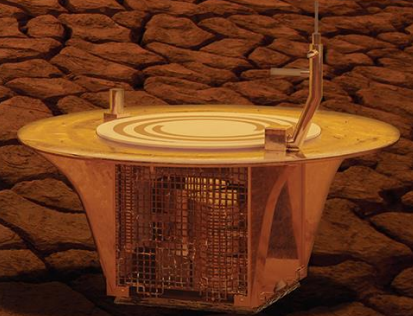




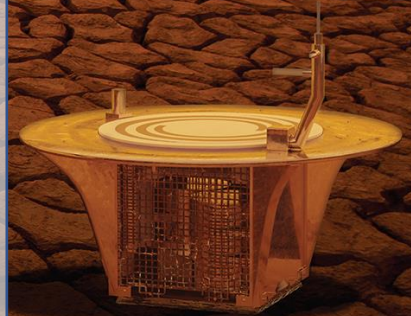
Venus Surface Mission Capabilities



Outline



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



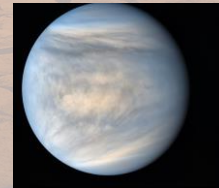
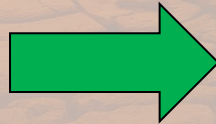
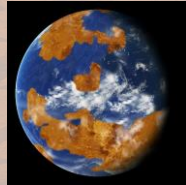
Motivation: Venus Scientific Goals

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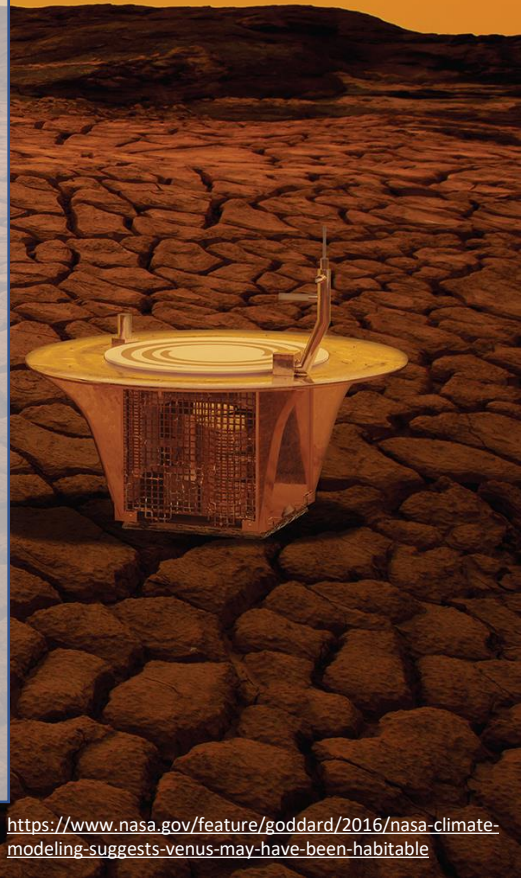
- Venus and Earth have several similarities
 - Almost same size, location in the solar system, mass
- However, in many ways they are very different
 - Atmosphere composition, temperature, H₂O, magnetic field, spin, etc...

Why?
How?



- Small In situ landers like LLISSE, or the SAEVe lander concept, will help answer these and other other high-priority questions such as:

- *How volcanically and tectonically active is Venus today?*
- *What may we learn about exoplanets - from our backyard?*
- *Why and when did the climates of Venus and Earth diverge?*



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

-93° C

-43° C

-23° C

67° C

142° C

210° C

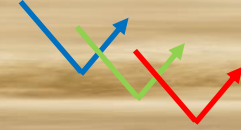
390° C

410° C

455° 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.

Power at the surface is THE big challenge for surface missions

Temperatures over 450°C



Reactive Chemistry



Crushing pressure



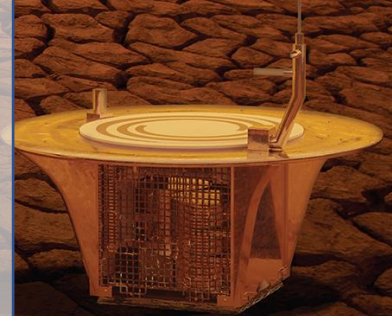
Essentially no magnetic field

Solution Approaches to Tackling Challenges of Surface Operations

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- Historically approach has been to use large thermal mass and slow down heat transfer into lander (~ 127 minutes – best lifetime to date)
 - Same general approach planned for next Venus probe - DaVinci
- 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 do
- Make all aspects of lander(s) to operate nominally in harsh temperature, pressure, and chemical environment
- Focus on enabling science with small and simple landers



