Venus Technology Plan

Presentation to

Venus Technology Forum

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Nov 19, 2013

Topics

- Objectives
- Impact of Venus Environment
- Mission Heritage
- Mission Modes – Priority Order
- Mission Modes and Technology

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Impact of Venus Environment

- In orbit the thermal environment is challenging but less so than for Mercury
- During planetary atmospheric entry, the velocity and thermal conditions are more severe than for entry at Earth or Mars (but less than Jupiter)
- Once in the atmosphere, missions operating high in the atmosphere can experience a benign environment in terms of temperature and pressure but are exposed to sulfuric acid clouds
- Landing on Venus is less challenging because of the dense atmosphere which eases both the initial parachute phase and terminal descent relative to Mars
- Surface operations using conventional electronics and passive thermal control systems are limited to a few hours by the high temperatures.
  - Long duration missions require components and packaging that will function in Venus ambient and/or have active thermal control systems.

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Heritage

- More than 30 spacecraft have flown to Venus since Mariner 2 flew by the planet 50 years ago.
- These missions have included flybys, orbiters, probes, short-lived landers and balloons.
- Most of the missions occurred in the first 25 years; only 2 successful missions to Venus have occurred since 1987, neither of which was done by the US.
- The absence of recent activity has resulted in loss of some of the technical capabilities important in Venus exploration. Some capabilities are not easily reproduced.
- Past successes provide a proof of principle that orbiters, probes, short-lived landers and balloons could be successfully deployed at Venus.

Mission Modes in Exploration Roadmap

- Remote Sensing from Space
  - Orbiter
  - Flyby
- Deep probes
  - Single
  - Multiple
- Lander – Short Duration
  - Smooth terrain
  - Rough terrain
- Lander – Long Duration
  - Single
  - Multiple – Network
- Aerial Platform
  - Sustained – fixed altitude
  - Sustained – Variable altitude
  - With drop sondes
- Surface or near surface platform with regional mobility
  - Surface – wheeled vehicle
  - Near surface – buoyant vehicle

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Mission Modes – Priority Order

Near-Term (Note 1)	Mid-Term	Far-Term
Active remote sensing orbiter (radar, topography, emissivity, gravity)	Deep multi-probes	Surface (or near-surface) platform with regional mobility
Sustained aerial platform	Short-duration lander to challenging terrain (tessera)	Long-lived lander network for seismic studies
Deep probe	Long-lived geophysical lander	
Short-duration lander		
Dropsondes or multi-probes		
Remote sensing orbiter or multi-flybys		

Note 1: Near term missions do not require new technology except to enhance capabilities

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Mission Modes and Applicable Technologies

	Mission Mode	Remote sensing from space		Deep Probes		Lander Short Duration		Lander Long Duration		Mobile* Platform Long Duration		Aerial Platform Mid Atmosphere		
		Orbiter	Multiple flybys	Single	Multiple	Smooth Terrain	Rough Terrain	Single	Network	Surface	Near Surface	Fixed altitude	Variable Altitude	Drop Sondes
System Technologies	Entry			X	X	X	X	X	X	X	X	X	X	X
	Descent and Deployment			X	X	X	X	X	X	X	X	X	X	X
	Landing					X	X	X	X	X				
	Aerial Platforms										X	X	X	X
	Landers - Short Durations					X	X							
	Landers Long Duration - Geophysica							X	X					
	Mobile Platform - Surface or near surface									X	X			
Subsystem Technologies	Energy Storage- Batteries	X	X	X	X	X	X	X	X	X	X	X	X	X
	Energy Generation - Solar	X	X									X	X	
	Energy Generation - Radioisotope Power									X	X		X	
	Thermal Control - Passive					X	X						X	X
	Thermal Control - Active									X	X			
	High temperature mechanisms					X	X	X	X	X	X			
	High temperature electronics					X	X	X	X	X	X			
	Communications			X	X	X	X	X	X	X	X	X	X	X
	Guidance, Navigation and Control							X	X	X	X	X	X	X
Insutrument	Remote Sensing - Active	X	X											
	Remote Sensing - Passive	X	X											
	Probe - Aerial Platform			X	X							X	X	X
	In Situ Surface - Short Duration					X	X							
	IN Situ Surface - Long Duration - Geophysical							X	X					
	In Situ Surface - Long Duration - Mobile Lab									X	X			

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Mission Modes and Technology Maturity

	Mission Mode	Remote sensing from space		Deep Probes		Lander Short Duration		Lander Long Duration		Mobile* Platform Long Duration		Aerial Platform Mid Atmosphere		
		Orbiter	Multiple flybys	Single	Multiple	Smooth Terrain	Rough Terrain	Single	Network	Surface	Near Surface	Fixed altitude	Variable Altitude	Drop Sondes
Applicable Technologies – System Technologies	Entry			X	X	X	X	X	X	X	X	X	X	X
	Descent and Deployment			X	X	X	X	X	X	X	X	X	X	X
	Landing					X	X	X	X	X				
	Aerial Platforms										X	X	X	X
	Landers - Short Durations					X	X							
	Landers Long Duration - Geophysica							X	X					
	Mobile Platform - Surface or near surface									X	X			
Subsystem Technologies	Energy Storage- Batteries	X	X	X	X	X	X	X	X	X	X	X	X	X
	Energy Generation - Solar	X	X									X	X	
	Energy Generation - Radioisotope Power									X	X		X	
	Thermal Control - Passive					X	X						X	X
	Thermal Control - Active									X	X			
	High temperature mechanisms					X	X	X	X	X	X			
	High temperature electronics					X	X	X	X	X	X			
	Communications			X	X	X	X	X	X	X	X	X	X	X
	Guidance, Navigation and Control							X	X	X	X	X	X	X
Insutrument	Remote Sensing - Active	X	X											
	Remote Sensing - Passive	X	X											
	Probe - Aerial Platform			X	X							X	X	X
	In Situ Surface - Short Duration					X	X							
	IN Situ Surface - Long Duration - Geophysical							X	X					
	In Situ Surface - Long Duration - Mobile Lab									X	X			

