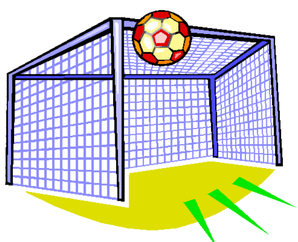
Division of Engineering
Brown University

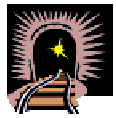
ENGN1300: Structural Analysis

Spring, 2010

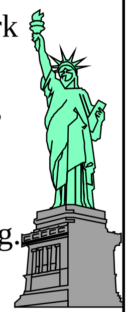


The goal of the course is to enable you to analyze relatively complex structures by creating appropriate mathematical idealizations, and studying these using various solid mechanics concepts, most notably energy methods.

Objectives



1. Be able to analyze complex structures, such as frames, trusses, and suspension bridges using matrix and energy minimization methods
2. Be able to analyze truss, beam, and frame structures using the finite element method – understanding the derivation of the equations by means of the principle of virtual work and write simple finite element codes.
3. Be able to compute natural frequencies and mode shapes for various
4. Be able predict and understand the dynamic response of structures to wind, earthquake, and other periodic forcing.



Course Outline

- 1. Introduction
- 2. Analysis of trusses
  - 2.1 Joints (ENGN0030 review)
  - 2.3 Matrix methods
  - 2.2 Energy methods
- 3. Frames
  - 3.1 Beam theory
  - 3.2 Matrix analsys
  - 3.3 Finite element analysis
- 4. Arches and Cable structures
- 5. Structural Dynamics
  - 5.1 Free vibrations of single and multi degree of freedom structures
  - 5.2 Forced vibrations of single and multi degree of freedom structures
  - 5.3 Vibrations of continuous systems (beams)

Organization

- **Instructor**

  J. A. Blume, 741 B&H
  Office hours MW 11-12am,
  or any other time
  janet_blume@brown.edu

- **TA**
  Jennet Toyjanova
  Office Hourse Monday, 8-9pm, BH 096
  jennet_toyjanova@brown.edu

Grading

- **Homework: 30% (Lowest grade will be dropped)**
- **Midterm Exam (in class, Wednesday 3/24): 20%**
- **Final Exam: (9am Monday, 5/17): 40%**
- **Class attendance and participation: 10%**

Exams are open notes.

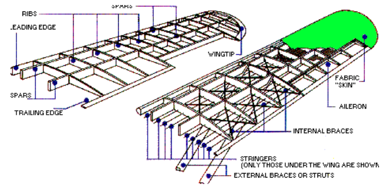
Issues in Structural Design

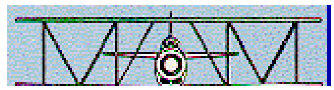
- Strength?
- Life?
- Deformation?
- Stability?
- Vibrations?

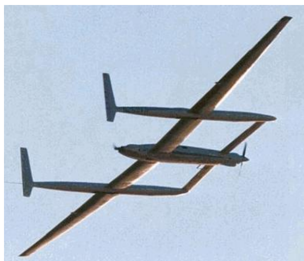
- Material Selection
- Shape Optimization
- Cost
- Manufacturability

