

6

FEM Modeling: Introduction

FEM Terminology

degrees of freedom (abbrv: DOF)

state (primary) variables: displacements in mechanics

conjugate variables: forces in mechanics

stiffness matrix

master stiffness equations

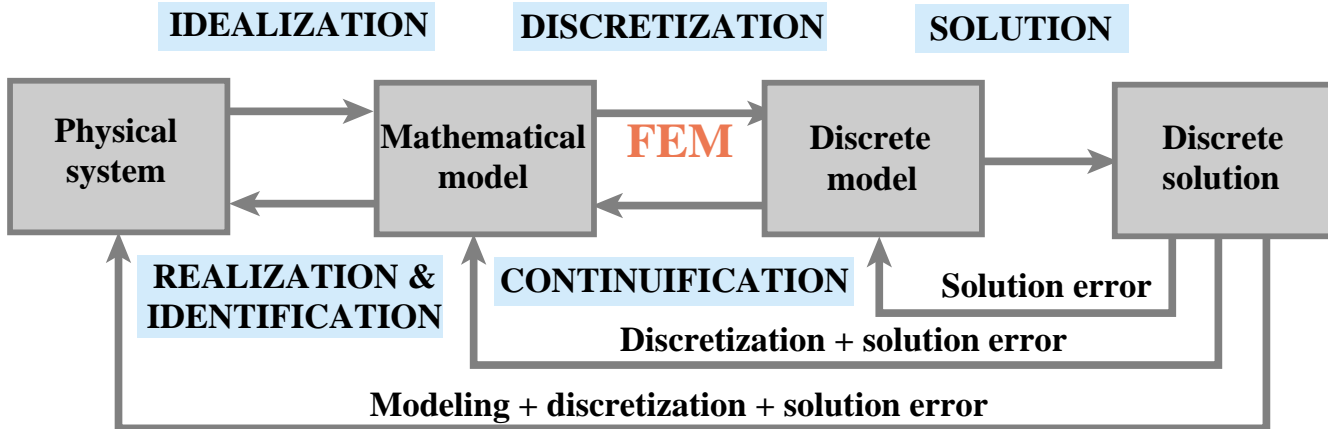
$$\mathbf{K} \mathbf{u} = \mathbf{f}$$

$$\mathbf{K} \mathbf{u} = \mathbf{f}_M + \mathbf{f}_I$$

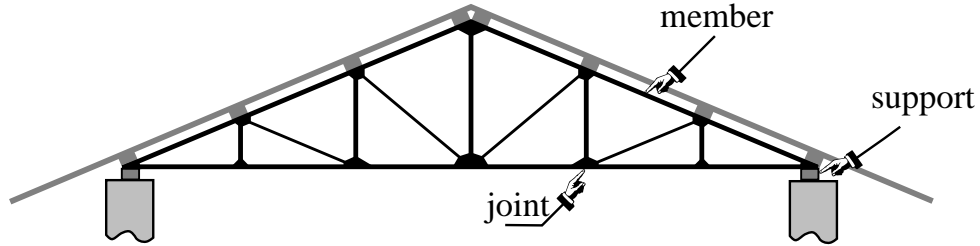
Physical Significance of Vectors \mathbf{u} and \mathbf{f} in Miscellaneous FEM Applications

<i>Application Problem</i>	<i>State (DOF) vector \mathbf{u} represents</i>	<i>Forcing vector \mathbf{f} represents</i>
Structures and solid mechanics	Displacement	Mechanical force
Heat conduction	Temperature	Heat flux
Acoustic fluid	Displacement potential	Particle velocity
Potential flows	Pressure	Particle velocity
General flows	Velocity	Fluxes
Electrostatics	Electric potential	Charge density
Magnetostatics	Magnetic potential	Magnetic intensity

Where FEM Fits (from Chapter 1)



