SAND2011-1125P

LNG Cascading Damage Project
3rd External Panel Meeting

Introduction & Background

Vessel Model Development

February 23 and 24, 2011

Outline

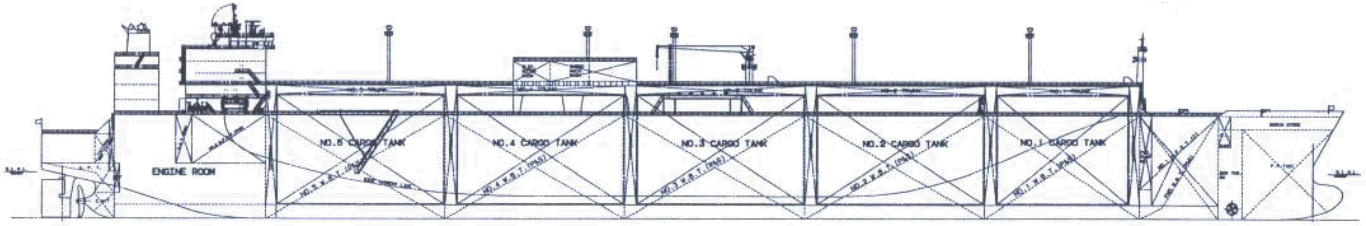
- LNG Tasks and Schedule
- Revisit Problem and Scope of Project
- Vessel Model Development
- Final Analysis Strategy

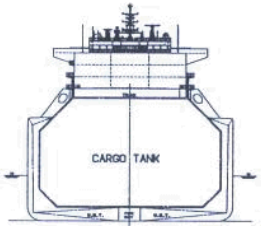
LNG Cascading Damage Program Schedule

Task Description	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
Large-scale LNG Fire Testing and Analysis		Review Draft - DOE, SNL, PRG		Respond to Comments		Final Report					
Large-scale LNG Fire Modeling and Analysis	Model development for attached and unattached fires with water entrainment and Draft Report					Review Draft- DOE, SNL, PRG	Respond to Comments		Final Report		
Cryogenic Fracture Testing and Modeling	Complete data analysis and Draft Report		Review Draft DOE, SNL, PRG		Respond to Comments	Final Report					
LNG Spill Flow Modeling and Analysis	Complete modeling and Draft Report			Review Draft Report – DOE, SNL, PRG	Respond to Commen	Final Report					
Insulation Damage Modeling, Testing, and Analysis			Testing and analysis and Draft Report				Review Draft - DOE, SNL, Industry, PRG		Respond to Comments	Final Report	
Internal Flammability Modeling and Analysis			Evaluation of flammability data and Draft Report			Review Draft -DOE, SNL, PRG	Respond to Comments		Final Report		
Standoff Mitigation Modeling and Analysis		Modeling and analysis of standoff distance impacts on breach mitigation and Draft Report					Review Draft – DOE, SNL, PRG		Respond to Comments	Final Report	
Relief Valve Pressurization and Release Analysis				Modeling, Analysis and Draft Report			Review Draft- DOE, SNL, PRG		Respond to Comments	Final Report	
Ship Damage and Stability Modeling and Analysis	Analysis of LNG carrier damage and stability and Draft Report						Review Draft DOE, SNL, PRG		Respond to Comments	Final Report	
LNG Fire and Cascading Damage Report to Congress							Help DOE Prepare Draft Report to Congress		Respond to OMB Comments		

LNG Cascading Damage Scenario

Can an LNG tank breach event cascade throughout the tank, extend to other tanks, and experience further damaged due to an external fire?





Membrane LNG Carrier

LNG Cascading Damage
Initial Conditions & Assumptions

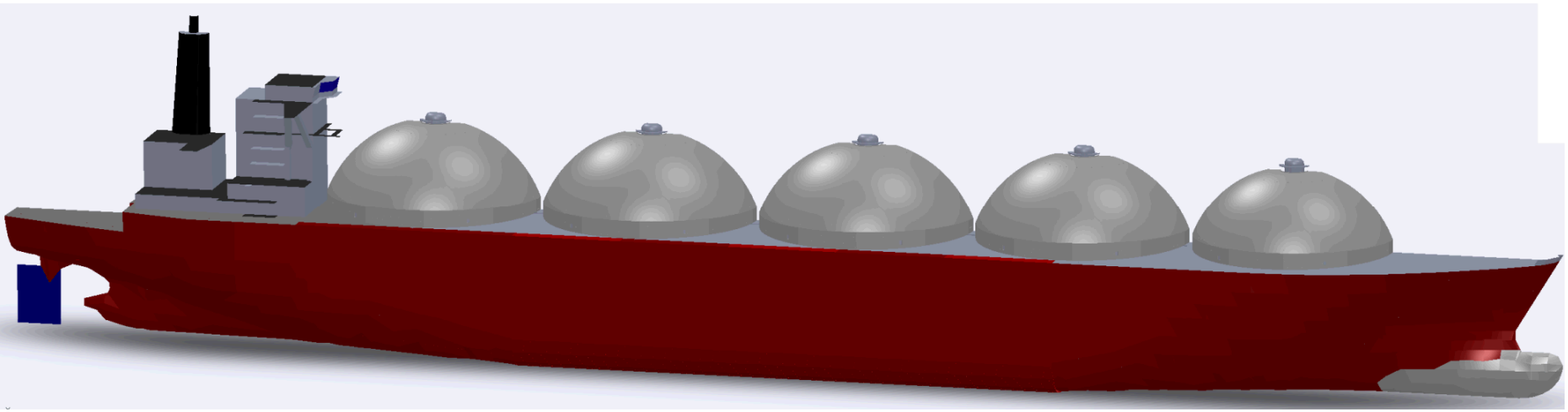
- Two vessels examined: Membrane and Moss
- Two breach scenarios evaluated for each class of ship
  - Above and Near waterline (these define the initial conditions for this study)
- Conditions analyzed are near shore, calm water
- Each scenario must examine
  - Extent of LNG flow
  - Cooling of the steel structure
  - Determine extent of damage due to cryogenic temperatures
  - Determine external fire and heat-up of steel structure
  - Assess final damage states of each vessel

Full Vessel Model Development

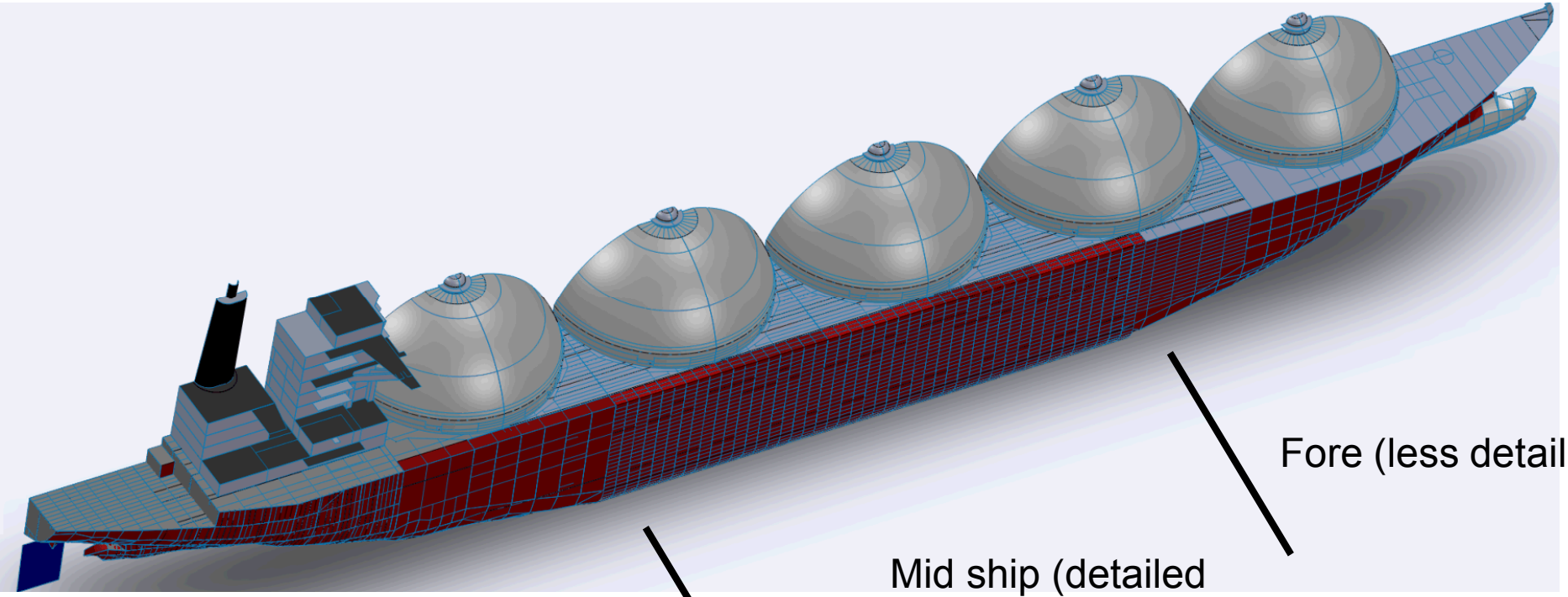
- Detailed drawings and information on Membrane and Moss vessels received in April 2009
- Structural components have been explicitly represented with some simplifications in aft and forward regions
- Weight distribution for non-structural items and LNG cargo are represented with appropriate loading functions
- ~4.5 million elements are being used for Moss and Membrane vessels

Dimension	Moss	Membrane
Length	280 m	330 m
Breadth	45 m	54 m
Depth	25 m	27 m
LNG Cargo Capacity	140,000 m^3	260,000 m^3

