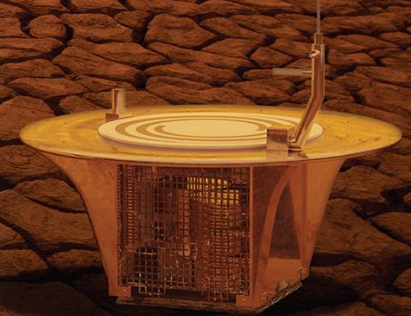




Preparing For Venus Insitu Surface Science, Including Seismometry



Presented by: Tibor Kremic, Principal Investigator
Presented to: University of Fairbanks faculty, staff and students
June, 2023

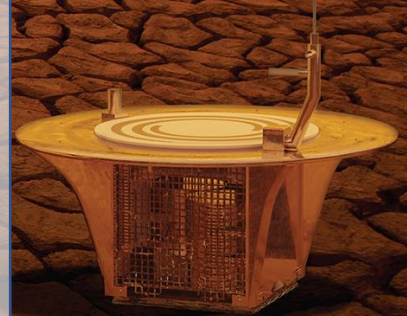
Motivation: Venus Scientific Goals

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Outline

1. Science Motivation and Challenges
2. Long-Duration Lander Characteristics
3. Status of System / Capability



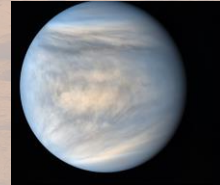
Motivation: Venus Scientific Goals

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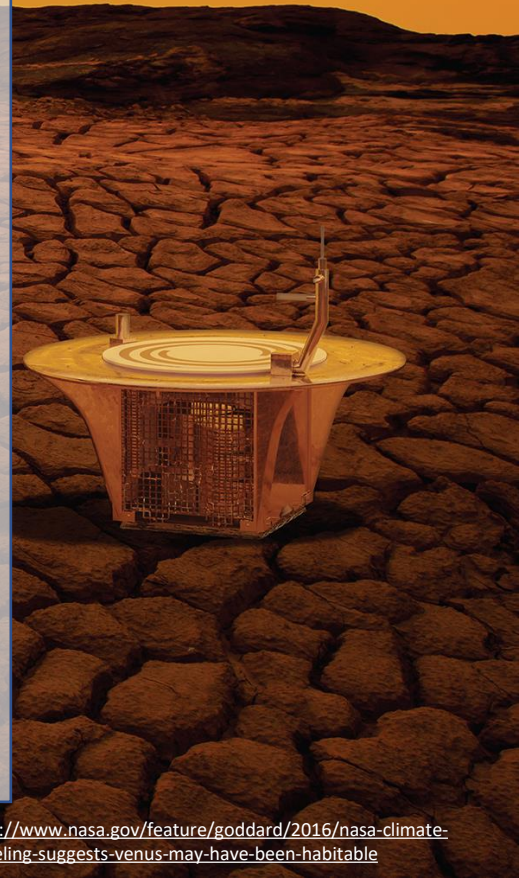
- Venus and Earth have several similarities
 - Almost same size, location in the solar system, mass, composition
- However, in many ways they are **very** different
 - Atmosphere, temperature, water, magnetic field, etc...

Why?



- Insitu small surface landers like the Seismic and Atmospheric Exploration of Venus (SAEVe)¹ may help answer this and other high-priority questions such as:
 - *How volcanically and tectonically active is Venus today?*
 - *Why and when did the climates of Venus and Earth diverge?*

Ref 1: Long-duration Venus Lander for seismic and atmospheric science, Kremic et al, Planetary and Space Science 190 (2020) 104961



Motivation: Venus Scientific Goals

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- The SAEVe (**S**eismic and **A**tmospheric **E**xploration of **V**enus) lander is a small long-duration lander concept designed to help address the Venus science objectives
- SAEVe's unique strengths are acquiring *In situ temporal data from the Venus surface*
 - Venus seismicity, lithosphere structure and bulk composition
 - Meteorology, Chemistry variability
- SAEVe also contributes to rock and soil distribution and morphology, estimating momentum exchange, surface energy balance, and potentially more

2 Landers

Science Objectives Tackled

- 1) Determine if Venus is seismically active and characterize the rate and style of activity,
- 2) Determine crust and lithosphere thickness and composition
- 3) Acquire temporal meteorological data to guide global circulation models
- 4) Estimate the momentum exchange between the planet and its atmosphere
- 5) Measure atmospheric chemistry variability
- 6) Determine current rate of heat loss from the Venus interior
- 7) Examine rock and soil distribution and morphology

