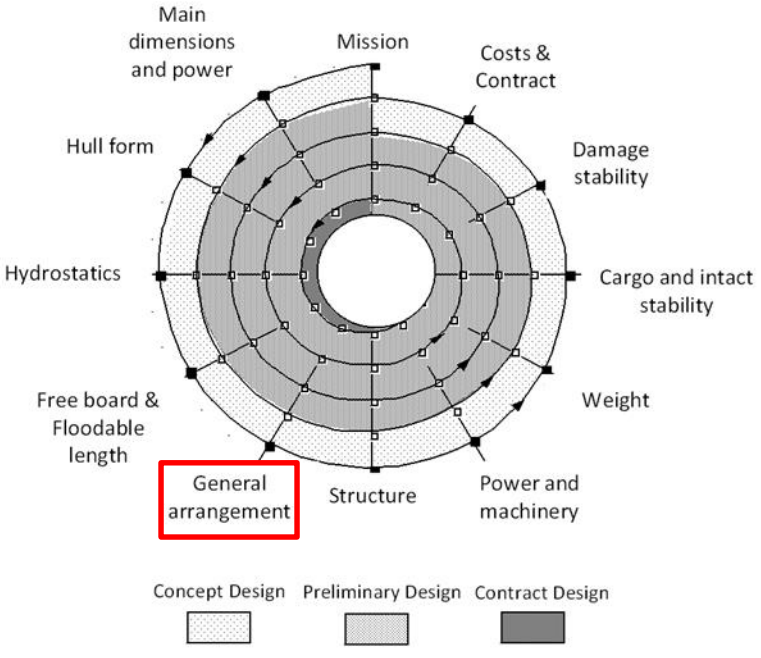
Aalto University
School of Engineering

MEC-E1004 Principles of Naval Architecture

Lecture 6 – General Arrangement

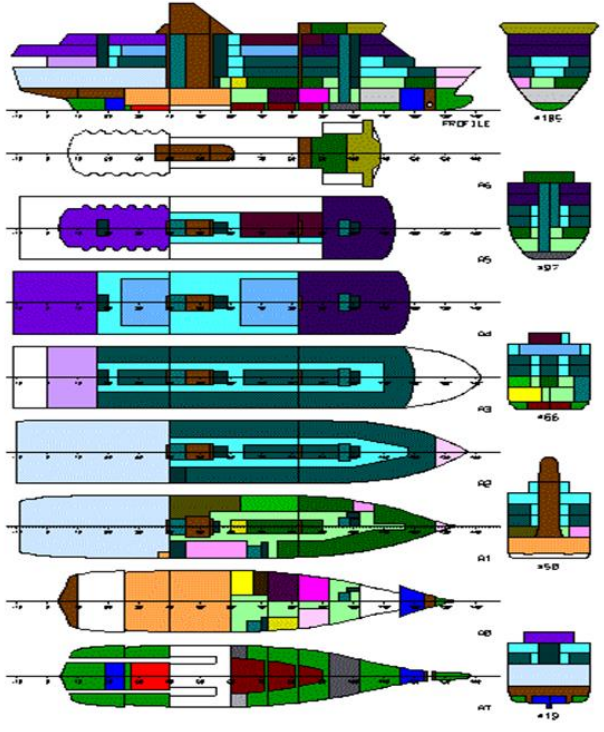
Learning points !

- After the lecture, you will be able to
  - *List and explain the main design criteria for a ship's General Arrangement (GA)*
  - *Create & draft a GA for your project ship*



Assignment 6 – General Arrangement

- Define an initial general arrangement for you ship. Consider the following :
  - Various types of capacity/space/area requirements concerning for instance
    - ✓ Public spaces, accommodation, technical spaces (e.g. machinery)
    - ✓ Cargo capacity, tanks
  - Functional requirements concerning for instance
    - ✓ Safety and Environmental performance
    - ✓ People and cargo flows/handling (logistics).
    - ✓ Cargo handling (e.g. deck cranes), auxiliary (e.g. fuel, waste treatment, air conditioning), and safety (e.g. evacuation) systems
  - Rules and regulations (e.g. fire zones, watertight compartments)



GA – Objectives and criteria

- 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

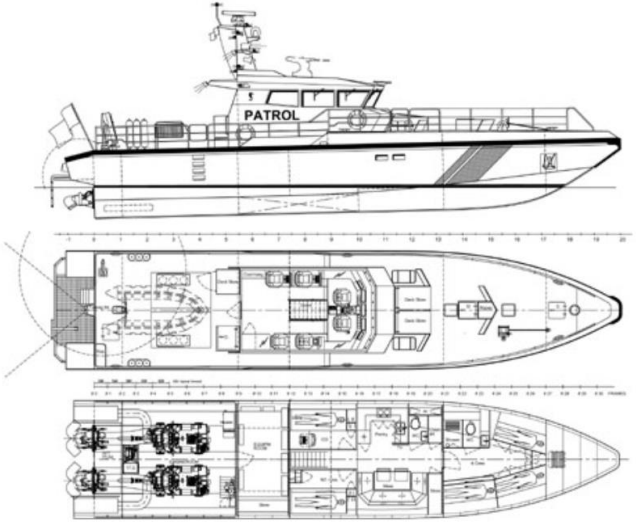


Image credit Docksta Varvet

General arrangement

Question: What is the starting point for the determination of a ship's GA, i.e., what input do you need to get started?

