



NASA SBIR 2020 Phase I Solicitation

H5.01 Lunar Surface Solar Array Structures

Lead Center: LaRC

Participating Center(s): GRC

Technology Area: TA12 Materials, Structures, Mechanical Systems and Manufacturing

Scope Description

NASA intends to land near the lunar south pole (between 85-90 S latitude) by 2024 in Phase 1 of the Artemis Program, and then to establish a sustainable long-term presence by 2028 in Phase 2. At exactly the lunar south pole (90 S), the Sun elevation angle varies between -1.5 deg and 1.5 deg during the year. At 85 S latitude, the elevation angle variation increases to between -6.5 deg and 6.5 deg. These persistently shallow sun grazing angles result in the interior of many polar craters never receiving sunlight while some nearby elevated ridges and plateaus receive sunlight up to 100% of the time in the summer and up to about 70% of the time in the winter. For this reason, these elevated sites are promising locations for human exploration and settlement because they avoid the excessively cold 14-day nights found elsewhere on the Moon while providing nearly continuous sunlight for site illumination, moderate temperatures, and solar power [Refs. 1-2].

This subtopic seeks structural and mechanical innovations for 10+ kW lightweight solar arrays near the south pole for powering landers, In-Situ Resource Utilization (ISRU) equipment, lunar bases, and rovers, and that can deploy and retract at least 5 times. Retraction will allow solar array hardware to be relocated, repurposed, or refurbished and possibly also to minimize nearby rocket plume loads and dust accumulation. Also, innovations to raise the bottom of the solar array by up to 10 m to reduce shadowing from local terrain are of interest [Ref. 3]. Suitable innovations and variations of existing array concepts [e.g., Ref. 4] are of special interest.

Design guidelines for these deployable/retractable solar arrays are:

- Deployed area: 35 m² (10 kW) initially; up to 140 m² (40 kW) eventually per unit.
- Single-axis sun tracking about the vertical axis.
- Adjustable leveling to within 10 deg of vertical.
- Retractable for relocating, repurposing, or refurbishing.
- Number of deploy/retract cycles in service: >5; stretch goal >10.
- Optional 10 m height extension boom to reduce shadowing from local terrain.
- Lunar dust, radiation, and temperature resistant mechanical and electrical components.
- Factor of safety of 1.5 on all components.
- Specific mass: >150 W/kg at 35 m²; >100 W/kg at 140 m².
- Specific packing volume: >60 kW/m³ at 35 m²; >40 kW/m³ at 140 m².
- Lifetime: >15 years.

Suggested areas of innovation include:

- Novel packaging, deployment, retraction, and modularity concepts.
- Lightweight, compact components including booms, ribs, substrates, and mechanisms.
- Novel actuators for telescoping solar arrays with tubular segments of ~4 m length and ~0.2 m diameter such as gear/rack, piezoelectric, ratcheting, or rubber-wheel drive devices.
- Mechanisms with exceptionally high resistance to lunar dust.
- Load-limiting devices to avoid damage during deployment, retraction, and solar tracking.
- Optimized use of advanced lightweight materials (but not materials development).
- Validated modeling, analysis, and simulation techniques.
- High-fidelity, functioning laboratory models and test methods.
- Scaled flight hardware for demonstration on small or mid-size landers.
- Modular and adaptable solar array concepts for multiple lunar surface use cases.
- Completely new concepts; e.g., thinned π -rigid panel π ; or 3D printed solar arrays, non-rotating telescoping chimney π ; arrays, or lightweight reflectors to redirect sunlight onto solar arrays or into dark craters.

Proposals should emphasize structural and mechanical innovations, not photovoltaics, electrical, or energy storage innovations, although a complete solar array systems analysis is encouraged. If solar concentrators are proposed, strong arguments must be developed to justify why this approach is better from technical, cost, and risk points of view over unconcentrated planar solar arrays.

In Phase I, contractors should prove the feasibility of proposed innovations using suitable analyses and tests. In Phase II, significant hardware or software capabilities that can be tested at NASA should be developed to advance their Technology Readiness Level (TRL). TRL at the end of Phase II of 4 or higher is desired.

NASA has plans to purchase services for delivery of payloads to the Moon through the Commercial Lunar Payload Services (CLPS) contract. Under this subtopic, proposals may include efforts to develop payloads for flight demonstration of relevant technologies in the lunar environment. The CLPS payload accommodations will vary depending on the particular service provider and mission characteristics. Additional information on the CLPS program and providers can be found at this link: <https://www.nasa.gov/content/commercial-lunar-payload-services>. CLPS missions will typically carry multiple payloads for multiple customers. Smaller, simpler, and more self-sufficient payloads are more easily accommodated and would be more likely to be considered for a NASA-sponsored flight opportunity. Commercial payload delivery services may begin as early as 2020 and flight opportunities are expected to continue well into the future. In future years it is expected that larger and more complex payloads will be accommodated. Selection for award under this solicitation will not guarantee selection for a lunar flight opportunity.

References

1. Burke, J., π ;Merits of a Lunar Pole Base Location, π ; in Lunar Bases and Space Activities of the 21st Century, Mendell, W. (editor), 1985, https://www.lpi.usra.edu/publications/books/lunar_bases/
2. Fincannon, J., π ;Characterization of Lunar Polar Illumination from a Power System Perspective, π ; NASA TM-2008-215186, May 2008, <https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20080045536.pdf>.
3. Mazarico, E. et al., π ;Illumination Conditions of the Lunar Polar Regions Using LOLA Topography, π ; Icarus, February 2011, <https://doi.org/10.1016/j.icarus.2010.10.030>.
4. McEachen, M. et al., π ;Compact Telescoping Array: Advancement from Concept to Reality, π ; AIAA Paper 2018-1945, January 2018, <https://doi.org/10.2514/6.2018-1945>.

Expected TRL or TRL range at completion of the project: 4 to 5

Desired Deliverables of Phase II

Prototype, Analysis, Hardware, Software, Research

Desired Deliverables Description

In Phase I, contractors should prove the feasibility of proposed innovations using suitable analyses and tests. In Phase II, significant hardware or software capabilities that can be tested at NASA should be developed to advance their Technology Readiness Level (TRL). TRLs at the end of Phase II of 4 or higher are desired.

State of the Art and Critical Gaps

Deployable solar arrays power almost all spacecraft, but they primarily consist of hinged, rigid panels. This traditional design is too heavy and packages too inefficiently for larger sizes of arrays above about 20 kW. Furthermore, there is usually no reason to retract the arrays in space, so self-retractable solar array concepts are unavailable except for rare exceptions such as the special-purpose International Space Station (ISS) solar array wings. In recent years, several lightweight solar array concepts have been developed but none of them have motorized retraction capability either. The critical technology gap filled by this subtopic is a lightweight, vertically deployed, retractable 10+ kW solar arrays for the surface power for ISRU, lunar bases, dedicated power landers and rovers.

Relevance / Science Traceability

Robust, lightweight, redeployable solar arrays for lunar surface applications are a topic of great current interest to NASA on its path back to the moon. New this year, the subtopic extends the focus area from landers to other powered elements of the lunar surface architecture along with refined design guidelines. There are likely several infusion paths into ongoing and future lunar surface programs, both within NASA and also with commercial entities currently exploring options for a variety of lunar surface missions. Given the focus on the lunar South Pole, NASA will need vertically deployed and retractable solar arrays that generate 10-40 kW of power. 10 kW class solar array structures are also applicable for Science Mission Directorate (SMD) ConOps on the Moon to charge a Mars Science Laboratory (MSL)-class rover.