LNG Moss Model Development

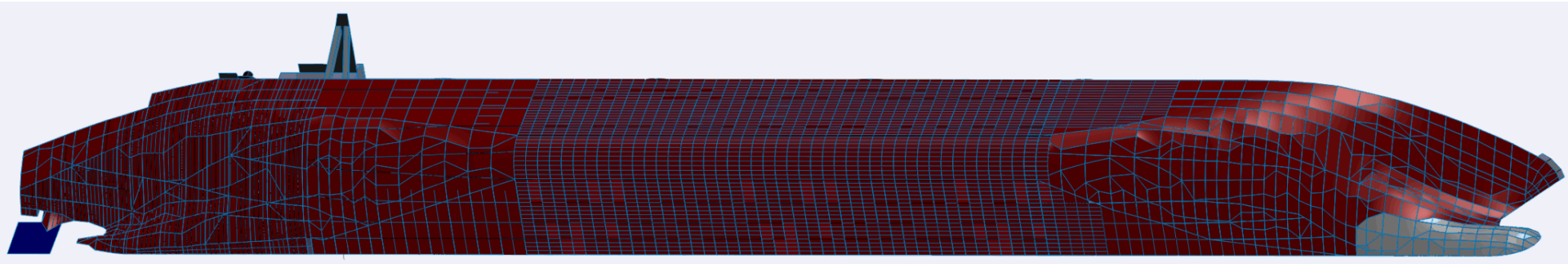


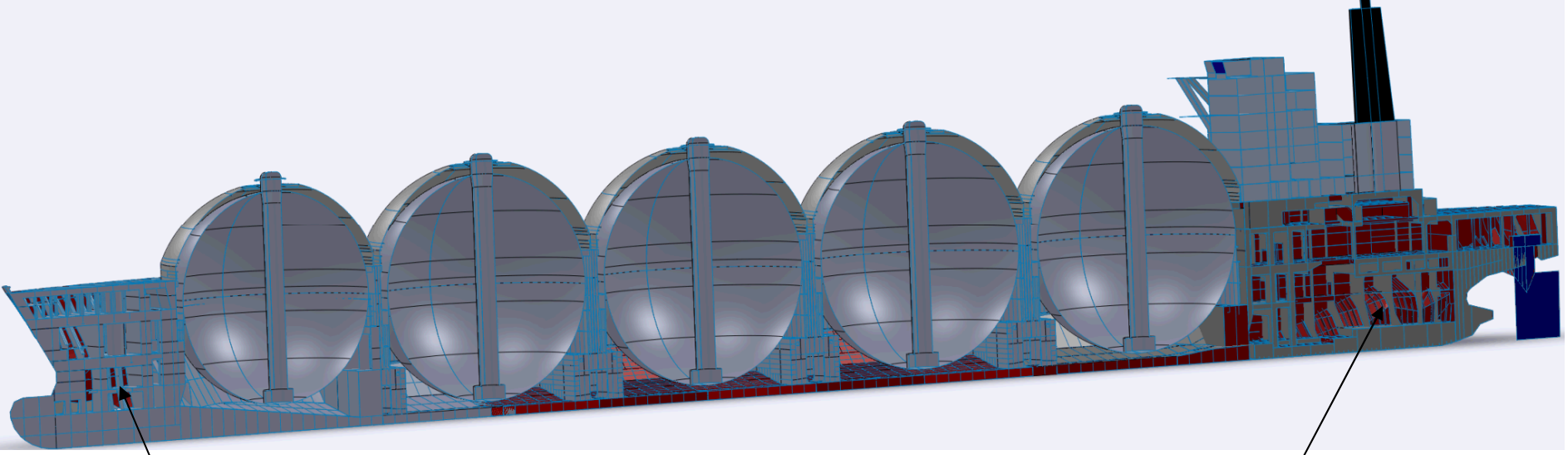
Moss Regions



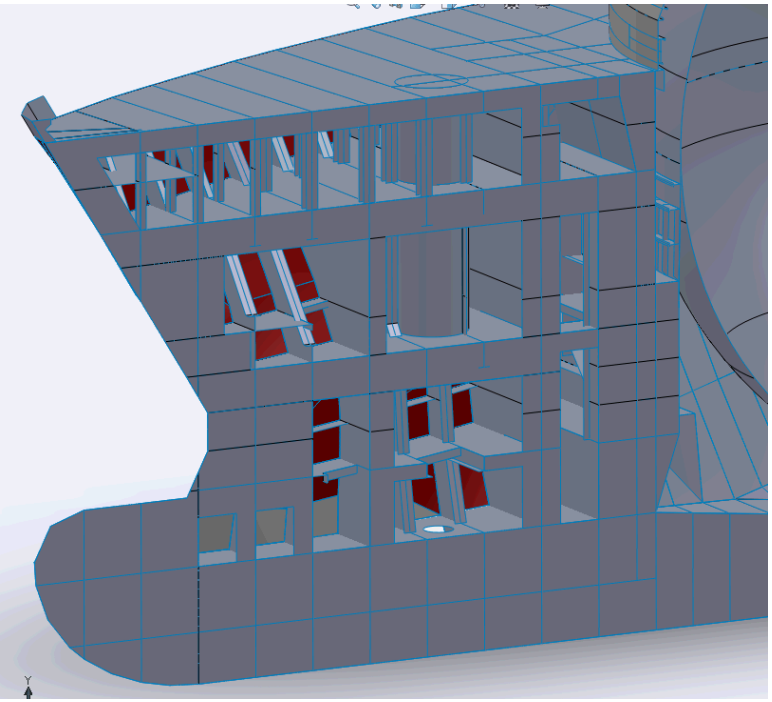
Moss Hull

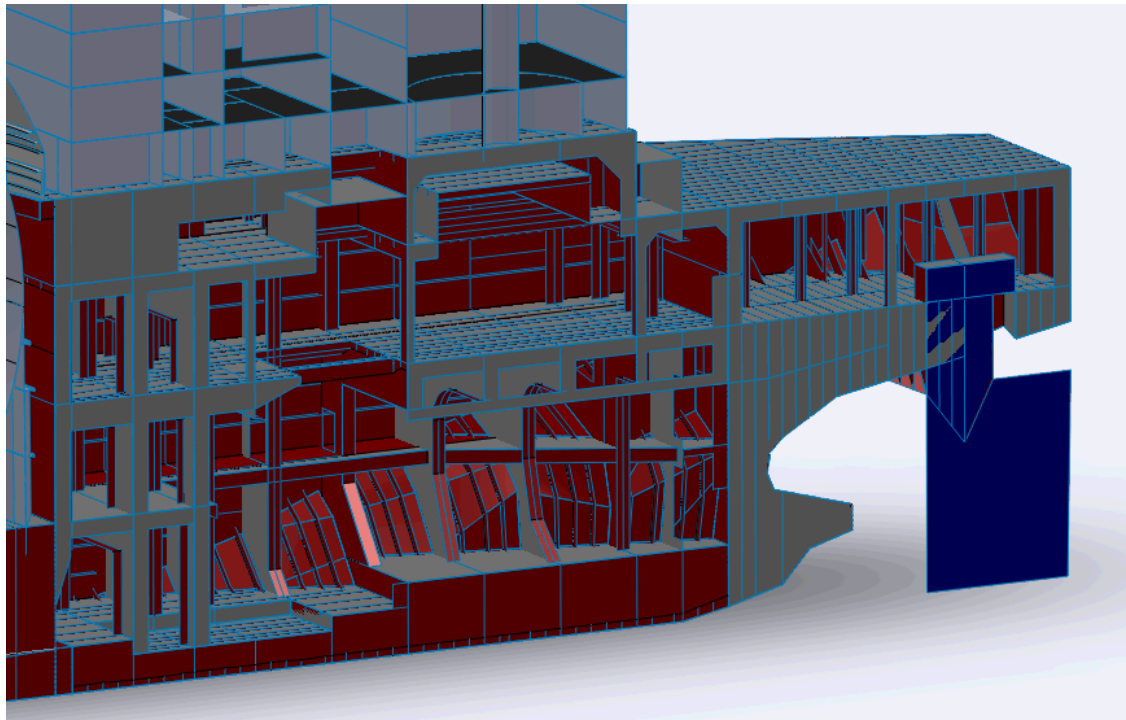
- Linear geometry used to approximate curvature
- Triangular Planes and lofted surfaces between four lines compose the hull