GA – Key items for consideration

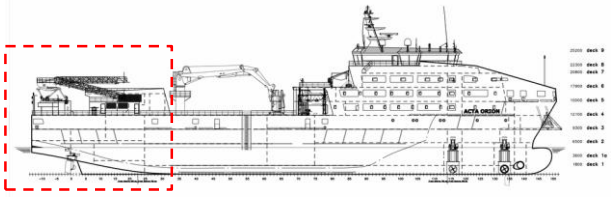
- Ship main dimensions, hull shape, frame spacing
  - *These define the available space, strength, stability etc.*

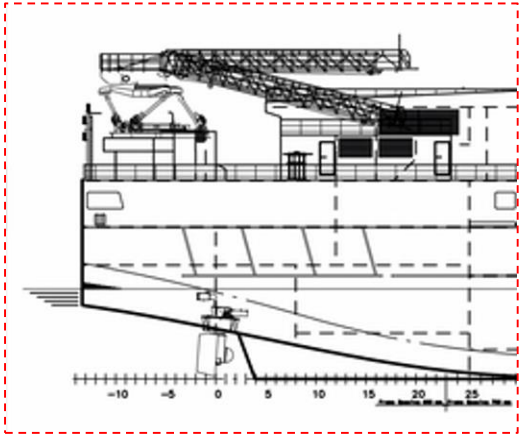
- Capacity requirements concerning
  - *Cargo type and amount*
  - *Cargo handling capability requirements*
  - *Passenger capacity (no. of passengers, standard of cabins and other areas in [m2/person])*
  - *Crew capacity (no. of crew and their comfort standard [m2/person, regulated], windows required 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





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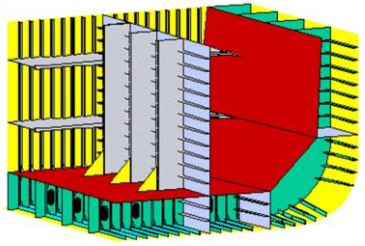
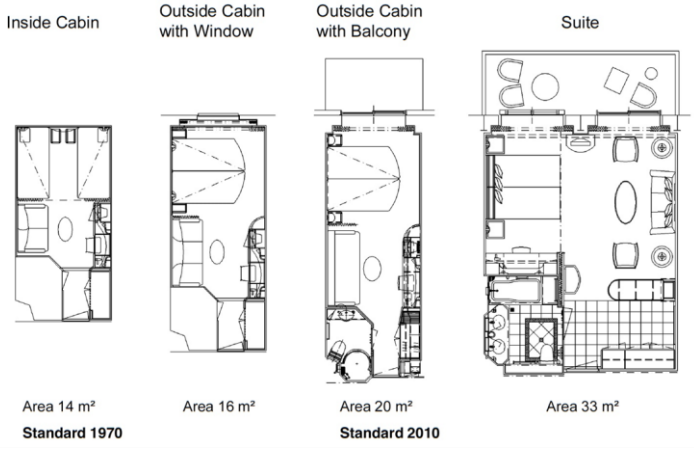
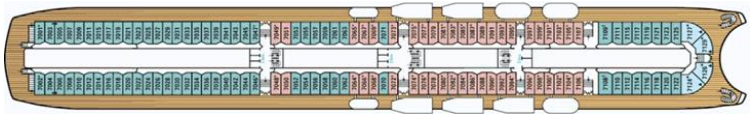
GA – Frame Spacing

- Frame spacing (s) varies between 500 - 900 mm as a function of ship length L
- Web frame spacing S = n * s; n = 3,4
- Frame spacing is the basic module length
- Frame location defined by frame number





