

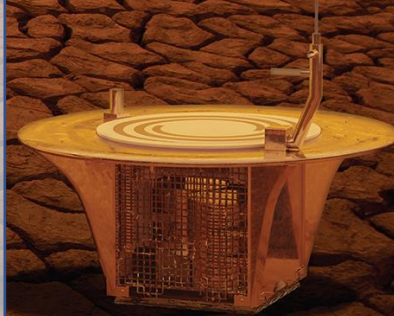
Capabilities for Long-Duration Landers in Extreme Environments

Tibor Kremic,
Chief Space Science Projects Office, NASA Glenn
PI for several system development projects for extreme environment applications

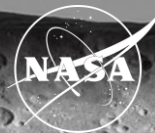
Outline



1. Motivation
2. Technical Challenges
3. Solution Approach and Capabilities
4. Development Status

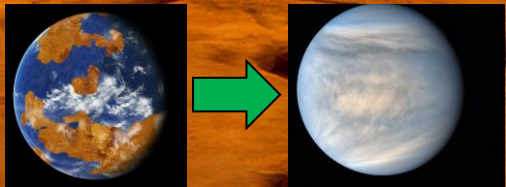


Science Motivation



- Venus and Earth have several similarities
- However, in many ways they are very different

Why?
How?



- Small surface landers like LLISSE will help answer these and other high-priority questions

- Understand surface composition and geology
 - E.g. What are the sources and processes for the unexpected abundance of volatiles on the surface (E.g. sulfur and sodium)
- Understand the nature of tectonic activity. History of the large core
- Understand the interactions and relationships between the weak magnetic field and the surface / solar winds

The Technical Challenges of Venus Surface Operations

Entry challenges due to velocities and nature of atmosphere of Venus

80 km

70 km

60 km

50 km

40 km

30 km

20 km

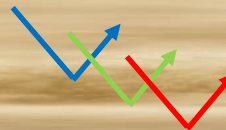
10 km

0 km Surface

Temperatures over 450°C



Layers of thick Sulfuric Acid clouds limit remote sensing below clouds



High Pressure – CO₂ laden atmosphere

Little solar energy reaches surface

Extreme temperatures kill lander electronics and systems.



Reactive Chemistry

Power at the surface is THE big challenge for surface missions



Crushing pressure

Essentially no magnetic field

-93° C

-43° C

-23° C

67° C

142° C

210° C

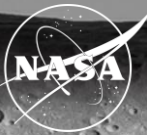
390° C

410° C

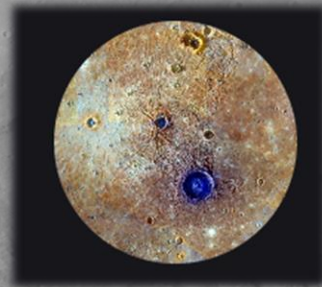
455° C

Technical Challenges on Mercury

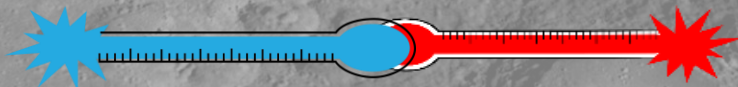
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Long day/night cycles
challenge thermal and
power systems



Challenges of capture, landing,
and orbit keeping of assets



Extreme Temperature ranges:
-180°C to 430°C

Communication to Earth,
especially by surface assets



Venus is more difficult for lander operations, in most cases.

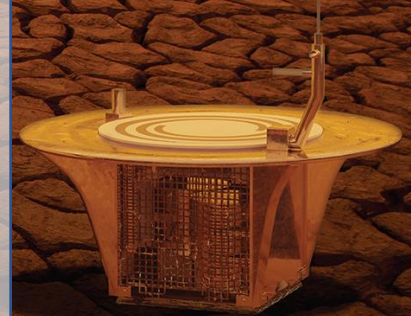
Rest of this talk is oriented toward Venus but captures most of Mercury needs as well

Solution Approaches to Tackling Challenges of Venus Surface Operations

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Space Administration



- For Venus, historical approach has been to use large thermal mass and slow down heat transfer into lander (~ 127 minutes – best lifetime to date)
- Our approach - leverage decades of development in high-temperature systems (E.g. jet engines)
 - Si electronics do not work at Venus temperatures, but SiC electronics can
- All aspects of lander(s) will be happy in harsh temperature, pressure, and chemical environment.
- Will enable first ever temporal science data from places like Venus (seismology, meteorology, chemical and physical variability / weathering)



