# Abstract

## Results of NASA's Workshop on Extreme Environments Technologies for Space Exploration

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During the next 20 years, NASA is challenged to develop the necessary technologies to support missions to extremely diverse environments. At one extreme, Venus Surface Exploration and Venus Sample Return both require surface operation, including sample acquisition from 15-20 cm depth of hard rock and in-situ sensing (temperature, pressure etc.). In order to acquire the sample, the lander must not only survive on the surface of Venus for at least an hour at about 460°C and 90-bar pressure, but it must also pass through extremely corrosive sulfuric acid clouds at higher altitudes of the Venus atmosphere. Also of interest to the scientific community are long-term (one year) missions. Survivability in extremely high temperatures (380°C) and high pressures (90 Bar) are required for deep atmospheric multi-probes to Giant planets as well. On the other extreme, Comet Nucleus Sample Return, Titan In-Situ, and missions to Europa have to survive in extremely cold environments in the -140 to -180°C temperature range. In addition, the Europa mission presents a challenge of surviving in an extremely cold temperature (-160°C) and high radiation (5 Mrad) environment.

On May 14th 2003, NASA held a three-day workshop in Pasadena California for identifying technology challenges for supporting missions to extreme environments. The primary objective of this workshop was to bring together industry, government and the academic research community to assist NASA in assessing state-of-the-art technologies for systems operating in extreme environments. The workshop was organized into several sessions. Each session addressed a specific technology topic for operation under extreme environments. Sessions one and three of the workshop addressed electronic devices and circuits for extreme temperatures. Session one focused on cold temperature electronics, with speakers discussing the application of suitable technologies such as CMOS and SiGe BI CMOS for this purpose. Session three focused on high temperature electronics, with speakers addressing the challenges of using new wide band-gap devices such as SiC based transistors for high temperature applications. Session two was about transducers, materials and packaging for extreme environments. This session included discussions on metallurgical interconnections for high/low temperature use in microelectronics. Sessions four and five were on systems and applications for extreme environments. Session four focused on cryogenic systems, while session five was on high temperature systems, including discussions on automotive electronics, electronic systems for measuring while drilling in the petroleum industry and precision data conversion technology for high temperatures. Sessions six and seven were on power generation and storage for extreme environments. Session six focused on high temperature and session seven on low temperature, including a discussion of batteries and electrochemical power sources for extreme environment. Finally, session eight was on thermal control for low and high temperatures. The workshop also included two plenary sessions. The first one focused on "low temperature technology, with concentration on the outer planets, Titan, Comets, Asteroids, the Moon and Mars" and the second one focused on "high temperature/high pressure, with concentration on Venus, Jupiter Probes, and Solar Probe".

During the International Workshop on Planetary Probe Atmospheric Entry and Descent Trajectory Analysis and Science we will report on the findings of this workshop. We will further discuss results on the state-of-the-art technologies for extreme environments, including thermal control, electronics, packaging, sensors and actuators and their industry roadmaps.