UNIVERSITÀ DEGLI STUDI DI GENOVA

BAGLIETTO 1854

Development of a parametric model for analysing temperature effects of solar radiation on yachts

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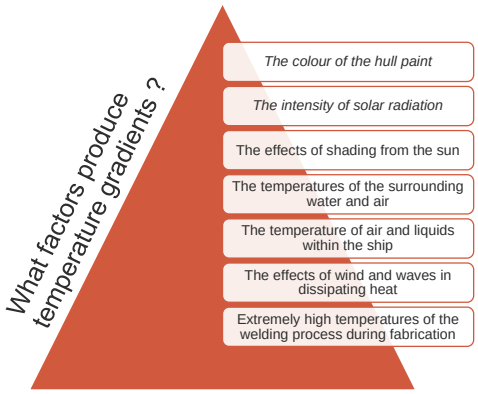
EMSHip Week – Master Thesis Presentation

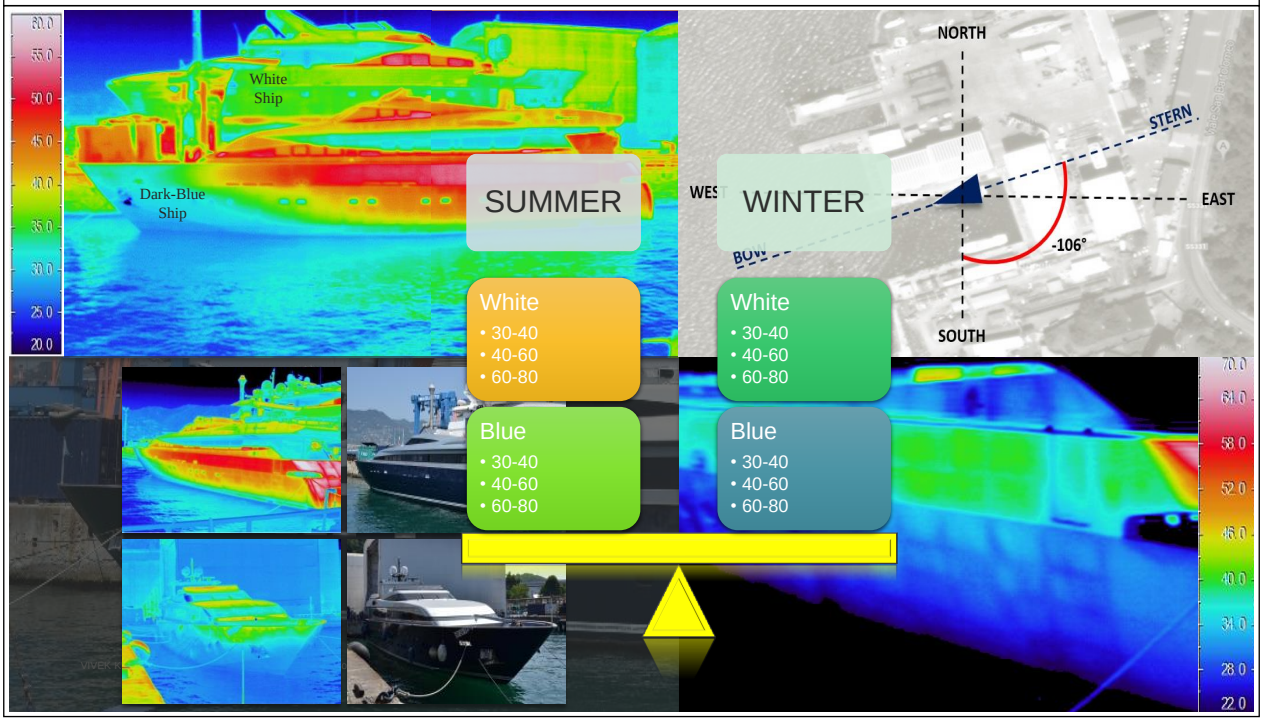
17th February 2014, La Spezia, Italy

INTRODUCTION

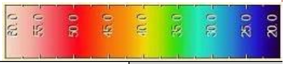
- Why is a yacht typically white ?



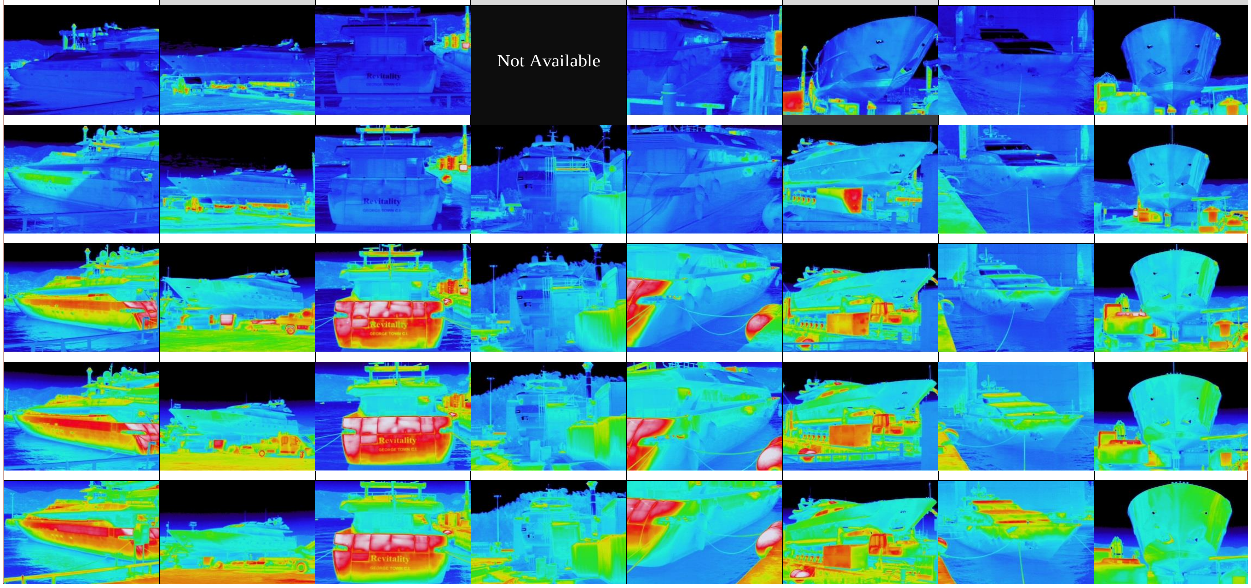
- Cheaper
- Forgives Imperfections
- Does not excessively glitter and reflect
- Dark surfaces show more dirt and splashes
- Doesn't fade so fast
- Pseudo-standard
- MUCH COOLER under solar radiation