Capability Summary

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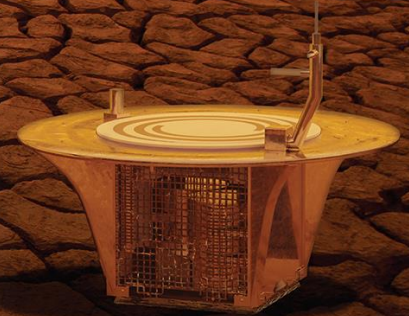
- Sensors and electronics will be based on SiC devices / architectures. Have already operated for 1000's hours at or above 500 C and in Venus atmosphere.
- Power system will support 120 day mission using only primary batteries. With potential solar or wind trickle charging - could have indefinite life
 - Simple Concept of Operations is planned: initial 1 hour full system operations then "normal" operations mode being 8 hours sleep/time keeping and then 2 minutes of data collection and transmission, ... repeat. - science beacon
 - If a seismometer is included in the science payload, it would monitor for motion and, if detected, capture and send seismic data for 10 minutes then return to normal mode.
- 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

Capability Summary Continued

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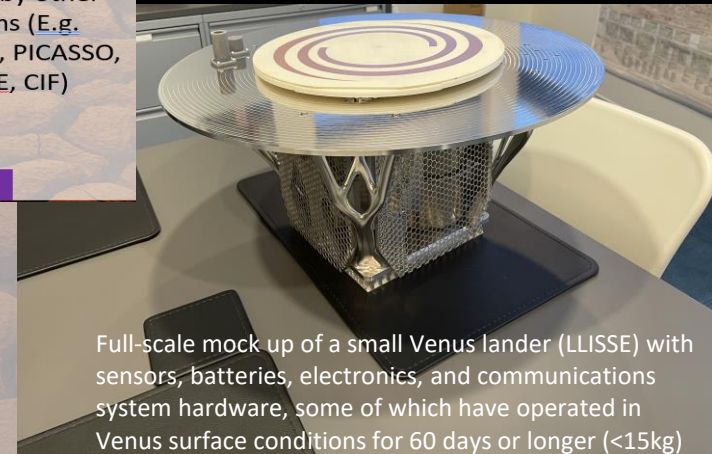
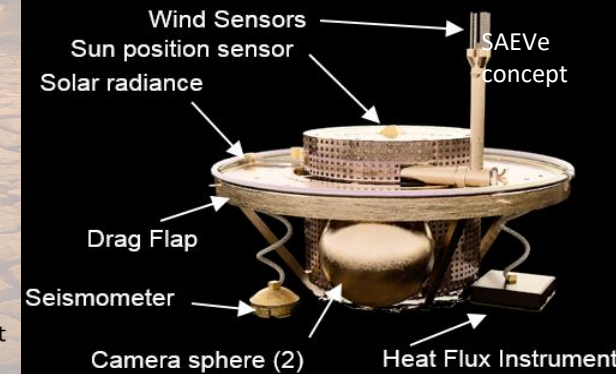
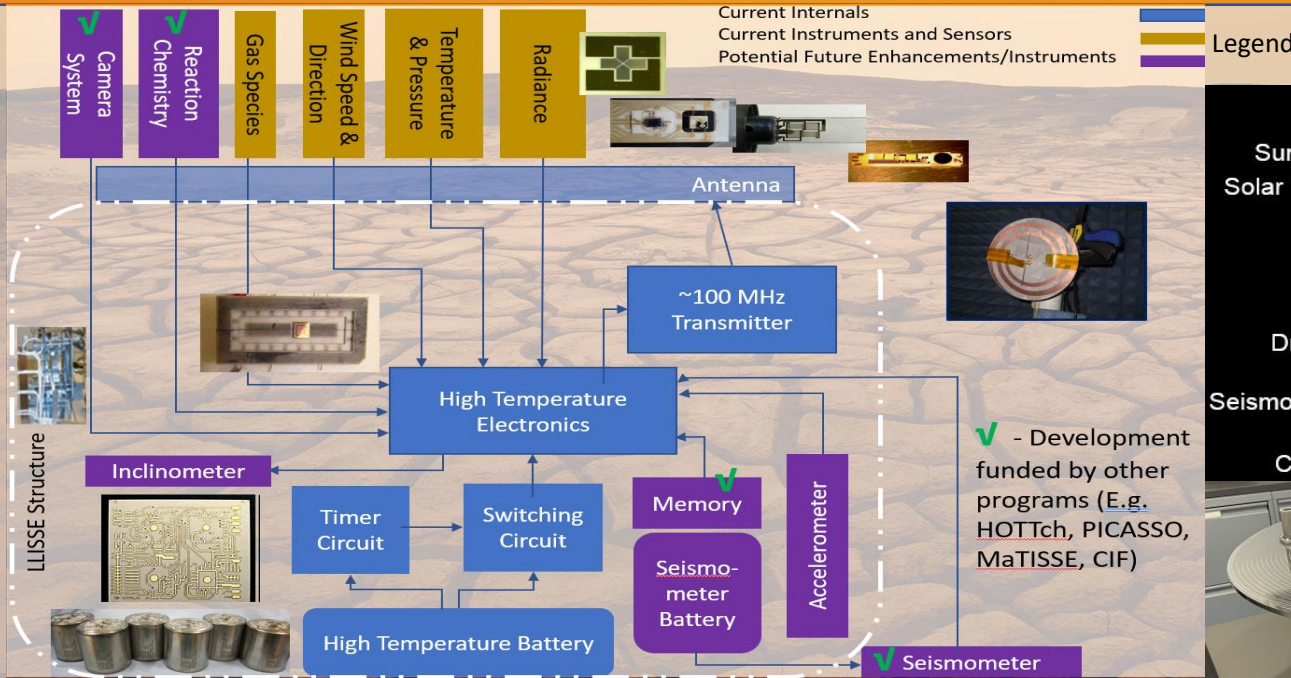


