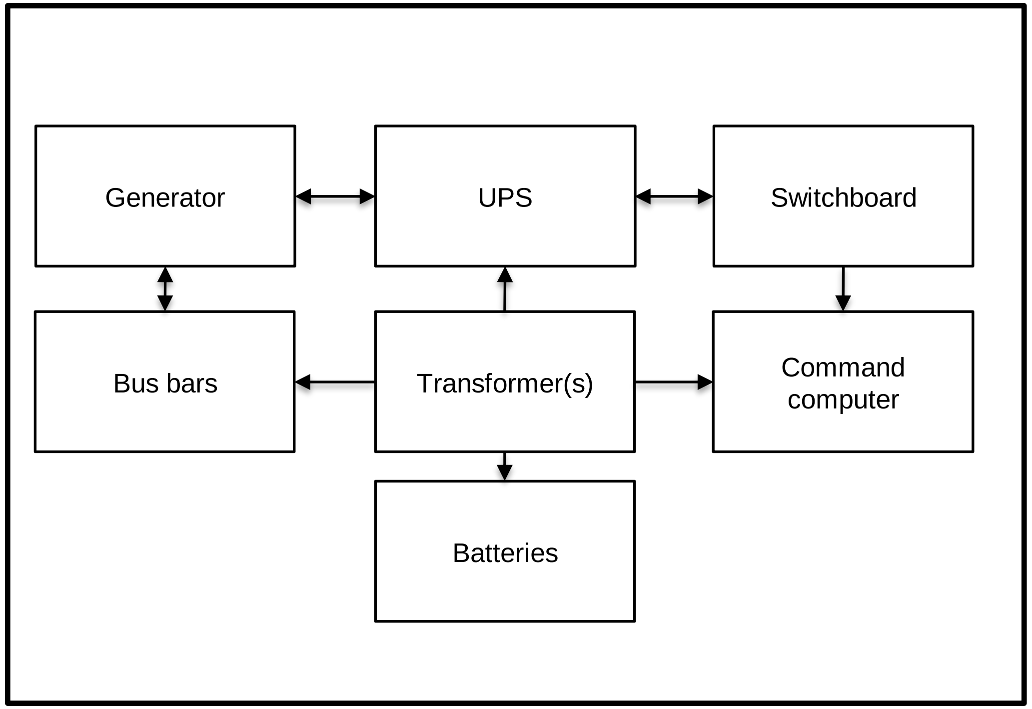
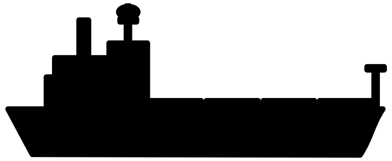
Auxiliary power management (2)

PMS (Components):



PMS on board

Ship systems



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Auxiliary machinery operation (1)

Machinery, other than the main propulsion unit, is usually called 'auxiliary' even though without some auxiliaries the main machinery would not operate for long.

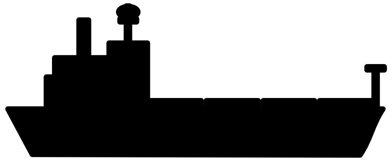
Examples of auxiliary machinery:

- Compressed air systems
- Coolers
- Distillation systems
- Bilge and ballast piping systems
- *Sewage treatment system*
- Stabilising fins
- Etc.

Functions:

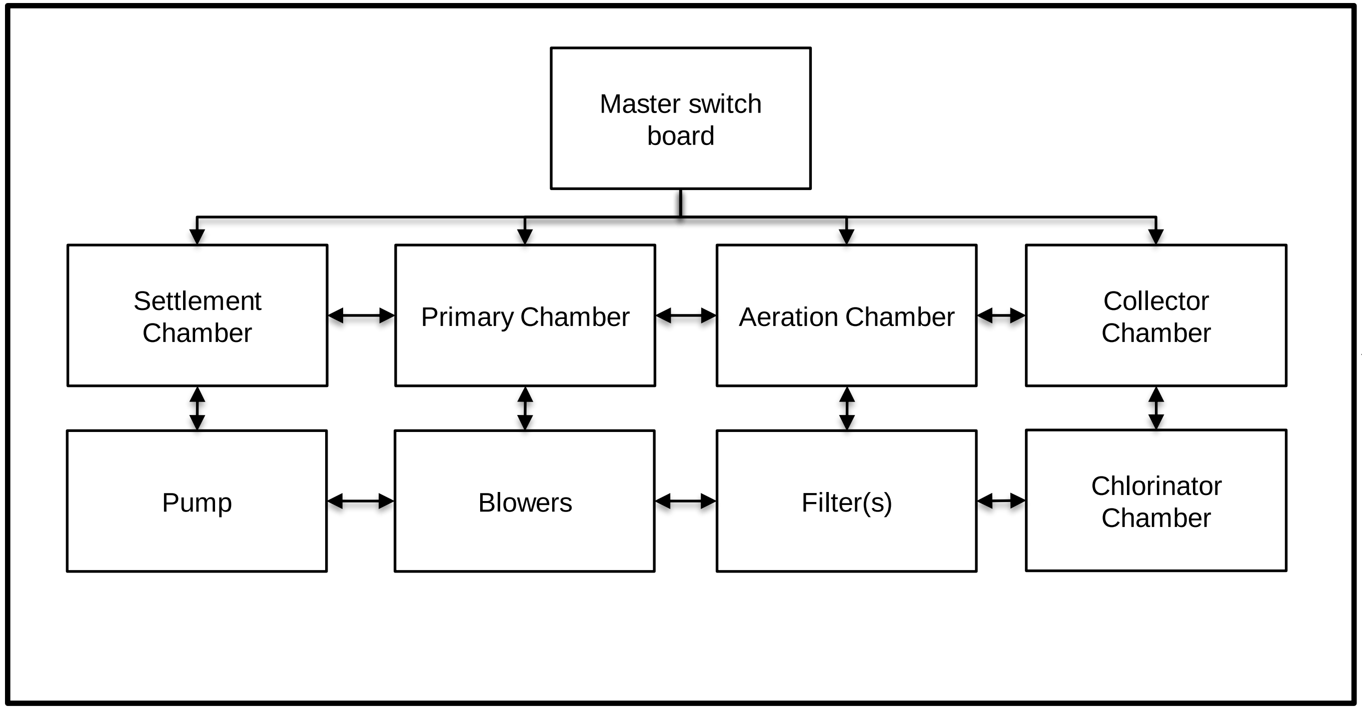
Supply the needs of the main engines and boilers; keep ship dry and trimmed; mooring the ship and handle cargo; safety provision, etc.

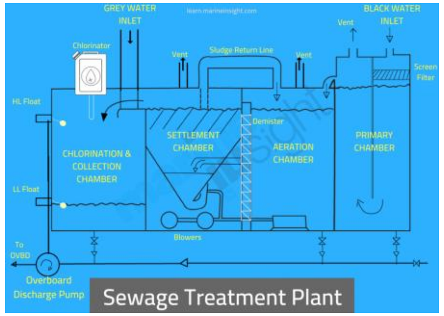
Ship systems



Auxiliary machinery operation (2)

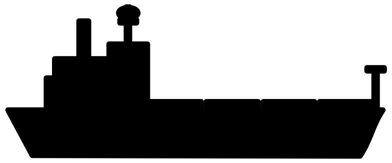
Sewage treatment system (Components):





Seawage Treatment Plant (Marine Insight)

Ship systems



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Navigation and maneuvering (1)

The factor of maneuverability of a vessel is extremely important to a designer or a seafarer, along with other aspects such as structural design, machinery, propulsion, stability and seakeeping.