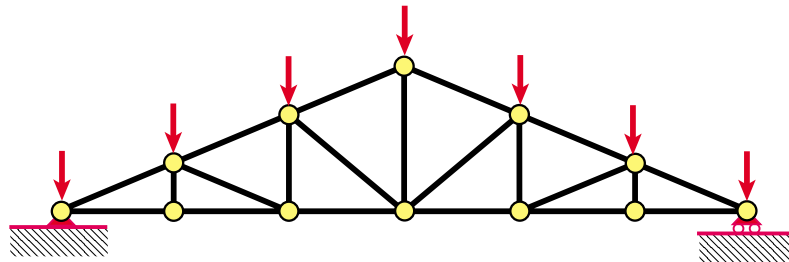
Idealization Process (from Chapter 2)



Physical System



IDEALIZATION



Mathematical Model

Mathematical Model Definition

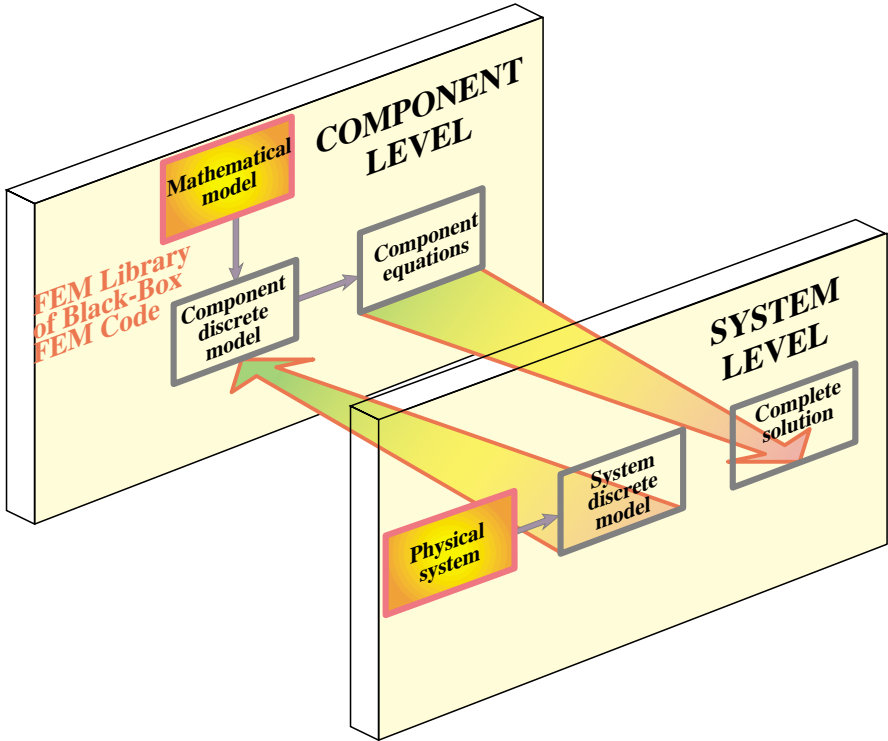
Traditional definition

*Scaled fabricated version of a physical system
(think of a car or train model)*

Simulation oriented definition

*A model is a symbolic device built to simulate
and predict aspects of behavior of a system*

Implicit Modeling



Recall the "Breakdown" DSM Steps

Breakdown {
 Disconnection
 Localization
 Member (Element) Formation
 -> **generic elements**

Let Stop Here and
Study **Generic Elements** next

... Because Most of the Remaining DSM Steps

Globalization

Merge

Application of BCs

Solution

Recovery of Node Forces

are Element Independent

Attributes of Mechanical Finite Elements

Dimensionality

Nodes serve two purposes:

geometric definition

home for DOFs (connectors)

Degrees of freedom (DOFs) or "freedoms"

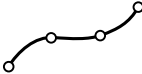
Conjugate node forces

Material properties

Fabrication properties

Element Geometry Is Defined by Node Locations

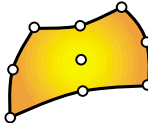
1D



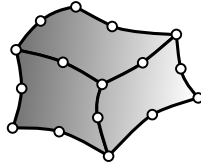
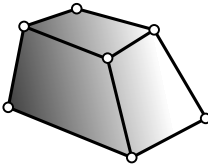
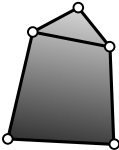
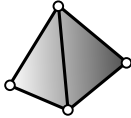
2D



