



The Light Bender Concept for Power Distribution on a Lunar Base

Bradford Robertson, Matthew Rines: Georgia Institute of Technology
Charles Taylor, Aboubakar Traore, James Burgess, and Travis Turner: NASA
Timothy Roach: Science and Technology Corporation

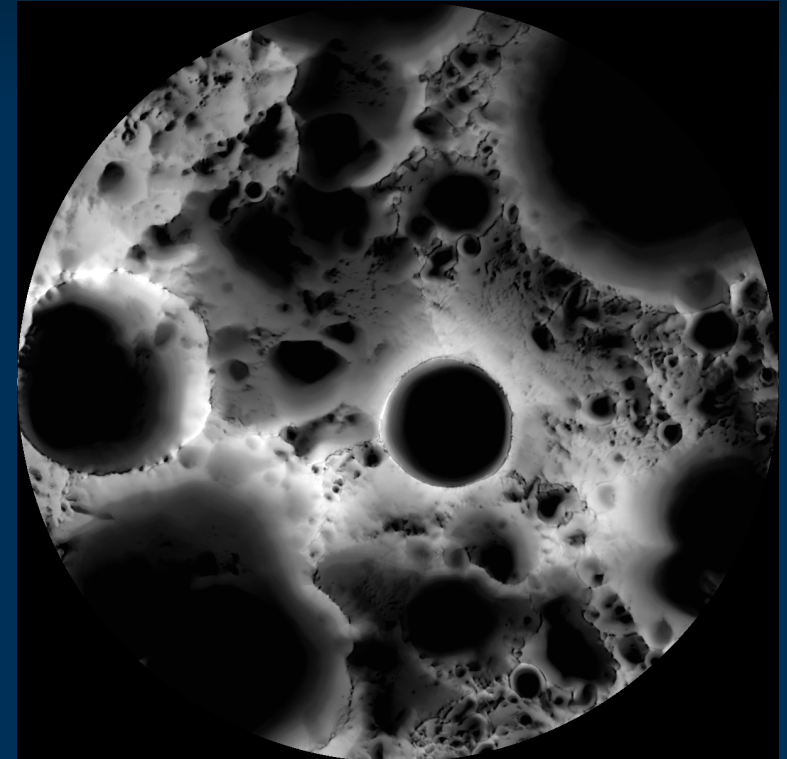
**This material is a work of the U.S. Government
and is not subject to copyright protection in the
United States.**

**Presented by: Bradford Robertson,
Georgia Institute of Technology**

EDS



- Craters on the lunar south pole are in **complete darkness**, but contain **strategic resources**
- Power still needs to be delivered to equipment in the crater
- Power collection and distribution
 - Photovoltaic power generation
 - Collect and generate electricity at the crater rim
 - Utilize Vertical Solar Array Technology (VSAT)
 - Distribution
 - Power cables
 - Deploy cables from VSAT to various consumer nodes in the crater
 - Laser beaming
 - Convert electricity to optical beam and deliver to consumer nodes in the crater



Illumination map of lunar south pole [1]

Challenges

- Power cables would have to be deployed on steep crater walls
- Cables would be stationary once deployed
- Laser beaming has low efficiency due to extra energy conversion
 - solar → electricity → optical → electricity