Applications: Buildings/shelters

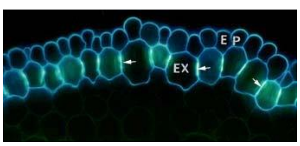
Aerospace

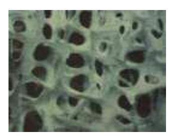


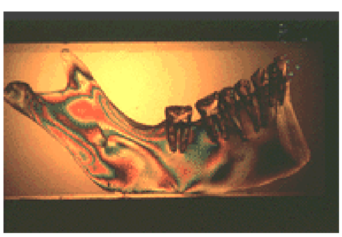


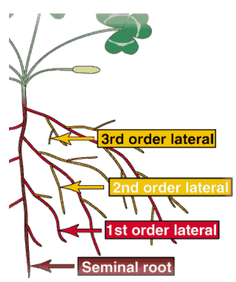


Biological Structure

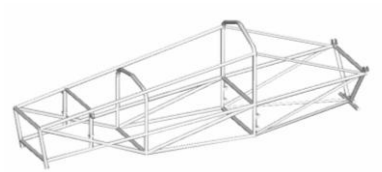






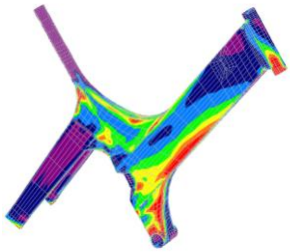


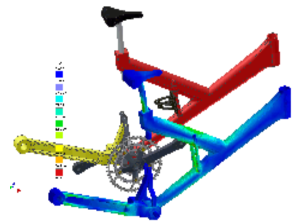
Automotive Industry

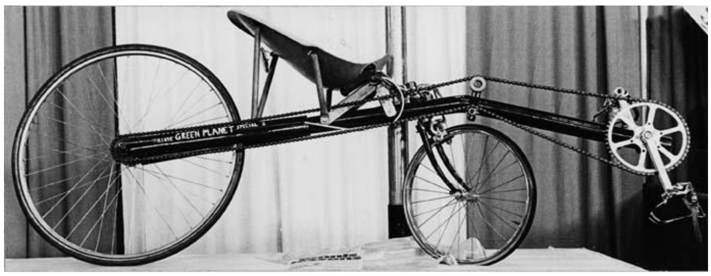


Of Course: Bridges

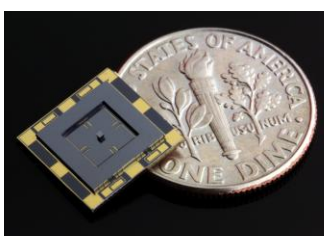
Bicycles

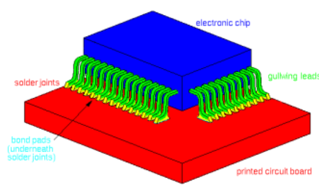


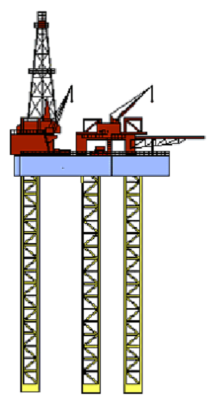


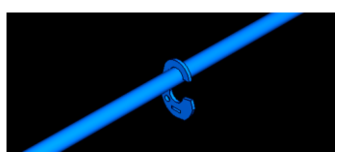


More!







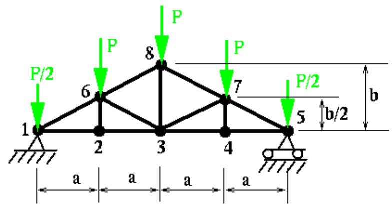


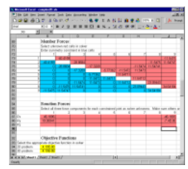
This is What You Need:

- Physical Intuition

- Numerical determination of force, deflection

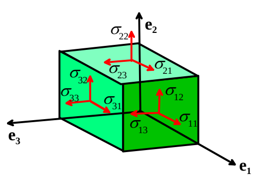
- Analytical methods for solution for force, deflection



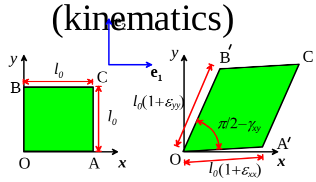


Ingredients:

- Newton’s Laws (kinetics)

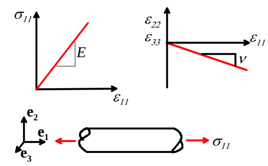


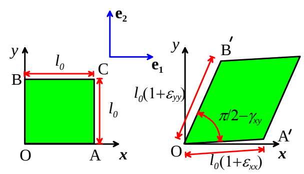
- Deformation (kinematics)

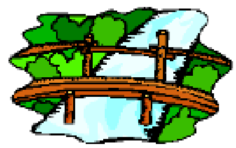


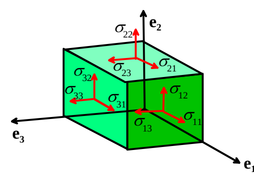
Last But Not Least….

