NASA SBIR 2019 Phase I Solicitation

S3.06 Thermal Control Systems

Lead Center: GSFC

Participating Center(s): JPL, LaRC, MSFC

Technology Area: TA14 Thermal Management Systems

Future Spacecraft and instruments for NASA's Science Mission Directorate (SMD) will require increasingly sophisticated thermal control technology. Innovative proposals for the cross-cutting thermal control discipline are sought in the following areas/scopes. Research should be conducted to demonstrate technical feasibility during Phase I and show a path toward a Phase II hardware demonstration. Phase II should deliver a demonstration unit for NASA testing at the completion of the Phase II effort.

Advanced Thermal Devices

Advanced thermal devices capable of maintaining components within their specified temperature ranges are needed for future advanced spacecraft. Some examples are:

- High thermal conductivity, vacuum-compatible interface materials that minimize losses across make/break interfaces
- High flux heat acquisition and transport devices
- High performance, low cost insulation systems for diverse environments
- Durable, radiation stable, electrically dissipative, high emittance, low and high absorptance coatings at cryogenic temperatures below 50K
- Radiator heat rejection turndown devices (e.g., mini heat switches, mini louvers)

These high-performance devices would have widespread applicability to upcoming missions and enable missions that are currently not feasible with present technology.

New generations of electronics used on numerous missions have much higher power densities than in the past. High conductivity, vacuum-compatible interface materials are needed in order to reduce interface temperature gradients and facilitate efficient heat removal. Also needed are high flux heat acquisition and transport devices such as high heat flux heat pipes and loop heat pipes.

Exploration science missions beyond earth orbit require systems which can withstand extreme temperatures ranging from high temperatures on Venus to the cryogenic temperatures of the outer planets. High performance insulation systems, which are more easily fabricated than traditional multi-layer (MLI) systems, are required for both hot and cold environments. Potential applications include traditional vacuum environments, low pressure carbon dioxide atmospheres on Mars, and high pressure atmospheres found on Venus.

There are few options for electrically dissipative, low and high absorptance exterior coatings that exhibit high IR emittance characteristics at cryogenic temperatures at or below 50K and that applied conformally coat complex structures with durability to not become particle contamination or entrapment risks during I&T operations. White and black inorganic silicate-based coatings exhibit durability and particle generation risks. White silicone-based systems lack optical stability for long duration exposures. Other structural solutions such as coated honeycomb are not durable and represent particle entrapment risks.

High radiator heat rejection turn down devices are needed for future NASA missions. A radiator is typically designed to dissipate the maximum heat load at the highest sink temperature. At low sink temperatures, there is a desire to turn down the radiator's heat rejection to reduce heat loss from the instrument to the space and to save the survival heater power.

Flexible Cryogenic Heat Pipe

Heat pipes are efficient and versatile heat transfer devices that can transport a large heat load over a long distance with a small temperature difference. Existing heat pipes are designed mainly for room temperature applications. Some instruments require heat pipes to operate in the cryogenic temperature range. Furthermore, some flight missions call for flexible heat pipes to allow an instrument to track a target during orbit, to allow the deployment of radiator panels, or to minimize mechanical loads and vibration from a cryocooler into an instrument to be cooled. Constant conductance heat pipes (CCHPs) operating below 90 Kelvin with the ability for repeated cycles of pipe flexing are needed.

SMD missions involving cryogenic temperature applications such as Wide Field Infrared Survey Telescope (WFIRST); Plankton, Aerosol, Cloud, ocean Ecosystem (PACE); and SWOT can utilize such devices.

The expected Technology Readiness Level (TRL) range at completion of this project is 5 to 6.

Software Improvements for Integrated Thermal-Structural-Optical Performance Analysis

Sensitive optical components and systems, as are frequently used on space science missions, require structural, thermal, and optical performance (STOP) analysis in their design process to validate performance in expected mission environments. Current STOP analysis codes are tailored to specific optical components or systems, lacking the generality that would make the codes more useful to a range of designs. Improvement in existing STOP analysis codes is needed such that they can be applied to any optical system and integrated with mechanical, structural, thermal, and optical analysis software used at NASA. The improved STOP analysis code should be user-friendly and generate performance predictions based on the optical system mechanical design and structural/thermal material properties.

Any mission/project in which optical components or systems are used will require STOP analyses to be completed. As such, a general, integrated, and easy-to-use STOP software is a common desire among engineers of different disciplines.

