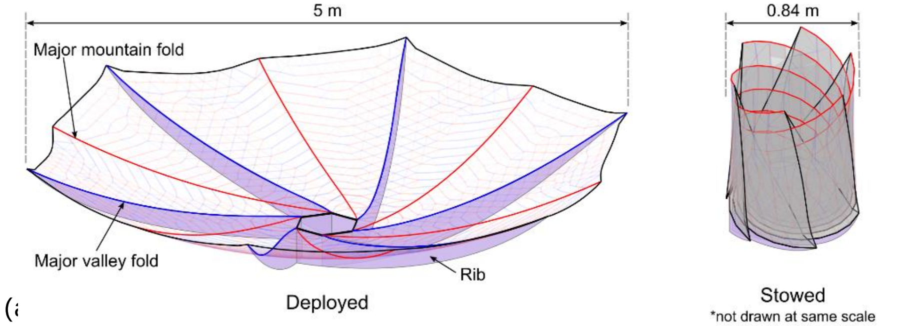
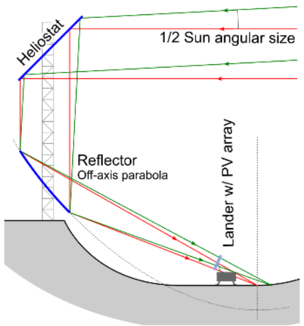
"Lightweight Deployable Solar Reflectors", Manan Arya, Stanford U.





(a) Stowage scheme for paraboloidal reflector segment with a representative deployed diameter.

(b) Potential "periscope" architecture for a power delivery system. The heliostat tracks the sun and the off-axis paraboloidal reflector projects sunlight to a lander. A reflector with 30 m dia. (composed of 5 m dia. segments) could deliver 500 W (electric) power to a lander 10 km away with a 4 m dia. photovoltaic (PV) array.

Research Objectives

- The proposed work will advance lightweight, highly compactible, stiff, low-cost-of-production modular solar reflectors to enable power delivery to small systems in permanently shadowed regions (PSRs) on the Moon
- Key innovation: rational, mechanics-based algorithmic design of fold patterns on doubly curved surfaces that allows for compact and reversible stowage of paraboloidal shell structures without cuts or slits

Comparison to State-of-Art:

- Higher stiffness and predictable deployment compared to membrane reflectors with inflatable supports
- Compared to flat reflectors, parabolic reflectors generate 50% to 100% higher solar flux at the target for relevant scales
- Compared to parabolic reflectors consisting of hinged rigid panels, the proposed ultrathin composite construction has reduced mass and simpler assembly using surface-replication molding techniques
- Cuts and slits can be used for packaging, but at the cost of discontinuities in the reflective surface, which degrade stiffness and optical performance

TRL Assessment

- The reflector starts at TRL 2 with the concept and application identified
- At the end, the reflector concept will be at TRL 3, with documented experimental and analytical predictions of key performance parameters

Approach

Year 1:

- System-level trade studies to prescribe optimal architectures for various mission concepts. Set reflector performance requirements. Consider two categories of architectures: (1) large apertures with many co-pointed segments, and (2) spatially distributed independent reflectors. Use numerical ray tracing to analyze optical performance.
- Develop origami design algorithms for folding off-axis paraboloids. Validate algorithm using high-fidelity structural finite element analysis (FEA) of reflector stowage. Develop shape actuation concepts.
- Optimize existing designs of towers for particular loading cases.

Year 2:

- Fabricate 0.5 m-diameter reflector prototype using carbon composites to demonstrate stowage. Measure surface shape accuracy after repeated deployments and long-term stowage.
- Demonstrate shape actuation.

Year 3:

- Calibrate FEA using the results from the testing campaign. Use calibrated models to predict in-space performance of full-scale reflectors.
- Analyze system-level performance in detail for a particular mission concept using high-resolution digital elevation maps and solar illumination models.

Potential Impact

- Reflectors are common critical components in several envisioned system architectures for power delivery in PSRs; the proposed work enables these architectures
- For a particular architecture, 100 W to 1 kW (electric) power could be delivered from a sunlit reflector to an asset with a PV array kilometers away
- Novel origami fold-pattern design algorithms will be developed, based on strain energy minimization, which guides the placement of folds on doubly curved surfaces to provide stowage with minimal in-plane stretching and bending strains. Indeed, such algorithms allow for strict limits on strains when folded, such that the material remains entirely in the elastic regime. This provides elastic stowage and recovery of as-built shape.
- The thin-shell construction realizes significant mass savings, allowing for large reflectors to be fielded
- Such paraboloidal solar reflectors could also be used for concentrated photovoltaics for deep space missions, for solar thermal propulsion, and for thermal mining
- If sufficient shape recovery can be realized, such paraboloidal solar reflectors would be useful for radio remote-sensing instruments