N93-26409

cSc

Structural Load Control During Construction

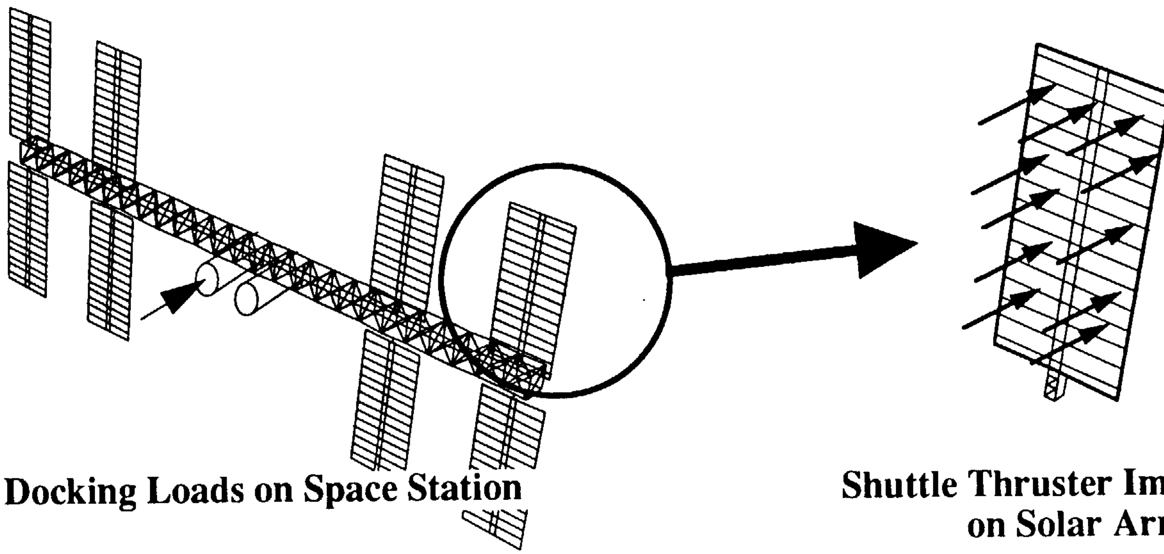
Martin Mikulas

Very specific problem being addressed. Rost energy absorber on a long truss.

Third Annual Symposium
November 21 & 22, 1991

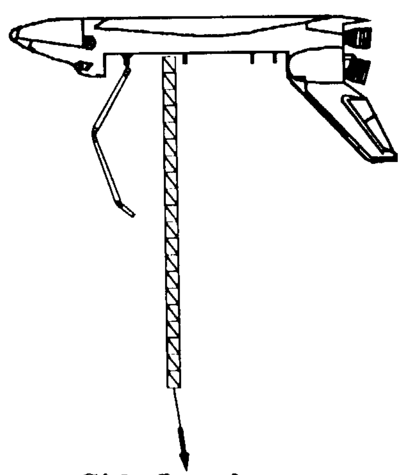
A NASA Space Engineering Research Center at the University of Colorado

EXAMPLES OF HIGH TRANSIENT LOADINGS ON LARGE SPACE STRUCTURES

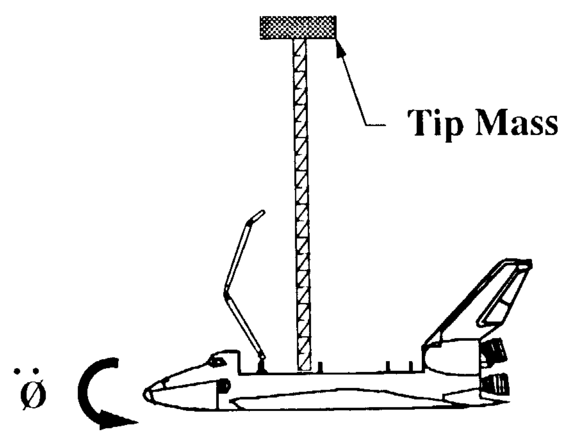


Docking Loads on Space Station

Shuttle Thruster Impingement on Solar Arrays



Side Loads From Tethers



Shuttle Accelerations Applied to Attached Beam

ENERGY ABSORBING/LOAD LIMITING STRUT RESEARCH OBJECTIVES

Explore feasibility of using energy-absorbing/load-limiting struts in large space structures subjected to transient loadings

Develop analytical and design capability for energy absorbing struts

Develop several energy absorbing strut concepts (passive & active)

Experimentally demonstrate application of energy absorbing struts

SCOPE OF RESEARCH ON ENERGY ABSORBING STRUTS TO DATE

Rigid body analysis developed to scope problem

Intial contacts made with LeRC to understand solar array problem

— Kornel Nagy

Visit made to JSC to understand their effort on energy absorbers

Preliminary finite element analysis conducted on uniform beam solar array model

Studies conducted to size springs in energy absorbers

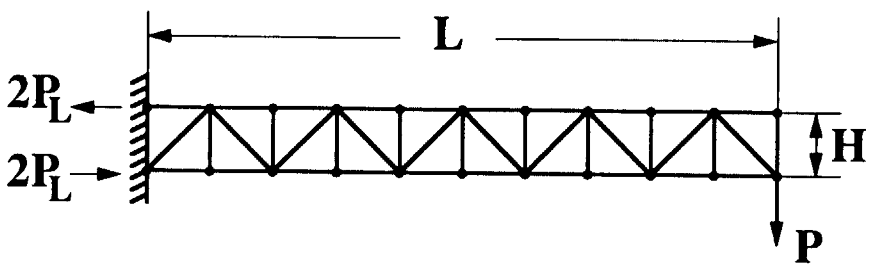
Test bed for energy absorbers designed and under construction

Porter Davis

Cooperative agreement made with Honeywell to co-develop an energy absorber

ENERGY CHARACTERISTICS OF CANTILEVERED TRUSSES WITH A TIP LOAD.

