Venus Exploration Targets Workshop: A Retrospective

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May 19-21, 2014
Lunar and Planetary Institute

Workshop Goal

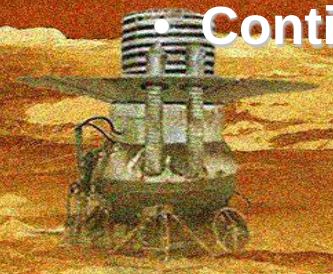
- To *identify* and *evaluate* key locations, transects, and regions for future exploration of Venus.
  - On the surface or within the atmosphere
  - Appropriate candidate targets include those requiring
    - landers,
    - atmospheric probes, gliders, or balloons, and
    - orbital missions.

Workshop Structure

- **Day 1:**
  - **AM: Introductory Plenary, including short 'poster' talks**
    - **Opportunity for everyone to present orally**
  - **PM: Poster discussion followed by first breakout session**
    - **Breakouts organized around where the payload would be located: *on the surface*, *in the atmosphere*, *from orbit***
    - **First effort to define targets to meet VEXAG GOI**
    - **Encouraged participants to circulate between sessions**

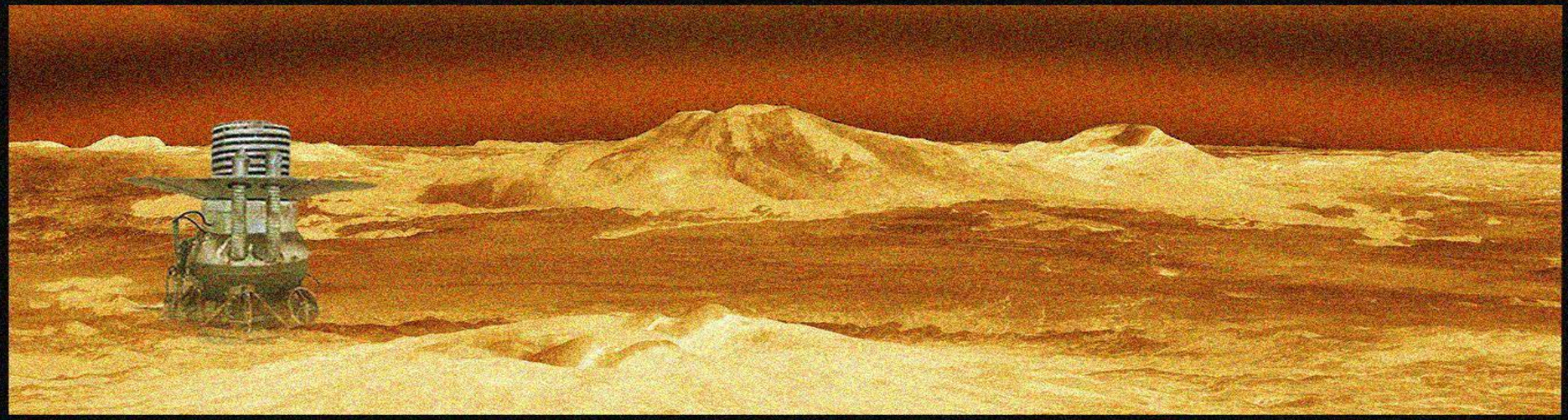
Workshop Structure

- **Day 2:**
  - **Morning Plenary**
    - Session leads summarized Day 1 progress
  - **Morning Breakout Session**
    - Continue to define targets
    - Consider approaches needed at each target
  - **Afternoon Plenary**
  - **Afternoon Breakout Session**
    - Continue discussions; add data requirements



Workshop Structure

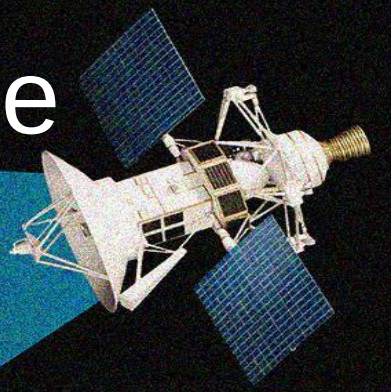
- **Day 3:**
  - **Capstone Plenary**
    - **Extended discussion of workshop progress**
  - **Adjourned at Noon**
  - **PM: Organizers convened to discuss results & path forward.**