One Lander

Science Objectives Tackled

- 1) Determine if Venus is seismically active and characterize the rate and style of activity,
- 2) Acquire temporal meteorological data to guide global circulation models
- 3) Estimate the momentum exchange between the planet and its atmosphere
- 4) Measure atmospheric chemistry variability
- 5) Determine current rate of heat loss from the Venus interior
- 6) Examine rock and soil distribution and morphology

De-Scoped Lander

Science Objectives Tackled

- 1) Determine if Venus is seismically active and characterize the rate and style of activity,
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Science Ladder

Fun Facts / Mysteries about Venus

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Similar to Earth
but Sooo..
Different

Layers of Acid Clouds

Winds at Tornado
like speeds

Crushing pressure



Temps approaching 900°F



Some of 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

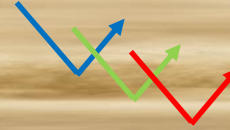
10 km

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

Approach to Tackling Challenges

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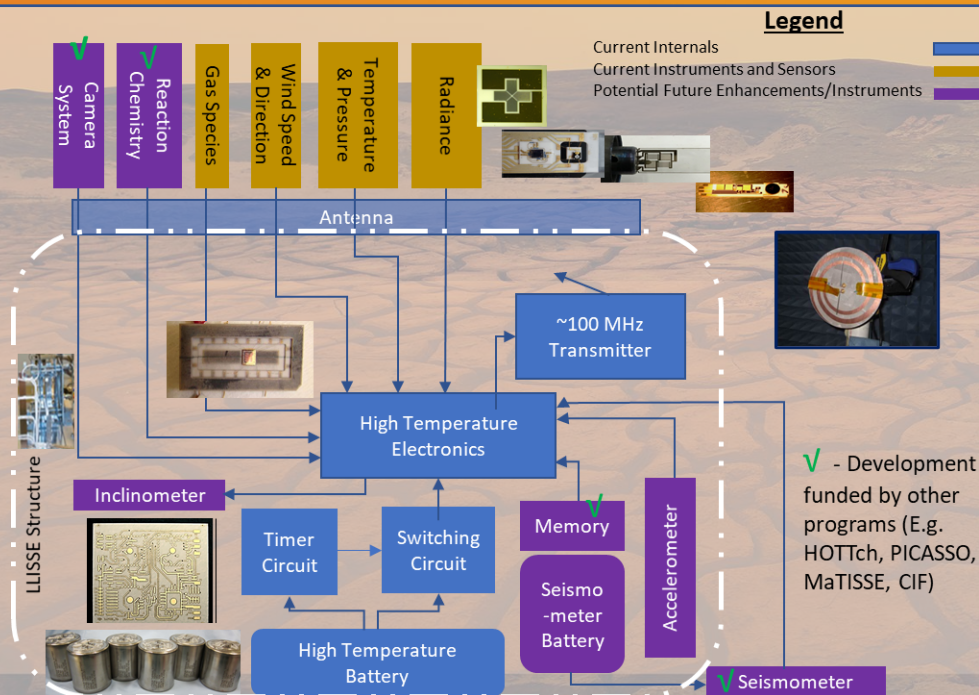


- Historically approach has been to use large thermal mass and slow down heat transfer into lander ~ 127 minutes – best lifetime to date
 - Same general approach planned for DaVinci
- Our approach - leverage decades of development in high-temperature systems
 - Si electronics do not work at Venus temperatures, but SiC electronics do
- All aspects of lander(s) will be happy in harsh temperature pressure and chemical environment
- Simple small landers will operate for 120 days returning science via an orbiter (~3 times per day plus whenever a seismic event occurs)
- SAEVe is a larger version of the Long-Lived Insitu Solar System Explorer (LLISSE) project which has been developing the system capabilities



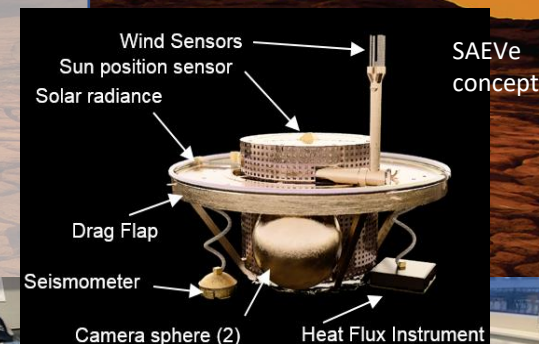
Long-duration Venus Lander Characteristics

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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
- SAEVe, which uses LLISSSE subsystems and adds life and more instruments is anticipated to be ~ 25 kg, operate for 120 days or more, and ~50cm at widest point
- Landar transmits science data to an orbiter periodically and when a seismic event is occurring

