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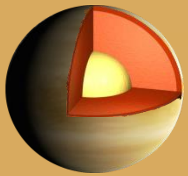

Short Duration Landed Missions Experimental Approaches

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Venus Surface Platform Study Meeting

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Topics

- Venera VEGA Context
- Descent and Surface Images
- Elemental and Lithological Analysis
- Geophysical Instruments
- Conclusions

This presentation borrowed presentations given at a short course entitled Destination Venus: Science, Technology and Mission Architectures by James Cutts, Larry Esposito and Lori Glaze The short course was conducted as part of the International Planetary Probe.Workshop 2016

Venera – Vega *in situ Measuremen*

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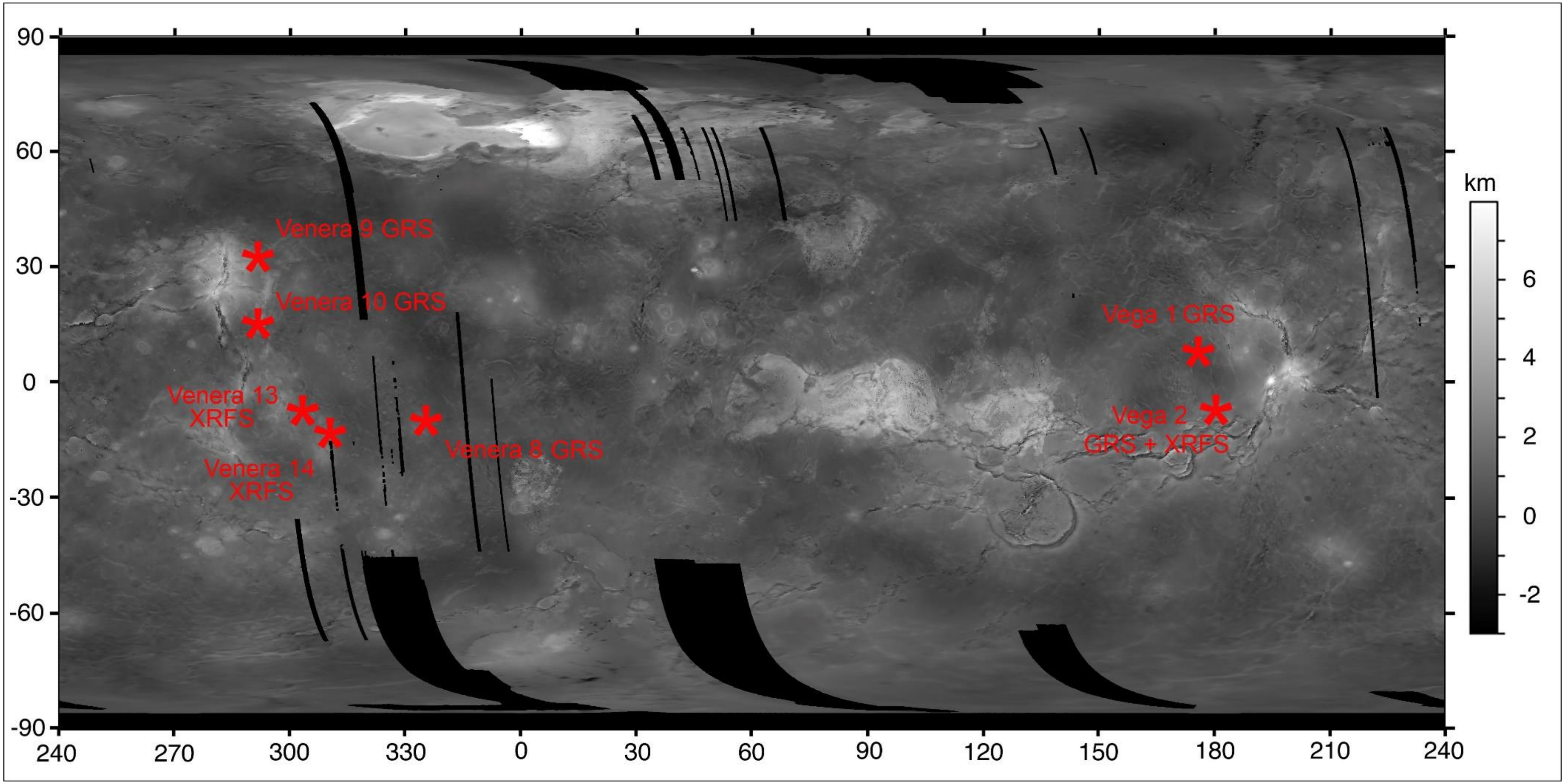

In situ measurements in 7 sites:

Venera 8, 9, 10, Vega 1 => GRS => K, U, Th

Venera 13, 14 => XRFS => Major elements

Vega 2 => GRS + XRFS => K, U, Th + Major elements

Venus Surface Images

- Platy bedrock with apparent layering or exfoliated surfaces (V10,13,14)
- Thin, unconsolidated material a few cm thick, distributed on top of the platy unit (V10,13)
- Blocky, sloping surface with no bedrock-like exposures (V9)
- Geochemistry indicates basalt, but is it exfoliated bedrock, lithified aeolian or pyroclastic deposits, or platy lava flow?