2D



3D



Classification of Mechanical Finite Elements

Primitive Structural

Continuum

Special

Macroelements

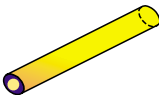

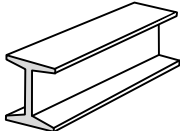

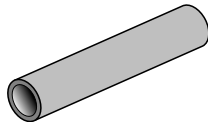

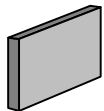

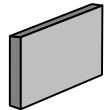
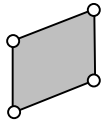
Substructures



Superelements

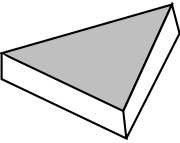
Primitive Structural Elements

(often built from MoM models)

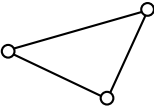
Physical Structural Component	Mathematical Model Name	Finite Element Discretization
	bar	
	beam	
	tube, pipe	
	spar (web)	
	shear panel (2D version of above)	

Continuum Elements

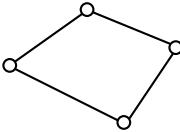
Physical



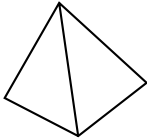
Finite element idealization



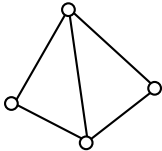
plates



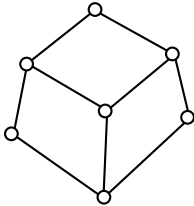
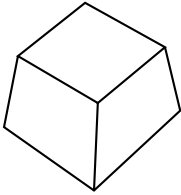
Physical



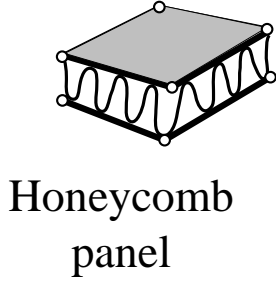
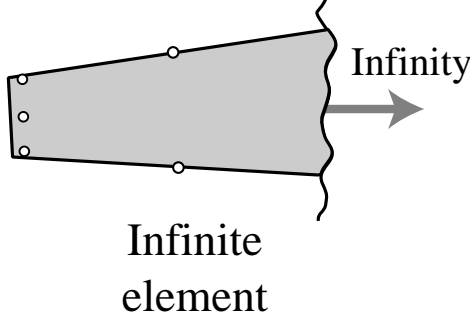
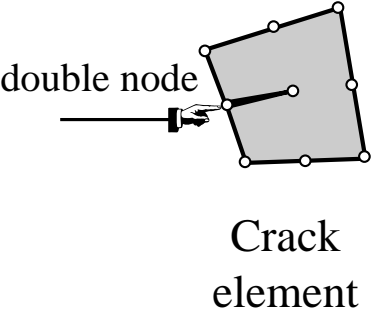
Finite element idealization



