

The Venus Science and Technology Team

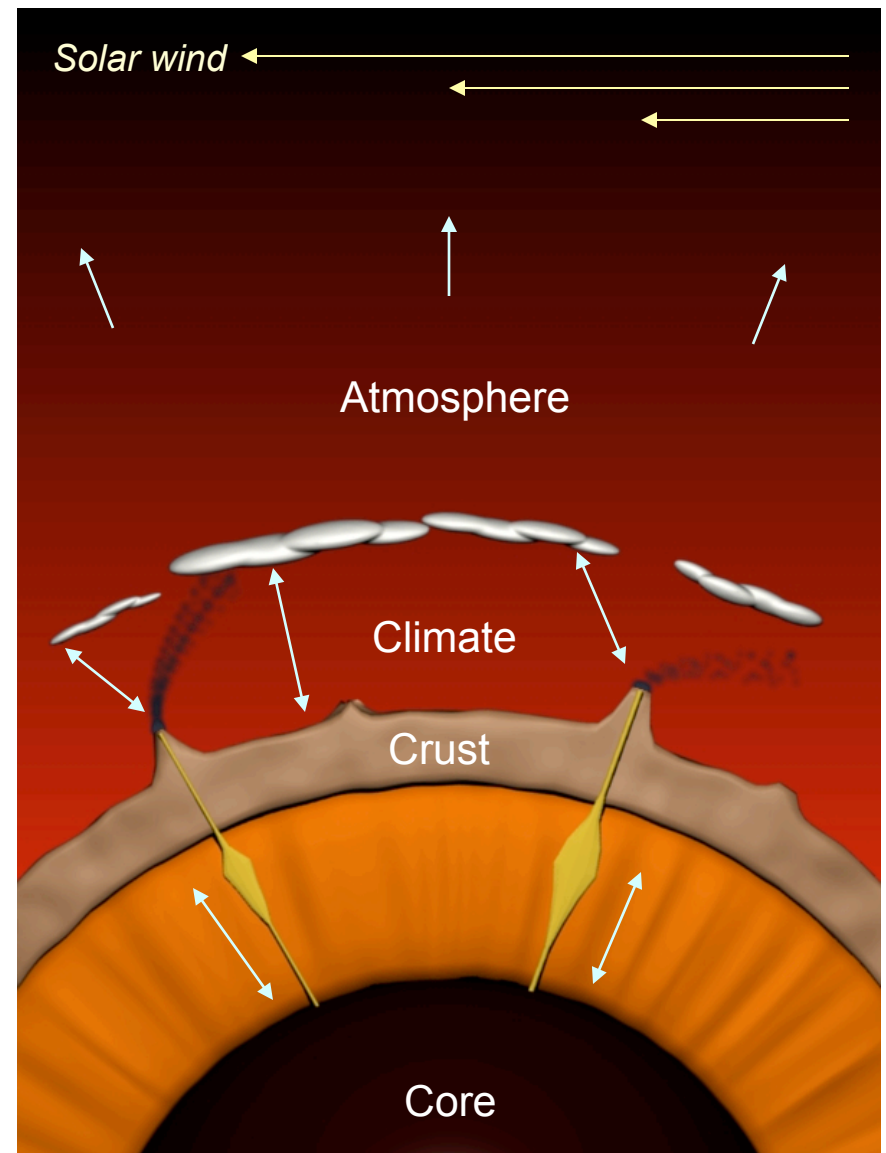
Report to VEXAG

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Venus STDT

Why a Venus Flagship Mission?

- **What does the Venus greenhouse tell us about climate change?**
 - Probes through atmosphere simultaneously with balloons
- **How active is Venus?**
 - Highly capable orbiter with high resolution radar imaging, topography, and temporal changes. InSAR probably cannot be done with New Frontiers
- **When and where did the water go?**
 - Geochemistry and mineralogy at 2 locations on Venus. Cannot be done with New Frontiers
- **A Venus Flagship mission in 2020-2025 can be done with a low technology investment and relatively low risk.**



Venus STDT Goals

- Define the science objectives for a flagship-class mission to Venus
- Define the scientific investigations required to meet the Venus flagship mission science objectives
- Investigate the effectiveness of several mission architectures to accomplish the science objectives at Venus
- Pick the optimal mission architecture for accomplishing the science objectives within the design constraints
 - 2020-2025 launch
 - Launch capability \leq Delta IVH
 - TRL 6 for all instruments and components by 2015
 - Total mission cost \$3-4B
- Define the payload
- Design the mission
- Identify the technological development required to fly the mission
- Publish a final report by April 13, 2009

Top-Level Science Questions

- Is Venus geologically active today?
- How does Venus' atmospheric greenhouse work?
- What does the observable surface say about Venus' geological history?
- What is the circulation of Venus' atmosphere, and how does Venus' atmospheric superrotation work?
- How do the surface and atmosphere interact to affect their compositions?
- How are the clouds formed and maintained?
- How is sunlight absorbed in the Venus atmosphere?
- What atmospheric loss mechanisms are currently at work?

Top-Level Science Questions

- What kind of basalts make up Venus' lava flows, and are there evolved, continental-like rocks on Venus?
- How is heat transported in the mantle, and how thick is the thermal lithosphere?
- What happened on Venus to erase 80% of its geologic history?
- Did Venus ever have oceans, and if so, for how long?
- Did Venus' early atmosphere experience catastrophic loss, either due to hydrodynamic escape or a large impact?
- Did Venus have a magnetic field, and does it have a remanent one now?

