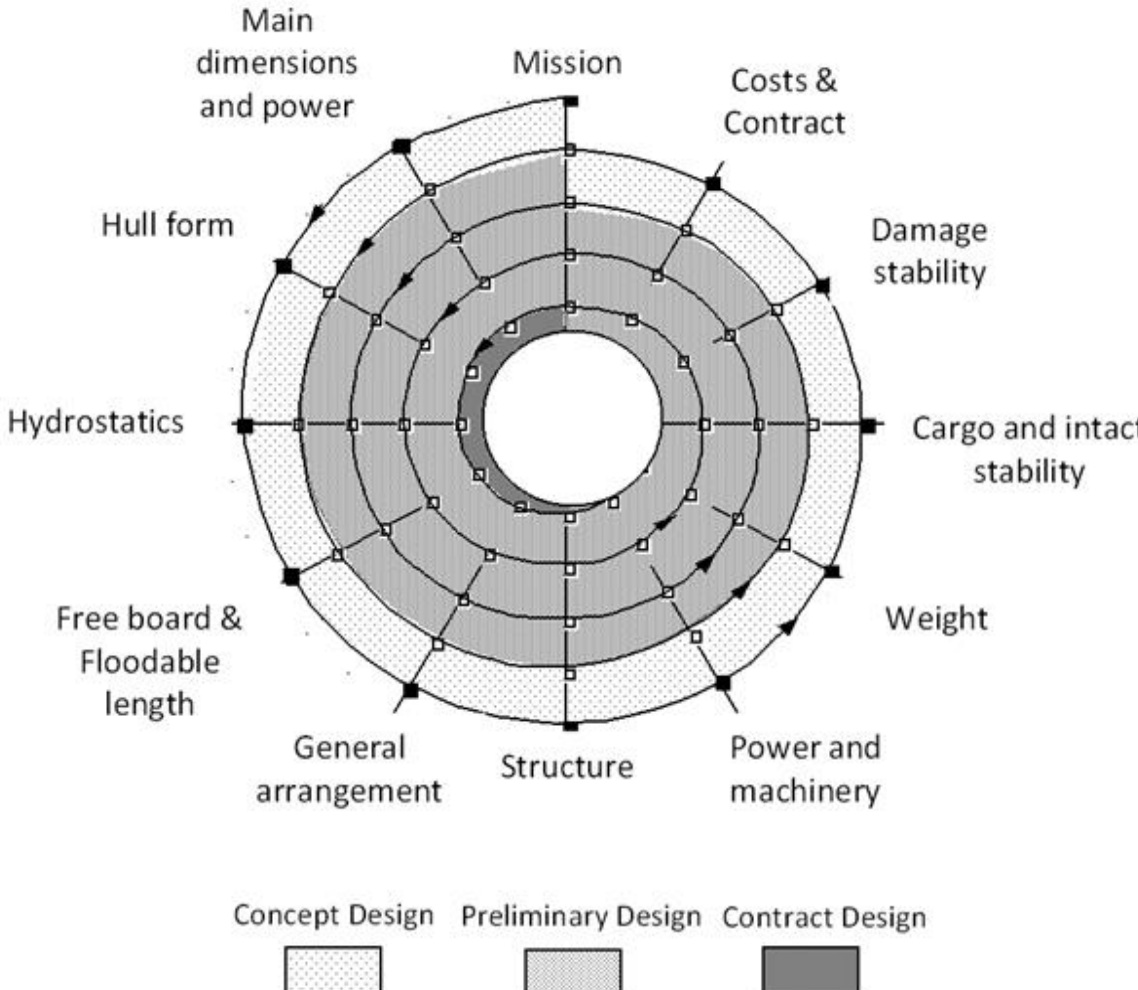
Aalto University
School of Engineering

# MEC-E1004 Principles of Naval Architecture

*Final revision*

# Exam rules of engagement

- Open book, you may use the web and any calculator you like
- You might have to use the xls sheets you have been using for your assignment
- You cannot text or call each other
- Your camera has to be open at all times
- Multiple choice and essay questions to be answered over 3hrs
- 5 questions corresponding to lectures 1 – 5 + one bonus question
- You have to submit online and on time !!!


Main dimensions and power
Mission
Costs & Contract
Damage stability
Cargo and intact stability
Weight
Power and machinery
Structure
General arrangement
Free board & Floodable length
Hydrostatics
Hull form
Concept Design
Preliminary Design
Contract Design

# Lecture 6 – Ship General Arrangement

- Describe objectives, criteria and process (see tutorial) – Be able to rationally explain those with application to your ship

- The GA defines a ship's spaces and layout

- General objectives / criteria
  - *To efficiently meet the ship's mission and functional requirements (e.g. efficient internal connections)*
  - *Structural continuity and a clean layout*
    - ✓ For structural strength
    - ✓ To minimize vibration and noise
    - ✓ For a cost-efficient manufacturing process (e.g. to facilitate the use of prefabricated modules - trend)
  - *Safety requirements (SOLAS)*
    - ✓ Fire protection, flooding mitigation, evacuation, intact/damage stability, seakeeping
  - *Aesthetics*
    - ✓ Especially important for passenger ships

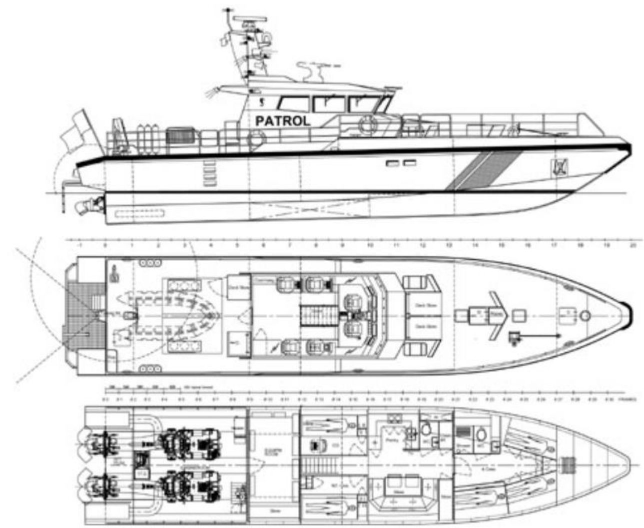
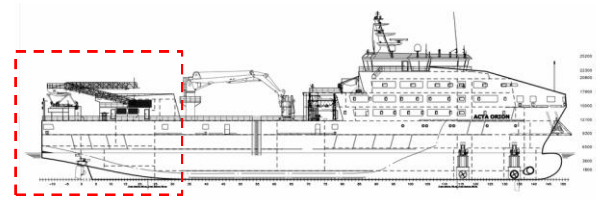