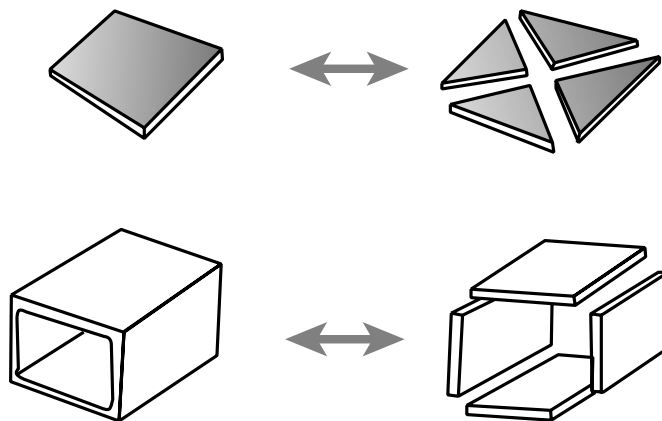
3D solids



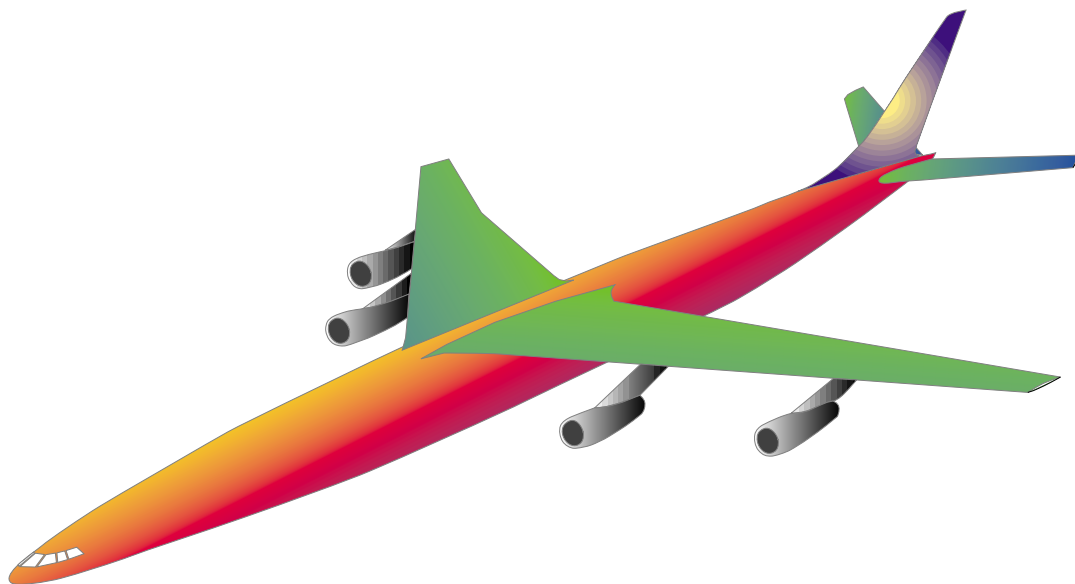
Special Elements



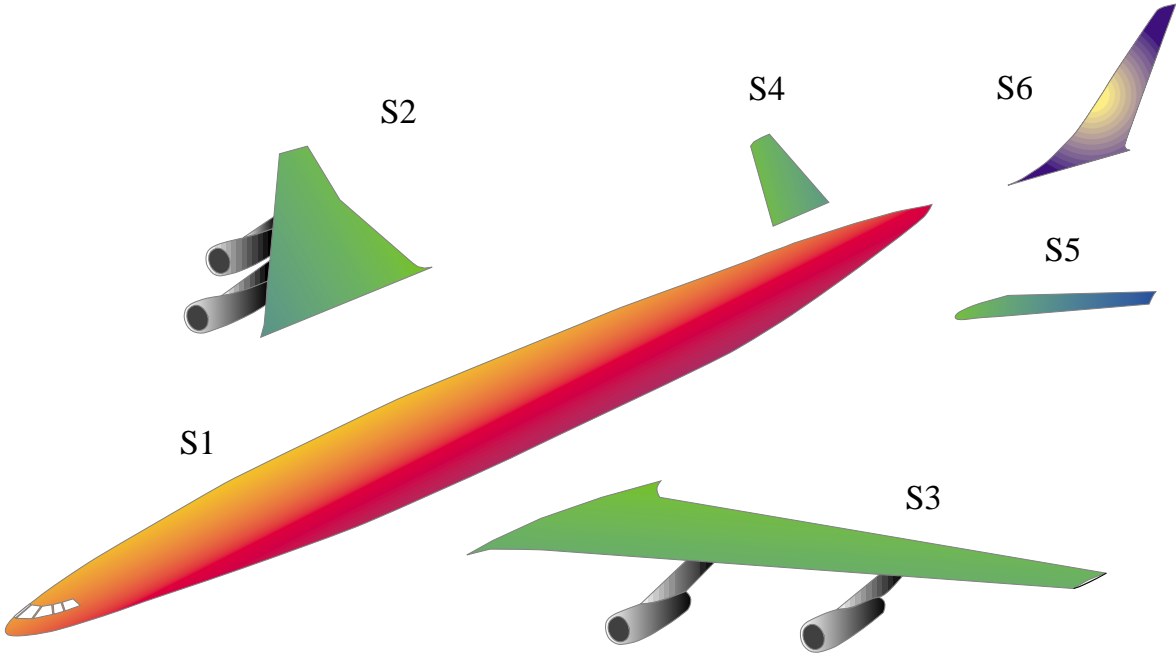
MacroElements



Substructures

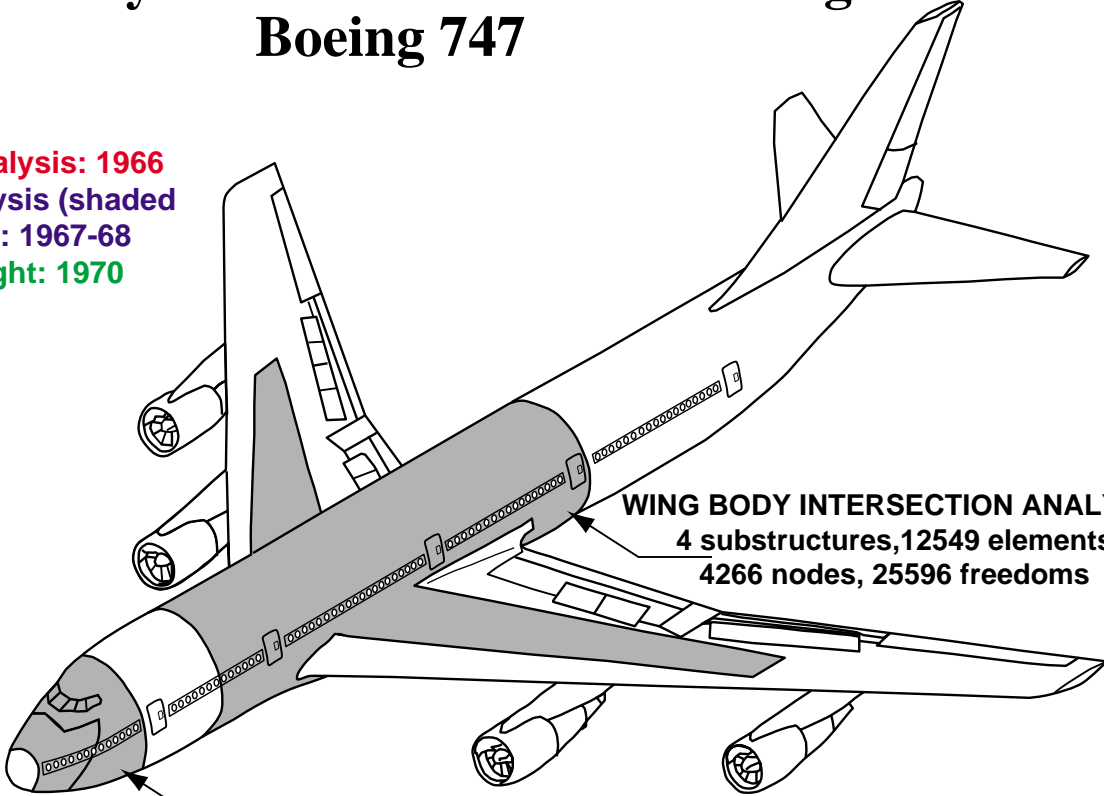


Substructures (cont'd)



An Early Use of FEM Substructuring Boeing 747

Global Analysis: 1966
Local Analysis (shaded regions): 1967-68
First flight: 1970



WING BODY INTERSECTION ANALYSIS
4 substructures, 12549 elements
4266 nodes, 25596 freedoms

CARGO DOOR CABIN ANALYSIS



747 Regions Analyzed with FEM-DSM at Boeing

Boundary Conditions (BCs)