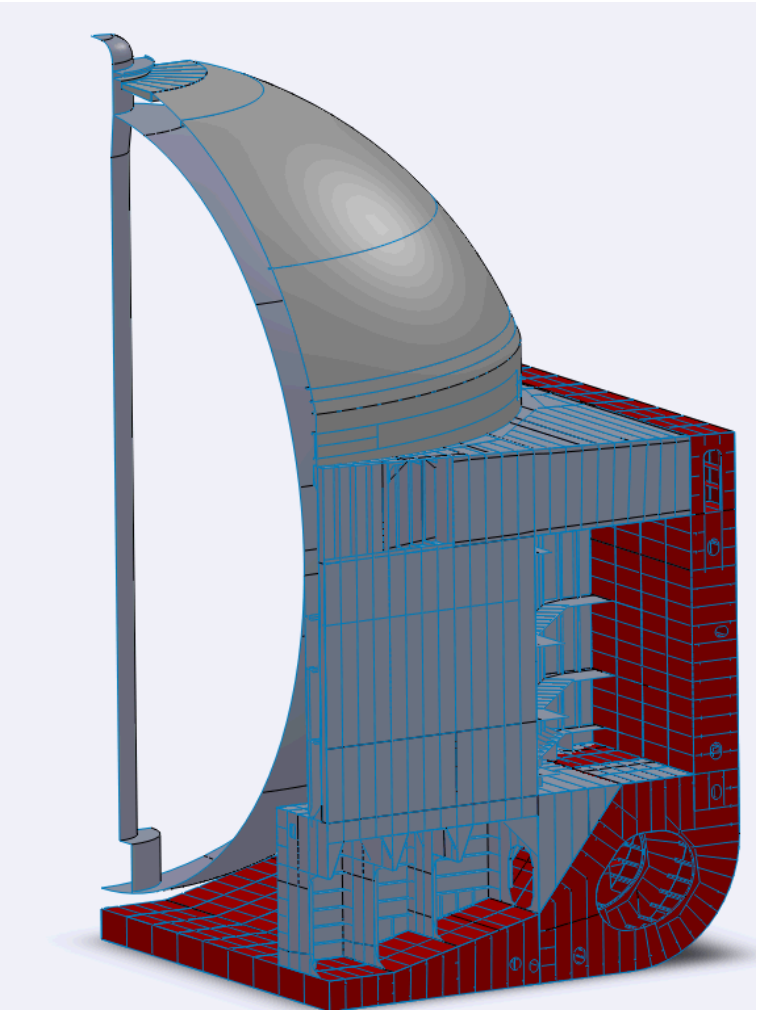


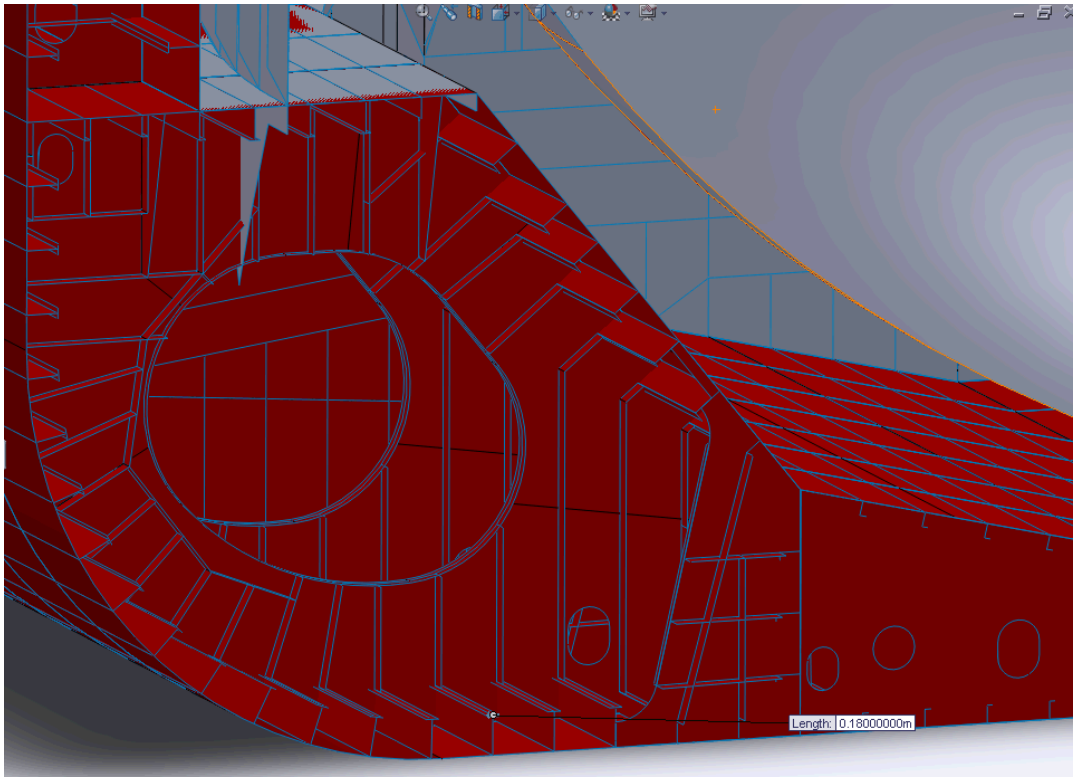
Ends modeled with frames, decks and bulkheads
but stiffeners neglected to reduce complexity