Image credit Docksta Varvet

# GA – Key items for consideration

- Ship main dimensions, hull shape, frame spacing
  - *These define the available space, strength, stability etc.*
- Capacity requirements concerning
  - *Cargo type and amount*
  - *Cargo handling capability requirements*
  - *Passenger capacity (no. of passengers, standard of cabins and other areas in [m2/person])*
  - *Crew capacity (no. of crew and their comfort standard [m2/person, regulated], windows required for crew cabins)*
  - *Machinery (type, size, no. of engines, type of power transmission)*
  - *Tanks (other than cargo) for fuel, system liquids, ballast water,…*
- Rules and regulations
  - *Criteria regarding watertight compartment and fire zones (e.g. number and location of watertight bulkheads and fire bulkheads on upper decks)*
- Dimensions of cabin and other prefabricated modules
- Frame and web-frame spacing



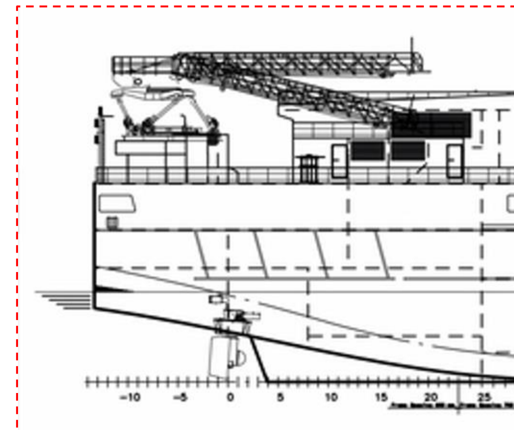
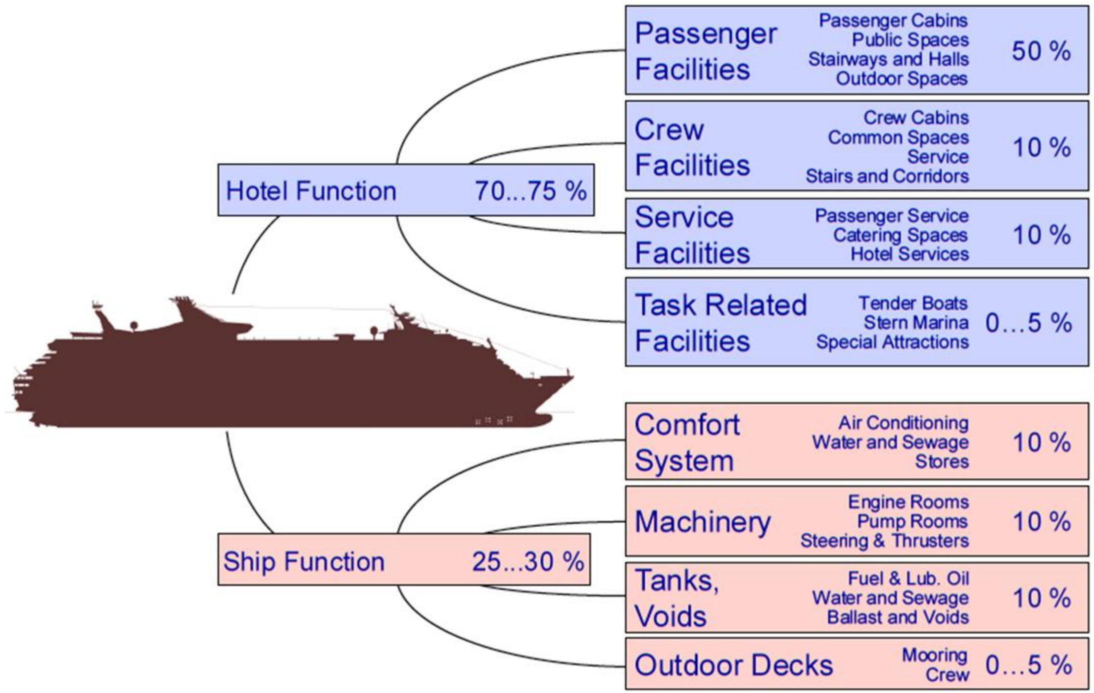
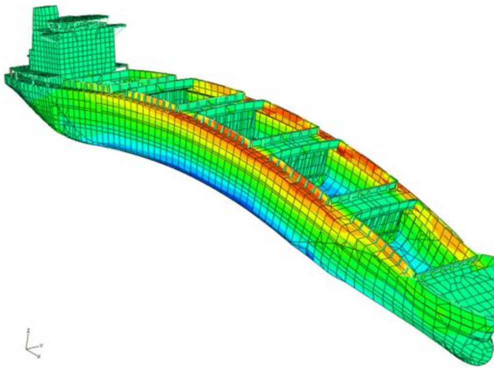



Image credit poland@sea

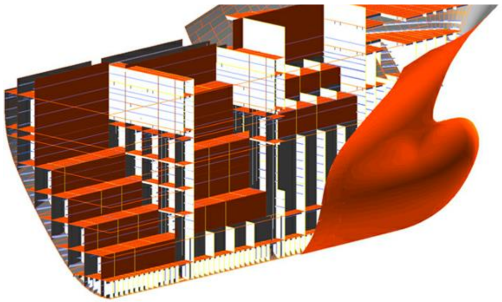
# Example: space distribution



# Lecture 7 – Ship Structures



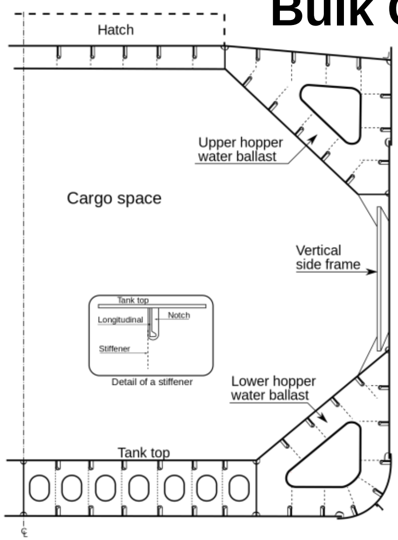
- List and discuss structural requirements
  - *Regulatory requirements*
    - Longitudinal (bending) strength
    - Shear strength
    - Hull girder ultimate strength
    - Structural continuity
  - *Ship specific challenges (e.g. structural challenges caused by its GA)*
  - *General and functional requirements*
  - *Terminology (loads, strength, responses, strgnth hierarchy levels, internal versus external loads, wave loads)*
  - *What is structural failure and how rules compensate for this ?*



# Different mid ship sections (1)

- Different types of ships have different midship sections. The structural arrangement and their scantlings are shown in these plans. These are statutory structural plans which are to be approved by the concerned classification society prior to actual construction of ship.

