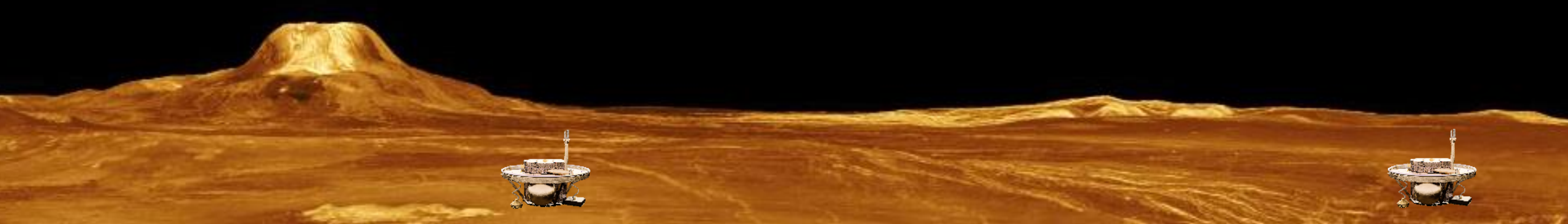
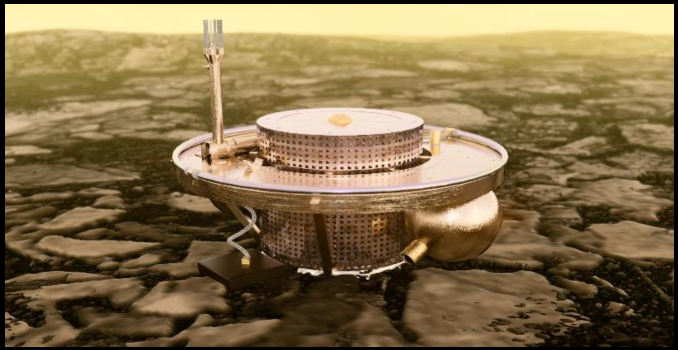
SAEVe (Seismic and Atmospheric Exploration of Venus)

A long – lived lander concept for Venus

Presented by Tibor Kremic (NASA GRC) on behalf of the SAEVe team



SAEVe Overview



Tibor Kremic	NASA Glenn Research Center
Richard Ghail	Imperial College London
Martha Gilmore	Wesleyan University
Gary Hunter	NASA Glenn Research Center
Walter Kiefer	Lunar and Planetary Institute
Sanjay Limaye	University of Wisconsin
Michael Pauken	Jet Propulsion Laboratory
Colin Wilson	University of Oxford

Science Team Members/Institutions

PM and study support by Carol Tolbert and the GRC COMPASS **team**

Science Objectives:

1) Determine if Venus is seismically active and characterize the rate and style of activity
2) Determine the thickness and composition of the crust
3) Acquire temporal near surface meteorological data to guide global circulation models
4) Estimate moment 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

Mission Overview:

Two landers delivered to Venus via ride along

- Landers enter Venus atmosphere via Genesis like entry capsules
- Landers descend through the thickening atmosphere
- Turn themselves on and begin transmitting science data at pre-determined intervals
- **Operate for 120 days, 3 orders magnitude > than current record**

Landers will:

Measure seismic activity, heat flux, wind speed and direction, incident and reflected solar radiation, abundance of selected atmospheric species and ambient temperature and pressure — **over a period of 120 days!**

Transmit the data to an orbiting spacecraft/comm relay, at preset intervals *(orbiter by others)*

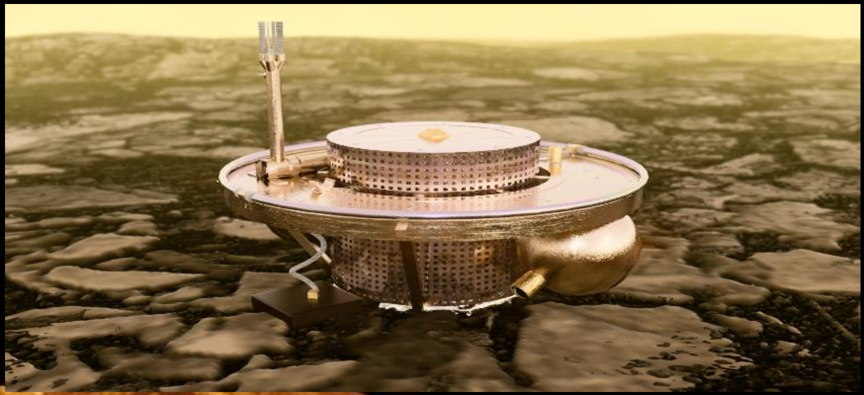
Validate high-temperature and pressure technologies paving the way for larger, more complex Venus lander missions in the future

