NASA SBIR 2020 Phase I Solicitation

Z2.01  Spacecraft Thermal Management

Lead Center: JSC

Participating Center(s): GRC, GSFC, JPL, MSFC

Technology Area: TA14 Thermal Management Systems

Scope Description

NASA seeks new technologies that will facilitate low mass and highly reliable thermal control systems for the exploration of our solar system. This solicitation specifically targets new technologies and methods for two-phase mechanically pumped deployable radiators, novel three-way valves that can operate as either mix or split single phase fluid flow passively, global access lunar lander technologies, and improved integrated human thermal modeling. Proposed improvements are expected to demonstrate analytical and/or empirical proof-of-concept results at the end of Phase I and delivery of a prototype (or better) at the end of Phase II.

Two-Phase Deployable Radiators:

NASA seeks novel deployable radiator designs for two-phase (vapor/liquid) mechanically pumped fluid loop system that provide passive turn-down capability via stagnation and freeze of the ammonia working fluid in the radiator condenser (three-phase compatible design). A stretch goal of compatibility with other working fluids is acceptable. Proposed technologies must address all of the following design goals:

- Condensing radiators with passive, variable heat rejection turn-down capability of greater than 200:1 achieved through partial to complete coolant freezing and built-in flow bypass
- Compatible with a segmented radiator design where panels are one-time deployable
- Mass goal of < 8 kg/m² including fluid and deployable hardware
- Scalable design up to 3 m² consisting of 1 m² panels
- Materials and structures should be compatible with 15-year life in environments ranging from low Lunar orbit, Jupiter orbit (radiation exposure), and inner to outer planet exploration (temperature exposures)
- Working pressures and freeze-tolerance turn-down technologies should assume ammonia as the working fluid

Passive Three-Way Valves:

NASA seeks novel three-way valves that can operate as either a mixing valve (two liquid input ports and one liquid output port) or splitting valve (one liquid input port and two liquid output ports) that can be used to passively control loop temperatures by the degree fraction of radiator bypass. Such miniature passive thermal control valves could find use in a number of single-phase mechanically pumped fluid thermal control systems. Proposed technologies must address the following design goals:
- Design shall autonomously operate without power
- <0.1% flow rate through the shut off port, with a goal of having a provision for no leakage/adjustable leakage through the use of a pre-installed orifice
- Control range of 5-10 °C, with pre-adjustable set-point control
- Operational temperature limits -55 °C to 90 °C, non-operational limits of -55 °C to 125 °C
- Designs shall be compatible with FC-72 working fluid as well as those used on the ISS thermal control loops (water and ammonia). Retrofit of soft goods are acceptable.
- Mass desire <250 grams (maximum mass 500 g)
- Unit volume <50 cm³ (maximum 100 cm³)
- Leak rate $1 \times 10^{-6}$ scc/s gHe at 200 PSIA
- Minimum 4000 full actuation cycles, desired 17,500 cycles
- Rad hard to 300 krad
- 200 psia maximum expected operating pressure, 200 psia proof pressure, 800 psia burst pressure
- Pressure drop <1.5 psi at 1.5 liters per minute of FC-72 working fluid

Global Access Lunar Technology Development:

NASA is seeking focused efforts to develop large human class lunar lander technologies. Technologies should address a gap associated to long duration habitation on the lunar surface where temperatures range from -193° C in shadow regions (including night) to 120° C at the subsolar point. System technologies should be orientation insensitive; for example, lander side mounted radiators must provide their function regardless of lunar surface temperature condition. Technologies are needed that allow a single vehicle design to operate in all these environments. Technologies should address reduction in mass, volume, and power usage relative to current solutions. Adding heaters can add significant vehicle mass to accommodate an additional power source and are not considered a novel architecture approach. Proposed radiator technologies should also address Micrometeoroid and Orbital Debris (MMOD) robustness and protection potential where appropriate.

Examples of other challenges to address in this area include: the deposition of dust on radiators leading to degraded optical properties, contamination insensitive evaporators/sublimators to enable long mission life, and self-healing coolant tubes for MMOD impact resilience.

Technologies should be suitable for use in medium sized landers that operate near 1 kW average heat dissipation capacity. Proposed technologies should also be extensible to human class landers that will have variable heat loads, and average loads between 3-6 kW. All technologies should support a minimum flight duration of 5 years and be compatible with the encountered aerospace environment.

This subtopic is different from S3.06 subtopic, which is focused on thermal control technologies for payloads and smaller robotic landers.

Human Thermal Modeling:

Human thermal analysis for space applications has primarily focused on Extravehicular Activity (EVAs), and typically utilized standalone tools for these short duration assessments. As NASA moves beyond low earth orbit to long duration missions, crew member induced loads to an exploration vehicle's thermal control, environmental control, and life support systems need conjugate analytical assessments between crew and vehicle to determine the most mass efficient capacity for these systems. Additionally, these missions will require an exercise prescription at high metabolic rates for the crew which drives the system sizing for CO₂, water (vapor and liquid), and metabolic heat removal. The provided human thermal model should be capable of interfacing with Systems Improved Numerical Differencing Analyzer (SINDA) compatible analysis tools to enable conjugate assessments of crew-induced loads and vehicle thermal control systems.

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](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

Science Missions. ICES-2016-129.

Control Valves. NASA Thermal and Fluids Analysis Workshop, TFAWS18-AT-14.

and Multiple Radiators for Spacecraft Applications. ICES-2017-221.


automatic thermal control. Journal of biomechanical engineering, 123(1), 114-120.

biophysics, 26(2), 147-166.


gesamte Physiologie des Menschen und der Tiere, 291(2), 129-162.


Expected TRL or TRL range at completion of the project: 3 to 5

Desired Deliverables of Phase II

Prototype, Analysis, Hardware, Software

Desired Deliverables Description

Phase I awards are expected to provide a proof-of-concept analysis and supporting hardware/software which
demonstrates the ability of the organization to meet the goals stated in the solicitation.

At the culmination of a Phase II contract, deliverables would include math modeling that has been correlated to test
data, raw and reduced test data, and delivery of the new hardware or software package to NASA.

State of the Art and Critical Gaps

These focus areas strive to reduce mass, volume, and power of a thermal control system in the next generation of
robotic and human class spacecrafts. These improvements may come through either novel hardware solutions or
modernization of software tools used to assess human vehicle interactions. The current state-of-the-art (SOA) in
thermal control results in vehicle power and mass impact of greater than 25-30% due to old technologies still in
use. Furthermore, as missions become more variable (dormancy, environments, etc.) the need for intelligent
control (both actively and passively) within the thermal control system becomes more apparent. As science payloads continue to decrease in size, increase in power, and require precise temperature control, all of which cannot be provided by traditional thermal control methods due to vehicle level impacts of mass/volume and power.

Relevance / Science Traceability

- Gateway
- Europa Clipper/Lander
- Lunar Lander
- Long duration habitats (moon, mars. etc.)