An Introduction To Buckling

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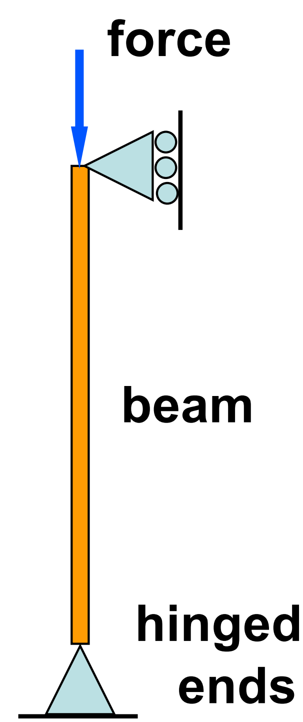
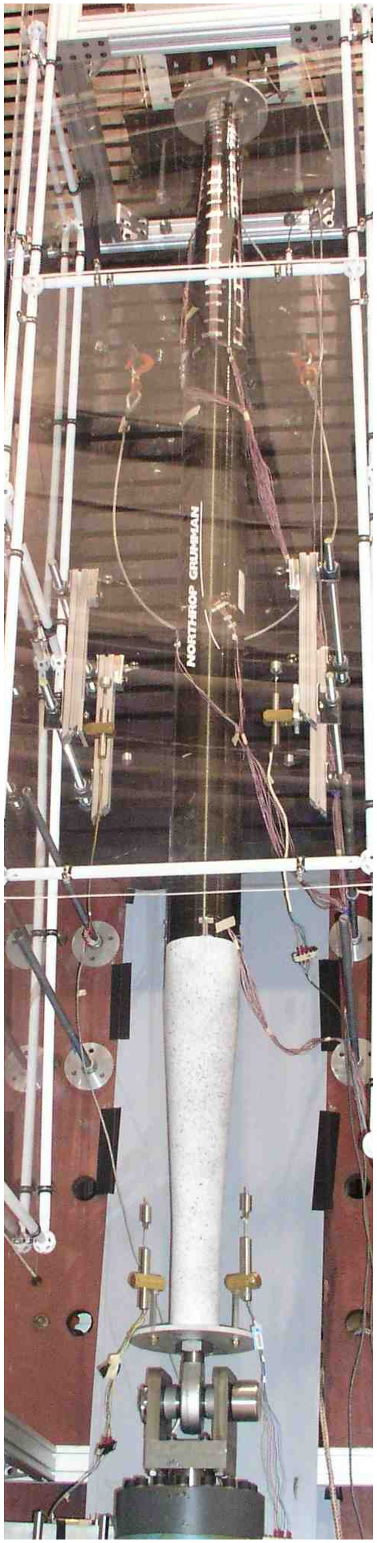
Beam Buckling

- Leonhard Euler (1744) =>
- Stability of beam with pinned ends loaded in compression
- Abrupt transition from axial compression to bending
- Less than material strength for slender beams
- $P_{euler} = \pi^2 EI/L^2$, function of geometry, material *stiffness*