## Bulk Carrier




## Tanker

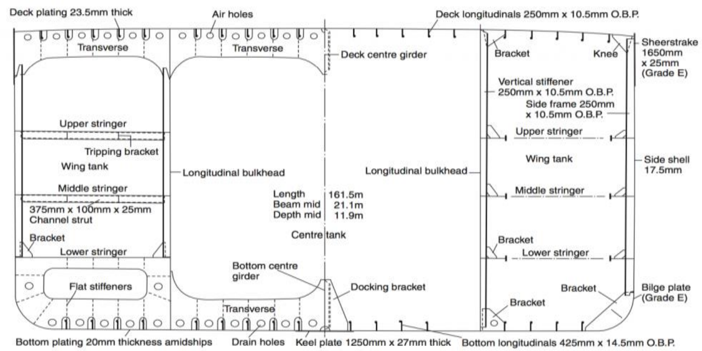
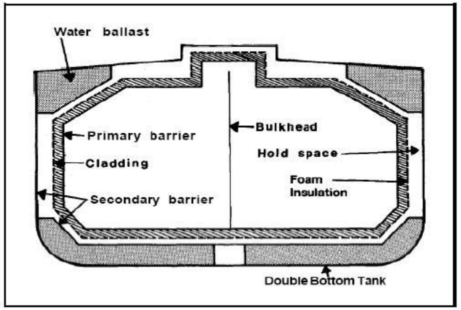



FIGURE 22.2 Midship section of oil tanker

## LNG



# Section Modulus (Home work)

- Claculate the section modulus of your ship's mid ship section (this is part of your assignment)

- Refer to :
  - *Tutorial background notes files : T7_Background notes 1.pdf, T7_Background notes 2.pdf*
  - *Section modulus calculation *.xls.*

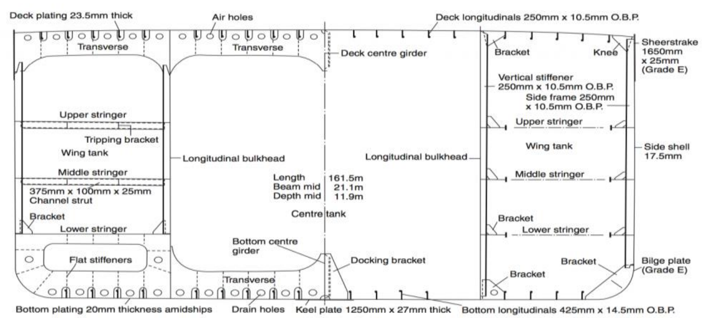



FIGURE 22.2 Midship section of oil tanker

# Shipbuilding materials

- Steels are the most common materials being used for shipbuilding (AH36 typical)
  - *Provide a favorable combination of a relatively high strength/weight ratio, producibility, and costs*

- Alternative materials include
  - *Composites*
    - Lightweight, strong, and stiff (+)
    - Do not corrode (+)
    - Excellent fatigue properties (+)
    - Fire safety issues (-)
    - High building costs (-)
  - *Aluminum*
    - High strength/weight ratio (+)
    - Corrosion resistant (+)
    - Challenging to work with (-)
    - Fire safety issues (-)

Composite vessels. Image credit DAMEN


Aluminium catamaran. Image credit Meyer Turku

# Lecture 8 – ship power and machinery

- *List and explain the function of the main components of a ship's machinery*
- *List and explain the main characteristics of common types of ship engines, machinery configurations, power transmission, and propulsion systems*
- *Create and justify a machinery for your project ship*
- *Define basic ship outfitting systems and explain their purpose and function*
- *Select appropriate outfitting systems for your project ship considering its mission*
- *Integrate the selected outfitting systems into your project ship design*

# Ship Operational profile

Helps determine a ship's speed and power demand over a specific period of time (often a typical voyage)

- Needed to determine a ship' total power demand
  - *What is the maximum peak load?*

- Must be considered when determining a ship's machinery configuration (e.g. number and types of engines)
  - *The specific fuel consumption (SFC) and emissions of a typical marine engine depends on the engine load*

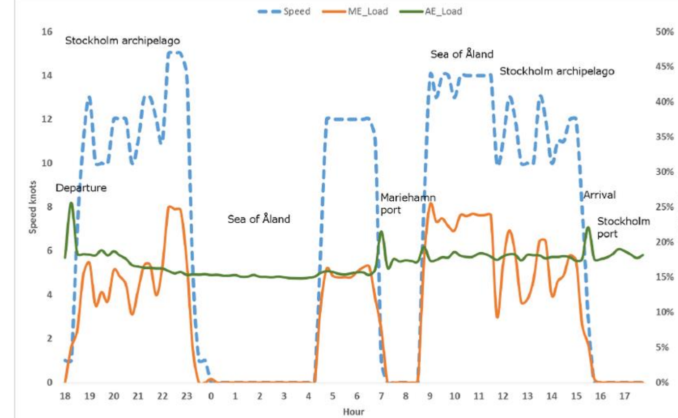



Image credit Francesco Baldi et al.

