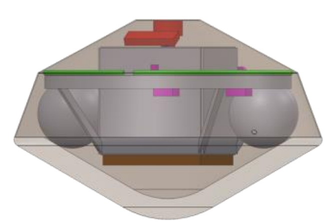
SAEVe: A concept study for a long duration small sat class Venus lander, Tibor Kremic[1] (Tibor.Kremic@nasa.gov), Richard Ghail[2], Martha Gilmore[3], Walter Kiefer[4], Sanjay Limaye[5], Gary Hunter[1], Carol Tolbert[1], Michael Pauken[6], Colin Wilson[7] 1, NASA Glenn Research Center, Cleveland, OH 2, Imperial College of London, London, UK, 3, Wesleyan University, Middletown, CO 4, Lunar and Planetary Institute, Houston, TX 5, University of Wisconsin, Madison, WI 6, Jet Propulsion Laboratory, Pasadena, CA 7, University of Oxford, UK

NASA's science mission directorate has new emphasis on innovative, smaller, and lower cost missions to achieve their science objectives. Evidence of this was the recent call by the Planetary Science Division for cube and small satellite concepts expected to cost $100M or less. Over 100 proposals were submitted indicating that indeed this size of mission is worthy of being considered in future planning. One of the missions selected in this competitive process for further study was a long-lived Venus lander concept called SAEVe, which stands for **S**eismic and **A**tmospheric **E**xploration of **Ve**nus. The SAEVe study concludes in early 2018 and the results will be presented at a special pre-LPSC session at the Woodlands, TX.

As its name implies, the SAEVe mission concept would leverage new advances in high temperature electronics and systems to develop an innovative solution to long duration operation on the Venus surface where the primary science goals would include seismic and atmospheric investigations. At the time of abstract submission the study is not complete, but enough work has been accomplished to demonstrate that a compelling mission focusing on these science objectives can be realized within the constraints of the **P**lanetary **S**cience **D**eep **S**pace **S**mall **S**at **S**tudies (PSDS3) call.

The science questions SAEVe would begin to address include: Is Venus seismically active? If multiple stations are deployed data could also be obtained to begin to locate potential sources in the interior. Other questions to be tackled include: What can be learned about its evolutionary history of or about surface / atmosphere interactions? Key data returned by SAEVe would help us begin to understand the nature of the deep Venus atmosphere and potential ramifications for the superrotation puzzle. The data returned will further our understanding of the solar system and Earth, and aid in meeting the NASA Science Plan goal to "**ascertain the content, origin, and evolution of the solar system…" and "the chemical and physical processes in our solar system…" [1]**

To achieve these science objectives SAEVe would be outfitted with a suite of sensors and simple instruments. The meteorology sensors include temperature, pressure and 2D wind speed measurements. Wind direction data will be derived from probe orientation information using a communication technique but multi-directional light level sensors will also be employed to determine how accurately one could get orientation from potential sensing of sun position. For energy deposition and balance, three sensors will be used, a single surface mounted heat flux sensor to measure heat from the interior, and upward and downward looking radiance sensors to measure incident and reflected solar energy. A key instrument that needs extended surface operations will be a high temperature seismometer. This seismometer will be a variant of the seismometer used on the Insight mission [2]. This capable instrument will help determine how seismically active Venus is. All sensors, and supporting avionics, will be fabricated to survive on Venus with no cooling. An instrument that does need thermal control and would only last about 90 minutes is an imager. The two imaging package(s) would collectively take five images, 2 context images, 2 images to ascertain seismometer to surface coupling, and one to allow for some basic morphology. This suite of instruments provides a well suited and balanced set for the SAEVe concept.



SAEVe would be delivered to Venus as a ride-along with a larger Venus orbiter mission. It is assumed that that mission will orbit Venus for at least 120 days and can serve as a data relay while the SAEVe station(s) are operating. SAEVe, as costed and studied, includes a Stardust-like aeroshell so the host mission would have to carry a spin table and release SAEVE's entry capsule(s) at the correct time(s). Upon entry, the dense atmosphere will slow down the entry shell which will release the probe at a predetermined altitude above the surface. The probe(s) continue to decelerate in the thickening atmosphere to touchdown at less than 6 m/s. The primary battery, which will operate SAEVe for its mission, will have turned on during the descent to enable taking and transmitting chemical species abundance, temperature, and pressure measurements during a portion of the descent. It will continue powering the surface operations. At the surface all meteorological, energy and chemical sensors and instruments will continue to run, as long as the orbiter is in view, for a specified period of time, perhaps the first 24 hours after landing. For that first initial period, seismometer data will also be transmitted continuously.

After that initial period all measurements (temperature, pressure, winds, radiance, chemical species abundances, heat flux, and seismometer readings) will be collected and transmitted at regular intervals, the interval selected to maximize data returned via the orbiter. The seismometer will be monitoring continuously and if an event is detected that exceeds some pre-determined threshold amplitude selected to minimize wind events, then it will immediately collect and transmit recordings for a period of time, on the order on 10 mins. It is understood that the orbiter will not always be in view so the data transmitted may not be "heard". However, for a 24 hour elliptical orbit, deployment can be achieved such that the orbit is in view a vast majority of time over the 120 Earth day life goal. This mission was costed to fit within the $100M cost cap prescribed by PSDS3.

The study explores various trades and options. For example, an imaging package would be highly desired to provide local context, public engagement, and potentially insight into coupling between the seismometer and surface. In addition, local morphology and rudimentary mineralogy may be feasible. Such a package is included in the study and costed. While the imaging package did not strictly fit within the $100M cost, the additional cost if relatively small and therefore is included in the study as an optional capability. Also costed was a second copy of a station. While that too does not strictly fit within the $100M cost cap, it does offer enhanced science opportunities in a number of areas including the potential for getting some insight into the interior, which would be unique and compelling contribution.

The study also addresses a number of important aspects of this concept such as what are the driving science requirements and the mission parameters that begin to constrain science objectives. Other results include identification of key technology development needs and potential mission readiness dates.

The SAEVe team explored and presents an exciting concept that could begin to address long standing and compelling science questions. SAEVe would begin to take temporal science data from the Venus surface for the first time ever and the lander is tuned to maximize science. At the $100M cost cap, the small lander provides compelling and unique new science return and in addition would be a powerful pathfinder to collect critical environmental data to enable future larger and more sophisticated (and expensive) missions.

Science Objectives	Anticipated Instruments/ Measurement
Determine if Venus is seismically active	Seismometer(s)
Begin to understand seismic environment – pathfinder to enable future more capable seismic mission	Seismometer(s) and wind sensors
Measure current rate of energy loss from the interior	Heat flux
Estimate the momentum exchange between the planet and its atmosphere	Wind speed and direction, temperature, and pressure
Acquire acquire meteorological measurements to update global circulation models	Winds, temperature, pressure, and chemical composition
Estimate sources of atmospheric chemistry variability	Chemical composition, temper-ature, pressure, and winds
Potential: Examine rock and soil distribution and morphology	Potential: Camera package

Team	
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References:

[1] National Aeronautics and Space Administration Science Plan (2014). https://cor.gsfc.nasa.gov/docs/2014_Science_Plan.pdf.

[2] Website http://www.mps.mpg.de/planetary-science/insight-seis