Workshop Findings

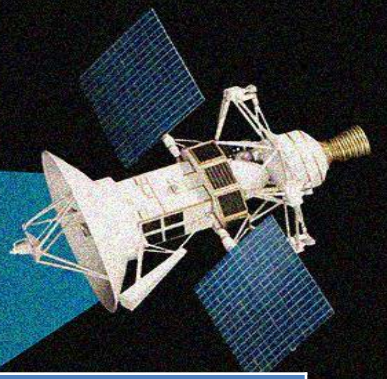
- **Surface:**
  - **Significant science achievable from low-risk areas such as plains**
    - **Meets majority of objectives in VEXAG Goals II (Surface & Interior Evolution) & III (Interior-Surface-Atmosphere Interactions; Liquid water ever present?)**
    - **Improved measurements of crust and lower atmosphere**
    - **Best: older plains devoid of ejecta, deformation features**
  - **Tessera lander site would be scientifically optimal but risky; risk mitigated by:**
    - **High-resolution imaging and topography**
    - **Autonomous hazard avoidance technologies**

Surface Targets for Future Exploration



- Top targets: tessera, plains, young lava flows, volcanoes (e.g., Maat Mons)
- Many atmospheric measurements can be made from the surface and/or on descent – similar to those “from atmosphere”
- Measurement needs focus is on geochemistry and mineralogy of surface target sites

Surface Objectives



Needs	GOI numbers from VEXAG				
Major Elements	2.B.1	3.B.2	3.A.3		
Sulfur	2.B.1	3.B.2	3.A.3	3.B.4	
Chlorine	2.B.1	3.B.2	3.A.3		
Heat Producing Elements		3.B.2			2.B.5
Mineralogy	2.B.1	3.B.2	3.A.3		
Wants	**GOI numbers from VEXAG**				
Trace Elements	2.B.1	3.B.2			
Fluorine	2.B.1	3.B.2	3.A.3		
Fe-Oxidation State	2.B.1	3.B.2	3.A.3		
Carbon	2.B.1	3.B.2	3.A.3		

Surface Needs

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	
FeOT	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	

Surface Needs

Heat Producing Elements - Guidelines		
Reference from the Earth with uncertainty based on average composition chosen.		
	PPM	+/-
K	3000	300
Th	2.4	0.2
U	0.6	0.06

Surface Needs

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	
	Carbondates	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 %

More Findings

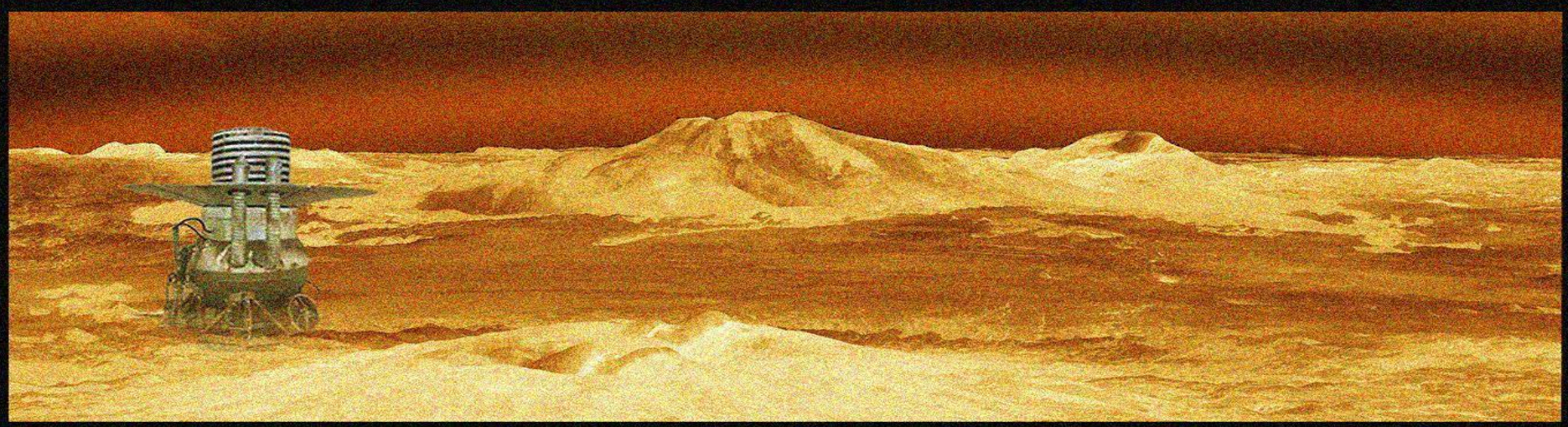
- **Atmosphere:**
  - **Challenged by the complex matrix of '<u>domains</u>':**
    - **Geographic location (x, y), height, time, duration**
    - **No single, static 'target' is adequate**
  - **Long-term, high spatial and temporal measurement of meteorological parameters is ideal but unrealistic.**
    - **Group focused on prioritizing among domains.**
  - **Can make remote surface observations from low altitude.**
  - **Many target and approach suggestions would benefit from coincident orbital observations.**