Approved for Public Release

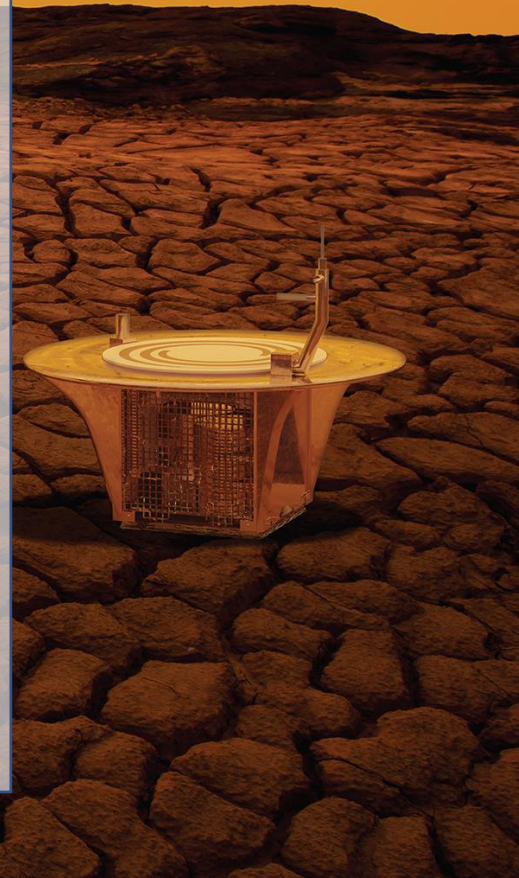


Differences from SOA Terrestrial Applications

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- Little to no a priori knowledge of seismic activity on Venus (magnitude, frequency, background noise, etc...)
 - Evidence in form of surface features from radar data
- Simple architecture / system is required. Ultra simple deployment(s), currently lander is planned to be totally autonomous (currently no receive capability)
- No long-duration power sources – limited energy for a mission
 - Highly constrained power budget
 - Drives concept of operations, volume of data that can be returned, and mission lifetime
- High temperature electronics have reduced performance relative to standard electronics. Slower operating frequency and lower data resolution

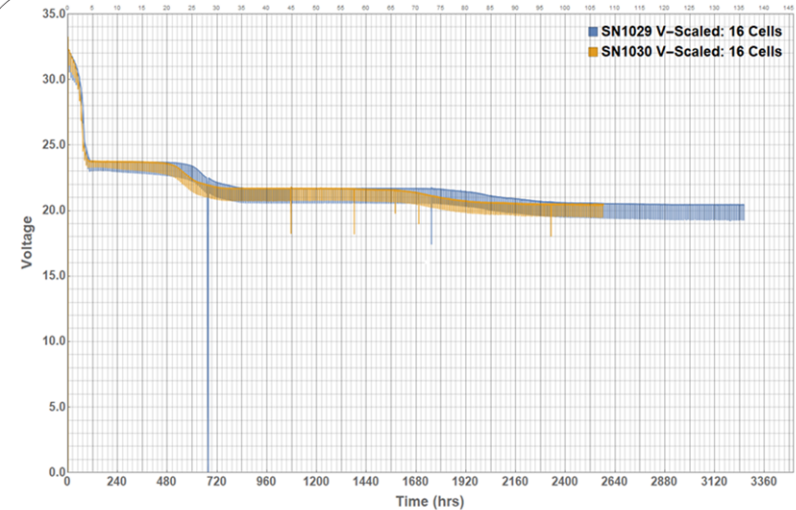
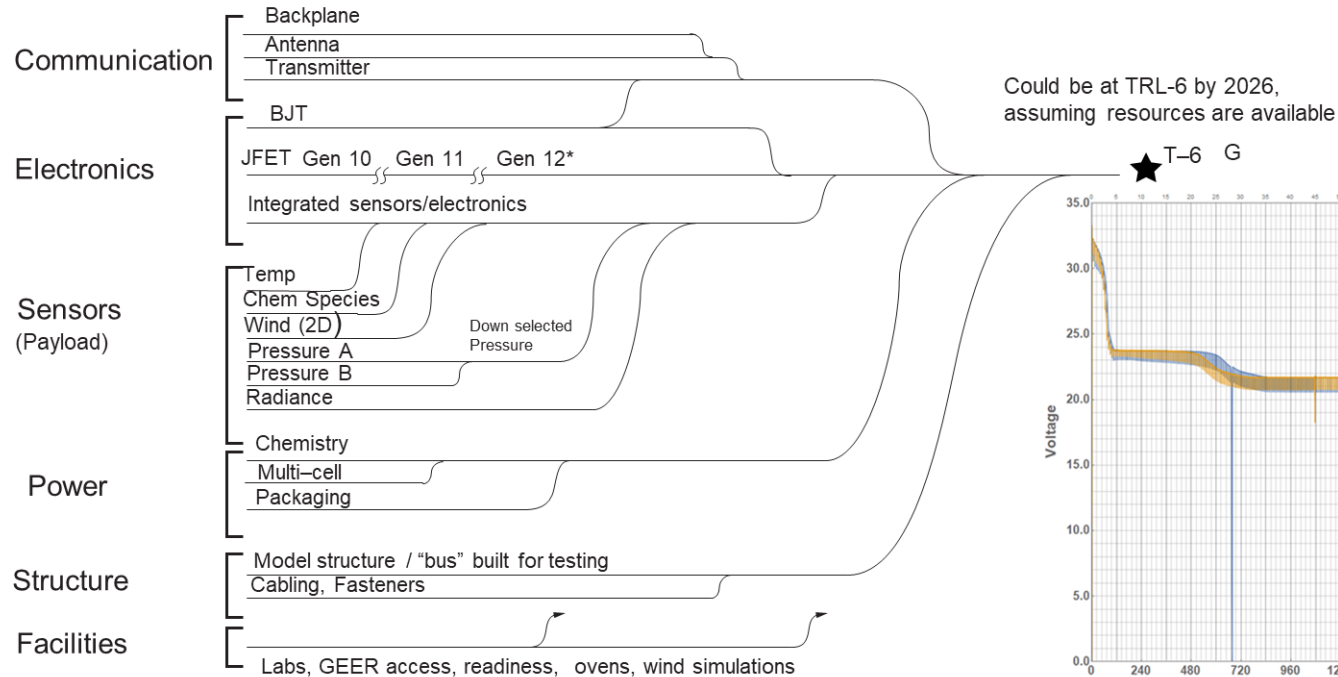


