GIGANTISM IN SHIPBUILDING

AND

CORRELATIVE SAFETY REQUIREMENTS

LE RENDEZ-VOUS DE L'ASSURANCE TRANSPORTS - CANNES
28 ET 29 AVRIL 2009

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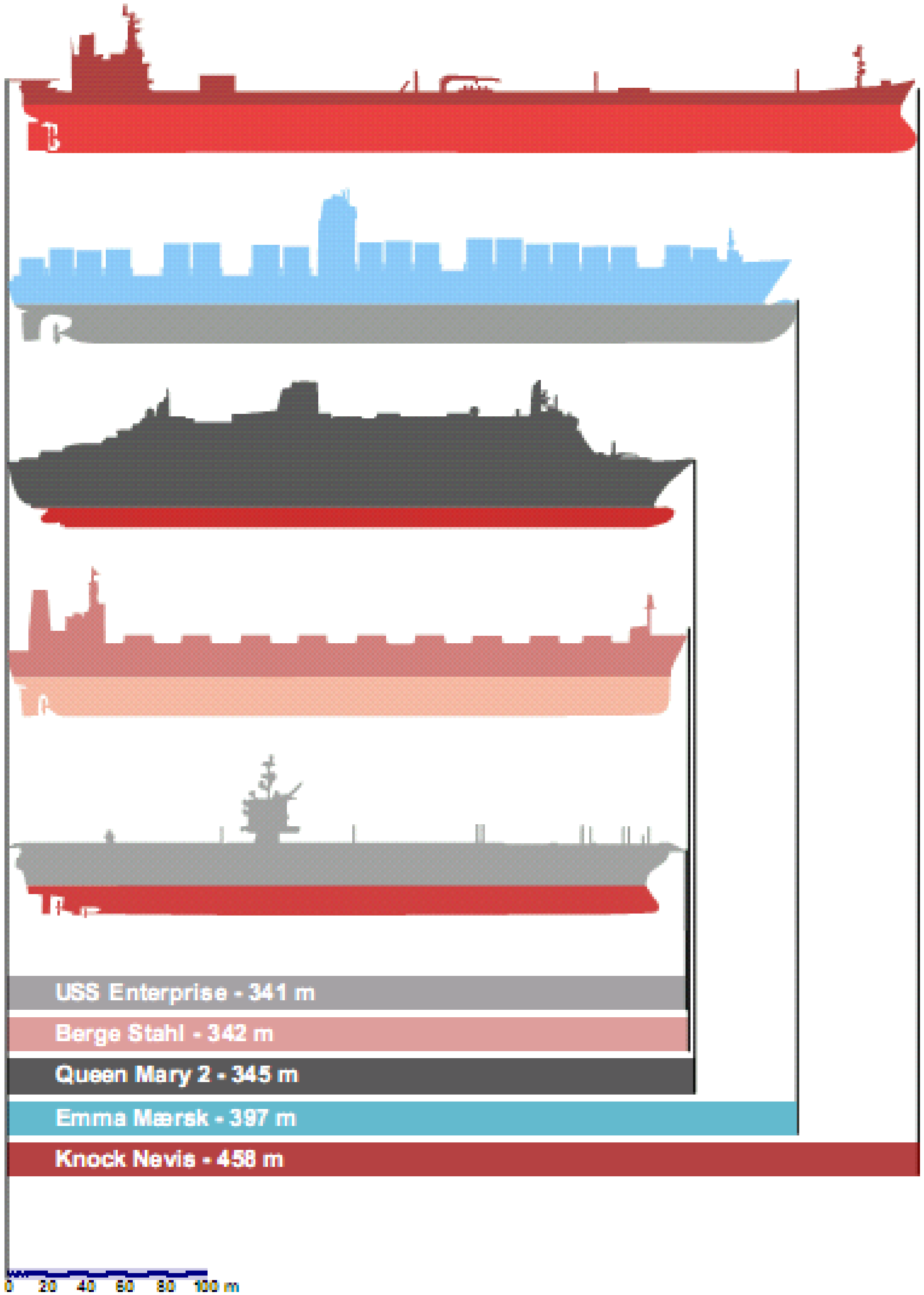
THE GLOBAL PICTURE

- Economy of scale: less carrying cost per unit of cargo or passenger
- Imperative to ensure a sufficient filling ratio
- Reduced flexibility is a disadvantage:
  - Reduced number of port facilities
  - Shortage of docking facilities
  - Not allowed in Panama & Suez canals. Malacca strait in the future?
- Volume of casualties

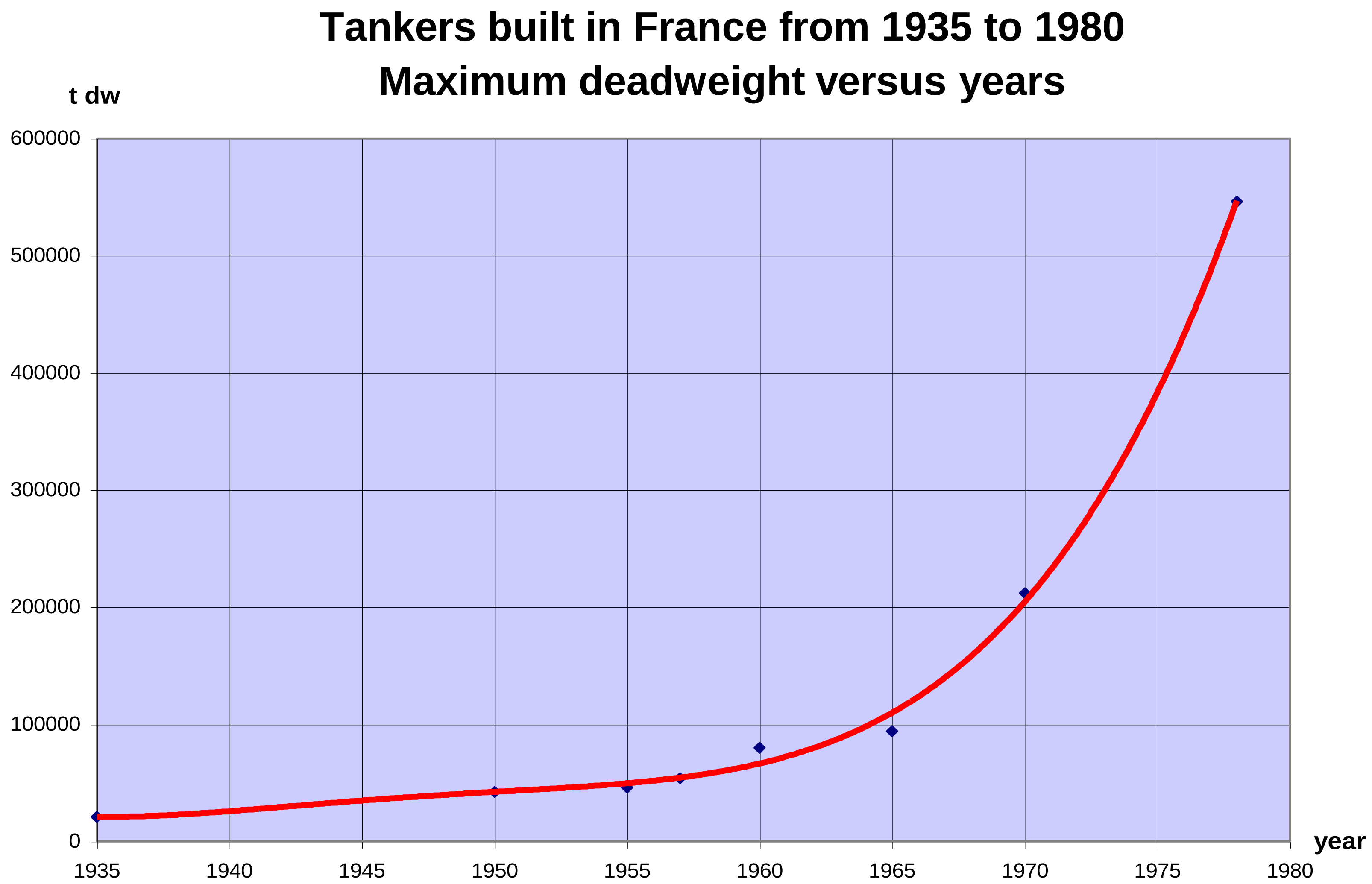
SHEER SIZE


USS Enterprise - 341 m
Berge Stahl - 342 m
Queen Mary 2 - 345 m
Emma Mærsk - 397 m
Knock Nevis - 458 m
0 20 40 60 80 100 m

CONCERNED SHIPS

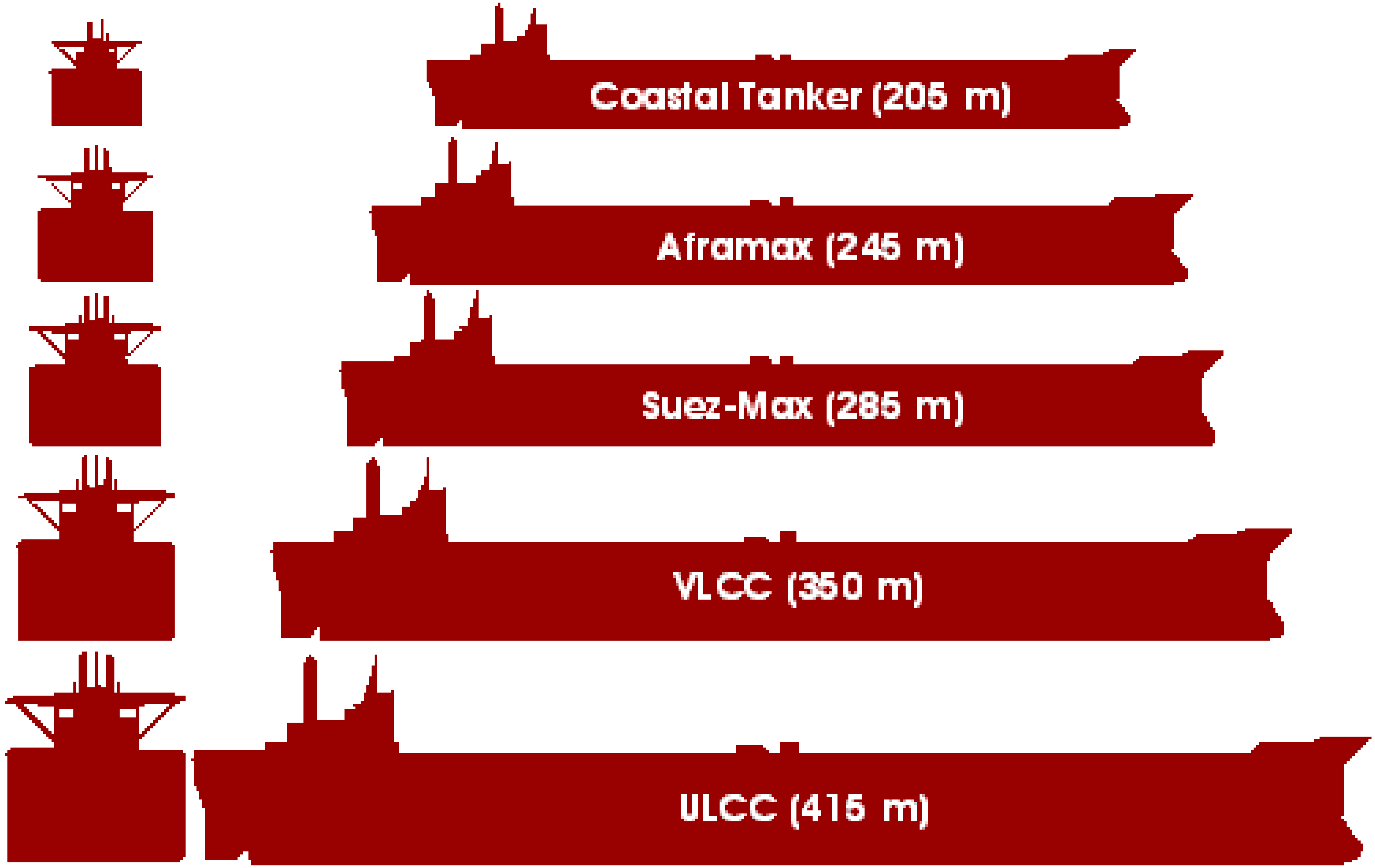
1. Tankers
2. Bulk carriers
3. Container ships
4. Cruise-liners

TANKERS



and studies for 1,000,000 tdw tankers

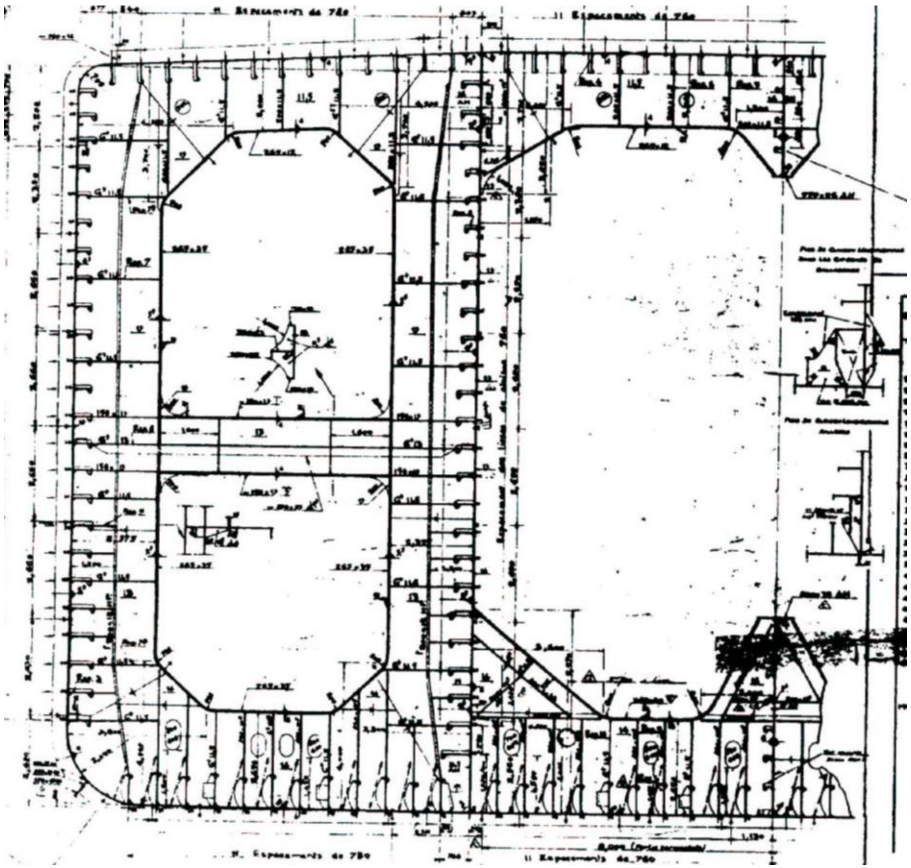
TANKERS



Coastal Tanker (205 m)
Aframax (245 m)
Suez-Max (285 m)
VLCC (350 m)
ULCC (415 m)