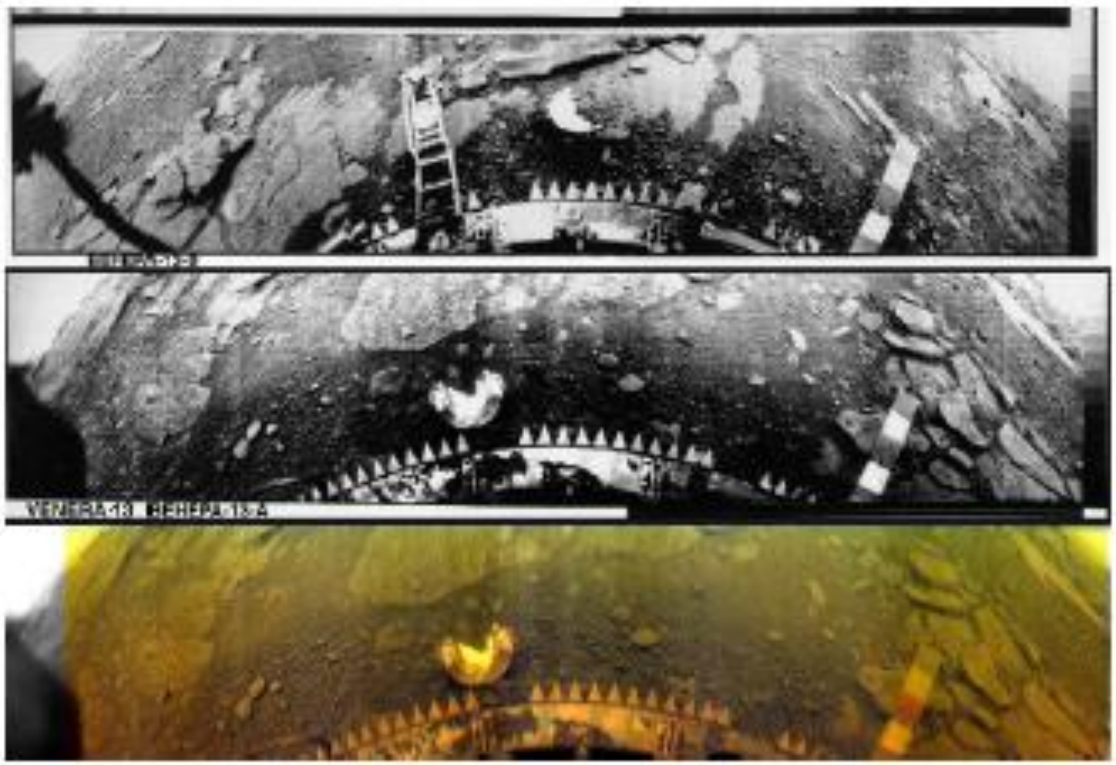

Figure 1: B/W and Color views of Venus surface from Venera 13

Venera 9-10 Panoramas

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Venera 9

Venera 10

Lighter (a = 5-10%) layered rocks and darker (a = 3-5%) soil are seen

Venera 13-14 Panoramas

Venera 13

Venera 14

Lighter (a = 5-10%) layered rocks and darker (a = 3-5%) soil are seen

Descent Timeline Thumbnail

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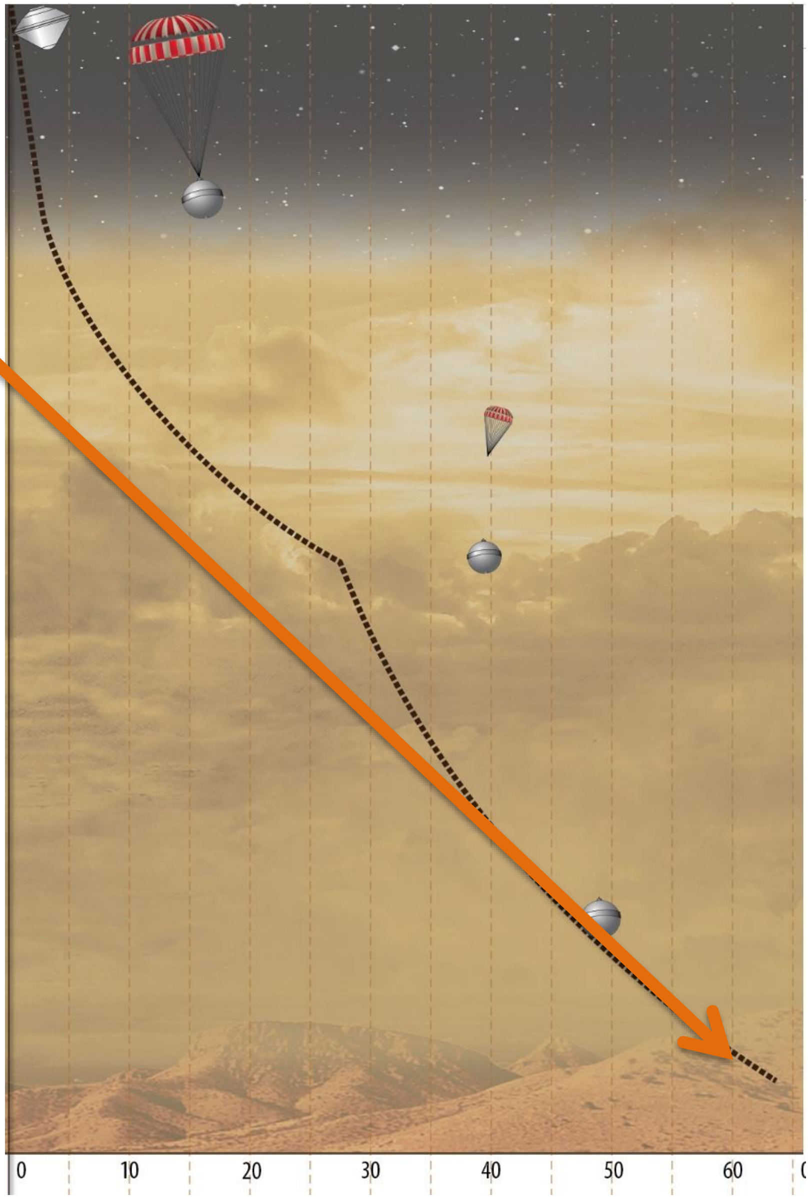
Near the Surface:

- CO_2 window at ~1μm should allow surface to be visible from about 10 km altitude [Moroz, 2002].
- Images can characterize the morphology, structure, and weathering regime at the surface