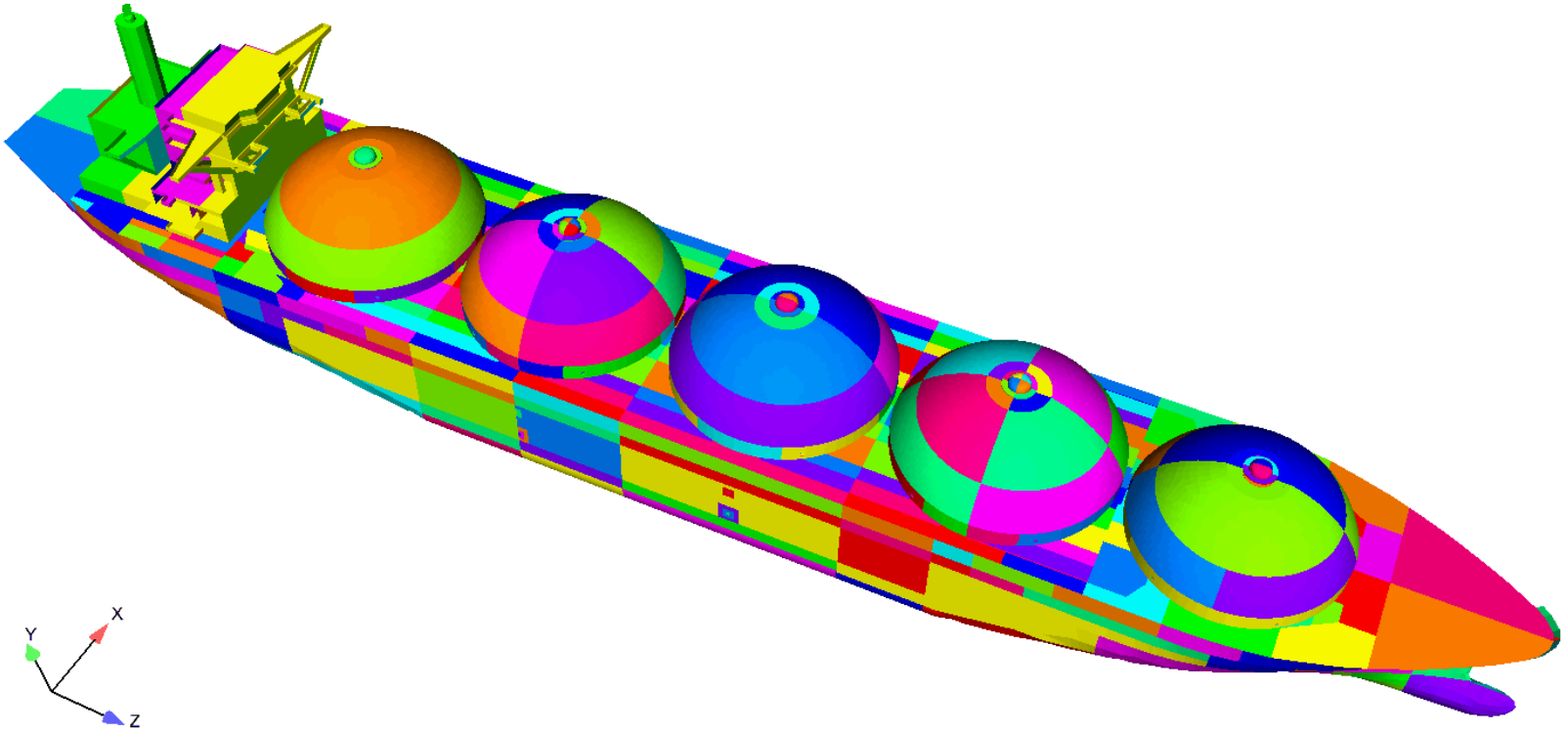


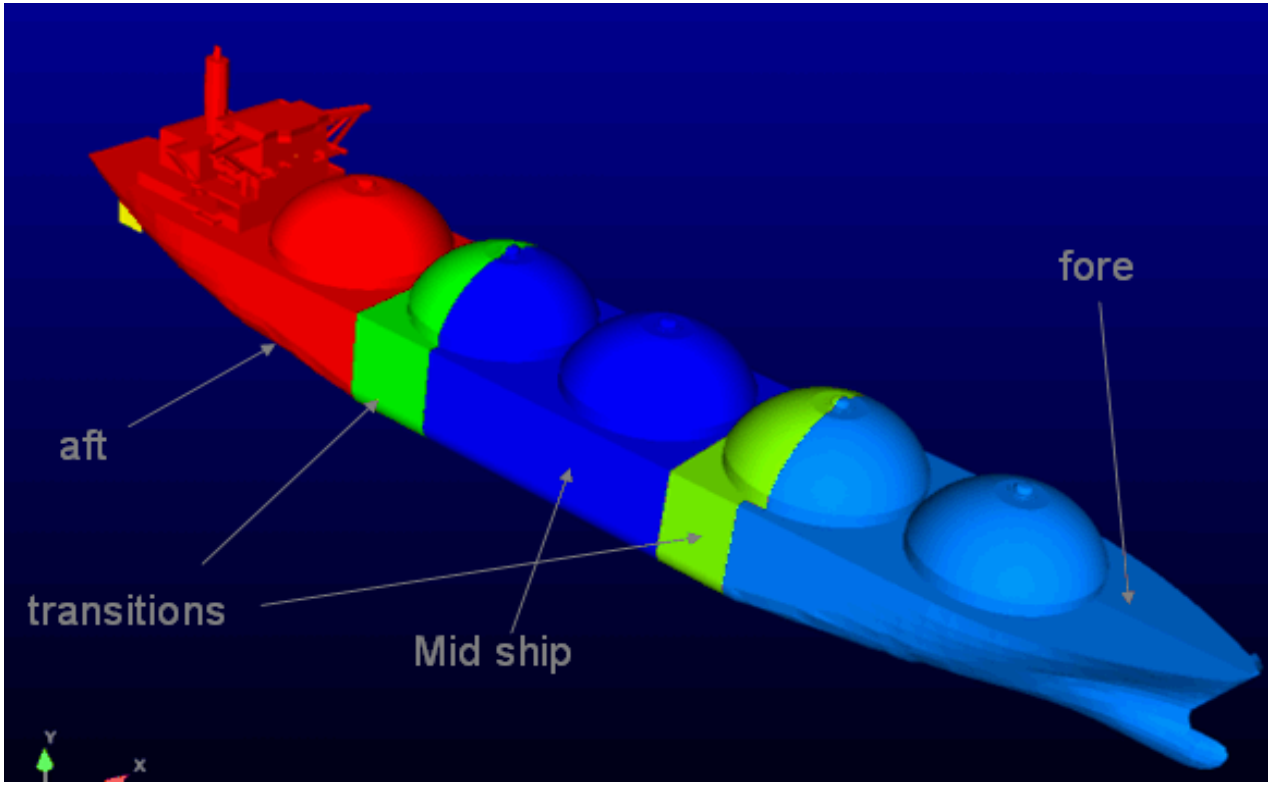
Moss Details





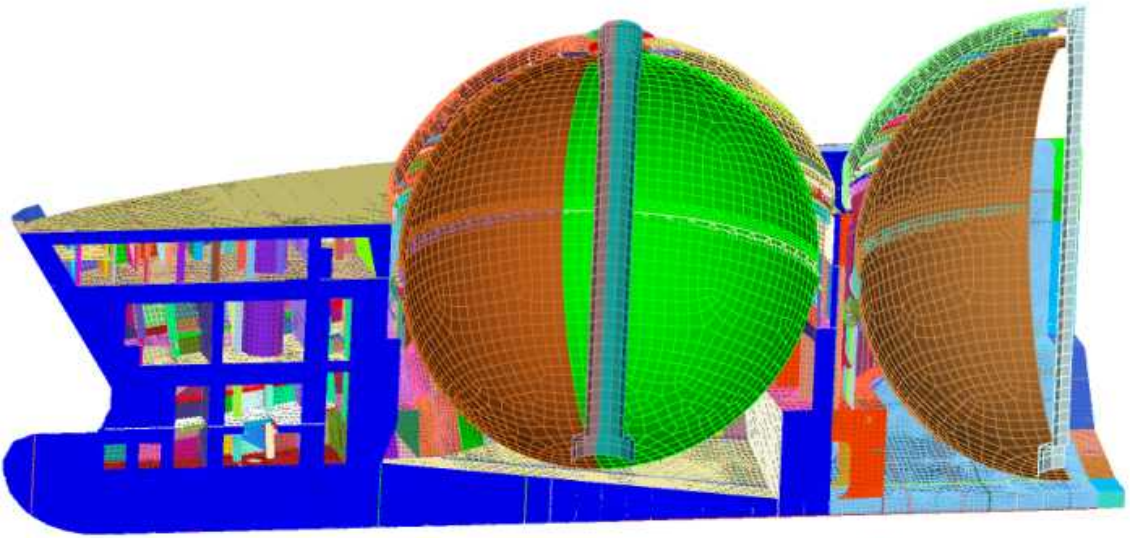
Moss FEM Partitions

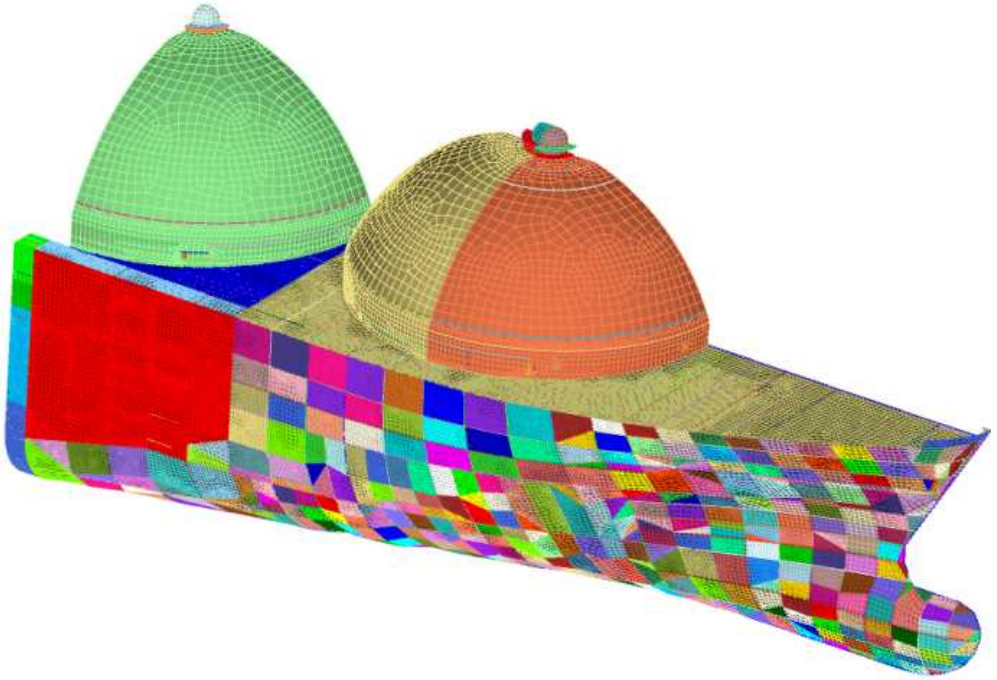