- Material Behavior









- Deformation
- Stress

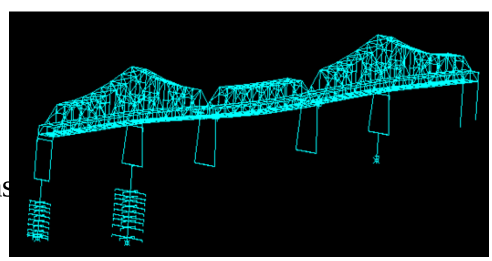
Typical Problems in Structural Mechanics

Given

- Initial geometry
- Material Properties
- Applied Loads
- Applied Temps/Heat
- Initial Conditions

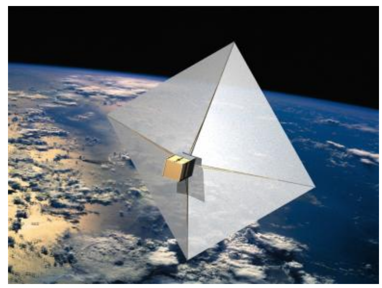
Wanted

- Deformed geometry
- Internal forces/Stresses
- Accelerations
- Temperature distributions

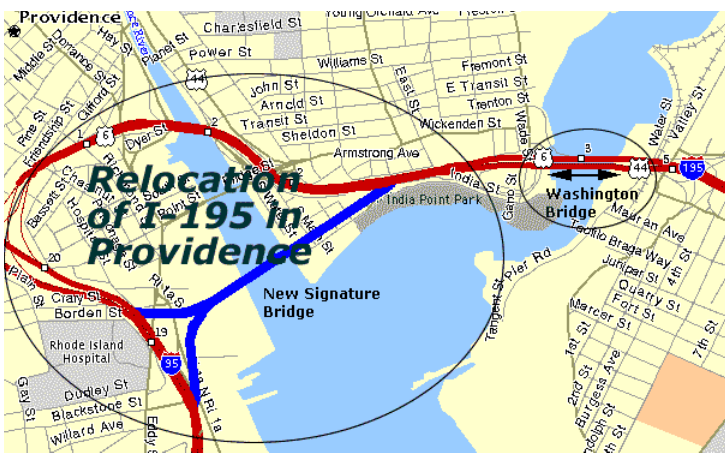


Examples of structural analysis

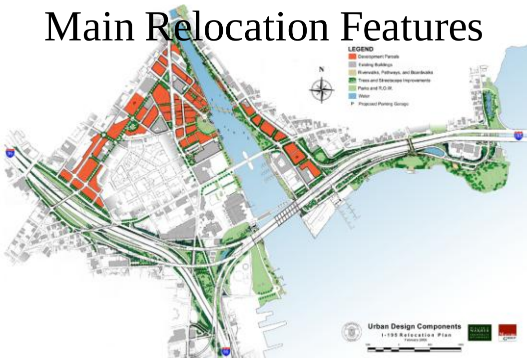
- The new I-195 bridge spanning the Providence River
- Deployable satellite deorbiting braking system
- Sierra Designs Tents



Rte 195 Relocation Project
RIDOT and the Maguire Group



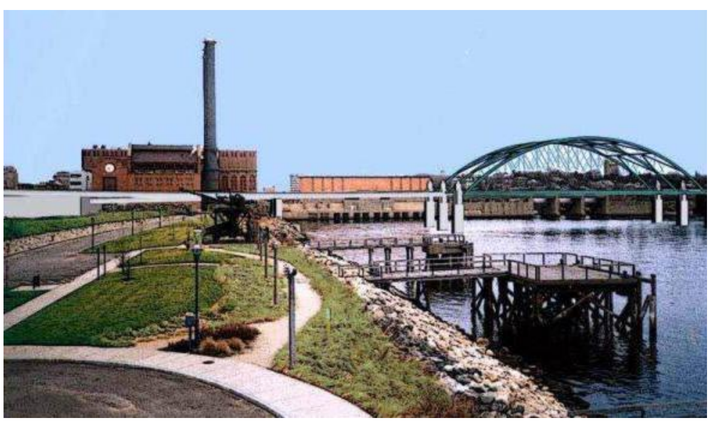
Main Relocation Features



- 1 mile of new rte 195
- 1.5 miles of resurfaced and realigned 195
- New interchange with rte 95
- 13 new ramp bridges
- 50-ft wide pedestrian bridge over 195 to India Point Park
- Network Arch signature span over the Providence River (950 ft bridge)