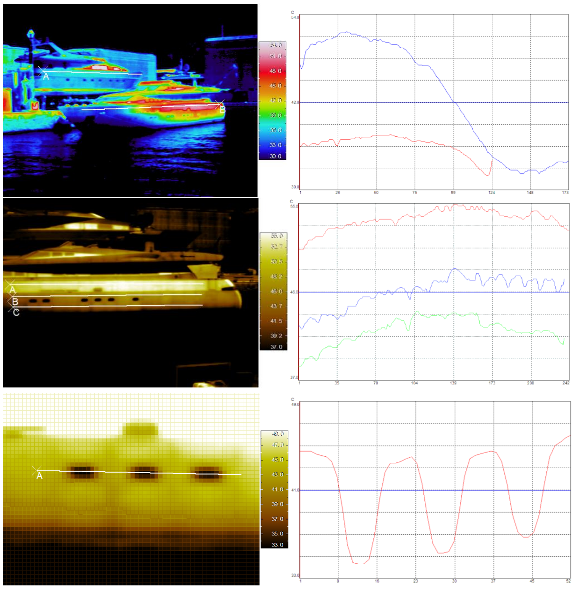
MEASUREMENTS – Temperature Variation



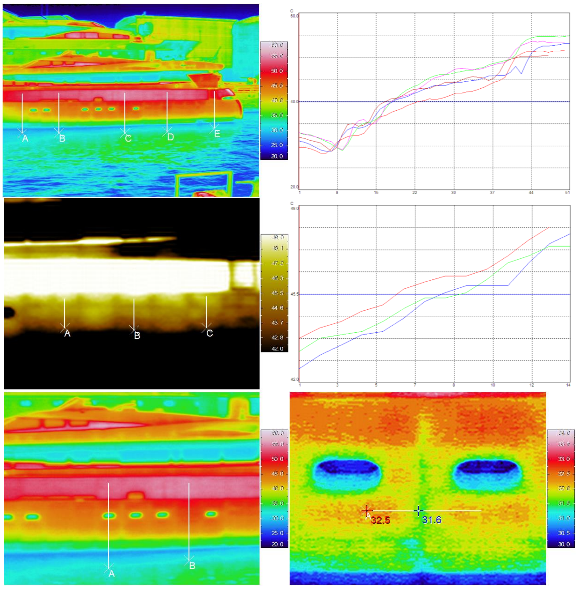
Blue Ship [Port]	White Ship [Port]	Blue Ship [Stern]	White Ship [Stern]	Blue Ship [Starboard]	White Ship [Starboard]	Blue Ship [Bow]	White Ship [Bow]

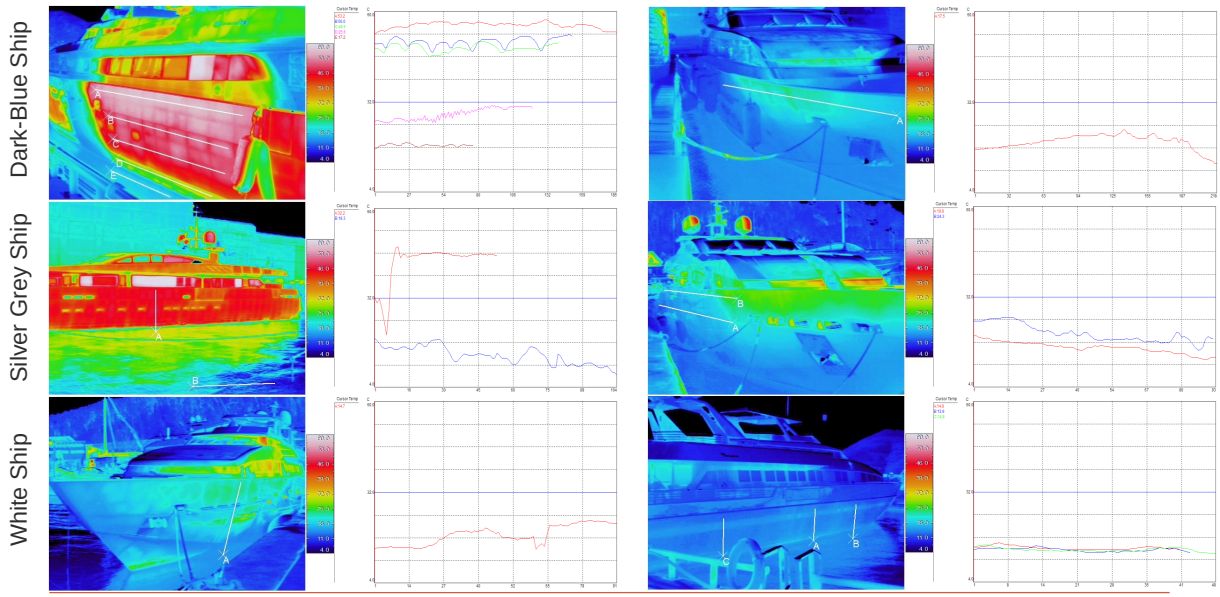


Longitudinal temperature variation

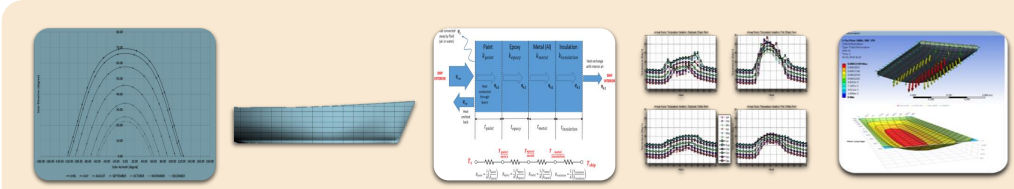


Vertical temperature variation





DEVELOPMENT OF THE PARAMETRIC MODEL



1. Perform Solar Ray Tracing

- Sun Elevation
- Sun Azimuth

2. Calculate Ship Geometry

- Panel creation
- Ship-surface azimuths and tilt angles

3. Calculate Heat Transfers

- Energy Balance
- Surface Temperatures

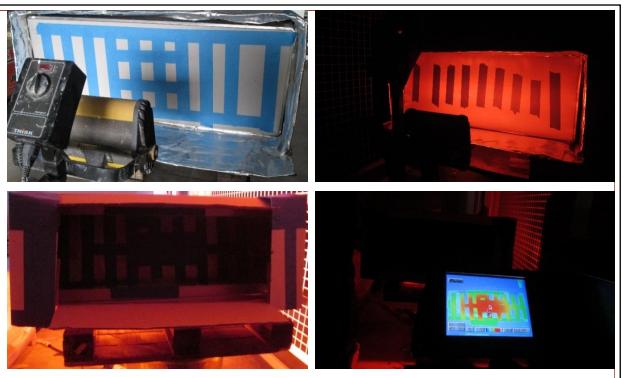
4. Parametric Evaluations

5. Calculate Temperature Effects

- Deflections
- Optical Distortions
- Energy Usage

Experimental Setup

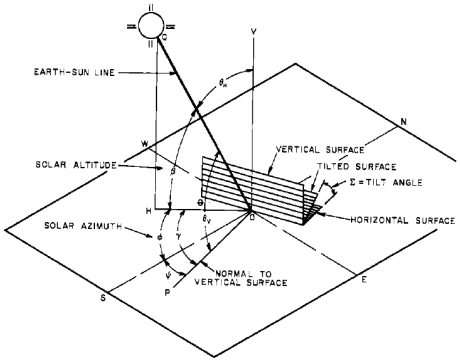
Part	Dimensions
Plate	1000mm x 400mm
Epoxy Layer	Test-1 : 10mm / Test-2 : 20mm
Aluminium 5083 H111 Layer	5mm
Transverse Frames	200mm x 5mm (Web)
Longitudinal Stringer	60mm x 4mm (Web), 60mm x 4mm (Flange)
Lamp	Halogen Lamp capable of 450°C, fixed 500mm from the plate for simulating temperature of 65°C (corresponding to black colour)



