This subtopic is composed of two elements: (1) Technologies for High Temperature/High Pressure Environments and (2) Technologies for Aerial Mobility. Both areas are focused on the future in situ exploration needs for Titan and Venus, worlds featuring dense atmospheres with low and high temperature extremes, respectively. Note that some technologies developed for the cryogenic environment of Titan will also be applicable to other severe low temperature destinations such as asteroids, comets, and Europa.

Titan is the second largest moon in the solar system and the only one that features a sufficiently dense atmosphere for buoyant vehicle flight. The atmosphere is predominantly nitrogen with a surface temperature of approximately 90 K. Targeted for exploration by Cassini-Huygens in 2004 and beyond, Titan is expected to be a geologically and chemically diverse world containing important clues on the nature of prebiotic chemistry. NASA is starting to lay the ground work for post-Cassini-Huygens exploration of Titan using autonomous, self-propelled aerobots capable of surveying many widely separated locations and potentially including surface sampling and composition analysis.

Venus is the second planet from the Sun and features a dense, CO$_2$ atmosphere completely covered by clouds with sulfuric acid aerosols, a surface temperature of 460ºC and a surface pressure of 90 atmospheres. Although already explored by various orbiters and short-lived atmospheric probes and landers, Venus retains many secrets pertaining to its formation and evolution. NASA is interested in expanding its ability to explore the deep atmosphere and surface of Venus through use of long lived (days or weeks) balloons and landers.

**Technologies for High Temperature and High Pressure Environments**

- Advanced thermal control for Venus, including lightweight (50 kg/m$^3$), insulated pressure vessels able to protect the electronics and instruments enclosed inside for a few hours at 460ºC and 100 bar; new lightweight thermal insulation materials (0.1 W/mK at 460ºC), thermal storage (with 300–1000 J/kg energy density), thermal switches (over 1 W/K for “on” and 0.01 W/K for “off” mode), and high performance heat pipes (0.05 W/mK at 460 ºC and 100 bar).

- Science and engineering sensors able to operate at 460ºC and 100 bar, including seismometers.

- High temperature electronics and electronic packaging for sensor and actuator interfaces at 460 ºC, including low noise (10 nV/sqHz) preamplifiers, transmitters (S-band), drivers (with 0–100 V digital output for driving piezoelectric, electrostatic, or electromagnetic actuators), and high value (on the order of one to
hundreds of micro Farad) capacitors.

- High temperature primary batteries (200 Whr/kg, 100 cycles) for operation at 460°C.
- Sample handling and acquisition systems including high temperature drills, motors, and actuators able to operate in the 460°C, 90 atmosphere surface environment of Venus.

Technologies for Aerial Mobility

In addition to the severe environment technologies above, innovative technologies are also sought in the following areas of robotic technologies for aerial mobility:

- Concepts and devices for a low mass (~1–2 kg), high efficiency electric drive motor for the 90 K Titan environment. This motor needs to operate continuously for up to 12 months on Titan and drive the main propulsion propeller at up to 5 revolutions per second with a controllable power input across the range of 0–50 W.
- Concepts and devices for a low mass (concept)
- Concepts and devices for surface sample acquisition from an aerobot in the 90 K surface environment of Titan. These can include, but are not limited to, station keeping, landed or anchored (tethered) aerobots. Both liquid and solid (ice or rock; loose particle or drilled core) samples are of interest.

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