SAEVe revolutionizes our paradigm for exploring the deep atmosphere, surface, and geophysical activity of Venus via enabling new technologies

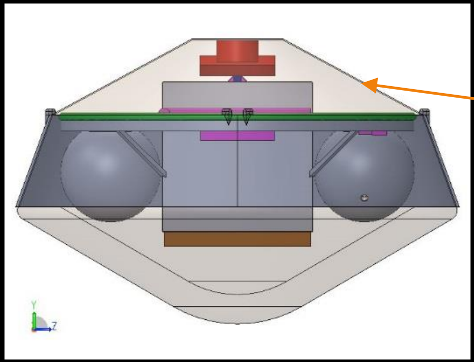
Approved for public release

SAEVe Basics

- SAEVe is a compact lander concept based on high temperature systems being developed under the LLISSE project
- The concept as costed includes two stations that are placed 300 - 800 km apart
- Each station has its own entry shell, and is carried and released by the orbiter
- Stations would operate for 120 days (> 1 Venus solar day)
- Transmits periodically – except when seismic event detected – LLISSE approach



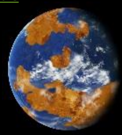
~.5 m



Aeroshell containment

60 cm

https://www.nasa.gov/feature/goddard/2016/nasa-climate-modeling-suggests-venus-may-have-been-habitable



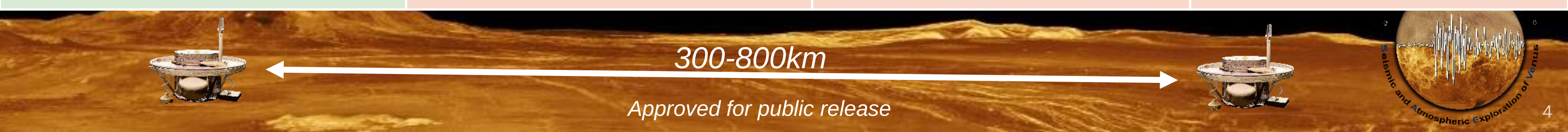
SAEVe Science

?

http://www.planetary.org/multimedia/space-images/venus/venus-in-ultraviolet-from-akatsuki.html

How volcanically and tectonically active is Venus today?
Why and when did the climates of Venus and Earth diverge?

Decadal Survey Goals	SAEVe Science Objectives	Measurements	Instrument Requirements
A) Characterize planetary interiors	1) Determine if Venus is currently active, characterize the rate and style of seismic activity	Measure seismic waveform of seismic waves Concurrent wind data at time of seismic measurement	3-axis (1 axis) seismometer 3-axis wind sensor
	2) Determine the thickness and composition of the crust and lithosphere	Same as above	Two stations with instrumentation as above
B) Define the current climate on the terrestrial planets	3) Acquire temporal meteorological data	Measurement of p, T, u, v and light	3-axis wind sensor measurements, radiance
	4) Estimate momentum exchange between the surface and the atmosphere	Same as above	Same as above during Venus day and night
C) Understand chemistry of the middle, upper and lower atmosphere	5) Determine the key atmospheric species at the surface over time	Measure the abundance of gases H_2O, SOx, CO, HF, HCl, HCN, OCS, NO, O_2	Chemical sensor measurements during descent and on surface
D) Understand the major heat loss mechanisms	6) Determine the current rate of energy loss at the Venus surface	Measure heat flux at Venus surface	Heat flow measurements, surface temperature, radiance
E) Characterize planetary surfaces	7) Determine the morphology of the local landing site(s)	Quantify dimensions, structures and textures of surface materials on plains unit based on 5 images	Cameras: descent and landed

