

Capabilities for Long-Duration Landers in Extreme Environments

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Abstract

Missions to the surface of planets that experience high temperatures, like Venus or Mercury, have had limited consideration and development in recent decades partially because of the extreme temperatures and environments the planets experience. In the case of Mercury this is up to 430C for nearly 30 days and for Venus almost 60 days at 460C. Several landers have been sent to Venus many decades ago but 127 minutes was the longest any operated on the surface. Venus, and Mercury, hold many mysteries and successful surface missions will result in compelling new science that will have significant bearing on us here on Earth. To enable this compelling new science, NASA has been developing capabilities for a small lander that is designed to operate for months in the extreme temperatures found on Venus and Mercury [1], [2]. The capabilities promise to enable new missions not yet considered. This work summarizes technical advances that are preparing us for long-duration (months) operations in extreme environments on other planets.

1. Introduction

The challenges to the exploration of the surfaces and interiors of Venus and Mercury worry scientists and spacecraft designers in that the surface temperatures are extremely challenging for landers. NASA has begun tackling operation in these extreme conditions by using an approach that leverages decades of investment in sensors, electronics and spacecraft subsystems systems that not only can handle and operate in the extreme heat but can operate in the extreme cold conditions as well. This briefing will discuss progress on the development of components, subsystems, and systems that target extended (months) operations in such hostile conditions.

2. Relevant Capabilities

NASA is continuing to support developments to overcome the noted challenges. For example, high temperature sensors with heritage back to aeronautics applications have been modified and demonstrated to function at temperatures in excess of 500C for thousands of hours. Wide band gap, SiC based electronics have been demonstrated to function successfully for extended periods of time at over 500°C and in Venus simulated conditions [3], [4] [5]. On the cold end these same electronics have operated at temperatures down to -190°C,[6]. In addition to electronics, a number of other subsystems are in development [1],[2] including power in the form of high temperature batteries and power management devices, communications including antennas, transmitters and other components, materials [7], and structures and mechanisms.

Examples of some recent progress for high temperature components include: the world's first demonstration of stable electrical operation of semiconductor integrated circuits (ICs) for over one year at 500 °C in air atmosphere was achieved, including operation of a packaged SiC clock circuit. This level of complexity is more than a factor of 7 beyond what was previously shown.

Electronic circuits with the capability to provide basic functionality for small lander / surface science beacon are being designed, fabricated and tested. This includes transistors associated with lower frequency communications. Sensor development has been on-going as well with several reaching a higher level of maturity. For Venus, a four species chemical sensor has shown operation for 60 days at 500°C with stable response and limited drift over the test period [8].

These electronics that have shown operation at 500° C and above have also operated across a total temperature range from low (-190°C) to high temperatures (961°C), a span more than 1000°C [6]. The design of the electronics structure enables this operation over such a wide temperature range without changing signal/supply input voltages and implies operation in cold environments without “cold start” issues.

NASA is currently funding the development of a high temperature seismometer at its Glenn Research Center [9]. This seismometer is being designed to operate at near 500C for 6 months or longer on

battery power. High-temperature solar arrays are also being developed at NASA through the Jet Propulsion Laboratory (JPL). While these arrays are not expected to produce large amounts of power on Venus, they may provide enough power to charge a battery and perhaps could help the lander operate over multiple Venus nights [10].

These are examples of some of the developments under NASA's recent Long Lived Insitu Solar System Exploration (LLISSE) project, HOTTech, and other NASA funded efforts.

3. Future Applications

If the ongoing developments continue one can envision near term (<10 year) applications that will acceleration and expand our paradigm about Venus and Mercury surface and interior science. The capabilities under development will usher in the ability to make temporal measurements to help us understand some of the mysteries about the terrestrial planets, and perhaps exoplanets. They will enable the capture of data that may reveal the seismicity of Mercury and Venus, and other important science.

4. Summary and Conclusions

Progress continues to be made toward a complete lander system that can operate in extreme surface conditions. The progress will enable near-term consideration of surface missions to the Venus and Mercury that can operate for months.

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