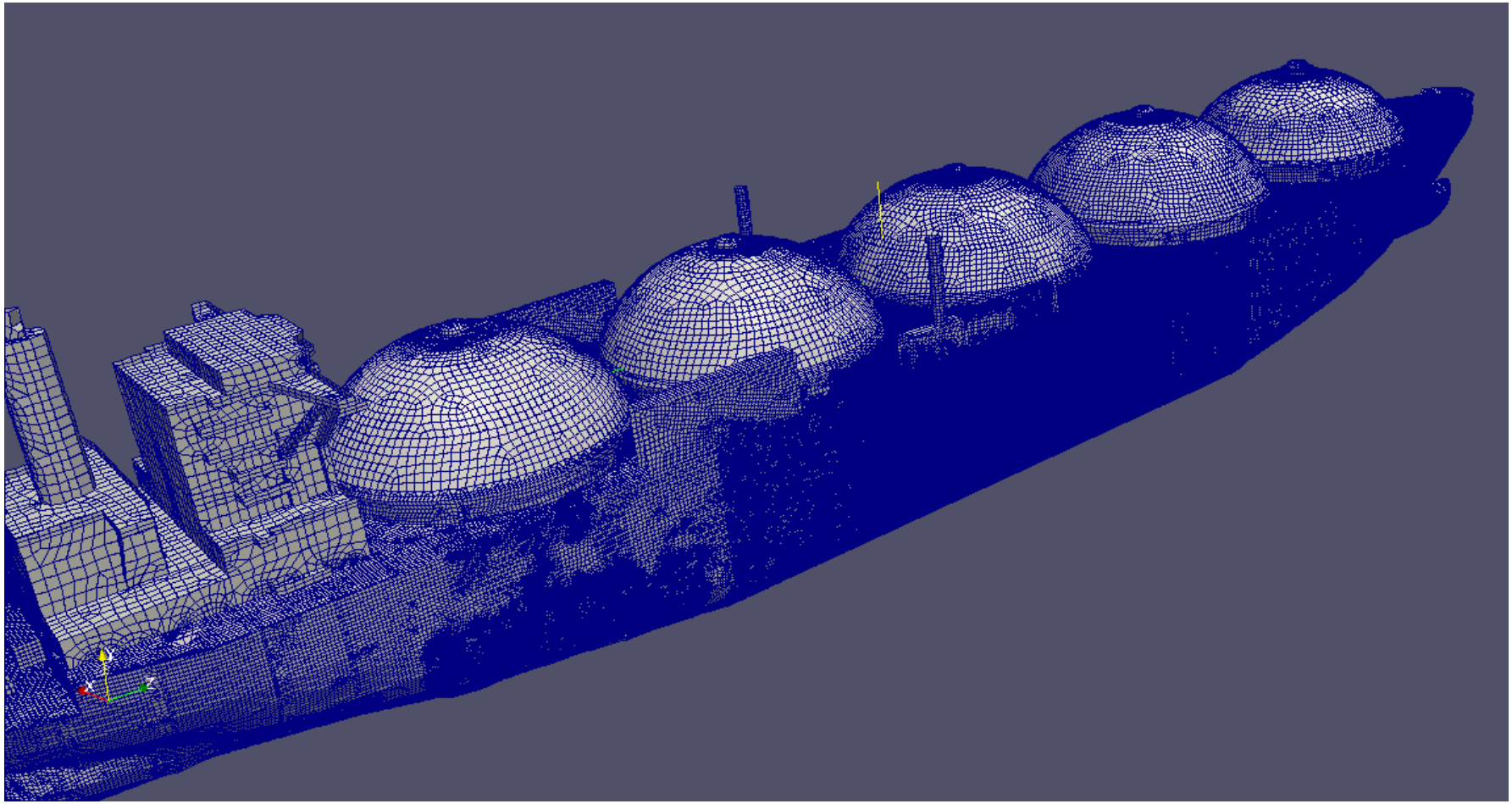


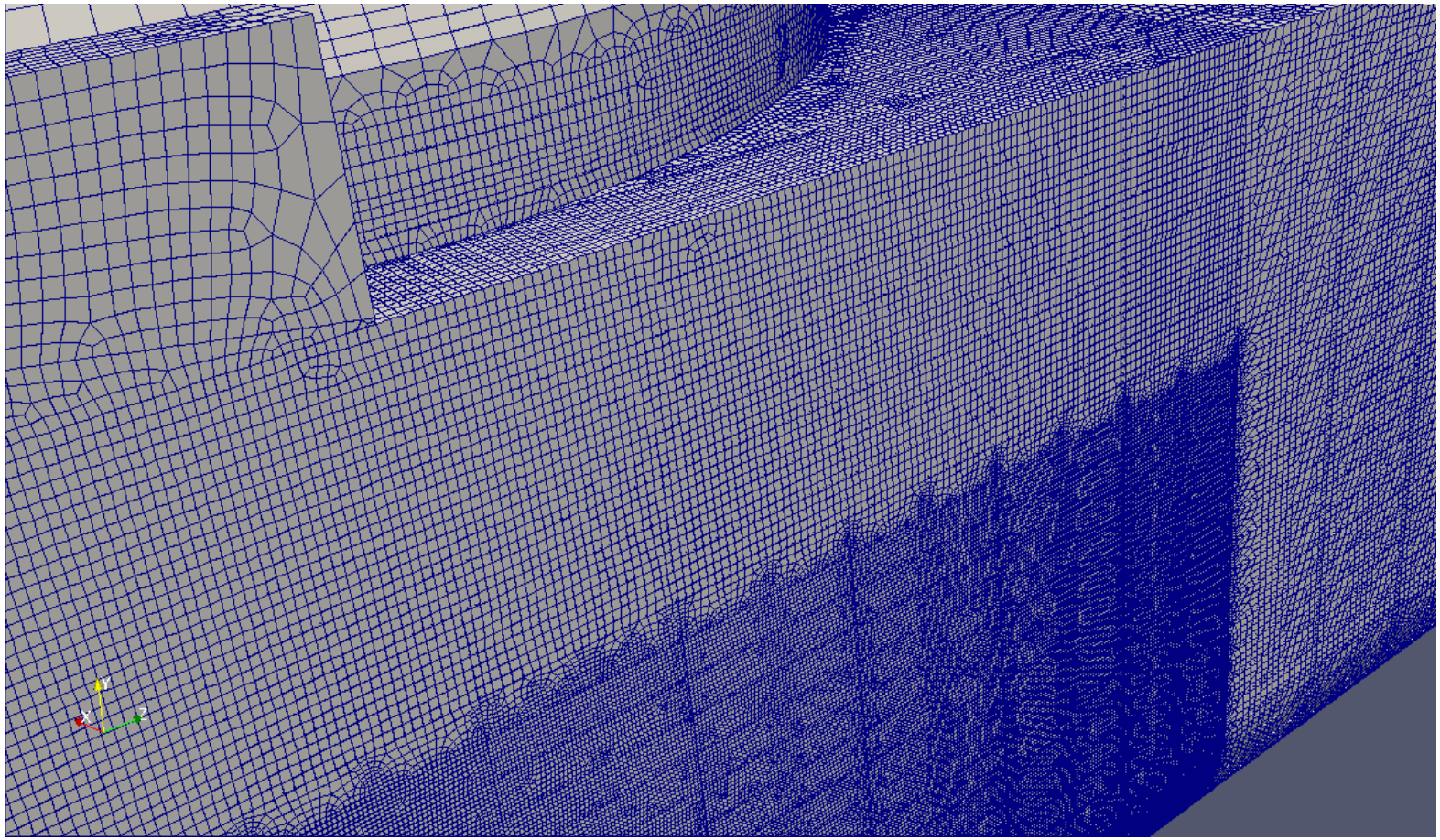
Number of Elements	Moss	Membrane
Fore	623178	202838
Mid Ship	3479082	3140930
Aft	775210	934284
Total	4877470	4278052
% in detailed regions	71.3	73.4