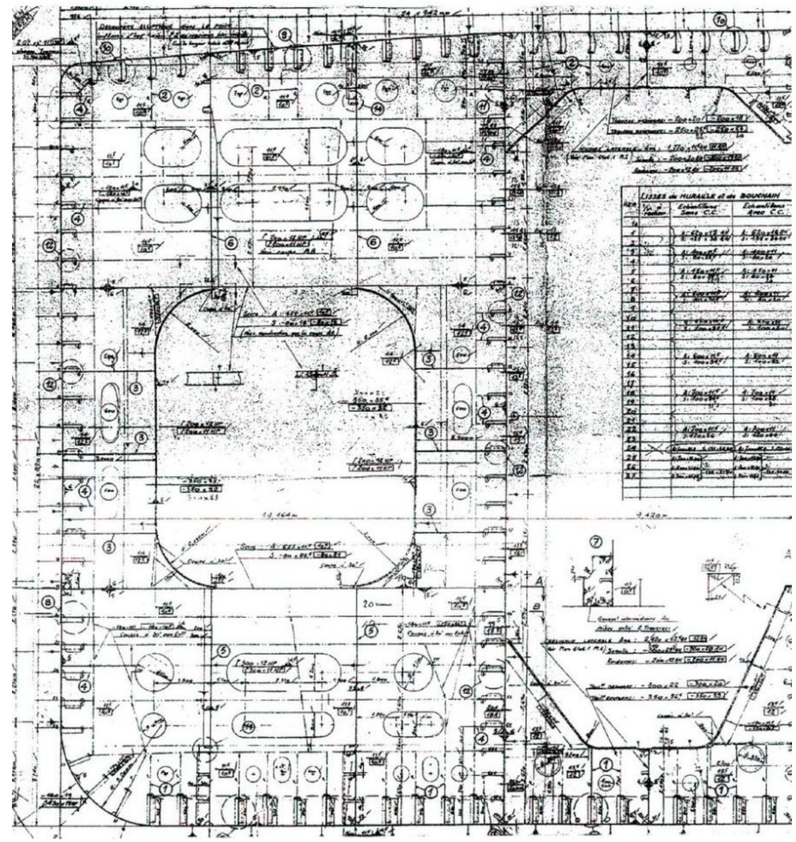
TANKERS

Bételgeuse : 120 000 tdw



L = 268.66 m B = 38.92 m D = 20.35 m d = 15.087 m
Bottom thickness = 26 mm DH

Magdala : 211 000 tdw



L = 307.47 m B = 47.17 m D = 24.5 m d = 17.68 m
Bottom thickness = 27 mm DH

TANKERS

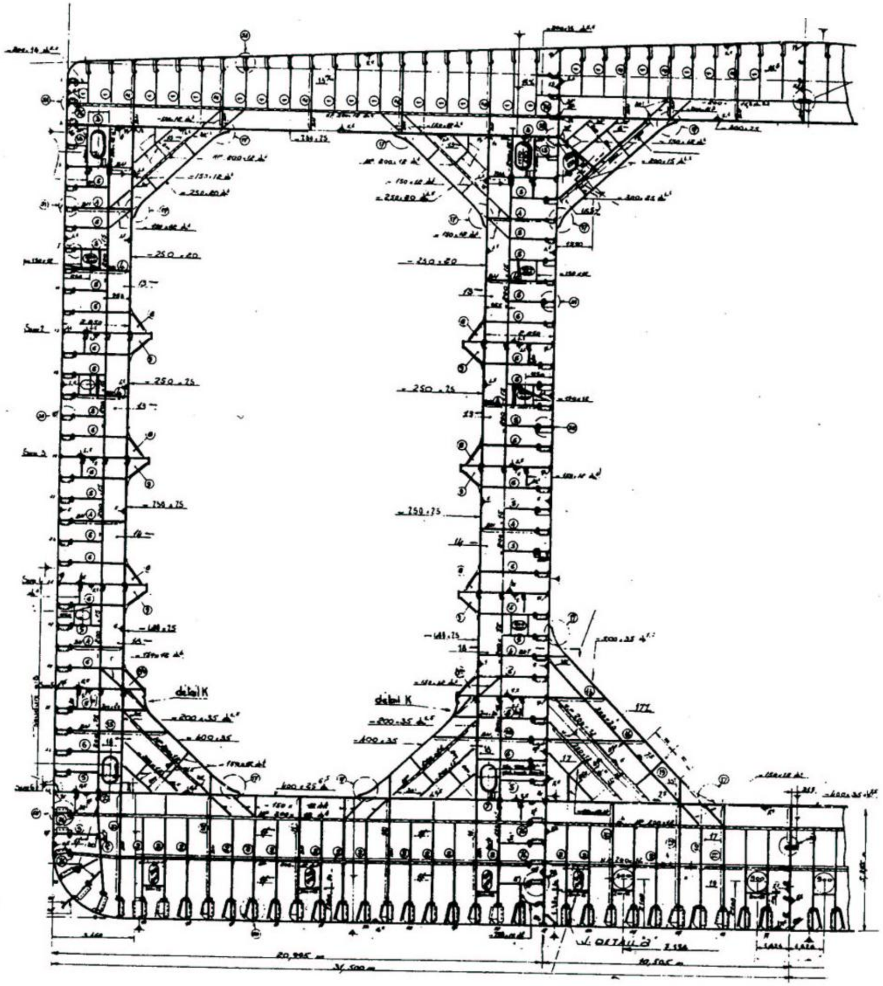
Batillus : 550 000 t - CA 1976 for Shell

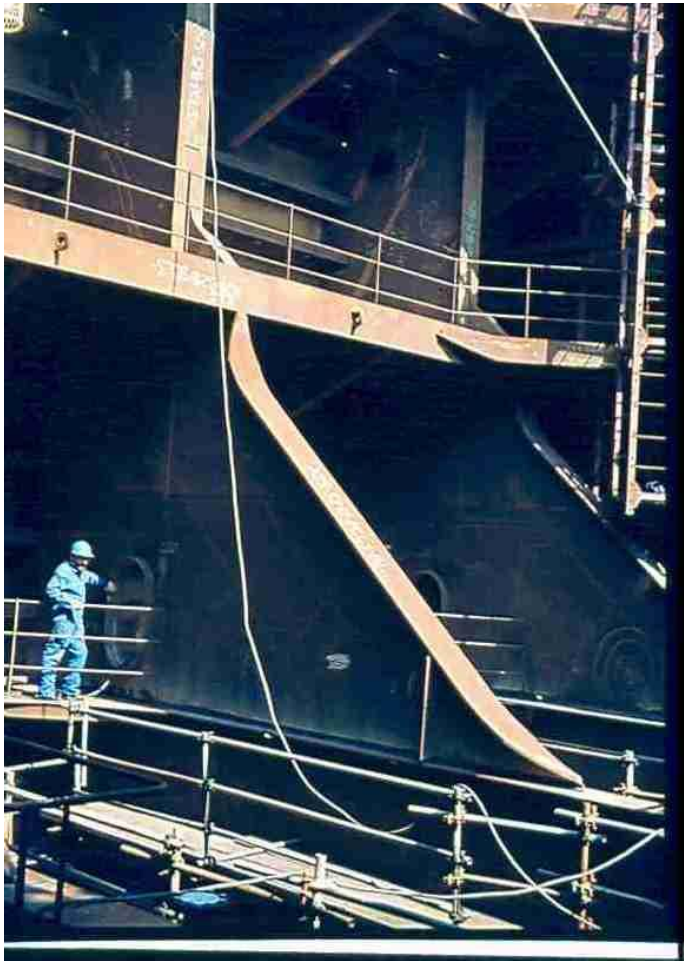
TANKERS

Batillus & Nordic Clansman

TANKERS

Batillus : 550,000 tdw





L = 414.22 m B = 63 m D = 35.9 m d = 28.6 m

Bottom thickness = 27,5 mm DH Side shell thickness = 25 m

Technical structural challenges

- **Magdala: shear buckling during tank tests**

  solved by measurements and stress computation (first time)

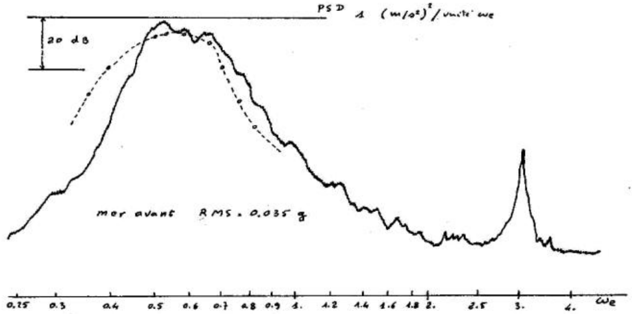
- **300,000 tdw with HS steel: early fatigue cracking**

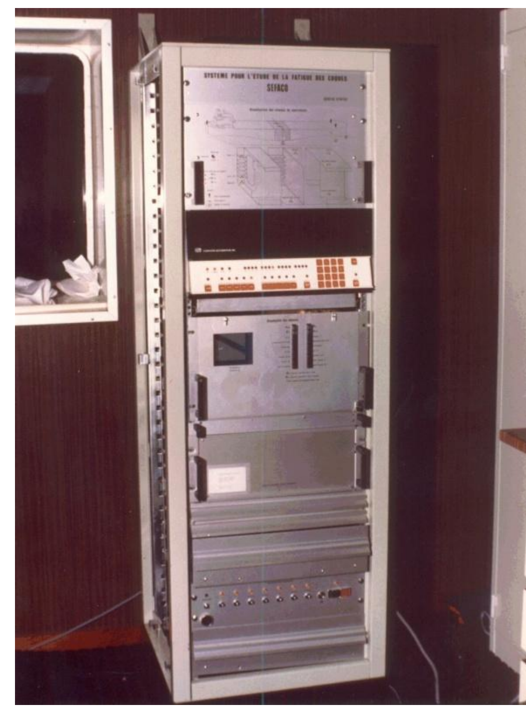
  solved by fatigue tests, detail new designs

- **550,000 tdw: springing phenomenon**

  solved by ship behaviour and structural response computation

  verified by hull stress monitoring





TANKERS

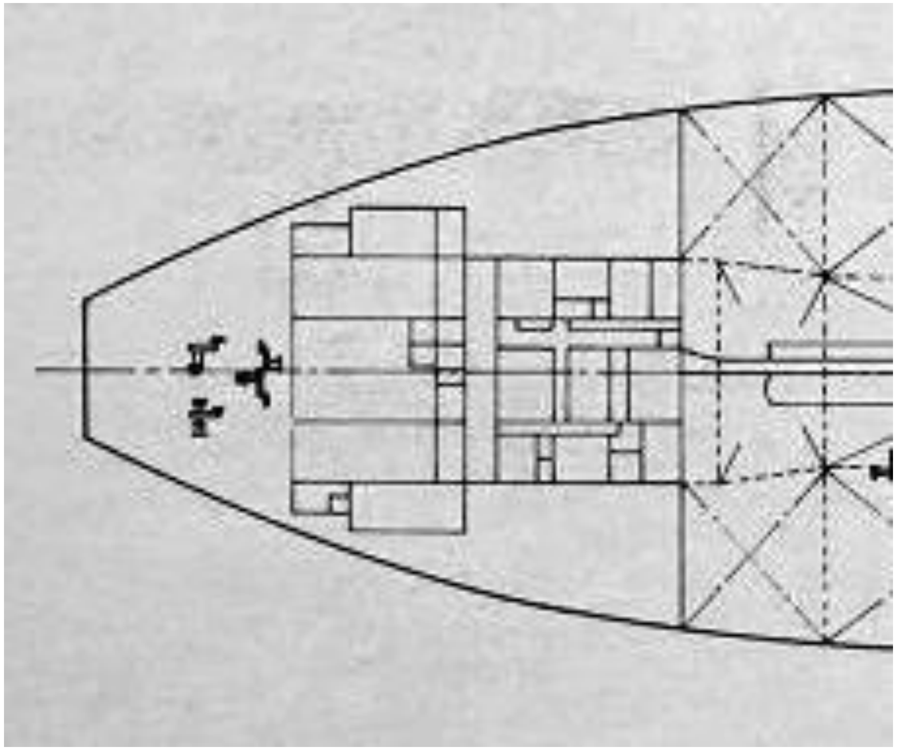
550,000 tdw operational safety

Stop length > 2 miles - Turning circle diameter > 1 mile

TANKERS

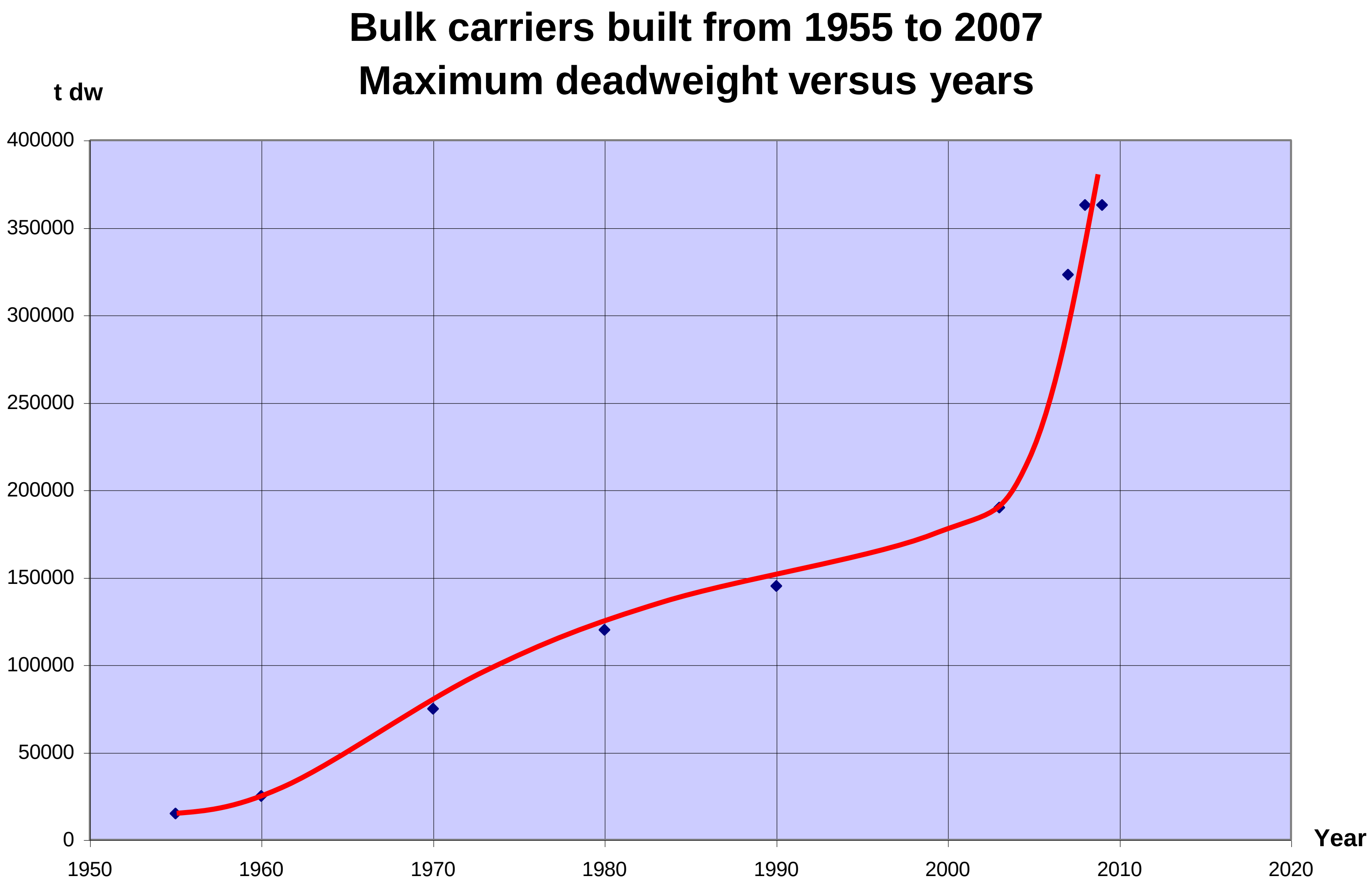
550,000 tdw operational safety

two independant engine rooms



two propellers, two rudders

BULK CARRIERS



BULK CARRIERS

Berge Stahl 364,000 tdw (9 ships)

Very Large Ore Carriers (VLOC)

MAIN PARTICULARS:	
L.O.A.	327.00m
B.MLD	55.00m
D.MLD.	29.00m
Summer Draft	21.40m
Gross Tonnage	152,305T
Net Tonnage	55,601T
Deadweight	297,592T
Speed	atb. 14.5Knots
MAIN ENGINE:	
MAN B&W 6S80MC-C Mk7	1set
M.C.O.	22,360kW(BHP)*73rpm
NOR.O.	19,000kW(BHP)*abt.69rpm

HE HENG

Source NACKS SHIPYARD

BULK CARRIERS

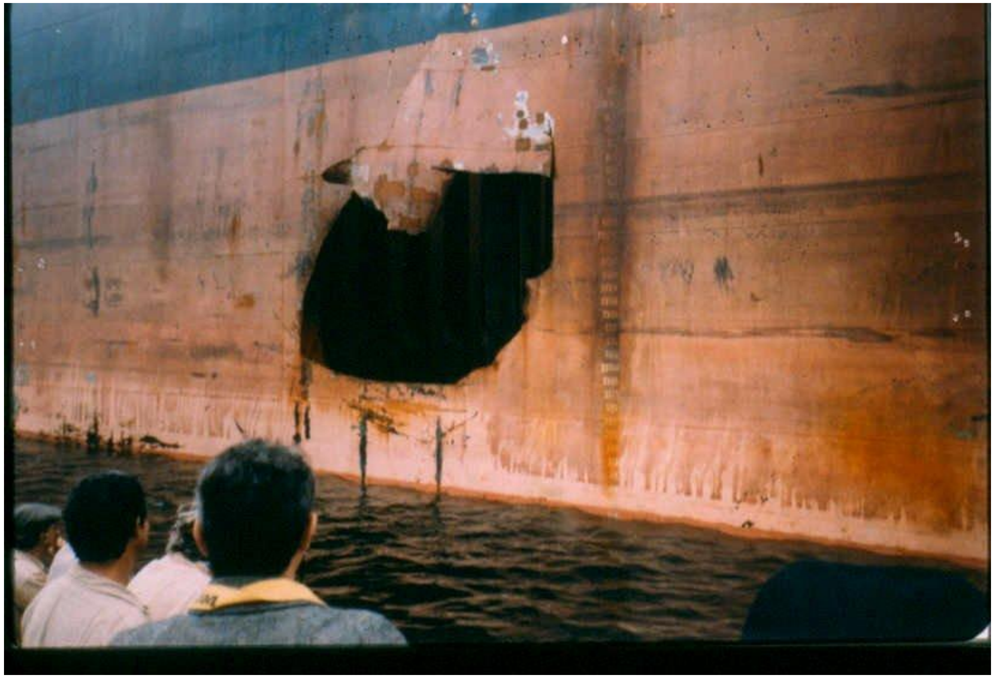
Technical structural challenges

- **First generation: lamellar tearing at bulkhead foot**
  solved by steel plate testing requirement (Z grade plates)
- **Hatchcoaming/hatchcover stiffnesses: hold tighness**
  solved by hatchcoaming deformation computations
- **Ballast in cargo tanks: sloshing and damages**
  solved by model tests and upper tank shape design
- **Fatigue cracks and domino effect: shell brittle fracture**
  solved by stress computations, fatigue and crack propagation
- **Fast loading by gravity (16,000 t/h): bottom pressure**
  solved by R&D and impact structural response computation

