

CSC

# Lunar Surface Structural Concepts and Construction Studies

Martin Mikulas

Third Annual Symposium  
November 21 & 22, 1991

N93-2641731

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p. 30



# LUNAR SURFACE STRUCTURES CONSTRUCTION RESEARCH AREAS

## RESEARCH AREA

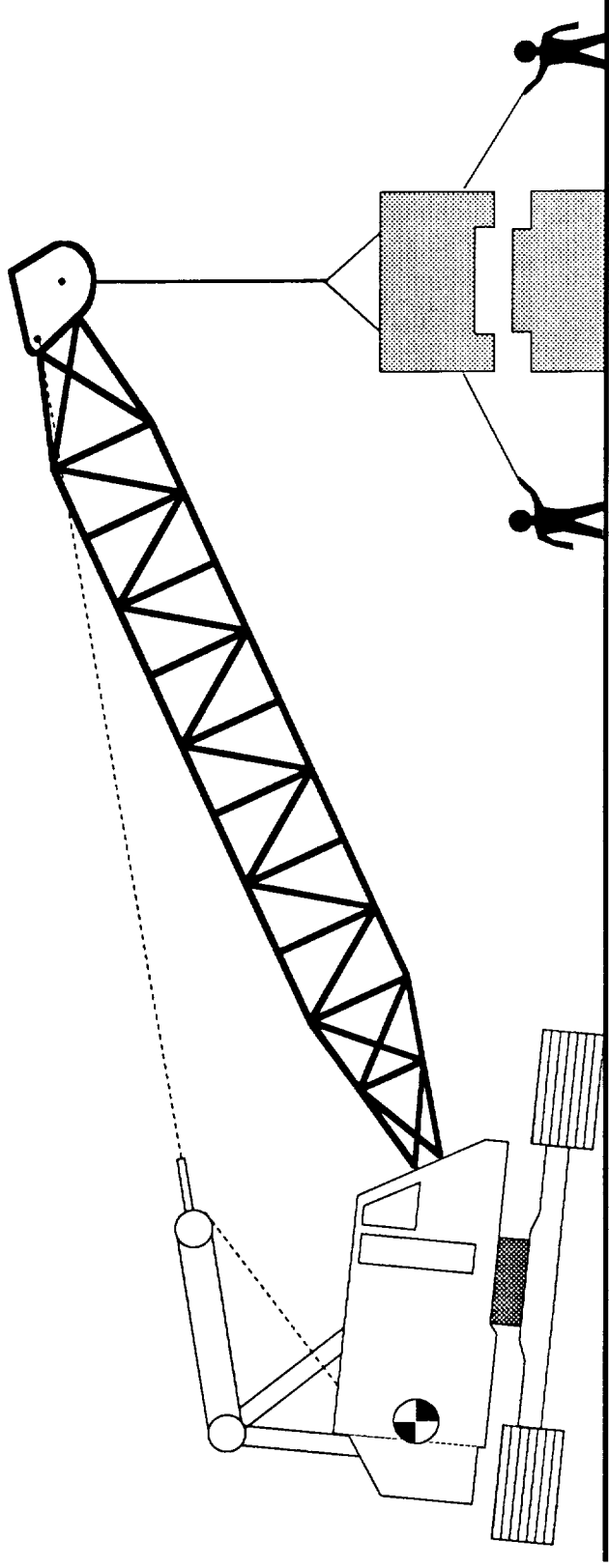
## OBJECTIVE

<ul style="list-style-type: none"> <li>- Multiple Cable Crane</li> <li>- Articulating Arm Crane</li> </ul>	<p style="text-align: center;"><b>Remote and/or Precision Positioning Capability For Lunar Construction</b></p>
<ul style="list-style-type: none"> <li>- Deployable Tower</li> </ul>	<p style="text-align: center;"><b>Automatically Deployable Towers and Beam Type Structures With Minimal Deployment Equipment</b></p>
<ul style="list-style-type: none"> <li>- Lunar Module Unloading Device</li> </ul>	<p style="text-align: center;"><b>Capability For Self Off-Loading of Modules &amp; Equipment</b></p>
<ul style="list-style-type: none"> <li>- Deployable Solar Concentrator</li> </ul>	<p style="text-align: center;"><b>Automatically Deployable Reflector With Minimal Deployment Equipment</b></p>

## **LUNAR CRANE RELATED DISCIPLINES**

- o Remote control and/or autonomous precision construction operations**
- o Multibody dynamics analysis and control of large flexible systems**
- o Analysis and control of cable structures**
- o Quantification of control actuator concepts for large flexible systems**
- o Design of large complex flexible systems**
- o System identification of nonlinear systems**

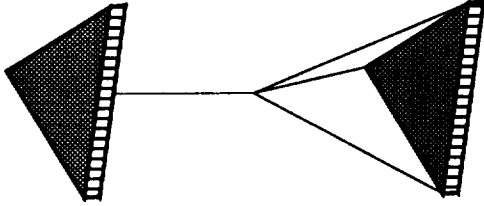
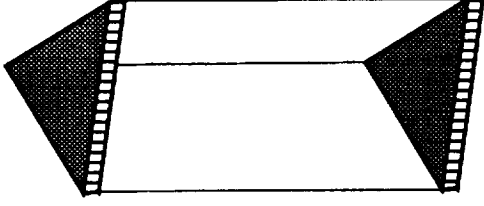
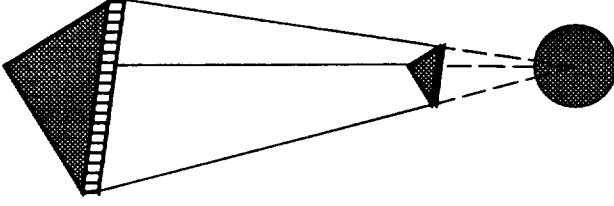
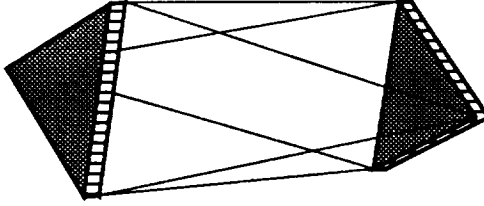
# TYPICAL MOBILE CRANE HAS TWO MAJOR SHORTCOMINGS FOR LUNAR BASE APPLICATION



1) Very large mass required to resist tipping

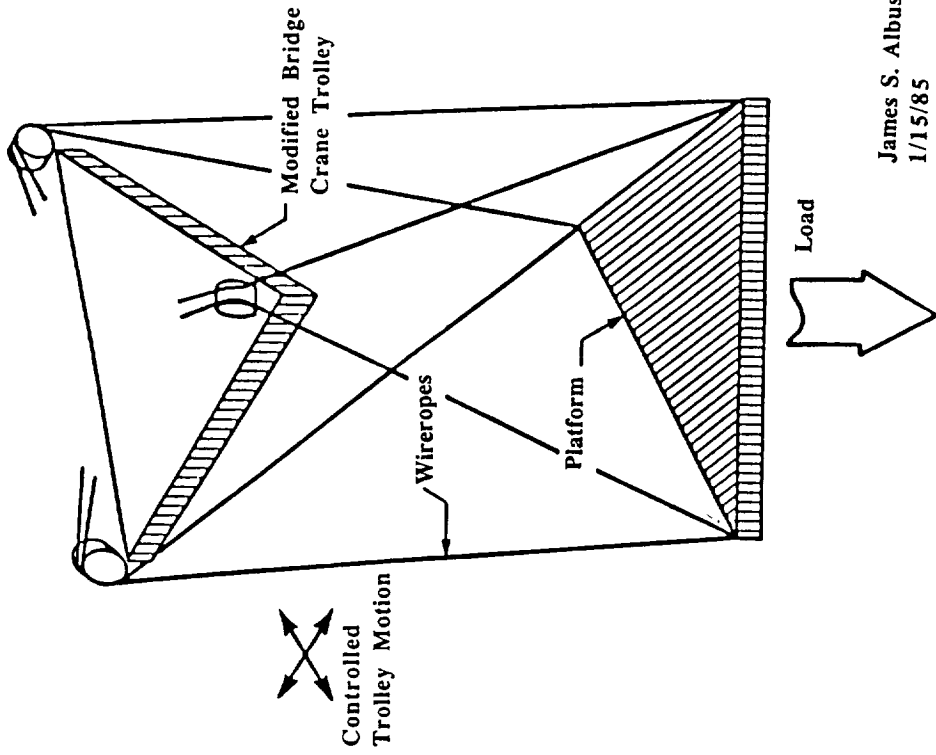
2) Human guidance required for accurate positioning

# CANDIDATE CRANE CABLE SUSPENSION SYSTEMS

			
<p><b>Single Cable</b></p>	<p><b>Three Cables</b></p>	<p><b>Three Cables</b></p>	<p><b>Six Cables</b></p>
<p><b>1 DOF</b> Structurally Stiff</p>	<p><b>3 DOF</b> Structurally Stiff</p>	<p><b>3 DOF</b> Structurally Stiff 3 DOF Stiffened by Triangulated Cables</p>	<p><b>6 DOF</b> Structurally Stiff</p>