From Lori Glaze presentation 2016

Future Needs -Descent and Surface Imaging

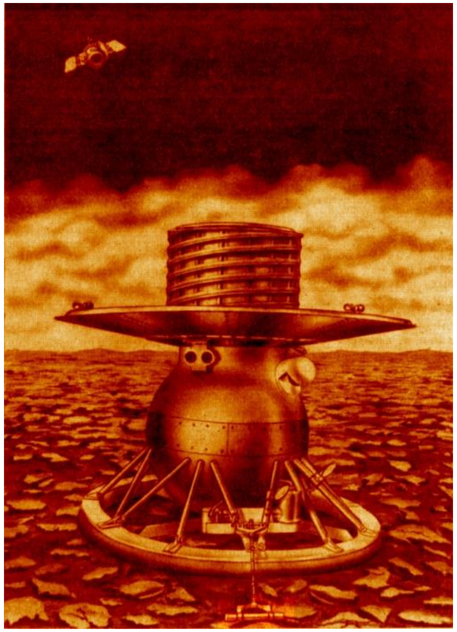
Descent Images

- Connect the orbital radar images with the landed images
- Provide ground truth for the orbital radar images

Surface images:

- Improved images can help to determine the local and regional geologic history
  - See individual grains and their variation with a microscopic camera
  - Measure composition from spectral reflectance and emissivity
  - Evaluate the texture of surface materials to constrain the weathering environment

Venera 8, 9, 10, Vega 1, 2 gamma-ray spectrometry

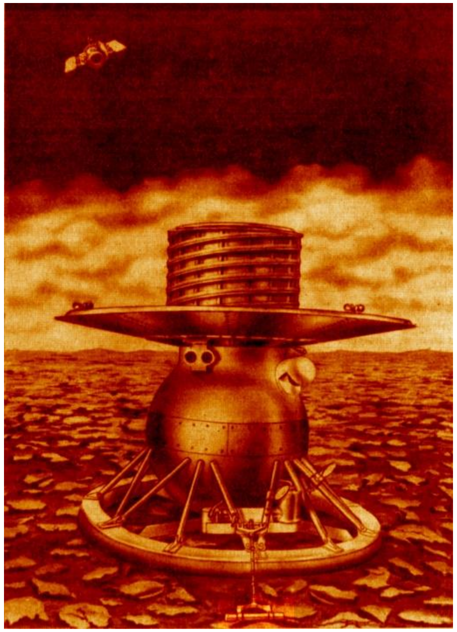


Element	Venera 8	Venera 9	Venera 10	Vega 1	Vega 2
K %	4.0 ± 1.2	0.5 ± 0.1	0.3 ± 0.2	0.45 ± 0.22	0.40 ± 0.20
U ppm	2.2 ± 0.7	0.6 ± 0.2	0.5 ± 0.3	0.64 ± 0.47	0.68 ± 0.38
Th ppm	6.5 ± 0.2	3.7 ± 0.4	0.7 ± 0.3	1.5 ± 1.2	2.0 ± 1.0

Basaltic range of K, U, Th contents

Venera – Vega *in situ* Measurements (2)

Venera 13, 14, Vega 2 X-ray fluorescence spectrometry



Oxide	Venera 13	Venera 14	Vega 2
SiO_2	45.1 ± 3.0	48.7 ± 3.6	45.6 ± 3.2
TiO_2	1.59 ± 0.45	1.25 ± 0.41	0.2 ± 0.1
Al_2O_3	15.8 ± 3.0	17.9 ± 2.6	16.0 ± 1.8
FeO	9.3 ± 2.2	8.8 ± 1.8	7.74 ± 1.1
MnO	0.2 ± 0.1	0.16 ± 0.08	0.14 ± 0.12
MgO	11.4 ± 3.0	8.1 ± 3.3	11.5 ± 3.7
CaO	7.1 ± 0.96	10.3 ± 1.2	7.5 ± 0.7
K_2O	4.0 ± 0.63	0.2 ± 0.07	0.1 ± 0.08
S	0.65 ± 0.4	0.35 ± 0.31	1.9 ± 0.6
Cl	<0.3	<0.4	<0.3

Mafic (basaltic) compositions

Surface Needs (1)

Major Elements - Guidelines

Reference from an average basalt on Earth. Uncertainty based on that average basaltic composition chosen but will vary for exotic compositions (i.e. granites and carbonatites)

	Basalt (wt%)	Minimum ± (wt.%)	Ideal ± (wt.%)
SiO_2	51.6	2	
TiO_2	0.8	0.1-0.2	
Al_2O_3	15.9	1	
Cr_2O_3	0.8	0.2	
FeO	8.5	0.5	
MnO	0.2	0.1	<<0.1
MgO	6.7	0.5	
CaO	11.7	0.8	
Na_2O	2.4	0.2	
K_2O	0.4	0.05	
P_2O_5	0.1	0.1	
SO_3	<3	0.3	
Cl	<1	0.1	

Mineralogy - Guidelines

Min detection limits in volume percent

		low amount	high amount
Silicates	Olivine	3 +/- 2 vol%	50 +/- 10 vol %
	Pyroxenes	3 +/- 2 vol%	50 +/- 10 vol %
	Plagioclase	3 +/- 2 vol%	50 +/- 10 vol %
	Alkali Feldspar	3 +/- 2 vol%	50 +/- 10 vol %
	Silica-polymorphs	3 +/- 2 vol%	50 +/- 5 vol %
Hydrous	Amphibole	detection - absolute presence	
	Mica	detection - absolute presence	
	Carbonates	detection - absolute presence	
	Phosphates	detection - absolute presence	
	Sulfates	3 +/- 2 vol%	50 +/- 10 vol %
	Hematite	3 +/- 2 vol%	50 +/- 10 vol %
	Magnetite	3 +/- 2 vol%	50 +/- 10 vol %

Short Duration Instruments Technology[1]