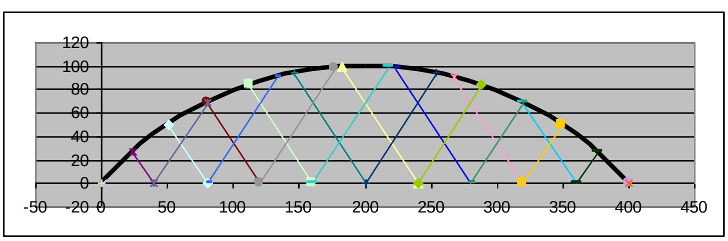
Main Bridge

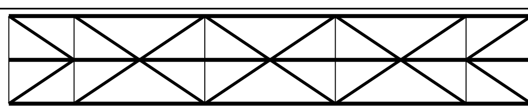
- 400 foot span triple barreled steel tied network arch with intersecting hangers, also known as a Nielson-Lohse bridge.

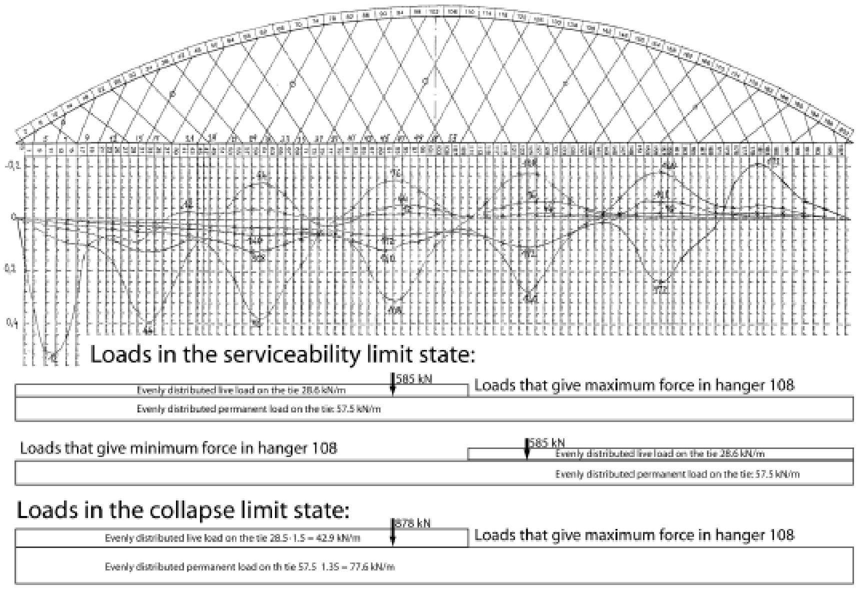


Some Basic Questions

- Stresses in the arch and deck
- Cable tensions: during construction and during service
- Vibrational behavior







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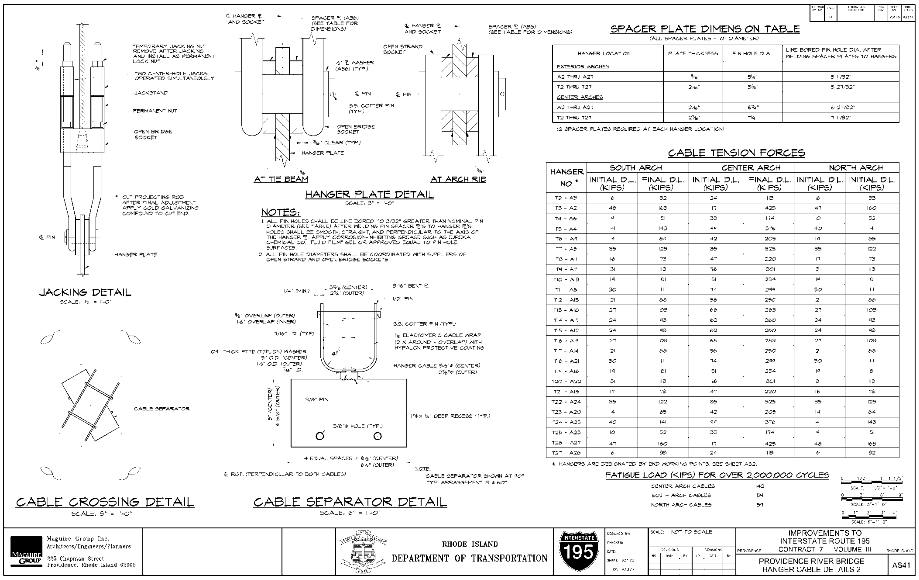
220 kips