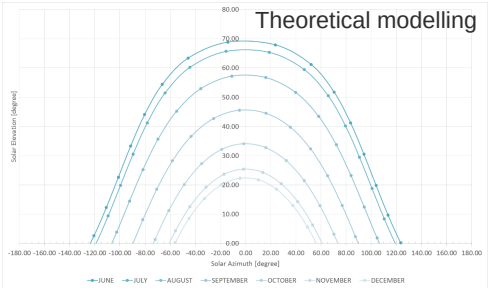
Panel Front Side (above) Back side (below)

1. Solar Ray Tracing

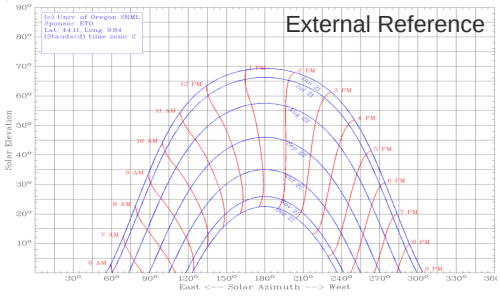
1. Selection of the ASHRAE model
    1. Practical to use
    2. Available data
    3. Well-established methods



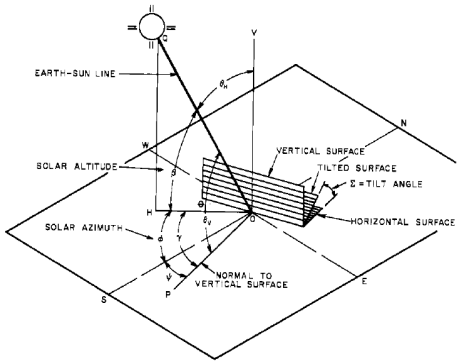
Theoretical modelling



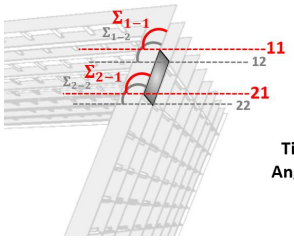
External Reference

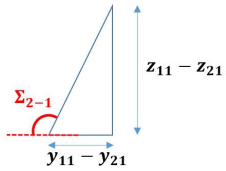


2. Ship Geometry

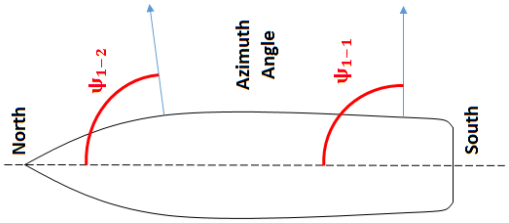


Tilt Angle



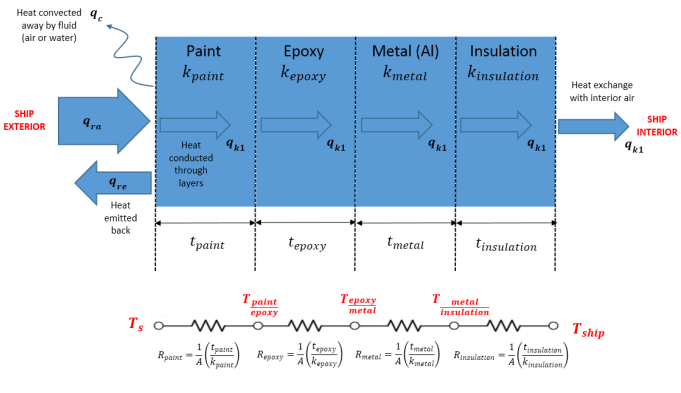


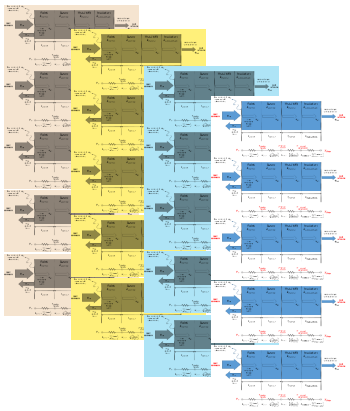
Surface Azimuth Angle



3. Heat Transfers

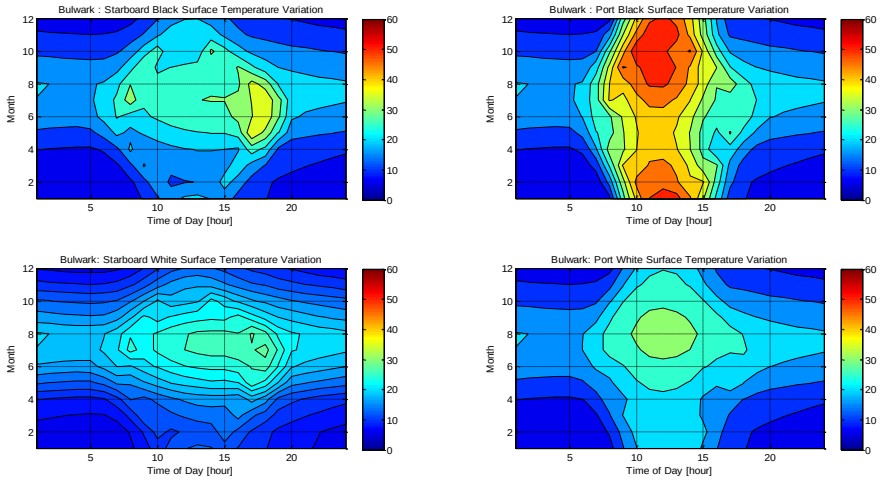
$$T_s^4(\epsilon\sigma A) + T_s\left(h_c A + \frac{1}{h_s - h_w} + \frac{1}{\mathrm{R_{overall}}}\right) - \left(\epsilon\sigma A T_{sky}^4 + h_c A T_\infty + \frac{T_{ship}}{\mathrm{R_{overall}}} + \frac{T_w}{h_s - h_w}\right) = 0$$



