LONG-LIFE IN-SITU SOLAR SYSTEM EXPLORER (LLISSE) PROBE CONCEPT AND ENABLING HIGH TEMPERATURE ELECTRONICS. Tibor Kremic[1], Gary W. Hunter[1], Philip G. Neudeck[1], David J. Spry[1], George E. Ponchak[1], Glenn M. Beheim[1], Robert Okojie[1], Maximilian C. Scardelletti[1], John D. Wrbanek[1], Daniel M. Vento[1], Leah M. Nakley[1], and Jeffrey Balcerski[1], [1]NASA Glenn Research Center, 21000 Brookpark Rd., Cleveland, OH 44135 USA (tibor.kremic@nasa.go)

Introduction: Venus, while having similar size, mass, and location in the solar system to Earth, varies vastly in many ways including its climate, atmosphere, and surface conditions. Surface conditions present formidable engineering challenges (due to the high temperature and pressure) such that to date, landed missions have not been able to last more than about 2 hours [1]. This has resulted in significant knowledge gaps about the surface conditions of this important body in the solar system. The science community has effectively no in-situ temporal data on Venus surface conditions (temperature, pressure, winds and chemistry). These data are critical for the development of a thorough understanding of Venus' weather and the processes by which chemical species interact with each other and are transported throughout the atmospheric column as well as helping understand aspects of the atmposhere / planet interactions such as momentum exchange. To date no capability has been available to enable a long lived surface probe to make these kinds of measurements. However, recently developed Silicon Carbide electronics, sensors, and other technologies have matured to a state where a very simple, but powerful long-life scientific probe would be feasible for Venus. Moreover, it is now possible to directly qualify the durability and functionality of these components in a simulated Venus surface environment.

Development has begun on an integrated probe system to enable such a long lived surface mission. This probe, the Long-Life In-situ Solar System Explorer (LLISSE), would provide key measurements to help make progress in our understanding of three key questions for Venus exploration as identified in the planetary science decadal survey and the Venus exploration Goals, Objectives, and Investigations document (GOI) as produced by the VEXAG. The key questions addressed by this probe include better knowledge of super-rotation of the atmosphere (Goal 1, Objective B), the climate and its evolution (Goal 1, Objective B), and surface – atmosphere interaction/weathering (Goal 3, Objective B). The purpose of this paper is to briefly describe LLISSE, and the enabling capabilities associated with its development.

LLISSE Concept Overview: The LLISSE project includes the design and demonstration of a prototype instrument suite and supporting system to function at the surface conditions of Venus and communicate periodic measurements of temperature, pressure, wind velocity and direction, and chemical composition to an orbiter [2] (Figure 1). These periodic (every 8 hours or better) measurements over the duration of a Venus daylight period including the transitions at either end, or approximately 60 Earth days, provide a unique and significant science impact. The main product for the first three years of development will be a primary battery powered version capable of surviving approximately 60 Earth days on the Venus surface with capability to transmit data at approximately 10 MHz. The fifth year product is the demonstration of the wind powered version and increasing transmit capability of the probe to between 50 and 150 MHz with a life expectancy of Venus year or more.

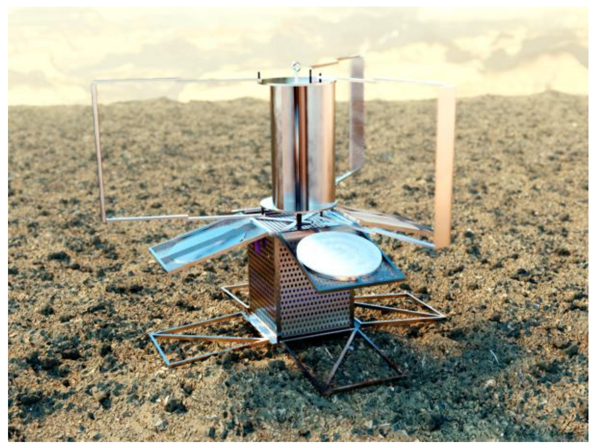

Figure 1. Notional wind powered version of the Long-Life In-situ Solar System Explorer Venus Probe Concept

The capabilites that enable LLISSE include:

- High temperature Sensors, Electronics, Communicastions, and Power Generation
- High fidelity test /validation capability, in particular the Glenn Extreme Envrionment Rig (GEER) [3]
- Creative operations approach including the simple operation premise of periodic data transmission.

High Temperature Electronics: Advancements in high temperature electronics are particularly enabling to multiple aspects of LLISSE. Standard electronics for planetary instrumentation/operations are often silicon (Si) based. However, Si-based electronics do not operate at Venus temperatures [4]. This implies a need to use wide bandgap electronics, such as silicon carbide (SiC), or other high temperature electronic systems. The design choices available in a small package, the capability to withstand harsh environments, including high pressure/temperature for potentially prolonged time periods, and the ability to form complex integrated circuits (IC's) suggest SiC as the most viable technology for multiple high temperature applications.

Recent work has notably expanded capabilities and produced the world's first microcircuits of moderate complexity (Medium Scale Integration) that have the potential for sustained operation at 500˚C [5-8]. These circuits contain 10's of JFETs and two metal interconnect layers, an order of magnitude more complicated than previous long-term 500°C demonstrations. This enables a wide range of on-board data processing, including signal amplification, local processing, and wireless transmission of data. Operational life at 500˚C of thousands of hours has been shown for several circuits. Table 1 shows a sample compilation of circuits fabricated that can enable other Venus and harsh environment applications. A direct extension of the processing provides other circuit types with prolonged 500˚C operational lifetimes.

Circuit	Standard Inputs	Outputs	Comments
Ring Oscillators	Capacitive sensors, Resonator Circuits	Frequency modulated signals	Can add on-chip large transistors for power amplification.
Binary RF Transmitter	Low power binary signal	High-Power RF signal to antenna	Conditions the signal for wireless transmission and feeds antenna
Op Amp, 2-Stage	Differential inputs	Voltage gains to 50	Crucial circuit building block for signal processing
4-Bit D/A	4 digital Inputs	1 analog	A/D circuit also achievable given these components
Logic gates	Up to 8 inputs/outputs	Typically 1 digital	Types include: NOT, NOR, NAND, XNOR
4X4 Bit Static RAM	Read, Write, Data Lines, Address Lines	4 bit parallel digital latch	Memory element

Table 1. A sampling of high temperature circuits fabricated and in development.

The most significant Venus relevant activity associated with this generation of moderately complex high temperature electronics was part of the PICASSO program [9]. *A notable aspect of this work involves testing high temperature electronics, including a high temperature ring oscillator, inside GEER in simulated Venus surface conditions.* To very briefly summarize [10], a packaged SiC JFET ring oscillator chip was immersed in the simulated Venus atmosphere for 21.7 days, which included temperature, pressure, and atmospheric species, before ending the test for scheduling reasons. The SiC ring oscillator integrated circuit fully functioned at 1.26 ± 0.06 MHz over the entire 521 hours (21.7 days) it was exposed to Venus surface atmospheric conditions. This was the worldsfirst demonstration of moderately complex electronics operating for extended periods in-situ in Venus surface atmospheric conditions and this represents a major advancement in technology, and notably expands potential for new Venus missions. It is upon this potential that not only missions such as LLISSE can be envisioned, but a new range of future planetary exploration.

References:

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