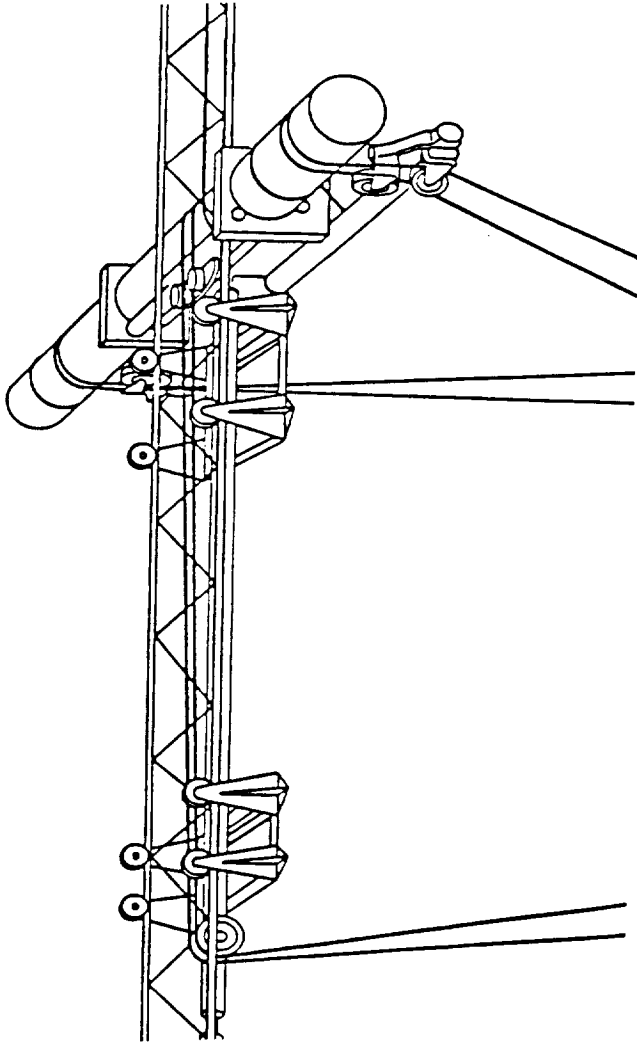
# NIST SIX-CABLE SUSPENSION CRANE

## Cable Geometry



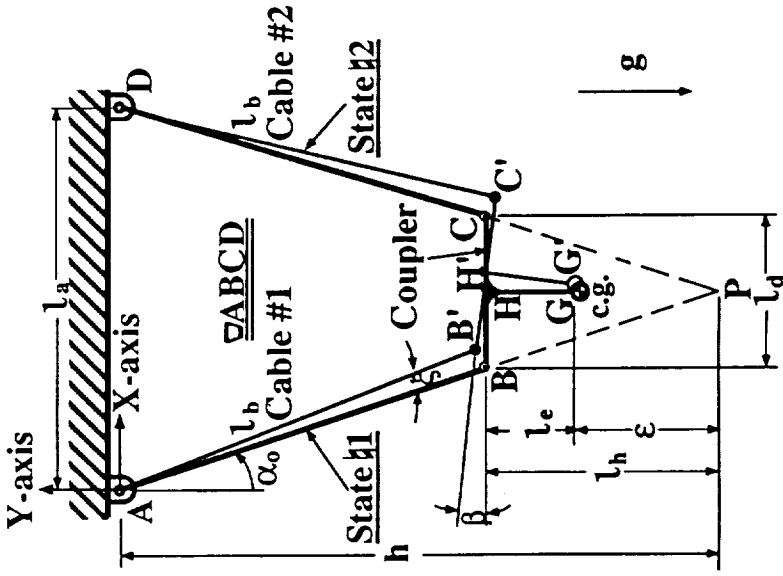
James S. Albus  
1/15/85

## Cable Drive System

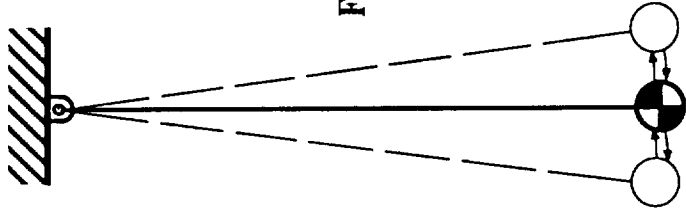


# NUMERICAL EXAMPLE OF NATURAL FREQUENCY

## A Symmetric Model

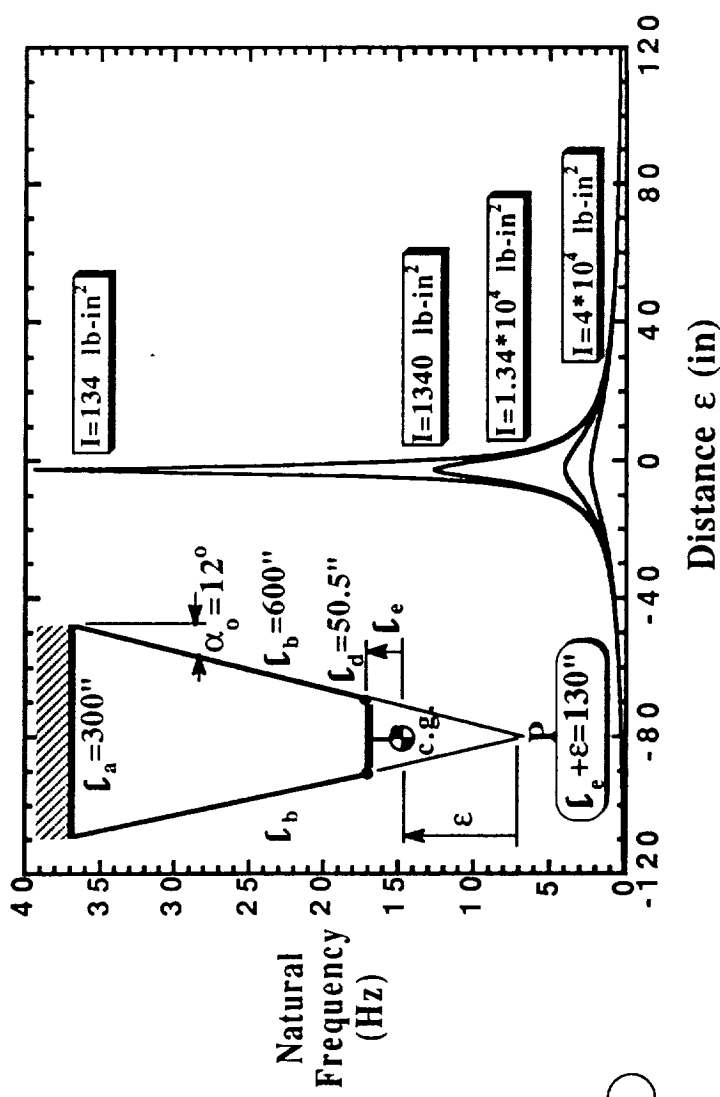


## A Swinging Pendulum



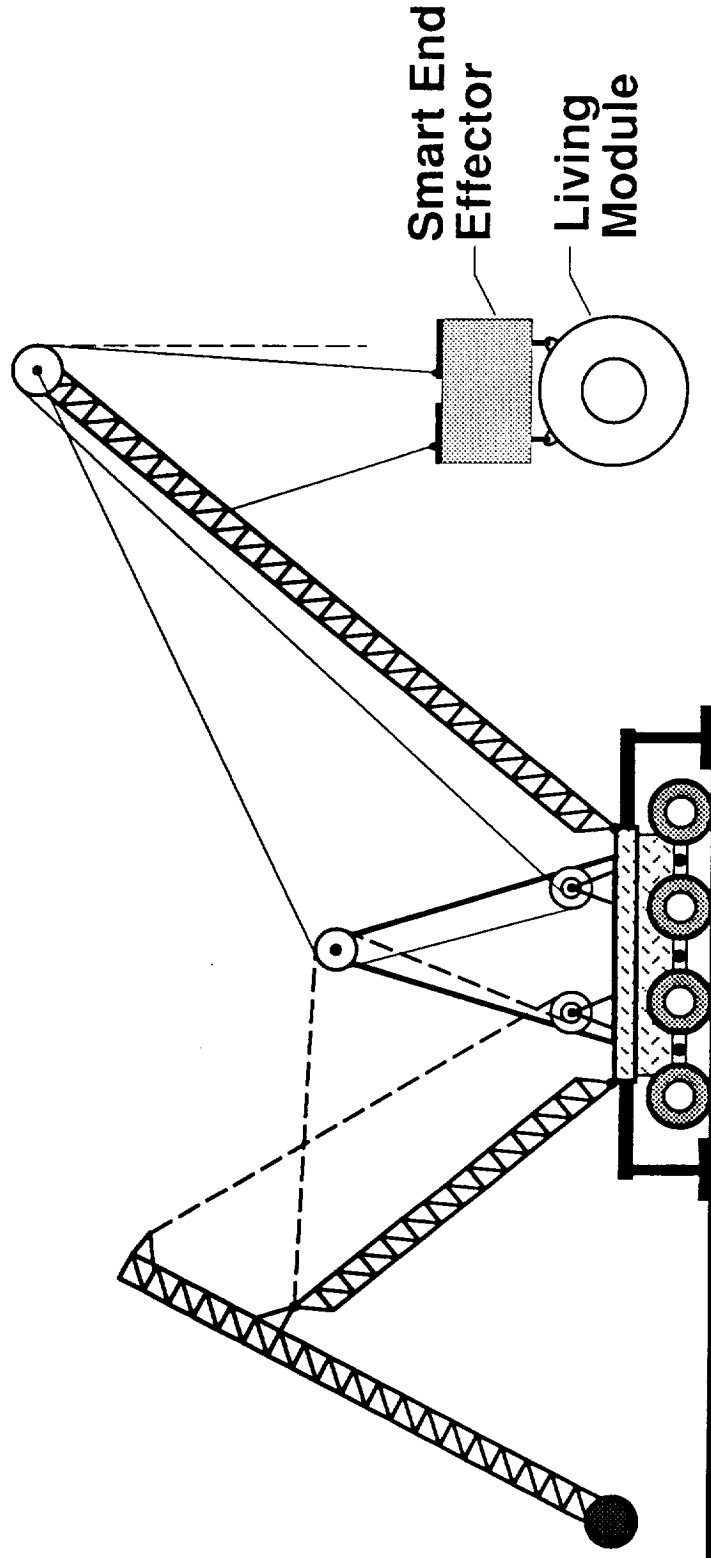
$$F = \sqrt{\frac{\left(\frac{l_h}{h-l_h}\right) \left[ l_h h + \frac{l_a^2}{4} \right] + l_e h}{\epsilon^2 + \rho^2}} F_{pendulum}$$

$$F_{pendulum} = \frac{1}{2\pi} \sqrt{\frac{g}{h}}$$





# COUNTER-BALANCED ACTIVELY-CONTROLLED LUNAR CRANE INCORPORATES TWO NEW FEATURES FOR IMPROVED PERFORMANCE



1) Active Counter Weight to Reduce Overturning Moment

2) Multiple Payload Suspension Cables to Provide Stable Precision Positioning

# LUNAR CRANE PENDULUM MECHANICS

**3 Translations Have Structural Stiffness**

**3 Rotations Have Pendulum Stiffness**

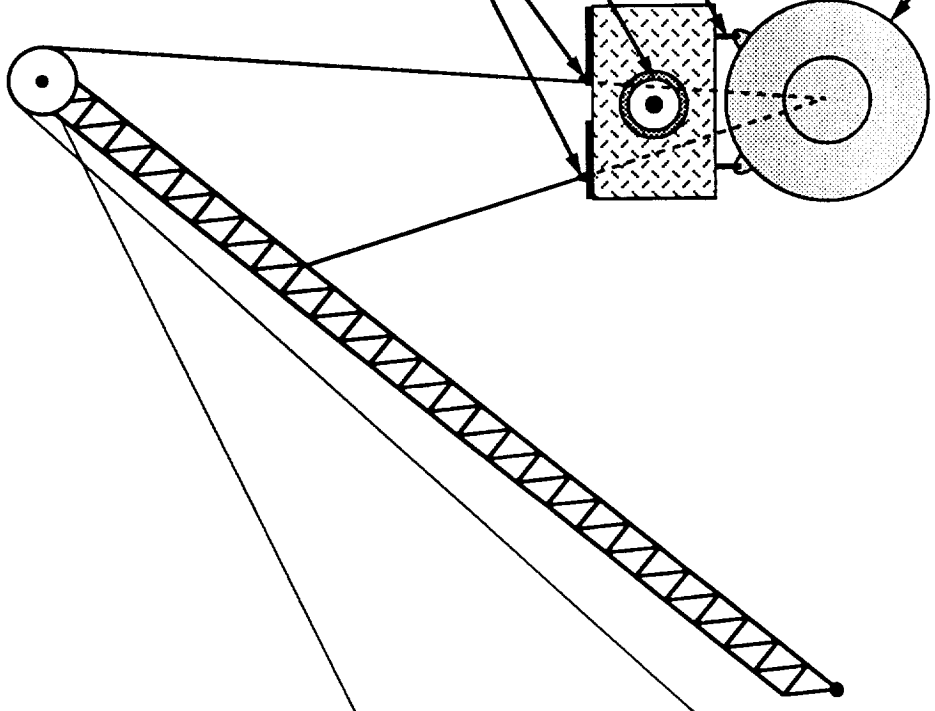
**Potential Control Mechanisms**

Active Cable Positioners

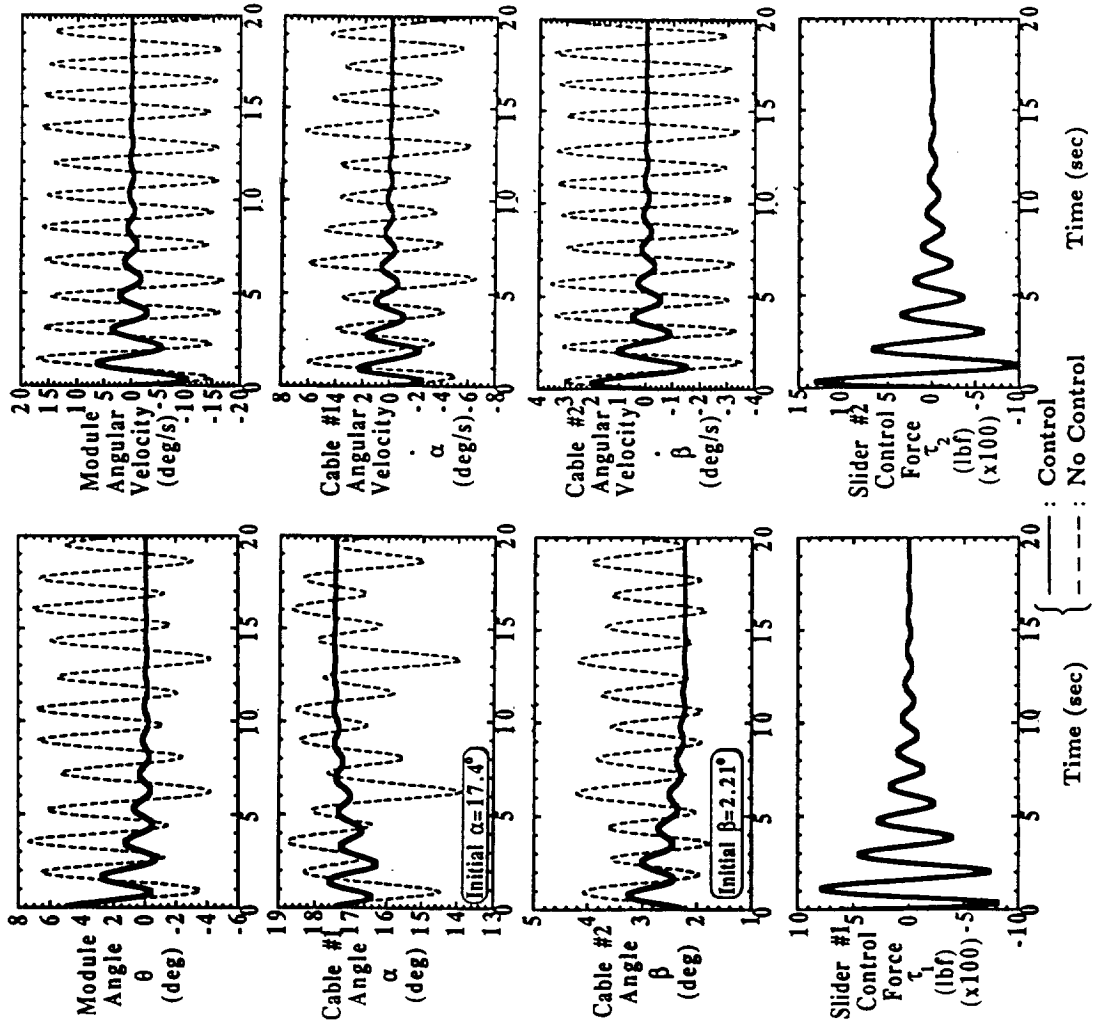
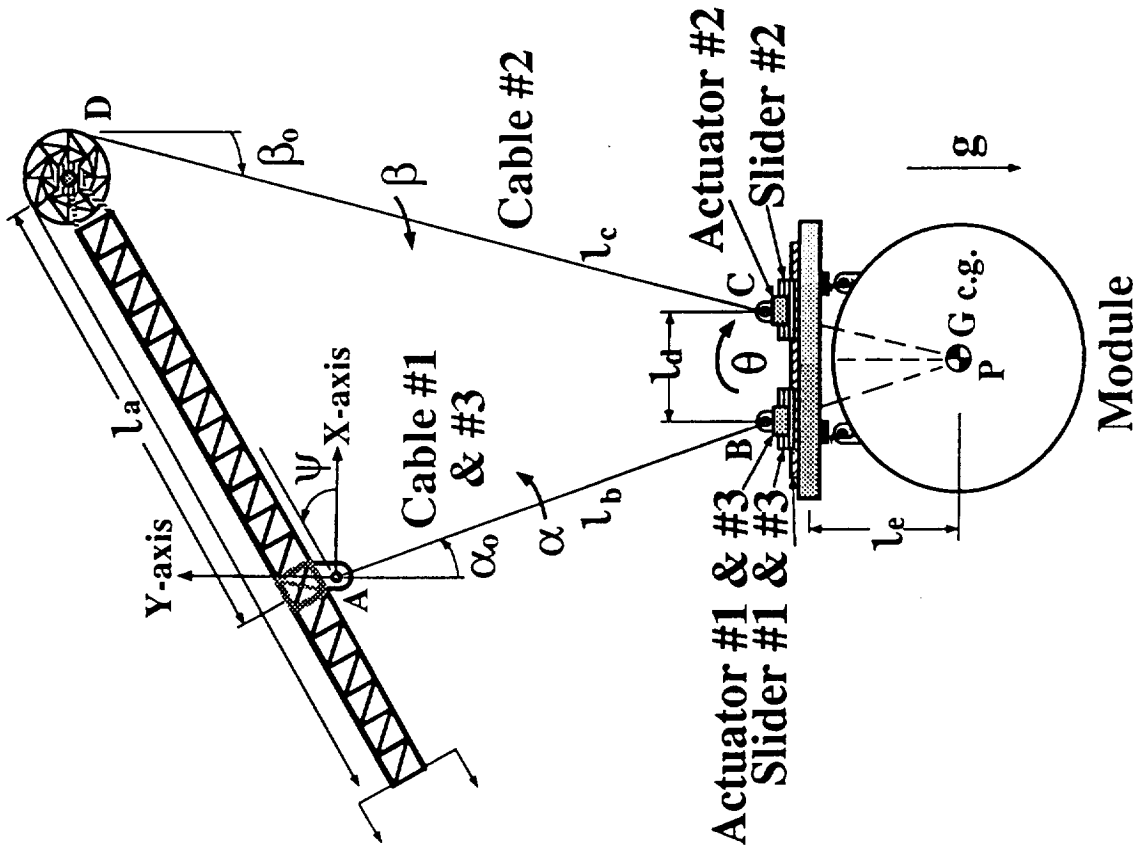
Active Inertia Wheels

Active Attachments

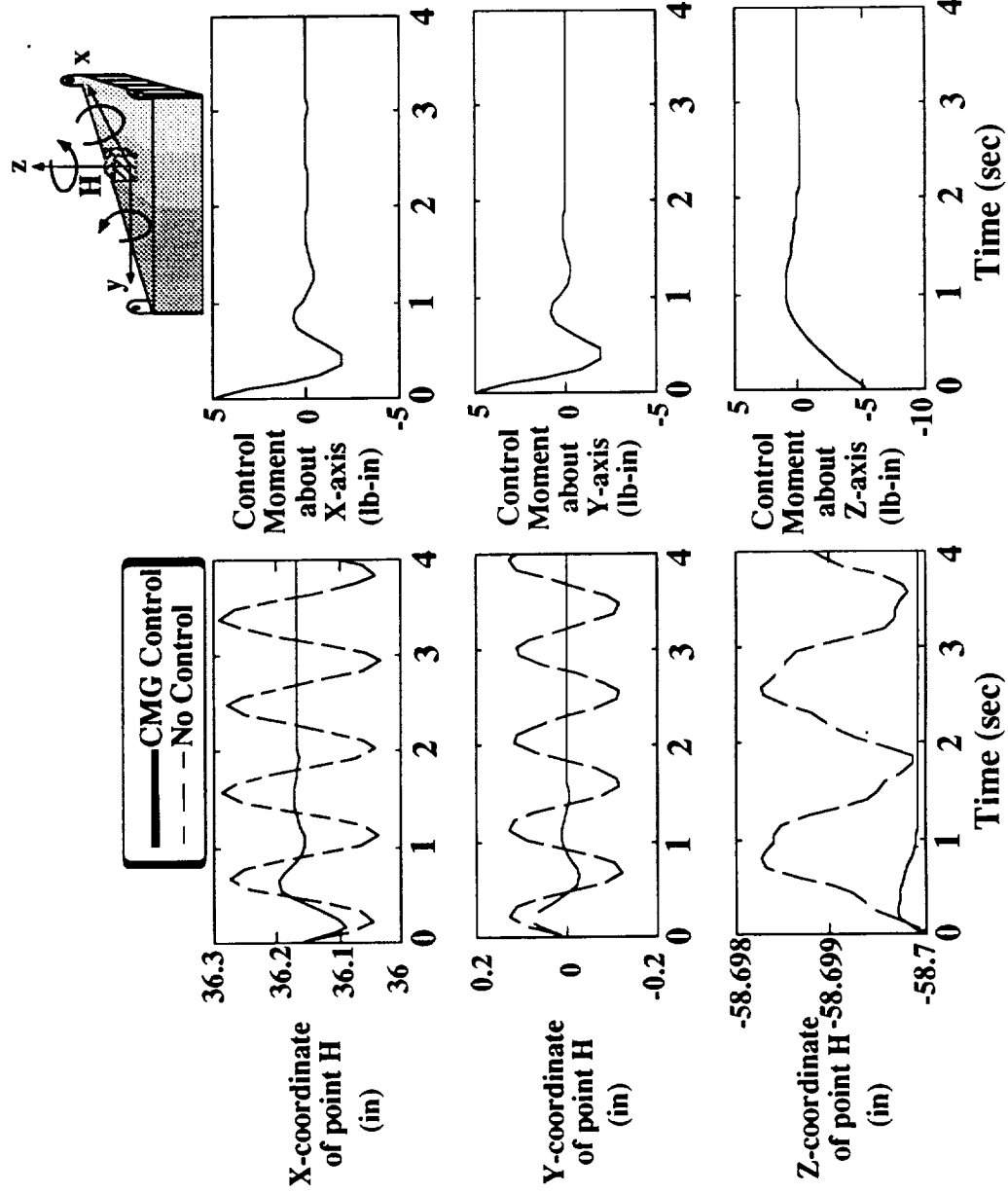
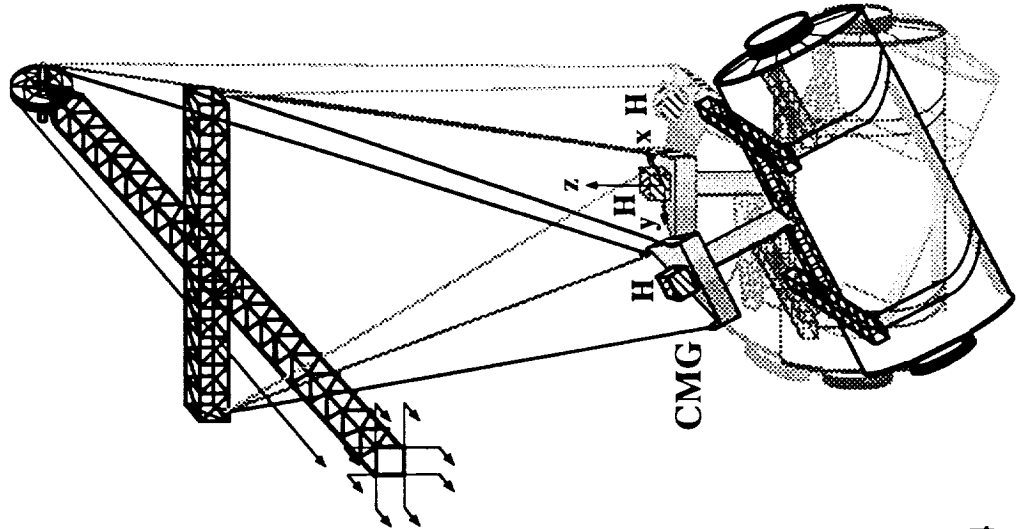
Payload (  $M, I$  )



# SIMULATION RESULTS (II)

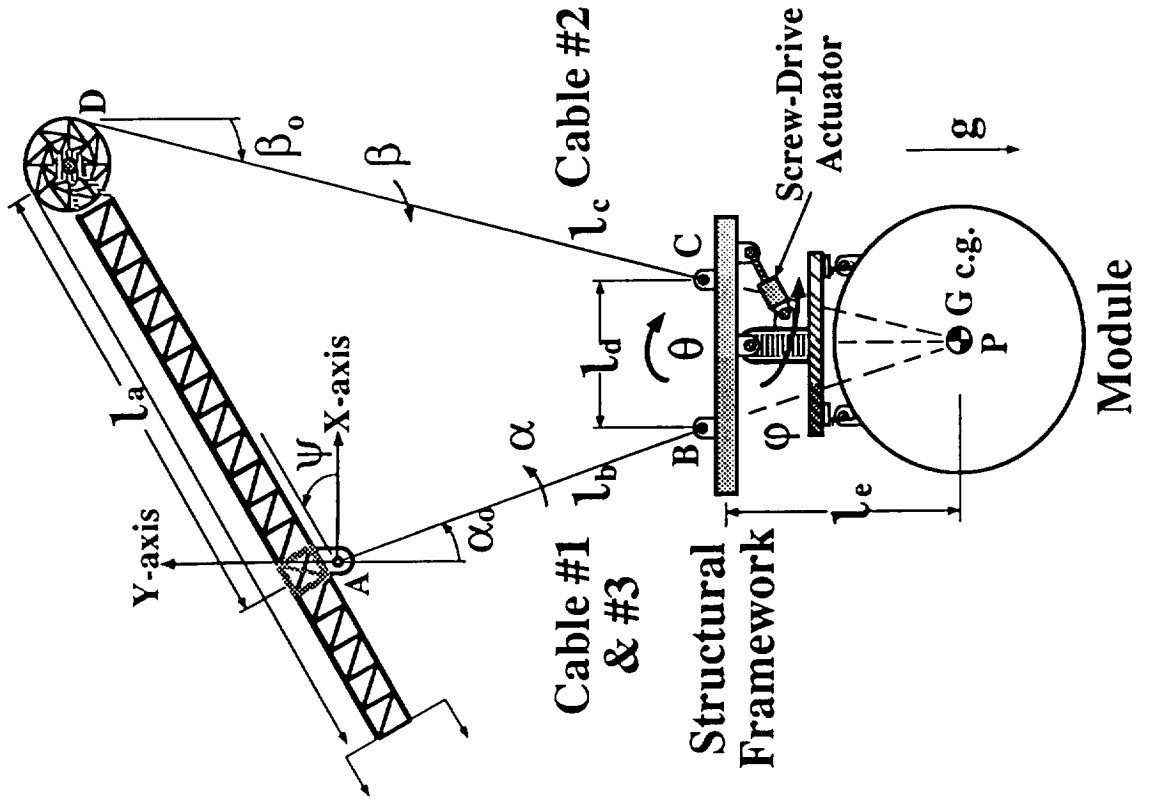
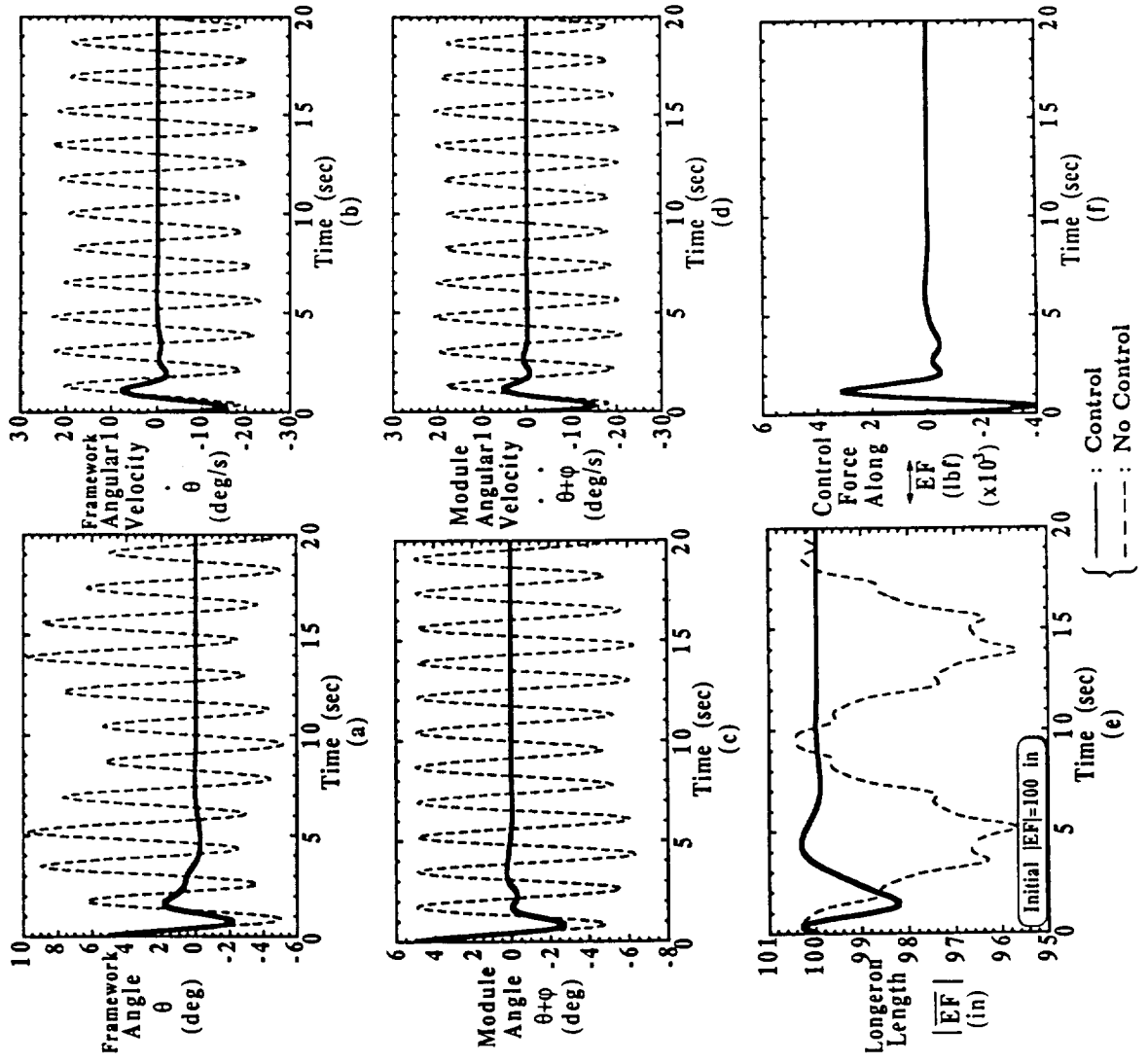