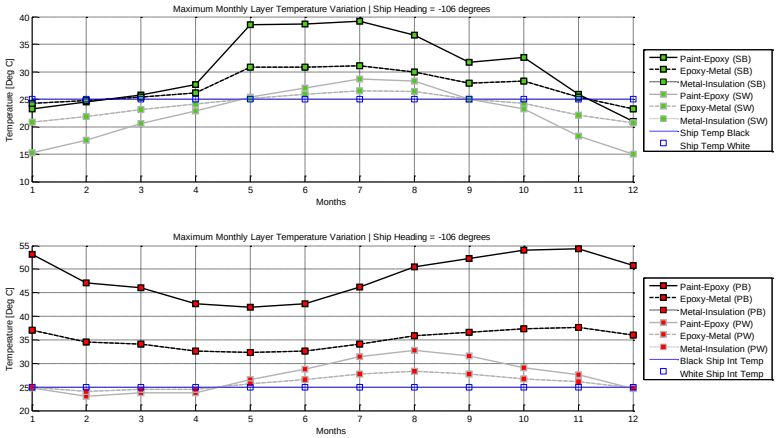


Parametric Analysis

Heat Transfers

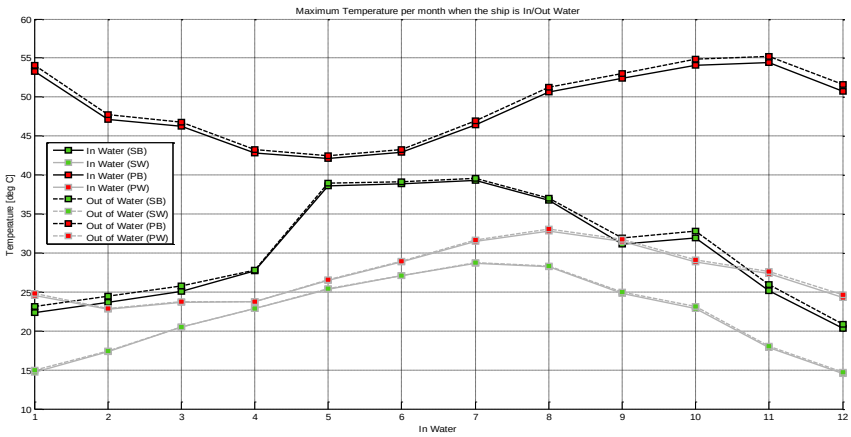


Effect of Paint Colour

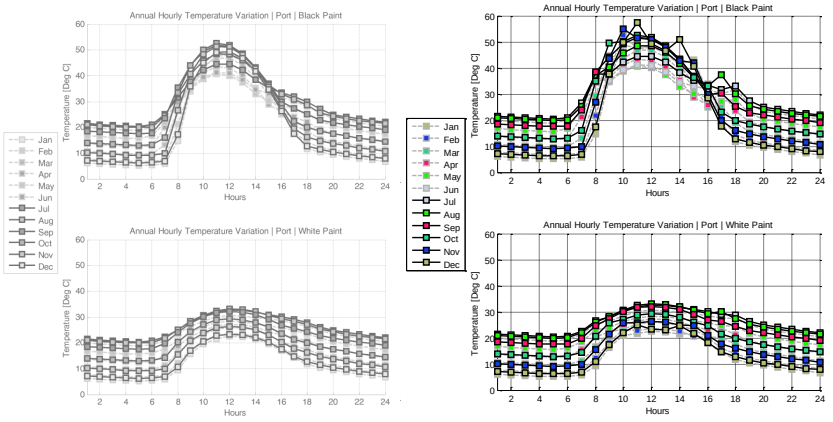


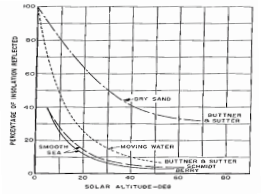
Surface Colour	Fraction of Incident Radiation Absorbed
White smooth surfaces	0.25 - 0.40
Grey to dark grey	0.40 - 0.50
Green, red and brown	0.50 - 0.70
Dark brown to blue	0.70 - 0.80
Dark blue to black	0.80 - 0.90

Ship berthed on land and water



Effect of Sun Elevation





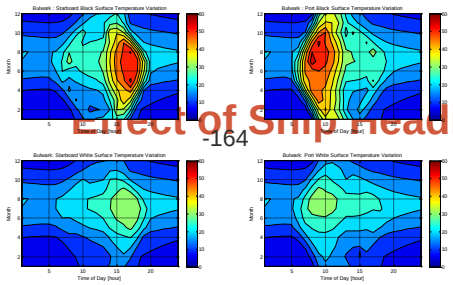
Effect of the incidence angle on the reflectivity of water
(Hechtman, 1956)

Foreground Surface	Reflectance
Water (large angle of incidences)	0.07
Coniferous forest (winter)	0.07
Bituminous and gravel roof	0.13
Dry bare ground	0.2
Weathered concrete	0.22
Green grass	0.26
Dry grassland	0.2 to 0.3
Desert sand	0.4
Light building surfaces	0.6
Snow-covered surfaces:	
Typical city centre	0.2
Typical urban site	0.4
Typical rural site	0.5
Isolated rural site	0.7

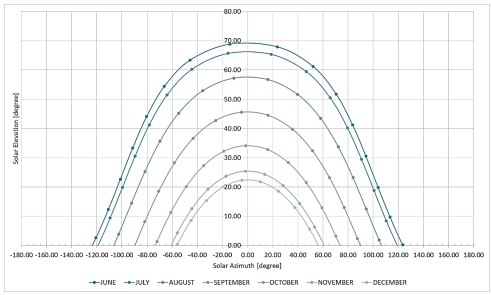
Source: Adapted from Thevenard and Haddad (2006).