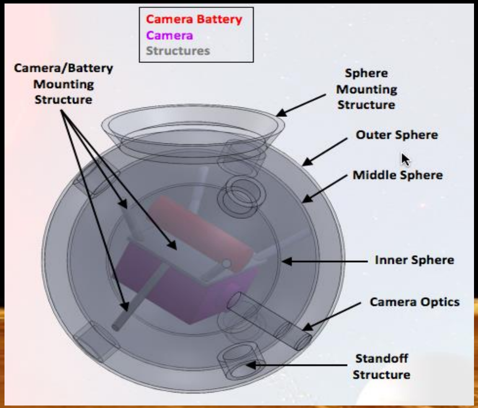


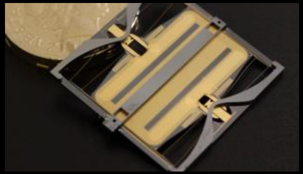
Rationale for Instruments / Sensors

Core science centers around ***long term*** measurements to obtain meteorological and seismic data over 1 Venus solar day (120 Earth days)

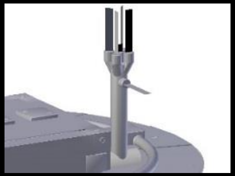
Instrument set includes:

- A 3-axis micro-machined Micro-Electro-Mechanical Systems (MEMS) seismometer (0.3 kg)
- Meteorological sensor suite (temperature, pressure, wind speed & direction, solar radiance, atmospheric chemical species abundances), and solar position sensors (0.7 kg) – LLISSE payload
- 2 COTS Cubesat cameras (0.1 kg each)
- Heat Flux instrument (0.3 kg)



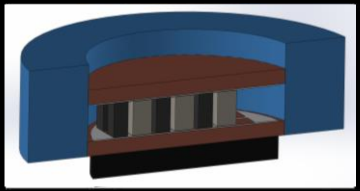


MEMS seismic event sensor
Courtesy: Tom Pike



Courtesy of D. Makel, Makel Engineering, Inc.

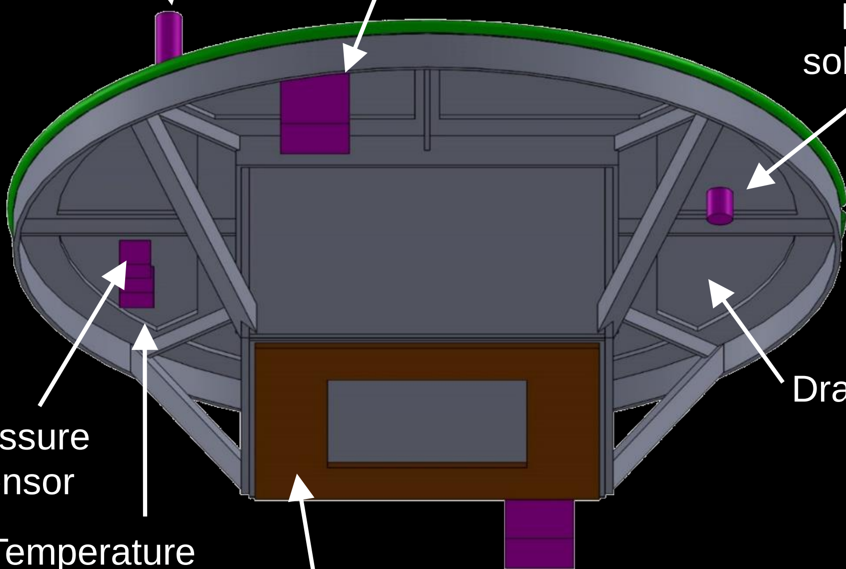
Sensors images – Courtesy: NASA GRC



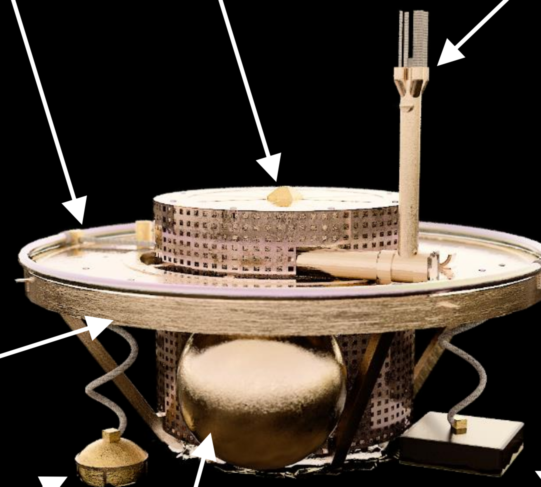
Heat Flux sensor - Courtesy: Mike Pauken