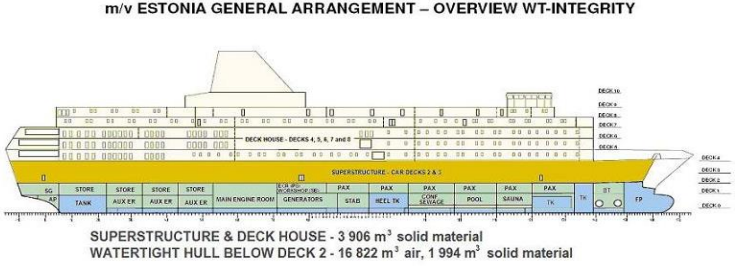


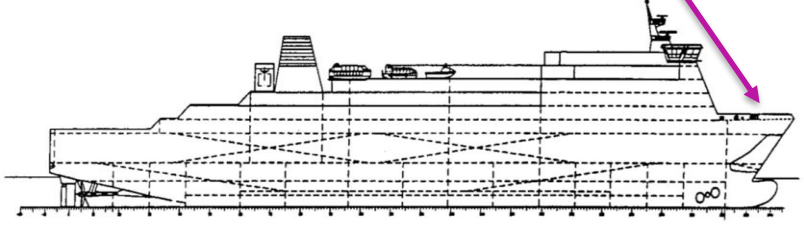
7th deck of Crystal Symphony (cruise ship)

GA – Bulkhead location

- Different types of bulkheads
  - *Fire bullheads*
    - Concern primarily the layout of the accommodation decks
  - *Watertight bulkheads*
    - Affects the lower / bulkhead decks → Large spaces not possible below the bulkhead deck
  - *Collision bulkheads*
    - No spaces for humans in front of the collision bulkhead

- Regulated by SOLAS



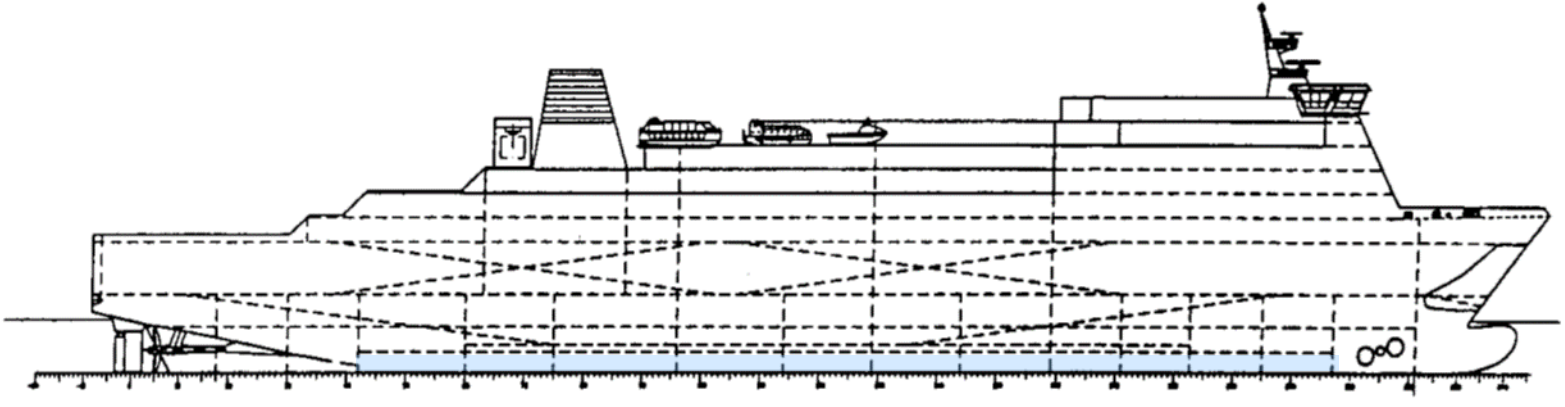


GA – Double bottom hull

- Double bottom (or equivalent) compulsory on passenger ships

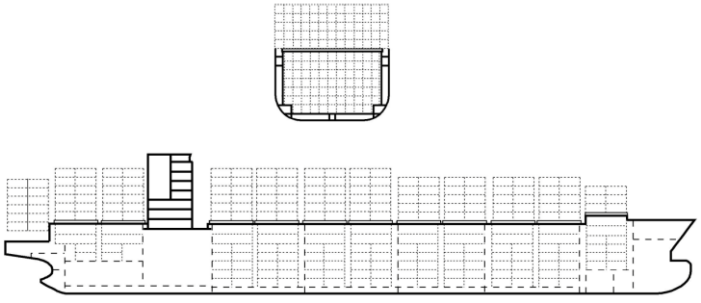
- Double hull (or equivalent) compulsory on tankers

Image credit BP



GA - Determination

- Module sizes (e.g. TEU containers, cabins)
- Space/volume requirement
  - *Stowage factors [m3/ton] indicates how many cubic meters of space one metric tonne of a particular type of cargo occupies in a cargo hold*
    - For certain type of cargo, some reserve capacity might be allowed for or judged necessary
- Stability requirements
  - *Might require the division of a cargo hold into separate sections / tanks*
- Requirements for efficient loading/unloading