Wikipedia



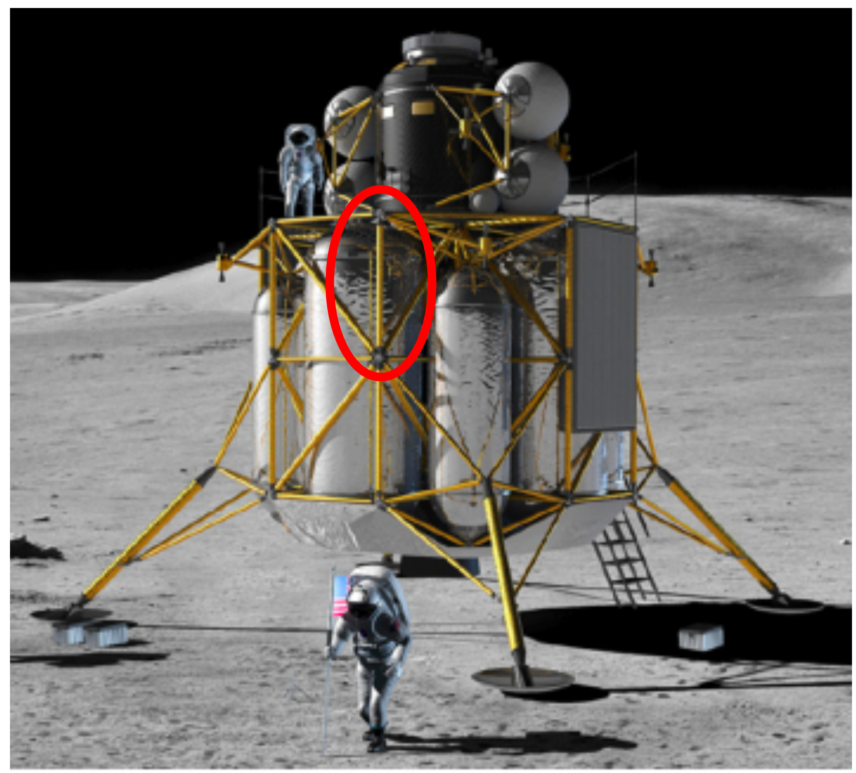


Composite Strut Test

127 in.-long, 6.2 in.-diam. strut,
weight = 26.3 lbs

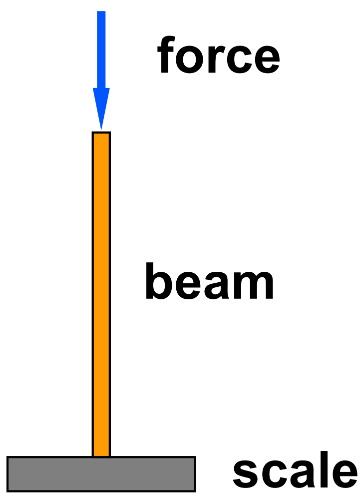
103.6 klb max compression load
measured in test

Estimated Euler buckling load
of 140 klbs



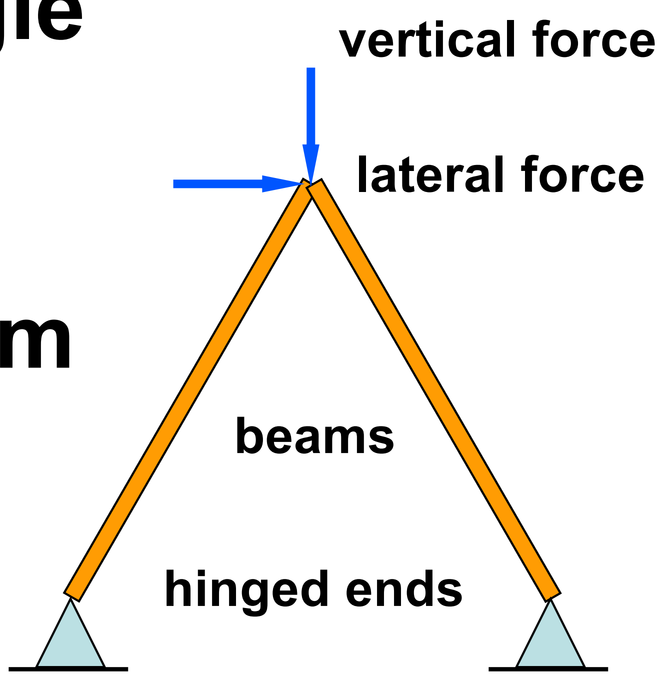
Beam Buckling Demonstration

- $E \sim 90{,}000\ lb/in^2$ (Google search…)
- Measured OD ~ 1 in., t ~ 0.08 in.
- $I \sim \pi r^3 t \Rightarrow 0.121\ in^4$
- Measured L ~ 41.5 inches
- Predicted $P_{euler} = \pi^2 EI/L^2 \sim 62$ lbs
- Now let's test!
- Does measured result match our prediction?
- Why, or (more likely) why not?