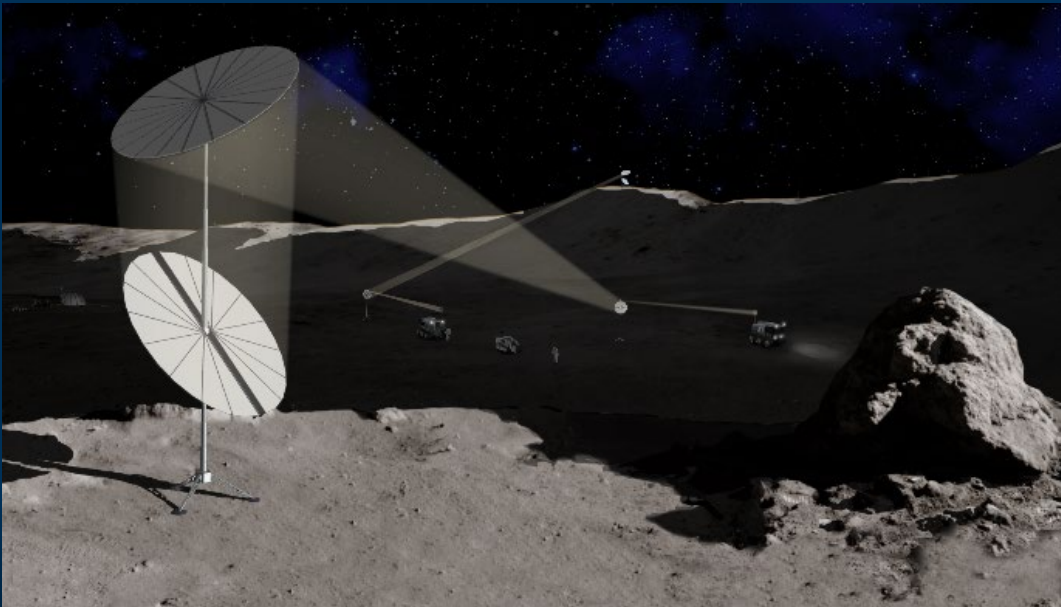
A New Power Distribution Concept

3

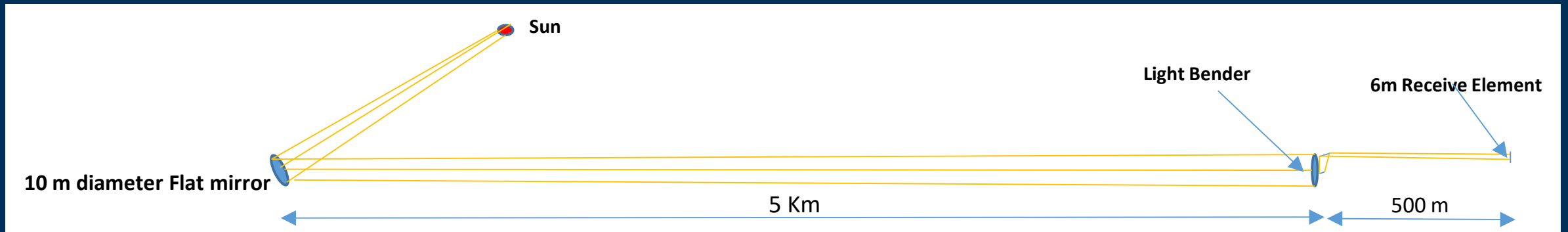
- Light Bender is a new power distribution Concept for the lunar surface that focuses on conversion of sunlight to energy at the point of use rather than the point of collection
 - A collection of flat mirrors for light redirection and parabolic mirrors and lens' for focusing and final distribution
 - System will land, deploy, and function autonomously or via remote control
 - Allows for dynamic power distribution architecture
- The present lunar architecture assumes that we will draw cables from energy producers to energy consumers
 - Cables are inherently heavy, cumbersome, and require additional support equipment
 - Once laid down cables represent a static system that is difficult to reconfigure
 - At times cables may not even be possible, e.g. deep craters
- Alternative architectures are based on RF/Laser Power Beaming
 - There are both reliability and mass penalties for pursuing this path

The goal is a Light Bender system that combines wireless power distribution with autonomous deployment for point-to-point applications of under 5km