Moss Meshing

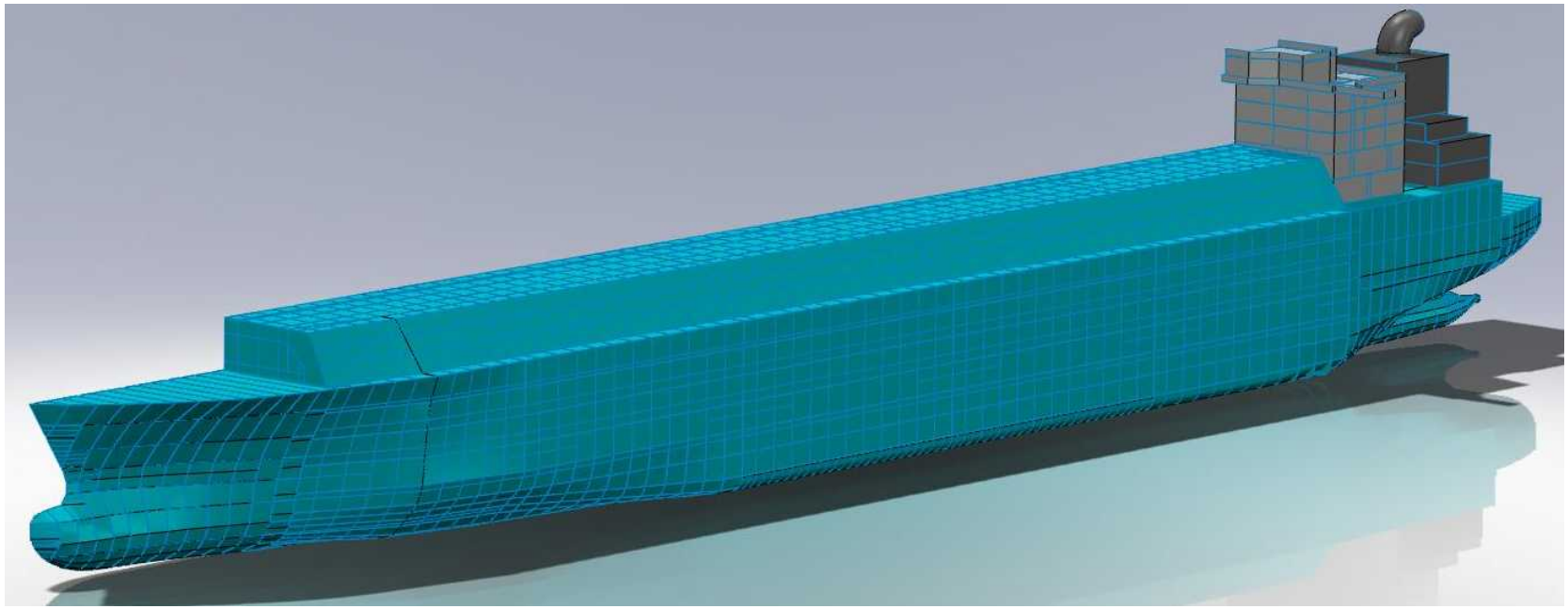


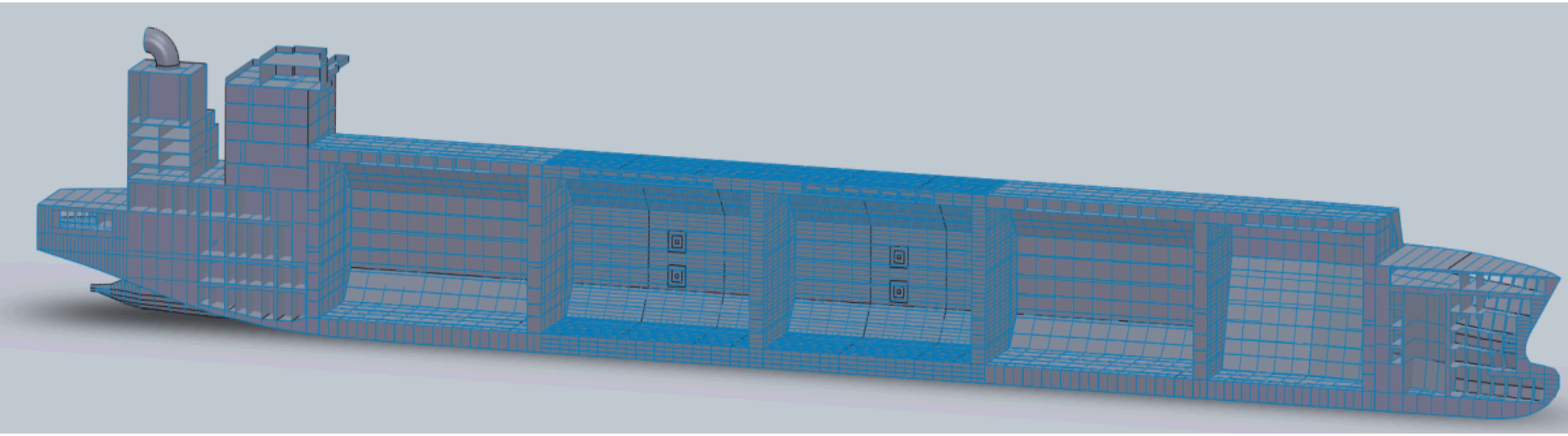






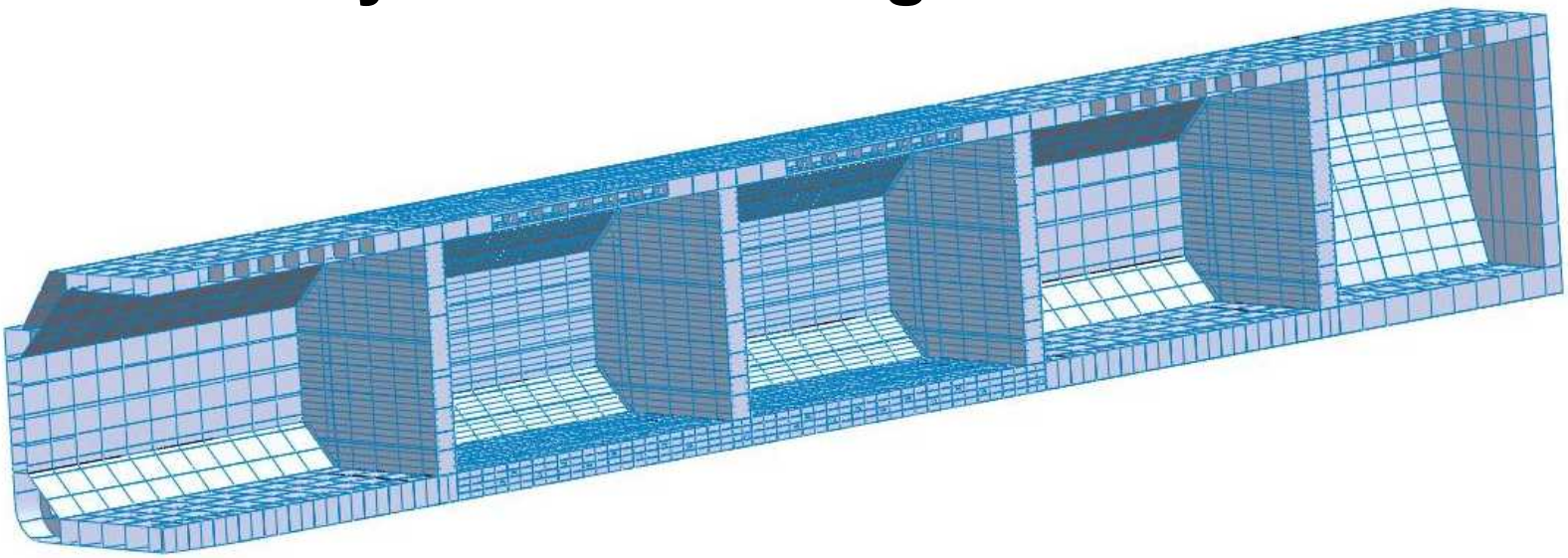
Membrane



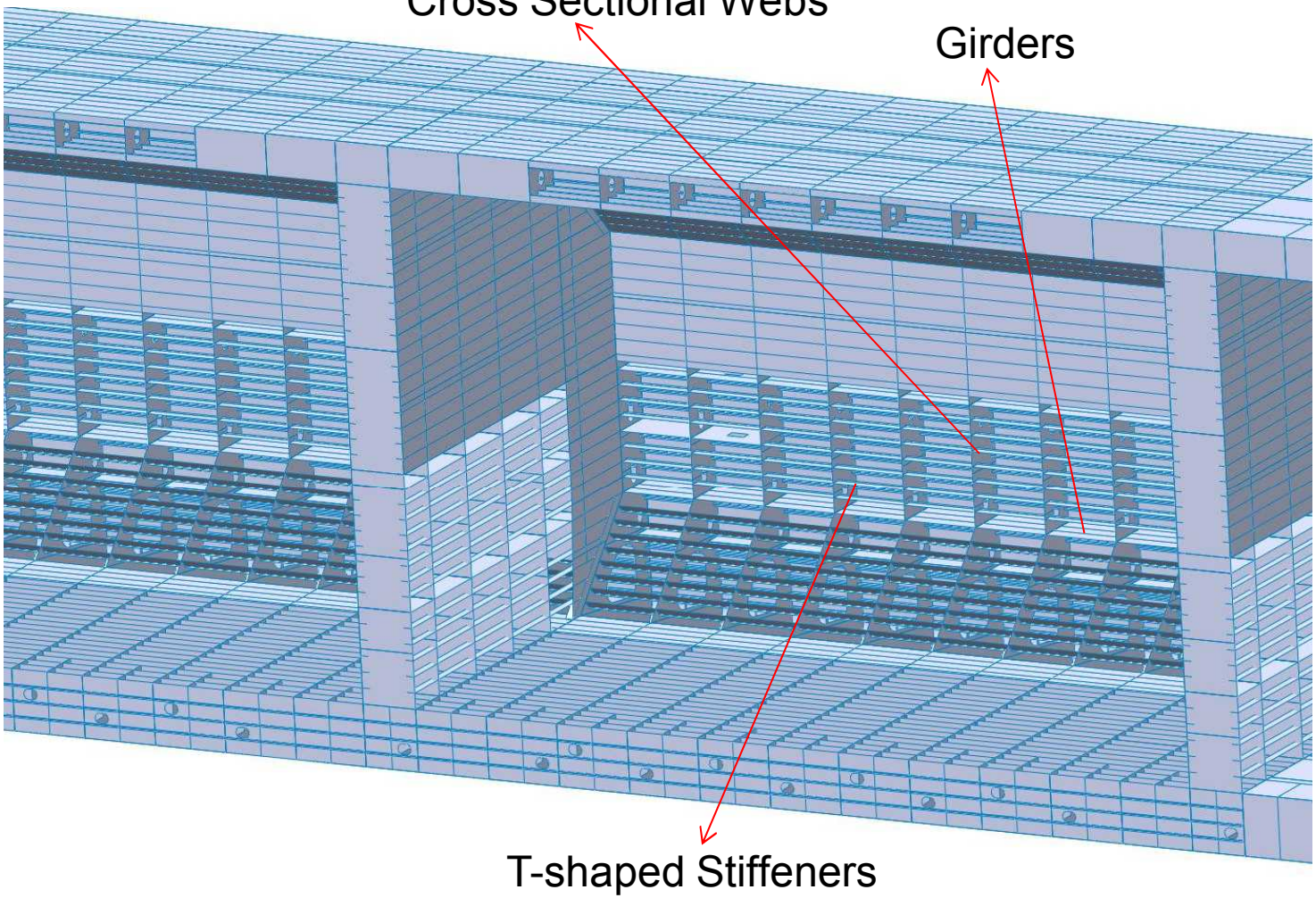


Membrane - Outer Shell of the Five Tanks

- All tanks are half-symmetrical only
- Only two tanks are the same – the rest taper
- Use straight line to accommodate curvature as best as possible
  - Frame by frame drawing in some cases

