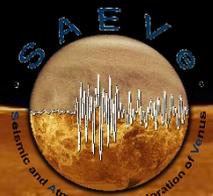
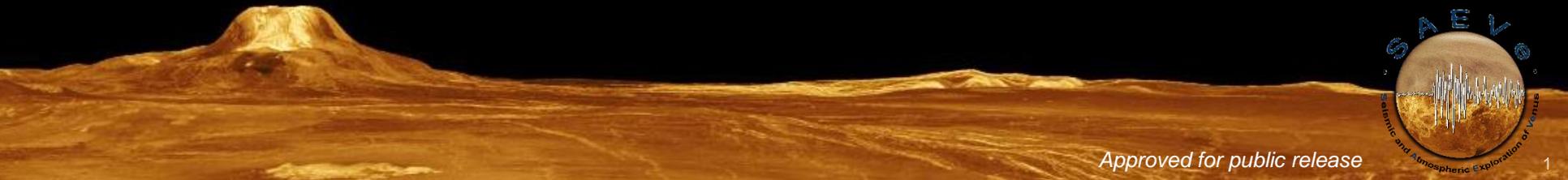


SAEVe: A Long Duration Small Sat Class Venus Lander

Seismic and Atmospheric Exploration of Venus

Tibor Kremic presenting on behalf of team: Richard Ghail, Martha Gilmore, Gary Hunter, Walter Kiefer, Sanjay Limaye, Michael Pauken, Carol Tolbert, Colin Wilson



SAEVe Objectives

SAEVe seeks to start tackling tough long standing scientific questions about Venus

Science Objectives

- Determine if Venus is seismically active and to what degree
- Determine the crust and lithosphere thickness and composition
- Determine the current rate of heat loss from the Venus interior
- Estimate the moment exchange between the planet and its atmosphere
- Acquire temporal data to update global circulation models
- Estimate sources of atmospheric chemistry variability
- *Potentially examine rock and soil distribution and morphology*
- *Potentially constrain mineralogy of surface materials*

Study Objectives

- Develop design concept that fits in \$100M cost, and <180kg
- Explore cost / mass sensitivities
- Assess technology tall poles and potential solutions

**Anticipated
Instruments /
Sensors**

Seismometer

**Wind speed
and Direction**

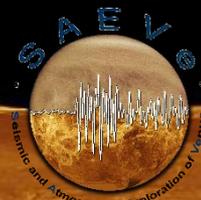
**Temperature and
Pressure**

Chemical composition

Radiance

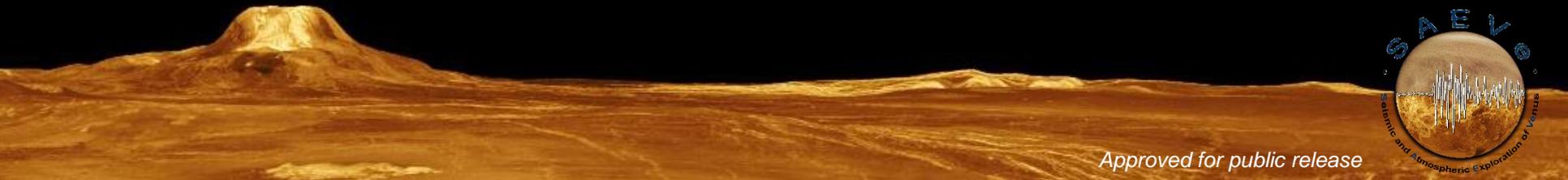
Heat Flux

**Potential: Camera
Package(s) Heat flux**



SAEVe – Instrument Suite Rationale

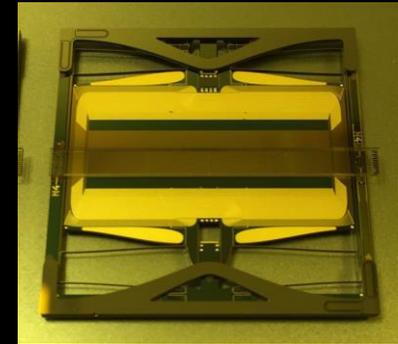
- Core science centers around long term measurements to obtain meteorological and seismic data (up to 120 Earth days)
- Core instrument package supports this objective
- Core instrument set includes mems seismometer, meteorological sensor suite, solar radiance, and chemical species sensors
 - Heat flux sensor is low data volume and a valuable inclusion
- Short duration imaging package **highly** desired but is a significant impact on system