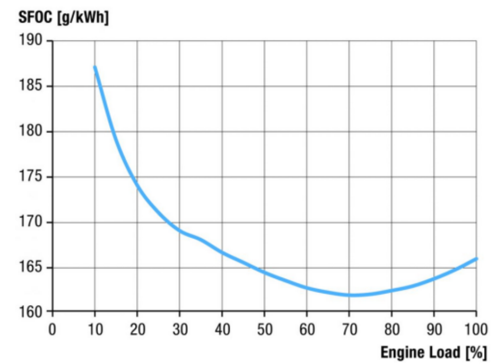



Image credit Motorship.com

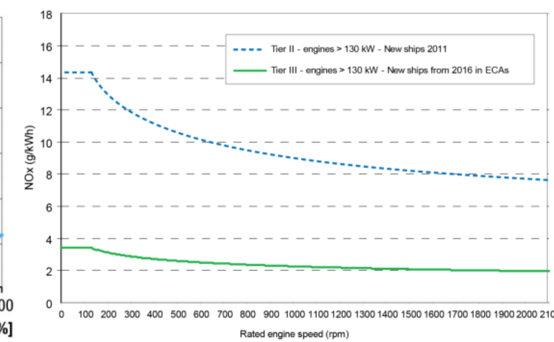
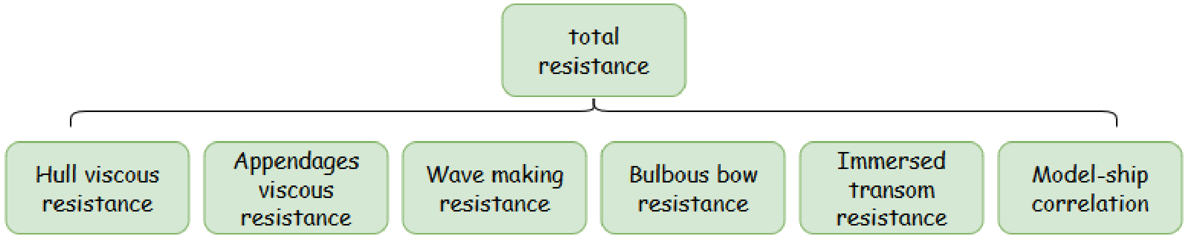



Image credit Wärtsilä

# Ship Resistance (see tutorial & *.xlsx)




$$R_{total} = R_v + R_{APP} + R_w + R_B + R_{TR} + R_A$$


- ❑ Holtrop, J. and Mennen, G.G.J, “A statistical power prediction method”, International Shipbuilding Progress, Vol. 25, 1978.
- ❑ Oosterveld, M.W.C. and Oossanen, P. van, “Further computer analyzed data of the Wageningen B-screw series”, International Shipbuilding Progress, July 1975.
- ❑ Bertram, Volker, “Practical Ship Hydrodynamics”, Elsevier, 2012.

# Ship Energy sources

- Fuel oil
  - *Various qualities: HFO, MDO, MGO,…*
- Natural gas (LNG)
- Bio-fuels
  - *Ethanol, methanol,…*
- Nuclear fuel
- Wind
- Sun

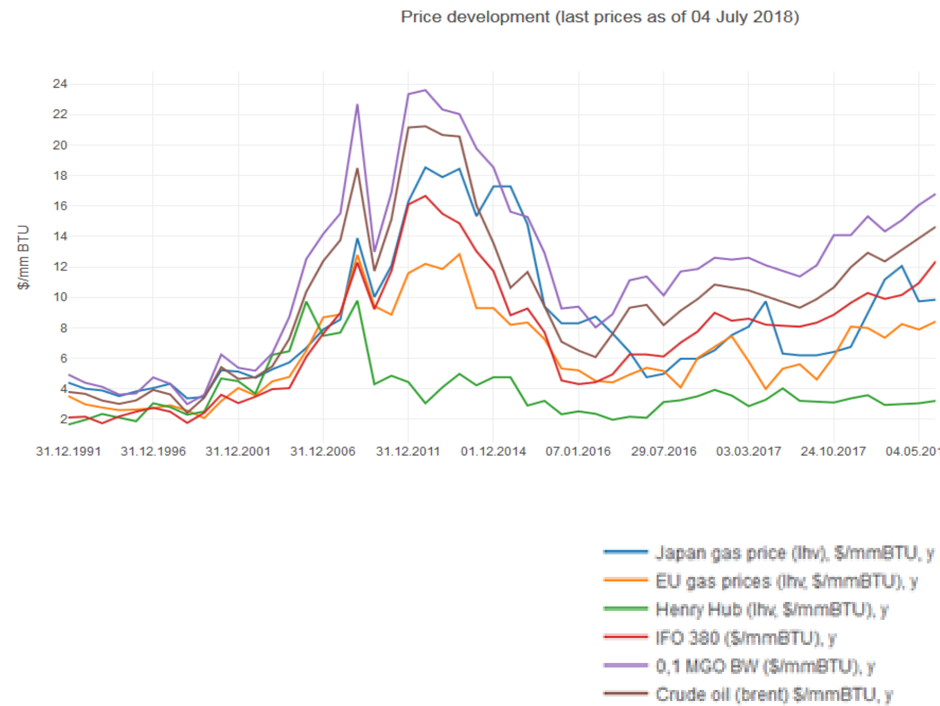


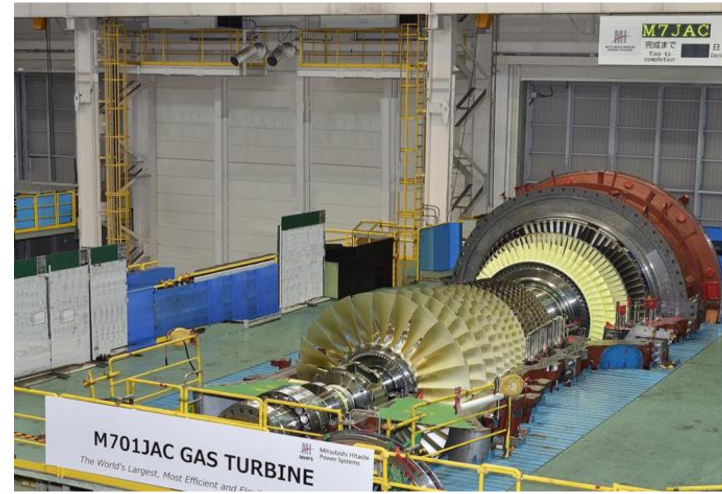

Image credit DNVGL

## Factors to be considered when choosing an energy source

- Energy density
- Price
- Availability
- Operational profile

Image
Kawasaki Heavy Industries

Image - MHI, Japan



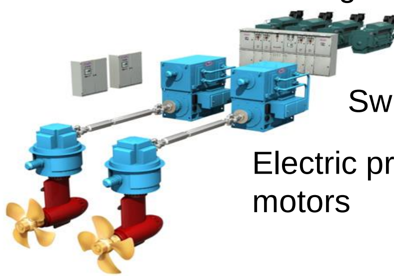
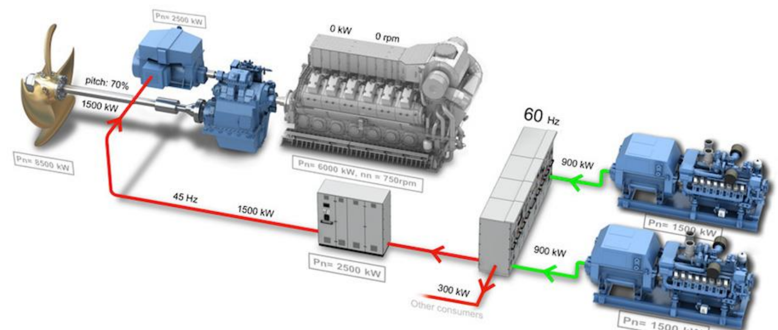
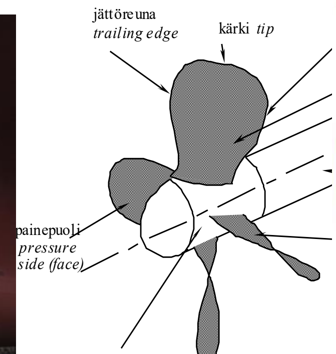



