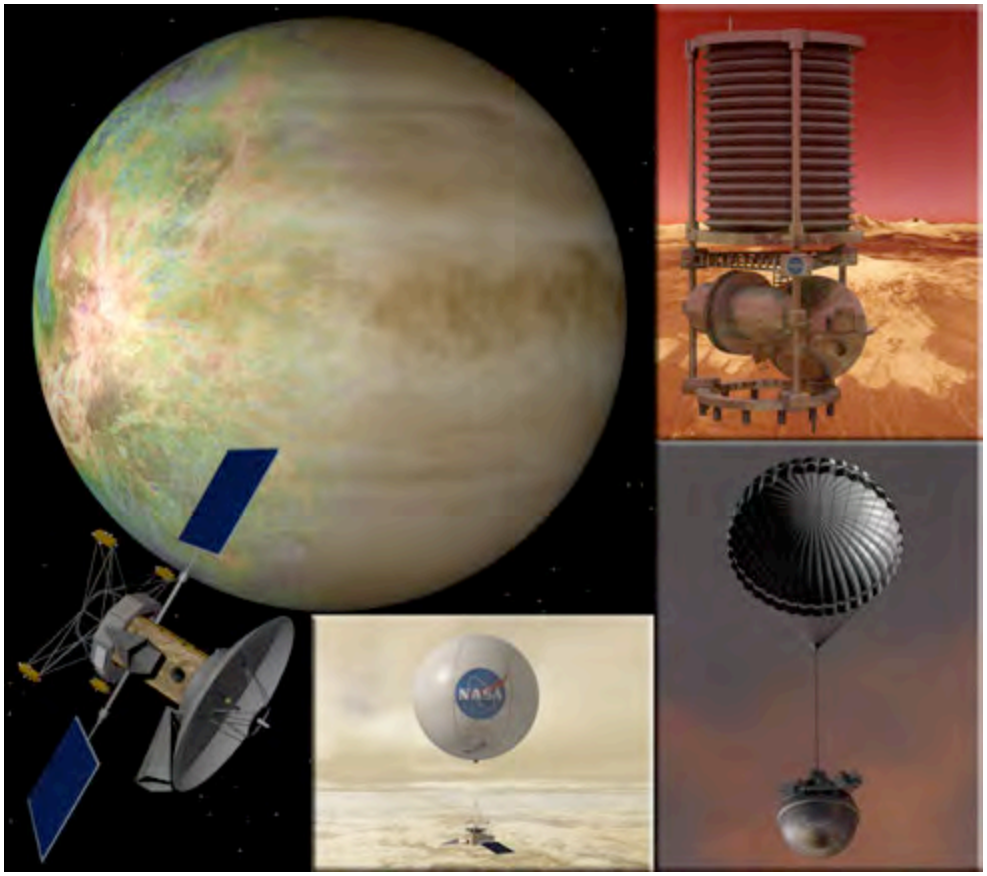
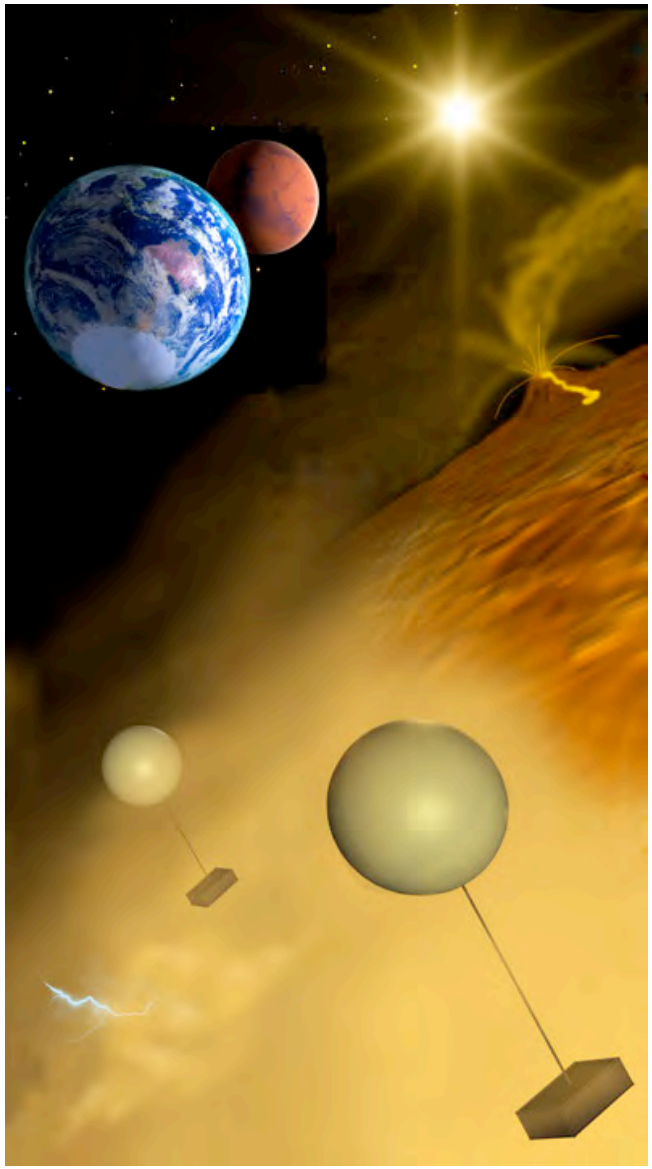