SAEVe – Conceptual Instrument Operations

Seismometry

- Measure seismic activity of crust
 - Landing sites in flat areas in Lakshmi Planum or near large volcanoes
- Considering measuring and transmitting continuously for first XX hours then switching to monitoring mode with 1-axis trigger and transitioning to 3-axis measurement / transmit mode when $>$ mag 6 event detected (operate for 120 days)
 - InSight-like sensors
 - **Sub nano g MEMS sensor between 0.1 and 10 Hz, 0.25 ng/rtHz noise floor**
- If two landers can be accommodated - considering shorter life (\sim 3 weeks) but constant measurements to capture ambient noise and seismic events (get interior structure data)



Courtesy: Tom Pike

Mems seismometer sensor

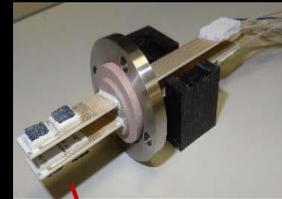


SAEVe – Conceptual Instrument Operations

Meteorological Instrument

High Priority

- **Measurement Support seismometry:** measure atmospheric noise simultaneously
 - Measure 2D horizontal wind velocity (u , v), at same sampling rate as seismometer
- **Low-frequency meteorology** – diurnal cycle & regional circulation
 - Measure sunlight at surface - Diurnal cycle and variability due to clouds
 - Measure temperature variability associated with diurnal cycle & regional circulation
 - Measure changes in pressure & wind with regional circulation
 - Measure p , T , u , v , light, gas composition once every 8 hours

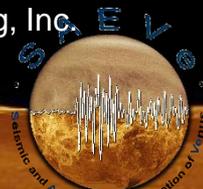


Gas Sensor Array

Medium Priority

- **High frequency meteorology** – characterize turbulence
 - Measure p , T , u , v , at 1 Hz for 1 hour

Courtesy of D. Makel, Makel Engineering, Inc.



SAEVe Instruments Candidates

Meteorological Instrument Measurement Targets

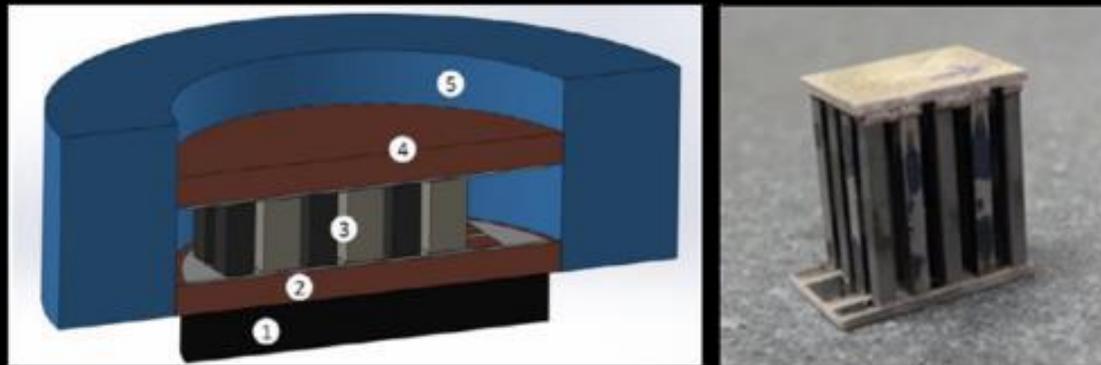
	Description	Number	Sensor Input	Sensor Output	Draft Requirements			
					Target Min	Target Max	Target Accuracy (+/-)	Target resolution
Wind Sensor	Al substrate with strain gage	3 perpendicular	voltage	voltage	0.25 m/s	2.5 m/s	0.1 m/s	0.05 m/s
Temperature Sensor	RTD in electronics	1	current	voltage	450 C	492 C	0.2 C	0.15 C
Pressure	Resistive	1	voltage	voltage	80 bar	92 bar	1 % full scale	0.6% full scale
	Capacitive		capacitance	voltage				
Chemical Species	SOx	1	voltage	voltage	0	400 ppm	0.3 ppm	10 ppb
	H2O	1	voltage	voltage	0	100 ppm	1 ppm	50 ppb
	OCS	1	voltage	resistance	0	50 ppm	1 ppm	10 ppb
	CO	1	voltage	resistance	0	50 ppm	1 ppm	10 ppb
	HCl	1	voltage	voltage	0	5 ppm	0.5 ppm	10 ppb
	HF	1	voltage	voltage	0	5 ppm	0.5 ppm	0.5 ppb
	NO	1	voltage	voltage	0	10 ppm	2 ppm	0.1 ppb
	H2	TBD	voltage	voltage	0	30 ppm	1 ppm	1 ppm
	O2	TBD	voltage	voltage	0	50 ppm	1 ppm	1 ppm
	HCN	TBD	voltage	voltage	1	50 ppm	1 ppm	1 ppm