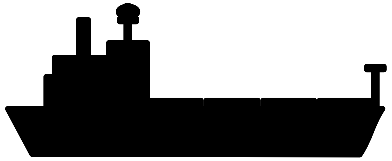
Closed-loop automatic navigation system:

- Maneuvering control system (Control Law and Control Allocation)
- Navigation measurement system (DGPS, INS)
- Guidance System (Path generator, Speed Assignment algorithm)
- External input (Weather routing program)

Typical Navigation Equipment:

Gyro and magnetic compass; Radar; Auto pilot; Automatic Radar Piloting Aid (ARPA); Tracking aid; Speed and distance log device; Echo sounder; Electronic Chart Display Information System; AIS; Lon Rate Tracking and Id System; Rudder Angle Indicator; GPS; Navigational Lights; Etc.

Ship systems



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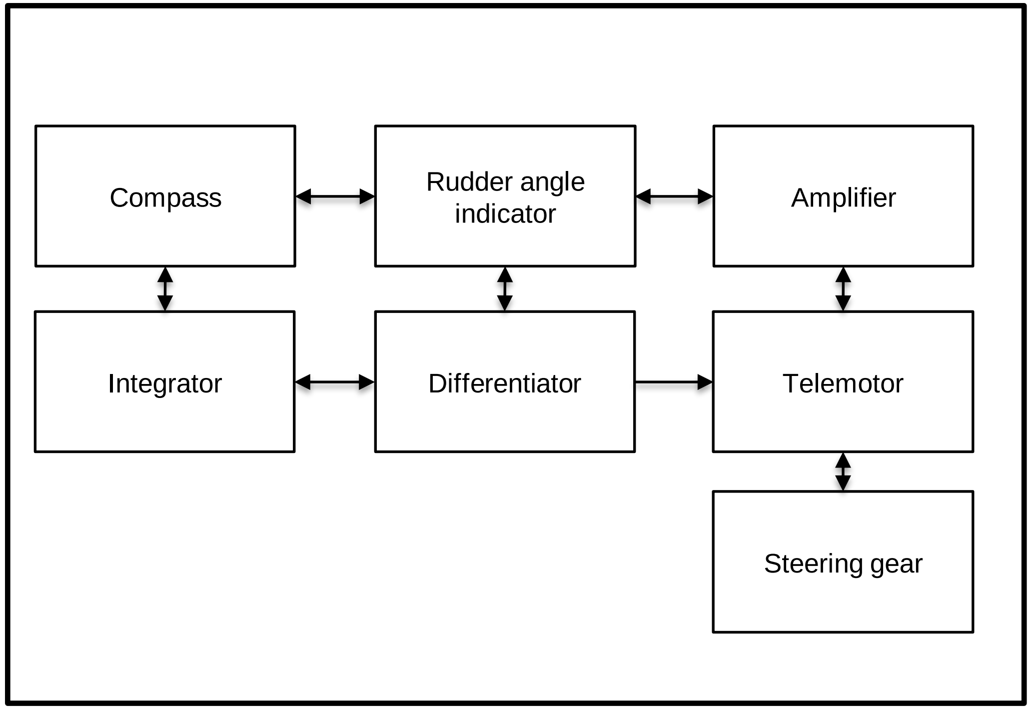
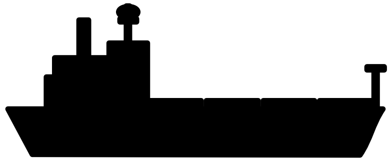
Navigation and maneuvering (2)

Auto-pilot system (Components):



Ship bridge

Ship systems



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IT and Communication systems (1)

Marine communication between ships or with the shore was carried with the help of on board systems through shore stations and satellites.

Standard ship communication:

Ship-to-ship communication was brought about by VHF radio, Digital Selective Calling (DSC) came up with digitally remote control commands to transmit or receive distress alert, urgent or safety calls, or routine priority messages.

