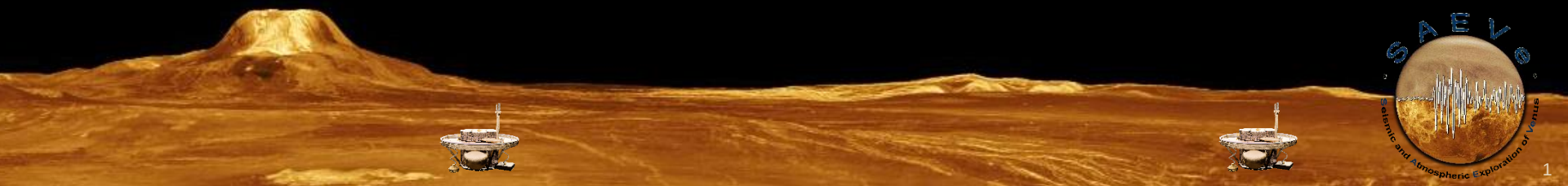
A Potential Venera-D Element : SAEVe (Seismic and Atmospheric Exploration of Venus)

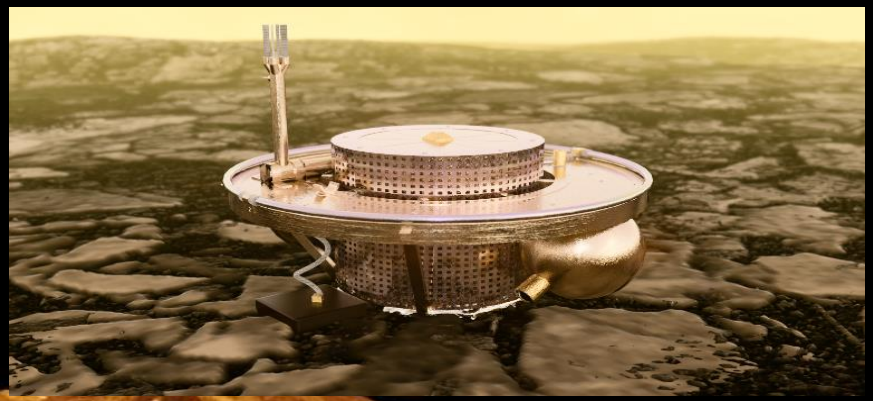
A lander concept that adds seismology, morphology, and heat flux measurements to a LLISSE-like platform

Tibor Kremic
NASA Glenn Research Center
Cleveland, Ohio

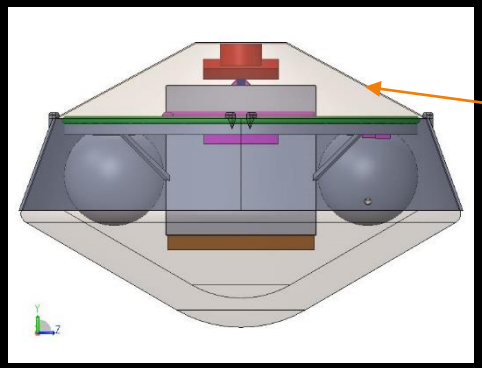


SAEVe Basics

- SAEVe is a compact lander concept based on LLISSE developments and capability
- The concept includes >1 SAEVes that are placed 300 - 800 km apart
- Each SAEVe has own entry shell , and is carried and released by the orbiter
- SAEVe stations would operate for 120 days, > 1 Venus solar day
  - Adds important new science capability in addition to longer life
- LLISSE approach is used, only transmits periodically – except when seismic event detected

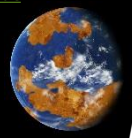


~.5 m



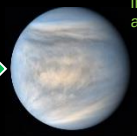
60 cm

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, SO_2, 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

300-800km

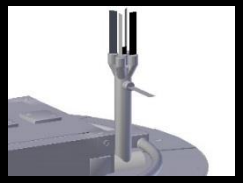
Rationale for Instruments / Sensors

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

Instrument set includes:

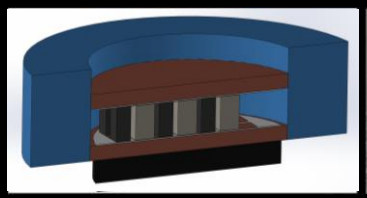
- A 3-axis micro-machined Micro-Electro-Mechanical Systems (MEMS) seismometer (0.3 kg)
- Meteorological sensor suite (temperature, pressure, wind speed & direction, solar radiance, atmospheric chemical species abundances), and solar position sensors (0.7 kg)
- 2 COTS Cubesat cameras (0.1 kg each)
- Heat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

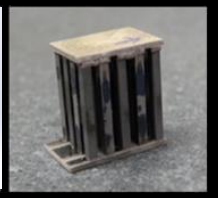
MEMS seismic event sensor
Courtesy: Tom Pike



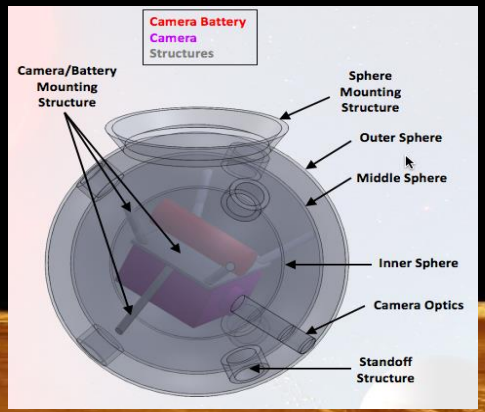
Courtesy of D. Makel,
Makel Engineering, Inc.