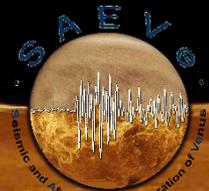
SAEVe – Conceptual Instrument Operations

Heat Flux

- Acquire at least two heat flux measurements during the mission
 - One during “day” and one during “night”
- Considering deployment options for best contact to surface
 - Measure heat flux of $10-100 \pm 5$ mW/m²



Courtesy: Mike Pauken

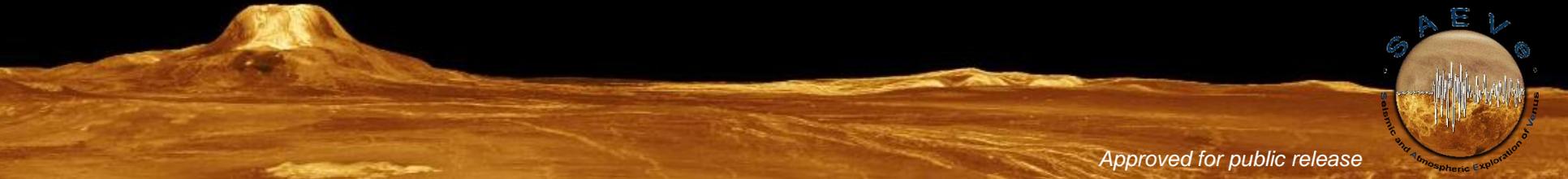


Approved for public release

SAEVe – Conceptual Instrument Operations

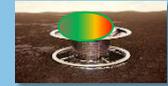
Imaging

- Imaging during and right after descent is **HIGHLY** desired
 - With near term technology, requires short duration “cold” package
 - Content within “cold” package under assessment
 - Getting data off lander “in time” is second hurdle
- Images desired (in priority)
 - Image of morphology and structure of surface where seismometer (& heat flux) will be placed (**visible through 1 μ m – 256 x 256 image min**)
 - Nadir image 5 km above surface
 - Images after deployment of seismometer and heat flux (coupling) and then additional descent images
- As possible add multispectral panoramic camera
 - Return 1 panoramic image before camera / transmission expires



ADDITIONAL SCIENCE QUESTIONS TACKLED

What is local mineralogy / morphology? How do IR images compare with orbiter's (for VEMs – like camera)



ARCHITECTURE SUMMARY AND KEY MEASUREMENTS

Two stations with the short lived imaging/comm packages augmented with a multi channel panoramic camera

Additional images to be transmitted to orbiter by short lived package

ADDITIONAL SCIENCE QUESTIONS TACKLED

What is estimated location of seismic activity? What is ambient seismic noise?



ARCHITECTURE SUMMARY AND KEY MEASUREMENTS

Two stations with short lived imaging/comm packages

“Baseline” data to be taken at two locations 300km - 500km apart (relative positions known to within 5 km)

ADDITIONAL SCIENCE QUESTIONS TACKLED

What is local surface morphology? What are local terrain features / context?

What is surface like under seismometer / heat flux and image of post deployment coupling



ARCHITECTURE SUMMARY AND KEY MEASUREMENTS

One core station augmented with short lived imaging/comm package

Additional data to be taken: 1-5 descent nadir images (below 5 km) plus 1 image of surface structure (1mm resolution) before deployment of seismometer / heat flux and 1 image after (all with 1 camera viewing at .8-1 μ m)

Short lived package lasts until data is transmitted to orbiter – rest of station same as core

CORE SCIENCE QUESTIONS TACKLED

How seismically active is Venus?