Example: The Global Maritime Distress Safety System (GMDSS) has four geographical divisions named as A1, A2, A3 and A4

Equipment by Area:

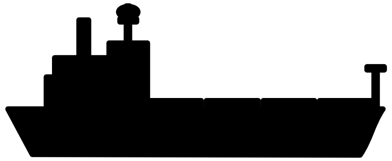
A1 (VHF, a DSC and a NAVTEX receiver)

A2 (A DSC, and radio telephone (MF RR) plus the equipment required for A1)

A3 (A high frequency radio and/or INMARSAT, a MSI system plus A1 and A2)

A4 (HF radio service plus A1, A2 and A3)

Ship systems



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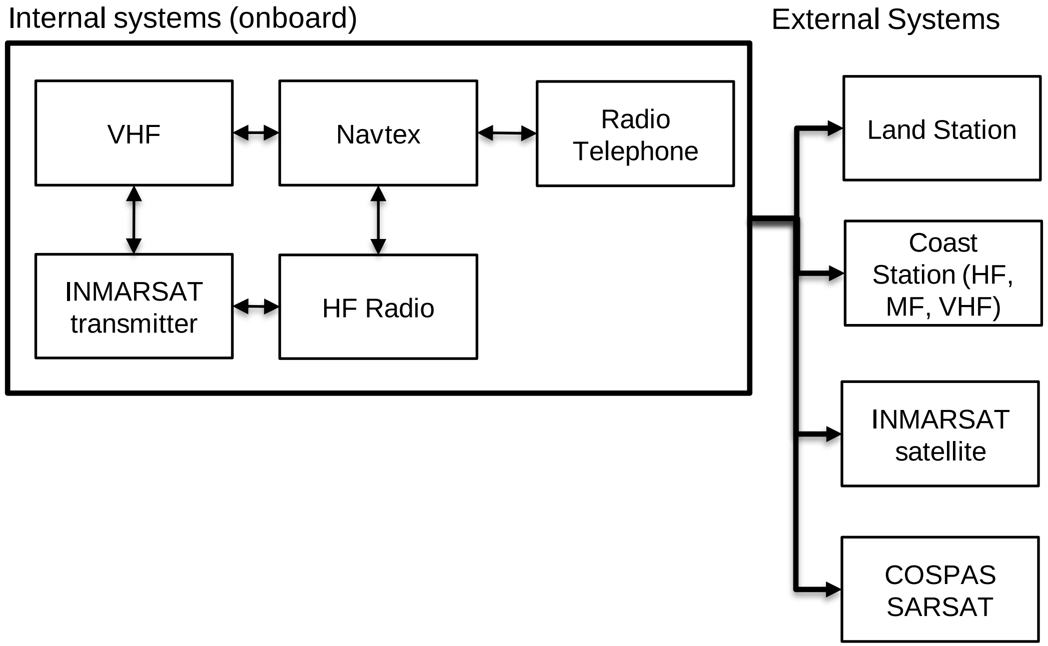
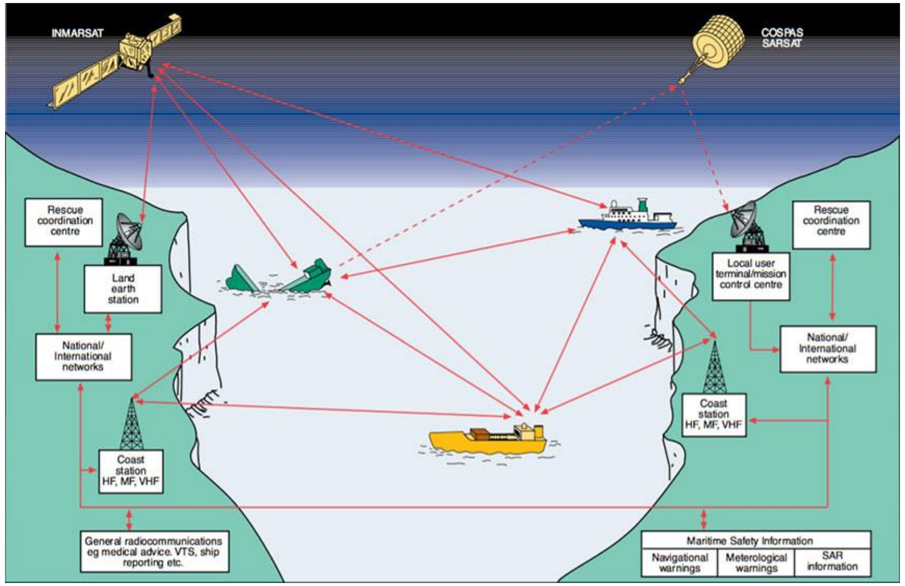
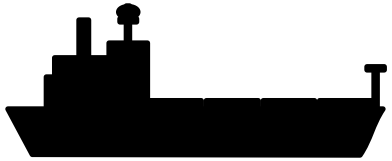
IT and Communication systems (2)