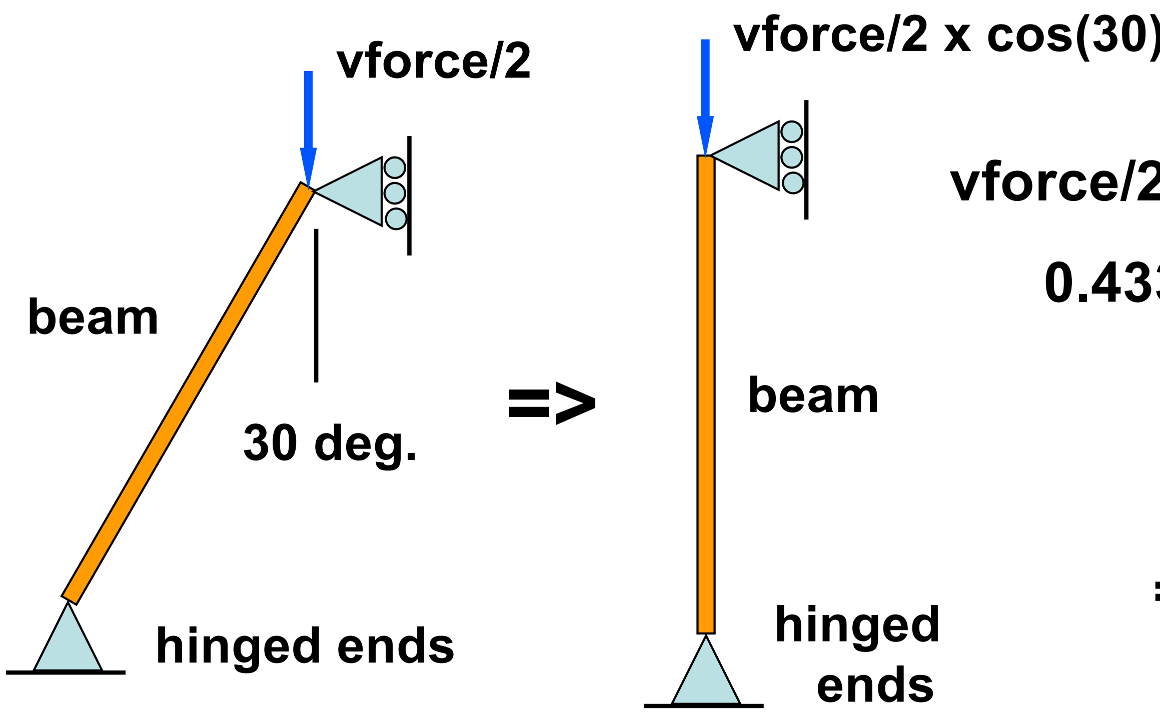
A More Complex Structure

- 62 lbs predicted buckling load for one beam alone
- Now connect two beams into an equilateral triangle (60-degree angles)
- This *bipod* is more stable than one beam
- Can take vertical *and* lateral forces (in-plane only)



Bipod Buckling

- How much vertical force can the bipod carry before it buckles?