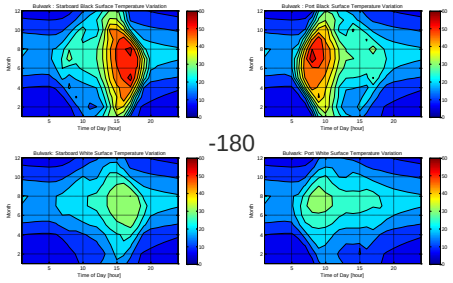
Ground reflectance values of typical surfaces
(ASHRAE,2009)

Effect of Ship Heading



-164





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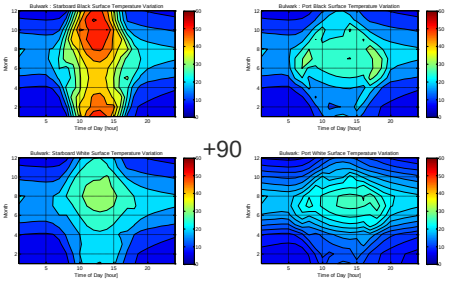
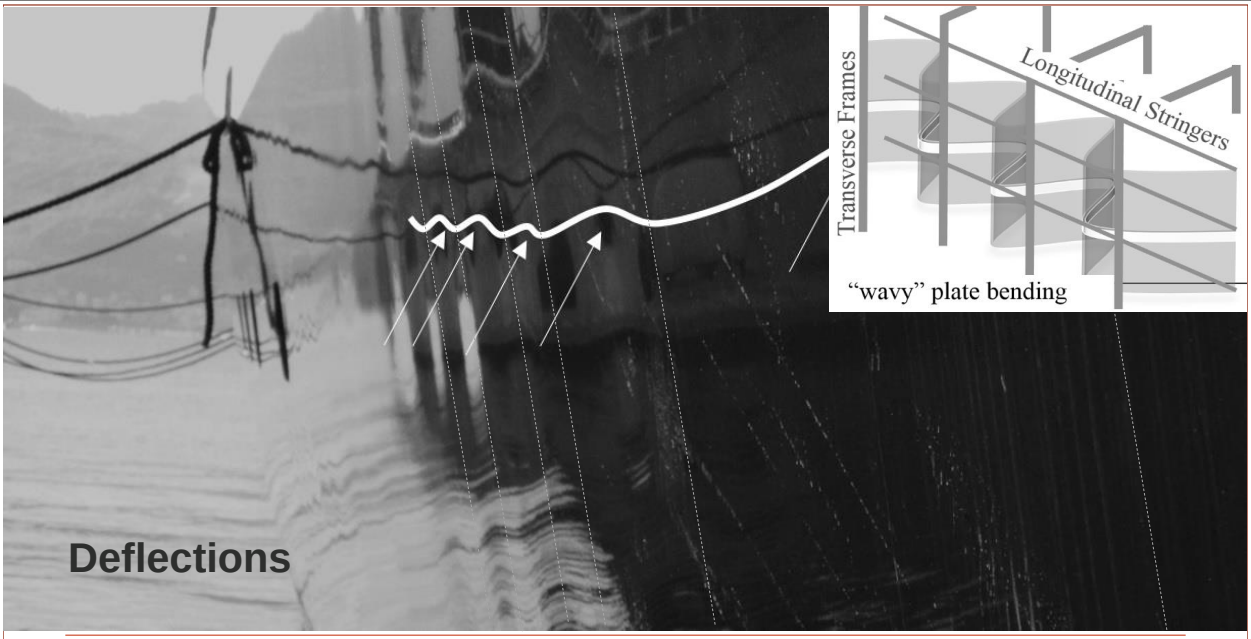


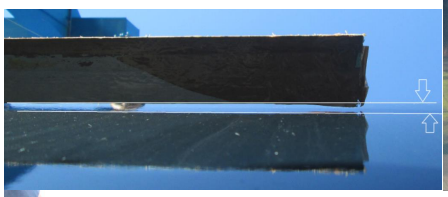
+90

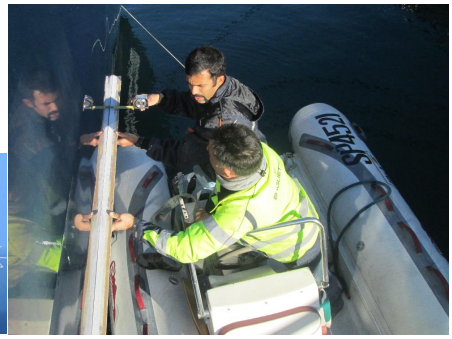
Effects of High Temperatures

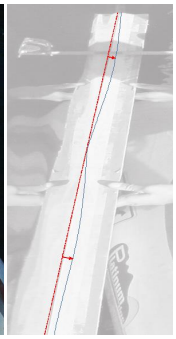
- Hull Deformations
- Optical Distortion Effects
- Hull Coating Defects
- Increased Cooling Loads
- Internal Hull Surface Condensation
- Thermal Comfort