Global Maritime Distress Safety System (Components):





Ship systems



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Ballast and Trim Management (1)

Ballast water (BW) is essential to control trim, list, draught, stability and stresses of a ship.

Relevant for port and voyage planning:

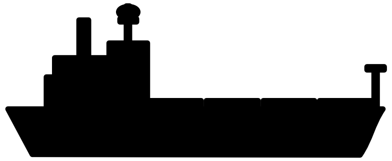
The amount of ballast water discharge/uptake in a port depends on type of vessel, amount cargo loaded/un-loaded and ship loading planning. The need to counterbalance the detrimental effects of weight distribution during and after loading/unloading must be addressed in ports. The cargo distribution should be considered as having an impact on the quantity of ballast as well as on the ability to optimize the trim without jeopardizing the ship's strength and stability.

Ballast Water System equipment:

Ballast pumps, relevant piping system and flow control methods.

Installed according to IMO guidelines and is operated in accordance with the system design criteria and the manufacture's operational and maintenance instructions.

Ship systems



Propulsion plant management

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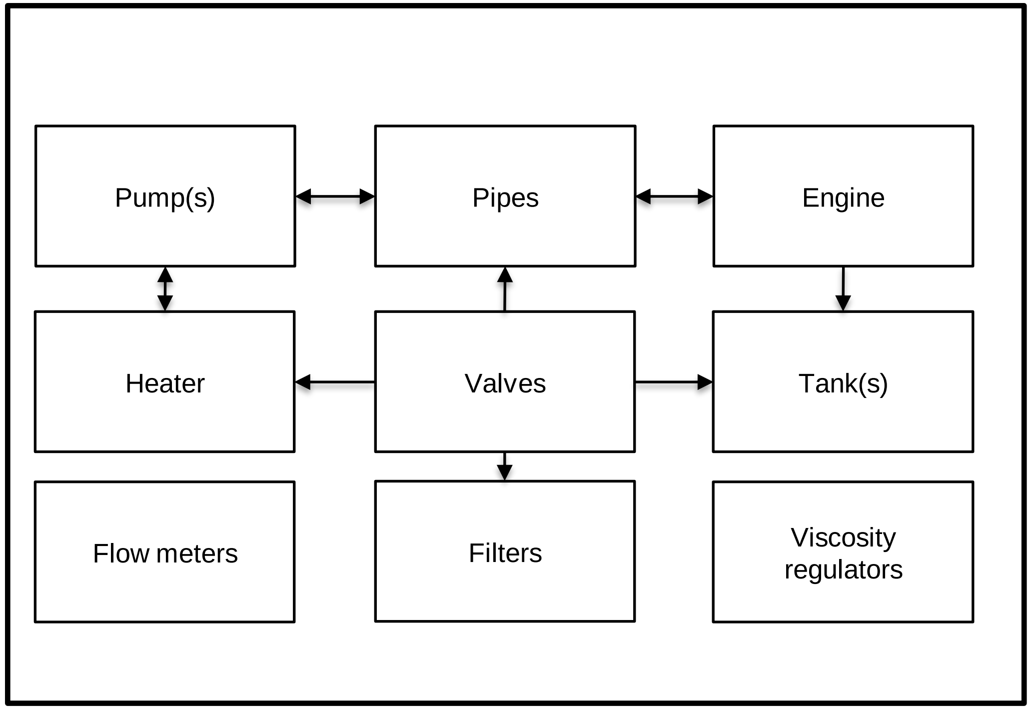
Ballast and Trim Management (2)