Measurements from the Atmosphere

GOI	Preferred Platform	Requirements
I.A.1	Long-term for improved accuracies	Measure most abundances and ratios to at least 5% levels.
I.A.2	Spatially separated measurements (mobile platform or multiple probes)	
I.B.1	Long-lived aerial platform or multiple probes	Global momentum and energy transport. Horizontal >> vertical
I.B.2	Multiple probes or constant altitude mobile platform for spatial coverage	Spectral >> Vertical >> Horizontal
I.B.3	Sustained aerial platform	Vertical >> horizontal Measure accelerations (precision not noted)
I.C.1	Mobile platform and aerosol characterization	Vertical res to 0.5km; Spatial res to 10^4 km for diurnal variability; 10-100km for small scale dynamics
I.C.2		
I.C.3	Long term observation for statistical significance	Did not quantify E-field measurement precision
I.C.4	See I.C.1,2 and I.A	See I.C.1,2 and I.A

Measurements from the Atmosphere

GOI	Platform	Requirements
II	Most requirements for observations and measurements of the surface from the atmospheric platform mirror those from orbit and the surface, or are impossible from a not surface bound platform. It was noted that observations from a lofted platform can allow observation of multiple physiographic terrain types.	
III	Most requirements here mirror either those described from Goal I or those associated with observations of the surface from the surface or atmosphere.	



More Findings

- **Orbit:**
  - **Indirect but provide important regional context for in situ measurements**
    - **Conversely, remote observations benefit from ground truth**
  - **Technological advances offer vast improvements over current surface observations**
    - **E.g., SAR image resolution; interferrometry, stereogrammetry, IR emissivity.**
  - **Surface targets were identified and atmospheric approaches were addressed.**

Targets from Orbit

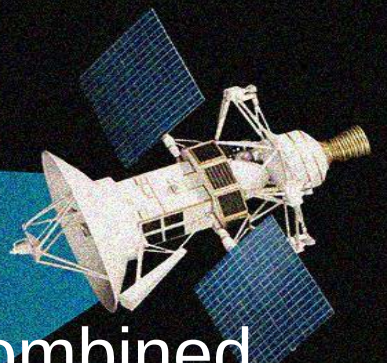
- Targets were split into five groups:
  - Atmosphere (chemistry and dynamics)
  - Volcanism
  - Crustal structures and tectonics
  - Impact craters and weathering
  - “Global” (focused on science questions that require global perspective, e.g., gravity)
- For each surface target category, guidelines were developed for selecting specific observational sites (e.g., coronae, chasmata) to address the full range of surface expressions on Venus

Orbit Needs

- Surface target groups identified very similar guidance for a small number of measurement categories that re-occur in several investigations:

Measurement Type		Guideline
Images	Moderate spatial resolution at contextual scales	• ~ factor of 3 better spatial resolution than Magellan • Image quality equal to or better than Magellan
	Targeted high spatial resolution	• ~ factor of 10 better spatial resolution than Magellan • Image quality equal to or better than Magellan
Topography	Regional scale	• “MOLA-class” horizontal scales • Vertical precision sufficient to resolve 5° slopes over 1 km baseline
	Targeted finer scale	• Finer postings • Finer vertical precision