Standard Truss



$$2P_L H = PL \quad \Rightarrow \quad P_L = \frac{PL}{2H}$$

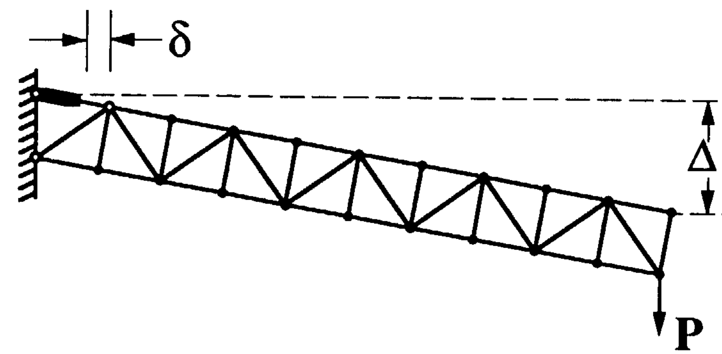
Truss strain energy is:

$$\Pi = \frac{1}{2} P \Delta$$

Where

$$\Delta = \frac{PL^3}{3EI}$$

Energy Absorbing Truss



$$\frac{\delta}{H} = \frac{\Delta}{L} \quad \Rightarrow \quad \Delta = \frac{L}{H}\delta$$

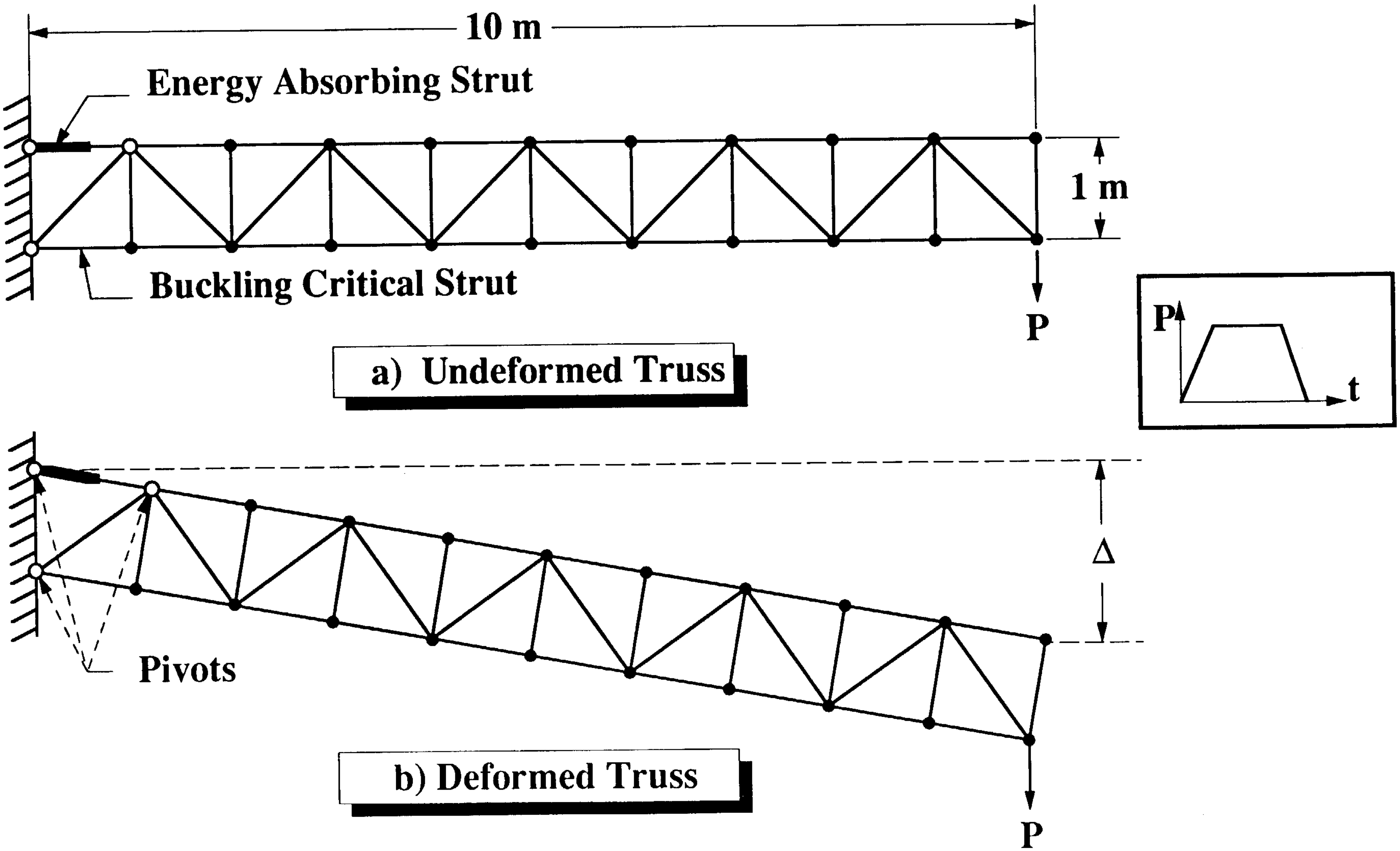
Truss absorbed energy is:

$$E = P\Delta$$

or

$$E = P\frac{L}{H}\delta = 2P_L\delta$$

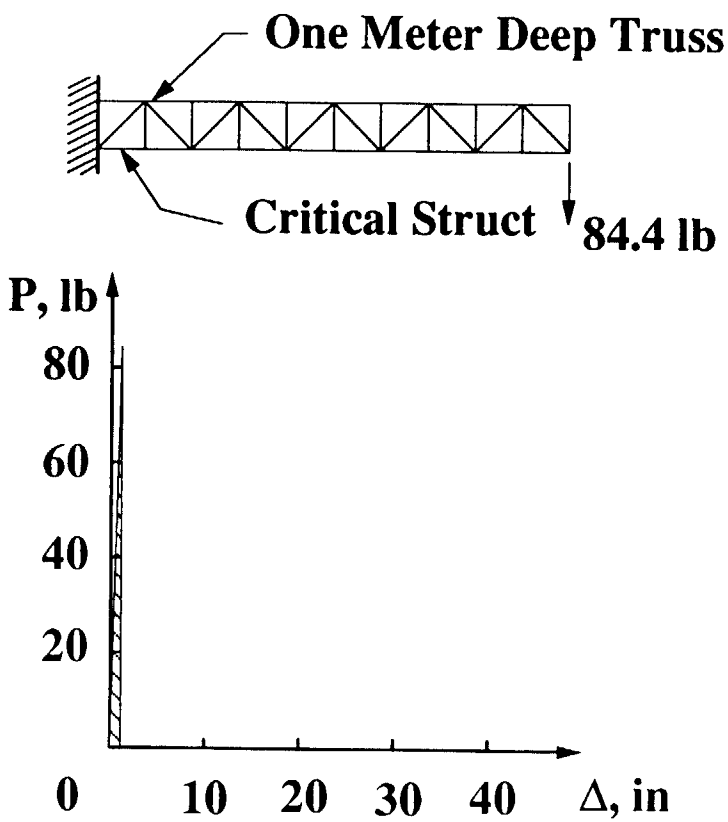
TEN BAY LONG RESILIENT TRUSS EXAMPLE



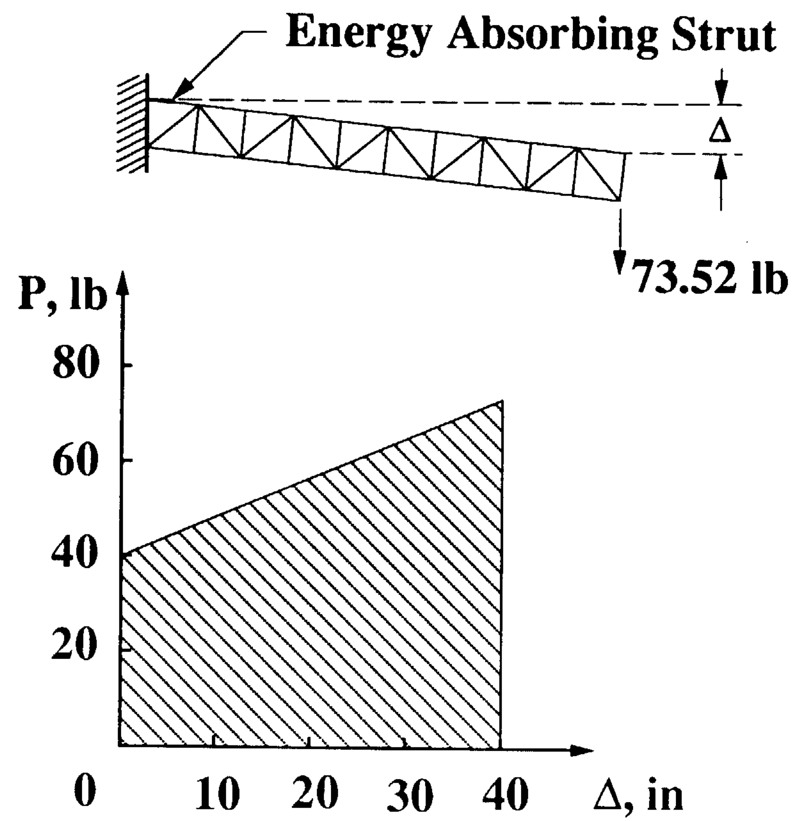
a) Undeformed Truss

b) Deformed Truss

STORED ENERGY CHARACTERISTICS OF ONE METER DEEP TRUSS.

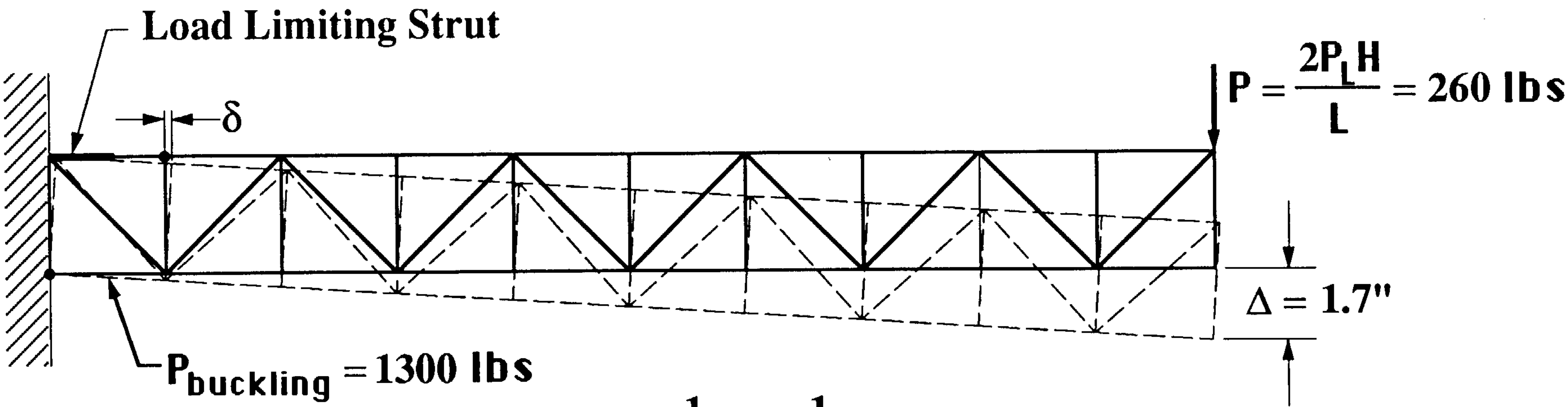


a) Strain energy stored in regular truss (50 in-lb)



b) Energy absorbed by resilient truss (2300 in-lb)

