NASA SBIR 2021 Phase I Solicitation

H5.01 Lunar Surface Solar Array Structures

Lead Center: LaRC

Participating Center(s): GRC

Scope Title:

Lunar Surface Solar Array Structures

Scope Description:

NASA intends to land near the lunar South Pole (between 85 and 90 S latitude) by 2024 in Phase I of the Artemis Program and then establish a sustainable long-term presence by 2028 in Phase II. At exactly the lunar South Pole (90 S), the Sun elevation angle varies between -1.5° and 1.5° during the year. At 85 S latitude, the elevation angle variation increases to between -6.5° and 6.5°. These persistently shallow Sun grazing angles result in the interior of many polar craters never receiving sunlight (and accumulating volatiles including water ice) 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 354-hr 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 relocatable solar arrays near the South Pole for powering in situ resource utilization (ISRU) equipment, lunar bases, dedicated power landers and rovers, and that can deploy and retract at least 5 times. Retraction will allow valuable 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 above the surface to reduce shadowing from local terrain are required [Ref. 3]. The ability to be relocated is assumed to be through use of a separate surface-mobility system (i.e., not part of the solar array system), but design of array structures and mechanisms should accommodate loads likely to be encountered during transport along the lunar surface. Suitable variations of existing array concepts [e.g., Ref. 4-5] are of special interest.

Design guidelines for these deployable/retractable solar arrays are:

- Deployed area: 35 m² (10 kW at beginning of life) per unit.
- Single-axis sun tracking about the vertical axis.
- Up to 10-m height extension boom to reduce shadowing from local terrain.
- Deployable, stable base for supporting tall vertical array on unprepared lunar surface.
• Base must accommodate a local 15º terrain slope.
• Adjustable leveling to within 1º of vertical.
• Retractable for relocating, repurposing, or refurbishing.
• Number of deploy/retract cycles in service: >5; stretch goal >10.
• Lunar dust, radiation, and temperature resistant components.
• Specific mass: >75 W/kg including all mechanical and electrical components.
• Specific packing volume: >20 kW/m³ including all mechanical and electrical components.
• Factor of safety of 1.5 on all components.
• Lifetime: 10 years.

Suggested areas of innovation include:

• Novel array and support base packaging, deployment, retraction, and modularity concepts.
• Lightweight, compact components including booms, trusses, ribs, substrates, and mechanisms.
• Novel actuators for telescoping solar arrays 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).
• Integration of existing structural health monitoring technologies.
• Validated modeling, analysis, and simulation techniques.
• Modular and adaptable solar array concepts for multiple lunar surface use cases.
• Completely new concepts; e.g., thinned rigid panel or 3D-printed solar arrays, nonrotating telescoping “chimney” 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. Solar array concepts should be compatible with state-of-the-art solar cell technologies with documented environmental degradation properties. Design, build, and test of scaled flight hardware or functioning lab models to validate proposed innovations is of high interest.

**Expected TRL or TRL Range at completion of the Project:** 4 to 5

**Primary Technology Taxonomy:**
- Level 1: TX 12 Materials, Structures, Mechanical Systems, and Manufacturing
- Level 2: TX 12.2 Structures

**Desired Deliverables of Phase I and Phase II:**

- Research
- Analysis
- Prototype
- Hardware
- Software

**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 lunar surface power. 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 array for surface electrical power near the lunar South Pole for diverse needs including ISRU, lunar bases, dedicated power landers, and rovers.

Relevance / Science Traceability:

Robust, lightweight, redeploable 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 to 40 kW of power. The 10-kW-class solar array structures are also applicable for Science Mission Directorate (SMD) ConOps (concept of operations) on the Moon to recharge batteries on a Mars Science Laboratory- (MSL-) class rover.

References: