Lunar Surface Structural Concepts and Construction Studies

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# LUNAR SURFACE STRUCTURES CONSTRUCTION RESEARCH AREAS

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<th>RESEARCH AREA</th>
<th>OBJECTIVE</th>
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<td>- Multiple Cable Crane</td>
<td>Remote and/or Precision Positioning Capability For Lunar Construction</td>
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<td>- Articulating Arm Crane</td>
<td>Automatic Electrically Deployable Towers and Beam Type Structures With Minimal Deployment Equipment</td>
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<td>- Deployable Tower</td>
<td>Capability For Self Off-Loading of Modules &amp; Equipment</td>
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<td>- Lunar Module Unloading Device</td>
<td>Automatically Deployable Reflector With Minimal Deployment Equipment</td>
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<td>- Deployable Solar Concentrator</td>
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LUNAR CRANE RELATED DISCIPLINES

- Remote control and/or autonomous precision construction operations
- Multibody dynamics analysis and control of large flexible systems
- Analysis and control of cable structures
- Quantification of control actuator concepts for large flexible systems
- Design of large complex flexible systems
- 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
<table>
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<th>Candidate Crane Cable Suspension Systems</th>
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<tr>
<td><img src="image1.png" alt="Diagram 1" /></td>
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<td><img src="image2.png" alt="Diagram 2" /></td>
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<td><img src="image3.png" alt="Diagram 3" /></td>
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<td><img src="image4.png" alt="Diagram 4" /></td>
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*Stiffened by Triangulated Cables*
NIST SIX-CABLE SUSPENSION CRANE

Cable Drive System

Cable Geometry

Modified Bridge Crane Trolley
Wires
Platform
Controlled Trolley Motion
Load
NUMERICAL EXAMPLE OF NATURAL FREQUENCY

A Swinging Pendulum

A Symmetric Model

\[ F = \sqrt{\left( \frac{L_1}{L_2} \right) \left[ \frac{e}{h} + \frac{e^2}{4} \right] + \frac{e^2 + p^2}{\sqrt{h^2}} \} F_{\text{pendulum}} = \frac{1}{2\pi} \sqrt{\frac{g}{h}} \]
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

X-coordinate of point H (in)

Y-coordinate of point H (in)

Z-coordinate of point H (in)

Control Moment about X-axis (lb-in)

Control Moment about Y-axis (lb-in)

Control Moment about Z-axis (lb-in)

Time (sec)
SIMULATION RESULTS
(I)

[Diagram showing a structural framework with cables and a module, along with various graphs showing angular and angular velocity over time.]
SLEWING SIMULATION RESULTS

60 deg. Maneuver

X-Y Plot of Point H on End-Effector

Y-Coord. of H
(in)

X-Coordinate of H (in)

Angles of End-Effector (deg)

Control Moment of Boom (lb-in)

Angles of Module (deg)

Time (sec)

Time (sec)
ONE-SIXTH SCALE LUNAR CRANE TEST-BED USING G.E. ROBOT FOR GLOBAL MANIPULATION.
BASIC DEPLOYABLE TRUSS APPROACHES

Warren Truss

Sequentially Deployable Truss

Synchronizing Bar

Synchronously Deployable Truss
BI-PANTOGRAPH ELEVATOR PLATFORM

- Warren Truss
- Fully Deployed
- Partially Deployed
- Work Platform
- Translational Joint
- Screw-Jack Actuator
- Fixed Pivot
COMPARISON OF ELEVATOR PLATFORMS

Pantograph

Bi-Pantograph
BI-PANTOGRAPH VS PANTOGRAPH STIFFNESS

![Graph showing the comparison of Bi-Pantograph and Pantograph stiffness with respect to theta, degrees.]
BI-PANTOGRAPH SYNCHRONOUSLY
DEPLOYABLE TOWER/BEAM

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

Stowed  30 degrees  45 Degrees  Fully Deployed

Warren Truss (18 Bays)
LUNAR MODULE OFF-LOADING CONCEPT

Module Rotation Arm

Module Rotation Pivot

Lowering Cable

Unloading Winch

Self-Positioning Regolith Auger

65'
63'
25'
19'
47.5'
13'
38'
LUNAR MODULE OFF-LOADER CONCEPT DURING VARIOUS PHASES OF OPERATION

$\phi = 0^\circ, \beta = 90^\circ$

$\phi = 20^\circ, \beta = 76.6^\circ$

$\phi = 90^\circ, \beta = 18.6^\circ$

$\phi = 107.7^\circ, \beta = 0^\circ$
MODULE OFF-LOADER CONCEPT PACKAGED
(REAR & SIDE VIEWS)

Stowed Cables

Regolith Auger
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
3 RING REFLECTOR DEPLOYMENT SCHEME

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

Panel Hinge
Deployment Arm
CROSS-SECTION OF PACKAGED STARBURST REFLECTOR

- Shuttle Dynamic Envelope
- Deployment Arm

Dimensions:
- 1.15 m
- 0.384 m
- 3.616 m
- 4.200 m
- 3"
FOCAL POINT AND THICKNESS
PACKAGING CONSIDERTIONS

(3 Ring, 20 m D eff.)
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
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