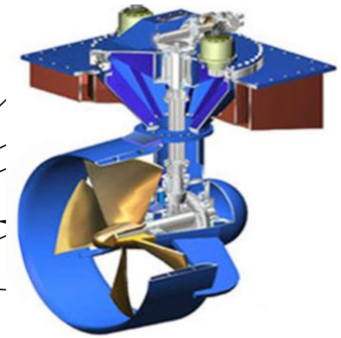

Image credit Marineinsight.com

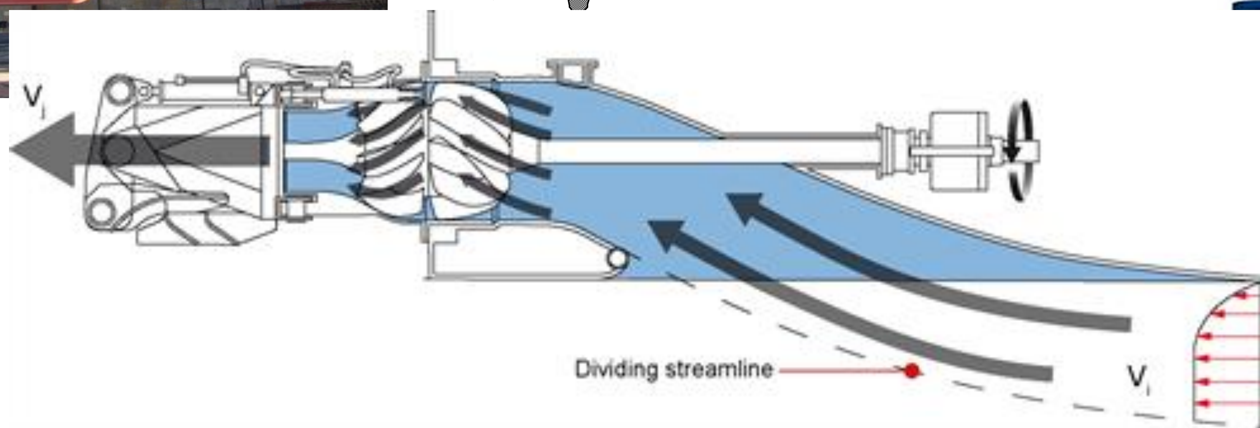



Hybrid propulsion system. Image credit Berger Maritiem

# Propulsors

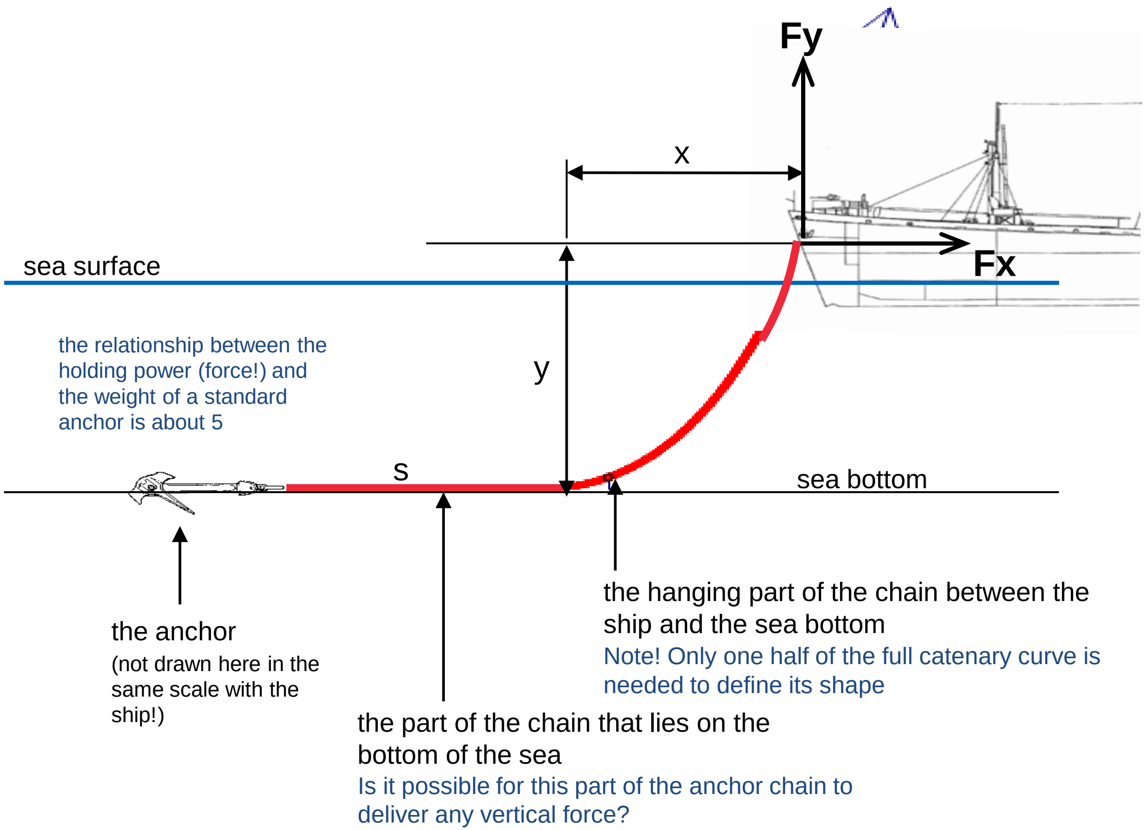


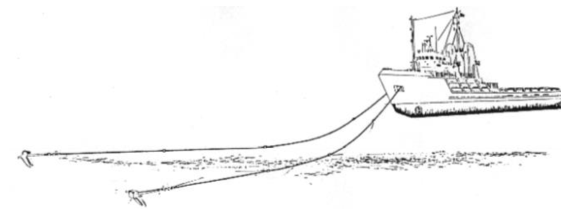






credit Wärtsilä

# Anchoring systems



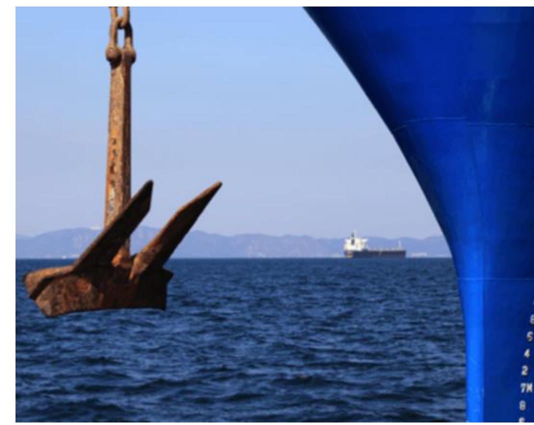


Image credit Marine Insight

# Evacuation system

## Evacuation/safety system components

- Escape routes, muster stations, life boat/rafts and related launch systems, life vests, …
- Related system: Ship condition monitoring
  - *Detection/analysis of damages/faults*
    - E.g. determination of the number of damaged watertight compartments following a grounding/collision

## Evacuation systems and equipment must enable / support

- Mustering (to muster stations)
  - *Requires efficient evacuation routes*
- Loading of lifeboats/life rafts
- Launching of lifeboats / life rafts
- Moving away from /disconnecting from evacuated ship
- Survival
- Rescue

Mustering onboard Grandeur of the Seas. Image credit AP

Evacuation from Costa Concordia. Image credit Giuseppe Modesti/AP

Life raft from MS Estonia (sank 29.09.1994). Image credit Jonas Lemberg

# Steering and manoeuvring

**System components**

- Steering device, transverse thrusters, control systems (hydraulics, etc.)

**Different types of steering devices**

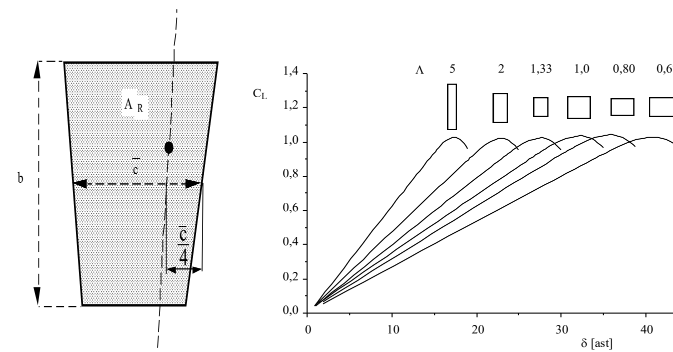
- Rudder
- Steering propeller (azimuth thruster)

**Rudder**

- Purpose: To generate a lateral force that adjusts/maintains the bearing of a ship
- Location: At the stern of the ship, behind the propeller(s), so that it directs the propeller stream
  - *One rudder behind each main propeller*
- Important measures
  - *The lateral (turning) force (lift) as a function of the rudder angle*
  - *The required moment to turn the rudder*
  - *Rudder area, which should be about 0.02*L*T*
  - *The maximum rudder angle (typically 35°)*
  - *Cross section profile (tandard profiles developed by the National Advisory Committee for Aeronautics (NACA) are commonly used)*

Image credit marineinsight.com

Image credit RM propulsion




Effect of rudder angle (d) and area ratio (L) on the rudder's lift coefficient (CL)

# Lecture 9 : Ship weights and stability

- *Explain the purpose of classification of ship systems and define classification standards*
- *Explain the importance of weight calculations in ship design*
- *Define the various stages of a ship weight calculation process and explain how they might be carried out*

# The SFI system

## Code letter system

- Also referred to as Littera systems
  - *Littera (Latin word !) is a code letter or number describing an object*

## Example of code letter systems

- SFI Coding & Classification System
  - *A system for developed and published by the Norge Skips Forsknings Institutt (NSFI) from Noruway, and which is now property of XANTIC (www.xantic.net).*
  - *Shipyard specific*

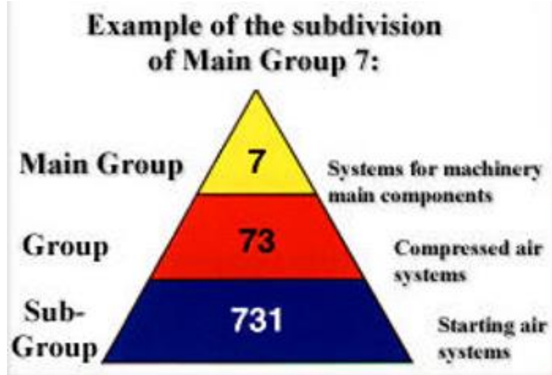



Image credit SFI Group System

**The SFI system defines 10 main groups (only 8 are currently utilized for Ships)**

0. (reserved)
1. Ship General
2. Hull
3. Equipment for Cargo
4. Ship Equipment
5. Equipment for Crew and Passengers
6. Machinery Main Components
7. Systems for Machinery Main Components
8. Ship Common Systems
9. (reserved)