Sensors images – Courtesy: NASA GRC

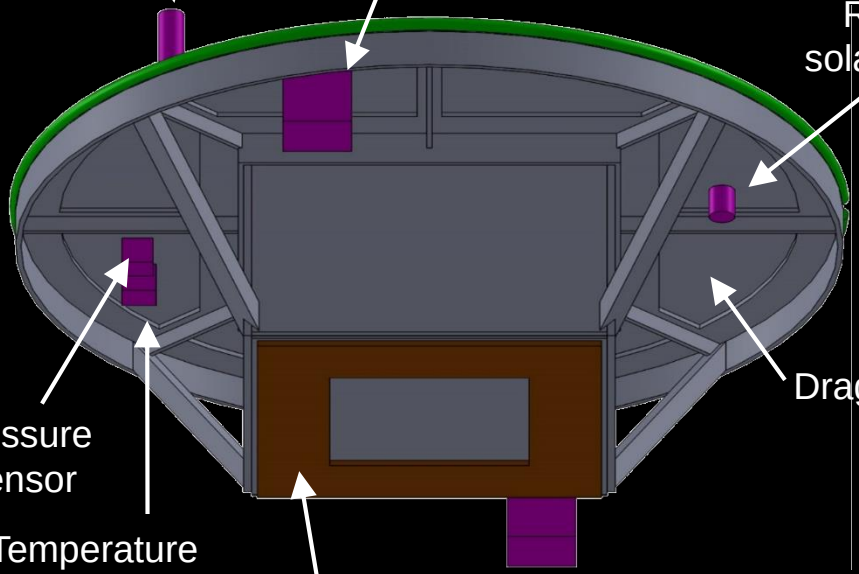


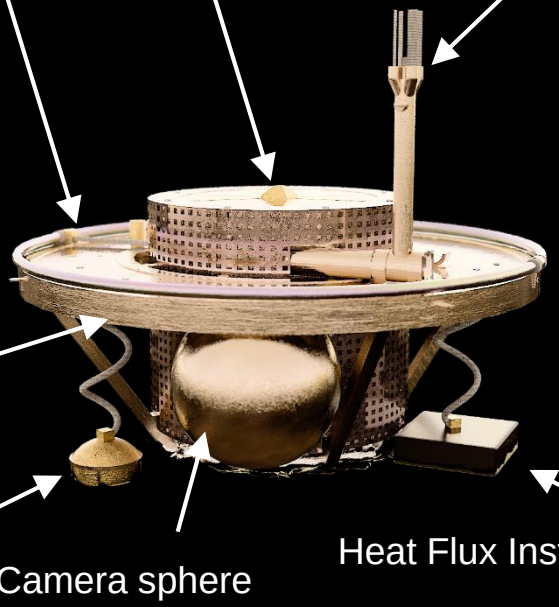


Heat Flux sensor - Courtesy: Mike Pauken



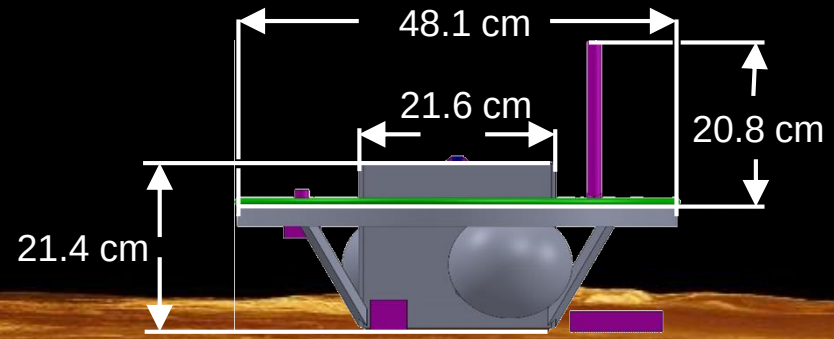
Lander Configuration





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

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



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 (e.g., < 2 min comm. or more battery)
- When seismic event detected, SAEVe will transmit data from all 3 axis within 100 ms and continue for 10 min
- During mission multiple pre-programmed seismic trigger levels may be employed

Technology Readiness

- 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**

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	Aug 2019	LLISSE (O)
Electronic circuits (SiC): power management	3-4	Sept 2021	LLISSE (O)
Communications (100 MHz)	3-4	Sept 2021	LLISSE (O)
Wind Sensor	4	Aug 2019	LLISSE (O)
Temperature Sensor	4-5	Aug 2019	LLISSE (O)
Pressure Sensor	4-5	Aug 2019	LLISSE (O)
Chemical Sensors	5	Aug 2019	LLISSE/HOTTech (O)
Bolometers	3-4	Sept 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	Sept 2020	Rocket University (O) – MaTISSE if needed
Solar Radiance	3-4	Sept. 2021	LLISSE (O)
High-Temp Battery	3	Aug 2019	LLISSE and HOTTech (O)
Entry Shell	4-5	TBD	HEET – need Venus specific design