The expected Technology Readiness Level (TRL) range at completion of this project is 5 to 6.

Advanced Thermoelectric Converter

Thermoelectric converters (TECs) have advantages of small size, long life, solid state design, and no moving parts or fluid operation. Although TECs can also be used for power generation, this solicitation specifically calls for TECs for thermal cooling applications. TECs are known to have a very low efficiency, and most existing TECs are designed for room temperature applications. Research and development in areas of advanced materials, processes, and designs are needed in order to improve its efficiency and extend its low temperature (< 90K) capability for space science application.

Many NASA missions have used TECs for localized cooling to remove heat or to achieve low temperatures. Because of the low efficiency of TECs, multi-staged TECs are often used, which adds complexity in the design and integration of this device. A high efficiency TEC will greatly simplify the design and enhance its reliability. A high efficiency, low temperature TEC can also be an enabling technology for many space missions.

The expected Technology Readiness Level (TRL) range at completion of this project is 5 to 6.

Approaches and Techniques for Surface Payload Survival through the Lunar Day/Night Cycle

NASA has plans to purchase services for delivery of small science and technology demonstration 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 are yet to be precisely defined, however at least for early missions, proposed payloads should not exceed 15 kilograms in mass and not require more than 8 watts of continuous power. Smaller, simpler, and more self-sufficient payloads are more likely to be accommodated. Commercial payload delivery services may begin as early as 2020. Selection for award under this solicitation will not guarantee selection for a lunar flight opportunity.

The lunar day/night cycle is approximately one earth month. During that time surface temperatures on the lunar surface can reach 400K at local solar noon or drop to below 100K during the lunar night, even colder in permanently shadowed regions. These hot and cold conditions can last several earth days due to the slow rotation of the moon and can pose significant challenges to small, low power, science payloads and supporting systems trying to operate for extended length missions encompassing multiple years. Lunar dust deposited on heat rejection surfaces and coatings may further exacerbate the challenge. As interest in the moon has renewed and potential ways to get there are being developed, updated and new thermal approaches, techniques, components are needed to enable missions to include continuous operation through the day night cycle despite the absence of extended heat sources like radio-isotopes which are typically prohibitive from a cost and safety perspective. As examples: technologies that minimize heat loss might help to survive the lunar night, but need to support heat rejection during the potentially hot lunar day; advanced thermal storage approaches could allow heat from the lunar day to be used to survive the long lunar night but need to consider mass and volume limitations; adding heaters for the lunar night will drive electrical power usage necessitating excessive battery mass. The technologies proposed for this subtopic may address a single aspect of the lunar thermal environment or may offer an approach for accommodating the full range of environmental features over a complete lunation.

SMD lunar surface science investigations will employ small, low power payloads that will require advanced thermal control approaches and techniques to survive and operate for extended durations through extreme thermal environments on the lunar surface.

The expected Technology Readiness Level (TRL) range at completion of this project is 3 to 4.

References:

Flexible Cryogenic Heat Pipe

- Wide Field Infrared Survey Telescope (WFIRST): https://wfirst.gsfc.nasa.gov/
- Plankton, Aerosol, Cloud, ocean Ecosystem (PACE): https://pace.gsfc.nasa.gov/
- Kobel, M., and J. Ku, “Thermal Vacuum Testing of Swift XRT Ethane Heat Pipes,” AIAA 1st IECEC, Paper No. 2003-6080, August 17-21, 2003, Portsmouth, Virginia.

Advanced Thermoelectric Converter

- Swift's X-Ray Telescope (XRT): https://swift.gsfc.nasa.gov/about_swift/xrt_desc.html
- https://www.marlow.com/resources/thermoelectric-technology-guide
- https://www.tellurex.com/services/thermoelectric-cooling-heating/

Approaches and Techniques for Surface Payload Survival through the Lunar Day/Night Cycle

- https://en.wikipedia.org/wiki/Commercial_Lunar_Payload_Services
- https://www.jpl.nasa.gov/news/news.php?release=2007-068
- https://history.nasa.gov/TM-3487/ch2-1.htm
- https://www.lpi.usra.edu/lunar/missions/surveyor/
- https://solarsystem.nasa.gov/missions/lunokhod-01/in-depth/
- https://solarsystem.nasa.gov/missions/lunokhod-02/in-depth/