# Important terminology

## Lightship weight ( ≈ a ships own weight)

- The weight of a ship in metric tons without cargo, fuel, lubricating oil, ballast water, fresh water and feed water in tanks, consumable stores, passengers and crew and their belongings
  - *Includes standard outfitting, inventory according to the List of Inventory, spare parts according to the Class Society requirements and with liquids in engine room systems*
  - *Does not include loose container lashing equipment, spare parts in excess of rule requirements, provision stores, crew and effects, fuel oil, diesel oil, lubricating oil, fresh water, ballast water in tanks*

## Deadweight ( ≈ the weight of what a ship is carrying)

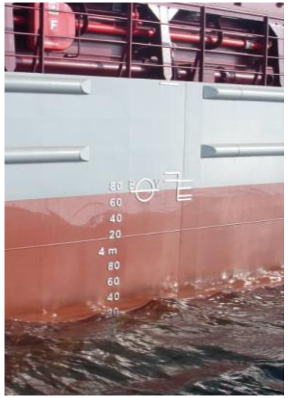
- Defined as the difference between an actual displacement and the lightship weight
  - *SOLAS: "Deadweight is the difference in tones between the displacement of a ship in water of a specific gravity of 1.025 at the load waterline corresponding to the assigned summer freeboard and the lightweight of the ship"*
  - *Expressed in either long tons or metric tons*
- A measure of ship's ability to carry various items: cargo, stores, ballast water, provisions and crew, etc.

## Displacement (= Lightship weight + Deadweight = Total ship weight)

- The weight of water displaced by this vessel at any waterline
  - *The product of the volume of its underwater portion and the density of the water in which it floats*
- Expressed in long/imperial tons (1 long ton ≈ 1.01605 metric tons)

# Important terminology

- Contract deadweight
  - *As specified by  the shipbuilding contract*
- Deadweight acceptance limit
  - *Value below of which a shipyard has to compensate the owner (€/ton)*
- Deadweight rejection limit
  - *Value below of which the owner has the right to reject the ship*
- Legal deadweight
  - *Value resulting from agreed on design modifications*



Load line mark. Image credit boatdesign.net

# Weight calculations - Examples

## Vasa

Image credit Vasamuseet

- Launched 1627, capsized and sank on its maiden voyage in 1628
- The original design was determined by the Dutch shipbuilder Henrik Hybertsson using an empirical method
  - *The theory of intact ship stability did not yet exist*
- Design modifications (e.g. a larger number of cannons) ordered by King Gustaf II Adolf during the building process → Too low freeboard

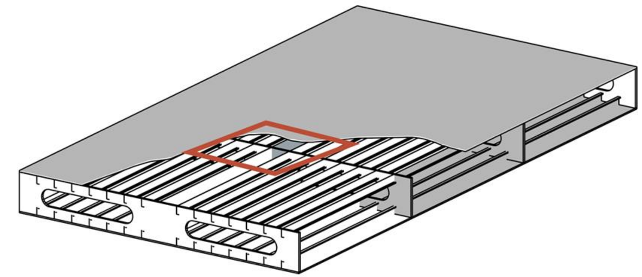
## Ro-pax ferry Berlin /Copenhagen

Image credit Scandlines

- Built by P+S Yards for Scandlines
- Ordered 2010, launched for the first time in 2012
- The owner (Scandlines) cancelled the vessels because they were 200 tons overweight
- In 2014 bought Scandlines the ferries from the now bankrupt shipwyard for 31,6 M€ instead of the origianl copntract proce of 184 M€

# Weight calculation

**Unit weight for stiffened plate field, in which the plate includes longitudinal stiffeners, longitudinal girders and transverse web frames**



$$W = t + \frac{1}{S_{FR}} W_{FR} + \frac{1}{S_{GIR}} W_{GIR} + \frac{1}{S_{STIF}} W_{STIF} [ton/m^2]$$

t – plate thickness [kg/m2]

$W_{xx}$ – weight of the component in [ton/m]

# Lecture 10 - Costs

- List and explain
  - *Different cost categories*
  - *Different types of economic KPIs for ships*
  - *Measures that can be taken to reduce shipbuilding costs*

# Running costs categories

### Operating costs

- Expenses involved in the day-to-day running of the ship—essentially those costs such as crew, stores and maintenance that will be incurred whatever trade the ship is engaged in

### Periodic maintenance costs

- Costs incurred when the ship is dry-docked for major repairs, usually at the time of its special survey

### Voyage costs

- Variable costs associated with a specific voyage and include such items as fuel, port charges and canal dues

### Capital costs

- Depend on the way the ship has been financed (e.g. dividends to equity, or interest and capital payments on debt finance)

### Cargo handling cost

- Expense of loading, stowing and discharging cargo

**Analysis of the major costs of running a bulk carrier**

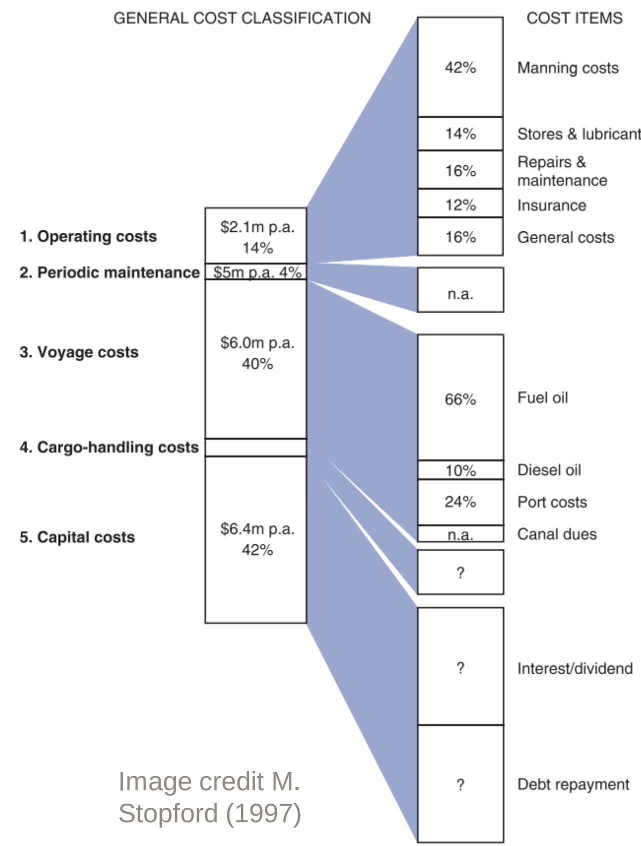



Image credit M. Stopford (1997)



Stopford M, 1997. Marine Economics, 2nd ed., Routledge, London. ISBN 0-203-75090-X.