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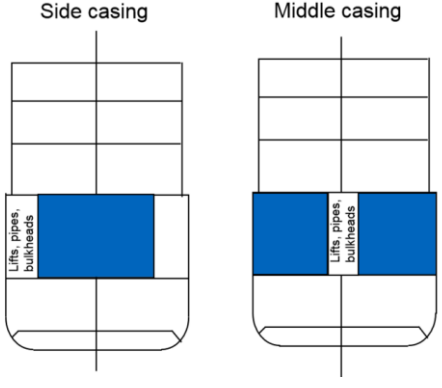


Different layouts of a RoPax ship's cargo hold

GA - Determination

TEU capacities for common container sizes

Length	Width	Height	Internal Volume	TEU
20 ft (6.1 m)	8 ft (2.44 m)	8 ft 6 in (2.59 m)	1,172 cu ft (33.2 m^3)	1[6]
40 ft (12.2 m)	8 ft (2.44 m)	8 ft 6 in (2.59 m)	2,389 cu ft (67.6 m^3)	2[6]
48 ft (14.6 m)	8 ft (2.44 m)	8 ft 6 in (2.59 m)	3,264 cu ft (92.4 m^3)	2.4
53 ft (16.2 m)	8 ft (2.44 m)	8 ft 6 in (2.59 m)	3,604 cu ft (102.1 m^3)	2.65
High cube				
20 ft (6.1 m)	8 ft (2.44 m)	9 ft 6 in (2.90 m)	1,520 cu ft (43 m^3)	1[2]
Half height				
20 ft (6.1 m)	8 ft (2.44 m)	4 ft 3 in (1.30 m)	680 cu ft (19.3 m^3)	1[2]

GA – Cargo hold design

- Different types of cargo requires different types of cargo holds and cargo handling systems

  - *Break bulk*
    - Cargo without standards (mainly in developing countries)
  - *Unitized cargo*
    - Standardized cargo units (e.g. TEU containers)
  - *Heavy units*
    - Massive pieces and equipment (e.g. industrial equipment, offshore structures)
  - *Dry bulk cargo (irtolasti)*
    - Homogeneous unpacked dry bulk cargo (e.g. minerals, coal, corn)
  - *Liquid bulk cargo*
    - Homogenized liquid cargo (e.g. crude oil, oil products, chemicals, LPG, LNG)
  - *Rolling (or wheeled) cargo*
    - Cargo on wheels (e.g. trucks, trailers)

Different types of cargo units

- Pallet
- Container
- Roll trailer
- Full or semi trailer
- Train carriage/wagon
- Barge

GA – How can we move cargo ?

- *Vertical (lift on - lift off, LOLO)*
  - Varying loading speed
    - For break bulk 20-60 ton/hr, for containers 300-800 ton/hr, for bulk 1,000-5,000 ton/hr)

- *Horizontal (roll on - roll-off, RORO): cargo is transported horizontally on wheels*
  - Requires ramps, lifts
  - Cargo can also be floated to/from ship
  - Cargo securing (fastening) important for safety

- *Pumping: transfer of liquid cargo to and from tanks by pumping*
  - The pumping capacity is often measured so that the pumping time is 24 hr

- The speed and cost of cargo handling are very important
  - *Cargo handling equipment onboard or ashore ?*

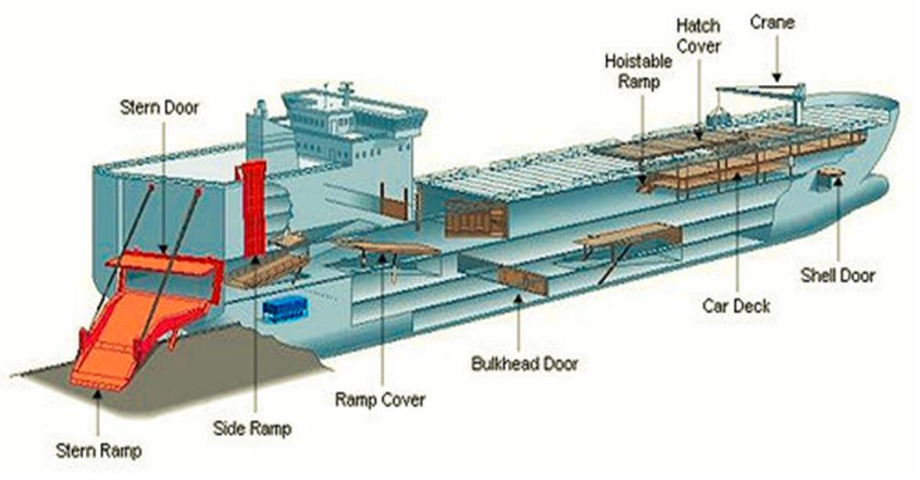
Image credit Liebherr

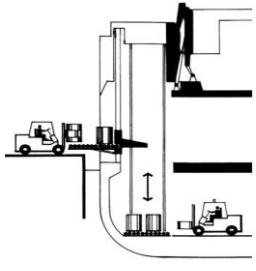

Image credit pacificmarine.net


Image credit portinfo.co.uk

GA – Cargo handling equipment

- Cargo gear /Cranes
- Hatch cover
  - *Different types: pontoon, rolling cover, folding cover, roll stowing conver,…*
- Doors
  - *Bow, side, stern doors*
- Lifts and ramps
  - *Stewing (turning) ramp, hoistable ramp,…*
- Mooring equipment





