



## NASA SBIR 2021 Phase I Solicitation

### S4.04 Extreme Environments Technology

Lead Center: JPL

Participating Center(s): GRC, GSFC, LaRC

Scope Title:

#### Extreme Environments Technology

#### Scope Description:

This subtopic addresses NASA's need to develop technologies for producing space systems that can operate without environmental protection housing in the extreme environments of NASA missions. Key performance parameters of interest are survivability and operation under the following conditions:

1. Very low temperature environments (e.g., temperatures at the surface of Titan and of other Ocean Worlds as low as  $-180\text{ }^{\circ}\text{C}$ ; and in permanently shadowed craters on the Moon).
2. Combination of low-temperature and radiation environments (e.g., surface conditions at Europa of  $-180\text{ }^{\circ}\text{C}$  with very high radiation).
3. Very high temperature, high pressure, and chemically corrosive environments (e.g., Venus surface conditions, having very high pressure and temperature of  $486\text{ }^{\circ}\text{C}$ ).

NASA is interested in expanding its ability to explore the deep atmospheres and surfaces of planets, asteroids, and comets through the use of long-lived (days or weeks) balloons and landers. Survivability in extreme high temperatures and high pressures is also required for deep atmospheric probes to the giant planets. Proposals are sought for technologies that are suitable for remote-sensing applications at cryogenic temperatures and in situ atmospheric and surface explorations in the high-temperature, high-pressure environment at the Venusian surface ( $485\text{ }^{\circ}\text{C}$ , 93 atm) or in low-temperature environments such as those of Titan ( $-180\text{ }^{\circ}\text{C}$ ), Europa ( $-220\text{ }^{\circ}\text{C}$ ), Ganymede ( $-200\text{ }^{\circ}\text{C}$ ), Mars, the Moon, asteroids, comets, and other small bodies.

Also, Europa-Jupiter missions may have a mission life of 10 years, and the radiation environment is estimated at 2.9 Mrad total ionizing dose (TID) behind 0.1-in-thick aluminum. Proposals are sought for technologies that enable NASA's long-duration missions to extreme wide-temperature and cosmic radiation environments. High reliability, ease of maintenance, low volume, low mass, and low outgassing characteristics are highly desirable. Special interest lies in development of the following technologies that are suitable for the environments discussed above:

- Wide-temperature-range precision mechanisms: for example, beam-steering, scanner, linear, and tilting multi-axis mechanisms.
- Radiation-tolerant/radiation-hardened low-power, low-noise, mixed-signal mechanism control electronics for precision actuators and sensors.

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- Wide-temperature-range feedback sensors with sub-arcsecond/nanometer precision.
  - Long-life, long-stroke, low-power, and high-torque force actuators with sub-arc-second/nanometer precision.
  - Long-life bearings/tribological surfaces/lubricants.
  - High-temperature analog and digital electronics, electronic components, and in-circuit energy storage (capacitors, inductors, etc.) elements.
  - High-temperature actuators and gear boxes for robotic arms and other mechanisms.
  - Low-power and wide-operating-temperature radiation-tolerant/radiation-hardened radio-frequency (RF) electronics.
  - Radiation-tolerant/radiation-hardened low-power/ultra-low-power, wide-operating-temperature, low-noise mixed-signal electronics for space-borne systems such as guidance and navigation avionics and instruments.
  - Radiation-tolerant/radiation-hardened wide-operating-temperature power electronics.
  - Radiation-tolerant/radiation-hardened electronic packaging (including shielding, passives, connectors, wiring harness, and materials used in advanced electronics assembly).

Research should be conducted to demonstrate technical feasibility during Phase I and show a path toward a Phase II hardware demonstration, and when possible, deliver a demonstration unit for functional and environmental testing at the completion of the Phase II contract.

**Expected TRL or TRL Range at completion of the Project:** 3 to 5

**Primary Technology Taxonomy:**

Level 1: TX 04 Robotics Systems

Level 2: TX 04.2 Mobility

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

- Prototype
- Hardware
- Research
- Analysis

**Desired Deliverables Description:**

Provide research and analysis for Phase I as a final report.

Deliverables for Phase II include proof-of-concept working prototypes that demonstrate the innovations defined in the proposal and enable direct operation in extreme environments.

**State of the Art and Critical Gaps:**

Future NASA missions to high-priority targets in our solar system will require systems that have to operate at extreme environmental conditions. NASA missions to the surfaces of Europa and other Ocean Worlds bodies will be exposed to temperatures as low as -180 °C and radiation levels that are at megarad levels. Operation in permanently shadowed craters on the Moon is also a region of particular interest. In addition, NASA missions to the Venus surface and deep atmospheric probes to Jupiter or Saturn will be exposed to high temperatures, high pressures, and chemically corrosive environments.

Current state-of-practice for development of space systems for the above missions is to place hardware developed with conventional technologies into bulky and power-inefficient environmentally protected housings. The use of environmental protection housing will severely increase the mass of the space system and limit the life of the mission and the corresponding science return. This solicitation seeks to change the state of the practice by support technologies that will enable development of lightweight, highly efficient systems that can readily survive and operate in these extreme environments without the need for the environmental protection systems.

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**Relevance / Science Traceability:**

Relevance to SMD (Science Mission Directorate) is high.

Low-temperature survivability is required for surface missions to Titan (-180 °C), Europa (-220 °C), Ganymede (-200 °C), small bodies, and comets. Mars diurnal temperatures range from -120 °C to +20 °C. For the Europa Clipper baseline concept with a mission life of 10 years, the radiation environment is estimated at 2.9 Mrad TID behind 0.1-in-thick aluminum. Lunar equatorial region temperatures swing from -180 °C to +130 °C during the lunar day/night cycle, and shadowed lunar pole temperatures can drop to -230 °C.

Advanced technologies for high-temperature systems (electronics, electromechanical, and mechanical) and pressure vessels are needed to ensure NASA can meet its long-duration (days instead of hours) life target for its science missions that operate in high-temperature and high-pressure environments.

**References:**

Proceedings of the Extreme Environment Sessions of the IEEE Aerospace Conference, <https://www.aeroconf.org/> or via IEEE *Xplore* Digital Library.

Proceedings of the meetings of the Venus Exploration Analysis Group (VEXAG), <https://www.lpi.usra.edu/vexag/>

Proceedings of the meetings of the Outer Planet Assessment Group (OPAG), <https://www.lpi.usra.edu/opag/>