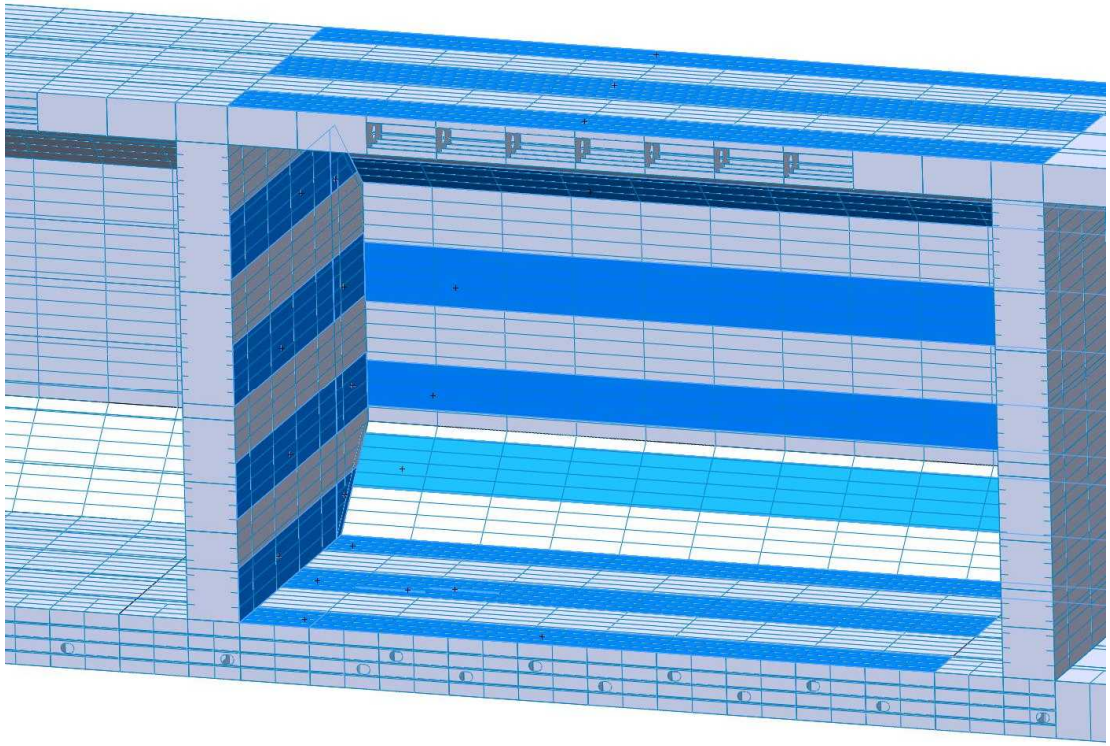


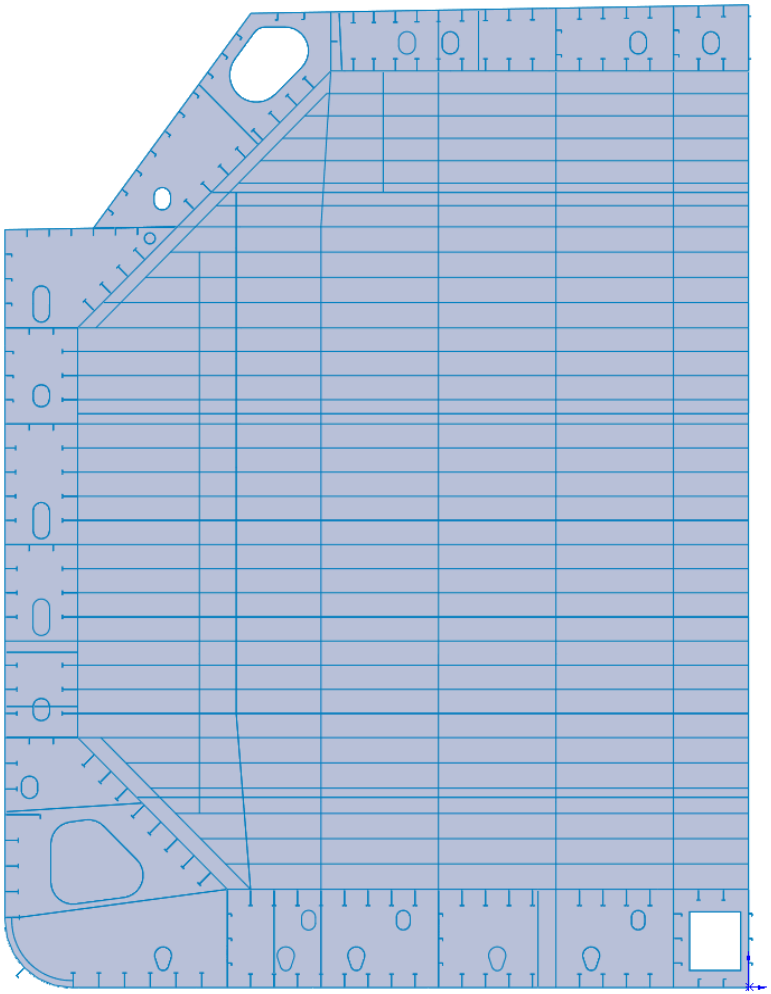
Membrane Details

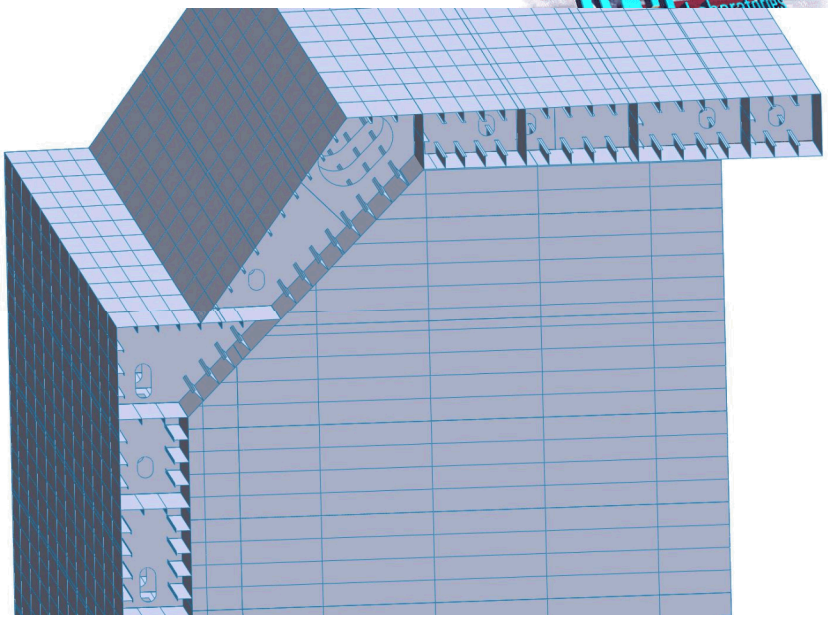


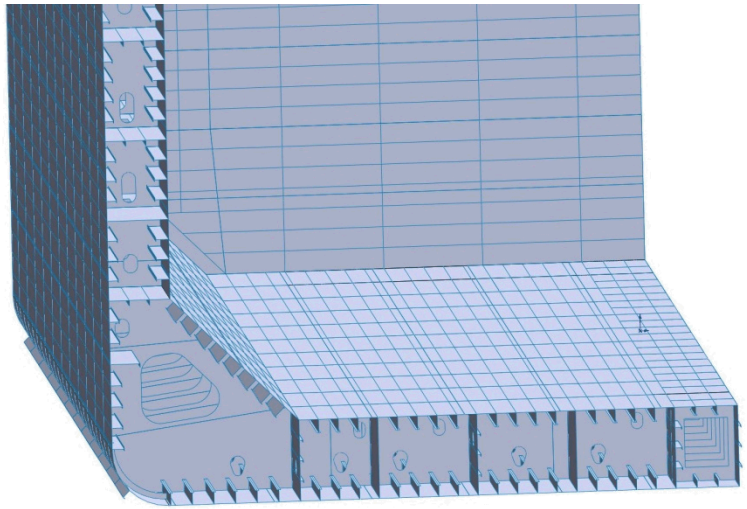
Material and Thickness Variations

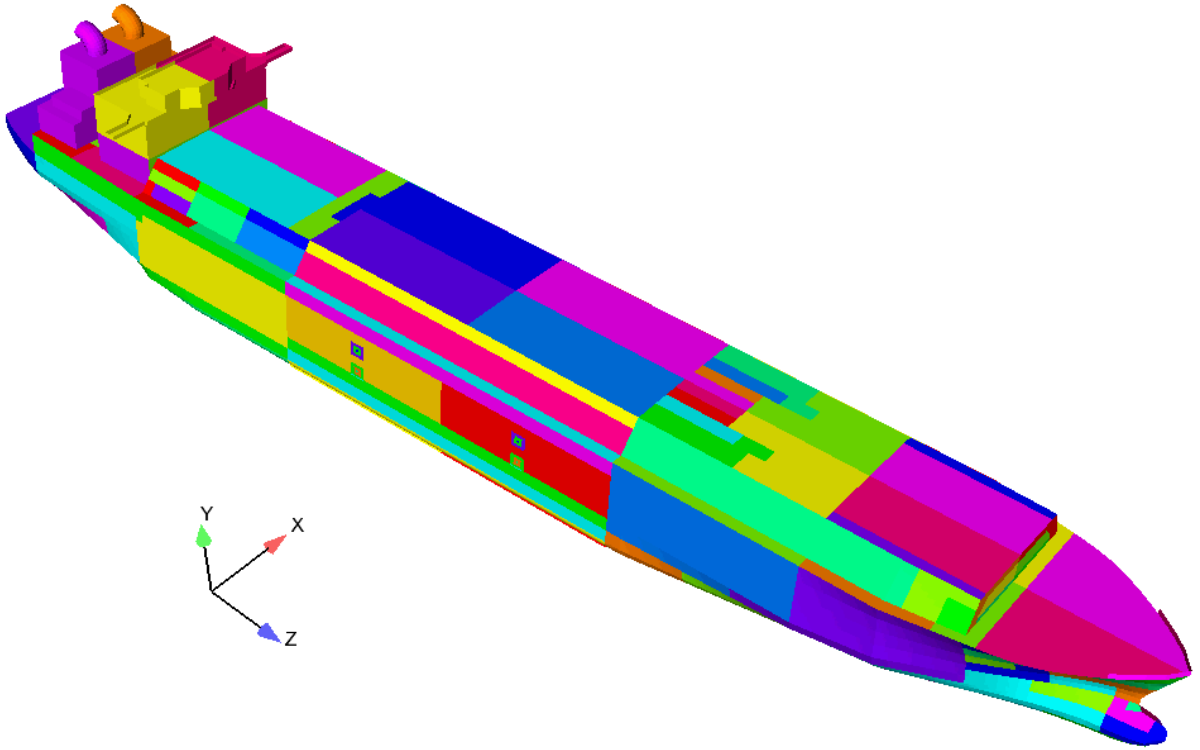
Materials and plate thickness vary throughout the tanks at regular intervals as indicated by the layered coloring scheme in the inner and outer halls of this figure