# CMG CONTROL SIMULATION RESULTS



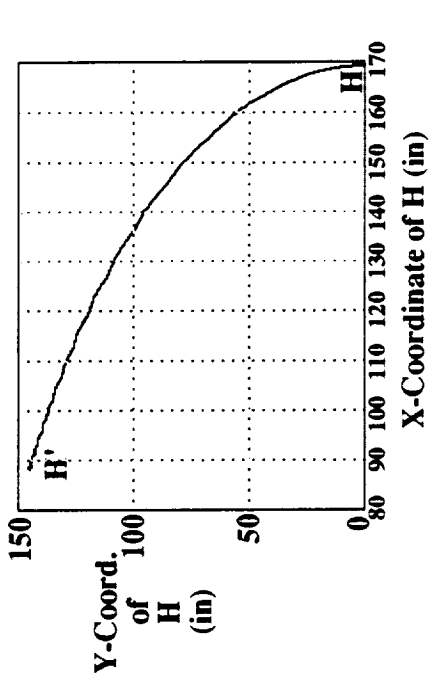
# SIMULATION RESULTS

(I)

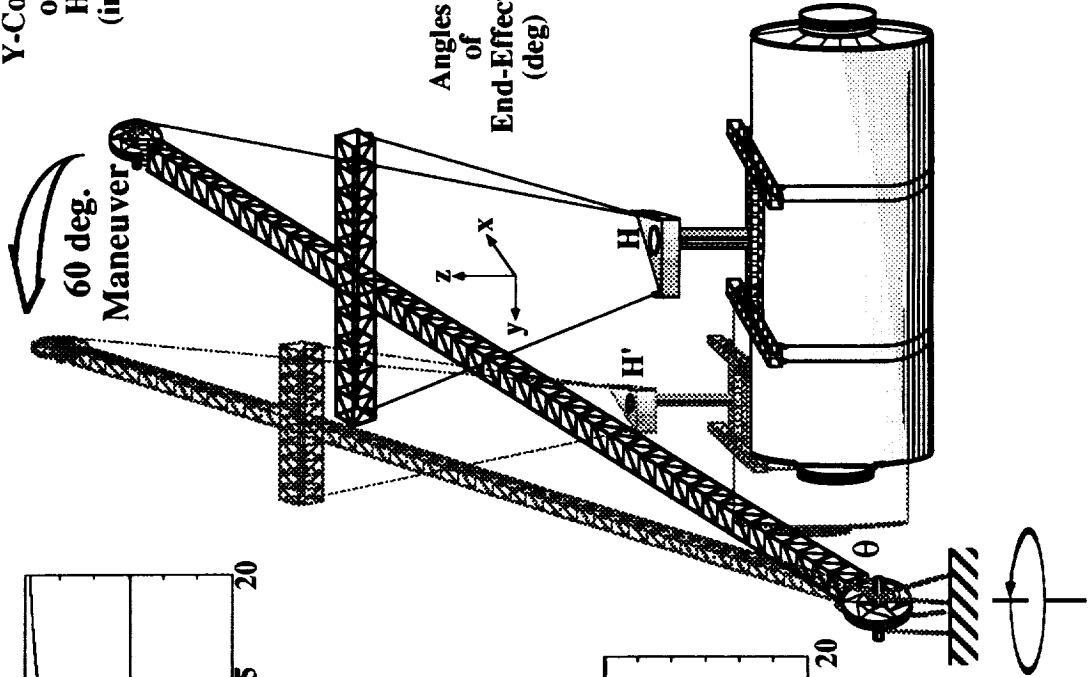
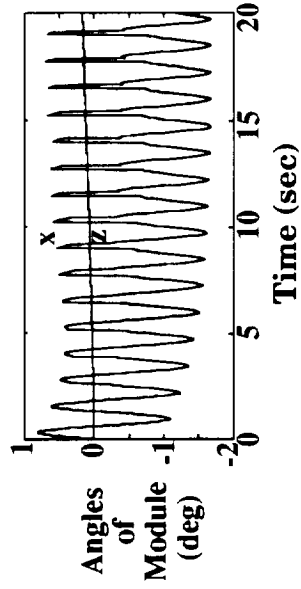
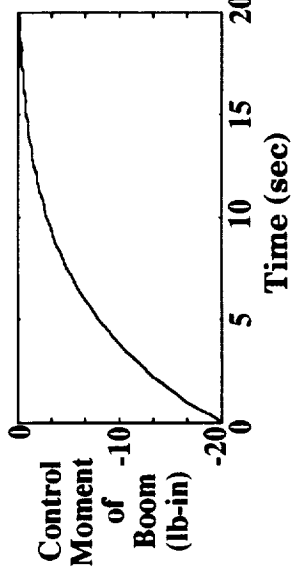
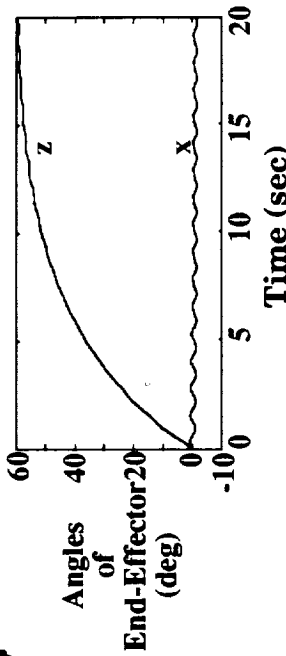
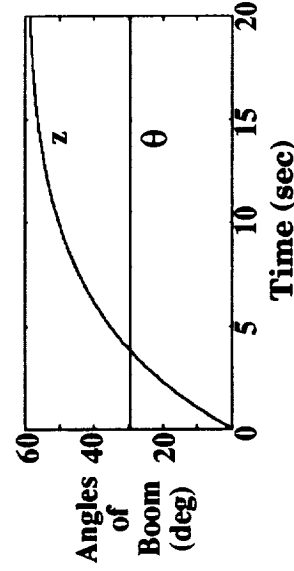


# SLEWING SIMULATION RESULTS

X-Y Plot of Point H on End-Effector

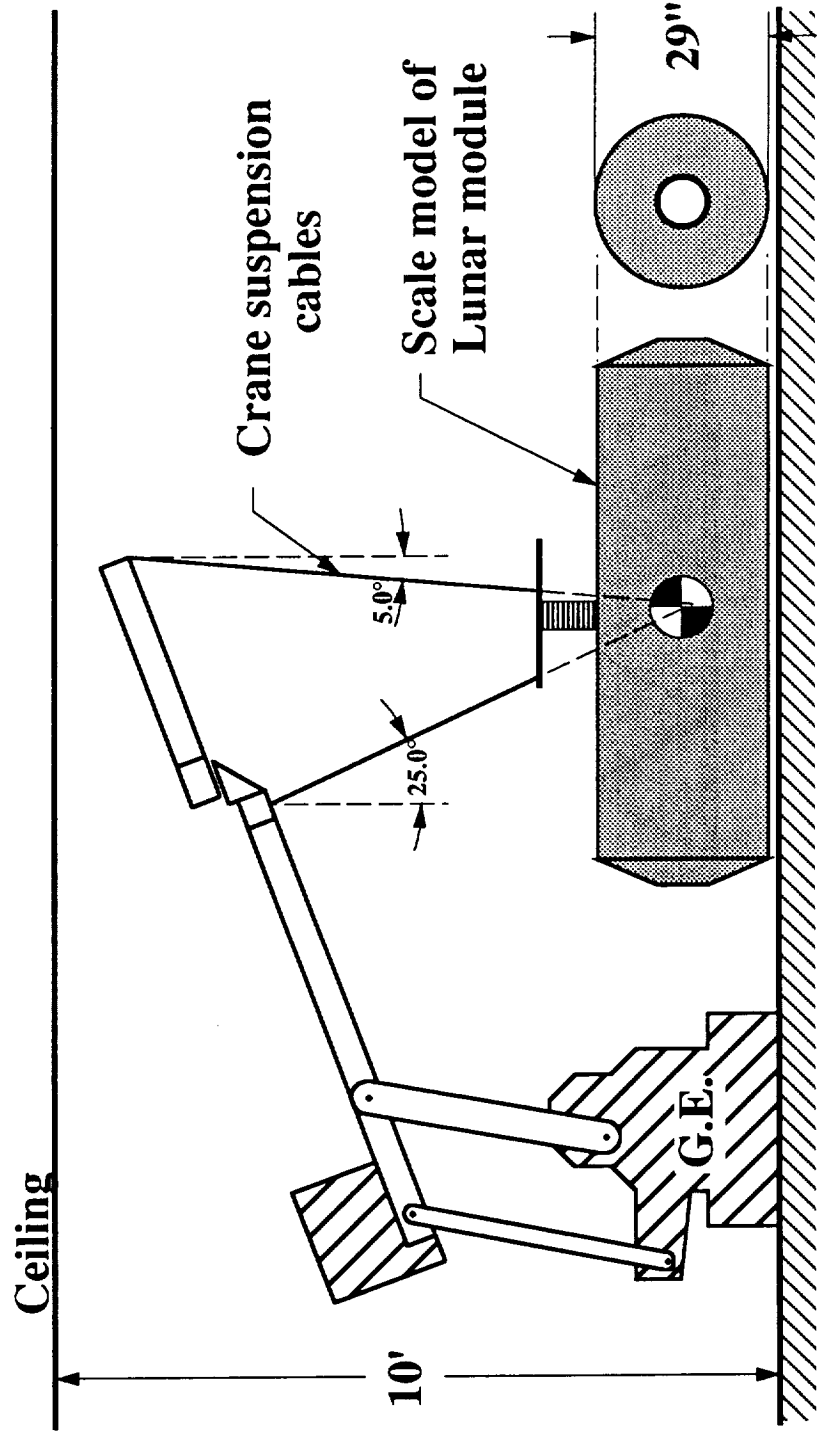


60 deg. Maneuver

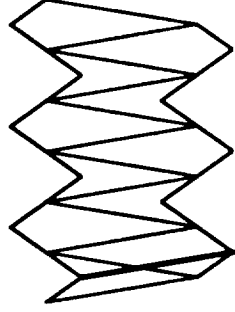
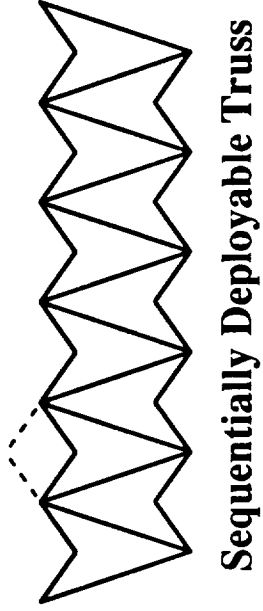
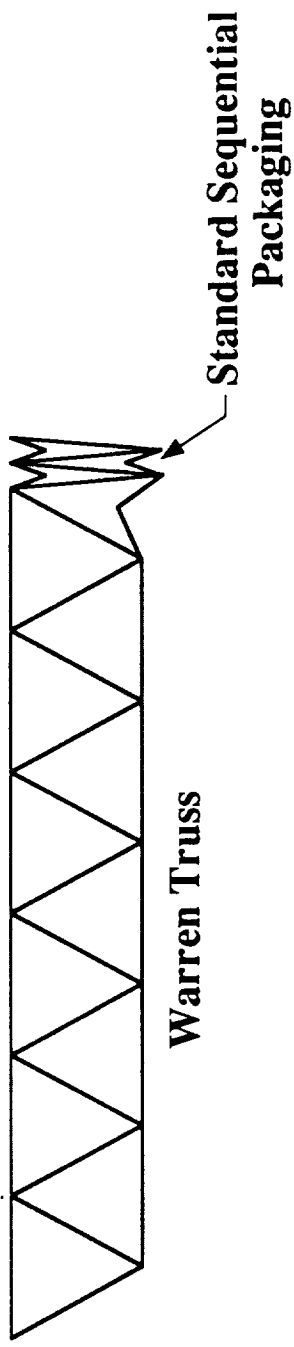


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# ONE-SIXTH SCALE LUNAR CRANE TEST-BED USING G.E. ROBOT FOR GLOBAL MANIPULATION.