- A primary focus of these missions is to perform elemental, mineralogical, and petrologic analysis on the surface of Venus. With such limited lifetimes on the surface, **time is of the essence** so the speed with which these measurements can be conducted is vital.
- Technical developments in the following instruments can have a major impact to enhance speed.
  - ***X ray Diffraction and Fluorescence***:
    - high-flux X-ray source based on a carbon nanotube X-ray emitter. Recommended first in the Venus Flagship Study 2007 report.
  - ***Laser Induced Breakdown Spectroscopy (LIBS/Raman):***
    - ***Exploit Curiosity heritage***
  - ***Fine Scale Elemental and Mineralogical Analysis***
    - Mars 2020 Science Definition Team recognized the geological importance of fine-scale imaging, fine-scale elemental analysis, and fine-scale mineralogy.
    - Similar requirements are ultimately going to be important on Venus.
    - Probably requires bringing sample into the interior of the lander where pressures and temperatures are much lower

1 **Findings of VEXAG Venus Technology Plan 2014**

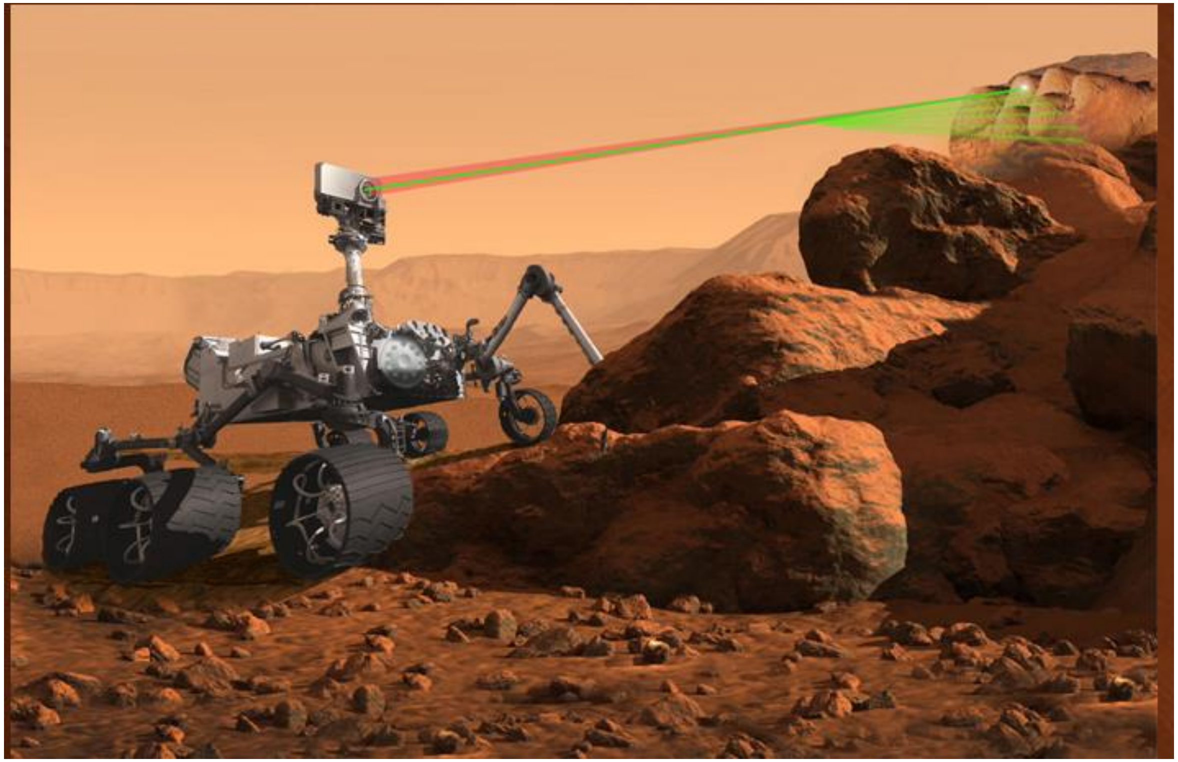
Instruments Concepts

- SuperCam (Mars 2020)
  - LIBS Raman
  - Imaging

- Small Scale Element Analysis and Mineralogy
  - Planetary Instrument for X ray Lithochemistry (PIXL) – Mars 2020
  - Scanning Habitable Environments with Raman and Luminescence for Organics and Chemicals (SHERLOC) – Mars2020
  - Sample Acquisition System – Needed for Venus