**The most difficult topic for FEM
program users ("the devil hides in
the boundary")**

Two types

Essential
Natural

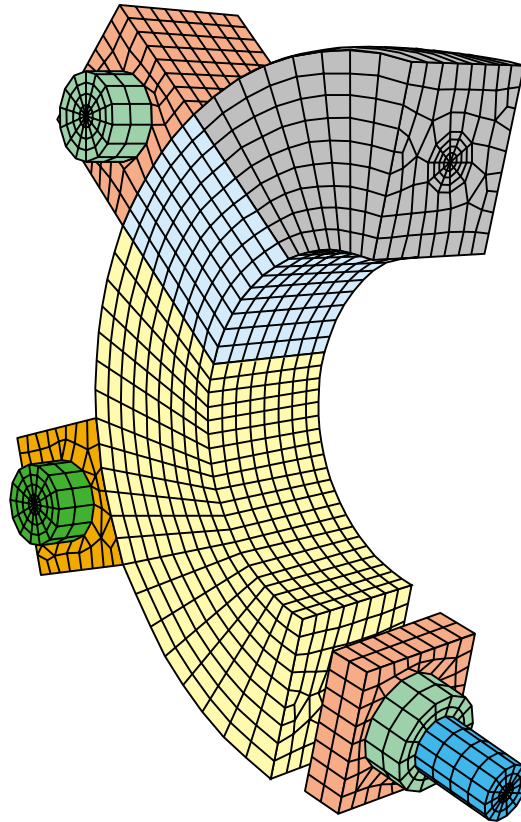
Boundary Conditions

Essential vs. Natural

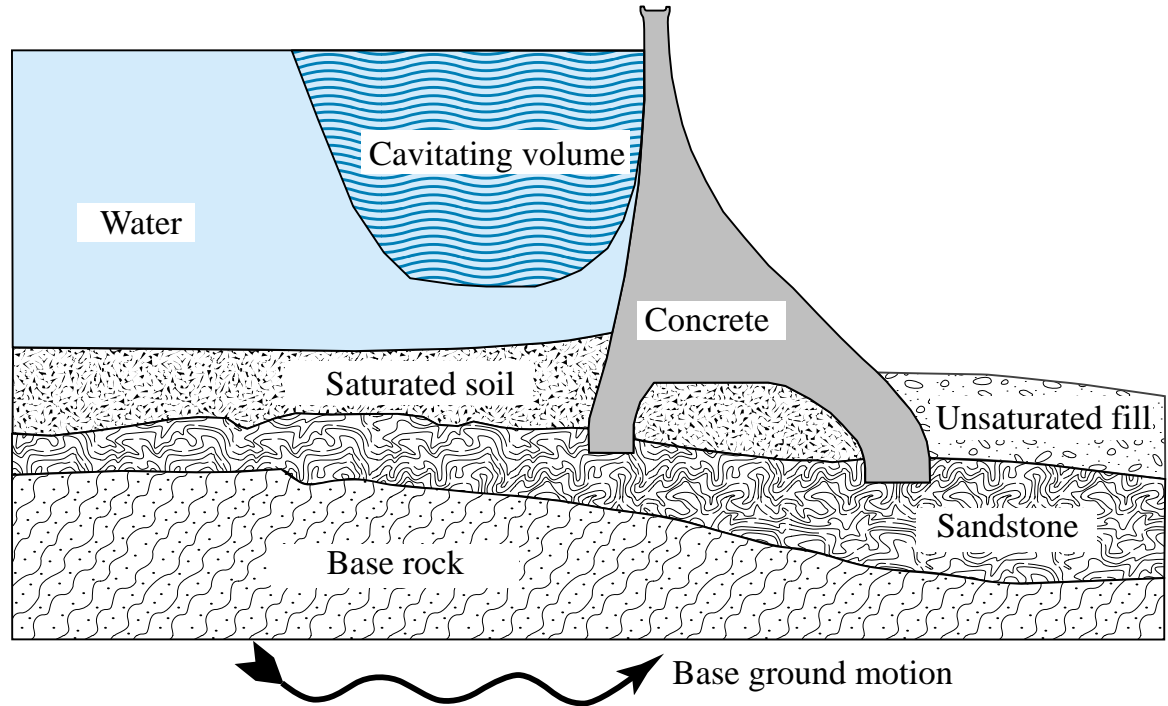
Recipe:

1. If a BC involves one or more DOF in a *direct* way, it is *essential* and goes to the **Left Hand Side** (LHS) of $Ku = f$
2. Otherwise it is *natural* and goes to the **Right Hand Side** (RHS) of $Ku = f$

Examples of Structural Models: Machine Component (Mech. Engrg)



Examples of Structural Models: Dam under Ground Motion (Civil Engrg)