# BASIC DEPLOYABLE TRUSS APPROACHES

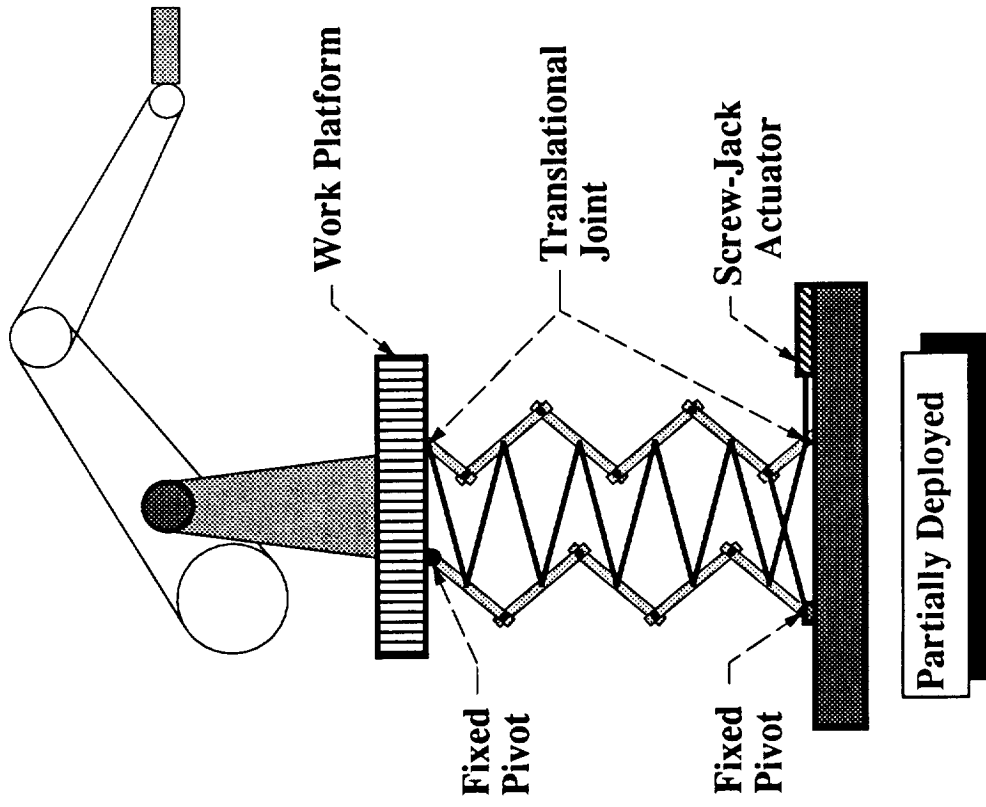
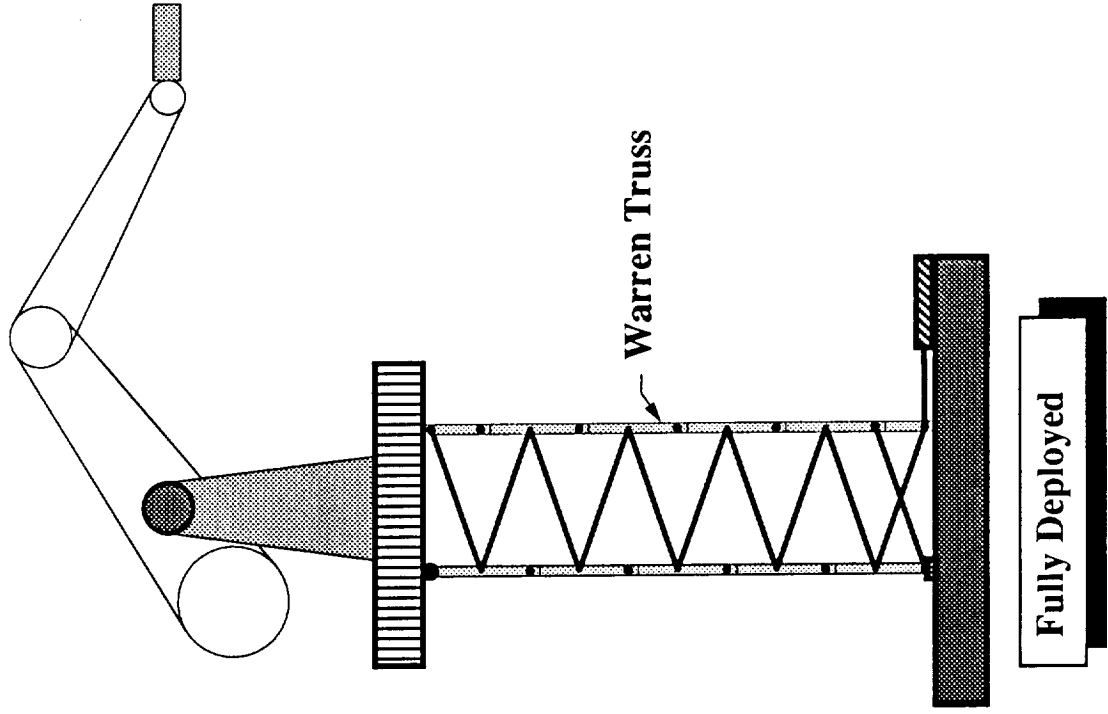