Maturity Scale

Green	**Very High. Ready for flight.**
Yellow	**High. Limited development and testing still needed**
Orange	**Moderate. Major R&D effort needed.**
Red	**Low. Major R&D effort needed with uncertainty about feasiblity.**

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Preliminary Findings (1 of 5)

Entry Technology:

- The thermal protection system (TPS) technology for missions involving entry into the Venus atmosphere has not been used for many decades and as a result has been lost.
- Two attractive options for replacing the prior technology, 3D Woven TPS and ADEPT technology, are currently under development under the sponsorship of the Space Technology Missions Directorate (STMD) with the goal of reaching TRL 5/6.
- These developments will not only enable the next generation of Venus entry missions but also promise to be a stable and enduring solution and one that is not prone to premature obsolescence.

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Preliminary Findings (2 of 5)

Testing Facilities:

- Testing facilities are important to the development of advanced TPS materials such as 3D Woven TPS and also for investigating and validating the performance of new technologies for operating deep in the Venus atmosphere.

- A number of facilities capable of high temperature and high pressure operations have been developed and these need to be equipped with diagnostics equipment.

- Larger facilities may be needed as we progress in technology development of long duration operations on the Venus surface.

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Preliminary Findings (3 of 5)

Landers – Short Duration:

- The technology for missions with lifetimes of 2 to 3 hours called for in the VER is available now.
- Technologies with the promise of extending lifetimes by a factor of 10 are looking increasingly promising.
- Maturation of these technologies could greatly increase the capabilities of Venus surface missions and enable the operations team to respond to information from the lander while it is still operating.

Landers – Long Duration:

- Advances in high temperature electronics may enable long duration missions on the surface of Venus operating for periods of up to a year
- Sensors and all other components would operate at Venus ambient.
- The types of measurement that can be made from these vehicles will be limited in scope and sensitivity

Preliminary Findings (4 of 5)

Aerial Platforms:

- After more than a decade of development, the technology for deploying balloon payloads approaching 100Kg with floating lifetimes in excess of 30 days near 55 km altitude has reached maturity.

- Vehicles for operation at higher and lower elevations in the atmosphere and with the ability to modify altitude are much less mature and need development.

- A buoyant vehicle, operating close to the Venus surface, is one option for the Regional Mobility Mission Mode called for in the VER but requires major development.

Preliminary Findings (5 of 5)

In Situ Instruments:

- Since the last Venus technology assessment performed in support of the Planetary Science Decadal Survey in 2011, there has been significant progress in instruments for surface geology and geochemistry.

- The utility of Laser Induced Breakdown Spectroscopy (LIBS) in conjunction with remote Raman spectroscopy has been demonstrated.

- Advances in other instruments for “rapid petrology” also appear possible spurred in part by the Mars program

- The best approach for pursuing the scientific objectives defined by the GOI team are not clear and a workshop focused on this topic would be highly desirable.

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Venus Technology - Summary Assessment

	Technology Area	Time Frame	Assessment
System Technologies	**Entry Descent and Landing**	N,M	Need new woven TPS or deployable technologies for entry at Venus since there is currently no technology that does the job. Descent and landing is much easier than for Mars and for airless bodies and is largely an engineering challenge
	Aerial Platforms	N,F	Technology for near term missions is mature. Near surface aerial capabiity would be one option for the "regional mobility platform" and does require substantial investment
	Landed Platforms	N,M,F	Three classes of landed platform will be needed of increasing technical challenge: short duration containing analytical instruments (current technology), long duration with geophysical sensors and long durations with a complex instrument suite and surface mobility
Subsystem Technologies	**Power**	M,F	Most compelling mid term need is for thermoelectric generators operating in a 460C environment. In the far term, the efficiency of Stirling would be highly desirable
	Thermal Control	M,F	Challenge is extending lifetime once on the surface. Prospects for extending life beyond several hours with passive cooling are low. Active cooling may be feasible for long life
	Extreme Environments	N,M,F	Advances in high temperature mechanisms would be enhancing for a first generation lander. High temperature electronics would be needed for the geophysical platform.
	Communications	N,M,F	Optical communications would be enhancing for an orbital radar mission. Proximity communications are needed to enhance data return from all in situ missions
	Guidance Navigation and Control	M,F	Miniaturized low power systems needed for localization and attitude knowledge on probes, aerial platforms, dropsondes and landers
Instruments	**Orbital Remote Sensing**	N	Technology for implementing these missions is hear today. Advances in radar and infrared techniques would be enhancidn
	Probe and Balloon	N,M,F	Instruments for middle atmosphere exist but should be miniaturized. Sensors for chemistry in the lower atmosphere need improvement
	Surface in situ	N,M,F	Need technologies in near term for "rapid petrology". In mid term need geophysical sensors that operate at Venus ambient. In far term need sensonrs for mobile laboratory