Venus Exploration Goals, Objectives, and Investigations: 2007

Janet Luhmann,
Steve Mackwell, Sushil Atreya, Tommy Thompson

VEXAG Meeting #4
November 4, 2007



History

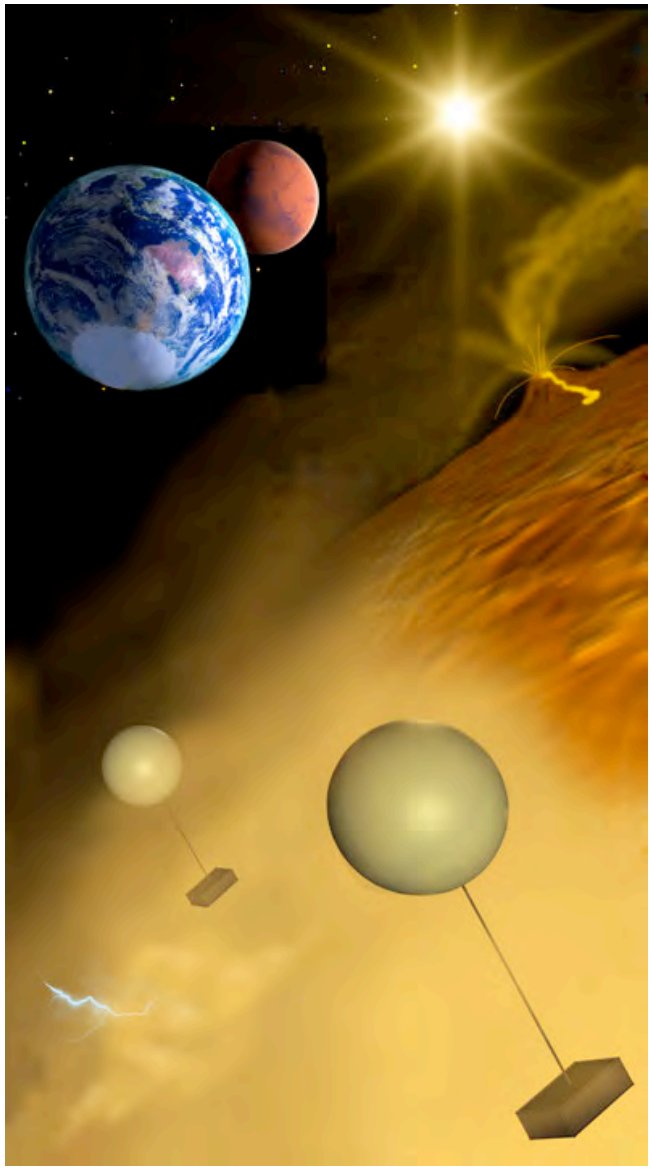
Goals, Objectives, and Investigations (and their relative priorities) were established by the VEXAG Task Groups at the previous VEXAG Meetings

Preliminary version was distributed at the Discovery at 15 Meeting in September

Updated version (minor updates) was distributed at the PSS meeting in early October

CD-ROM Contents

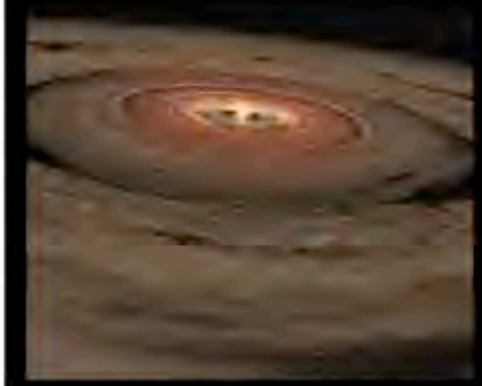
White paper (pdf), VEXAG Goals and Objectives poster and Photo Gallery