Synchronizing Bar

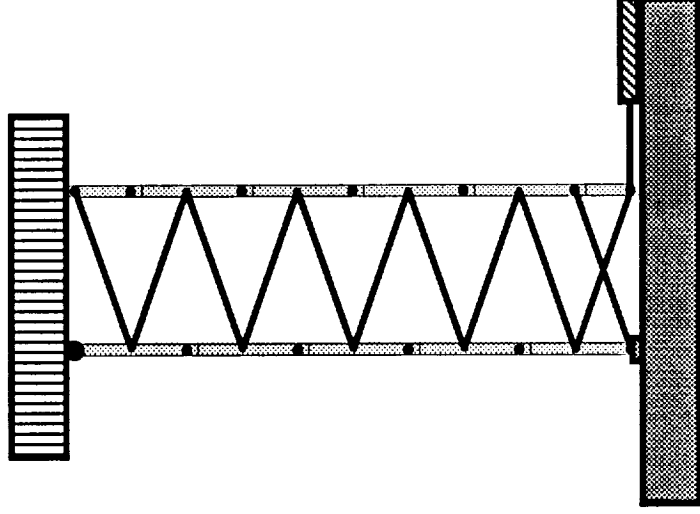
Synchronously Deployable Truss



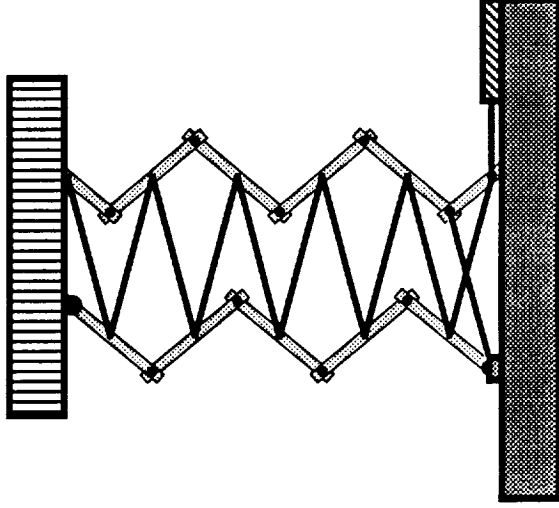
# BI-PANTOGRAPH ELEVATOR PLATFORM



# COMPARISON OF ELEVATOR PLATFORMS

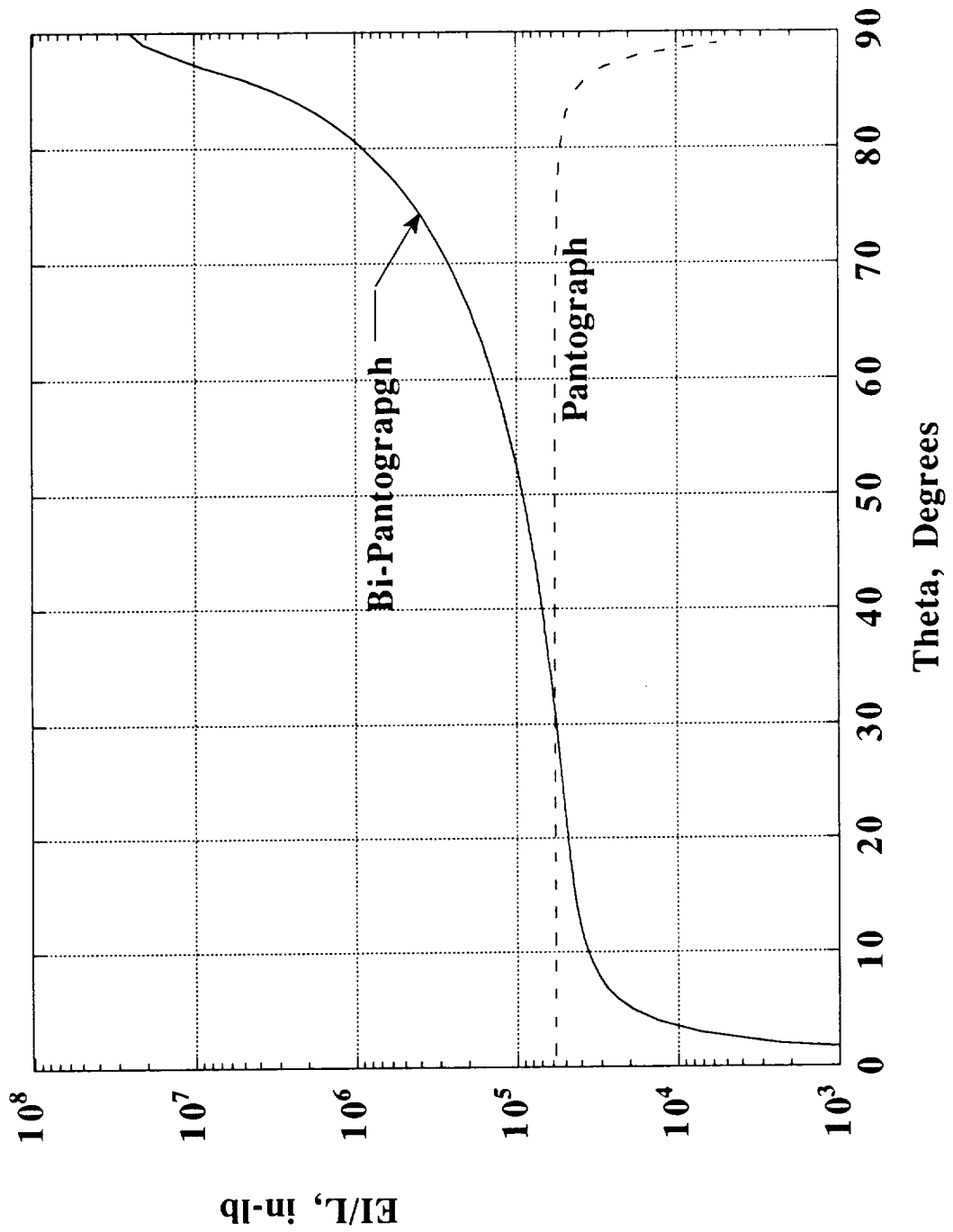


Bi-Pantograph

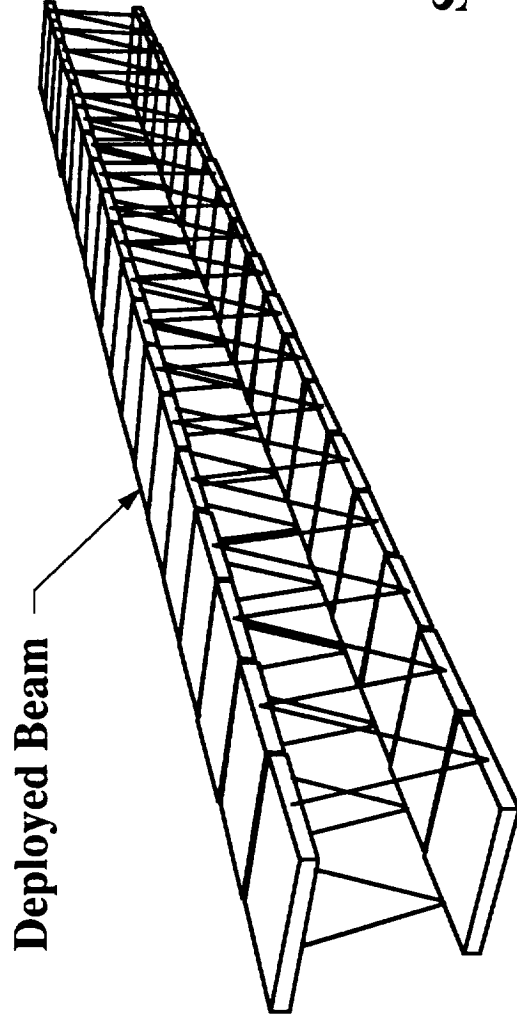


Pantograph

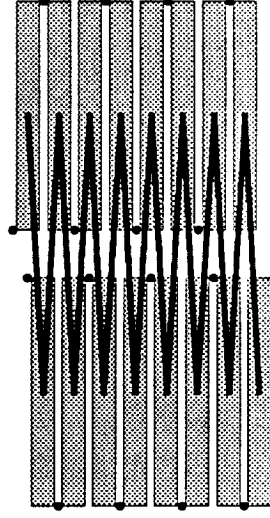
# BI-PANTOGRAPH VS PANTOGRAPH STIFFNESS



# PERSPECTIVE OF BI-PANTOGRAPH BEAM

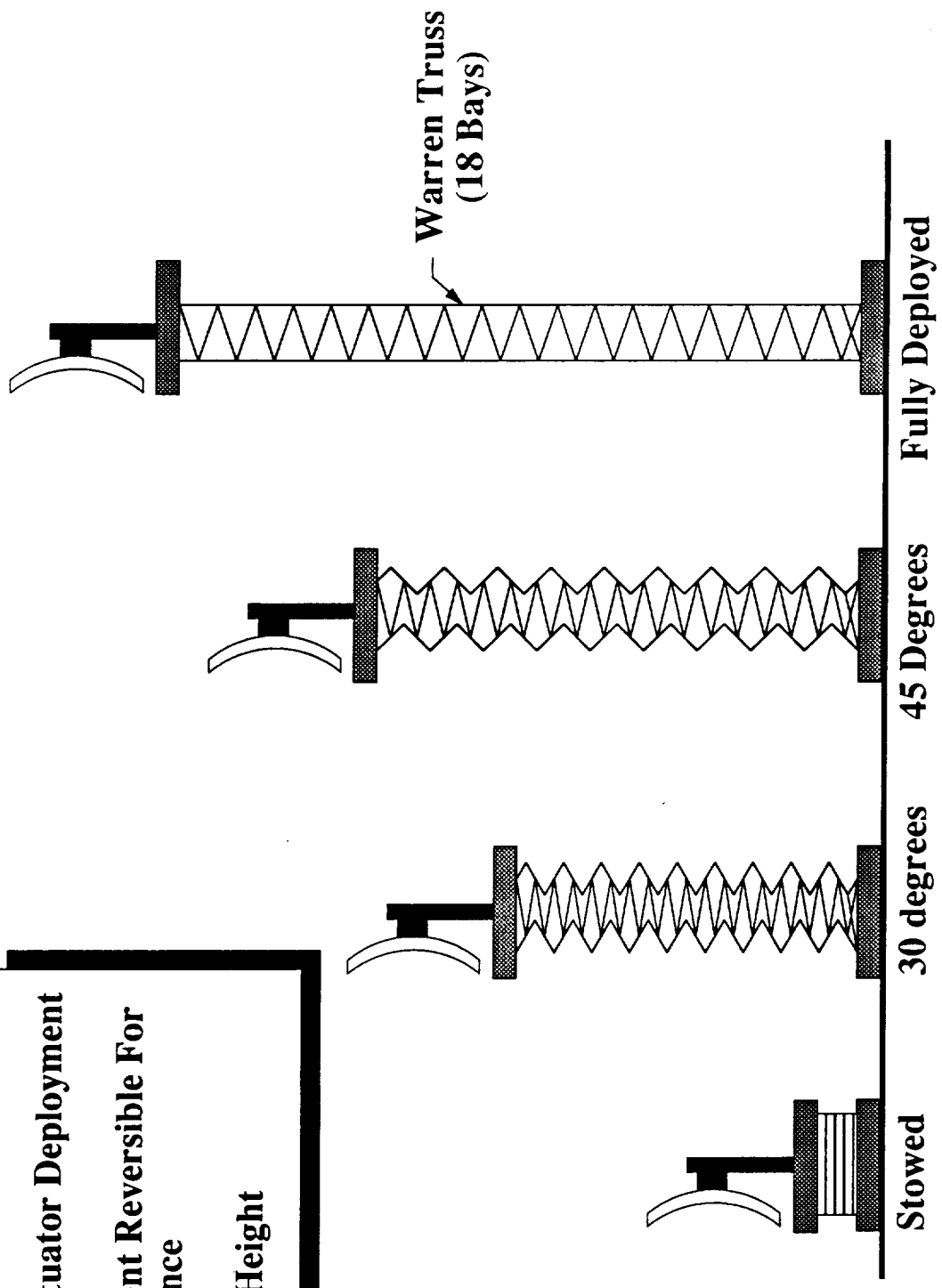


**Stowed Beam**

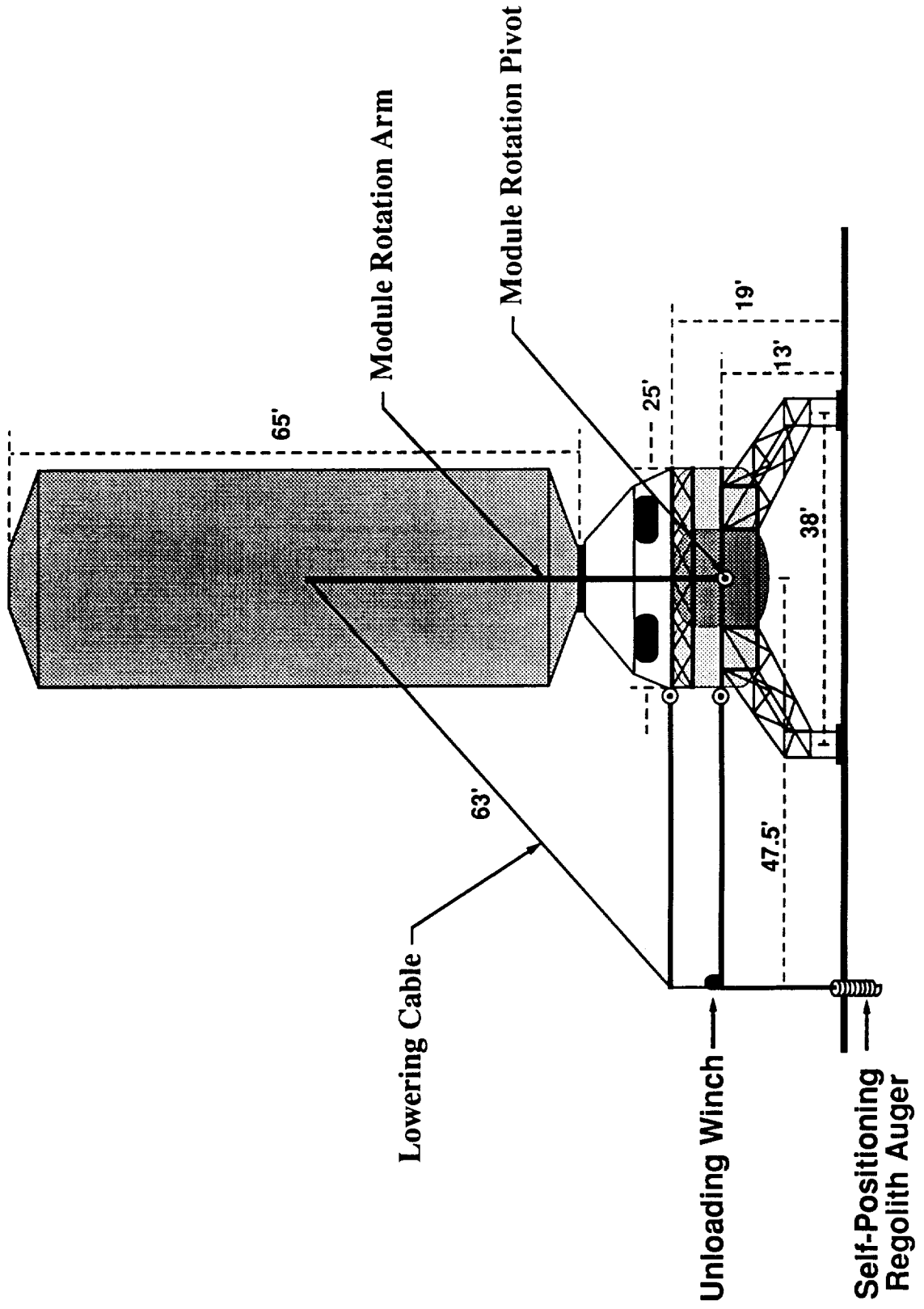


# BI-PANTOGRAPH SYNCHRONOUSLY DEPLOYABLE TOWER/BEAM

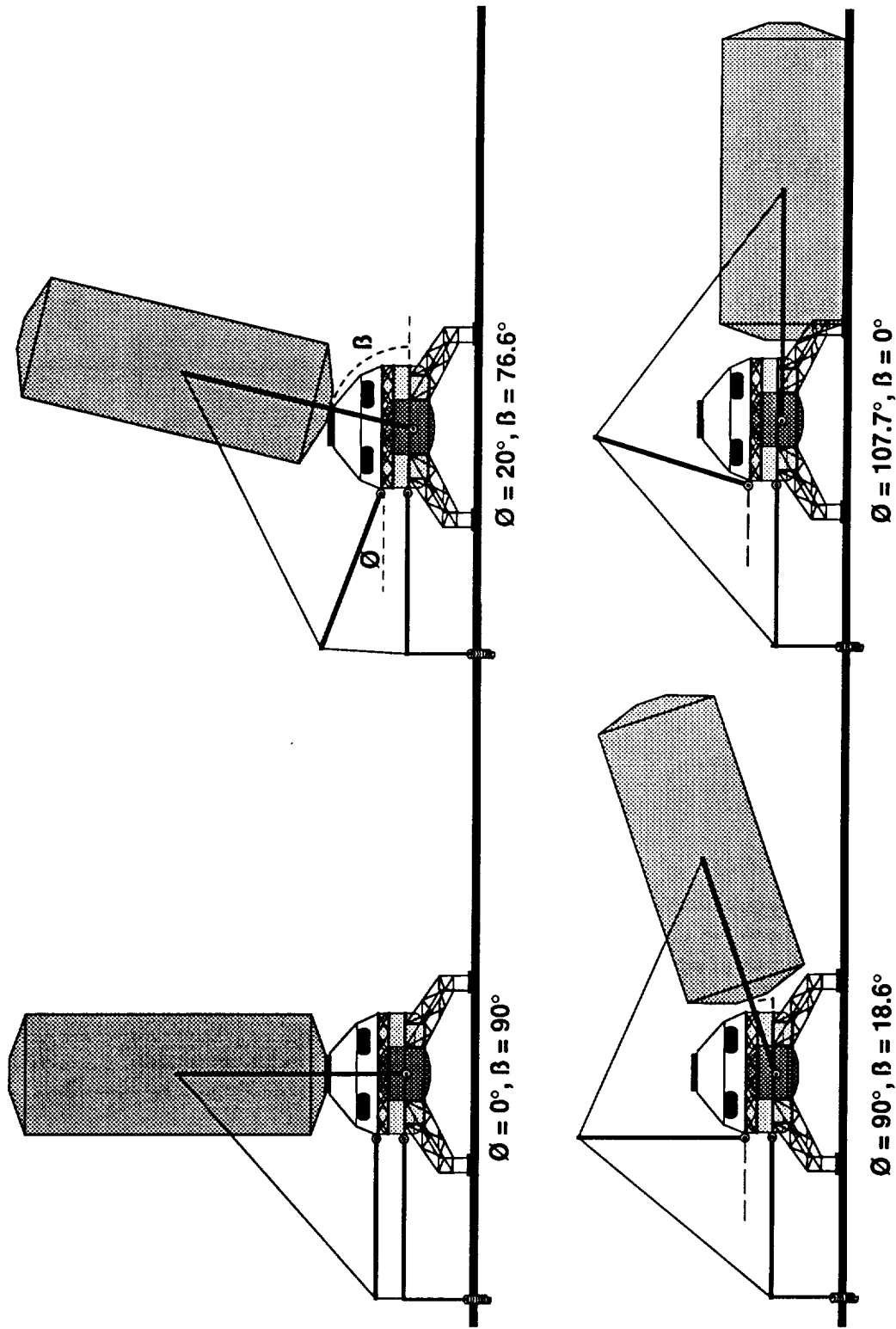
- Single Actuator Deployment
- Deployment Reversible For Maintenance
- Variable Height



