A Long-Lived Lander for Venus Surface Insitu Science

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Brief Presenter Biography: Dr. Kremic is the Chief of the Space Science Project Office and oversees NASA Glenn content related to science investigations, instrument and technology development, flight system builds and mission support roles, and NASA program support functions. In addition, Dr. Kremic is the Principal Investigator (PI) on the LLISSE development project, the PI on the development of a Venus seismometer, and is engaged in various formulation, execution, and science community support activities.

Introduction: Earth's sister planet, Venus, continues to hide important scientific clues about our solar system, terrestrial planets around other stars, and about our home planet as well. Venus was the first planet human-built spacecraft have flown by, several missions have orbited around it and many short-duration landers have landed on it, yet there are still many important and basic science questions that need answering about this mysterious body. This fact exists because the planet poses significant challenges to acquiring the needed data when relying on tradition planetary spacecraft design approaches.

This presentation will provide a short background, description, and status of a project that is taking a novel approach to meet some of the Venus challenges and prepare NASA to address the key science questions about the climate, surface, and eventually interior of Venus.

Challenges: Venus is perhaps most known for its extreme surface conditions. On most of the planet's surface, temperatures reach approximately 460 degrees celsius, which is hot enough to destroy all silicon-based electronics, and many materials as well. The pressure at the surface can reach 92 times what we see on Earth's surface (equivalent to nearly a kilometer under water). The atmosphere is reactive and will relatively quickly impact many materials that we use for tradition spacecraft systems, like copper. These extreme environmental conditions have limited the life of all landers to date to approximately 2 hours or less, which of course does not allow for temporal data collection.

The Venus atmosphere also poses challenges for remote sensing or aerial platforms. The dense CO_2 atmosphere, coupled with the thick cloud layers, significantly limit remote sensing opportunities and the sulfuric acid in the clouds provides engineering challenges for aerial platforms that may be planned for insitu operations in that region.

The impact of these challenges is that the science community has very limited data from the Venus surface and essentially no in-situ temporal data even for basic measurements such as temperature, pressure, or winds near the surface [1]. 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.

A solution: A team from NASA GRC, with support from other NASA centers and other institutions, have created an approach that includes development a small lander that will address the many challenges at the surface and enable long-duration operations. To accomplish this, the effort uses the latest advances in high-temperature systems and a novel concept of operations.

The small lander is called the Long-Lived Insitu Solar System Explorer (LLISSE) and is being developed to operate on the surface of Venus for 60 days or longer taking measurements and sending science data to a Venus orbiter.

LLISSE is intended to be an ~10kg lander powered by a high-temperature battery. It will carry a suite of small sensors to measure winds, radiance, temperature, pressure, and abundances of key atmospheric constituents.

A science traceability summary is provided in Table 1 below.

Table 1

LLISSE Science Objectives	Measurements	Instrument Requirements
1) Acquire temporal meteorological data	Measurement of pressure, temperature, wind speed and direction, and radiance	2-axis wind sensor measurements, radiance, measure temp. and press.
2) Estimate momentum exchange between the surface and the atmosphere	Same as above	Same as above
3) Determine key atmospheric species at the surface over time	Measure the abundance of gases H_2O, SO_2, CO, HF, HCl, HCN, OCS, NO, O_2	Chemical sensor measurements
4) Determine the rate of solar energy deposition at the Venus surface	Measure incident and reflected solar energy	Measurements of radiance

LLSSE is designed to be flexible and delivered to the surface in several ways. First, it can be fastened to a larger short-lived lander (as envisioned by the Venus Flagship Mission concept study team [2] or the Venera-D Joint Science Definition Team in their study report

[3]). Second it can be delivered via its own entry system and then descend and land as successfully done on previous Venera and VEGA missions or as studied in concepts like VBOSS [4], or third, given is low mass and small size (~20 cm body diameter), it can potentially be dropped from an aerial platform.

Once deployed, LLISSE would take real-time measurements and transmit the data periodically (~ every 8 hours) or as aligned with operations of the orbiter. This operations scheme (transmitting every 8 hours) will allow for 60 days of operations (> ½ solar day) and will return the first ever insitu temporal data from the Venus surface.