DEFLECTIONS

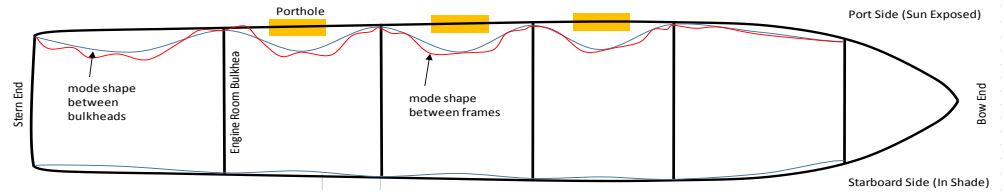


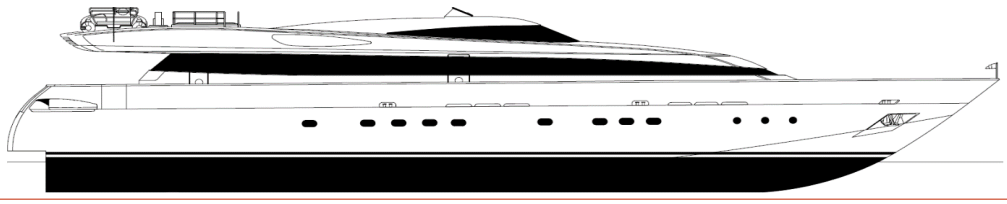




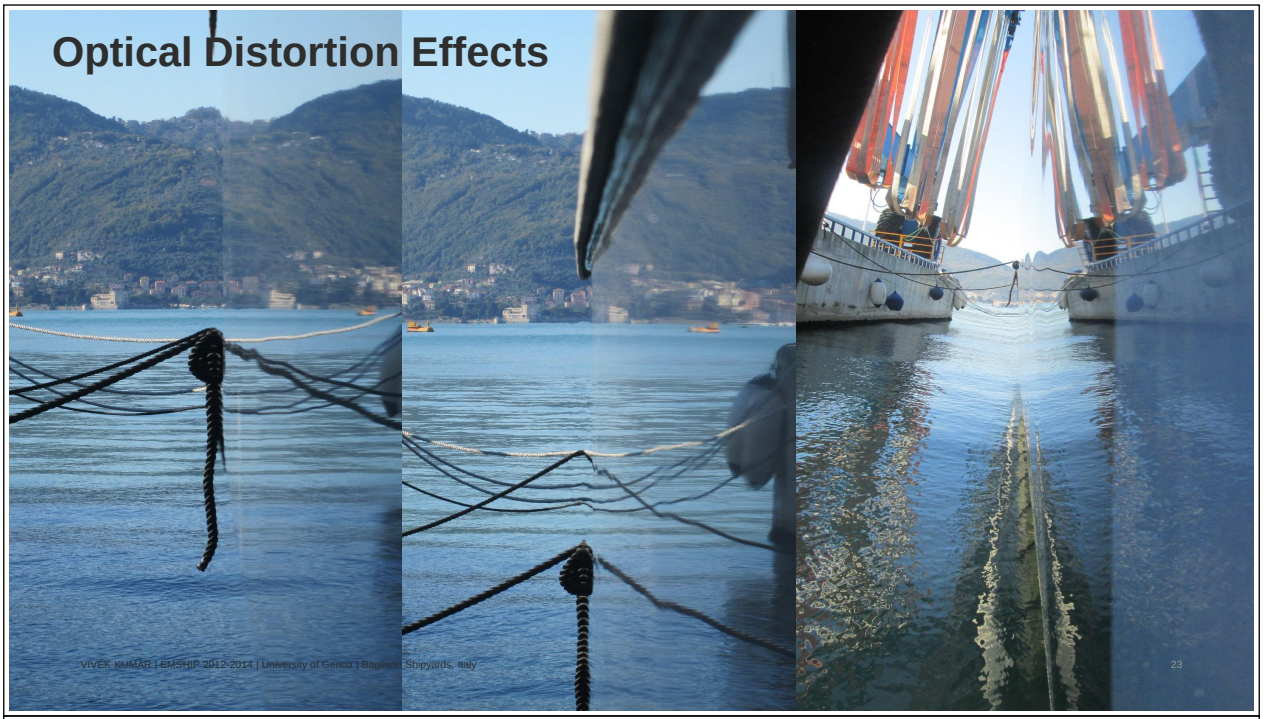
Section of ship	Plate Zone	Max [mm]	Avg. [mm]	Remarks
Aft	Bulwark	0.5	0	-
	Mid-plating	6	3	Bulge near engine room bulkhead
	Bottom-plating	2	2	-
Midships	Bulwark	1	0.5	-
	Mid-plating	5	2	4-6mm deflections near portholes
	Bottom-plating	3	2	-
Fore	Bulwark	0.5	0	Bow area under chine not measured
	Mid-plating	2	1	
	Bottom-plating	1	0.5	

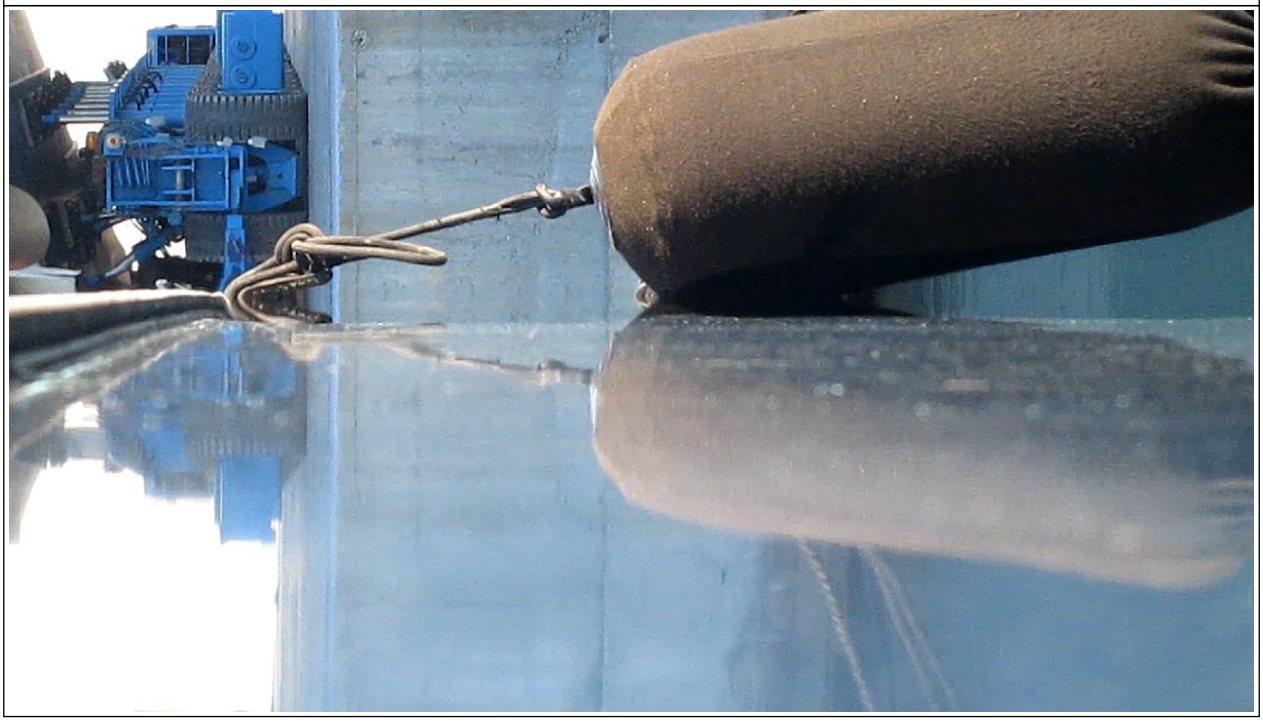
Deformation Analysis



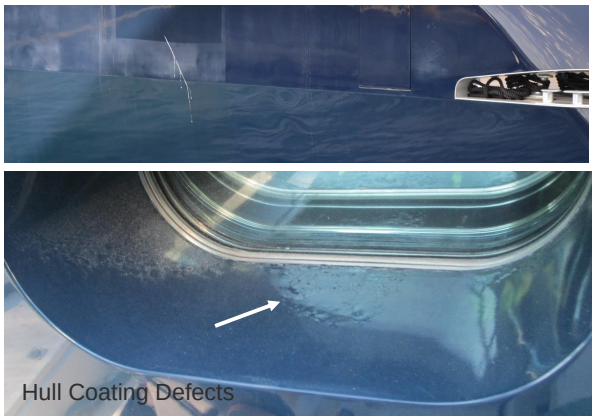


Optical Distortion Effects

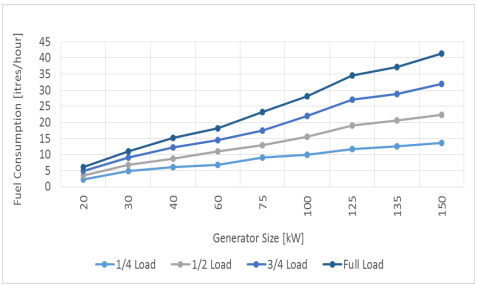




Other Effects of Temperature



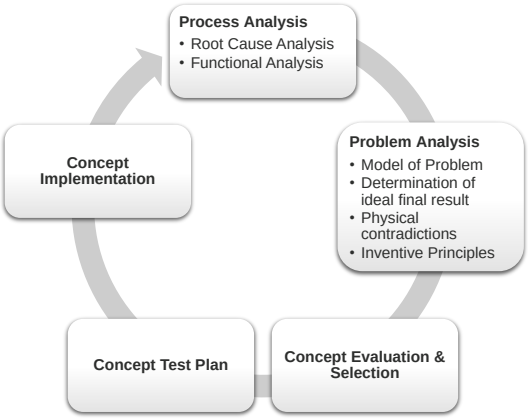
Hull Coating Defects



Fuel consumption variation with load (DieselService&Supply, 2014)