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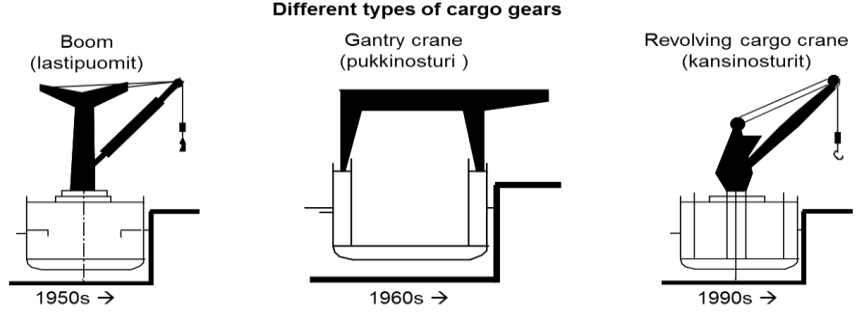


GA – Bow doors

- The MS Estonia accident
  - *https://safety4sea.com/cm-ms-estonia-sinking-one-of-the-deadliest-accidents-in-european-waters*
  - *https://www.youtube.com/watch?v=nJ8TASazLcA*

- Different types of bow doors
  - *Bow visor*
    - The bow visor of MS Estonia was “opened” by wave induced water pressure pushing it upwards
  - *Clam-type door*
    - Considered safer than a bow visor

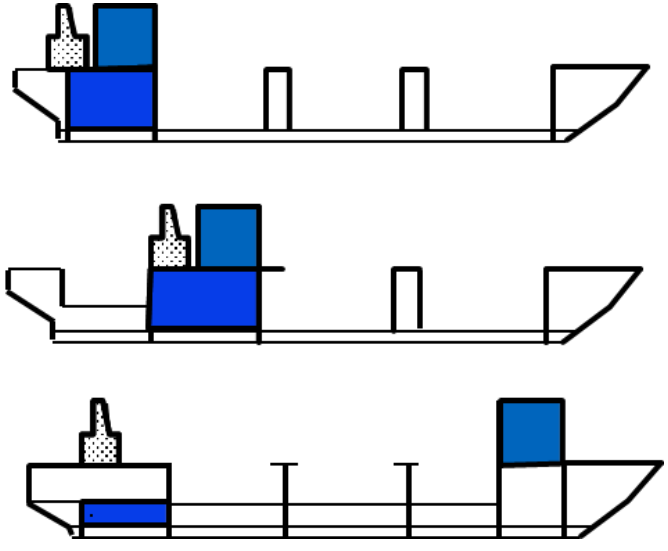
- The outer bow door is typically not watertight
  - *Behind the outer door is typically a watertight door that is often also used as ramp for cargo loading/ unloading*

Image credit SVT

Image credit Wärtsilä

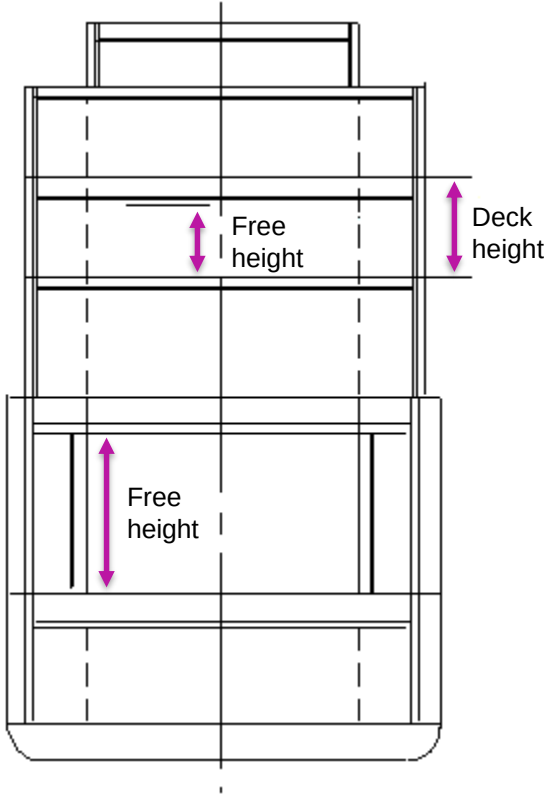
GA – Deckhouse location

- A high and narrow deckhouse is typically efficient with regards to the use of space
- Various possibilities:
  - *bow, 1/2L, 3/4L, aftship*
- Things to consider
  - *Comfort (ship movement, noise and vibrations)*
  - *Visibility from the wheelhouse*
  - *Connection to the engine room*
  - *Weight distribution (trim)*
  - *Construction costs*
  - *Continuity of the steel structures*
  - *Use of space*
- Engine casing can be located outside the deck house