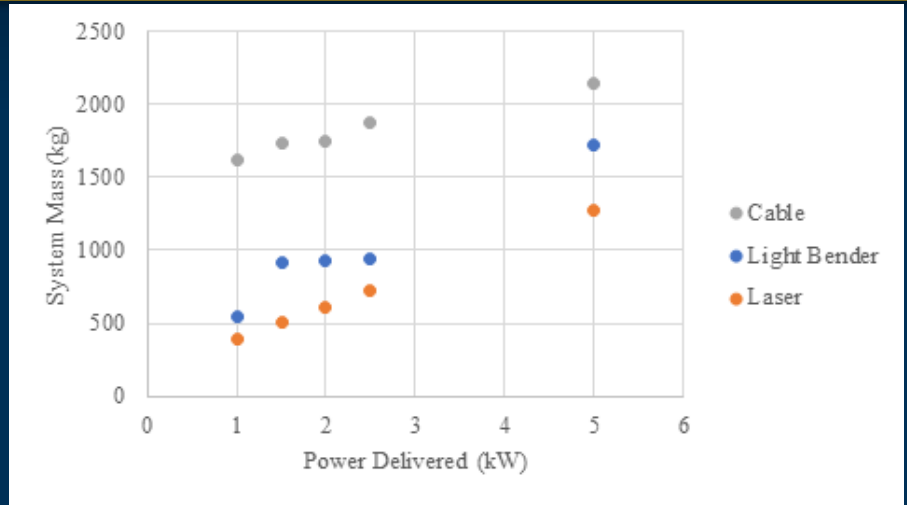
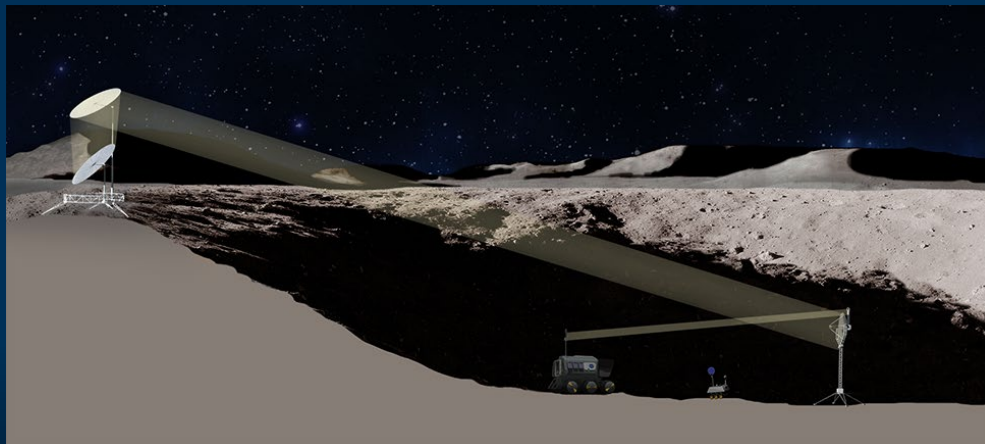
- Tandem Reflector Mirrors (TRM)
 - Heliostat on a 10 meter mast to collect and redirect sunlight into shaded crater
 - Tandem design enables tracking of sun while redirecting to a single location
 - Multiple TRMs can redirect light to the same target to increase power output
- Cassegrain Fresnel Distribution Optics (CFDO)
 - Cassegrain primary mirror collects light beamed from the TRM
 - Periscope assembly with an embedded Fresnel lens which focuses and redirects light to end user



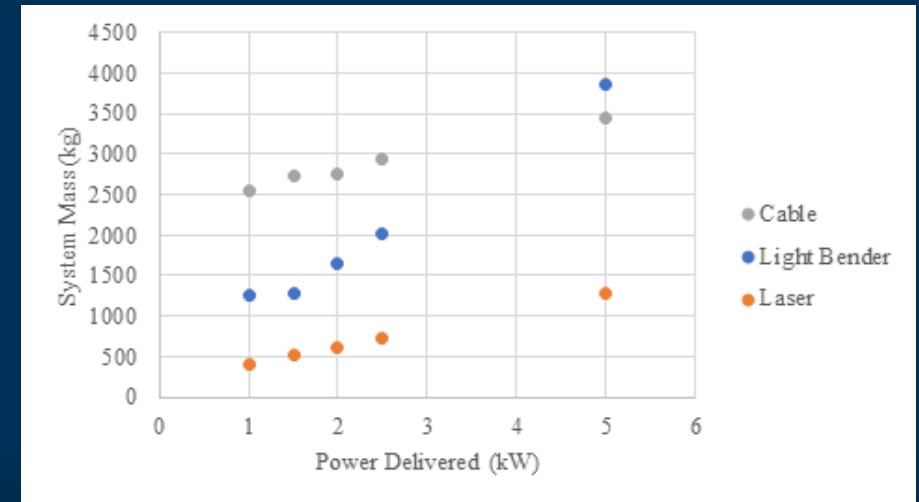
- TRM systems would be autonomously deployed on the rim of the crater
 - Multiple TRMs would redirect light at a CFDO in the permanently shaded region of a crater
- The CFDO acts as the “last mile” distribution by redirecting light to consumer nodes
 - Can split time between multiple consumers allowing batteries to charge
- Multiple TRM clusters can be placed along crater rim to limit probability of shading from all locations simultaneously



- Trade studies were conducted to determine how the overall mass of the Light Bender compared to DC power cables or laser power beaming
- Light bender is more massive than laser power beaming, but still comparable in mass per kW delivered at 3.5 to 5 km
- Further trades need to be done to further quantify the benefit of autonomous deployment

