Scope Title
Lunar Surface 50-kW-Class Solar Array Structures

Scope Description
NASA intends to land near the lunar South Pole (at S latitudes ranging from 85° to 90°) 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° 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 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 354-hr nights found elsewhere on the Moon while providing nearly continuous sunlight for site illumination, moderate temperatures, and solar power [Refs. 1-2].

Under a recently announced “Game Changing” project in NASA’s Space Technology Mission Directorate (STMD) named Vertical Solar Array Technology (VSAT), several firms are developing relocatable 10-kW vertical solar arrays for initial modular power generation at the lunar South Pole [Refs. 3-4]. These adaptable 10-kW arrays can be retracted and moved as needed to support evolving requirements for initial South Pole human occupation. Their relatively small size (35 m² of deployed area) allows them to be used individually or in combination to power loads up to a few tens of kilowatts. However, because the Sun is always near the horizon at lunar polar sites, using numerous small interconnected arrays for electrical power loads >>10 kW can result in excessive shadowing of one array onto another as well as considerable positioning, leveling, and deployment challenges when locating them at optimally illuminated locations.

This subtopic seeks structural and mechanical innovations for relocatable 50-kW-class (40- to 60-kW) lightweight solar arrays near the lunar South Pole for powering second-generation lunar base infrastructure including habitats and laboratories, rechargeable rovers, and in situ resource utilization (ISRU) mining and processing machines, and that can deploy and retract at least 5 times. Increasing the unit solar array size from first-generation 10 kW to second-generation ~50 kW is a logical course of action as power needs increase for new higher-power capabilities such as ISRU or the Foundation Surface Habitat, which can require >>10 kW of power. This increase in size by 5 times while maximizing specific power (>75 W/kg) needs structures and mechanisms innovations and development effort to ensure compact packaging, safe transportation in space and on the lunar surface, reliable deployment,
stable operation while sun tracking, and retraction and relocation as needed. Small Business Innovation Research (SBIR) contracts provide important near-term investment to flesh out specific technical requirements and new technical challenges for these larger 50-kW-class solar arrays based on VSAT results for smaller 10-kW arrays and on assumed Design, Development, Test, and Evaluation (DDT&E) schedules.

These 50-kW-class solar arrays are listed in NASA’s HEOMD-405 Integrated Exploration Capabilities Gap List as tier 1 (highest impact) development gap #03-04 for which at least 1 potential solution has been identified, but additional work is required to ensure feasibility of the new and/or novel performance or function in a specific operational application [Ref. 5]. The largest similar lightweight solar array under development is the 30-kW “ROSA” wing for NASA’s Lunar Gateway, but it is considerably smaller than desired for second-generation lunar surface arrays, and it is not designed to retract or to survive the unique lunar gravity, insolation, and dust and terrain environments. Exploration Capabilities Gap #03-04 is described as “Medium-power solar array technology for human-rated missions with specific power (>75 W/kg) and operation in mission specific environment.”

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. 6]. The ability to be relocated is assumed to be through use of a separate surface-mobility system (i.e., not necessarily 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 innovations, variations, or combinations of existing 10-kW array components to these much larger 40- to 60-kW arrays including those being developed under the VSAT project are of special interest.

Design guidelines for these deployable/retractable solar arrays are:

- Deployed area: 140 m² (40 kW) initially; up to 210 m² (60 kW) eventually per unit, assuming state-of-the-art space solar cells.
- 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 15° terrain slope with adjustable leveling to <0.5° 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 and 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 packaging, deployment, retraction, and modularity concepts.
- Novel lightweight, compact components including booms, ribs, solar cell blankets, 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.
- Methodology for stabilizing large vertical arrays such as compactly packageable support bases, using regolith as ballast mass, or novel guy wire and surface anchor systems.
- Optimized use of advanced lightweight materials, including composite materials with ultra-high modulus (>280 GPa) combined with low coefficient of thermal expansion (<0.1 m/m°C).
- Integration of novel 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 TRL. TRLs at the end of Phase II of 4 or higher are desired.

State of the Art and Critical Gaps

This subtopic addresses capability gap #03-04 in the 2021 HEOMD-405 Integrated Exploration Capabilities Gap List titled “50 kW class solar power generation systems.” Gap #03-04 is one of just three tier 1 (highest impact) capability gaps in the 03) Aerospace Power and Energy Storage category, and is considered to be a development gap for which at least one potential solution has been identified but additional work is required to ensure feasibility of the new and/or novel performance or function in a specific operational application.

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 50-kW-class (40- to 60-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, 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 human 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 20 kW of power for first-generation capabilities and 40 to 60 kW for second-generation capabilities.

References