BULK CARRIERS

Technical structural challenges

Resulting damage

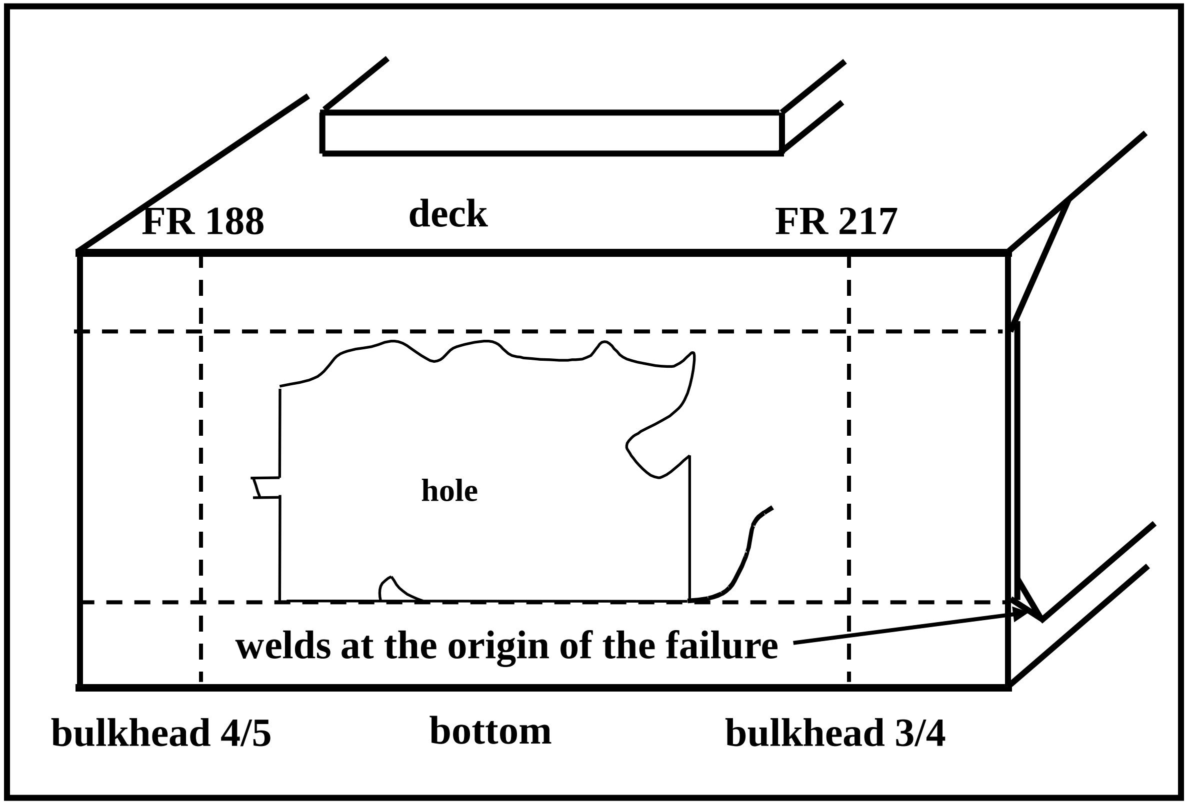


BULK CARRIERS

Technical structural challenges

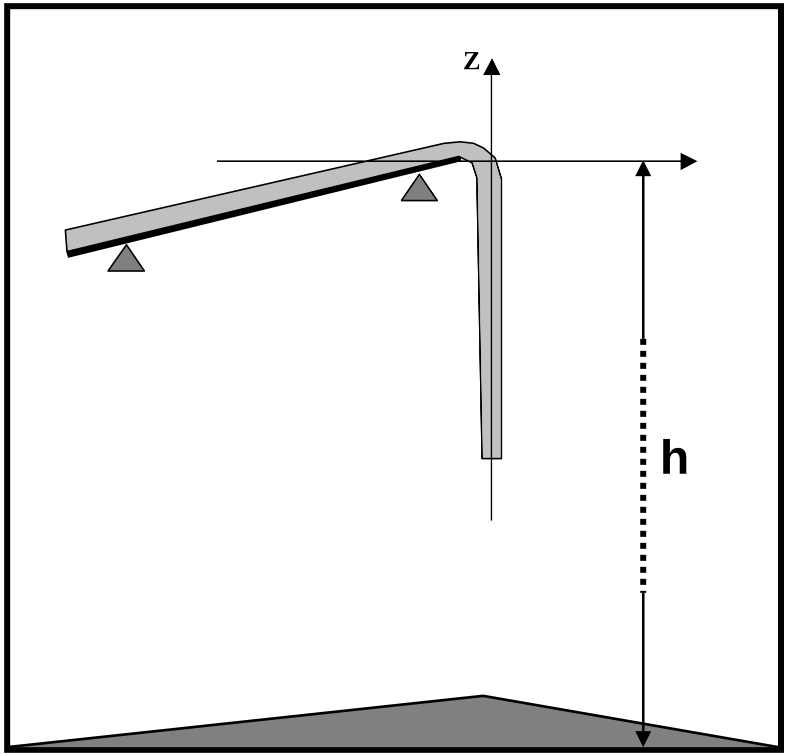
Fatigue cracks
Domino effect

Resulting damage



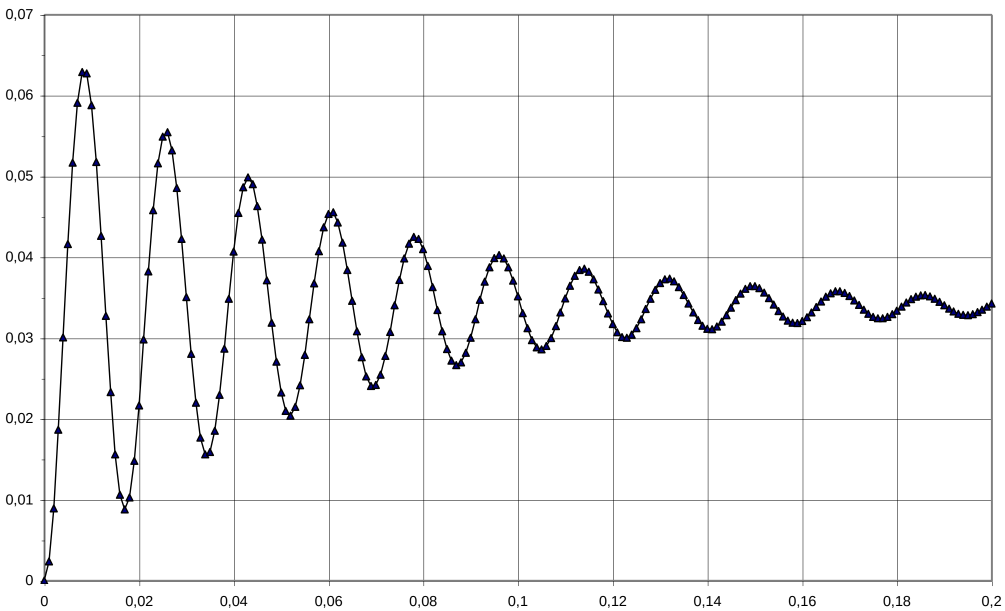
Technical structural challenges

Loading process



16,000 t/h h = 26 m

Plate dynamic response



Amplification factor / static = 1.85

BULK CARRIERS

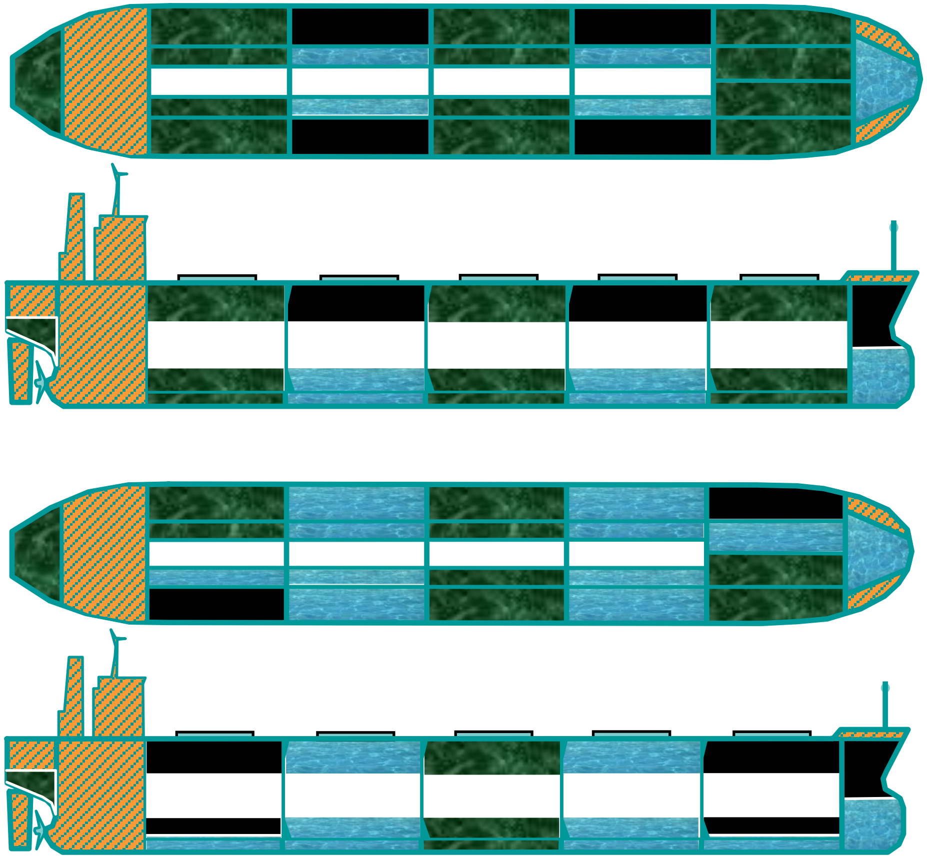
Operational safety

- **Green water on fore deck: ship losses**
  solved by R&D and new rules for fore part and monitoring
- **Ballast water exchanges: stability, crew safety**
  solved by computation, operational procedures

Water ballast exchange

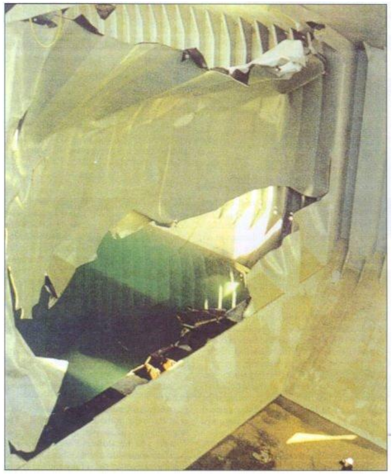
Flow through

Sequential exchange



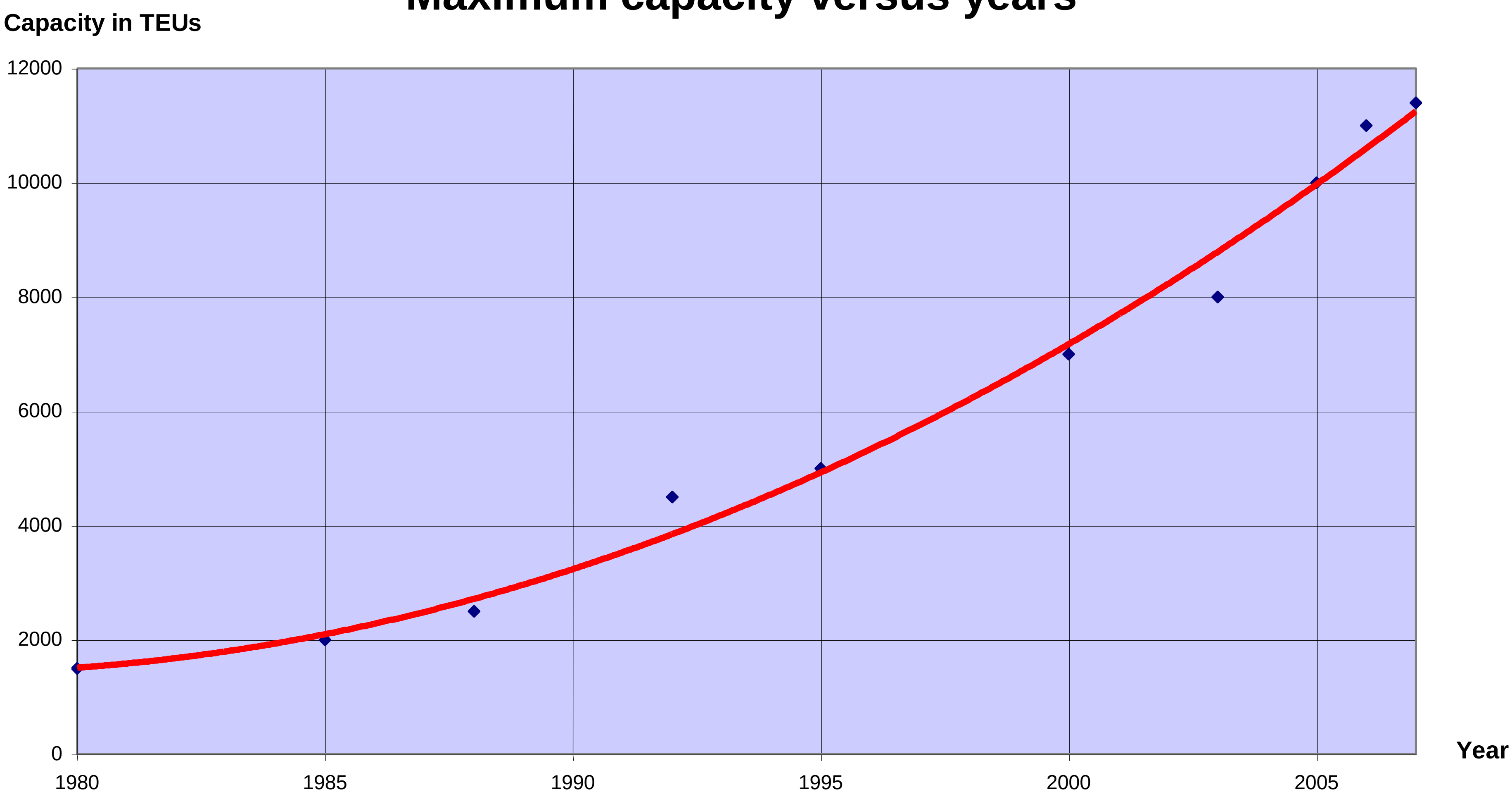
Green water on fore deck

1. Hitting of a strong wave ahead
2. Shipping of green water
3. Damage of the first hatch cover, water ingress in hold
4. Negative trim, cargo fluidisation, sloshing
5. Damage of the hold nb 1 / nb 2 bulkhead ⇨
6. Flooding of the hold nb 2, stability loss
7. Ship capsizing



CONTAINER SHIPS

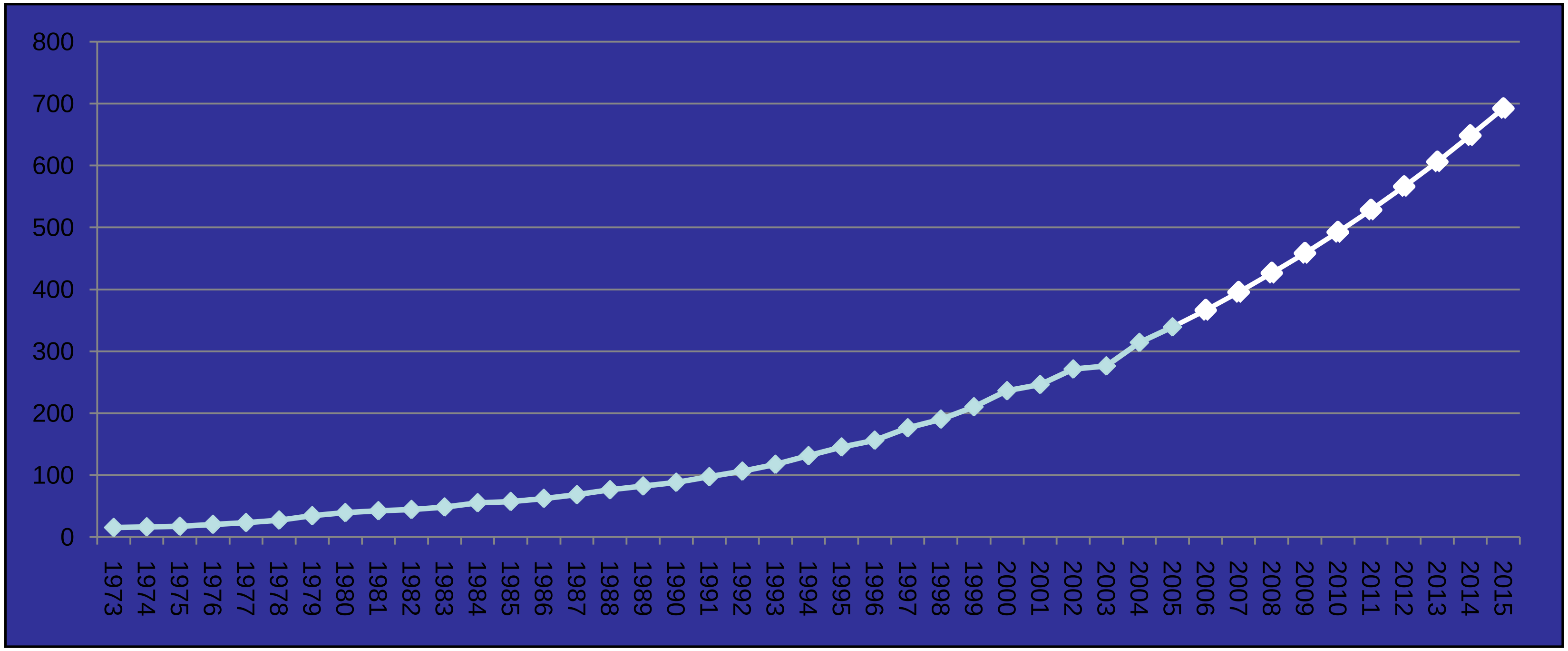
Container ship evolution from 1980 to 2007
Maximum capacity versus years



projects of 12,500 TEUs

Traffic TEUs worldwide (million TEUs)

Annual growth in the 9% order was expected before the economic downturn.

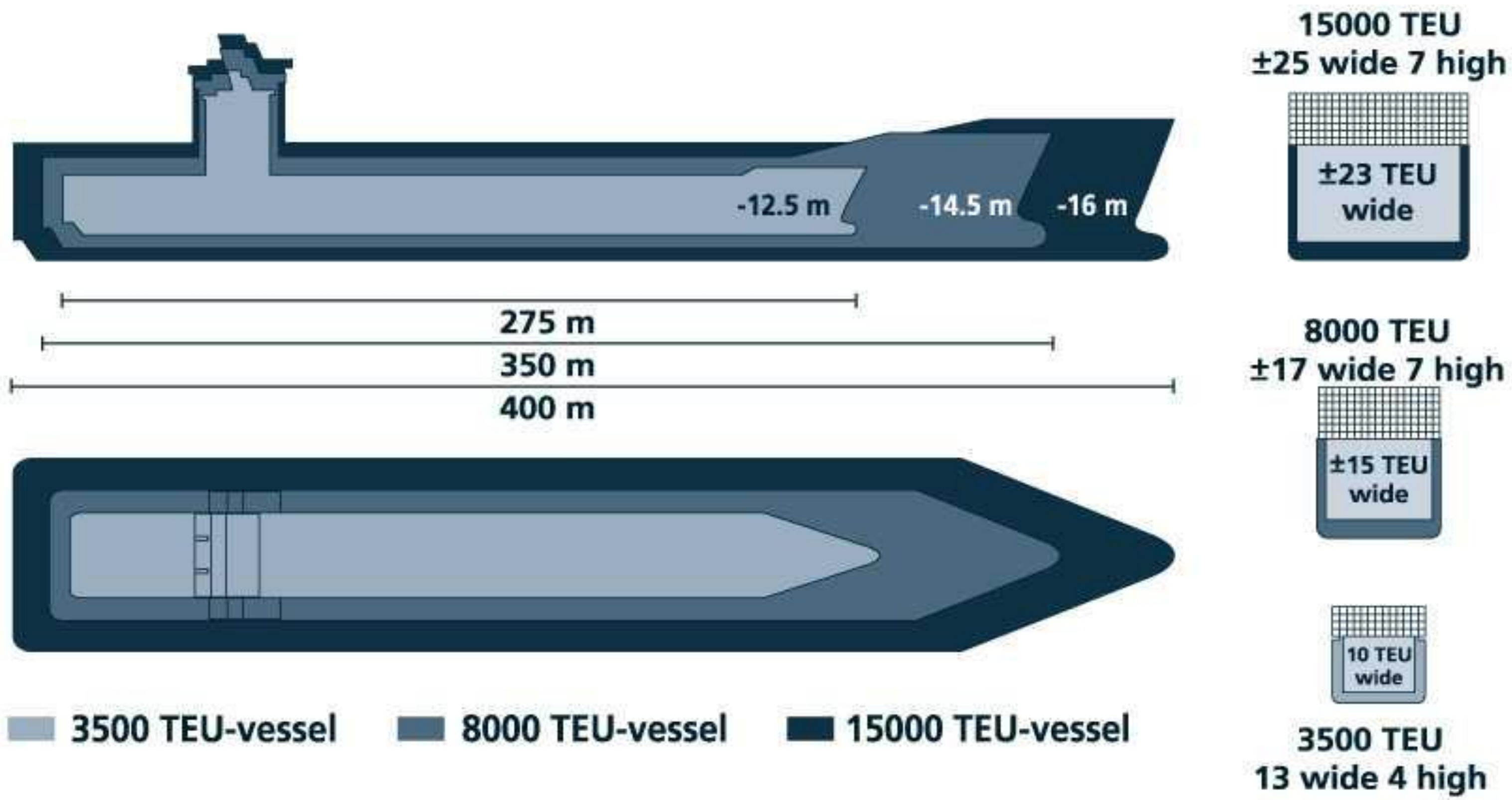


CONTAINER SHIPS

10,960 TEUS container ship

L = 346,5 m B = 43,2 m T = 15 m V = 25 knots

Ever Larger Vessels

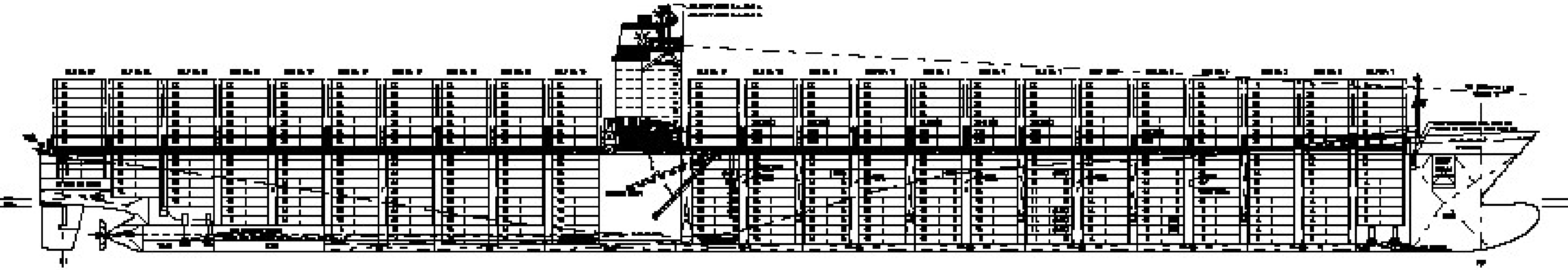


Representative ship dimensions

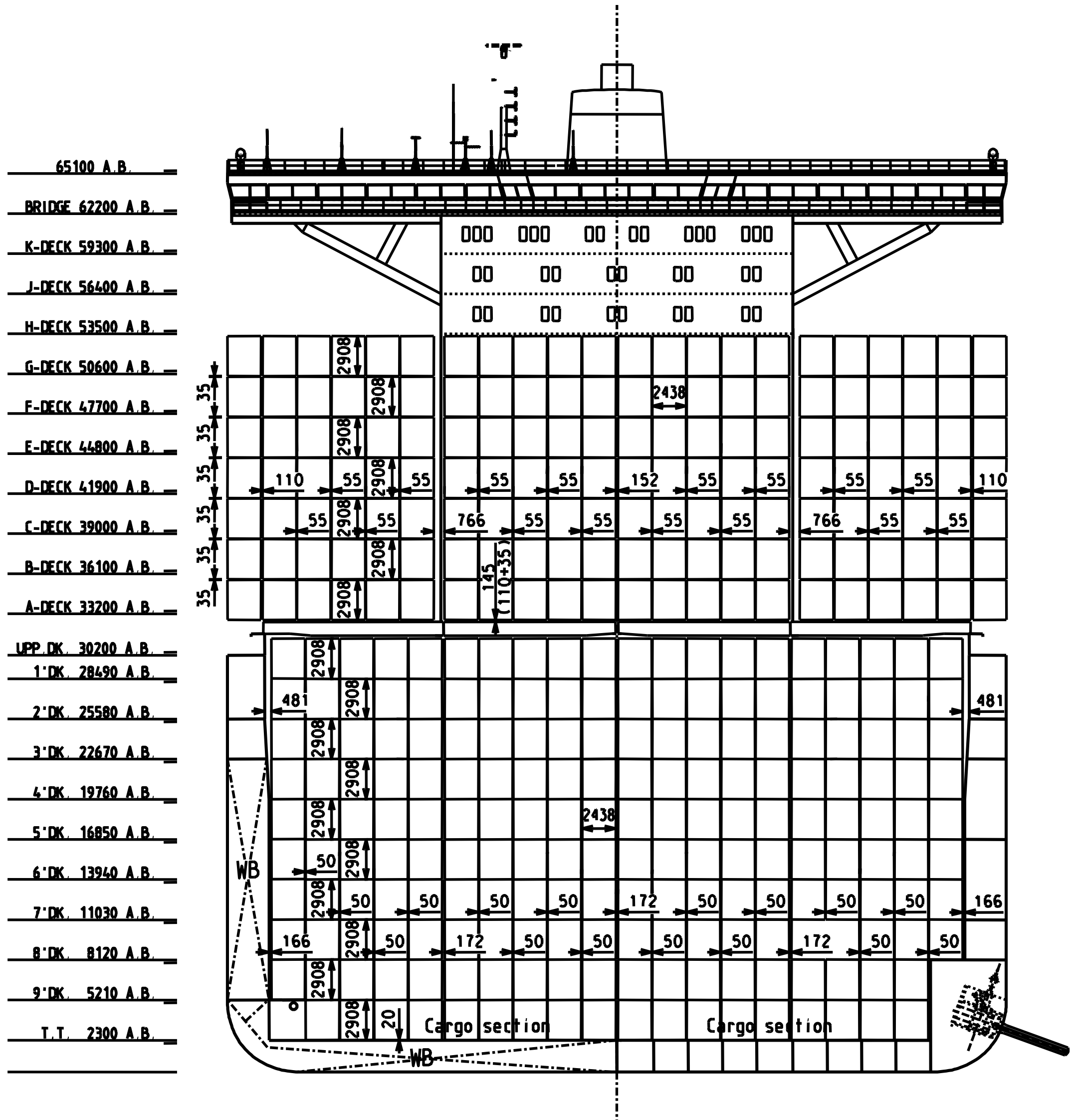
Ship	Year	TEU	Loa (m)	Beam (m)	Draft (m)	Speed (kn)
CMA-CGM Hugo	2004	8 200	334.1	42.8	14.5	
DSME	2009	9 000	347	45.2	15.5	24.3
HHI	2009	11 400	363	45.6	15.5	
DSME	2009	13 000	365.5	51.2	14.0	

Power is about 72 000 kw to 80 000 kw with 2-stroke low rpm
12 –14 cylinders Diesel engines
Operating draft between 14 m and 15 m
Air draft about 64.5 m

M/V EMMA MAERSK



M/V EMMA MAERSK



Implications for container terminals

In order to handle much larger vessels and consignment sizes terminals must both expand and make better use of existing facilities

In North Europe, consignment sizes are averaging nearly 2700TEU for 6000TEU+ sizes. For very large vessels, up to 5000TEUs have been handled at single port calls

These increases will be noted in all major front rank ports

ULCS*: The technical issue

- Large and slender hullform boxships have relatively small bending and torsional rigidity
- Therefore, the natural frequencies of hull girder vibrations are relatively small (large natural periods)
- High forward speed of container ships gives increases the wave encounter frequency (smaller wave encounter period)
- Consequently, dynamic phenomena which are second order for average size vessels may become of high importance for ULCS
- Main issue: vibratory structural response and associated fatigue damage caused by <u>whipping</u> and <u>springing</u>

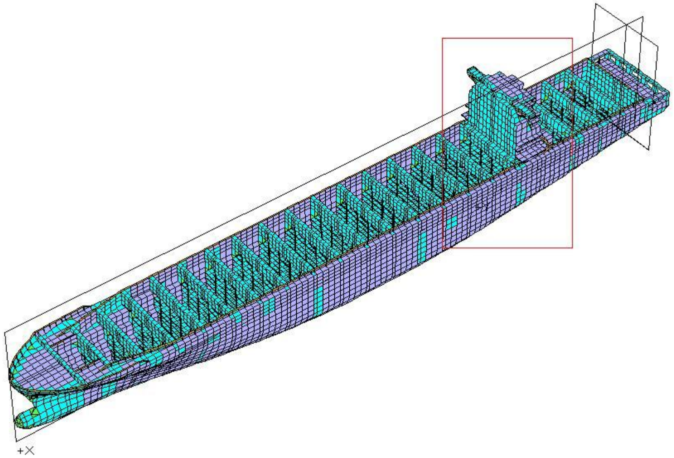
- Extrapolation of existing designs to ULCS dimensions risky business?

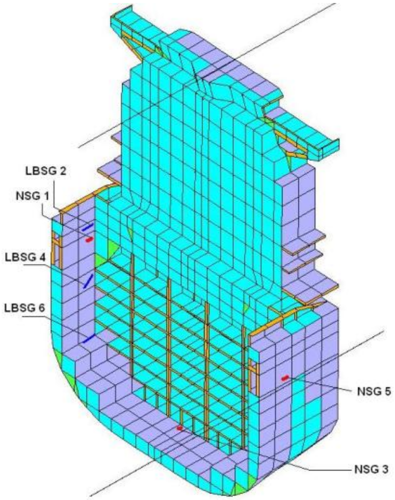
*** Ultra Large Container Ship: 10,000+ TEU**

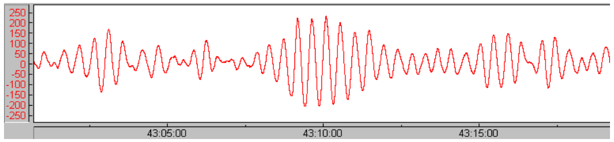
Whipping & Springing

- Whipping is a transient phenomenon characterised as hydrodynamic impact enforcing high frequency hull girder bending stresses (vibration)
  - Increased sagging and hogging wave bending moment (stress ampltitude)
  - Increased fatigue loading (small range high frequency damped cycles and low frequency stress range)
- Whipping generally occurs in head seas when sailing severe sea states; main vibration mode is vertical bending
- Springing is a resonant phenomenon characterised as small range high frequent bending stresses which are added to the large range wave frequent bending stresses
  - Increased fatigue loading (small range high frequency cycles)
- Springing generally occurs in quartering seas when sailing in non-severe sea states (waves with small period have limited height); main vibration modes are torsional bending, vertical bending and horizontal bending

Full scale measurements: Lashing@Sea







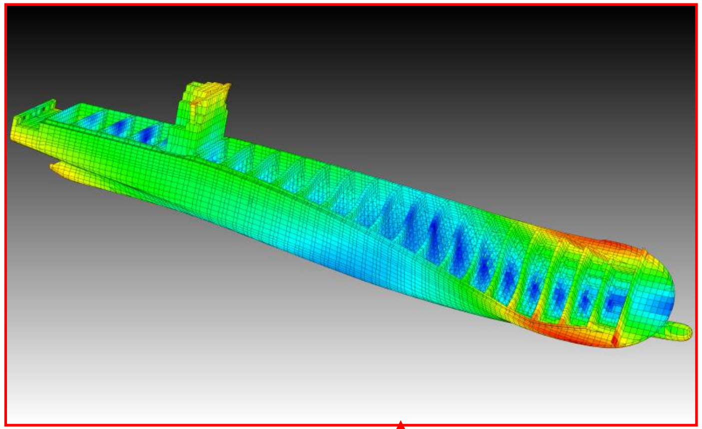
Transverse accelerations

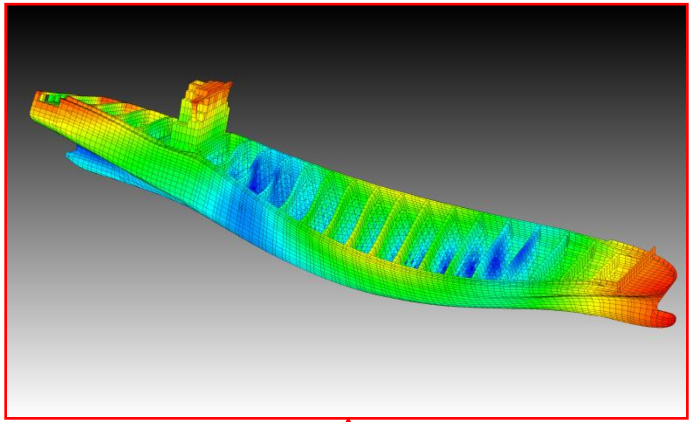
CMA CGM Rigoletto – 9400 TEU – BV Class

Measurement of hull stresses and container accelerations

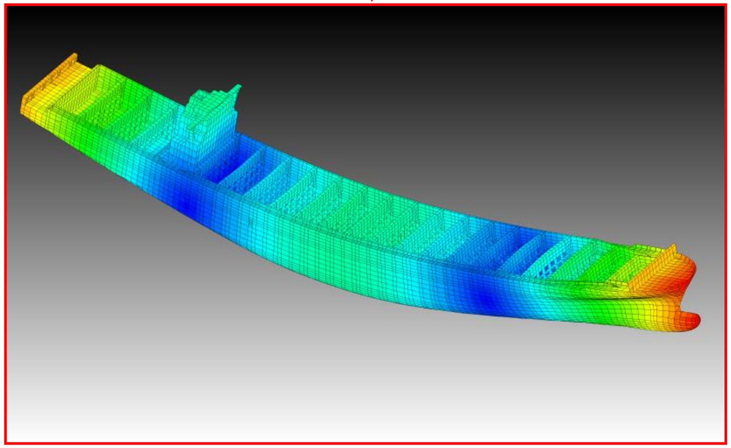
SPRINGING

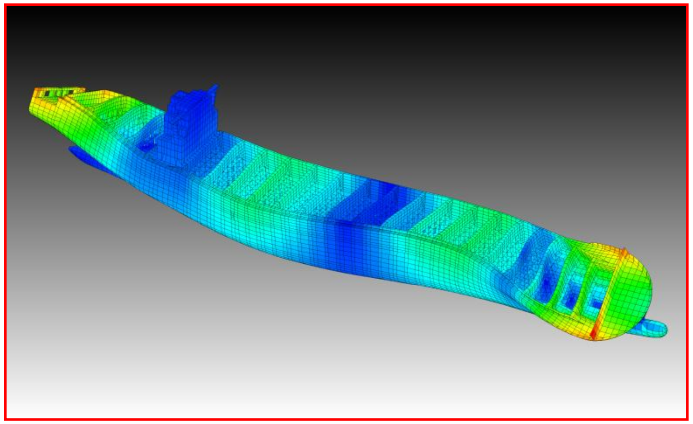
Results:





Frequencies	
Mode	**(Hz)**
torsion	0.366
flexion	0.496
torsion	0.499
torsion	0.899