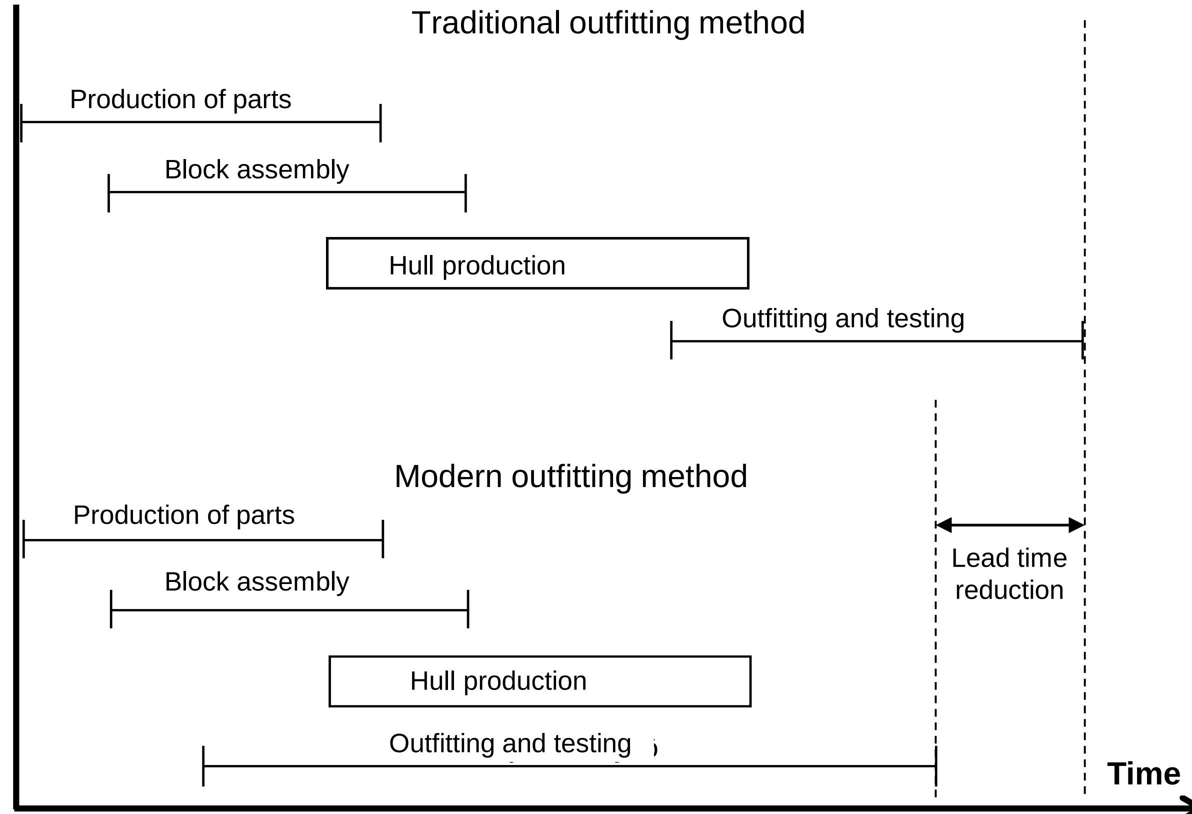
# Economic KPIs

## Example of economic KPIs of a ship

- Net present Value (NPV)
- Net Present Costs (NPC)
- Internal Rate of Return (IRR)
- Required Freight Rate (RFR)
- Payback period
- Average Annual Costs (AAC)
- Life Cycle Costs (LCC)

# Shipbuilding costs – Block Construction (2)

- Shipyards have been able to reduce their lead times by performing outfitting and testing already in the block assembly phase



# Shipbuilding costs - Modularisation

- Prefabrication → Minimization of on-board work → More efficient working environment → Efficiency and quality gains

- Facilitate standardized solutions
  - *Better knowledge on weight and performance of ship systems*
  - *Standards for commercial products with respect to price , quality, and performance*
  - *Supports the use of Computer Aided Manufacture (CAM)*

- Facilitate subcontracting

- Facilitates maintenance/refurbishment (if replaceable units)

- Advance commissioning (inspection, testing) of subsystems/modules possible

**Examples of modules**

- Machine modules, piping modules, cabin modules,..

Ready made cabin-module. Image credit Piikkio Works

# Shipyard organization

**A shipyard is an assembly place and a client for many suppliers**

- Propulsion machinery and machine systems
- Steel fabrication and welding equipment
- Outfitting including interior and cargo handling
- Management systems

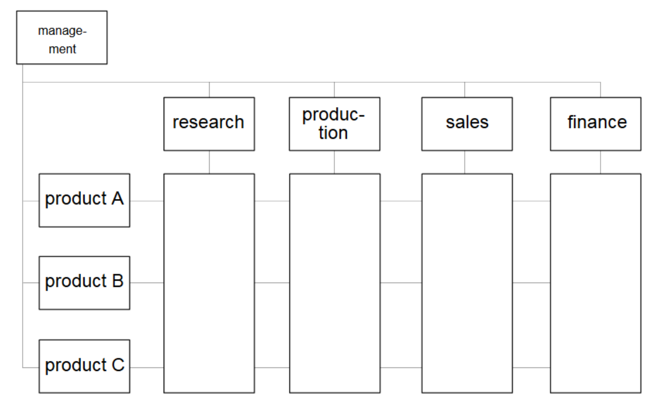
**Shipyard organization**

- Line organization
- Matrix management
- Shipbuilding project organization
  - *Often reflecting the prevailing trend; today's rend is non-hierarchical (light) and flexible organization*
  - *Responsibility and flexibility of individual workers tend to increase*

Example: Line organization


Image credit managementstudyguide.com

Example: Matrix organization



# Subcontracting challenges

- Delivery problems, delays
  - *Force majeure reasons*
- Transportation challenges
- Quality / performance issues
- Communications, information flow
  - *E.g. no information about delays*
  - *Cultural/language issues*
- Intellectual property rights (IPR) issues


Image credit E-ISG Asset Intelligence