Capability Summary for Venus

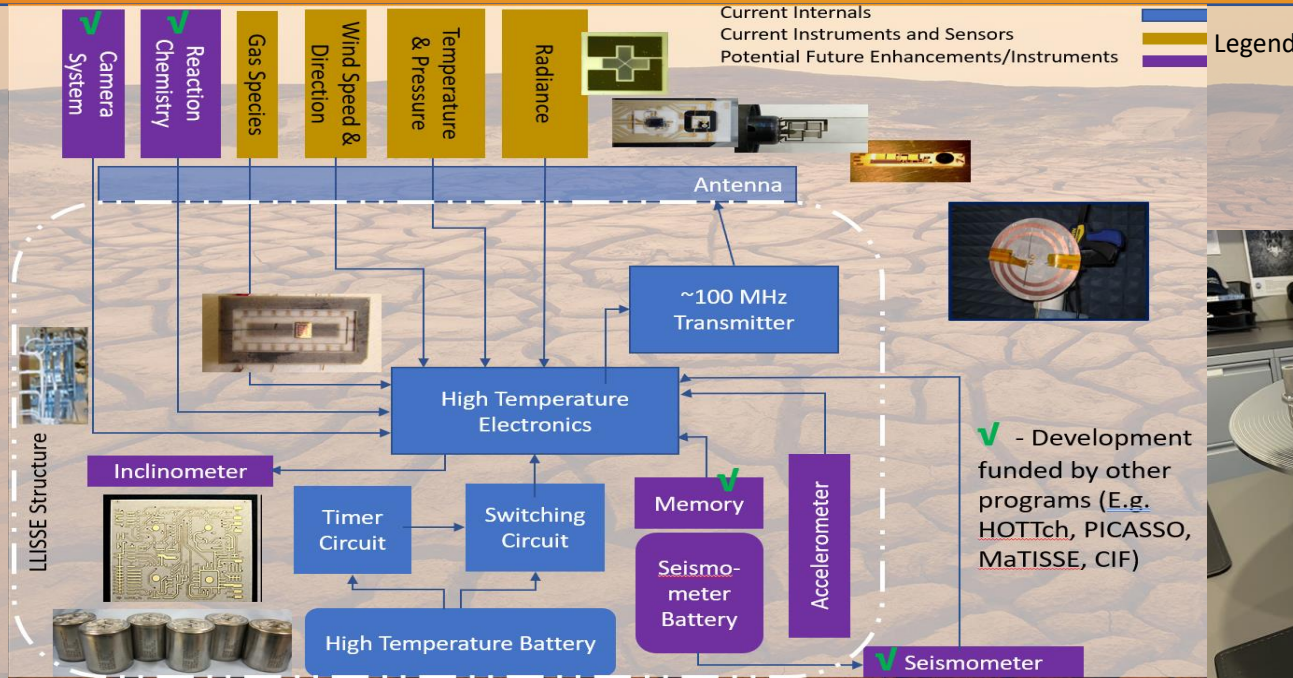
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- Sensors and electronics use SiC based architectures. Have already operated for 1000's hours at or above 500 C and in simulated Venus atmospheres. Also operated to temperatures down to -180 C.
- Battery systems alone can support 120 day missions. With potential trickle solar charging - could have indefinite life
- Structure will withstand entry and landing loads and execute simple post landing actions, if required (e.g. lift the mast, drop an instrument). Tolerate chemistry
- Communication system uses materials needed to achieve performance needs and be inert to reactive chemistry of the Venus atmosphere. Currently targeting VHF (100-150Mhz) but will be pushed higher as feasible.
- The unique Venus atmosphere properties enable a simple and robust landing system - only a drag plate.

Real Elements of a Long-duration Venus Lander

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- Technology advances being made under the LLISSE project are enabling the operation of a Venus lander for 120 days or longer (~15- 25kg depending on payload and lifetime)
- Lander transmits science data to an orbiter periodically and when a seismic event is occurring



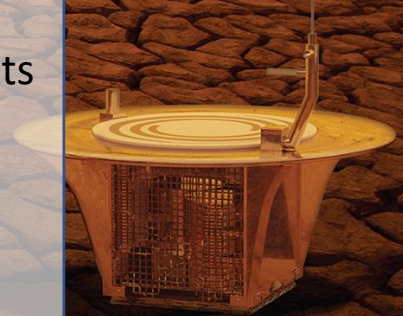
Full-scale mock up of a small Venus lander (LLISSE) with sensors, batteries, electronics, and communications system hardware, some of which have operated in Venus surface conditions for 60 days or longer (<15kg)

Development Status

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- A tremendous amount of progress has been made
- Status:
 - Robust high-temperature electronics fabrication in process
 - High-temperature batteries
 - Battery tested at temp. and under simulated loads for ~120 days
 - Antenna material confirmed and critical communication components in fabrication
 - High-temperature instruments & sensors
 - Varying technology readiness levels.
 - Operation of most sensors and core electronics in simulated Venus environment have been demonstrated several times and for long durations (E.g. 60 days)





Questions?