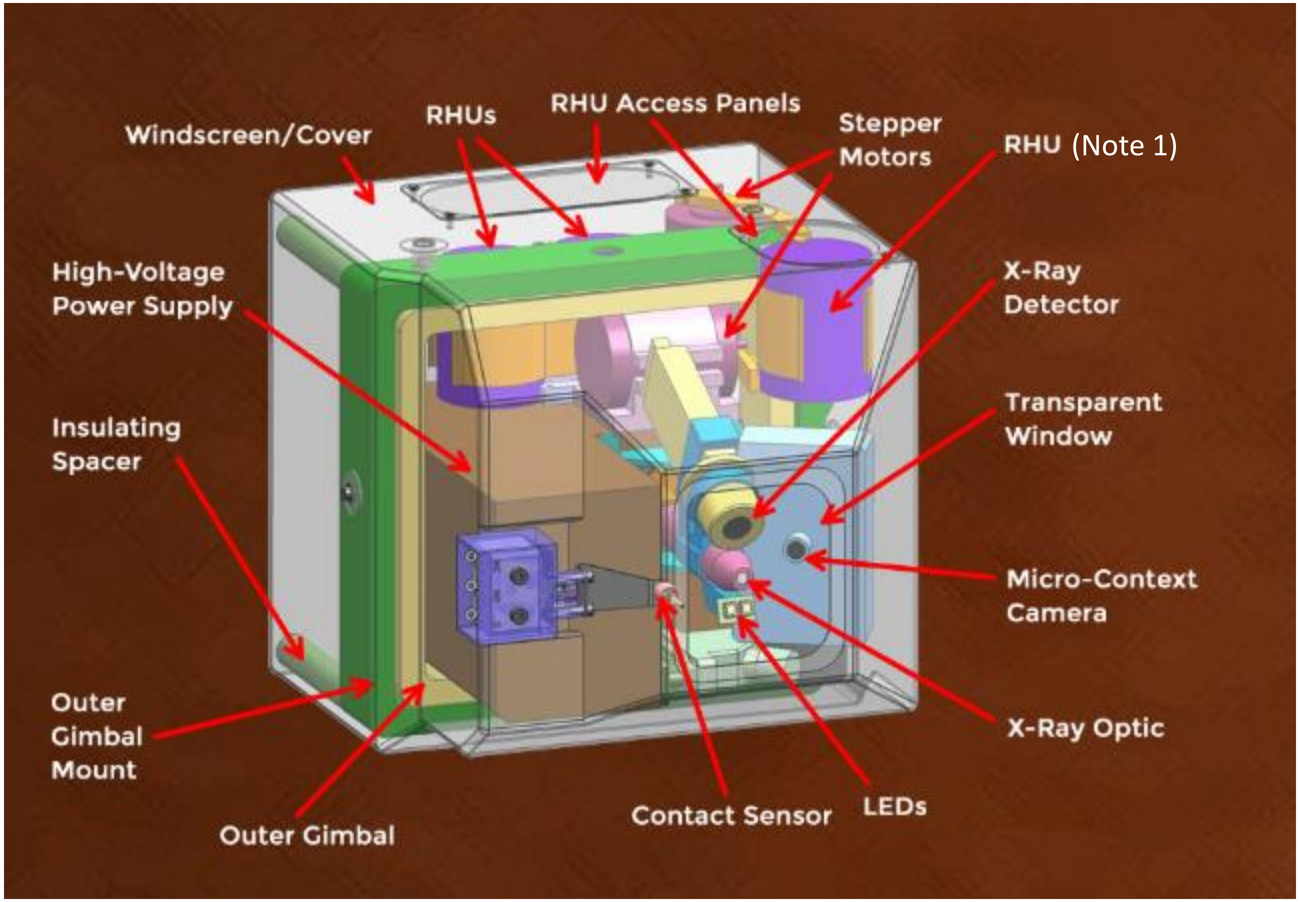
- Chemical (Elemental) Survey
  - Probing In Situ with Neutron and Gamma Ray (PING)

- Geophysical Instruments
  - Radar Imager from Mars Subsurface Experiment (RIMFAX)
  - Seismometer – short duration
  - Heat flow



Perform Laser Induced Breakdown Spectroscopy (LIBS), Raman Spectroscopy and Imaging from distances of up to 12 meter from a rock. Can also clean rock surface with the laser beam

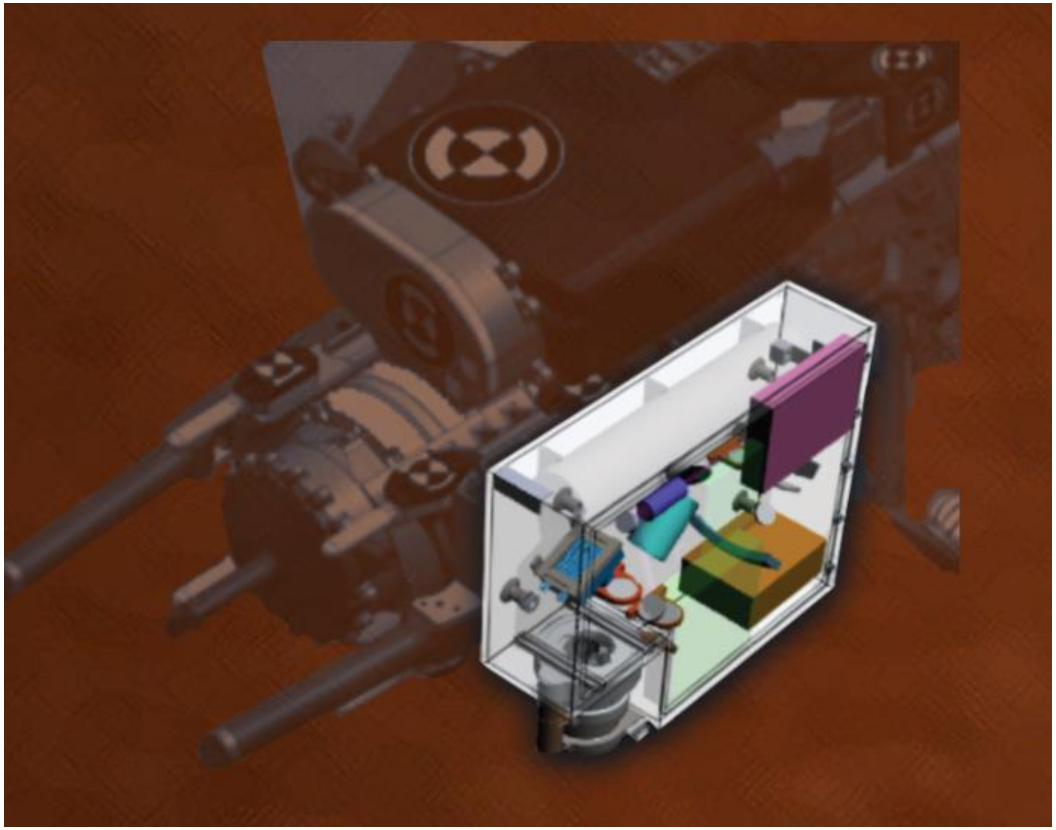
Planetary Instrument for X ray Lithochemistry(PIXL)



Identifies chemical elements on a very small scale using an X ray spectrometer Also includes a camera that takes super close-up pictures of rock and soil textures.