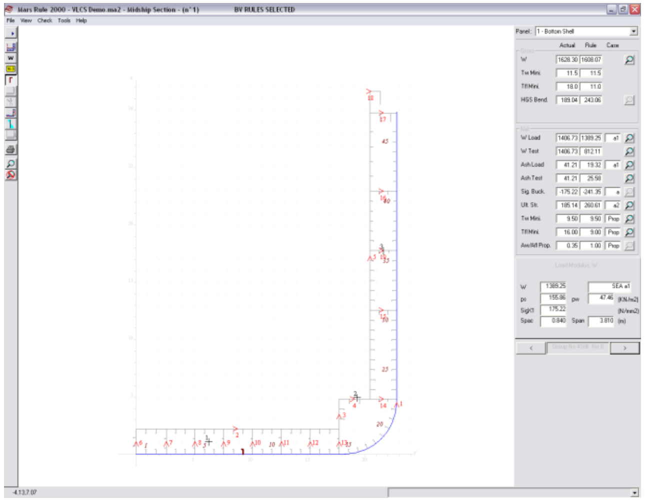


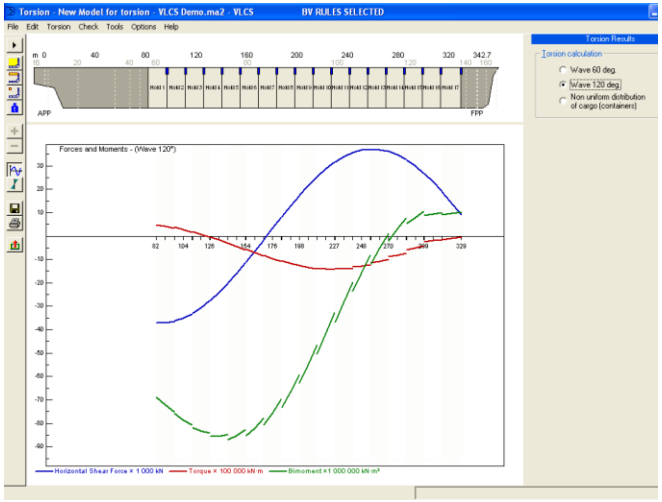


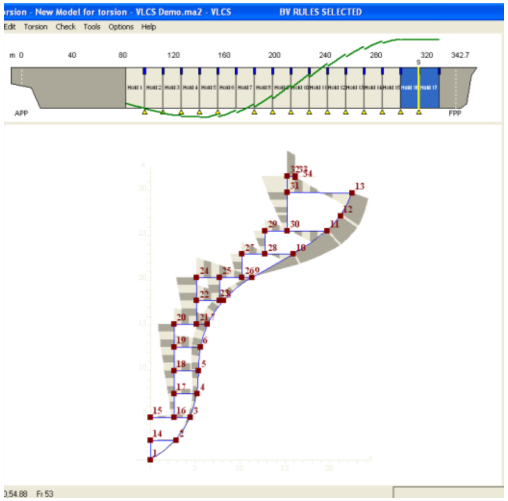
ULCS: What are the findings?

- Whipping can cause an increase in total vertical bending moment of about 20%
- The whipping induced increase in fatigue damage during the vessel lifetime has been found to be of the order of 3 to 5%
- The springing induced increase in fatigue damage during the vessel lifetime has been found to be of the order of 4 to 10%
- Consequences for the design of ULCS
  - The hull girder ultimate strength check will need to take into account the increase in dynamic hull girder loads
  - Increased attention required for the design of fatigue sensitive structural details (hatch corners, longitudinal connections, etc.)
- Effects of whipping and springing will become more important for new designs for container ships of over 400 m in length (over 13,000 TEU)

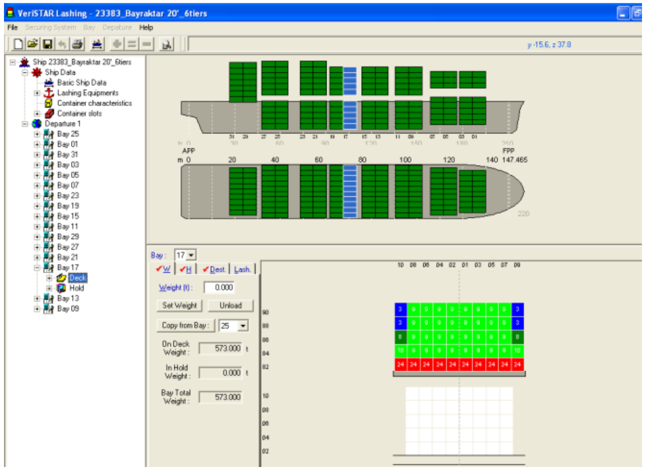
High quality user friendly tools for efficient design

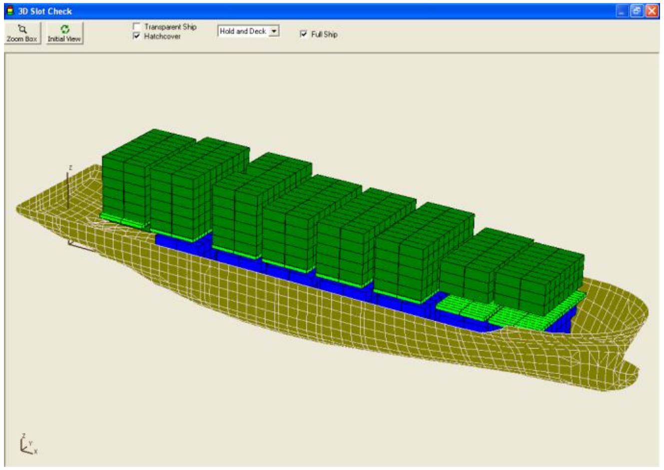


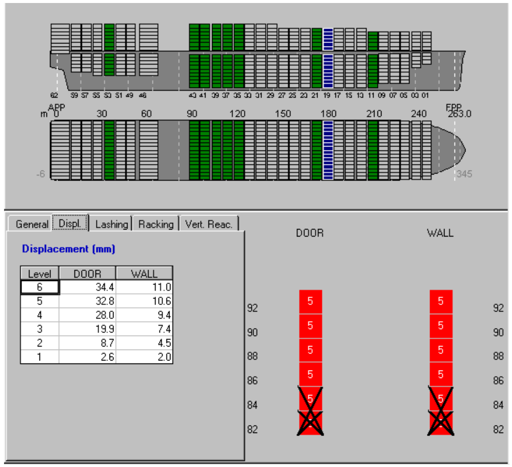




MARS2000: longitudinal & ultimate strength, transverse bulkheads, torsion, fatigue



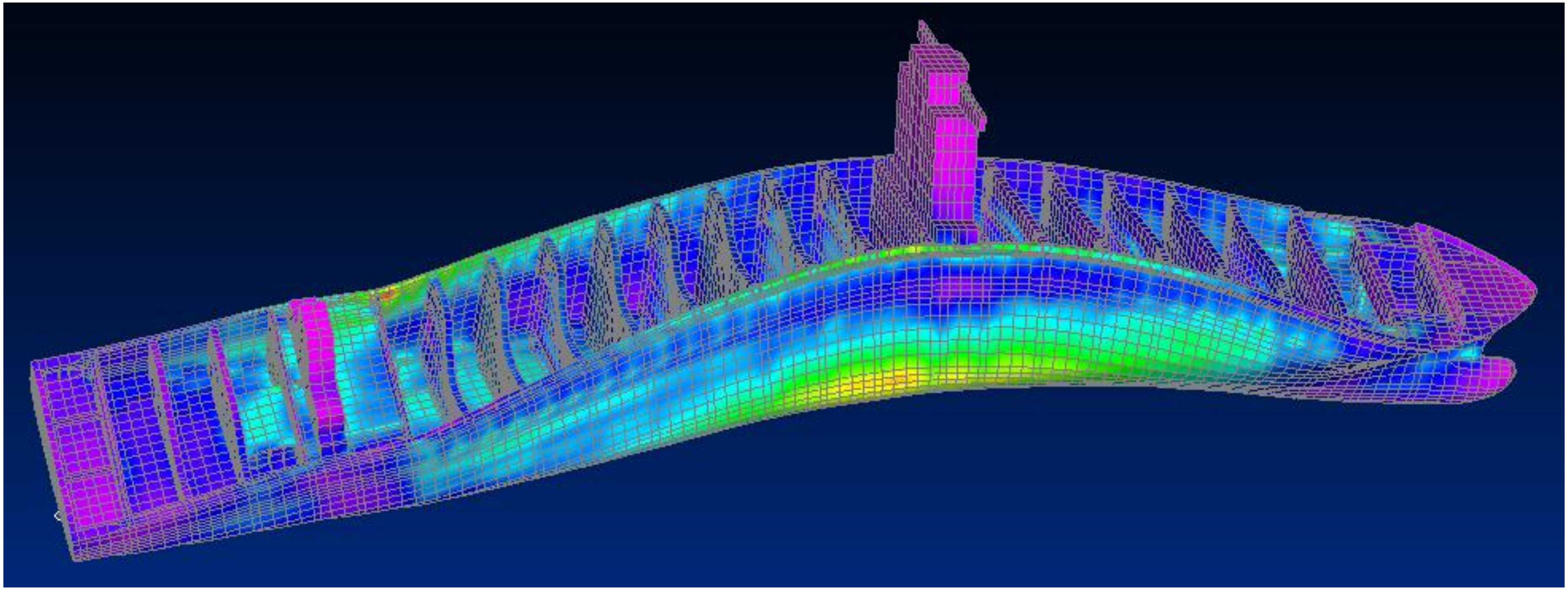




VeriSTAR LASHING: verification and optimisation of stackweight and lashing equipment

Direct Ship Analysis

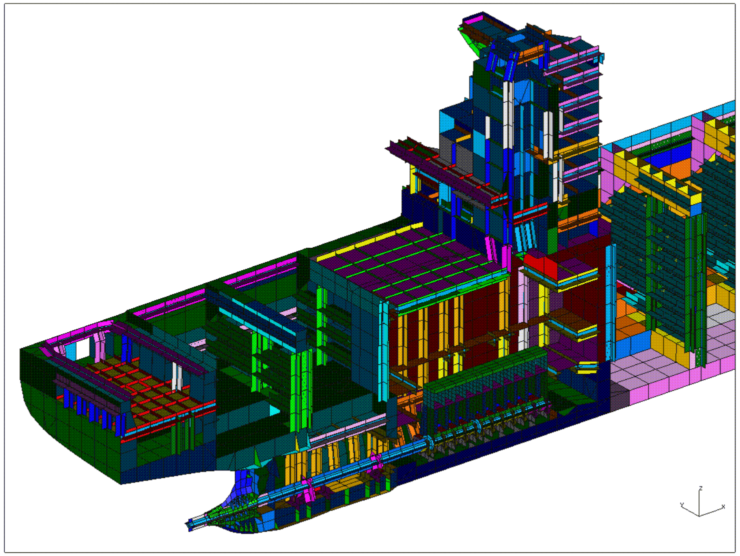
- Necessary for large container ships…



13,000+ TEU

container ships

- Flexible hull structure due to open box holds (vertical bending and torsion) and weight optimisation (FE calculations)
- High power output for high sustainable service speed
- Main engine and crankshaft stiffness are relevant parameters due to specific architecture of main engine
- Hydrodynamic design aspects for single screw high powered ships (vibrations excitations, cavitation erosion)
- Direct coupling between line shafting and crankshaft



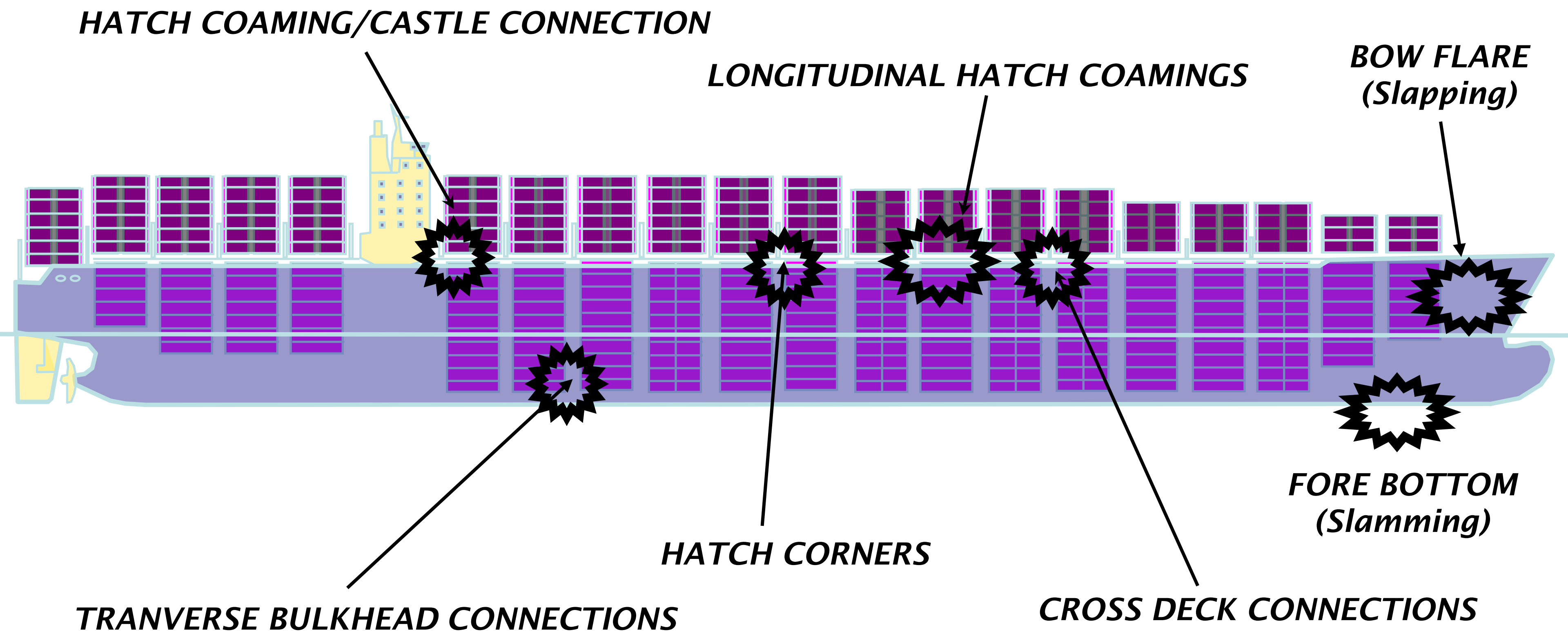
CONTAINER SHIPS

Technical structural challenges

- **Large open deck: torsion, fatigue in hatch corners**
  solved by measurements at sea, then stress computations
- **Wave impacts: slamming, slapping, green water**
  solved by hydrodynamic computations, hull monitoring
- **Dynamic wave loads: hull girder springing, whipping**
  solved by stress computation and fatigue verification
- **Motion accelerations: on deck container lashing**
  solved by load and stress computations, lashing design
- **Propulsion power: shaft alignment, rudder errosion**
  solved by elastic alignment, rudder shape and material

CONTAINER SHIPS

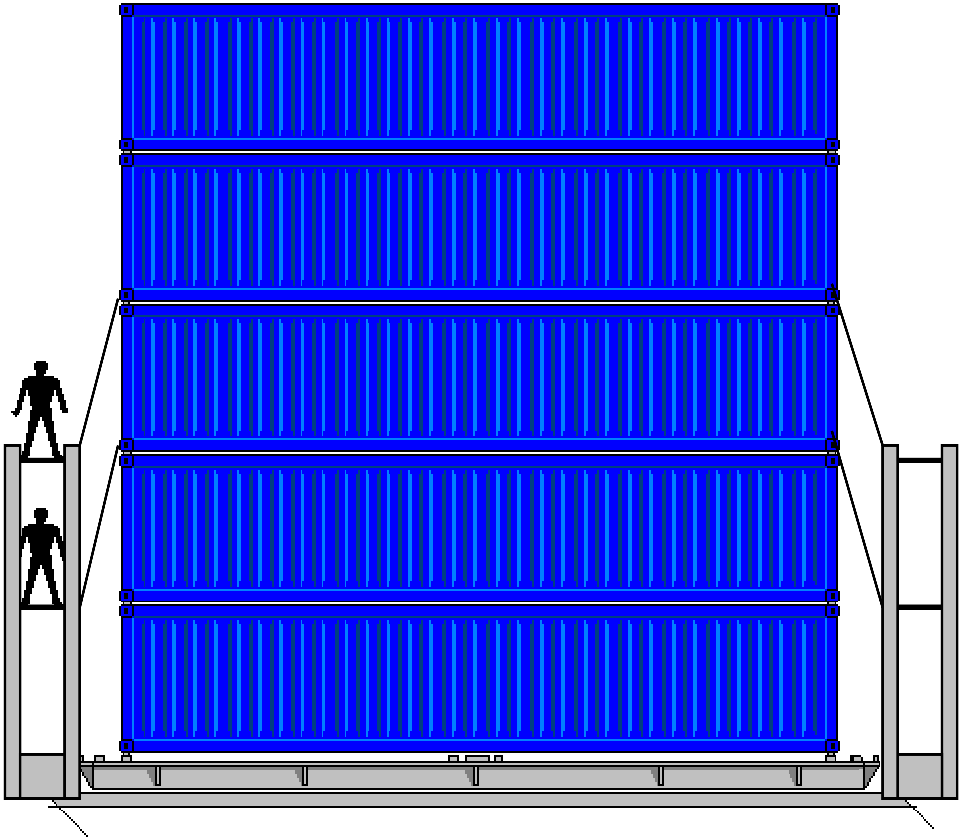
Structural critical areas



CONTAINER SHIPS

Container lashing failure

Container lashing innovation



Lashing deck on 2 levels

Advantages:

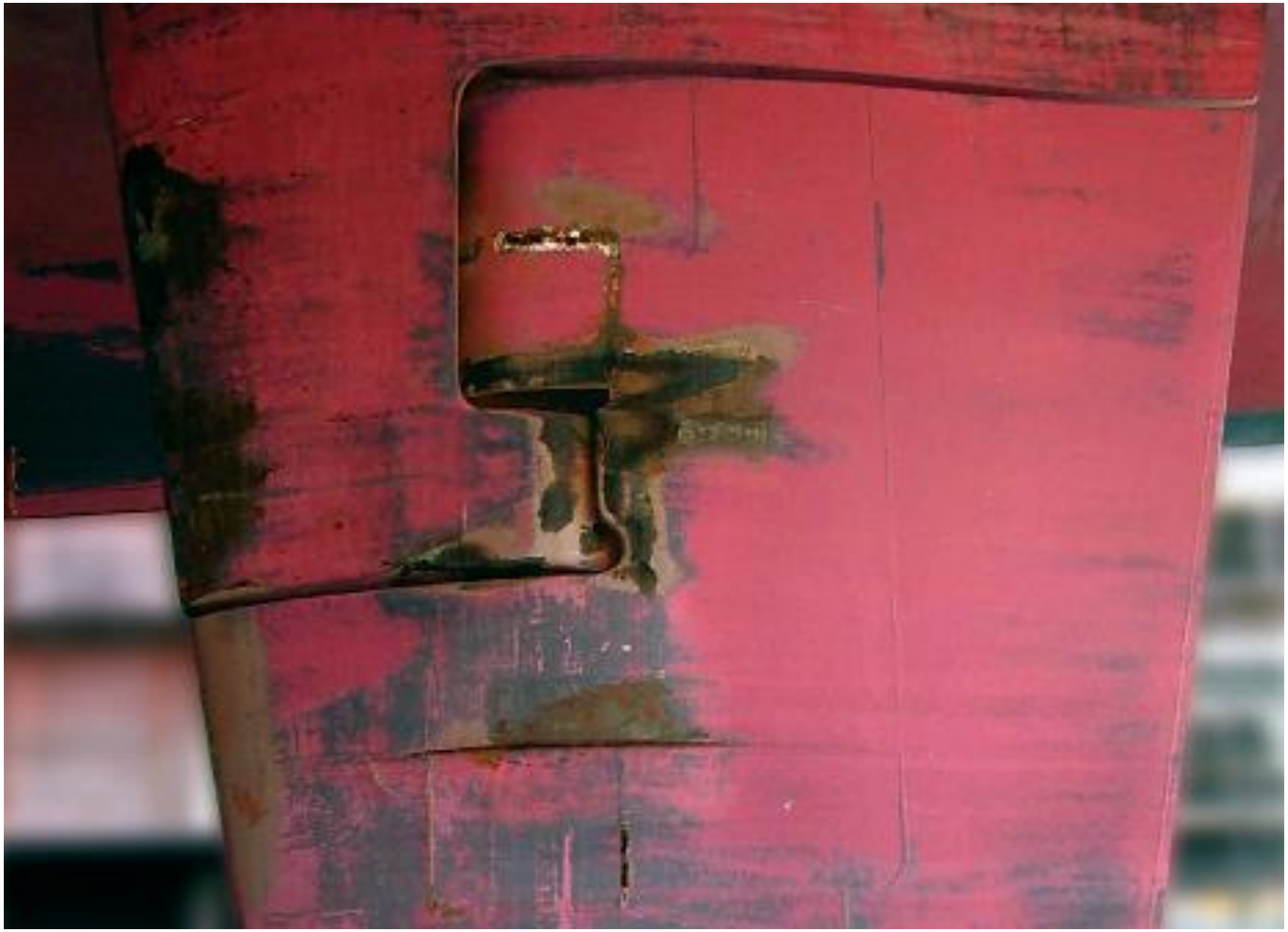
- Short lashing lines
- 2 workers at the same time
- Easier working conditions

Inconvenient:

- Heavier equipment

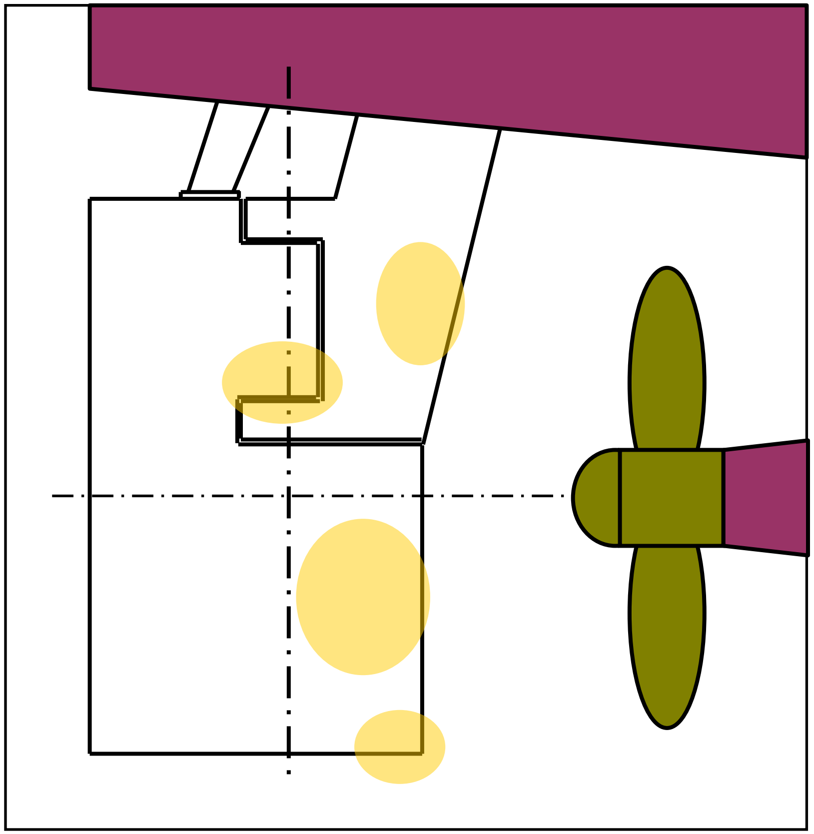
CONTAINER SHIPS

Rudder erosion

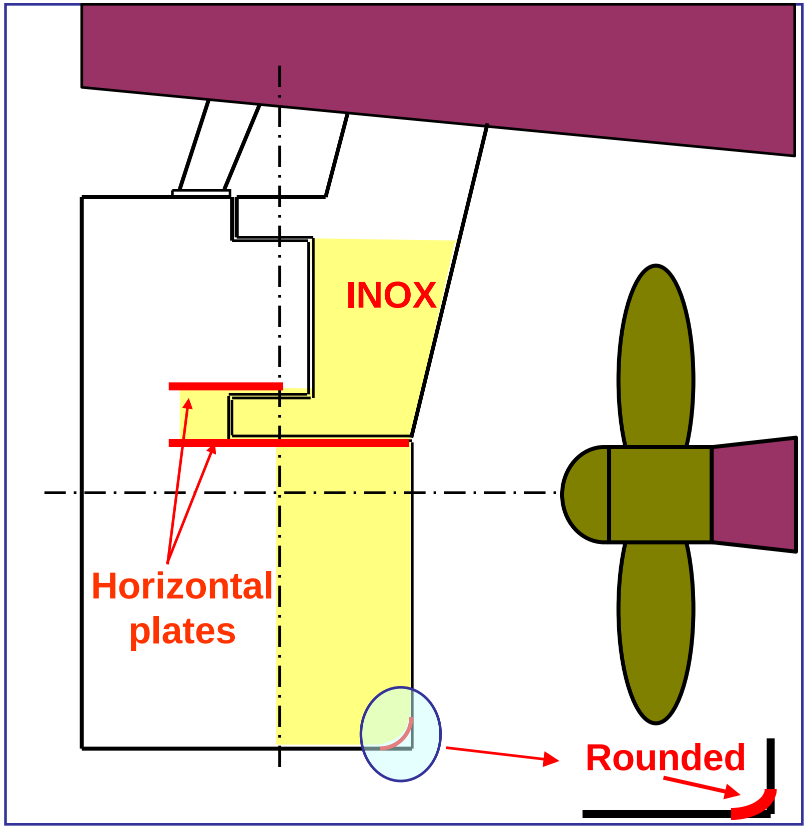


Rudder erosion

Concerned areas



Proposed solutions



CONTAINER SHIPS

Operational safety

- **Fast speed: collision risk**

  solved by manoeuvrabilty and navigation rules
- **Containers on deck: visibility, green water**

  solved by monitoring, bridge position
- **Containers on deck: parametric rolling**

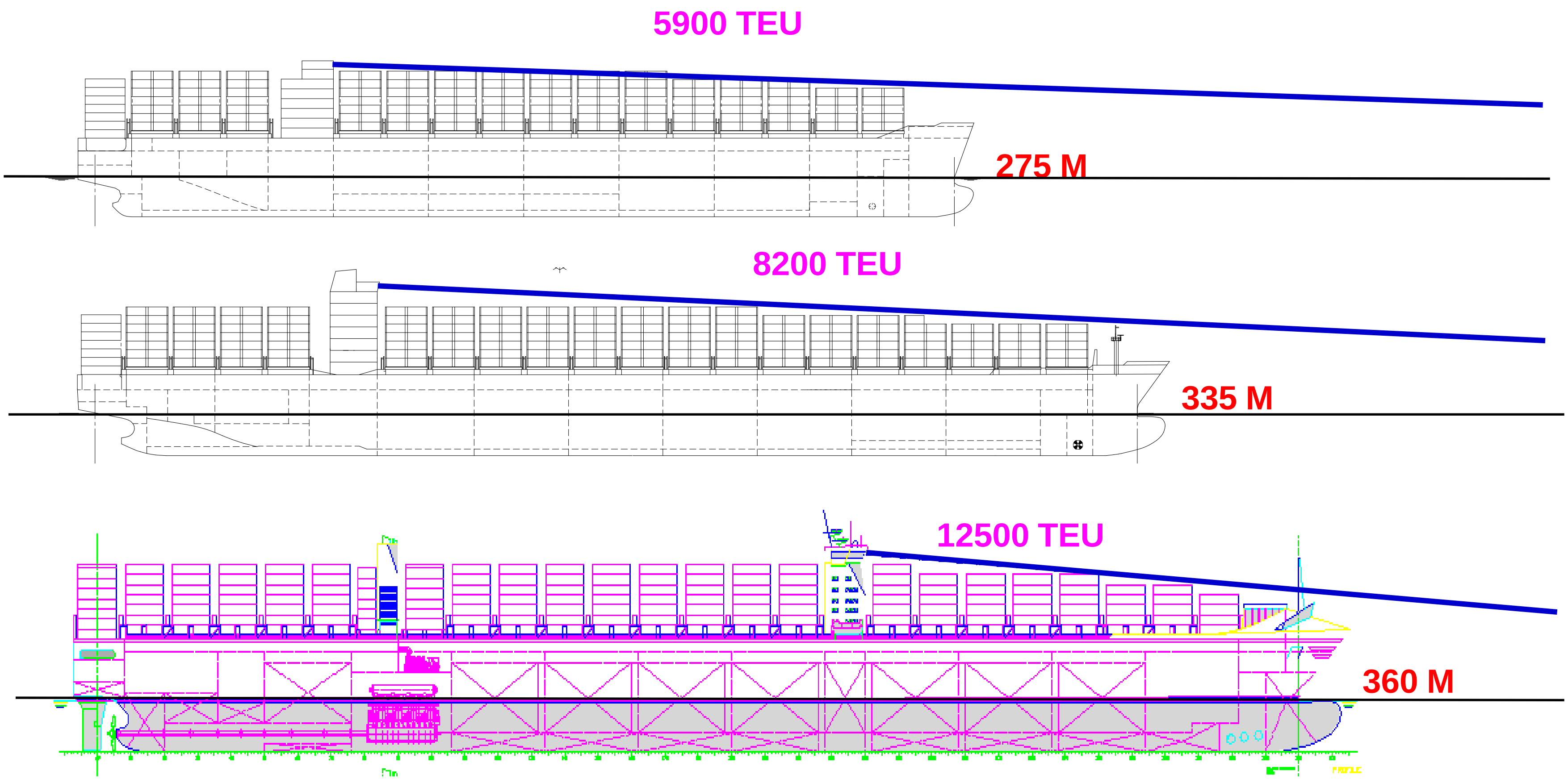
  solved by R&D, computation and navigation rules