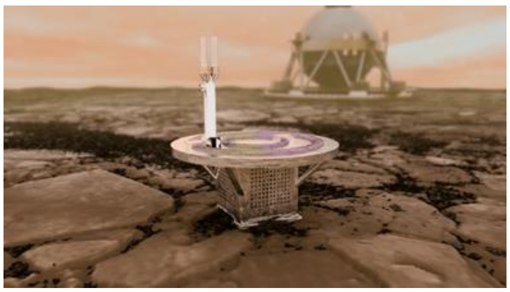

Figure 1. Conceptual image of LLISSE on the Venus

Status of LLISSE subsystems. A high-temperature power source (battery) has been developed and the chemistry has been demonstrated at temperature to enable the desired mission duration. In fact, under simulated loads, the batteries have demonstrated over 2 x required life (>120 days). Current activies are working packaging designs and full-scale builds are expected to be completed around the end of 2022/early 2023.

A critical subsystem is the high-temperature electronics that does the processing and operations. These electronics have been under development for some time and currently the Generation 12 version is in fabrication. If successful, this version will have the processing capability needed implement a first-generation version of LLISSE. Also in development are SiC based electronics using Bipolar Junction Transistor (BJT) device architecture. These devices will be used in power switching and for driving the transmitter. Functional BJT devices needed to implement LLISSE are scheduled to be completed and demonstrated this summer. If successful, this coupled with the successful build of the Gen 12 electronics noted earlier, will provide the elements that could be used to execute the first generation of LLISSE.

The sensors suite is at various levels of maturity, from nearly a Technology Readiness Level (TRL) of near 6, (e.g., SO_2 chemical sensor) to a TRL of 3 for the more recently added radiance sensor. Currently sensors are not funded under LLISSE due to recent budget impacts. Further sensor development is expected to occur under programs like MaTISSE and PICASSO.

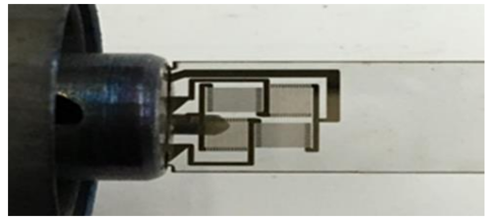

Figure 2. Venus Wind Sensor

Other items like the high-temperature antenna have also made progress. Material tests are wrapping up to demonstrate suitable performance, manufacturability, and robustness to the overall mission scenario. A notional "bus" structure has been developed and tested in the Glenn Extreme Environment Rig (GEER). Concept and some design work has been implemented for a Heatshield for Extreme Entry Environment Technology (HEEET) based aeroshell to enable delivery of LLISSE to the surface from a Venus flyby or orbiter mission [5].

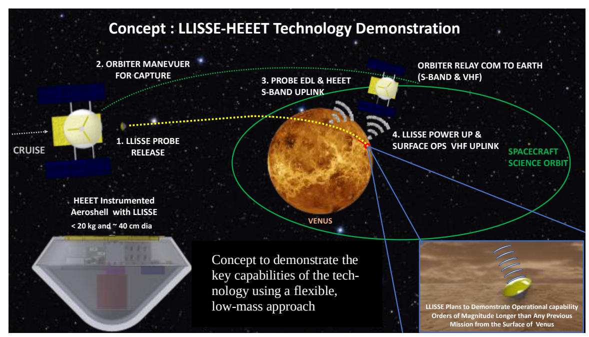

Figure 3. Conceptual technology demonstration of LLISSE and HEEET

Most subystems are currently in the TRL 4-5 range, and most of the remaining work to reach TRL-6 for the system will be with the communication system.

Summary and Acknowledgements: LLISSE offers an innovative and compelling solution to enable much needed insitu measurements at the surface of Venus. LLISSE has made steady progress on all subsystems. The project has demonstrated several worlds' firsts (long-duration operations of a battery at Venus temperatures; Complexity, life and performance of high-temperature electronics; and Operational sensors with electronics for Venus environments). Plans are to complete further demonstrations in 2022 and then perform a technology readiness assessment. LLISSE provides the core capability to enable long-duration surface missions. LLISSE capability can be augmented by work done on other programs and projects like HOTTCH, which is funding development of efforts such as a high-temperature seismometer. That seismometer would be suitable for a LLISSE-like platform and is consistent with what was envisioned by the SAEVe concept [6]. Other projects funded by HOTTch include high-temperature memory to enhance mission flexibility [7], and high-temperature solar cells [8] which may offer promise for operations beyond 60, or even 120 days.

The LLISSE team acknowledges the generous support of NASA's Planetary Science Division for their funding of LLISSE.

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