Orbit Needs



- Additional Global Measurements, when combined with imaging and topography, provide needed observations:

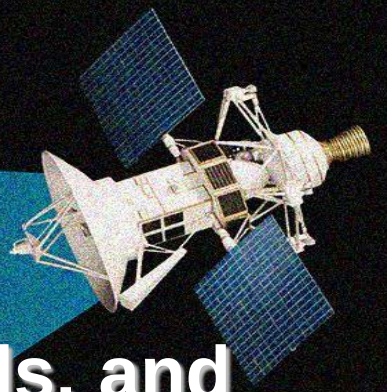
Measurement Type	Guideline
Gravity Field	• Globally resolved • Degree and order 120
Infrared Emission	• Ability to detect anomaly of a few Kelvin (~5K) relative to background
Microwave Emission	• No guideline provided
Magnetic Field	• No guideline provided

Orbit Needs

- Additional Targeted Measurements:

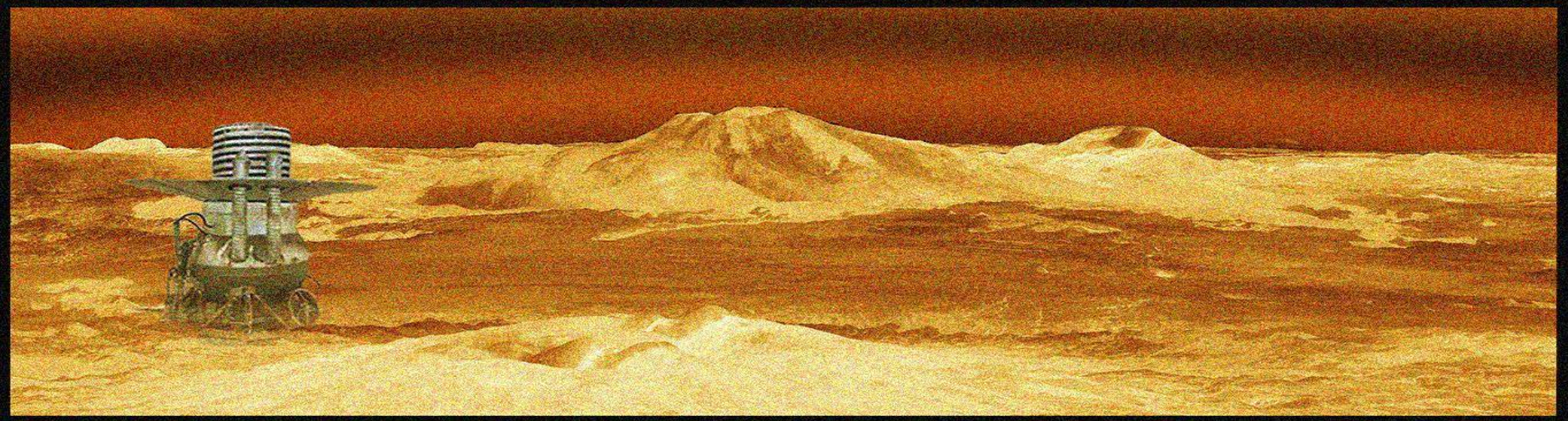
Measurement Type	Guideline
Microwave Polarimetry	• No guideline provided
Surface Penetrating Radar	• No guideline provided

Conclusions



- **Orbital science, atmospheric payloads, and landers are synegistic and complementary.**
  - **All are required to address the panoply intriguing questions surrounding the past and current state of Venus.**
- **A Venus Exploration Program – designed along the lines of MEP – is needed to bring Venus exploration to the level of Earth's other planetary neighbors.**
- **Perhaps *Discovery* and/or *New Frontiers* will spearhead this program.**

BACKUP



Environmental Factors

- Organizing Committee launched 5 Sept. 2013
  - Workshop dates set: 19-21 May 2014
  - Program designed; announcements circulated
  - Invited Venera D project scientists from Russia and US
- NASA HQ releases Discovery synopsis: Feb. 2014
  - Implementation & Science Teams off to the races
- Geopolitical tensions mount: March, 2014
  - Russian participants unable to attend workshop
- Nonetheless, the workshop attracted 51 participants from around the globe.