1000 kN



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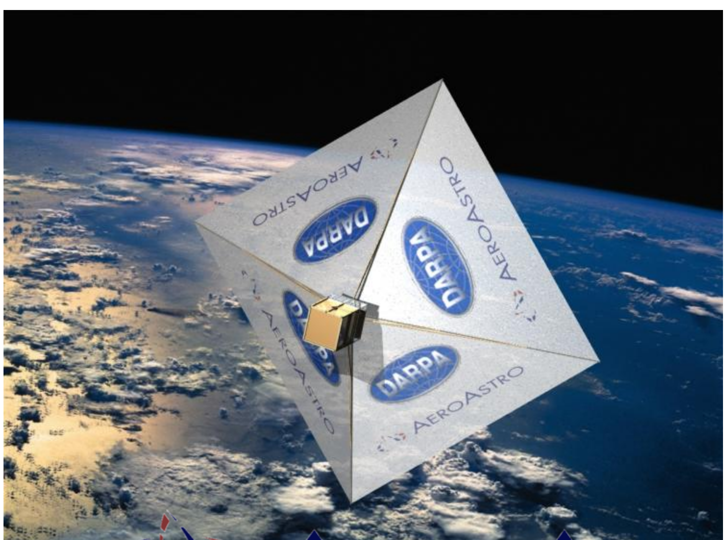
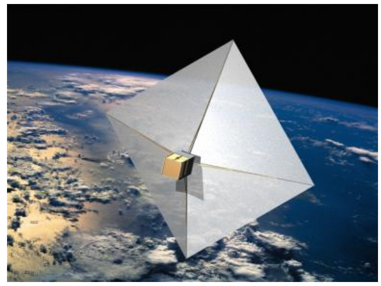
Aerobrake Deorbiting System - ADS



AeroAstro

The Problem and the Opportunity

- **Today a spacecraft remaining in LEO for any appreciable length of time will be struck by space debris, most likely several times.**
  - At best the impact will simply puncture a non-essential piece of structure;
  - At worst will cause a catastrophic failure of the spacecraft and generate additional debris.
  - AeroAstro's solution is a low-cost, robust, self-contained Aerobrake Deorbiting System (ADS), which will retire a space asset at the end of its useful lifetime.



- **The ADS sets itself apart from other technologies:**
  - It does not only target one class of spacecraft, but across multiple classes
  - Imposes only a small mass and size penalty to the target spacecraft – much less than maintaining a percentage of fuel in reserve for deorbiting purposes.
  - If only the aerobrake is deployed, and every other system fails, the ADS will hasten the time to deorbit
  - If the spacecraft angular rates are too high post-deployment, damping provided by embedded conductive wire. This will be embedded in the membrane structure near it's periphery.

AEROASTRO

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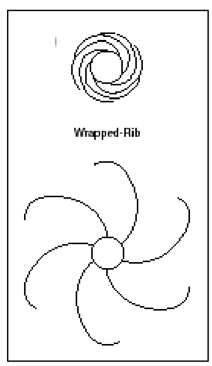
Boom Selection

- **Booms made from an advanced, flexible thermoplastic such as nylon, polycarbonate, or poly ether ether ketone (PEEK) reinforced with Stainless Steel.**
- **Material selected with assistance from Foster-Miller.**
- **Increase system strength and stiffness provided by a Kevlar tension cable truss.**



- **Booms angled back 25 deg from perpendicular for aerodynamic stability.**
- **Booms stow by wrapping around a central hub.**