GA – Height requirements

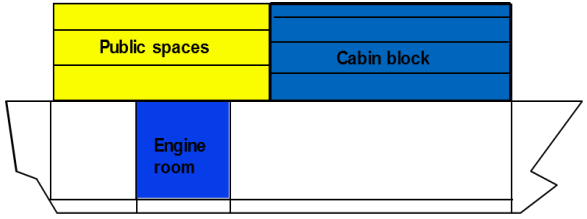
- Free height vs. deck height
  - *Deck height include structures and pipes*
- RORO decks
  - *The required free height is 4.3 m for lorries and 4.6 - 6 m for roll trailers*
- Accommodation (cabin) areas
  - *In cabin areas the minimum free height is 2.1 m*
    - Requires approx. 2.6 m deck height
  - *In public spaces deck height is typically 2,8m - 3,2 m, depending on the width of the space*
    - Spaces going through many decks also possible
- Deck curvature has to be considered

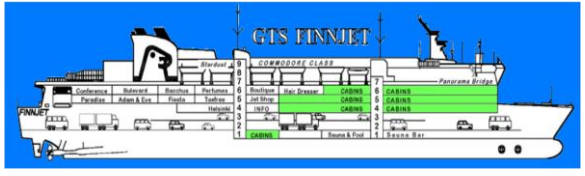


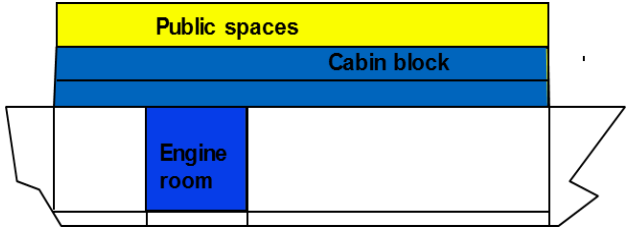
GA – Cabin Location (passenger ships)

- Concentration of cabins to a specific block/area
  - *Easy to meet noise and vibration criteria (+)*
  - *The cabin area might feel claustrophobic (-)*
  - *Longitudinal deck height variations → structural strength challenges (-)*

- Homogenous decks, distributed cabins
  - *Avoidance of claustrophobic cabin areas (+)*
  - *Continuous decks → High structural strength (+)*
  - *Can be challenging with regards to noise and vibration (-)*



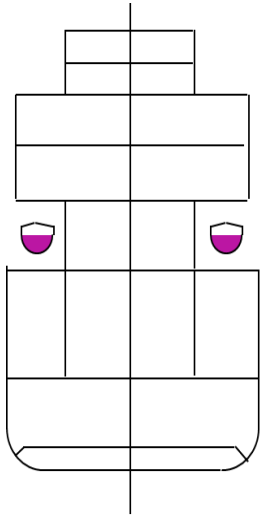




GA – Lifeboat location criteria (passenger ships)

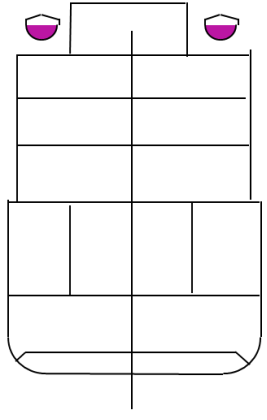
- On the main deck
  - *Modern standard*
  - *Short distance to the water (+)*
  - *Occupy valuable onboard space (-)*

Image credit RCCL



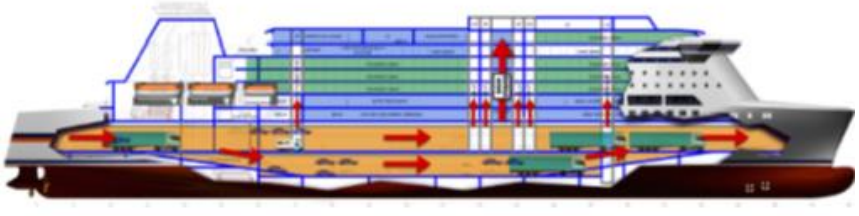
- On the top deck
  - *Not disturbed the functionality of the ship (+)*
  - *Long distance to water (-)*