ENERGY ABSORBING POTENTIAL FOR 10-BAY 5-METER DEEP TRUSS



$$E = \frac{1}{2}P\Delta = \frac{1}{2}260 \times 1.7 = 220 \text{ in-lb}$$

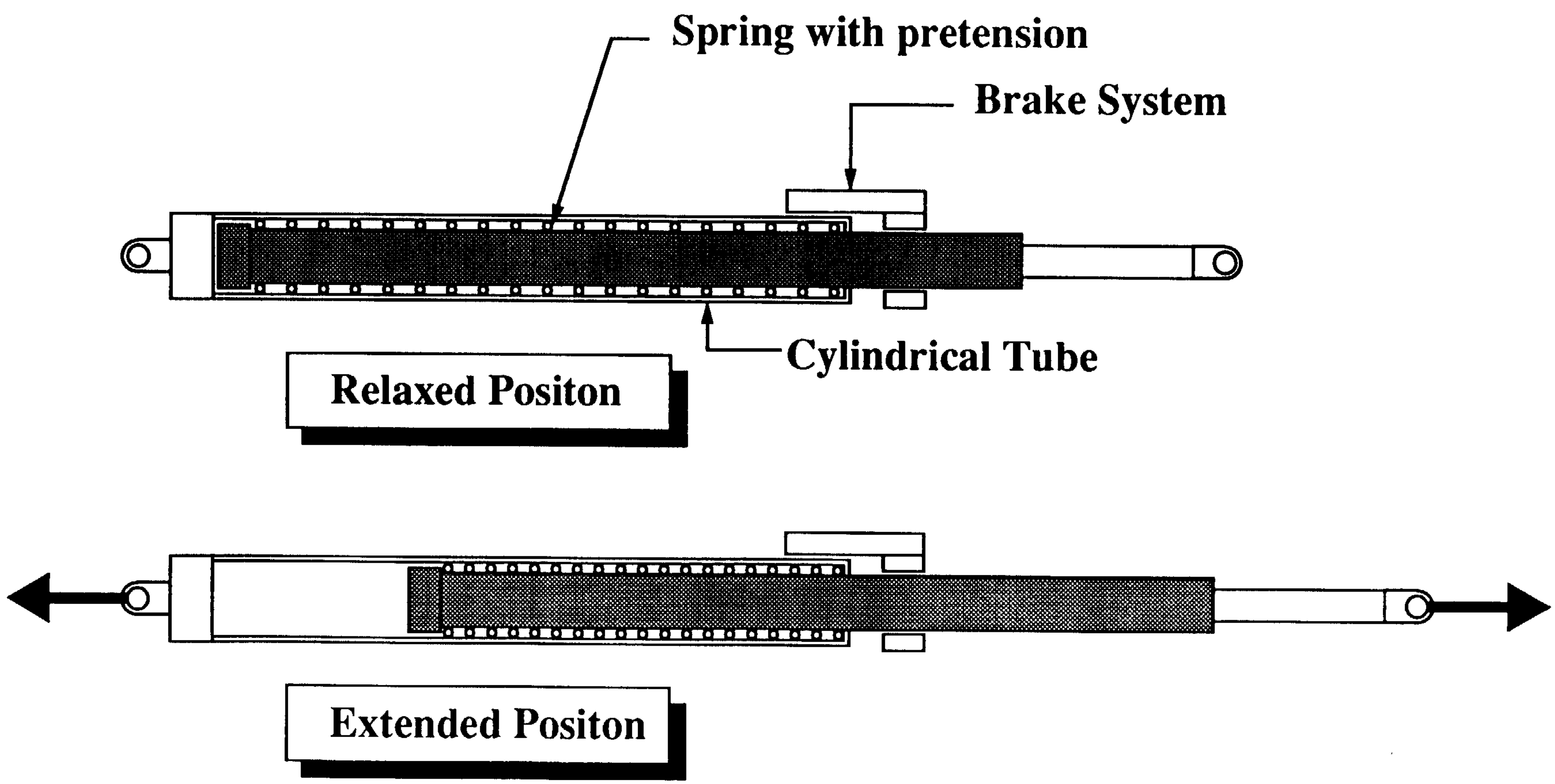
For load limiting strut with preload of 500 lbs and $\delta = 4''$

$$E = 2P_L\delta = 2 \times 500 \times 4 = 4000 \text{ in-lb}$$

$$\Delta = 10\delta = 40''$$

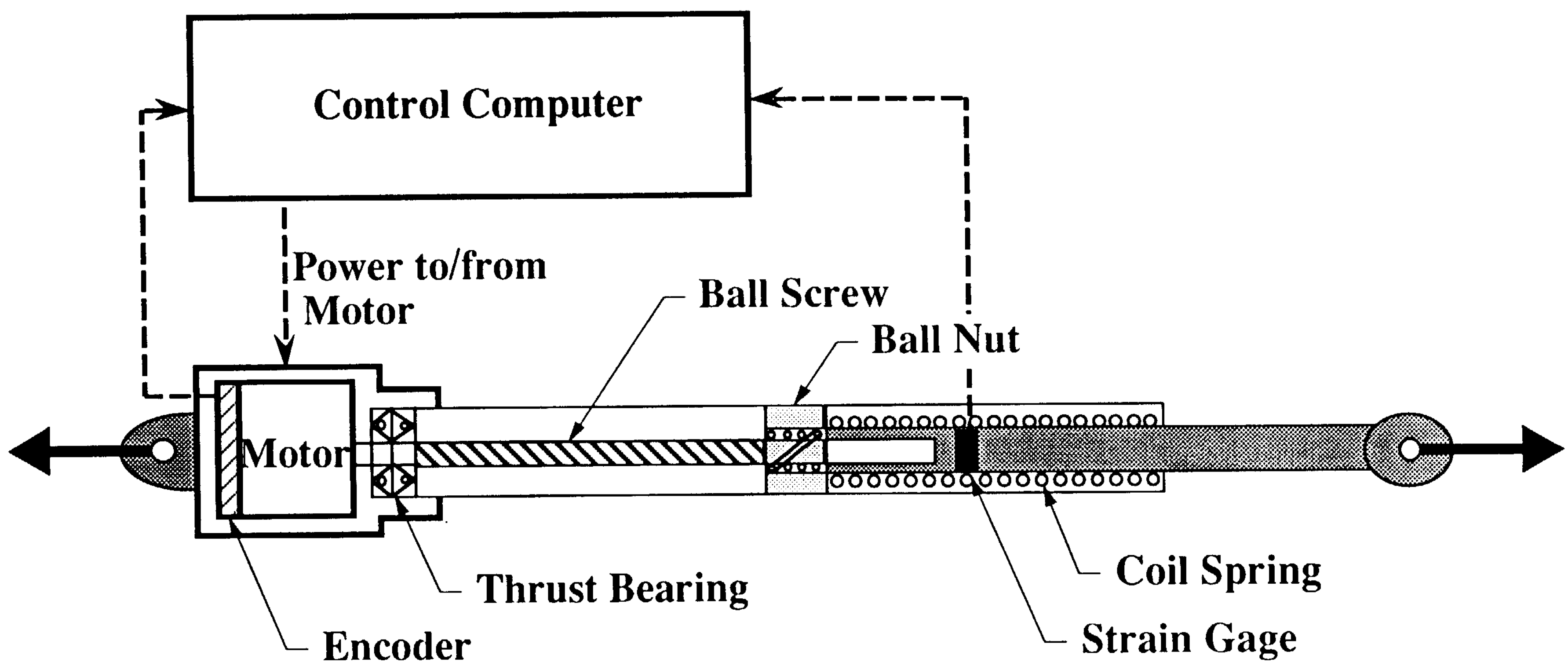
$$\frac{\Delta}{H} = \frac{40}{196} = .2$$