CONTAINER SHIPS

Visibilty from bridge

CONTAINER SHIPS

Visibilty from bridge



CONTAINER SHIPS

Shipping of green water

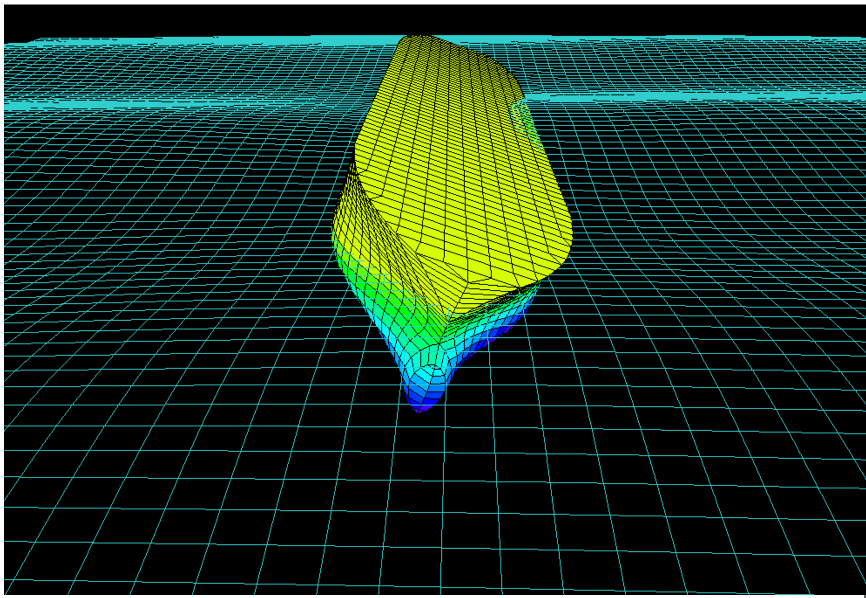
CONTAINER SHIPS

Shipping of green water effects

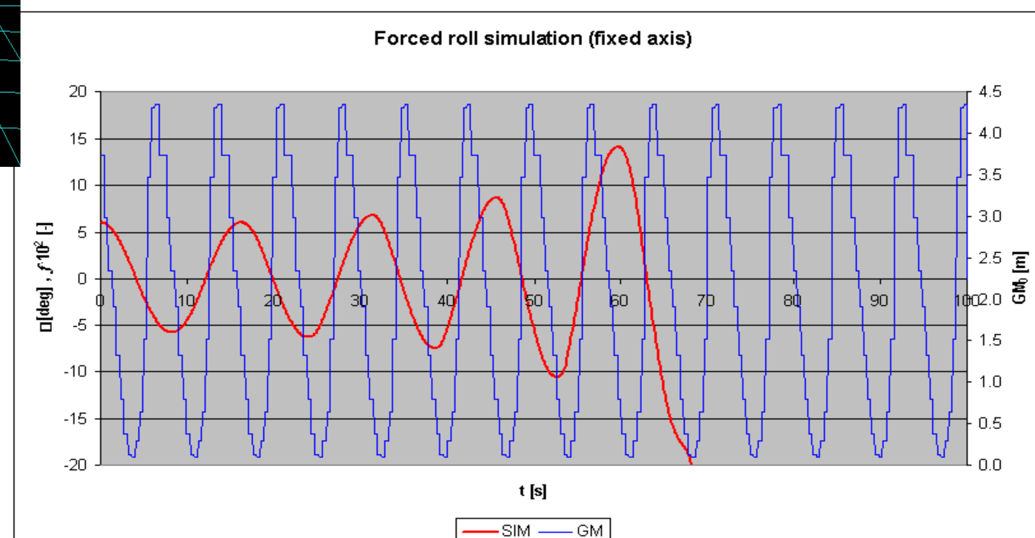
Parametric rolling effects

CONTAINER SHIPS

Parametric rolling computation

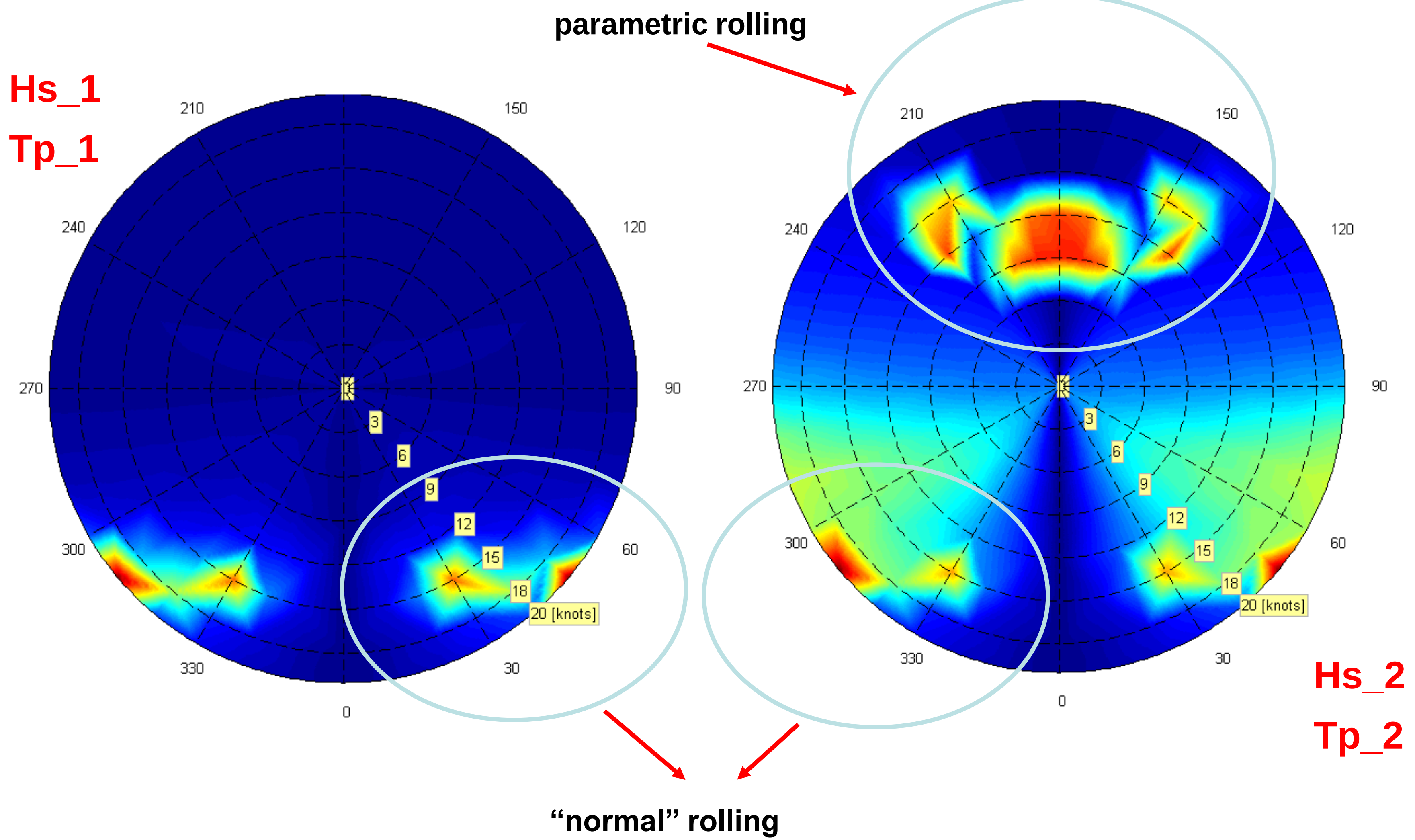


Roll time history



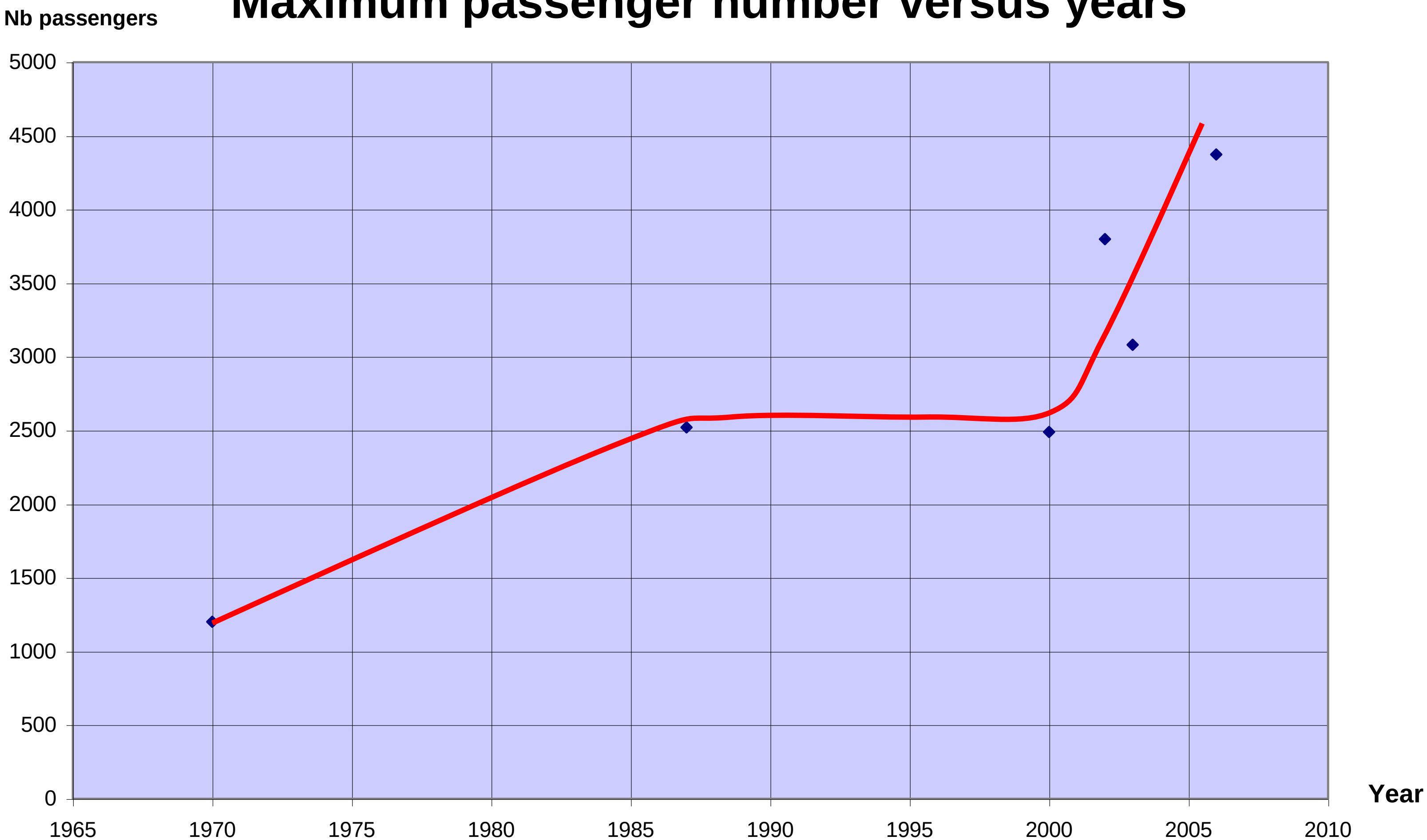
CONTAINER SHIPS

Parametric rolling risk prediction



CRUISE LINERS

Cruise liner evolution from 1970 to 2006
Maximum passenger number versus years



project of 5,600 passengers

CRUISE LINERS

Norway: 2000 passengers L = 315 m

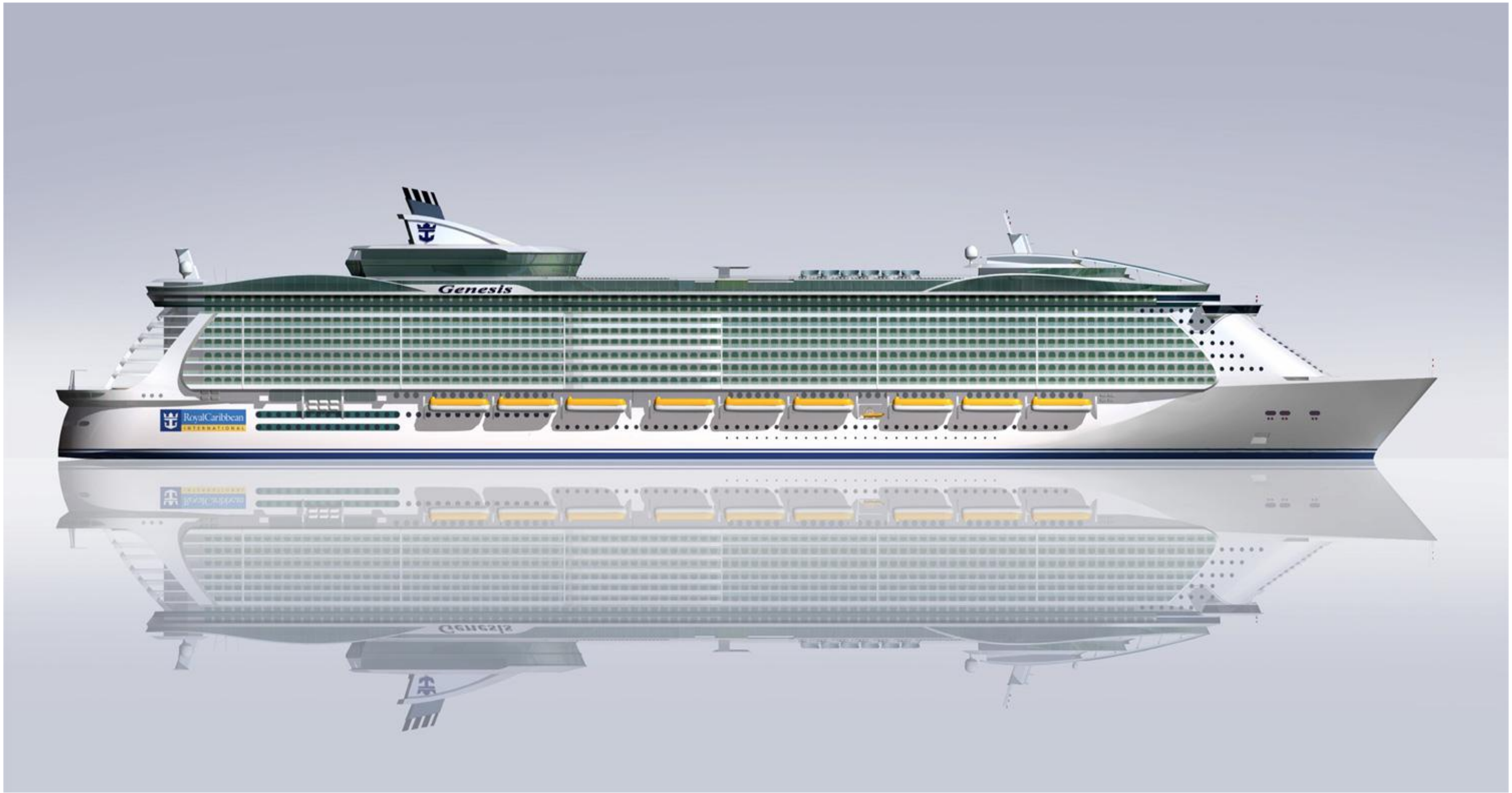
Queen Mary II

3080 passengers

L = 345 m

CRUISE LINERS

Genesis project: 5600 passengers L = 360 m

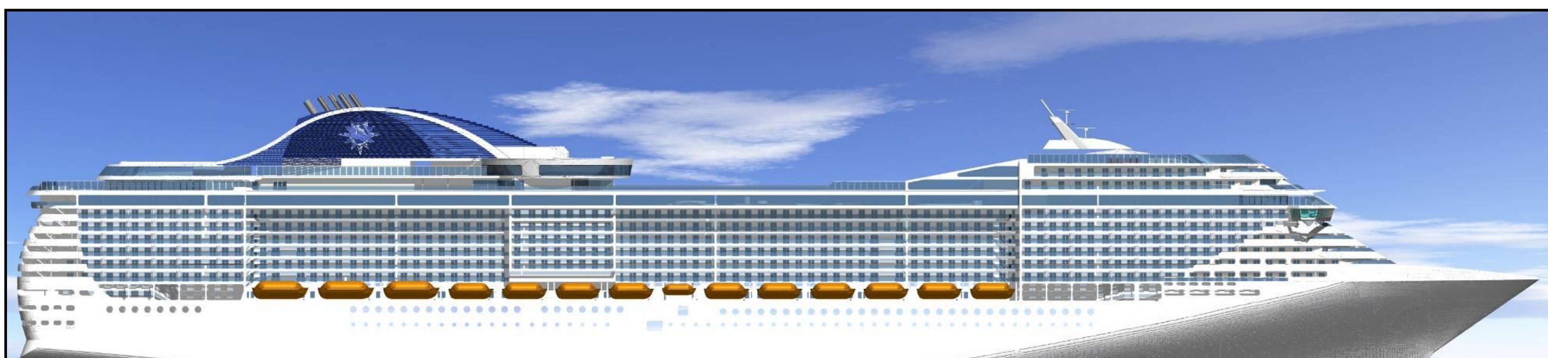


Technical structural challenges

- **Superstructures**: hull girder deformation loads
  solved by structural stress computations
- **Large wide spaces**: structural discontinuities
  solved by structural behaviour computations
- **Large shell opening**: structural discontinuities
  solved by structural behaviour computations
- **Passenger comfort**: reduced vibration, noise
  solved by structural behaviour computations
- **Propulsion**: large flexibility needed
  solved by PODS

CRUISE LINERS

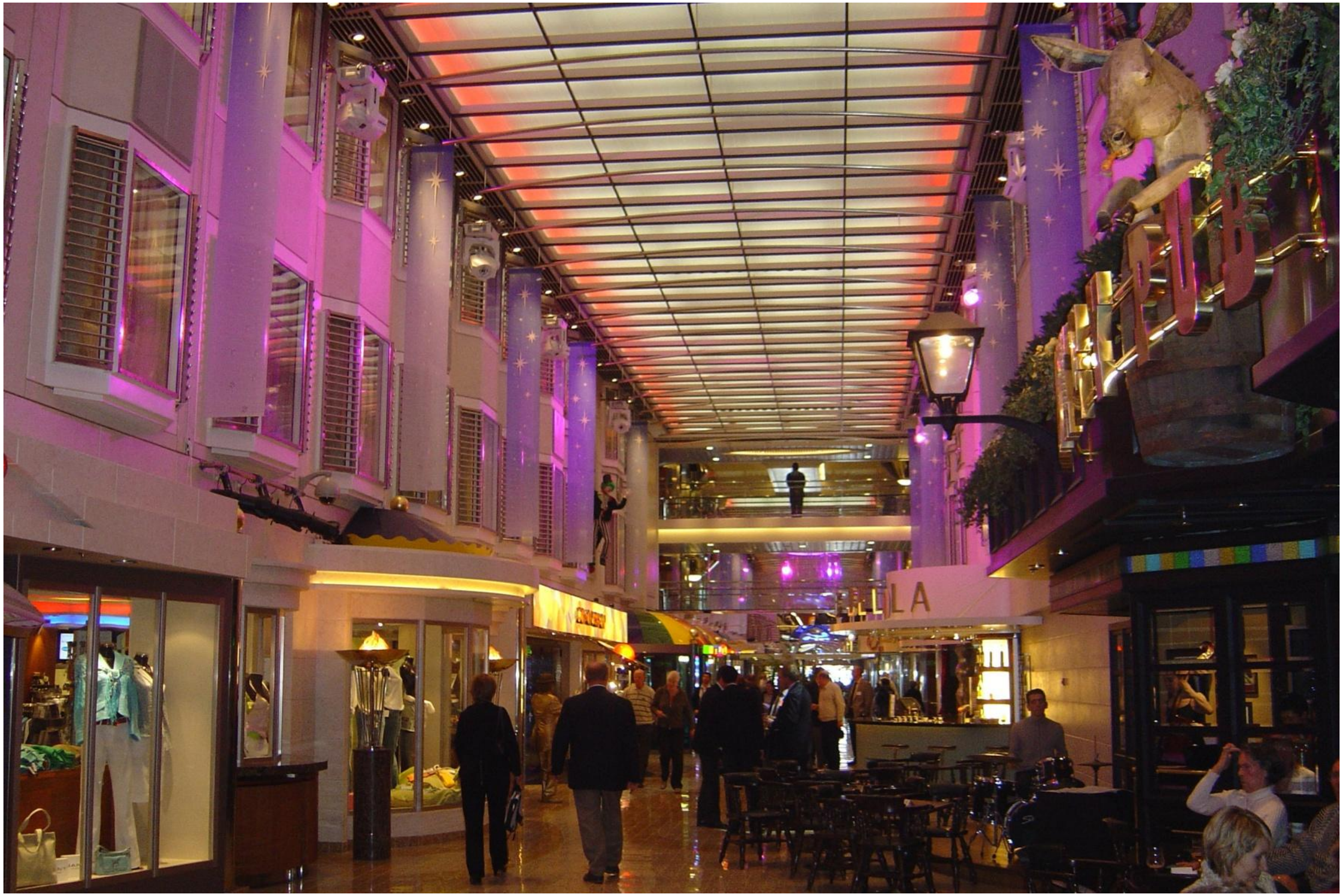
Large superstructures
submitted to hull girder deformations



