High-Temperature Lander Systems and Payloads Capability Summary

Prepared by: Tibor Kremic, NASA Glenn Research Center

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NASA has been developing technology and systems for use on future missions, such as potential Venus landers, under projects such as LLISSE and HOTTech [Ref 1 and 2]. A small (`15kg-50kg, depending on lifetime and science payload) Venus lander / entry shell system concept was developed as a potential ride along to a Venus orbiter [Ref 3]. The simple deployment approach is for the carrier/orbiter spacecraft to point the lander/shell combination and release it for autonomous entry. Deceleration and touchdown of the lander is accomplished just as done by Soviet landers several times in the past.

As the lander descends the rising temperature turns on the lander and it begins its operational sequence. For most of its extended surface life, the lander periodically queries the science payload and transmits data on a fixed schedule to the orbiter. When not transmitting, the lander is in sleep mode keeping track of time. If the lander is equipped with a high-temperature seismometer [Ref 4], it will also continuously monitor the vertical axis and if its algorithm detects the beginning of a quake will capture motion and immediately transmit data from all axes. The orbiter/carrier is required to relay data from the lander to Earth during over the lander's lifetime which can be up to 120 days depending on the science payload.

Potential high-temperature payloads that can be considered beyond a seismometer are shown in the table below along with planned measurement target range. The vision for the concept is well formulated and a range of component technologies have been matured with some have been tested in Venus simulated conditions for up to 60 days. Some examples are shown in Figures 1-5 below.

Table 1: High temperature payload and targeted measurements

Sensor	Description	Specifications	
		Min/Max	**Resolution**
Wind Sensor (2-D)	Strain gage	0.5-2.5 m/s	0.25 m/s
Solar Radiance	Thermopile	4-25 W/m^2	2 W/m^2
Temperature Sensor	RTD in electronics	450-470 C	0.2 C
Pressure	Resistive	85-95 bar	5% full scale
	Capacitive		
Chemical Species	SOx	3-400 ppm	1.6 ppm
	H2O	5-100 ppm	0.4 ppm
	OCS	1-45 ppm	0.2 ppm
	CO	5-50 ppm	0.2 ppm
	HF	1-5 ppm	20 ppb
	NO	4-10 ppm	39 ppb

Current estimated TRL for the various devices and subsystems is shown below.

Technology Element	Estimated TRL
Electronic circuits (SiC): sensors and data handling	5
Electronic circuits (SiC): power management	3
Communications (100 MHz)	3
Wind Sensor	4
Temperature Sensor	5
Chemical Sensors	5
Seismometer	2
High-Temp Battery	4
Entry Shell	6

Additionally, an independent team from several NASA centers assessed the TRL of the various devices and subsystems and the time and budget required to reach TRL-6. The team concluded that a LLISSE Venus lander could be at TRL-6 within 4 years given the budget profile presented to NASA.

Additional information about the lander concept of operations, status and capabilities can be found at these and other **references**:

1. "Long-duration Venus lander for seismic and atmospheric science", Kremic, T. et al, Planetary and Space Science, Volume 190, 1 October 2020, 104961.
2. "Long-Lived In-Situ Solar System Explorer (LLISSE): Potential Contributions to the Next Decade of Solar System Exploration", https://ntrs.nasa.gov/citations/20190034042
3. "Status of Long-Duration Lander Capabilities Developed Under the LLISSE project", T. Kremic, et al., 20th Meeting of VEXAG 2022, https://www.hou.usra.edu/meetings/vexagnovember2022/pdf/8022.pdf
4. HOTTech F2F Meeting, 2024, T. Kremic et al, https://ntrs.nasa.gov/api/citations/20230011587/downloads/HOTTech2%20F2F%20MEMS%20Final.pdf

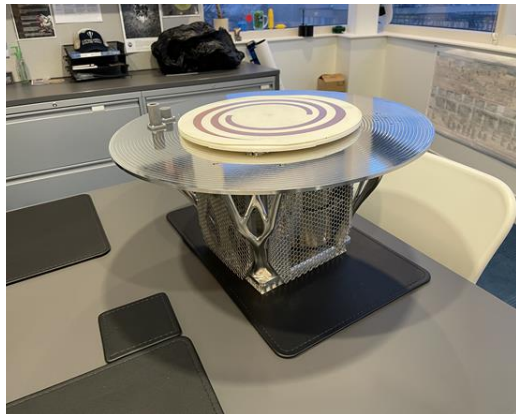

Figure 1. Full scale LLISSE lander model. Model contains many components that have successfully operated in Venus conditions for weeks to months.

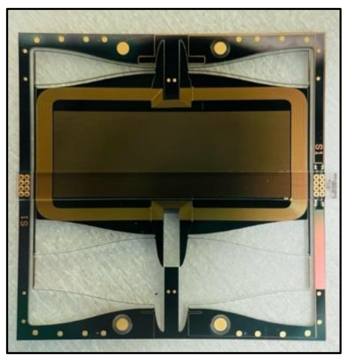

Figure 2. Seismic sensor from Insight mission (Produced by Imperial College London) - being re-designed for Venus surface operations.

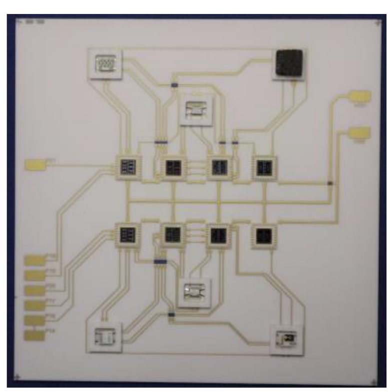

Figure 3. A 4.5” x 4.5” Ceramic Circuit – High Temperatuure Sic Chips And Chemical Sensors Array Integration

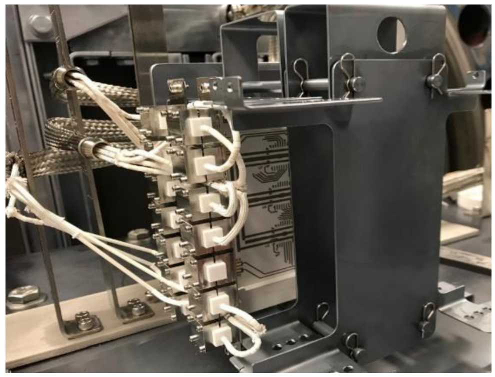

Figure 4. LLISSE Cube Test Structure: A Tested Framework to Integrate a Range of LLISSE electronic boards and sensors for testing in Venus simulated conditions

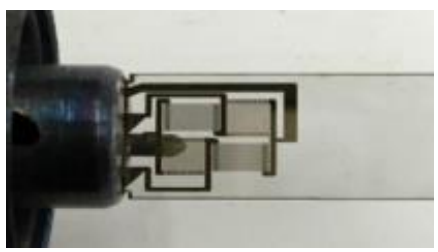

Figure 5. Wind sensor strain gage full bridge assembly. Tested and responsive in Venus simulated conditons