Approved for public release

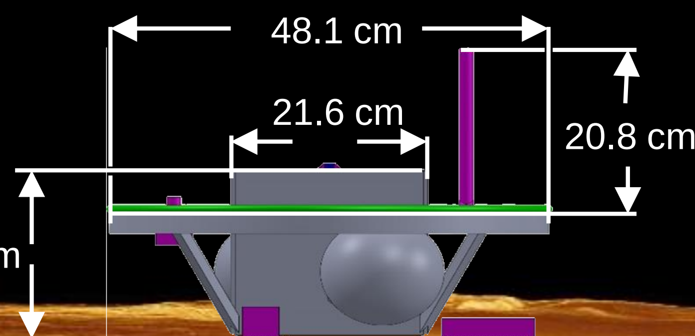
Lander Configuration



Note: Camera spheres and heat flux instrument not shown in this figure for clarity



Note: Antenna shown in image is backup approach using UHF Loop Antenna (1.5 m Circumference). Primary approach is planar spiral – 24 cm diameter



29 kg - < 50kg with entry shell

The Operations

- SAEVe will operate for > 120 days
- Communications and seismic monitoring are main energy users and hence, main limiters of lander lifetime
- Communications with orbiter is assumed to be for 2 min every 8 hr
  - Actual timing and frequency will be negotiated with orbiter
  - Opportunities exist to extend life
- When seismic event detected, SAEVe goes from 1 axis monitoring to transmitting signals from all 3 axis within 100 ms and continues that for 10 min

Approved for public release

Technology Readiness / Cost

- Major subsystems and instruments are currently at TRL 3-4 (lowest TRL components are seismometer & battery)
- Most elements of SAEVe are in ongoing development that will take them to ~ TRL 6 by 2021
- Cost for two stations is estimated to be $106M

Technology	Current TRL	Estimated to be at TRL 6	Funding Source: Ongoing (O) (to TRL 6) and Potential (P)
Electronic circuits (SiC): sensors and data handling	4-5	2019	LLISSE (O)
Electronic circuits (SiC): power management	3-4	2021	LLISSE (O)
Communications (100 MHz)	3-4	2021	LLISSE (O)
Wind Sensor	4	2019	LLISSE (O)
Temperature Sensor	4-5	2019	LLISSE (O)
Pressure Sensor	4-5	2019	LLISSE (O)
Chemical Sensors	5	2019	LLISSE/HOTTech (O)
Solar Radiance	3-4	2021	LLISSE (O)
Seismometer	3	TBD	LISSE (O) and possibly MaTISSE (P)
Heat Flux Sensor	3-4	TBD	PICASSO (O) - MaTISSE
Camera / imaging System	3-4	2020	Rocket University (O) – MaTISSE if needed
High-Temp Battery	3	2019	LLISSE and HOTTech (O)
Entry Shell	4-5	TBD	HEET – need Venus specific design

Approved for public release

SAEVe will revolutionize our paradigm for exploring the deep atmosphere, surface, and geophysical activity of Venus. This is enabled by new advances in high temperature electronics and systems.

SAEVe will operate on the surface of Venus for an unprecedented 120 days (full Venus solar day) returning seismic, meteorology, and energy deposition / release data

The SAEVe mission can be implemented for ~ $100M and would be an ideal candidate to ride along with a future Venus orbiter mission

SAEVe would serve as a pathfinder to prepare for larger and more capable landers in the future

Approved for public release

Thank you. Questions?

NASA

GRC

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

SAEVe
Seismic and Atmospheric Exploration of Venus

WESLEYAN
UNIVERSITY

JPL
Jet Propulsion Laboratory

Imperial College
London

UNIVERSITY OF
OXFORD

LUNAR AND
PLANETARY
INSTITUTE

Approved for public release