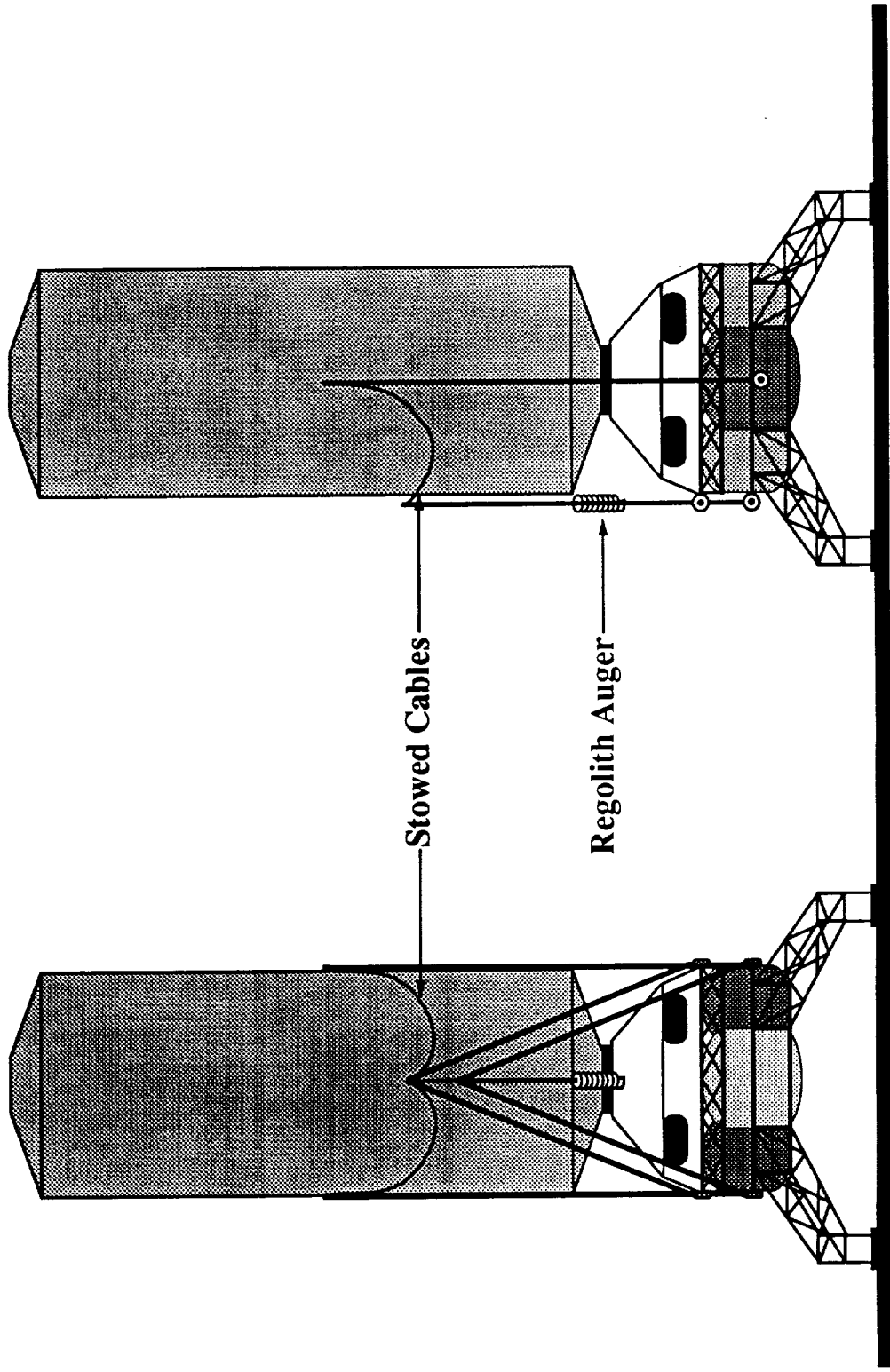
# LUNAR MODULE OFF-LOADING CONCEPT



# LUNAR MODULE OFF-LOADER CONCEPT DURING VARIOUS PHASES OF OPERATION



# MODULE OFF-LOADER CONCEPT PACKAGED (REAR & SIDE VIEWS)





# STARBURST DEPLOYABLE PRECISION REFLECTOR

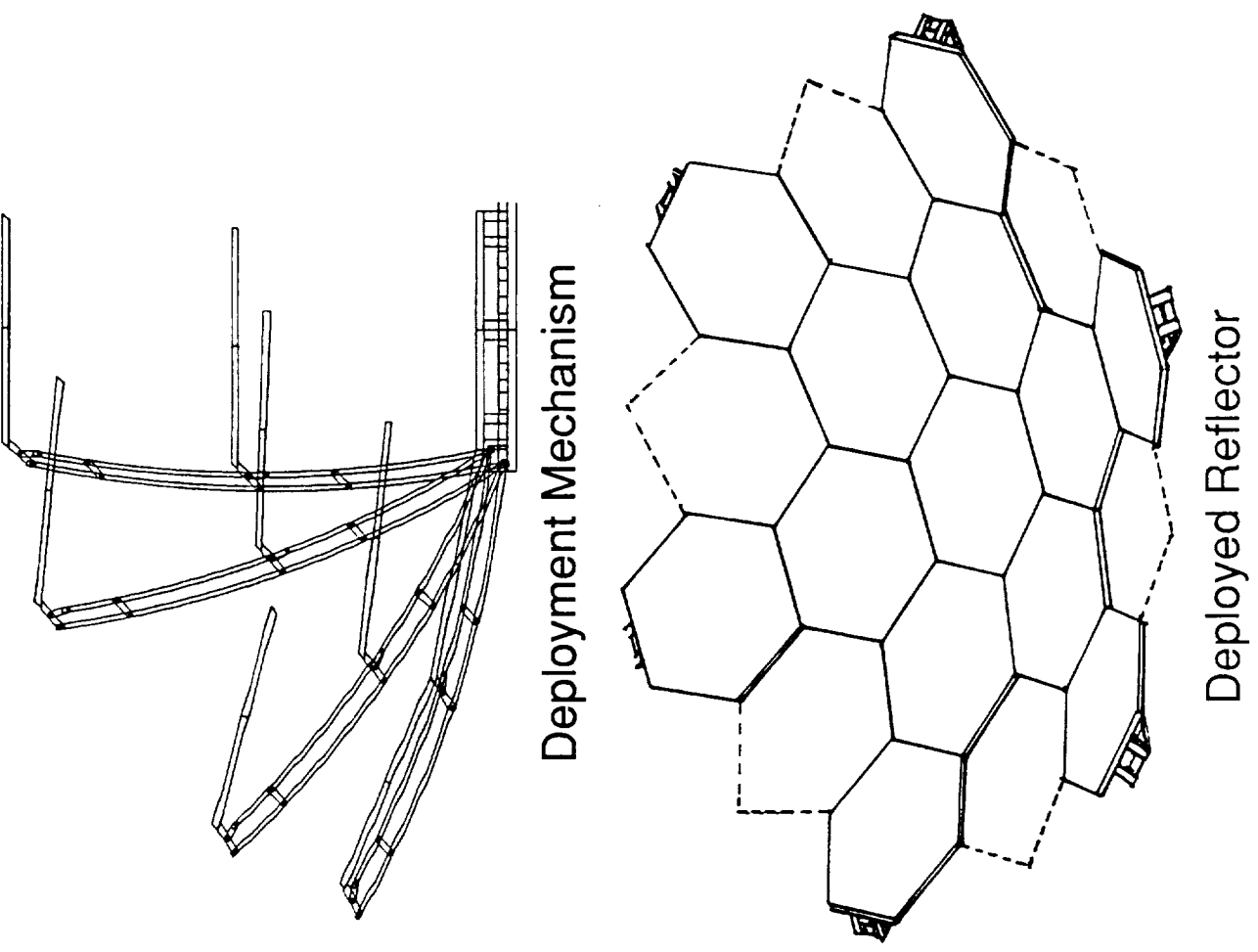
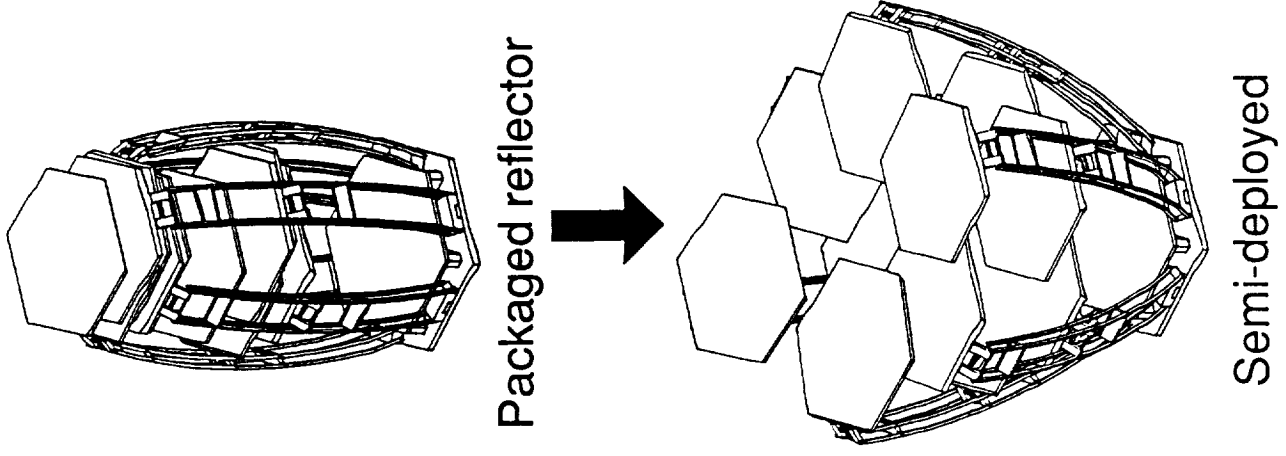
## Features

- Maximum packaging efficiency for reflector panels
- Simple one-degree-of-freedom deployment of reflector arms
- Permits integrated reflector system

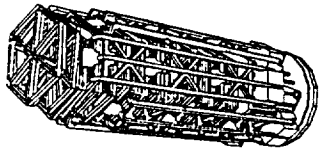
## Applications

- LDR-type telescopes
- Microwave radiometers
- Solar concentrators

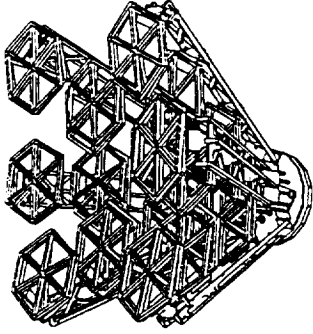
# “STAR BURST” CONCEPT HAS POTENTIAL FOR DEPLOYING 20 METER DIAMETER PRECISION DEFLECTOR



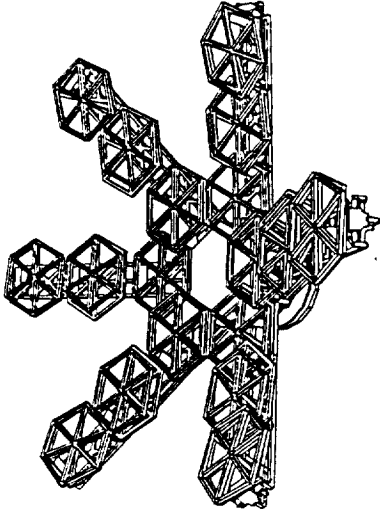
# STARBURST DEPLOYABLE PRECISION REFLECTOR



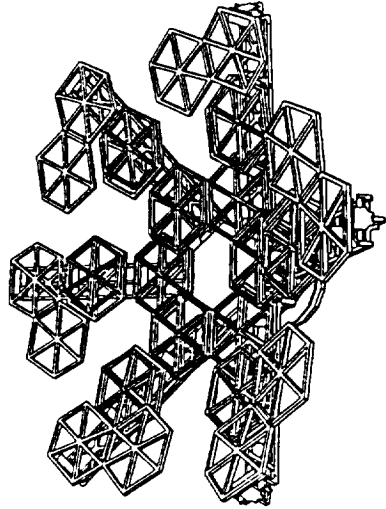
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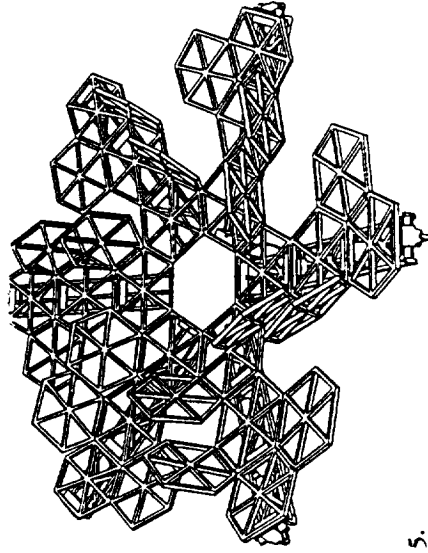
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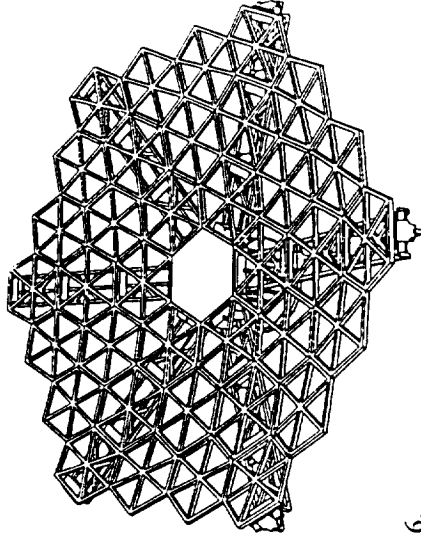
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4.