vforce/2 x cos(30) = compr. force

$0.433 \times \text{vforce} = P_{euler}$

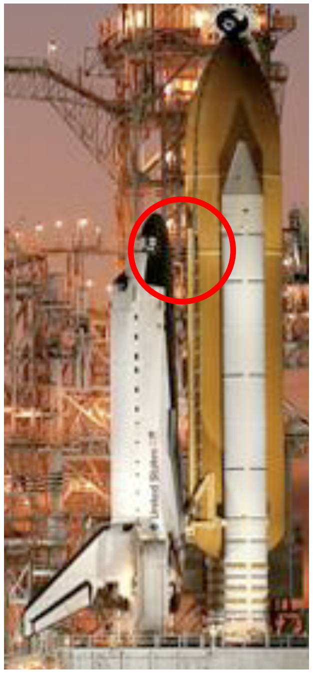
$= \pi^2 EI/L^2$

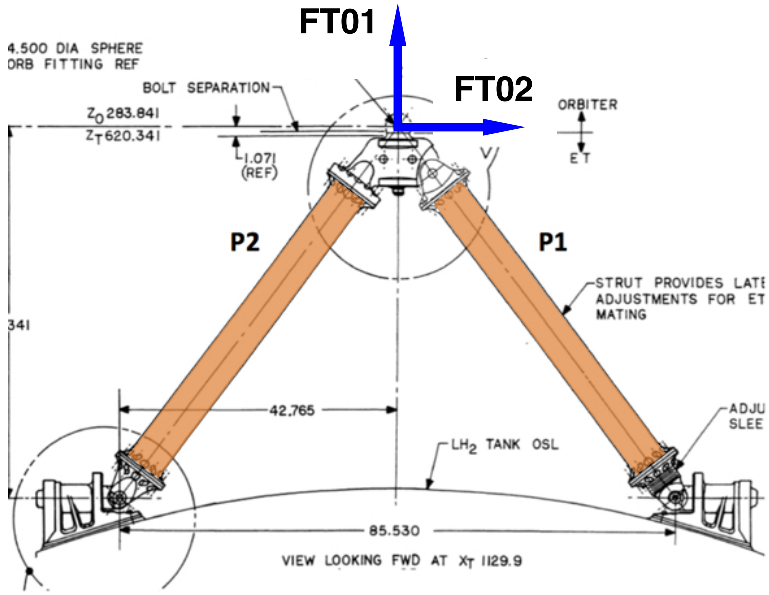
$= \sim 62$ lbs

=> vforce = 143 lbs

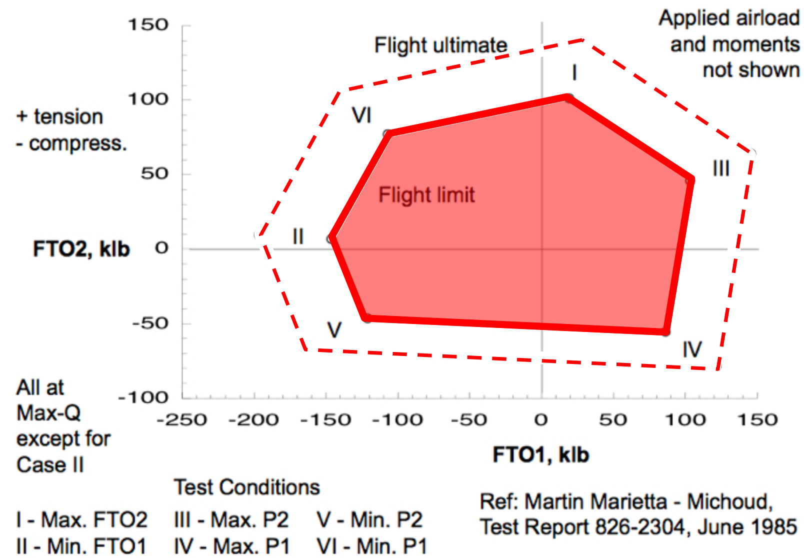
- Predict vertical buckling at 143 lbs

Space Shuttle Forward Bipod Loads Capability



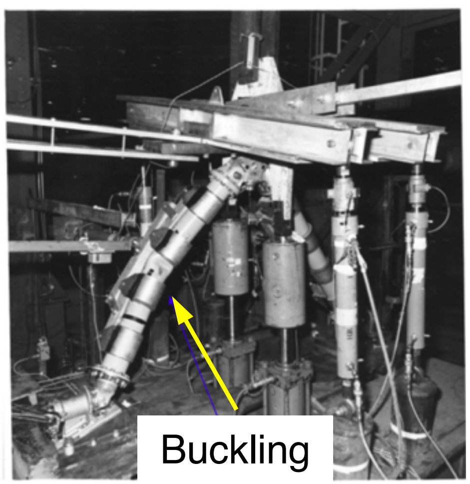


STS – forward bipod location circled in red

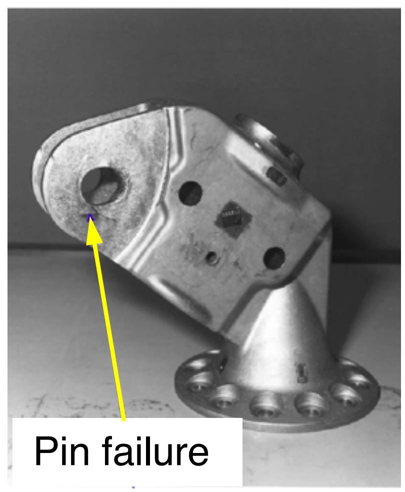