Contents

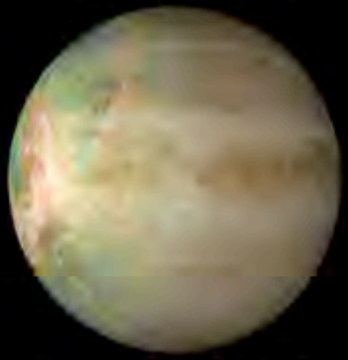
Venus Exploration Goals and Objectives

Goal 1:
Origin and Early Evolution of Venus:
How did Venus originate and evolve?



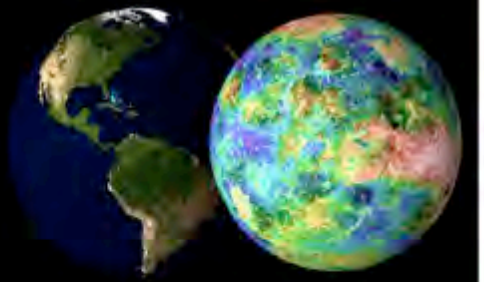
- *Determine isotopic composition of atmosphere*
- *Map the mineralogy and composition of the surface on a planetary scale*
- *Characterize the history of volatiles in the interior, surface and atmosphere*
- *Characterize the surface stratigraphy of lowland regions and the evidence for climate change*
- *Determine the ages of various rock units on Venus*

Goal 2:
Venus as a terrestrial planet:
What are the processes that have and still shape the planet?



- *Characterize and understand the radiative balance of the Venus atmosphere*
- *Investigate the resurface history and the role of tectonism, vulcanism, impact, erosion and weathering.*
- *Determine the chronology of volcanic activity and outgassing*
- *Determine the chronology of tectonic activity*
- *Investigate meteorological phenomena including waves, tides, clouds, lightning and precipitation.*

Goal 3:
What does Venus tell us about the fate of Earth's environment?



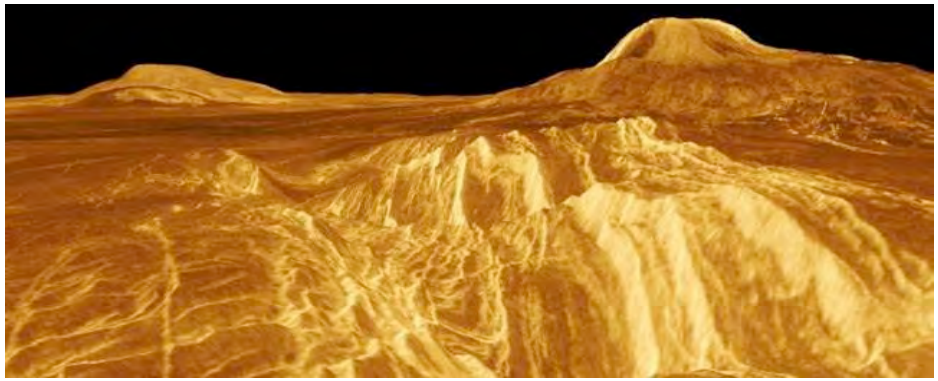
- *Search for fossil evidence of past climate change in the surface and atmospheric composition.*
- *Search for evidence of changes in interior dynamics and its impact on climate*
- *Characterize the Venus Greenhouse effect and its similarities to those on Earth and other planets*

Venus Exploration VEXAG Analysis Group

The Past → **The Present** → **The Future**

Outstanding Questions in Venus Exploration

- Was there ever an ocean on Venus, and if so, when did it exist and how did it disappear?
- Was the early Venus atmosphere like the early atmosphere of Earth, and at what point did it diverge in character so greatly and why?
- Why does Venus rotate so slowly and is the lack of a planetary dynamo a consequence? What was the impact on the evolution of Venus?
- Why does Venus' atmosphere rotate 60-times faster than its solid body?
- How are atmospheric heat and momentum transferred from equator to poles?
- What caused the extensive resurfacing of Venus during the last billion years? Is Venus still an active planet? Are the resurfacing and climate change related?
- Was Venus ever habitable?