How does meteorology and key atmospheric specie abundances vary with time?



CORE ARCHITECTURE SUMMARY AND KEY MEASUREMENTS

One station with Meteo package, a 3 axis mems seismometer, and a heat flux sensor. (Core)

Measurements to be taken one Venus solar day or longer. Consider capturing and transmitting continuously whenever orbiter is in view then monitor and transmit events >mag 6 only

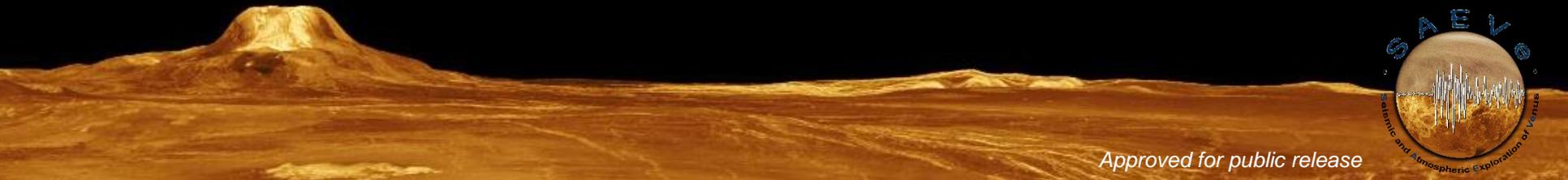
Meteo package consists of sensors to measure temperature, pressure, wind speed, atmospheric chemical specie abundance, and solar radiance



Approved for public release

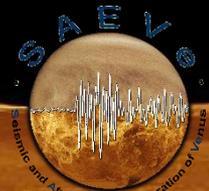
SAEVe - Current Status

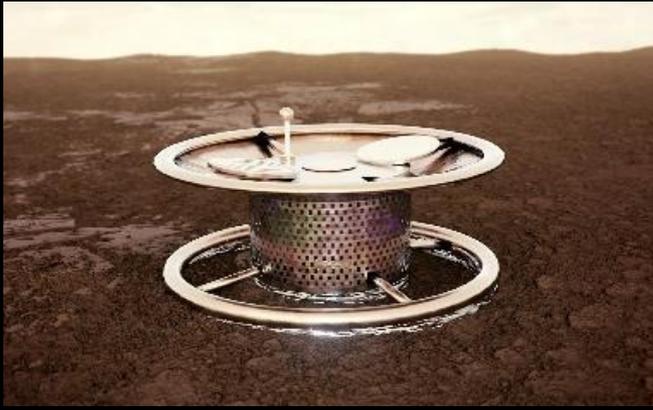
- Discussed science cases and priority for each area (meteorology, seismometry, heat flux, and imaging)
- Discussed and converged on mission science priorities
- Assessed sensor / instrument options
- Assessed technology readiness – system trades



SAEVe - Current Status

- In the midst of first COMPASS session –
 - Encouraged by results to date - although one never gets all that is desired given the constraints
- Technology investments that would benefit a SAEVe-like mission
 - High power density batteries
 - High temp and **Low** power memory & electronics
 - Higher performance comm to orbiters
 - High temp imagers
- More to come at LPSC!





Team Members/Institutions

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 Objectives:

- Determine if Venus is seismically active
- Constrain crust and lithosphere thickness, composition
- Determine current rate of heat loss from the interior
- Estimate moment exchange between planet & atmosphere
- Acquire temporal data to update GCMs
- Quantify near-surface atmospheric chemistry variability
- Potential: Examine rock and soil distribution & morphology

Mission Overview:

- One-two probes delivered to Venus via ride along
- Probe(s) enter Venus atmosphere via Stardust-like entry capsule
 - Probe(s) ejected at different times, descend through the thickening atmosphere onto the Venus surface
 - Turn themselves on and begin transmitting science data

Probes will

Measure seismic activity, heat flux, wind speed and direction, abundance of selected atmospheric species and ambient temperature and pressure—over a period of months or more

Transmit the data to an orbiting spacecraft/comm relay, at preset intervals

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 interior of Venus

Approved for public release