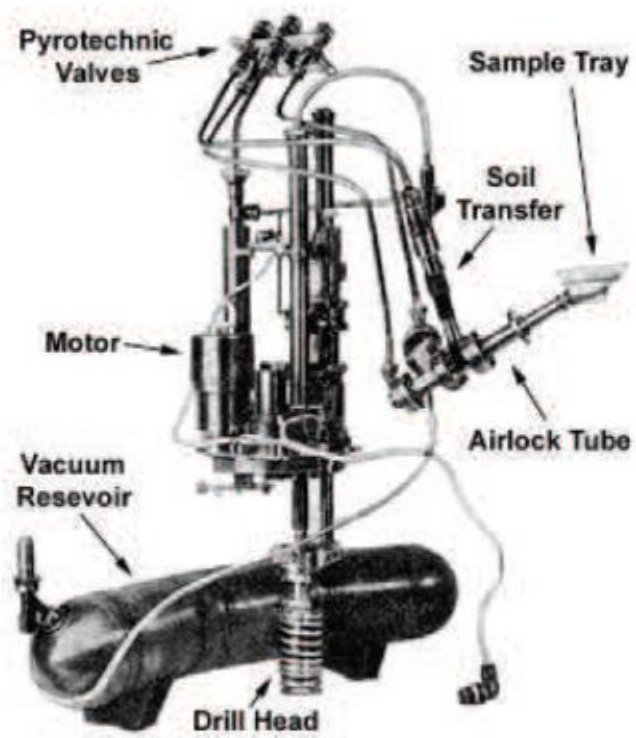
Note 1: Instrument as implemented no longer uses RHU

Scanning Habitable Environments with Raman and Luminescence for Organics and Chemicals (SHERLOC)



Searches for organics and minerals that have been altered by watery environments and may be signs of past microbial life. Uses spectrometers, a laser and a camera. Mounted on the rover's robotic arm

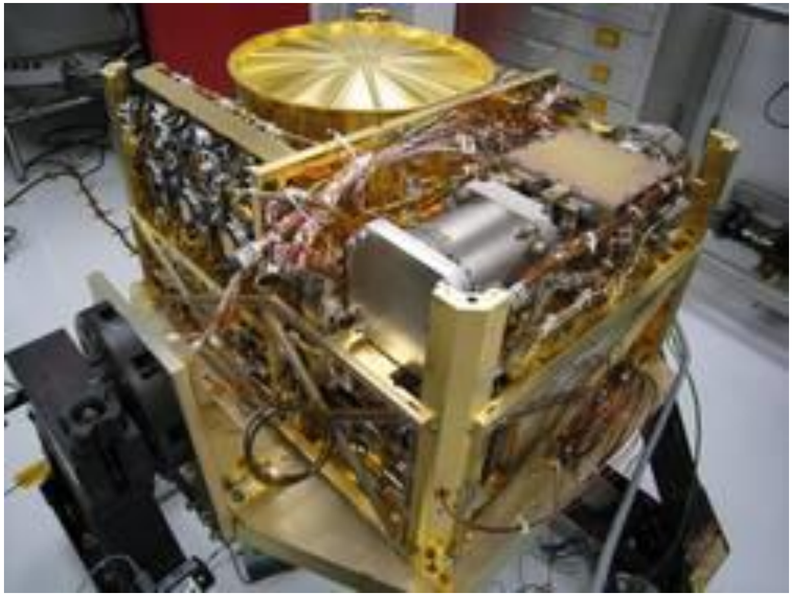
Sample Acquisition System for Venus application



Venera 13 and 14 sample collection system

Acquires and delivers a soil sample into a controlled environment in the lander where fine scale elemental and lithological analysis can be conducted