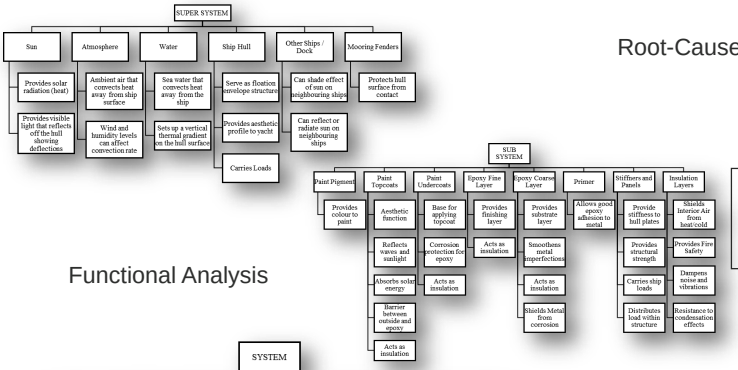
Solutions and Implementations

TRIZ
(Theory of Inventive Problem Solving)

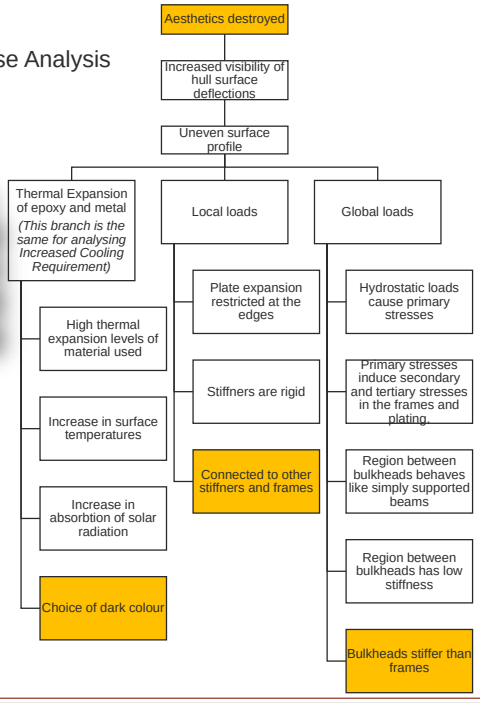


SUPER SYSTEM	SYSTEM	SUB SYSTEM
Sun	Paint	Paint Pigment
Atmosphere	Epoxy	Paint Topcoats
Water	Primer	Paint Undercoats
Ship Hull	Metal	Epoxy Fine Layer
Other Ships / Dock	Insulation	Epoxy Coarse Layer
Mooring Fenders	Interior Air	Primer
	Air Conditioner	Stiffners and Panels
	Generator	Insulation Layers

Functional Analysis



Root-Cause Analysis

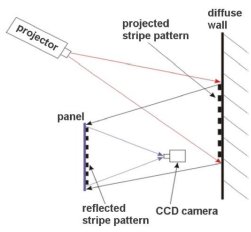


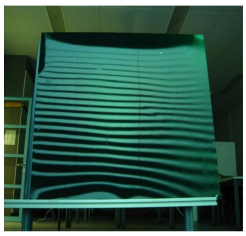
Solutions for reducing high temperatures and deformations

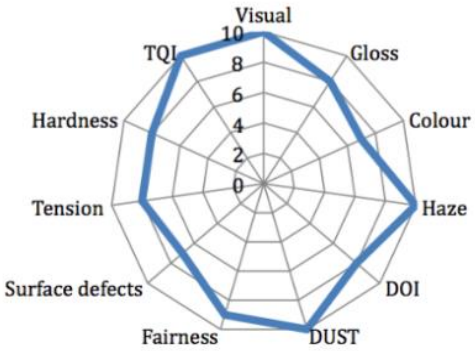
- Increase web height of frames and stiffeners in region between bulkheads
- Reduce spacing between longitudinal stiffeners in region between bulkheads
- Reduce porthole-hull area ratio
- Low Solar Absorption (LSA) paints reflect IR light but not visible light
- Use silver grey instead of dark grey (more reflective)
- Climate Controlled Chamberes
- Vinyl Paints
- Remove yacht from water when not in use and/or store in covered garage
- Align yacht with East-West direction so the sun hits only the bow or stern regions and not the hull directly.