- Communication system uses materials needed to achieve performance needs and be inert to reactive chemistry of the atmosphere. Currently targeting VHF (100-150Mhz) but will be pushed higher as capability is realized.
- Venus atmosphere properties enable a very simple and robust landing system - only a drag plate.



Long-duration Venus Lander Characteristics

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- Technology advances being made under the LLISSSE project are enabling the operation of a Venus lander for 120 days or longer
- The SAEVe concept which would use LLISSSE subsystems but adds life and more instruments would be ~ 25 kg, operate for 120 days or more, and ~50cm at widest point
- The SAEVe lander would transmit science data to an orbiter periodically and when a seismic event is occurring

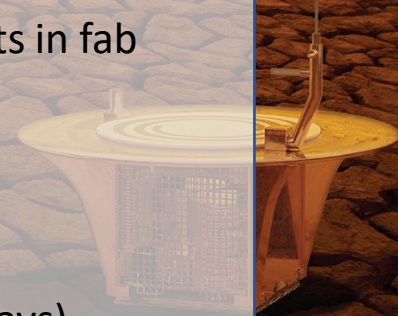
Full-scale mock up of a small Venus lander (LLISSE) with sensors, batteries, electronics, and communications system hardware, some of which have operated in Venus surface conditions for 60 days or longer (<15kg)

Development Status

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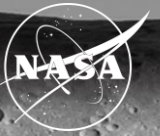


- Much progress has been made under the LLISSE project
- Status:
 - Robust high-temperature electronics fabrication in process
 - High-temperature batteries tested at temp. and under simulated loads for ~120 days
 - Antenna material identified and critical communication components in fab
 - High-temperature instruments & sensors
 - Varying technology readiness levels.
 - Seismometer in development under a different project
 - Operation of most sensors and core electronics in simulated Venus environment have been demonstrated for long durations (E.g. 60 days)
- *Happy to discuss how this may contribute to your mission interests*



Mercury Science Can Also be Enabled

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- Much of the hardware being developed for Venus could also contribute to a Mercury lander mission (dayside operations)
- The same electronics and sensors that enable operations at 460 C also operate down to -180 C
- The capabilities discussed could enable Mercury science via dayside operations. This could include:
 - *Understanding active processes at the surface of Mercury involved in producing the exosphere and altering surficial materials.*
 - *Understanding Mercury's interior including its structure, tectonic activity, and the operation of the magnetic field.*

Questions?

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