Atmospheric Composition

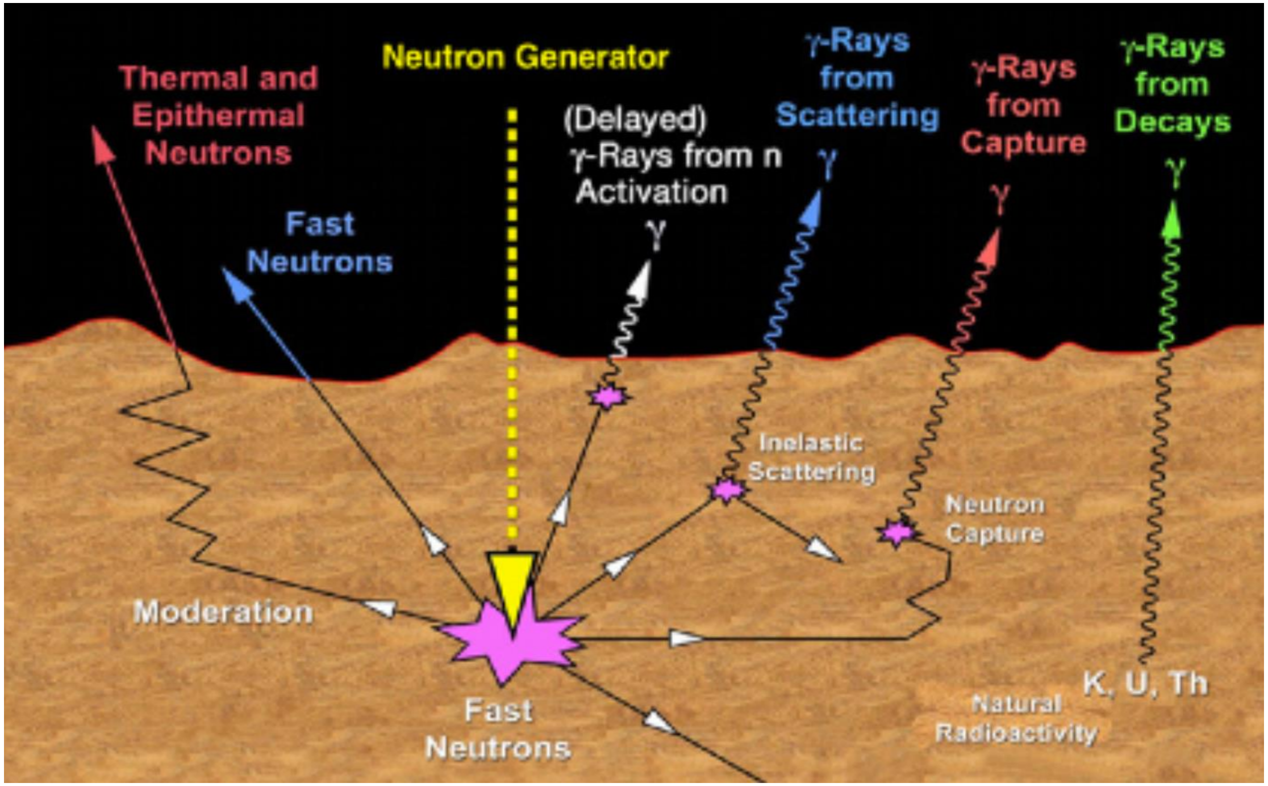


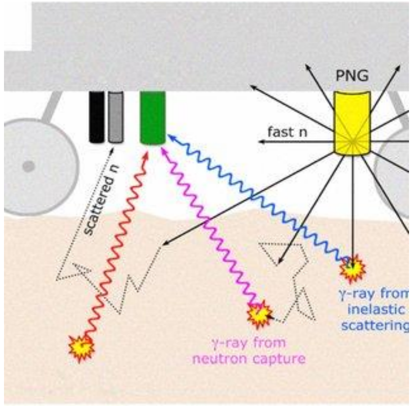
SAM Instrument – Curiosity
- Mass Spectrometer
- Gas Chromatograph
- Tunable Laser Spectrometer

- Analysis of atmospheric gas including isotopes
- Identification of near surface reactive species
- Identification of hydrous minerals including carbonates and sulfates

ISSUE: Can these measurements of hydrous minerals complement those acquired with Raman spectroscopy with either a Raman/LIBS or SHERLOC type instruments

Probing In situ with Neutrons and Gamma Rays (PING)





Concept for Mars rover

Identifies chemical elements on a larger scale using a pulsed neutron source and a gamma ray spectrometer. Both can penetrate the shell of the Venus lander.

Comparison of Elemental Analysis and Mineralogy Techniques

	LIBS/Raman	PIXL/SHERLOC	SAM/MSL	PINGS
Range from lander	12	<2m	<2m	2 meter
Resolution	1 mm	1/10mm	NA	1 meter
Depth	Microns(1)	microns	NA	50 cm
Elemental Analysis	Yes (LIBS)	Yes (PIXL)	No	Yes
Mineral Analysis	Yes (Raman)	Yes (SHERLOC,2)	Yes (SAM,3)	No
Soil sample	Yes	Yes	Yes	NA (3)
Rock Sample	Yes	Depends on drill	Depends on drill	NA
Remove weathering rind	Yes (<1mm)	Depends on drill	Depends on drill	NA

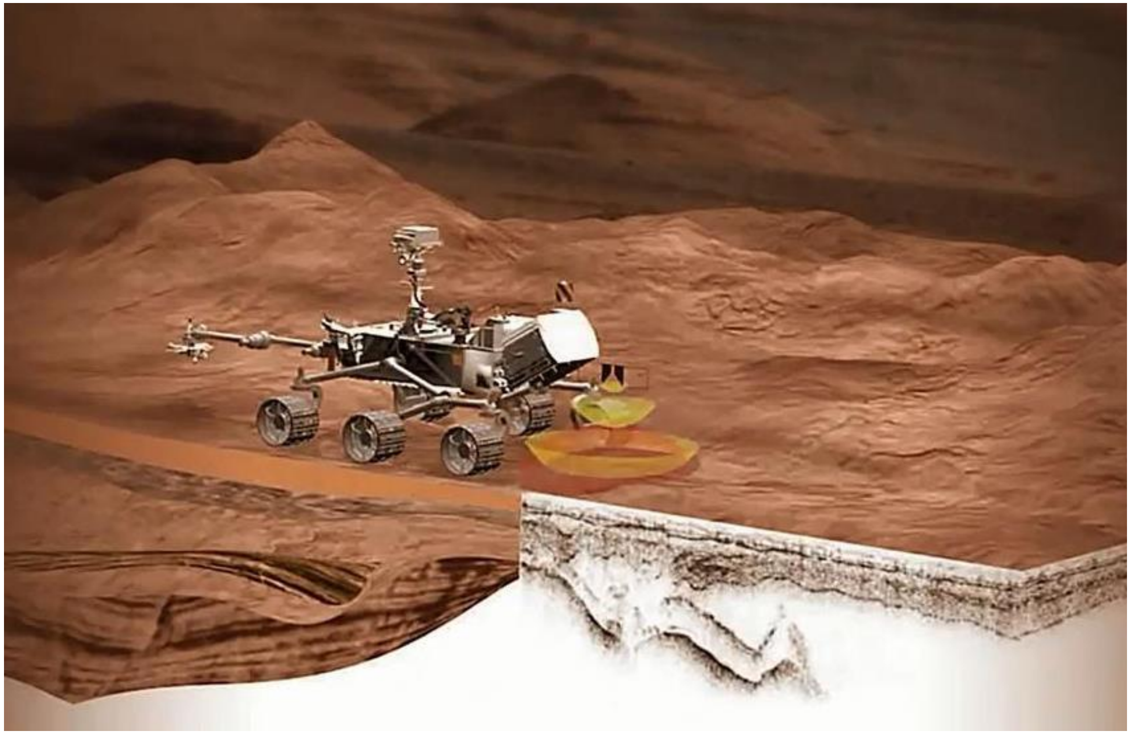
Note 1 LIBS can also ablates the surface by a fraction of a millimeter

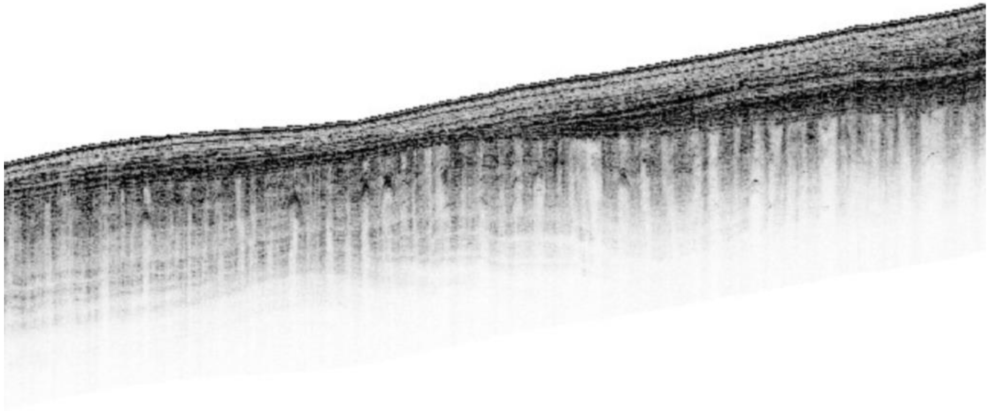
Note 2 SHERLOC uses Raman and fluorescence Spectroscopy for mineral and organic detection. No organics are expected on Venus