Development Flow

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* Gen 12 is level needed to execute a
LLISSE science mission



Legend: DG-X Decision gate G - GEER test (1 test can support multiple components)
T-X TRL Level A - Anticipated TRL at end of currently funded effort

Development Status

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- A tremendous amount of progress has been made on the needed capabilities under the LLISSE project
- SAEVe directly uses LLISSE subsystems and adds instruments and larger battery
- Status:
 - Robust high-temperature electronics fabrication in process
 - High-temperature batteries
 - Battery tested at temp. and under simulated loads for ~120 days
 - Project efforts now focused on packaging
 - Antenna material verification in process
 - Critical communication components in fabrication
 - High-temperature instruments & sensors
 - Varying readiness level – TRL 2 to 5+. Most ~ TRL 4
 - Seismometer in development under a HOTTech-2 project, with UAF support
 - Operation of most sensors and core electronics in simulated Venus environment have been demonstrated several times and for long durations

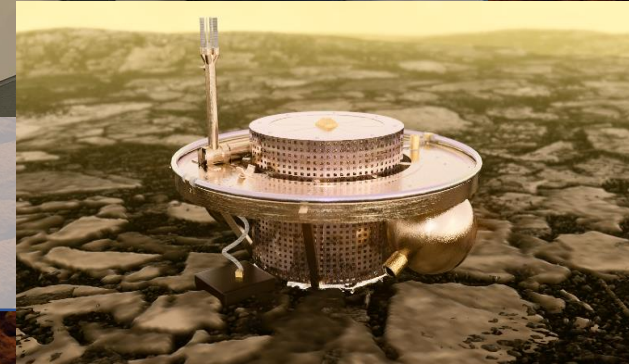
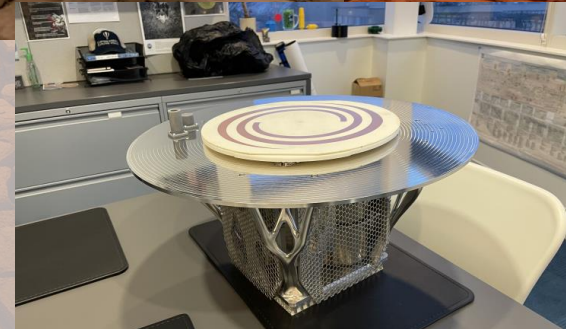


Major Take Aways

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- Continuing to maturing technology and engage potential mission partners
 - Could support a mission late in 2020's, with resource availability
- Hardware exists for sub-systems and various levels of testing have been completed
- Major SAEVe instrument, the seismometer, also in development under HOTTech-2, low power memory as well
- Happy to discuss more potential collaborations





Questions?