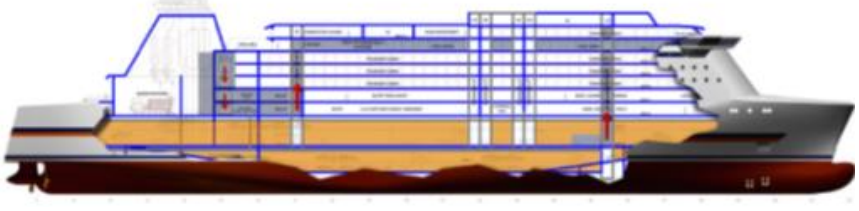
Image credit Viking Line

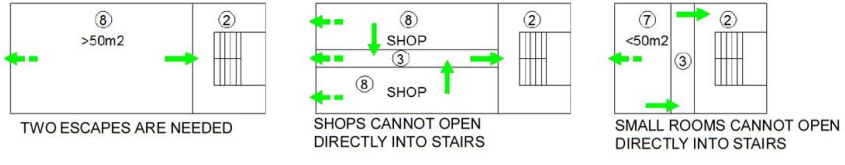


GA – Internal connections

- Examples of internal connections
  - *Corridors, staircases, lift casings, evacuation routes, lounges*
  - *Consideration of fire and watertight doors*
  - *Connections for hotel services, food delivery, waste, etc.*
  - *Connections for energy distribution, air conditioning and piping*
- Design criteria set by the ship's functional requirements
- Described by flow diagrams
- Design is based on system solutions
- All spaces on the ships have to reachable







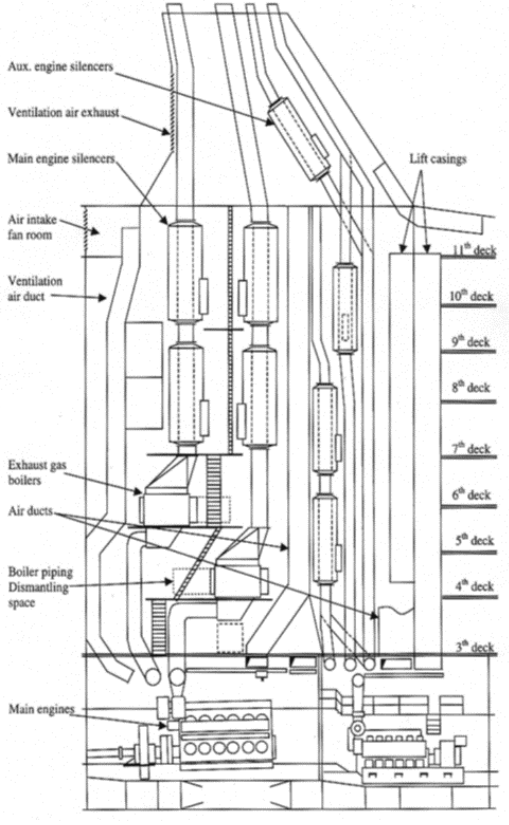
GA – Engine room

- The required amount of space depends on the main engine and propulsion system

- Factors to be considered:
  - *Engine room size and location vs. payload spaces*
  - *Length of propeller axis should be as short as possible*
  - *Requirements for damage stability*
  - *Requirements for trim*
  - *Service requirements and connection to the accommodation area*

- Location of the engine room
  - *AMidships → enough space for a large number of engines*
  - *1/4 L → good weight distribution*
  - *Aft end of ship → efficient use of space*

- Tanks: fuel, lubrication oil, fresh water, ballast water
  - *Centralized location of fuel tanks reduces production costs (painting, outfitting), but the trim requirements have to be fulfilled*
  - *The thermal distortions have to be accounted for*
  - *Consideration of environmental protection requirements (e.g. MARPOL)*