Certified Shuttle loads envelope

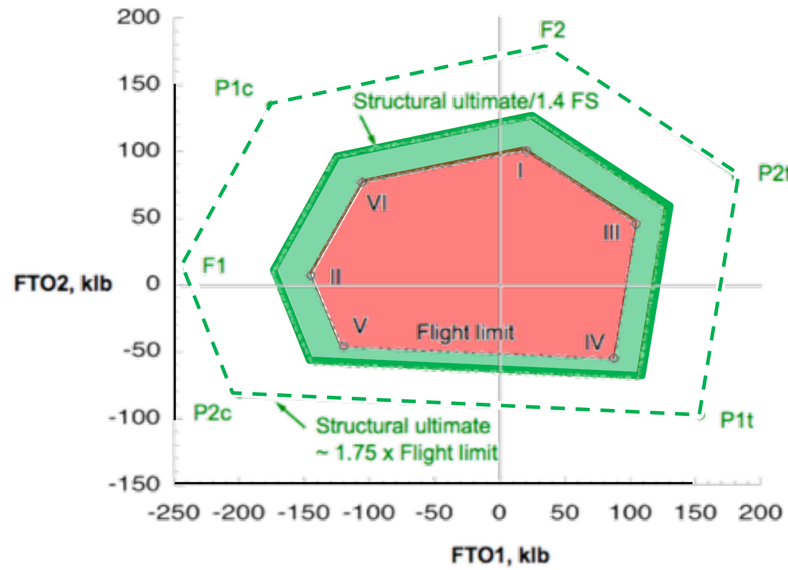
Compression



Tension



Tests performed to determine capabilities



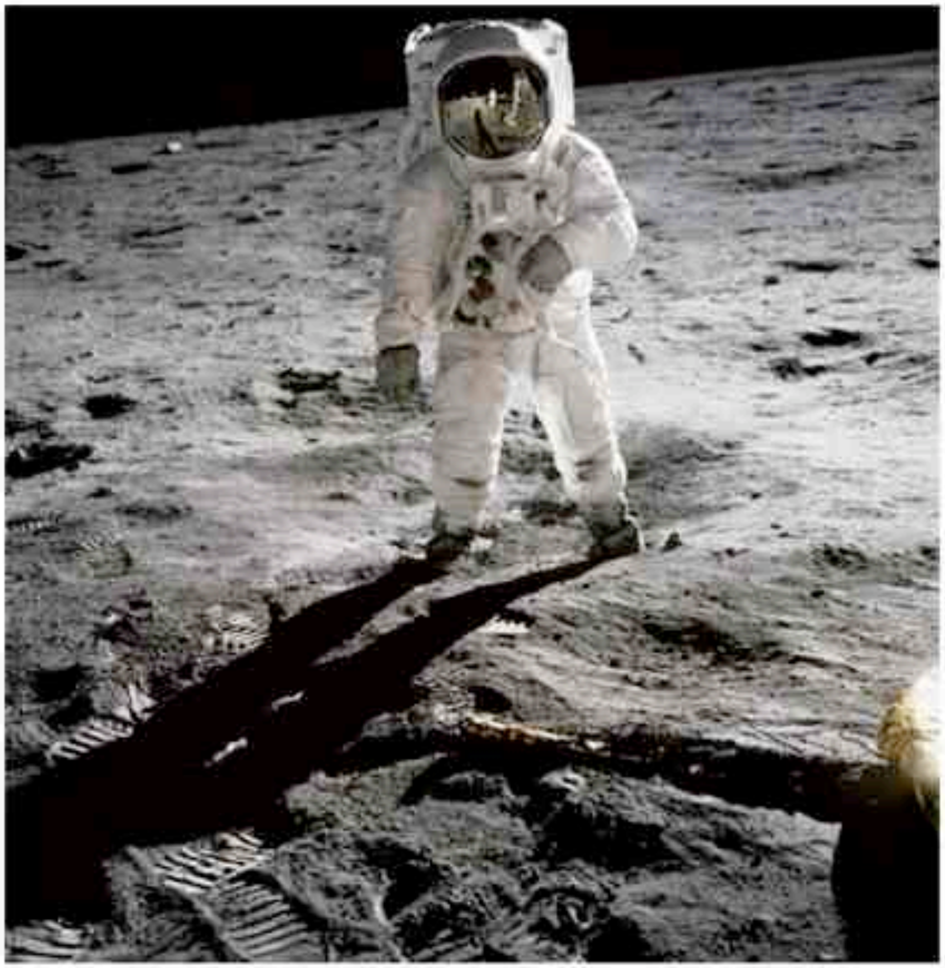
Expanded loads envelope; analysis of existing flight hardware

Side-mount SDHLV – higher mass and loads than STS

NASA Kennedy Space Center - April 2010

Space Shuttle Atlantis - STS-132

Our Next Giant Leap(s)…



The Moon - 1969, 2024

Mars - 20??