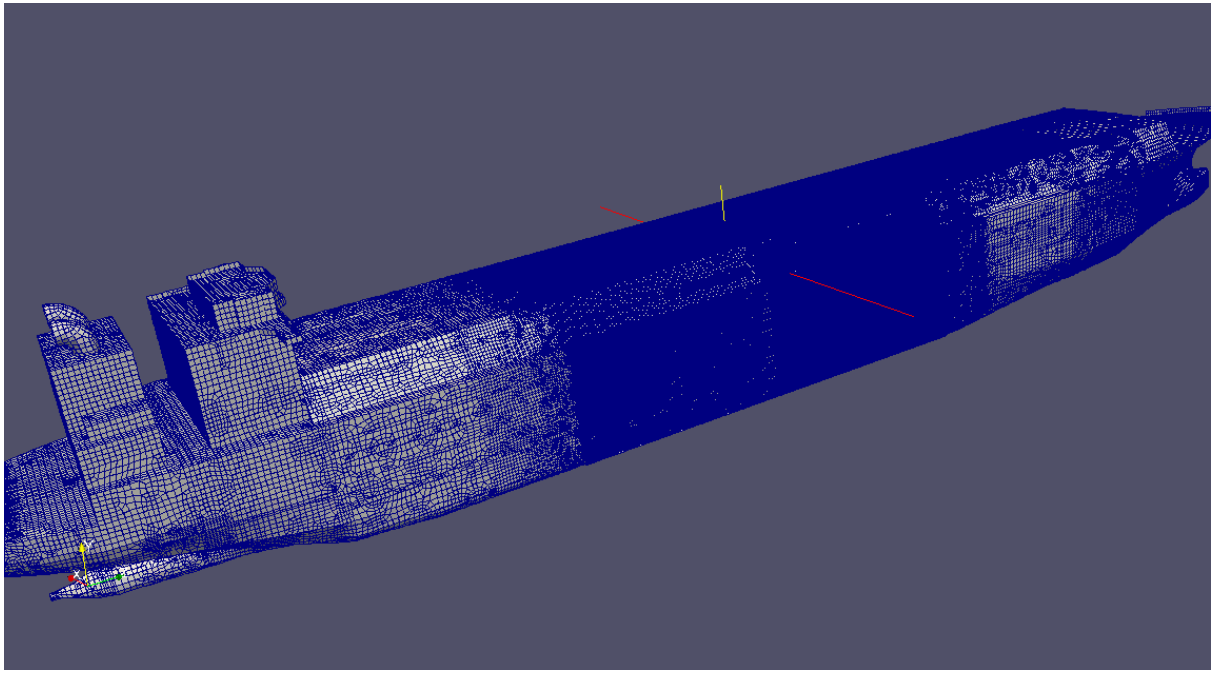


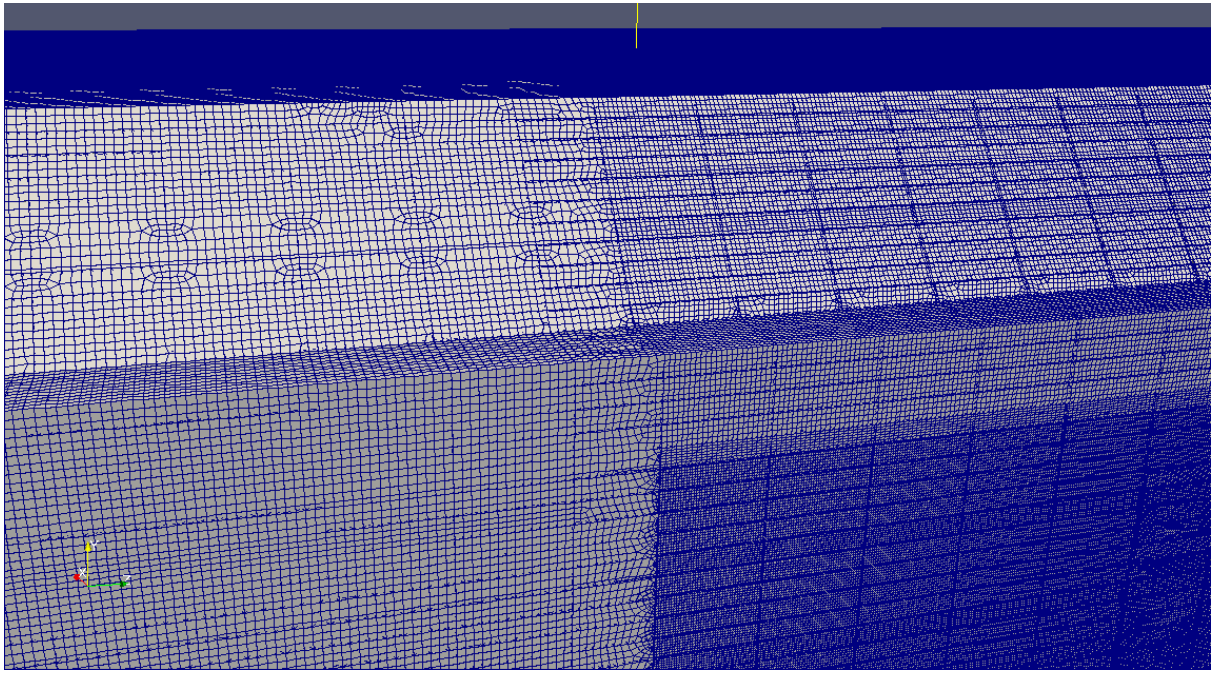


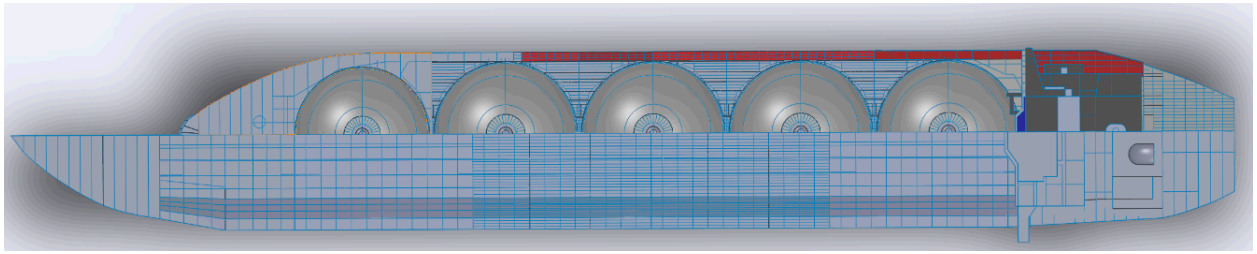





Y
X
Z

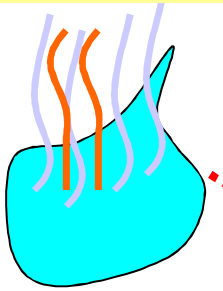






Multi-Physics Cascading Damage Coupled Analysis Approach

Fire Tests & Analysis



Fire Load
Simplified Boxes F(x)

Heat Transfer Tests

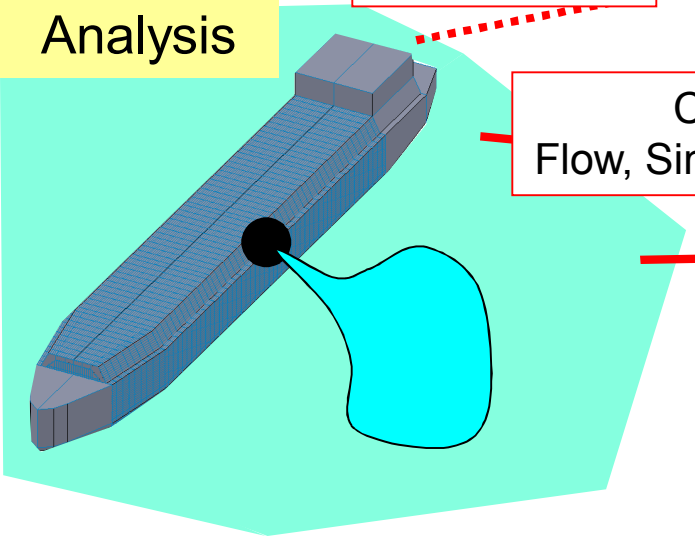
Cryo Damage Testing/Model Development

Exterior
LNG Pool
F(x,t)

Temperatures
F(t)

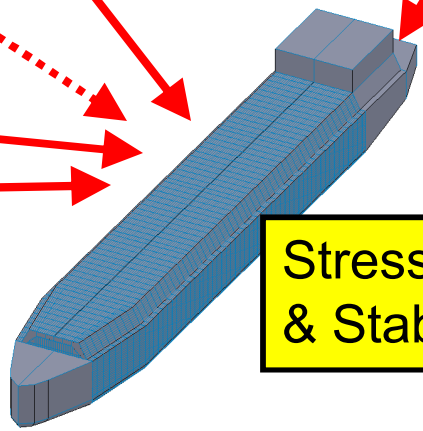
Structural Damage
Model

LNG Flow Analysis

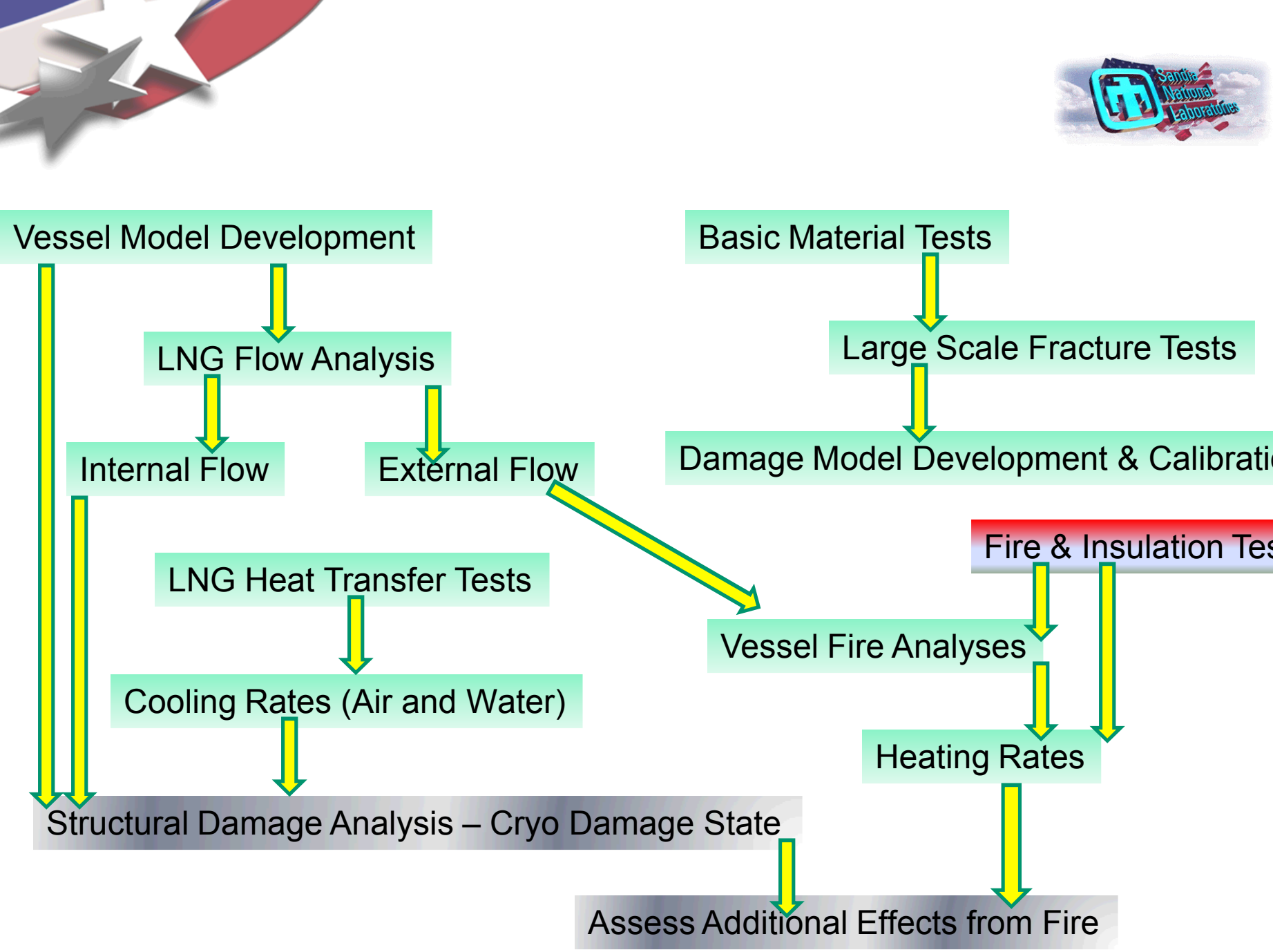


Cryo Interior
Flow, Simplified Boxes F(x)

Tank Draining
F(t)



Stress, Damage,
& Stability Analysis


Vessel Model Development
LNG Flow Analysis
Internal Flow
External Flow
LNG Heat Transfer Tests
Cooling Rates (Air and Water)
Structural Damage Analysis – Cryo Damage State
Basic Material Tests
Large Scale Fracture Tests
Damage Model Development & Calibration
Fire & Insulation Tests
Vessel Fire Analyses
Heating Rates
Assess Additional Effects from Fire