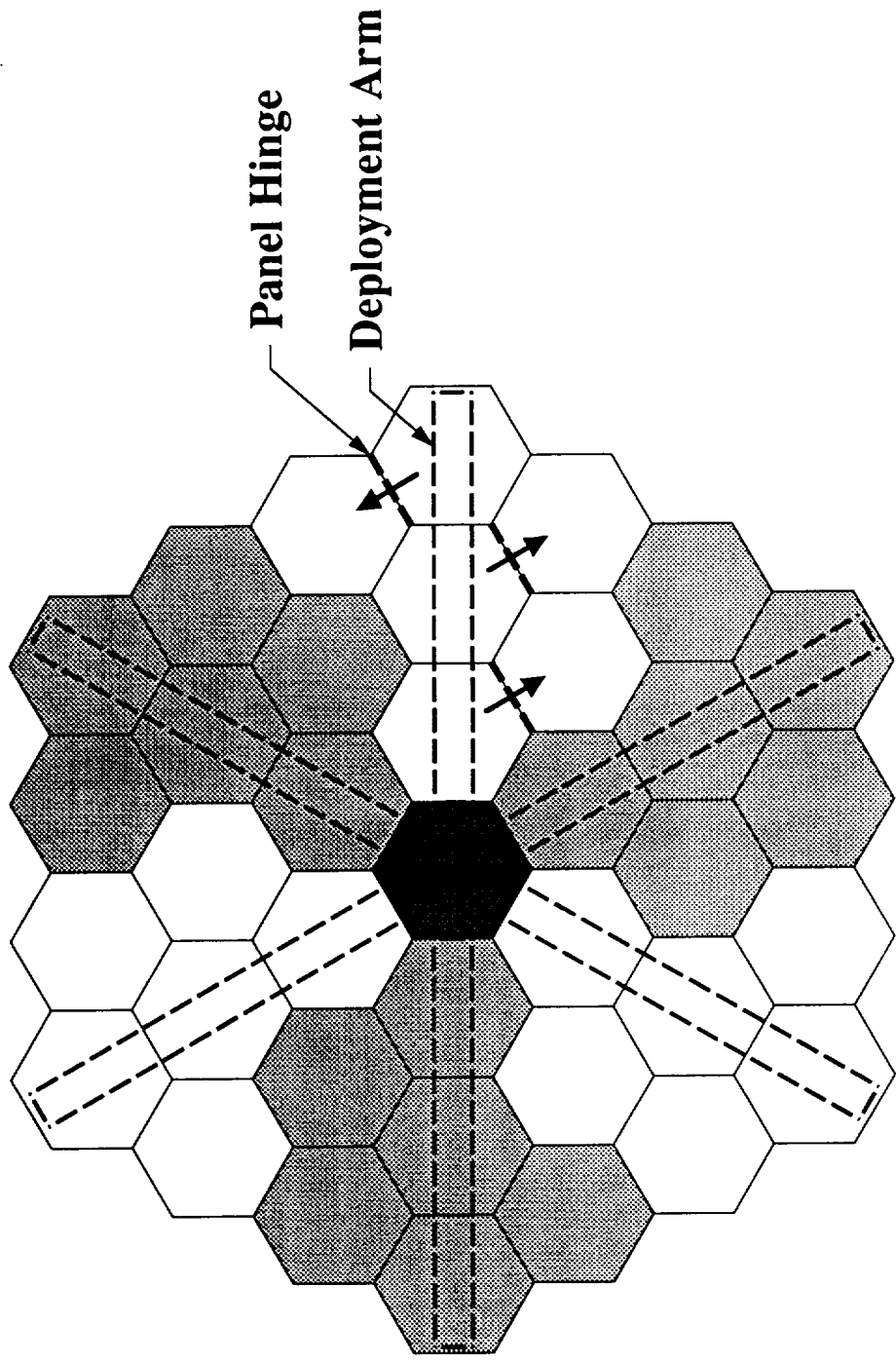
5.



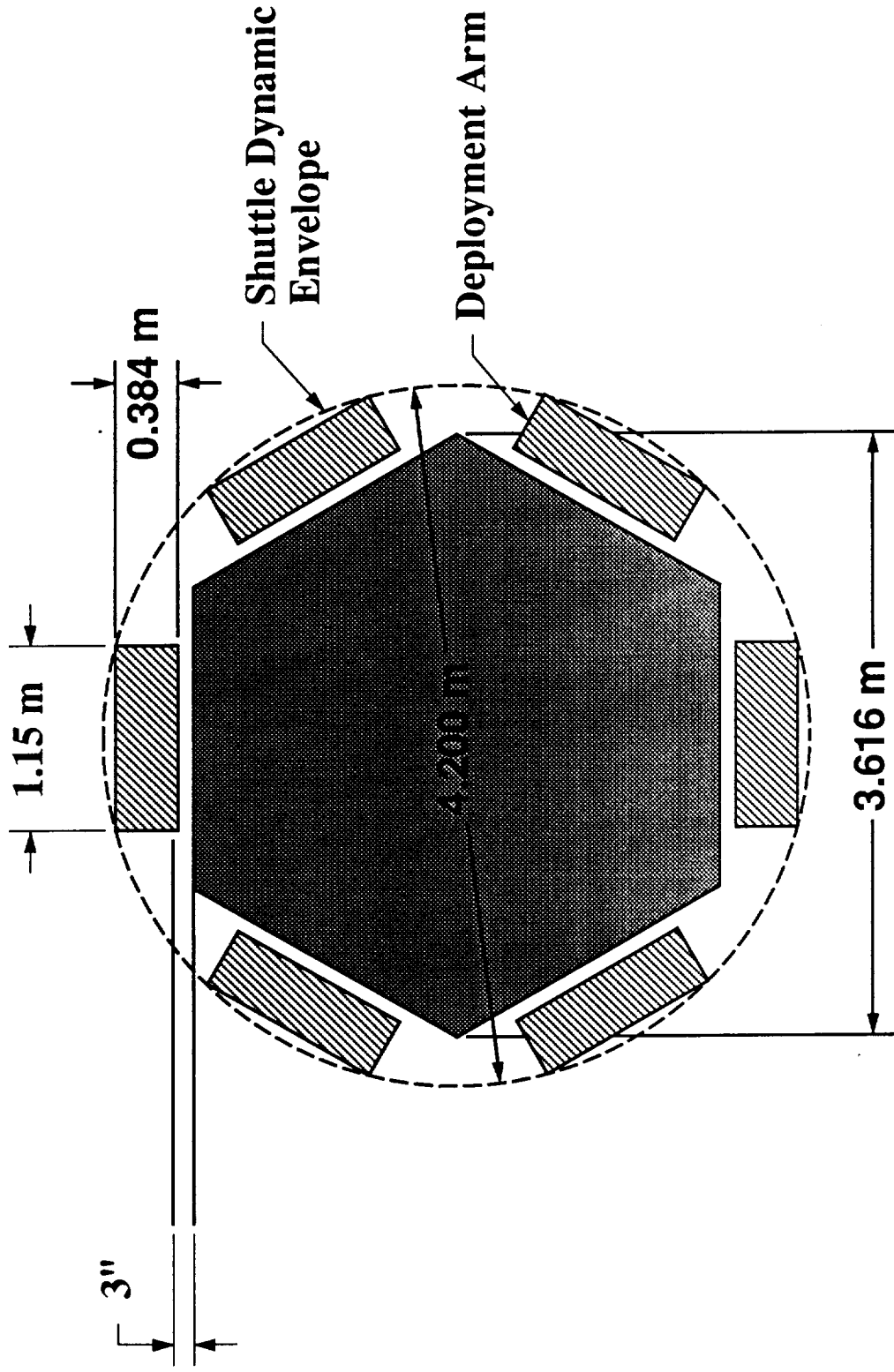
6.

# 3 RING REFLECTOR DEPLOYMENT SCHEME

- 37 Panels Total
- 6 Deployment Arms
- 6 Panels Per Deployment Arm

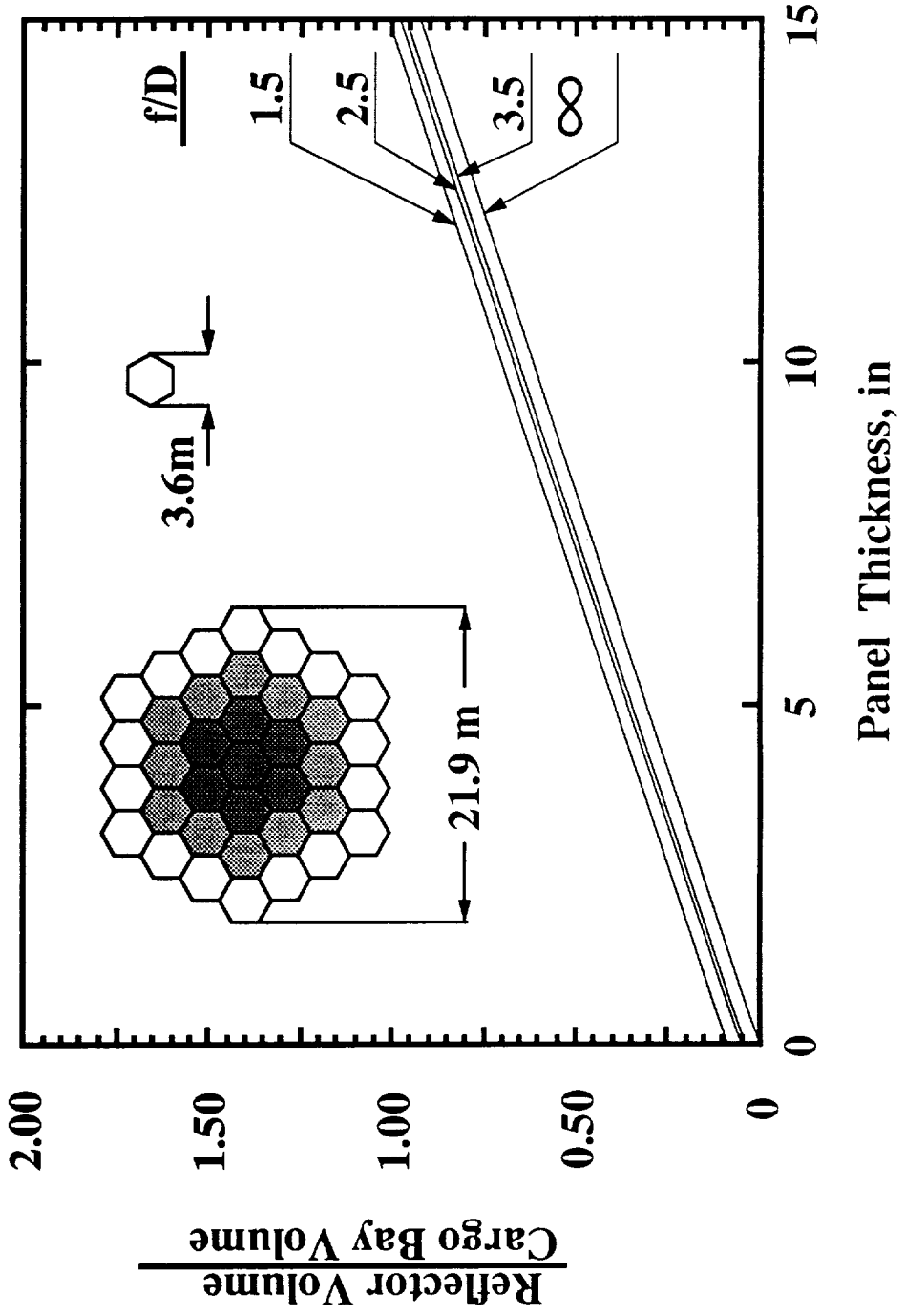


# CROSS-SECTION OF PACKAGED STARBURST REFLECTOR

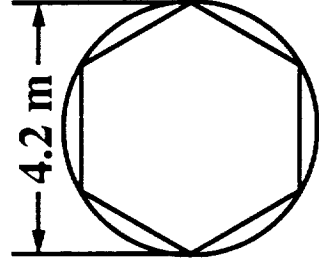


# FOCAL POINT AND THICKNESS PACKAGING CONSIDERTIONS

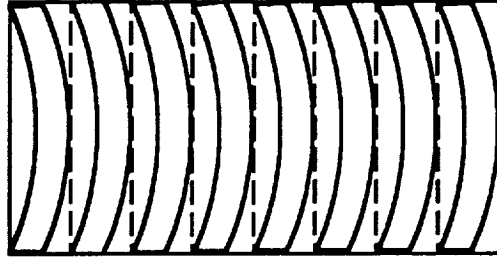
( 3 Ring, 20 m D eff )



Cargo Bay  
Representation



Top View



Side View

## **STARBURST COMMENTS**

**Low level of effort to date (Primarily a concept feasibility study)**

**Has potential for deploying 20 meter class reflectors from Shuttle-size cargo bay**

**Two basic deployment concepts**

- o Synchronized mechanism**
- o Distributed actuators**

**Further work needed**

- o Detailed packaging study for both concepts**
- o Deployment simulation for both concepts**
- o Build demonstration model**
- o Deployable support structure concept study**
- o Dynamic & accuracy active control operation simulation studies**





Center for Space Construction  
Third Annual Symposium  
November 21, 22, 1991

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