SCHEMETIC OF ENERGY ABSORBING STRUT

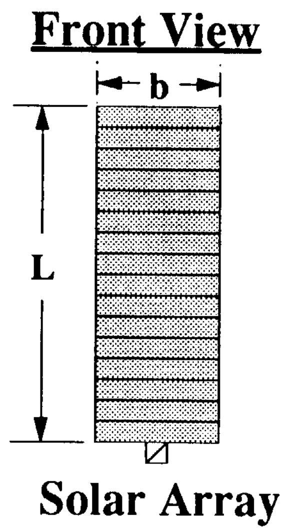


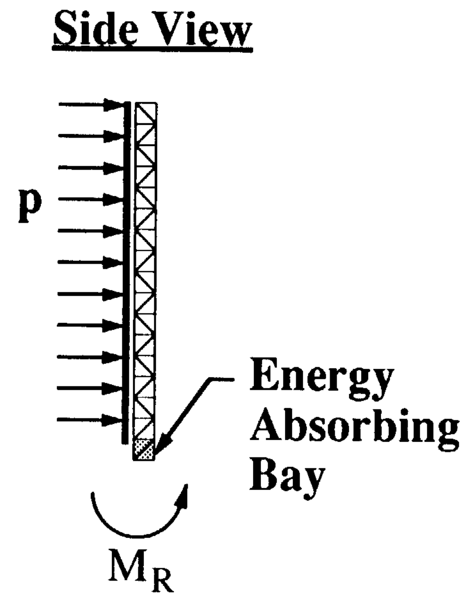
LINEAR LOAD AND MOTION CONTROL ACTUATOR

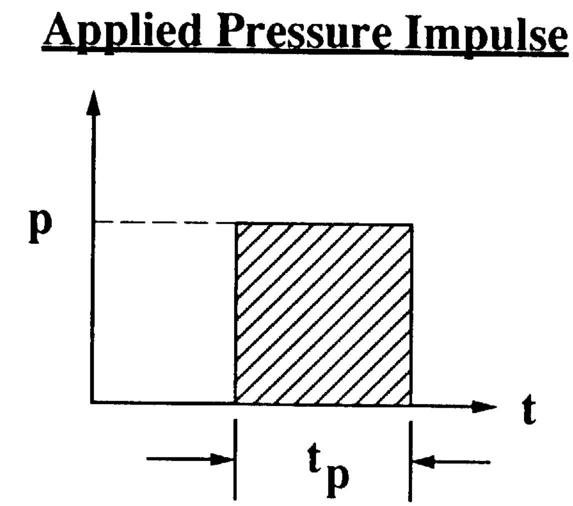
(Energy Absorbing Strut)

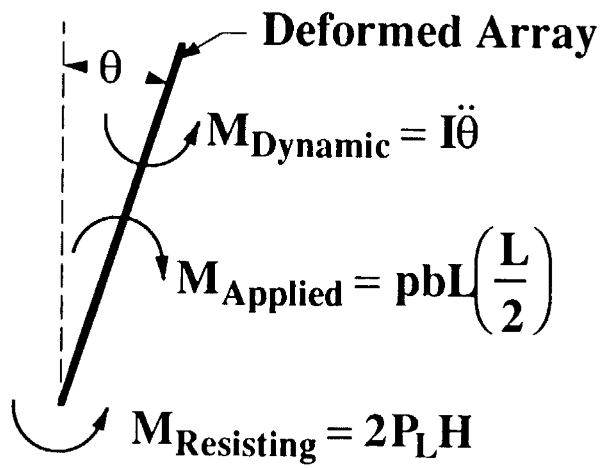


RIGID BODY RESPONSE OF A SOLAR ARRAY TO THE SHUTTLE THRUSTER PRESSURE IMPINGEMENT.









(1) $M_A - M_R = I\ddot{\theta}$

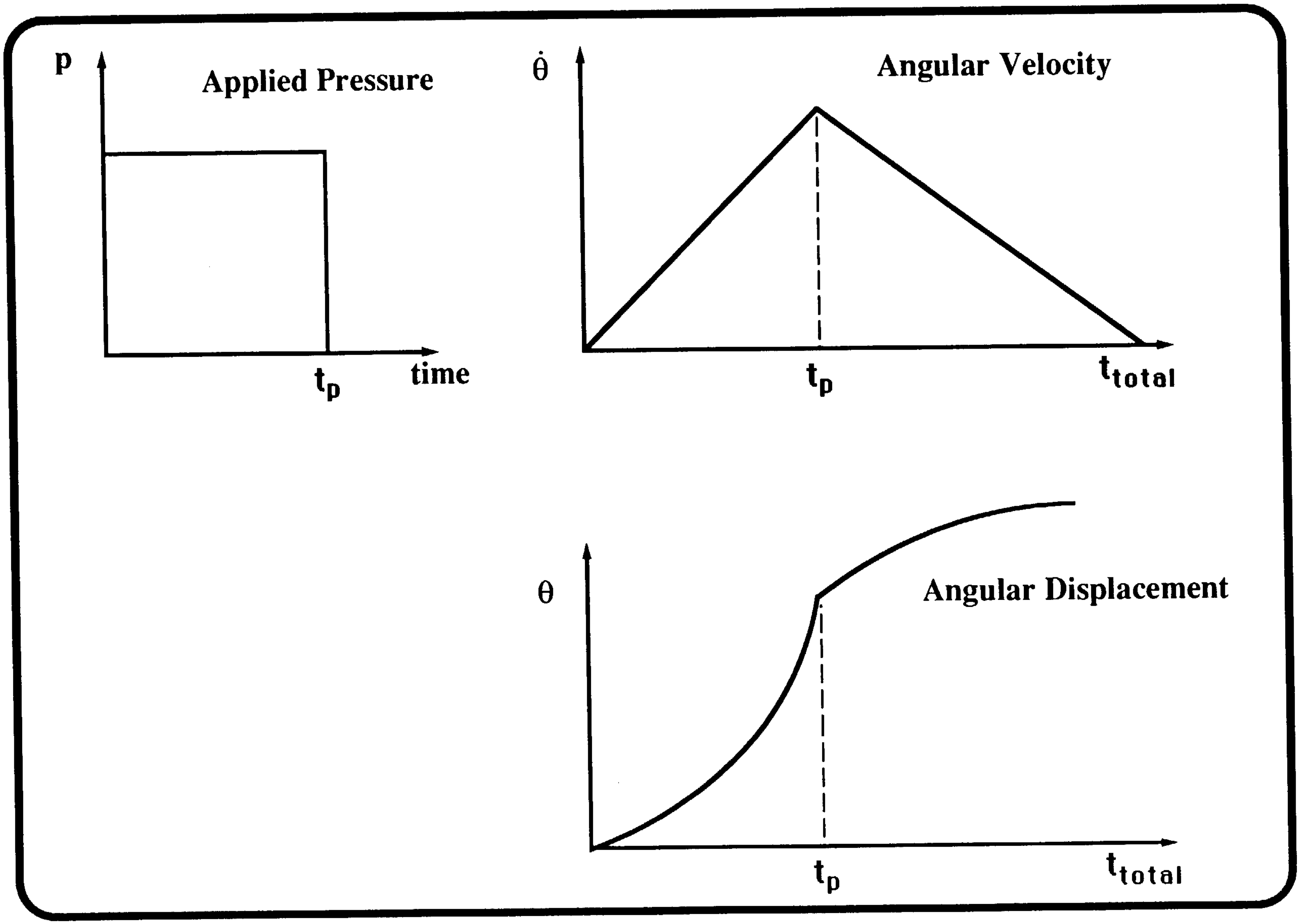
Integration Yields:

(2) $\theta = \frac{M_A t_p^2}{2I}\left(\frac{M_A}{M_R} - 1\right)$

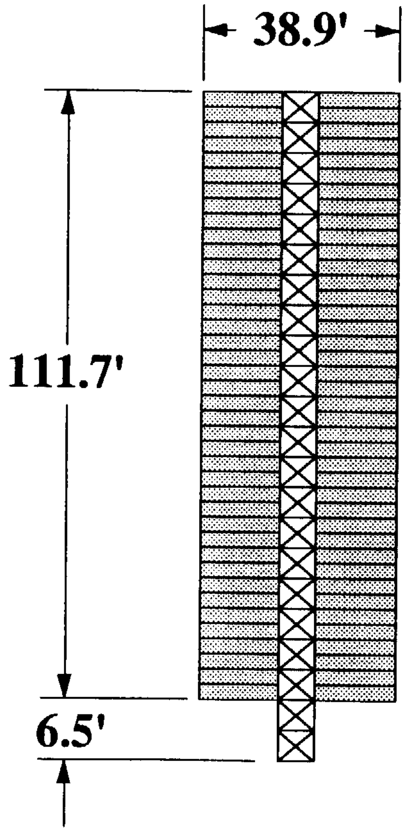
or

(3) $\delta = \frac{M_A t_p^2}{2I} H\left(\frac{M_A}{M_R} - 1\right)$

SOLAR ARRAY PIECEWISE LINEAR RESPONSE

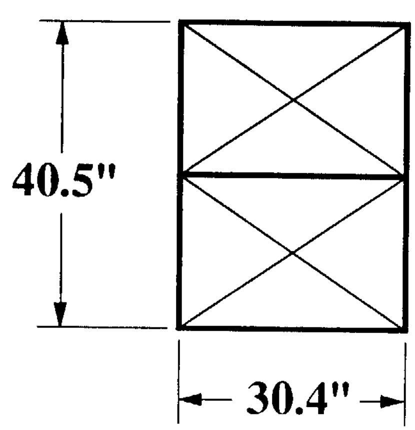


SOLAR ARRAY CHARACTERISTICS



Array Weight, lbs	
Tip	31
Truss beam	315.78
Canister	534.65
Array Blanket	1246.57
Total	2128

Array Beam (one bay)



Longeron properties

Area = .5x.5 = .25 in^2
E = 10e6
Pcrit = 1250 lbs

Truss bending stiffness

EI = .43x EI(theoretical)
= 98 lb-in^2 (Tom Irvine)

SOLAR ARRAY TIP DEFLECTION AND REQUIRED ACTUATOR STROKE

$$\delta = \frac{M_A t_p^2 H}{2I}\left(\frac{M_A}{M_R} - 1\right)$$

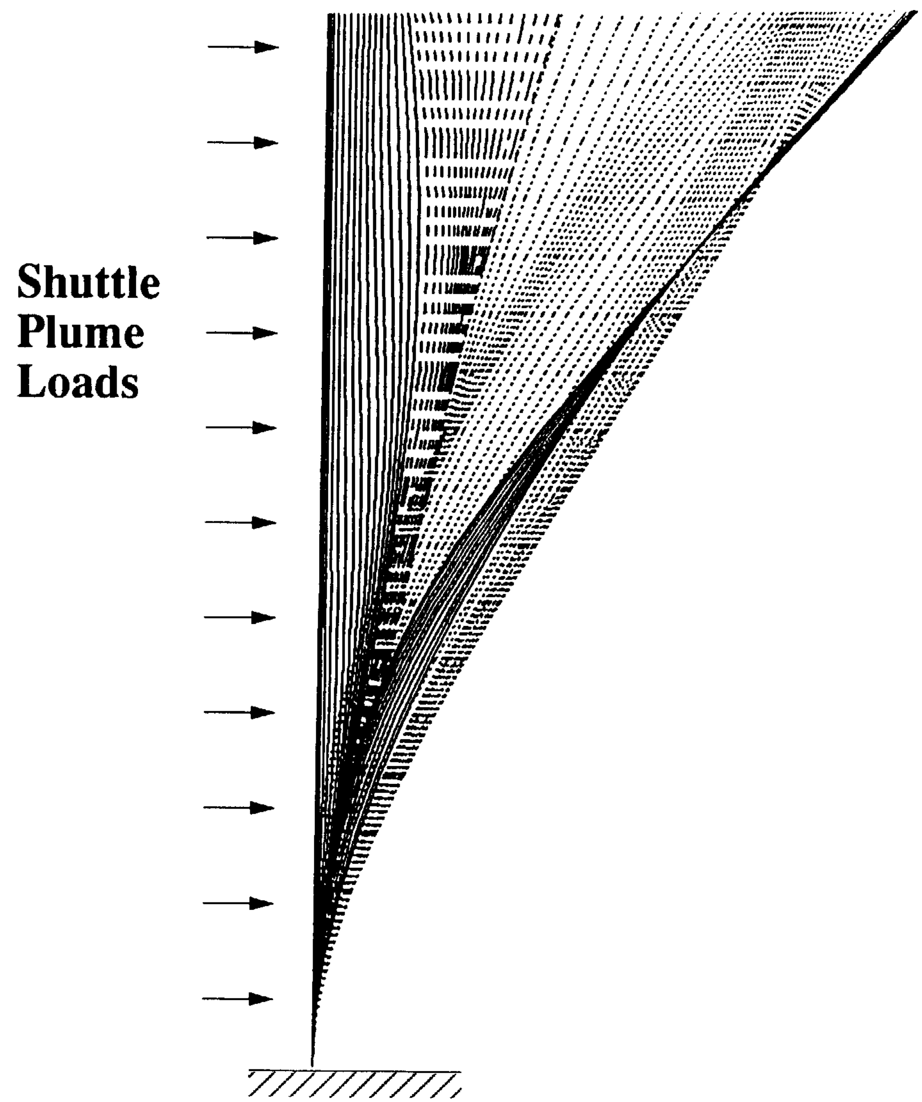
Array input quantities

tp = .75 sec
Plume pressure = .0002 psi
Total load on array = 104 lbs
Assumed actuator preload = 300lb