Overarching Goals for Venus Exploration:

1) ***Origin and Early Evolution of Venus: How did Venus originate and evolve, and what are the implications for the characteristic lifetimes and conditions of habitable environments on Venus and similar extrasolar systems?***

2) ***Venus as a Terrestrial Planet: What are the processes that have shaped and still shape the planet?***

3) ***Implications for Earth: What does Venus tell us about the fate of Earth's environment?***

VEXAG Findings
Venus Science

- ***Finding:*** Without additional resources, the U.S. Venus science community will fall further behind in Venus exploration leadership. There will be no opportunity to fully take advantage of the results of either the Venus Express mission or the MESSENGER flyby in our future plans for Venus exploration, or to train the next generation of Venus scientists.

- ***Proposed Action:*** In order to fully exploit the results from both the Venus Express and MESSENGER at Venus, made available via the Planetary Data System, funds should be identified to amend the NASA Research Announcement to include a Venus Data Analysis Program open to all.

- ***Current Status:*** NASA will pursue a Venus Data Analysis program in FY08 when both the Venus Express and MESSENGER data are available via the Planetary Data System.

VEXAG Findings
Technology Investments

- ***Findings:*** There are credible-technical approaches, leveraging from technologies developed in industry to achieving extended operation in the Venus environment. High-temperature electronics can enable systems to operate for extended periods in the corrosive, high-pressure on Venus' surface. Advanced radioisotope-power systems and active thermal-control systems could enable conventional components such as microprocessors or imaging sensors to operate for extended periods on Venus' surface. While further work on mission architectures will be needed to define specific performance goals and the technology focus, technology work can and should begin now. Without NASA's direct involvement, it will not be possible to apply the results from industry to the specific needs of in-situ and near-surface exploration.

VEXAG Proposed Actions
Technology Investments

Proposed Action: NASA should initiate a program to develop technologies for operation in Venus' extreme environment. These should include:

- Passive thermal-control technologies for extending operation on or near the surface from hours to days.
- Active thermal-control technologies and power-generation systems for extending Venus operations to many months.
- High-temperature electronics and other components capable of extended operation directly exposed to the Venus surface environment.
- Mobility systems for operation at the surface and in the lower atmosphere of Venus.
- A program of systems analyses to establish performance objectives and evaluate alternative approaches for mission architectures

VEXAG Findings
New Frontiers Missions

- ***Finding:*** VEXAG considers that the Venus In-Situ Explorer continues to be a vital mission to explore Venus and should be included in the FY08 New Frontiers AO. The scientific goals stipulated in the FY03 NF AO remain valid. In addition to its scientific value, the VISE mission offers a unique opportunity to validate capabilities that would be important to a future Flagship mission.

- ***Proposed Action:*** The Venus In-Situ Explorer should be included in the New Frontiers AO for 2008 and the general scientific goals for this mission should remain unchanged. NASA should consider implementing a technology-validation element for VISE in particular that would permit demonstration of technologies needed for a long-duration mobile mission but not necessary to the success of VISE itself.

VEXAG Proposed Actions
Venus Flagship Mission

- ***Finding:*** The completion by VEXAG of scientific goals and priorities now makes it timely to initiate a study of a Venus Flagship mission to define a concept in more detail and identify the technologies needed to implement the mission. This study should not be delayed because a path to addressing specific-technology challenges that the resulting mission-concept raises must be embarked upon at the earliest opportunity.

- ***Proposed Action:*** NASA should initiate a study of a Flagship mission to Venus at the earliest opportunity**.** The study should assess:
  - Key scientific questions that can be addressed by a long-duration mobile mission to the surface or near-surface of Venus.
  - Alternative-mission architectures for addressing these scientific questions.
  - Precursor-scientific measurements and technology validation that might be implemented with prior Discovery and New Frontiers missions.
  - Technology investments needed to enable the Venus Flagship mission emphasizing - long-lead time technologies needing early investment.

- ***Current Status: This will be pursued as a Venus STDT in FY08***

Take Home Messages

- There is a lot of exciting and important science to do above and on Venus, our closest neighbor in the solar system.
- Venus' proximity to earth makes it a highly accessible target
- Important science can be accomplished with existing technologies to address Venus science objectives including missions under the New Frontiers program
- However, investments in new technologies are required for next major steps forward in exploration following the scientific exploration pathway established for Mars
- Technology demonstrations in early missions will retire risk for later missions and should be considered as desirable and acceptable part of a New Frontiers mission to Venus

Back Up Charts

- Key Extreme Environment Technologies
- Mission Descriptions

Key Extreme Environment Technologies

Technology needs could be categorized into three general areas:

1) **Environmental protection** technologies providing isolation from extreme environments;

2) **Environmental tolerance** for exposed components or systems;

3) **Operations in extreme environments**.

