Large Telescope Using Holographically-Corrected Membrane Mirror

NASA Institute for Advanced Concepts

Large Telescope Using a Holographically-Corrected Membrane Mirror

(LTHM)

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Objective of the LTHM Program:

To demonstrate the feasibility and address the system issues of a holographically-corrected large aperture membrane telescope in the optical wavelengths.
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Inflatable Antenna Experiment
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Membrane Mirrors

3 m diameter HAIR reflector (on-axis)

1/5th sector of the IAE reflector (off-axis)
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State of the Art Surface Precision

Inflatable Antenna Experiment (IAE)

D=50 ft (offset), F/D=1
As-built rms: 1.5 mm RMS
RMS: center 11 meters

9.8 ft IAE Sector

D=9.8 ft, F/D=1
As-built rms: 0.6 mm RMS

IRD Inflatable Reflector

D=23 ft, F/D=1/2
As-built rms: 1.2 mm RMS

LIS Inflatable Reflector

D=9.8 ft, F/D=1/2
As-built rms: 0.86 mm RMS
Holographic Correction

(a) Recording: collimated light illuminates the aberrated primary to form the object beam. The hologram is written with a reference beam incident at an angle.

(b) Reconstruction: starlight (distant object) produces a reconstructed beam, which is focused to produce an unaberrated image.
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Holographic Correction

Focal spot images: (a) Before correction (actual size). (b) After correction (magnified 450X).
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Holographic Correction

1951 USAF resolution chart before and after holographic correction.
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Simulation using a 100m diameter Holographically-Corrected Telescope

Europa as viewed by the Hubble Space Telescope

Europa as viewed by a 100 m Holographically-Corrected Telescope
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Test Facilities

L’Garde, Inc., Tustin, California
- Analysis, design, & fabrication of membrane mirror
- Membrane materials testing
- Surface profile measurement of membrane mirror

USAF Academy, Colorado Springs
- Holographic tests and correction of membrane mirror
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Membrane Mirror Configurations

Inflatable Net-Membrane
Non-inflated Net-Membrane Configuration
Non-inflated Net-less Configuration
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Membrane Mirror Configurations
Non-inflated Net-Membrane

Use conical configuration to further reduce weight
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The Net-Less Membrane Mirror
# Membrane Mirror Configurations

<table>
<thead>
<tr>
<th>Purely Inflatable</th>
<th>Net-Membrane</th>
<th>Net-Less Membrane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smoothest surface</td>
<td>Nearly flat triangular facets</td>
<td>Cusps at tab locations</td>
</tr>
<tr>
<td>Highest surface accuracy</td>
<td>Moderate surface accuracy</td>
<td>Moderate surface accuracy</td>
</tr>
<tr>
<td>Canopy obscures signal</td>
<td>No canopy needed</td>
<td>No canopy needed</td>
</tr>
<tr>
<td>Needs makeup gas</td>
<td>No makeup gas needed</td>
<td>No makeup gas needed</td>
</tr>
<tr>
<td>Simplest to manufacture</td>
<td>More labor intensive</td>
<td>Simpler than net-membrane</td>
</tr>
<tr>
<td>Packageable into the smallest volume</td>
<td>Packageable into a small volume.</td>
<td>Packaging volume is smaller than that of Net-membrane but larger than that of purely inflatable</td>
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</tbody>
</table>
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Finite Element Simulation of Net-Less Membrane Mirror

Predicted Surface Accuracy: $\varepsilon = 0.25$ mm RMS
Phase I Tasks

• Conceptual design of a compact, space-based membrane telescope that incorporates a real-time holographic correction.

• Build on the work for the NRO where we will prove the holographic correction of a 1 m diameter membrane telescope.

• Analytically characterize the net-membrane and net-less membrane concepts – sensitivity analyses.

• Investigate the production of holograms in real-time and at several wavelengths \textit{in-situ}; e.g. use of photopolymers.

• Compare performance relative to each other: \textit{inflatable} v.s. \textit{net-membrane} v.s. \textit{net-less membrane} configuration.

• Identify and address the system issues.

• Chart a roadmap to an orbiting 10 m diameter imaging telescope using holographically-corrected membrane mirrors.
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System Issues

• Real-Time Holographic Correction
• Bandwidth
• Wideband holographic correction
• Holographic materials
  ➢ photopolymers
  ➢ FBAG
  ➢ OASLM
• Laser beacon source – “fixed” versus trailing
• Single hologram recorded at multiple wavelengths
• CTE and creep of membrane material – PBO has extremely low CTE.
• Space environment resistance
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Phase II Plans

• Build a 1m diameter membrane telescope with holographic correction in-situ.

• Carry out a full static and dynamic analysis of the concept selected for a 10 m diameter.

• Continue to investigate Real-Time holographic materials – suitability of photopolymers as a holographic medium in a space environment.

• Investigate the possibility of using a distant laser source in space – “trailing” or fixed at the ISS for example.

• Feasibility of a simple, secondary adaptive optics system.

• Modularizing and shielding of the telescope for optimum performance.