SAEVe : A mission concept for Seismic and Atmospheric Exploration of Venus

The Seismic and Atmospheric Exploration of Venus (SAEVe) is a mission concept to deliver two landers to the surface of Venus and have them return high value science for 120 days, over three orders magnitude longer than anything previously achieved! The science implemented by SAEVe is focused on seismometry and temporal meteorology, long standing gaps in our data on Venus and measurements that offer the most benefit from long duration operations. Table 1 presents the science objectives targeted by SAEVe.

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 (triggered)/ 1 axis continuous) 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, 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.	Descent and surface images

Table 1. *SAEVe Science Traceability*

The remarkable operating life of SAEVe is enabled by three key elements, 1) high temperature electronics and systems that operate without cooling at Venus surface conditions, 2) use of simple instrumentation and supporting avionics—with emphasis on low data volume instruments and sensors, and 3) minimizing energy utilization through a novel operations approach. Integrating these elements into an innovative mission concept allows SAEVe to return high-value science while meeting study objectives.

Each SAEVe lander will weigh approximately 25 kg (~ 40 kg together with aeroshell) and will carry a suite of synergistic instruments and sensors. The instruments in priority order are: seismometer, meteorology suite (which includes temperature, pressure, two or three dimension wind speed and direction, atmospheric chemical specie abundances, incident and reflected solar radiance sensors), an imaging package consisting of two cube sat cameras which will operate only a short time at the beginning of the mission. The potential addition of a heat flux sensor has been explored and could be considered as well. A sun position sensor set is also included as a demonstration of a potential simple technique to determine orientation of the lander relative to the surface.

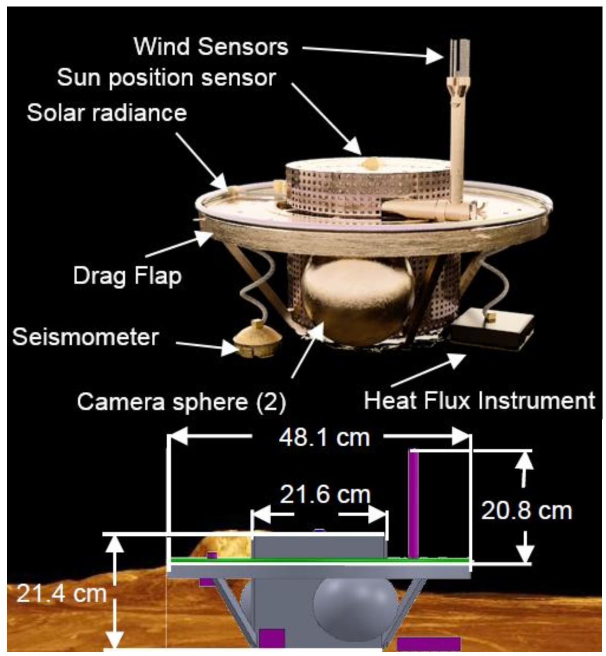

Figure 1.
SAEVe Lander Concept with Subset Instruments and Basic Dimensions

SAEVe is assumed to be delivered to Venus along with a short duration lander or by a Venus orbiting mission. SAEVe could also be a candidate for a SIMPLEX or secondary payload on a Venus flyby NASA or commercial mission if communication relay capability is in place at Venus. SAEVe will need to be transmitting to an orbiter, which will capture the transmitted data and forward it to Earth. Science and engineering data from the lander will transmitted periodically at 200 bps or faster and between 100 and 150 MHz although transmission at higher frequencies is being explored.

The SAEVe concept includes the required entry capsule and all support elements needed to allow safe entry and landing on the Venus surface. SAEVe enters the atmosphere and gradually slows down during descent due to the thickening atmosphere. At approximately 6 km above the Venus surface SAEVe separates from the shell, takes two images and begins transmitting as it completes its descent and touches down at around 5 m/s without the need for any parachute or complex deceleration devices, rather just using a drag plate, as succesful done by soviet landers of the past.

After touchdown an image of the local surface is taken which provide data for morphology science and also supports assessing seismometer coupling. The seismometer (and heat flux instrument, if included) is dropped to the surface and the remaining images are taken and transmitted. Once all images are returned all the other instruments begin operating and SAEVe transmits data for up to 1 hr continually. After this initial period, SAEVe goes into its nominal operating mode where it turns on and collects/transmits all instrument data for 2 min every 8 hr. At all times, SAEVe will be monitoring the vertical axis of the seismometer. An algorithm will be used to determine if a seismic event has occurred and, if so, SAEVe turns on and begins transmitting data from all three axis of seismometer within 100 ms. Three axis seismic data along with wind and pressure data are planned to be transmitted continually for 10 min after each event is detected. This innovative mode of operations is expected to capture up to 50 seismic events during the lifetime of each SAEVe station.

The particulars of the orbit influence how much contact time will exist between SAEVe stations and the orbiter and therefore how many events are expected to be captured returned, but, in ideal conditions the orbiter could be in view up to around 90% of the time during some portions of the mission. Contact time will vary over the mission life so some transmissions and seismic events may be missed but a significant fraction will be returned successfully over the 120 Earth days of operations.

SAEVe allows for easy scaling to address cost, mass, or other constraints. For example, the number of landers or instruments can easily be de-scoped from the small landers but, of course, the respective science will be impacted.

SAEVe leverages newly demonstrated technologies and readiness of technology is a driving aspect for a future SAEVe mission. It is however notable that most technologies have been funded and have made progress toward the desired TRL-6 by a mission PDR. Current technology readiness is summarized in Table 2. Continued maturation is occurring under programs like HOTTech which is funding the development of a Venus seismometer that, when completed, could achieve the science objectives on the SAEVe platform.

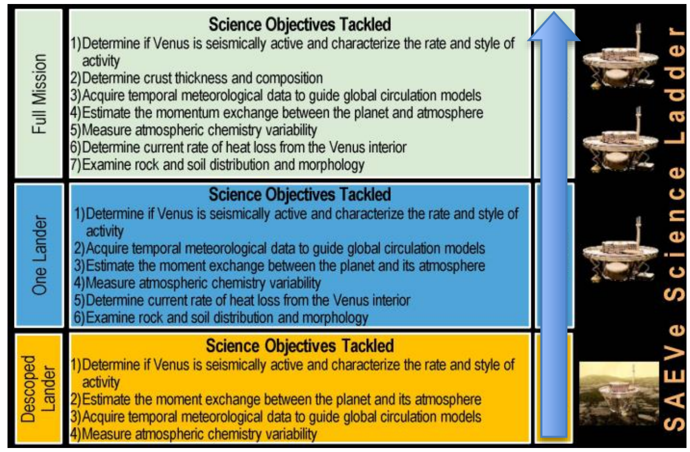

Figure 2. *SAEVe Science Ladder*

Technology	Current TRL
Electronic circuits (SiC): sensors and data handling	4-5
Electronic circuits (SiC): power management	4
Communications system	3
Wind Sensor	4
Temperature Sensor	5
Pressure Sensor	4
Chemical Sensors	5
Seismometer	3
Camera / imaging System	4
Solar Radiance	3
High-Temp Battery	4-5
Entry Shell TPS (HEEET)	6

Table 2. *Technology Readiness Assessment Summary*

SAEVe is an exciting mission concept that tackles long standing science questions about Venus using latest technologies and innovative approaches.

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