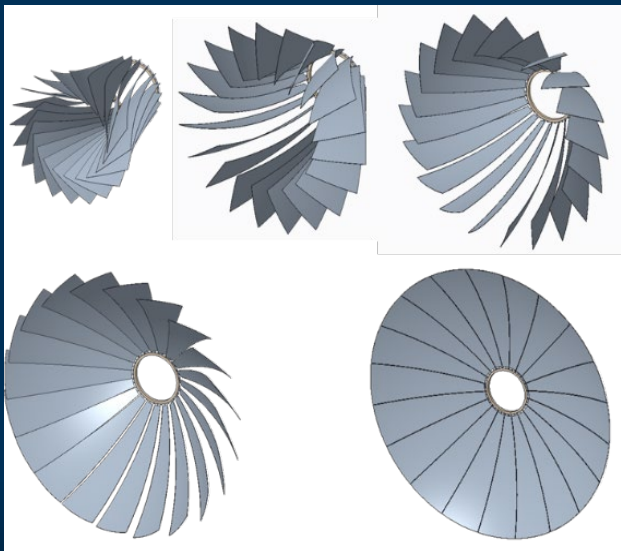


Scenario 1: 3.5 km, 0° elevation

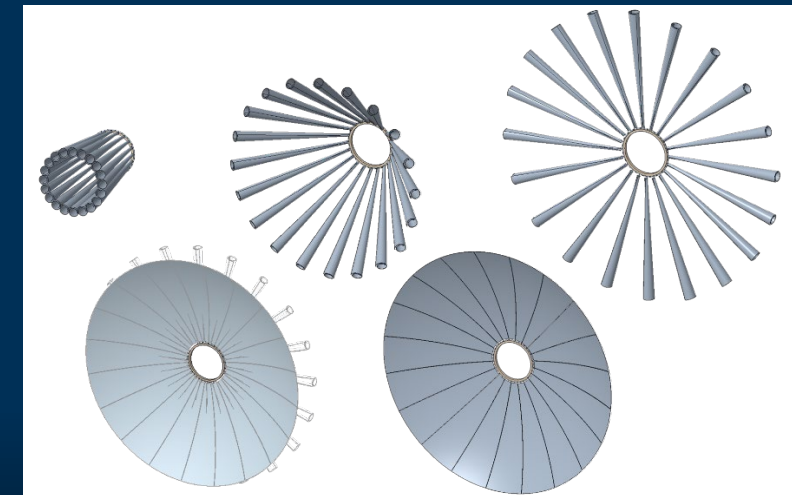
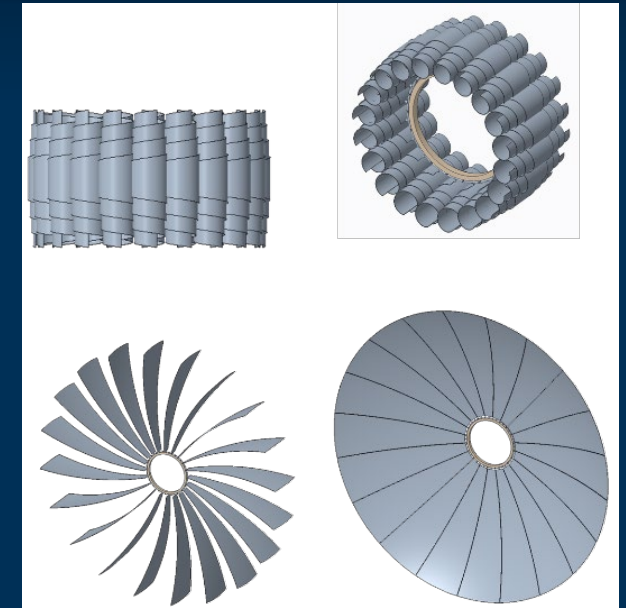


Scenario 2: 5.5 km, 0° elevation

- Key challenge: packaging of large optical systems
 - Need to minimize volume to fit on a small cargo lander
- Ribbed mirror deployment mechanism
 - Optical efficiency inversely proportional to the number of ribs
 - Need to maximize ribs in order to maintain optical efficiency
 - 20 section mirror– requires complex biaxial deployment sequence



- Shape Metal Alloys (SMA) as a potential alternative to a purely mechanical deployment scheme
 - SMA exhibit a phase transformation in response to changes in temperature and applied stress
- Mirror would be broken into 20 sections and set to deployed into its final parabolic shape
 - Mirror sections are reheated to their transition temperature and unroll to their parabolic shape
 - Enable lower mass and stowed volume
- Currently investigating this option as part of NIAC Phase I work to reduce technological uncertainties
 - Benchtop coupon testing is being performed on small parabolic shaped sections





Conclusion

9

- The Light Bender is a promising concept for distributing power into the permanently shaded region of a lunar crater
- Systems analysis shows that Light Bender is competitive with other power distribution concepts for the power levels and distances under consideration for initial lunar exploration
- Light bender optical systems can be autonomously deployed by small cargo landers
 - Utilizing shape memory alloys to enable efficient packaging while maintaining optical efficiency
- Technology maturation studies currently ongoing as part of the NASA Innovative Advanced Concepts Phase I award