Tip displacement

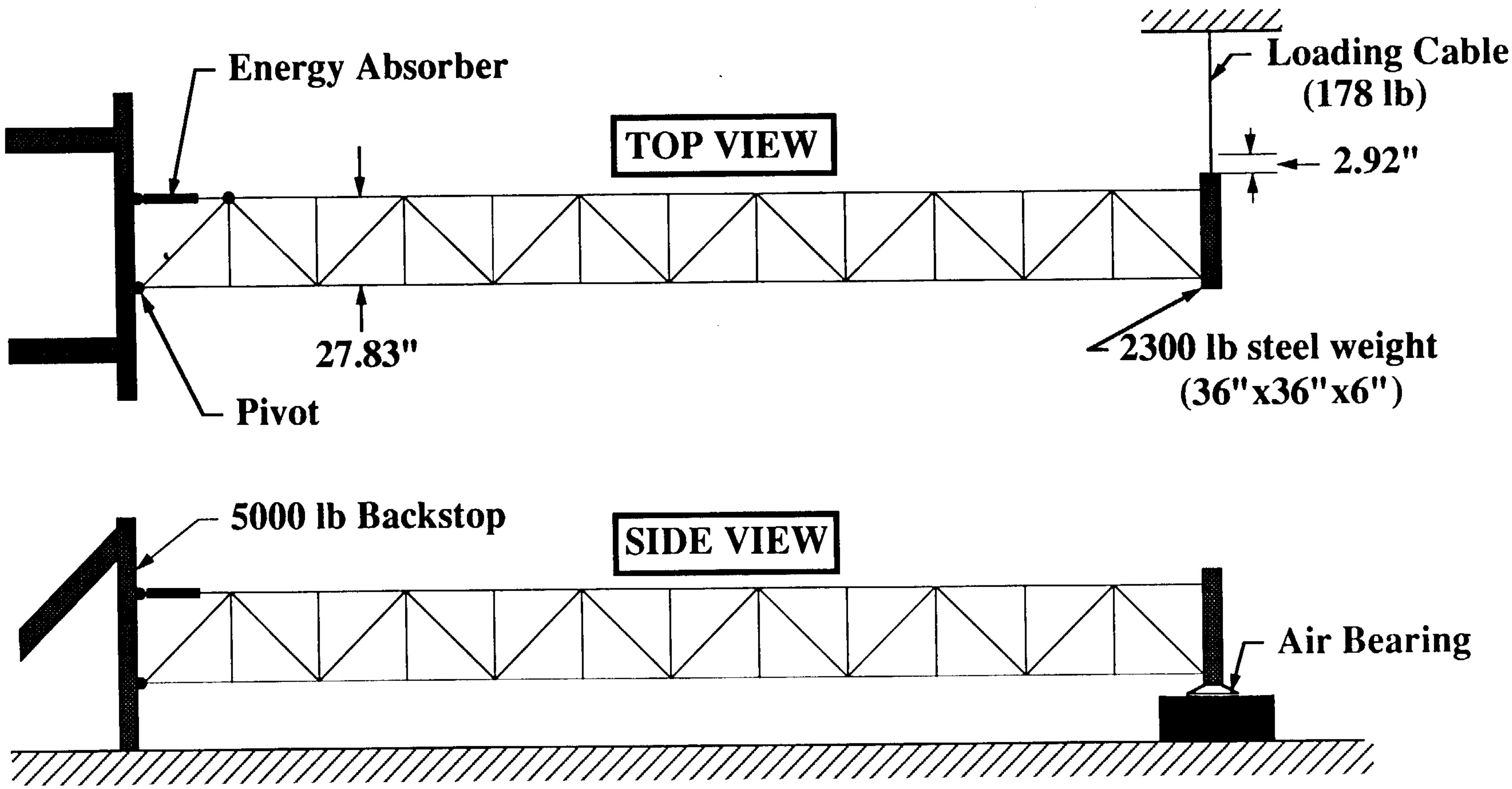
Rigid body - 31"
Finite Element - 98"; Actuator stroke = 2.1"

SOLAR ARRAY RESPONSE FROM FINITE ELEMENT ANALYSIS



12 BAY ENERGY ABSORBING TEST BED

(Beam Length = 27.83')