- Protection systems:
  - Hypervelocity Entry
  - Pressure Mitigation
  - Temperature Mitigation
- High-Temperature Electronics
- Power Storage
- Power Generation
- Mobility Technologies
  - Balloon and Parachute Materials
- Sample Acquisition & Mechanism
- Telecommunication Issues
- Testing for Extreme Environments

New Frontiers Class Mission Concept

Venus In-Situ Explorer

Scientific Objectives

- Composition and isotopic measurements of surface and atmosphere for determining origin and evolution
- Atmospheric dynamics
- Cloud structure, composition, properties
- Acquire and characterize a core sample
- Demonstrate key technologies for VSSR

Exploration Metrics

- Operate in Venus near-surface environment for several hours

Science Payload

- Chemistry package
- UV-VIS-IR cameras; optical package
- Atmospheric instrument (p,T, humidity)
- Gas chromatograph / mass spectrometer
- Instruments to measure elements and mineralogy of surface materials (if lander)
- Radiometer; nephelometer; lightning detector

Technology & Heritage

- Extreme environments technologies (pressure vessel, thermal management, corrosion)
- High-temperature electronics
- Sample acquisition and handling in Venus near-surface environment
- Passive insulation; phase change materials
- Component testing in relevant environments

Mission & LV Class

- Intermediate Class Mission
- Launch Vehicle: TBD

Flagship Class Mission Concept

Venus Geophysical Network

Scientific Objectives

- Determine the internal structure and seismic activity of the planet
- Monitor the circulation of the atmosphere

Exploration Metrics

- At least three stations on the surface of Venus
- Operate for at least one Earth year

Science Payload

- Camera, descent imager
- Seismometer network
- Meteorology station with pressure, temperature and wind velocity sensors

Technology & Heritage

- Extreme-environments technologies (pressure vessel, thermal management, corrosion)
- High-temperature electronics for telecom / high-data volume
- Radioisotope power system w/ active cooling
- Long-duration operations in situ
- Passive insulation and survival technology from VISE

Mission & LV Class

- Flagship Class Mission
- Launch Vehicle(s): TBD

Flagship Class Mission Concept

Venus Mobile Explorer

Scientific Objectives

- Composition and isotopic measurements of surface and atmosphere
- Near IR descent images
- Acquire and characterize core samples at multiple sites
- Demonstrate key technologies for VSSR

Exploration Metrics

- Operate in Venus surface environment for 90 days+
- Range and altitude if aerial vehicle TBD
- Range across surface if rover TBD

Science Payload

- Neutral-mass spectrometer with enrichment cell
- Instruments to measure elements and mineralogy of surface materials
- Imaging microscope

Technology & Heritage

- Extreme-environments technologies (pressure vessel, thermal management, corrosion)
- High-temperature electronics
- Sample acquisition and handling in Venus near-surface environment
- Air-mobility system (e.g., metallic bellows)
- Radioisotope power system w/ active cooling
- Long-duration operations in situ

Mission & LV Class

- Flagship Class Mission
- Launch Vehicle:
  - Delta-IV-H
  - Atlas V

Flagship Class Mission Concept

Venus Surface Sample Return

Scientific Objectives

- Measure isotopic composition of oxygen in surface rocks
- Measure isotopic composition of trace elements to characterize core-and-mantle formation
- Determine the age of returned rocks

Exploration Metrics

- Return samples of Venus rock soil and atmosphere for analysis on Earth
- Mission duration: TBD
- Time on surface: TBD (short lived)

Science Payload

- Camera and Descent imager
- Sample identification as needed
- Sample-acquisition system
- In-situ instrumentation

Technology & Heritage

- Extreme-environments technologies (pressure vessel, thermal management, corrosion)
- High-temperature electronics
- Sample acquisition and handling in Venus near-surface environment
- Multi-stage ascent air-mobility system to lift sample to launch altitude
- Rendezvous and sample-return systems inherited from Mars Sample Return
- Heritage from prior Venus missions: e.g., VISE, Venus Geophysical Network, VME

Mission & LV Class

- Flagship Class Mission
- Launch Vehicle: TBD