Bilge and ballast piping system (Components):



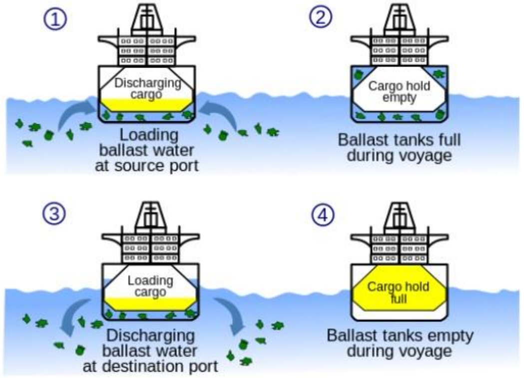
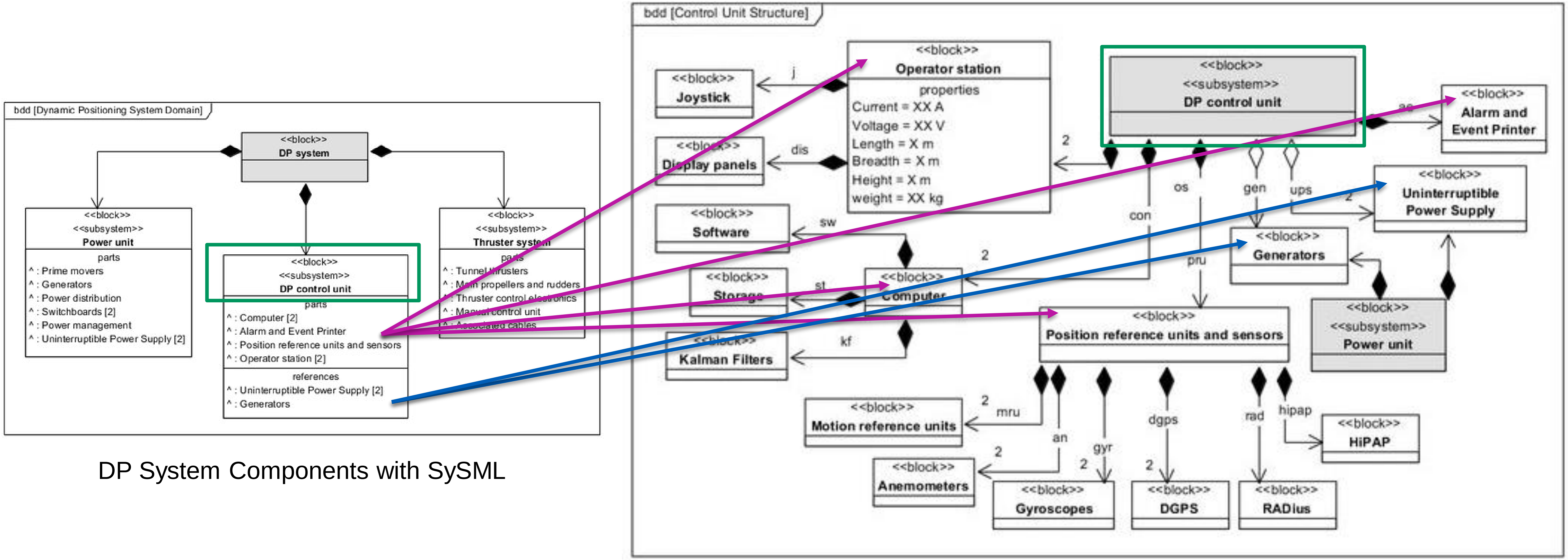


Figure 1: Transfer of bio-species due to ballast operations [Wikipedia]

Figure 3: Ballast water exchange

SoS project description (example)



DP System Components with SysML

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Thank you