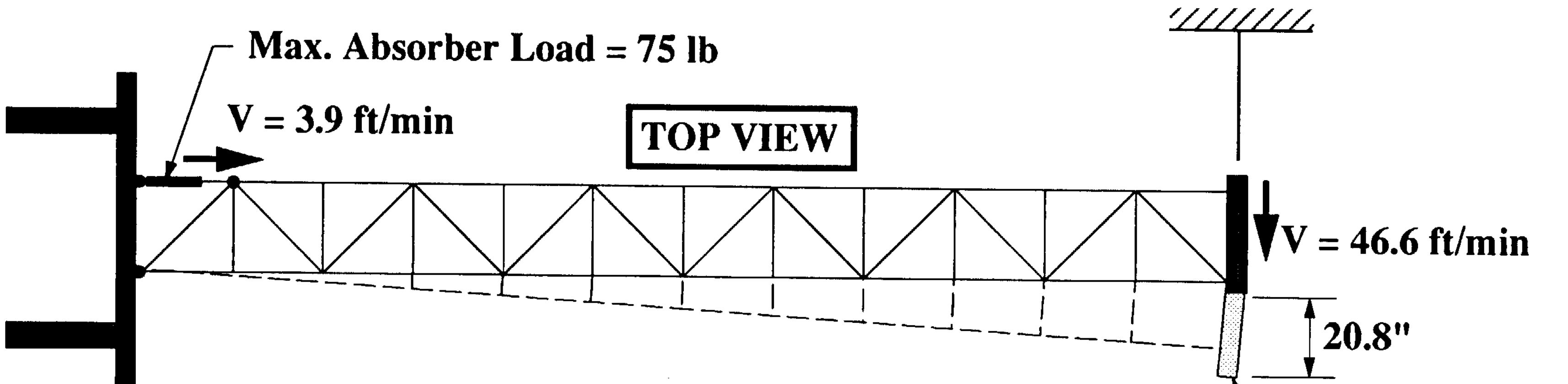


Beam Weight = 75.47 lb   Beam Frequency = . 5 Hz

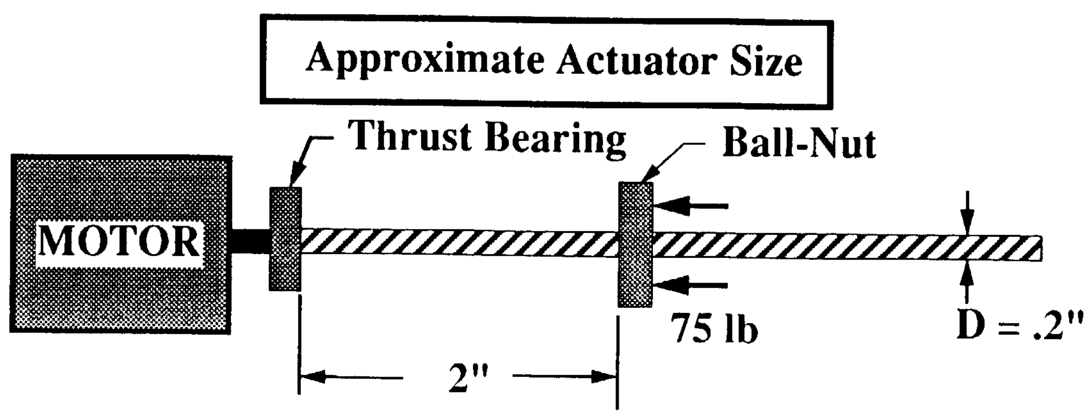
12 BAY ENERGY ABSORBING TEST BED DYNAMICS

(Beam Length = 27.83')

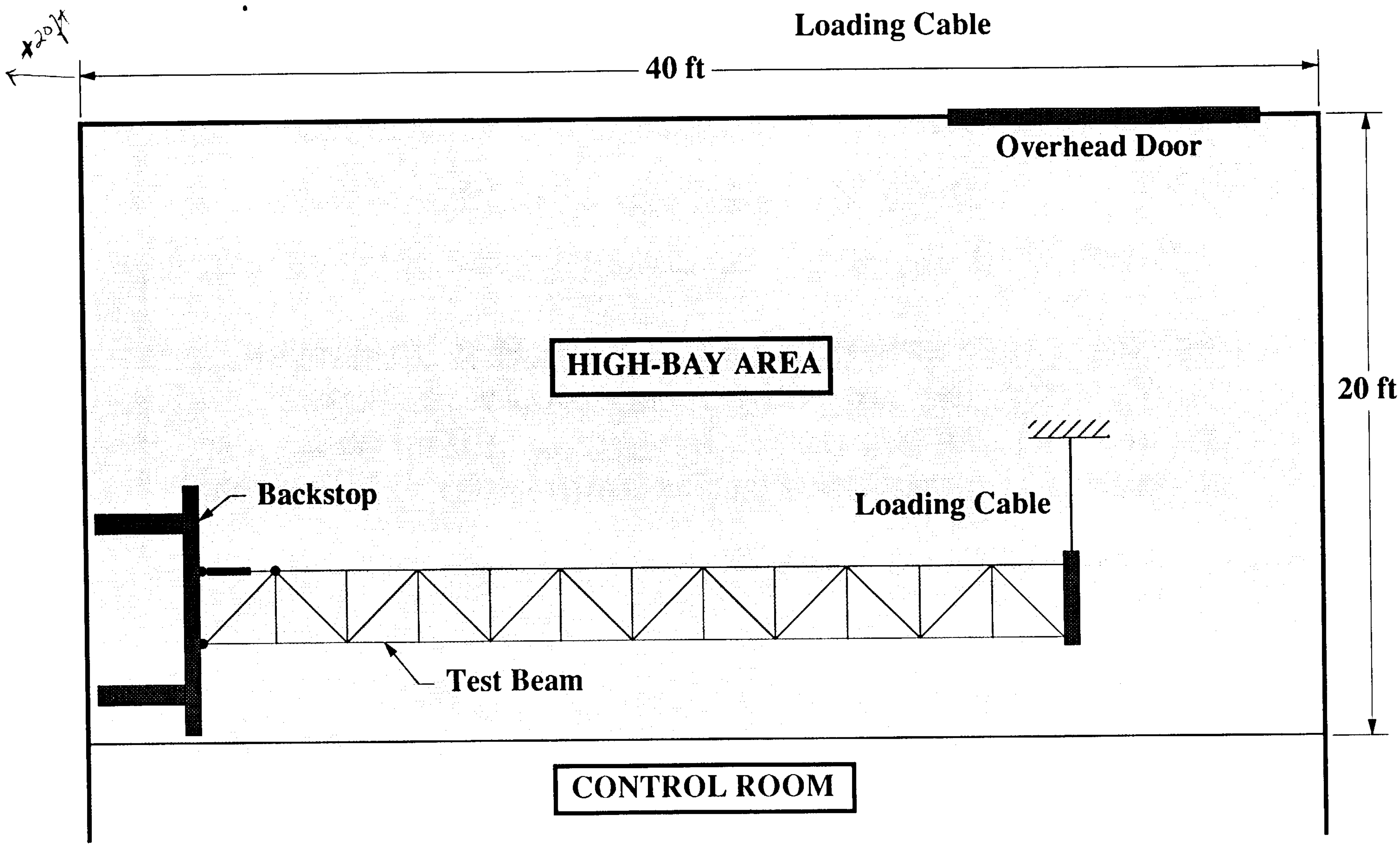
Beam Strain Energy = 260 in-lb = 22 ft-lb



Horsepower = (FxV)/33,000 = (75x3.9)/33,000 = .0088



NEW AERO-LAB WITH 12-BAY TEST BEAM



CONCLUDING REMARKS

All example cases analyzed to date indicate that there is a large payoff in efficiency and fail-safety by using energy absorbers as a "fuse"for limiting and absorbing transient loadings on space structures

Large scale experiments are needed to demonstrate the application of these devices