AEROASTRO

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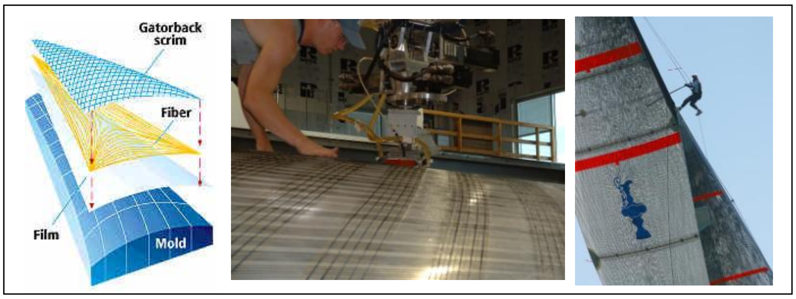
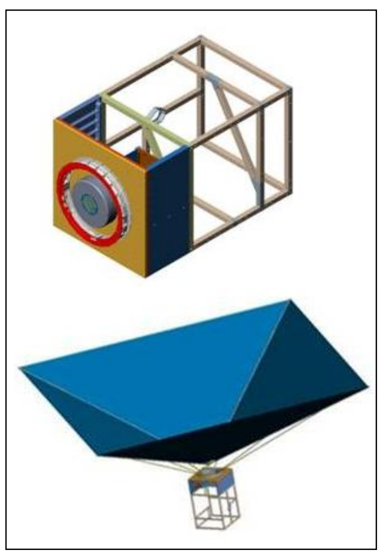
North Sails 3DL process

- The 3DL process was developed and patented by North Sails.
- They have been producing 3DL laminates since 1992 for the marine industry.
- The 3DL process laminates high strength and high modulus fibers between thin layers of Kapton or Mylar producing a flexible composite membrane.
- The 3DL process allows the strength and stiffness to be tailored the expected loads and loading direction.

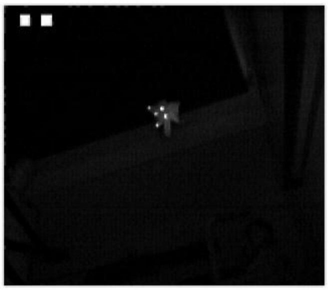


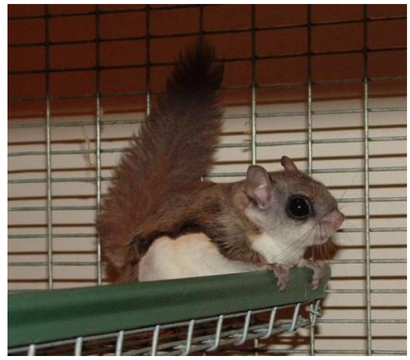
Deployment Sequence

1. Pin puller releases the shroud
2. Shroud springs away from the package and covers potential deployment hazards
3. Booms unwrap, pulling the membrane and cables with them
4. Hub expands to full height
5. Cables are pulled tight by the deploying booms



Nature's Aerobrake





AEROASTRO

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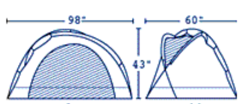
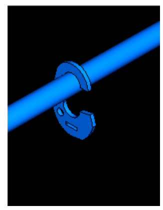
Sierra Designs Tents

SIERRA DESIGNS



Some Questions:

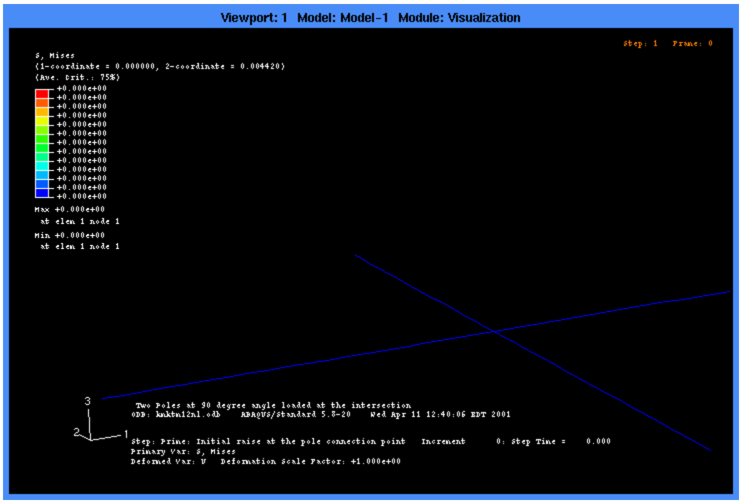
- How should the tent and poles connect? Clips? Sleeves? With or without friction?
- How should the poles interact? With a rigid joint?
- Can the benefit of internal or external guys be quantified?
- Can the benefits of Jake's Corners be quantified?



Some More Questions

- What type of joints perform best?
- What is the ideal pole configuration?
- What is the ideal choice of pole diameter/thickness?

Tent Assembly and static loads: Kevin Kingston Senior Thesis



Tent Performance: Wind Response

Tent Performance: Wind Response