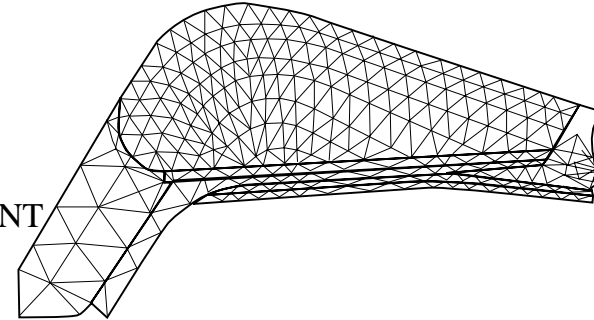
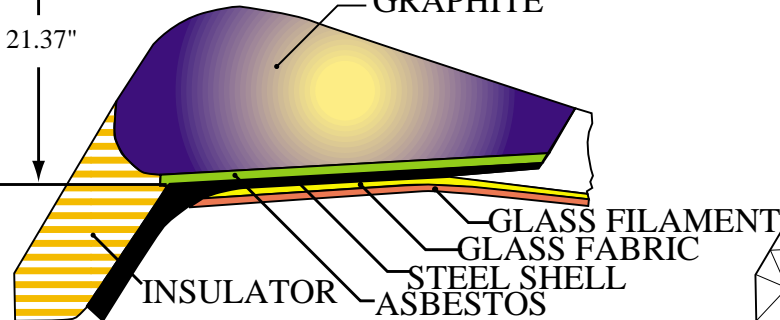


Examples of Structural Models: Rocket Nozzle (Aerospace Engrg)

Rotational axis



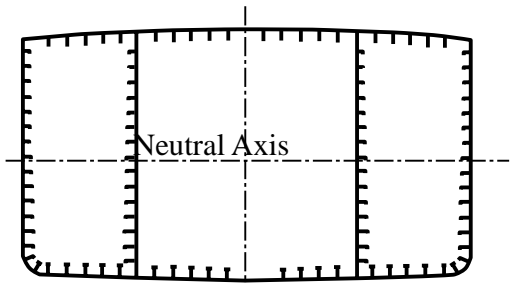
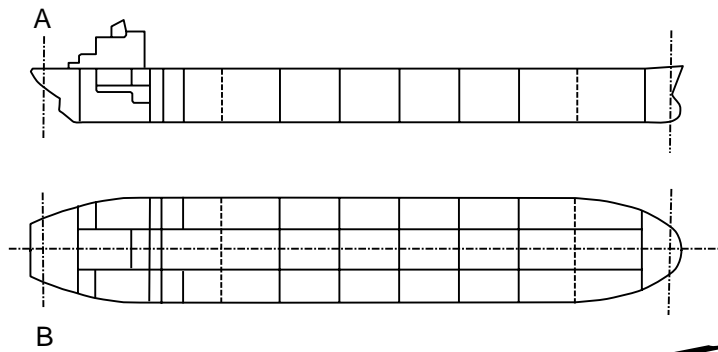
21.37"



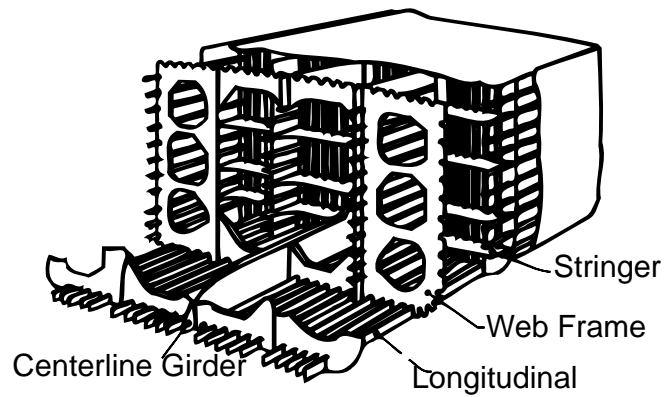
(a) Typical solid rocket nozzle
(Aerojet Corp., 1963)

(b) Finite element idealization

Examples of Structural Models: SuperTanker (Marine Engrg)



Cross section of tanker



Typical internal structure of tanker

Examples of Structural Models: F16 External View (Aero)



Examples of Structural Models: F16 Internal Structure (Aero)