Solutions for improving/assessing hull coatings

- Define ‘beauty’ objectively on a project-by-project basis
- Defectometry



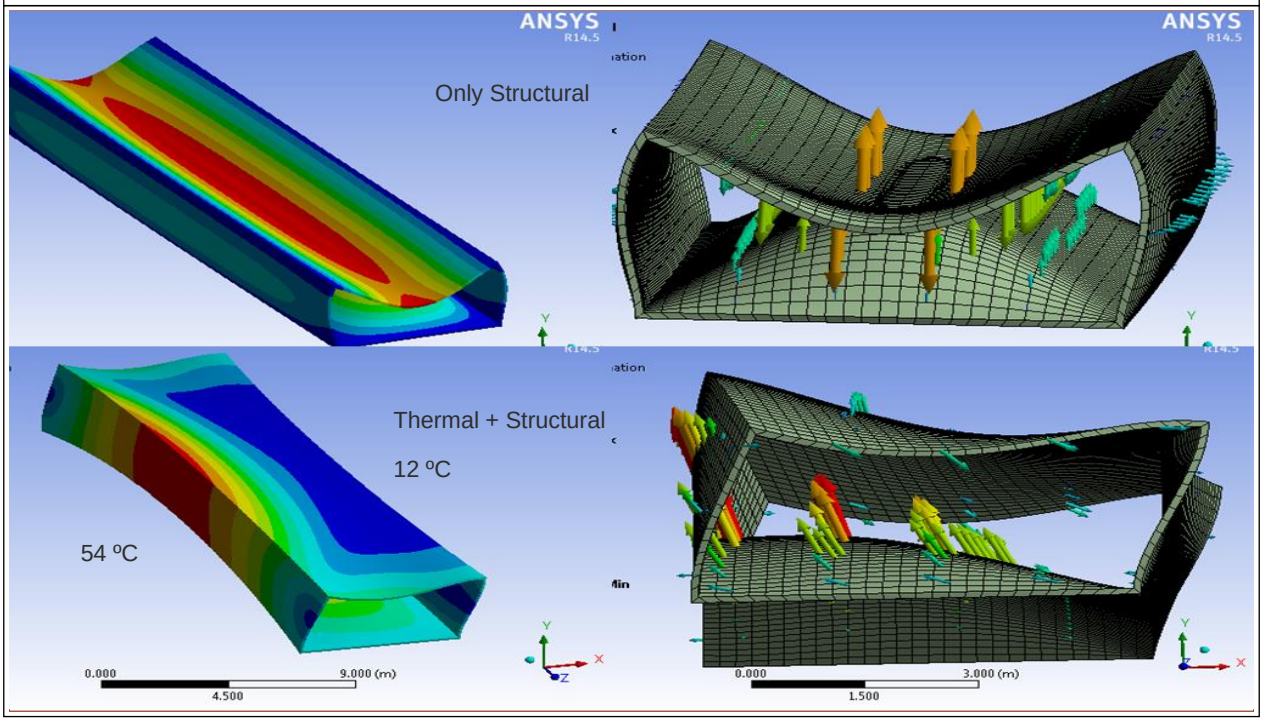




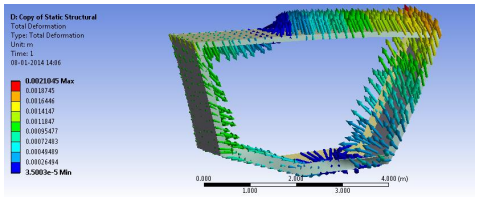
12-point appearance evaluation system ISO draft standard TC 8/ SC 12 and BIS 11347

Solutions for improving Energy Efficiency

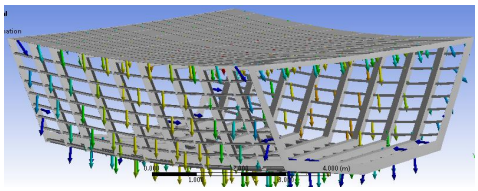
- Benchmark similar ships of different colours (energy use / fuel consumed…)
- Reduce porthole-hull area ratio
- Optimum balance between air conditioner size and insulation thickness
- Reuse waste heat energy from the engine
- Update old electrical equipment and wiring systems
- Separation of HVAC systems such that different areas of the ship are cooled differently
- Minimize impact of heat generating devices by using heat shields



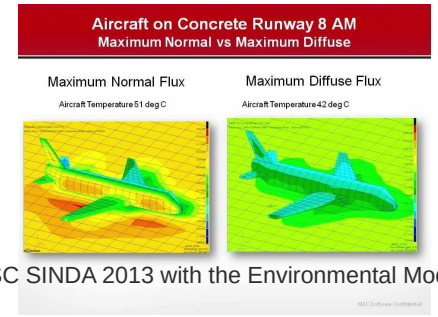
Detailed FEM for Ship Scale Thermal-Structural Analysis



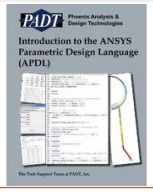
Temperature only deflections in a ship section



Structural only deflections in a ship section



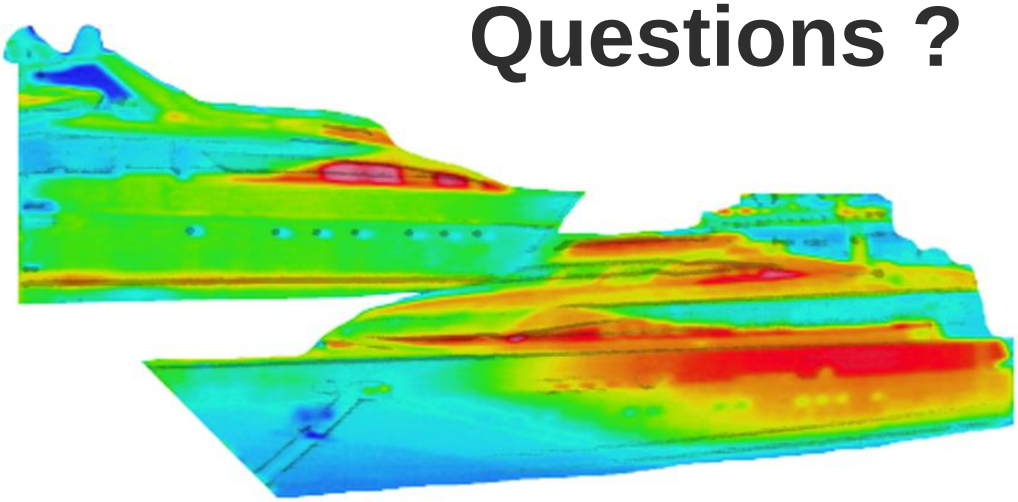
MSC SINDA 2013 with the Environmental Module



Conclusion

- From this this project, temperature variations of any metallic hulled ship can be analysed, anywhere in the world.
- Colour plays the most important role in deciding surface temperatures, followed by material and stiffness of the structure for deciding structural responses
- Port and starboard are asymmetrically exposed to solar radiation with a thermal gradient from bulwark to waterline, and from bow to stern
- Complex nature of ship structures - *each part of the structure exercises some restraint or contraction on adjacent structures*.
- Thermal and structural stresses interact, with material properties changing with temperature
- Yachts typically spend a majority of their time docked at the marina

Questions ?



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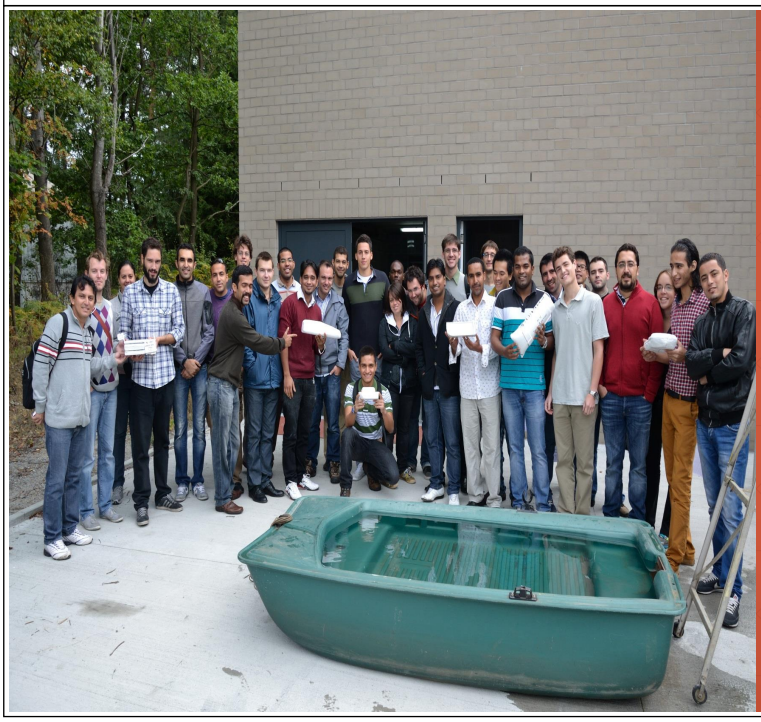

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