***MSC SERENATA** 133.000 GT 1.650 Pax Cabins Over-Panamax size - May 2009*

CRUISE LINERS

Wide space: commercial centre

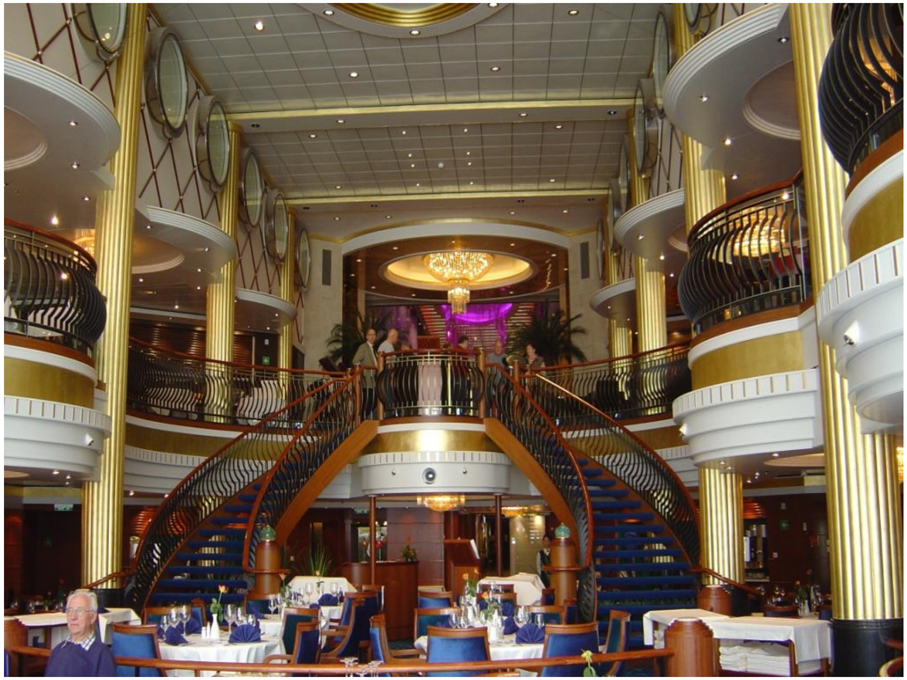


CRUISE LINERS

Wide open spaces

Theater

Main stair



CRUISE LINERS

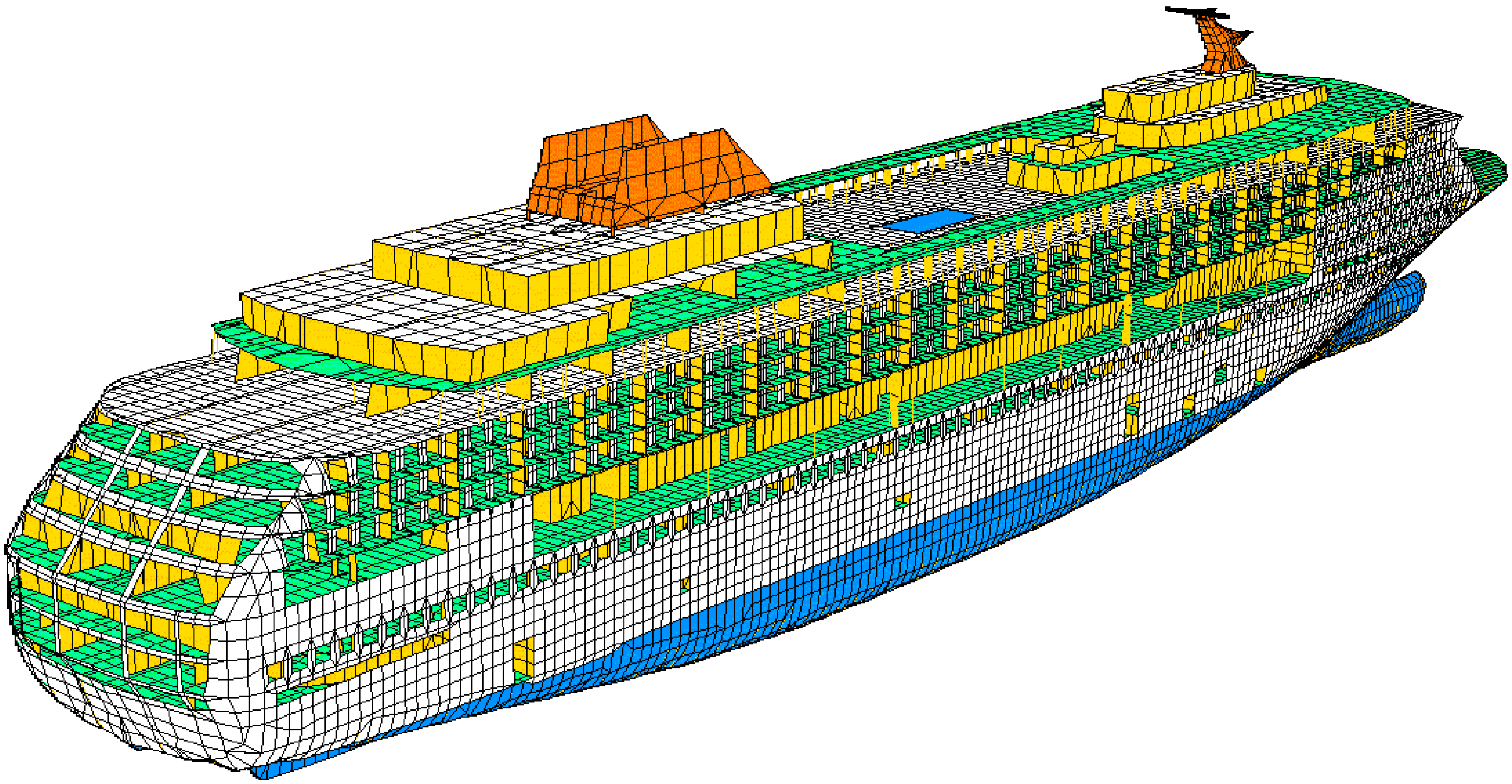
Passenger comfort

Bar and Restaurant

Cabin room

CRUISE LINERS

FE model for vibration and noise prediction computation



CRUISE LINERS

Propulsion flexibility

Queen Mary II PODS

Operational safety

- **Stability: ship capsize**
  solved by damage stability computations
- **Health: air conditioning, water, food**
  solved by procedures, maintenance, audits
- **Environment: garbage and sewage**
  solved by design and equipment
- **Fire: detection, protection, fighting**
  solved by specific rules and fire propagation computations
- **Evacuation: number of passengers and panic**
  solved by specific equipment and computer simulations

CRUISE LINERS

Lost of stability consequences

RoRo/Ferries losses

from 1987 to 2002

accidents	**9**
capsizings	**7**
victims	**3 644**

CRUISE LINERS

Contamination by air conditioning

Risk of legionella

CRUISE LINERS

Contamination by water

warm water

legionella

cold water

pseudomonas

CRUISE LINERS

Contamination by foods

CRUISE LINERS

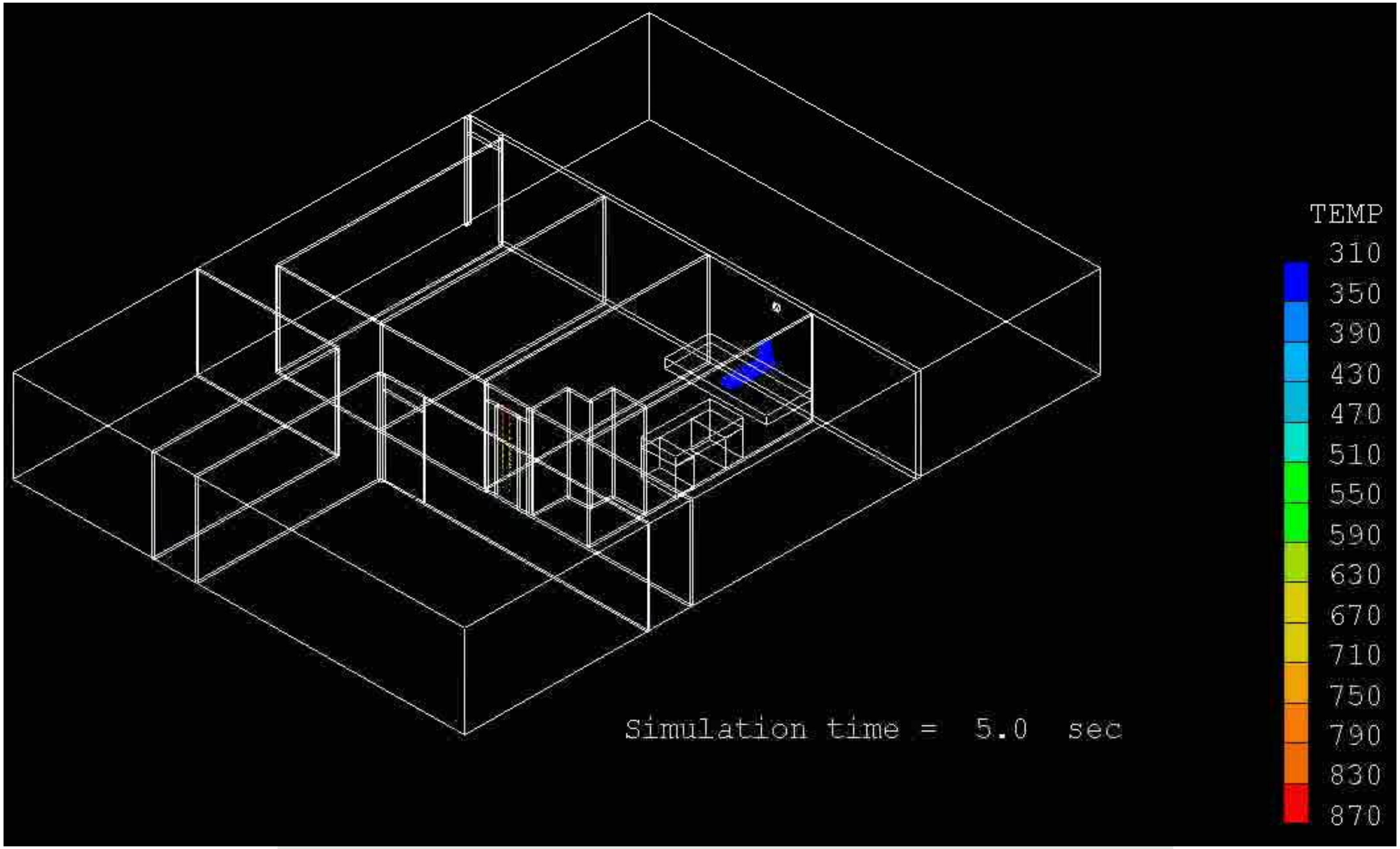
Waste quantities

Cruise liner of 3,000 passengers

Type of waste	kg or liter/person/day	tons or m^3/week
Plastic	0.1	2.1 t
Paper and pasteboard	1.0	21.0 t
Glass	1.0	21.0 t
Food garbage	0.7	14.7 t
Total solid	2.8	58.8 t
Black water (conventional system)	100	2 100 m^3
Black water (void system)	12	252 m^3
Grey waters	160	3 360 m^3
Wash houses	80	1 680 m^3
Kitchens	90	1 890 m^3
Total liquid	430 / 342	9 030 / 7 182 m^3

CRUISE LINERS

Fire propagation simulation



FIRE SAFETY ENGINEERING GROUP

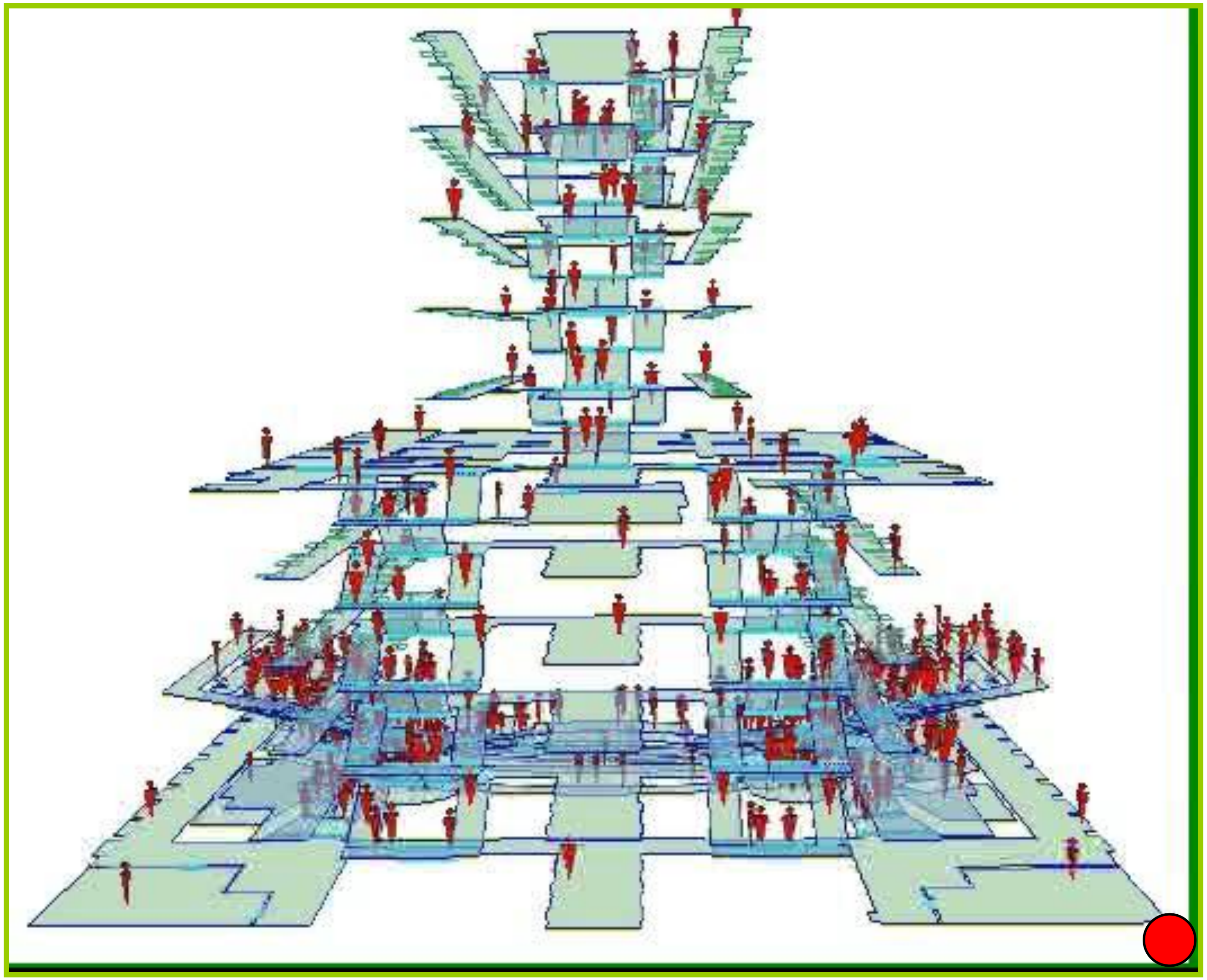
UNIVERSITY OF GREENWICH

CRUISE LINERS

Salvage crafts and evacuation training

CRUISE LINERS

Evacuation computer simulation



SYNTHESIS

- **SINCE MAGDALA TANKER (1969)**

  All ship structures are verified by structural computations

- **SINCE YEARS 70s**

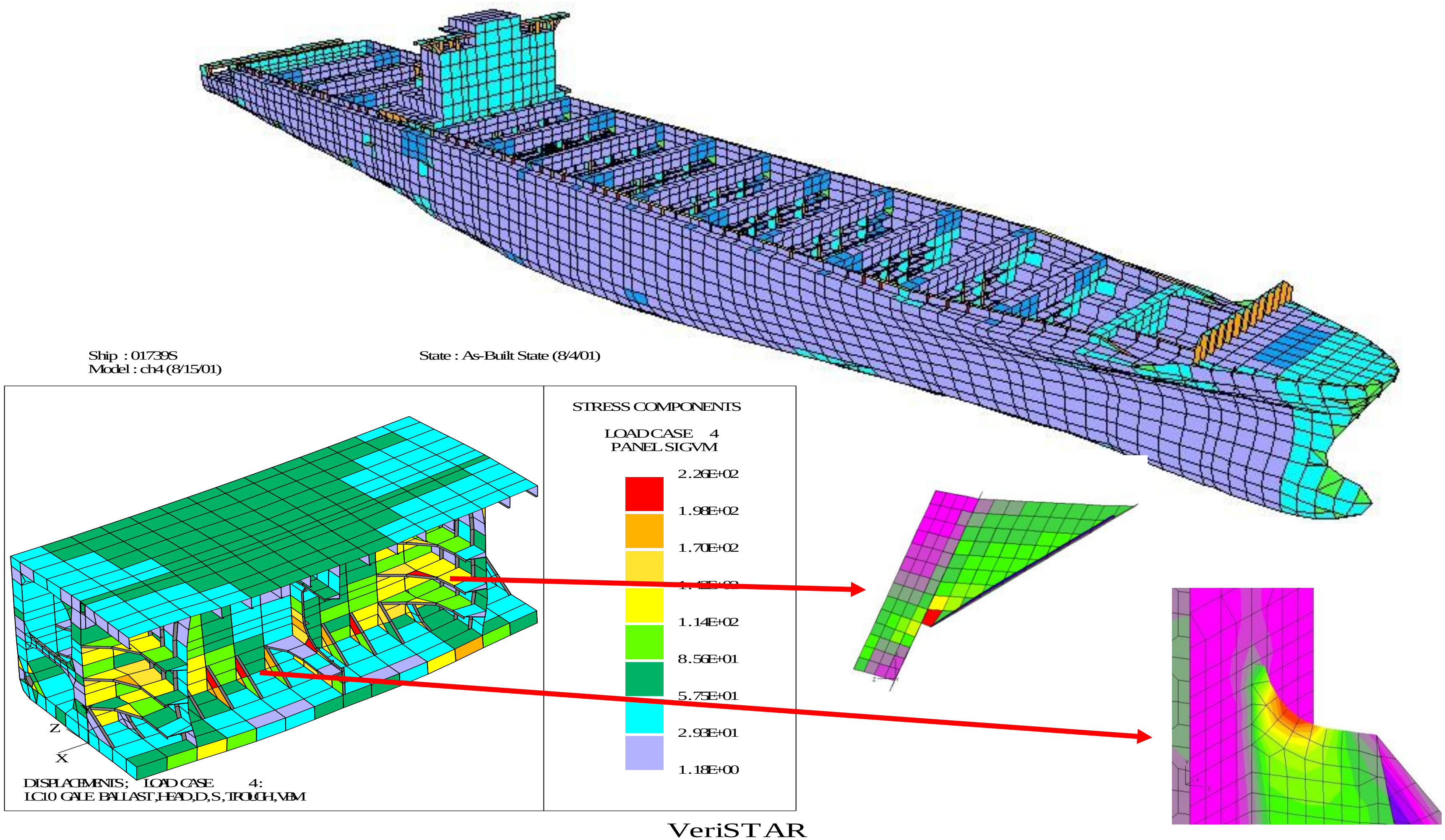
  All ship types have increased in size thanks to R&D and computer progresses

- **TODAY**

  Ship designers and operators have efficient tools for calculations and simulations

SYNTHESIS

Global and local hull stresses



END

Thank you for your attention

LE RENDEZ-VOUS DE L'ASSURANCE TRANSPORTS

Cannes

28th and 29th April 2009

CESAM

ASSURANCE TRANSPORTS 2009

LE RENDEZ-VOUS DE CANNES