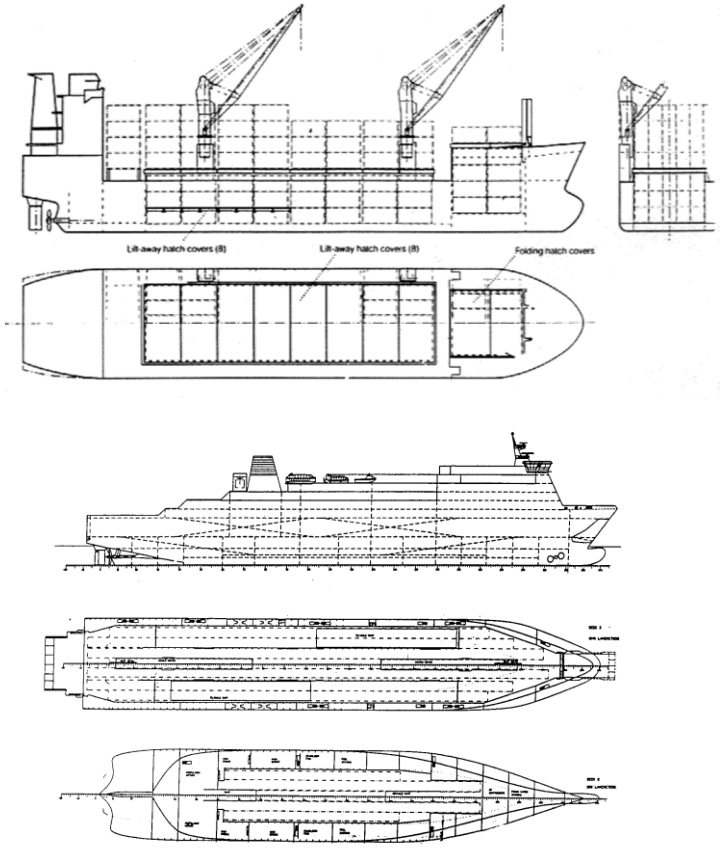


Summary

A well-designed GA is vital for a ship's functionality and safety

- Defined considering the ships functional requirements, (safety) regulations, and business model
  - *In passenger ships, the GA strongly affects the passengers' onboard experience*

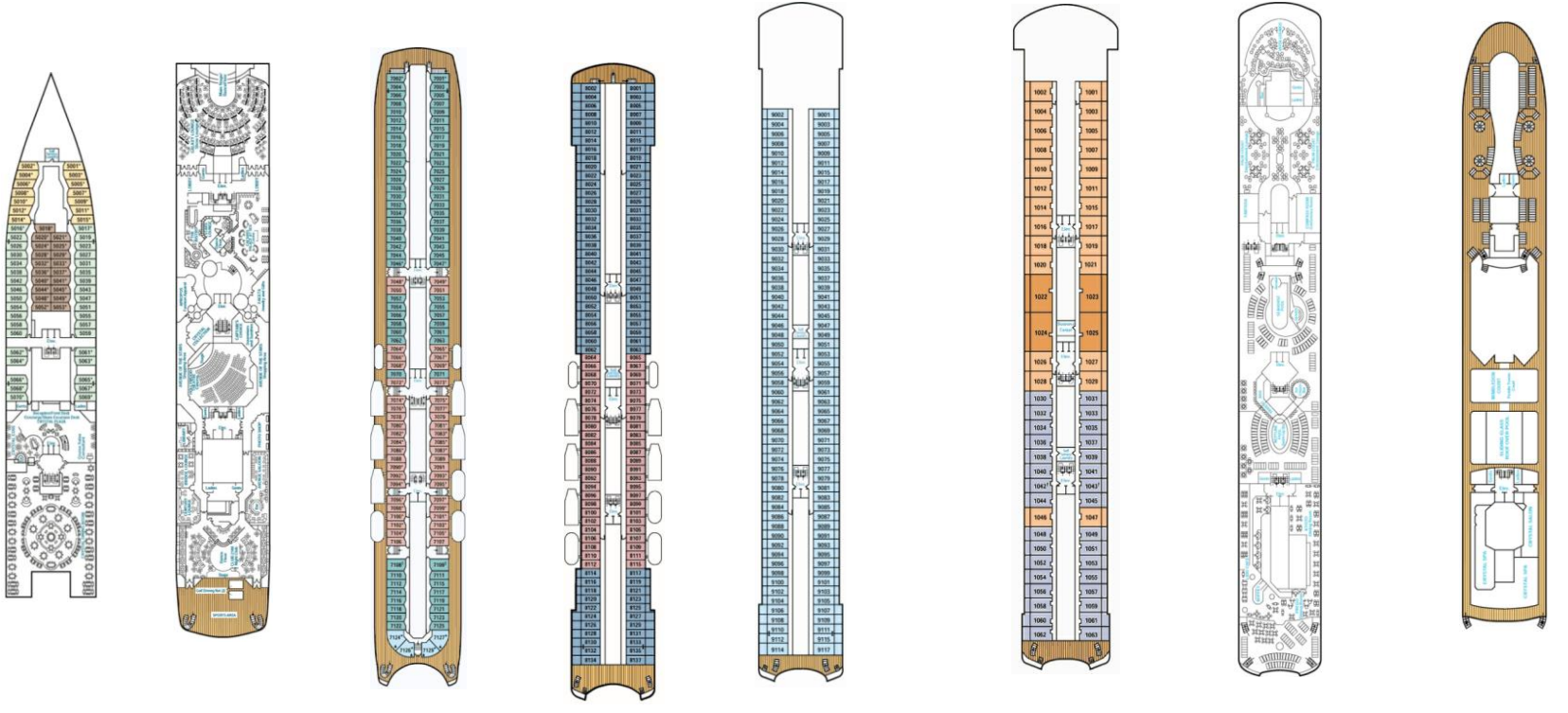
- Structural continuity is necessary to limit stress concentrations



Bonus material

Example: GA of MS Crystal Symphony

Deck 5 Deck 6 Deck 7 Deck 8 Deck 9 Deck 10 Deck 11 Deck 12



Example: space distribution