Note 3 Heating the sample makes it possible to detect poorly crystalline minerals at very low concentrations

Note 4 PINGS averages soils and rocks together

Radar Imager for Mars Subsurface Experiment (RIMFAX)





Profiles the subsurface of Mars along the track of the rover down to a depth of 10m

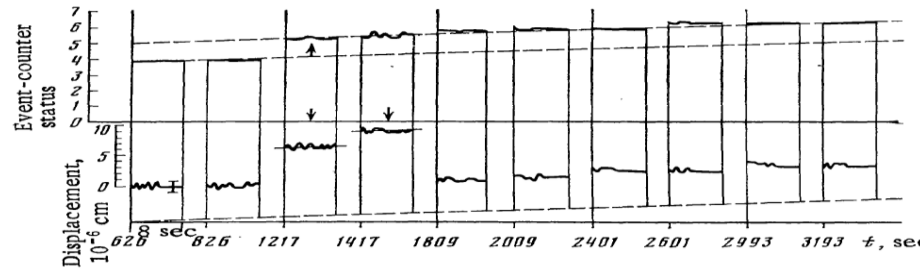
Seismic Experiment:

Venera 13 and 14 Groza 2 Experiment

- Venera 13 and 14 carried an experiment called Groza 2 that included both a microphone and a seismometer.

- The instrument was a single axis seismometer with a vertical sensitivity better than 1 μm located on the landing ring

- The goal of the very short lifetime missions (~ 2 hours) was to **determine the level and nature of background noise or microseismic activity on Venus.**



Signals Recorded on Venera 14 – vertical displacements (events) that occurred after landing are indicated by the arrows

- Some signals were recorded during the short lifetimes of both the Venera 13 and 14 experiment (2 hours).

- Due to the thermal variations of the probe signals are unlikely to be seismic

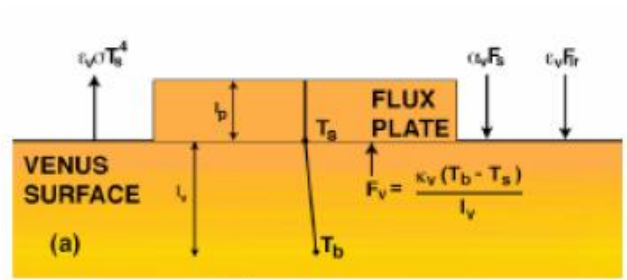
- **ISSUE Could a short duration seismic sensor be designed which would determine anything useful about seismic background on Venus?**

- Ksanfomaliti, L.V, V.M.Zubkova, N.M.Morozov and E.V.Petrova, Micoseisms at the Venera 13 and 14 sites, Sov. Astron. Letters, 8(4), July-Aug 241-242, 1982

Heat Flow:

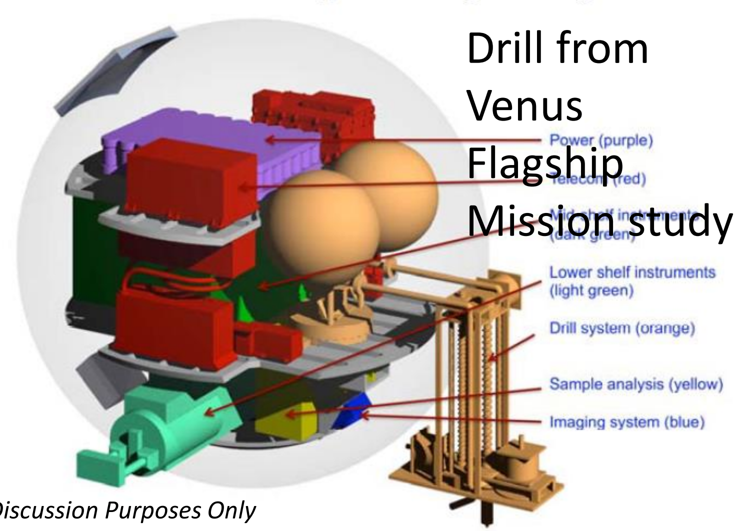
Heat flow measurements with short duration lander

- On the Earth, the Moon, and Mars, diurnal or seasonal variations in surface temperature require bore-hole temperature measurements over an extended period of time.
- On the Venus surface, where there is limited diurnal and seasonal temperature variation, a heat-flux measurement may be feasible from a short duration lander using a flux plate



Heat flow measurements with a hybrid lander

- Venus diurnal variations are still significant compared to the expected thermal gradients.
- Suggests a “hybrid experiment” in which
  - Short duration lander drills the hole
  - Long duration lander makes temperature measurements in the hole for a Venus years



Drill from Venus Flagship Mission study

Are other synergies between short duration and long duration landers with important science impact

Conclusions:

- Short duration missions can take advantage of many of the technologies developed by Mars and other planetary targets where high temperatures are not encountered
- Nevertheless the measurements strategy has to take account of the Venus environment
  - Standoff techniques like LIBS/Raman will be impacted by the dense atmosphere and this needs to be understood
  - Small scale elemental and mineral analysis requires bringing the sample into the interior of the spacecraft where both temperature and pressure can be optimized for the experiment.
- Geophysical experiments such as heat flow and seismology inherently require long duration on the surface. Potentially important precursive observations could be conducted by a short duration lander mission