Theme 1: What does the Venus greenhouse tell us about climate change?

- Characterize the dynamics, chemical cycles, and radiative balance of the Venus atmosphere
 - Orbiter visible-near infrared imaging spectrometer
 - Orbiter sub-millimeter sounder
 - Orbiter Langmuir probe
 - Balloon and descent atmospheric structure (P, T, winds, acceleration)
 - Balloon and descent nephelometers
 - Descent and lander net flux radiometers
 - Balloon high-precision tracking with ultrastable oscillators
 - Lander corner reflectors
- Place Constraints on the Evolution of Venus' Atmosphere
 - Orbiter ion-neutral mass spectrometer
 - Balloon, descent, and lander gas chromatograph/mass spectrometers

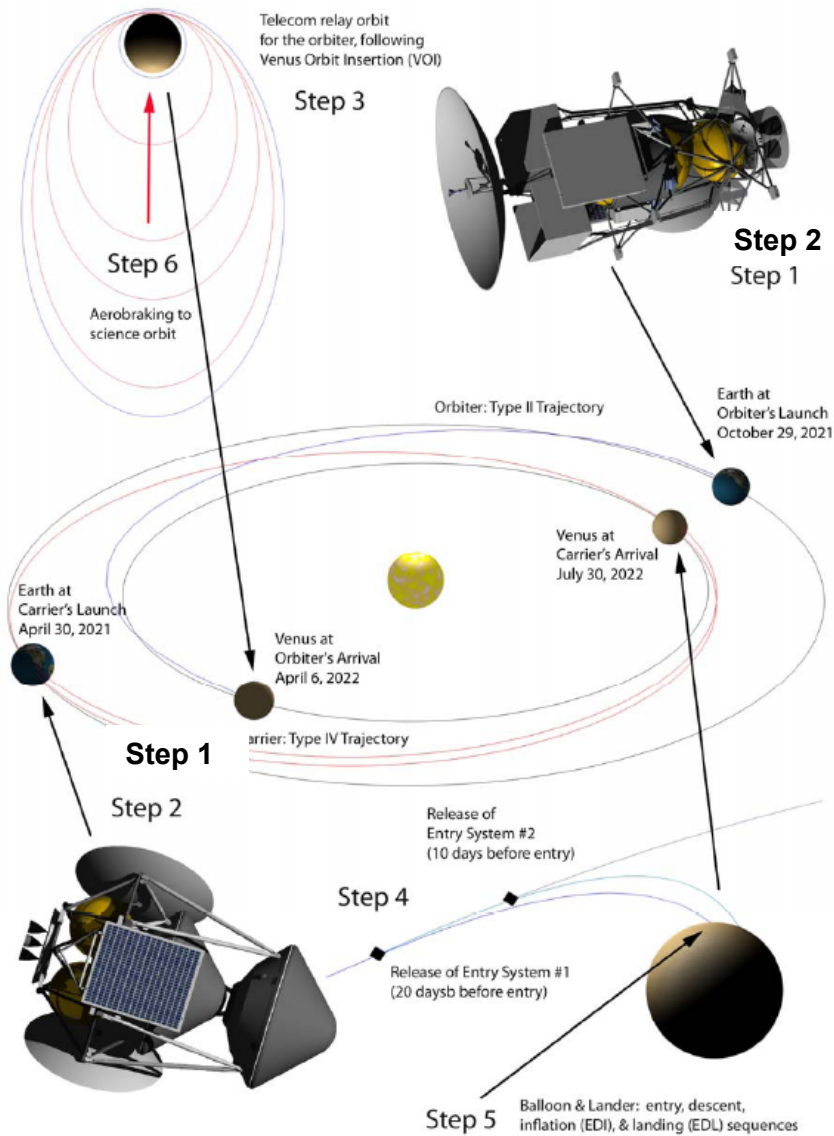
Theme 2: How active is Venus?

- Identify evidence for active tectonism and volcanism and place constraints on evolution of tectonic and volcanic styles
 - Orbiter Interferometric Synthetic Aperture Radar (InSAR)
 - Orbiter navigation precision with an ultrastable oscillator
- Characterize the structure and dynamics of the interior and place constraints on resurfacing
 - Orbiter, balloon, descent, and landing magnetometers
 - Lander heat flux plates
- Place constraints on stratigraphy, resurfacing, and other geologic processes
 - Balloon, descent, and lander near-IR cameras
 - Orbiter VIS-NIR imaging spectrometer

Theme 3: When and where did the water go?

- Identify evidence of past environmental conditions, including oceans
 - Balloon, descent, and lander gas chromatograph/mass spectrometers
 - Lander X-ray diffraction/X-ray fluorescence (XRD/XRF)
 - Lander γ -ray detectors
 - Lander drilling, sample acquisition, handling, and sample preparation
- Characterize geologic units in terms of chemical and mineralogical composition of the surface rocks in context of past and present environmental conditions
 - Descent and lander visible-near infrared cameras
 - Lander microscopic imagers
 - Lander X-ray diffraction/X-ray fluorescence
 - Lander γ -ray detectors
 - Lander drilling, sample acquisition, handling, and sample preparation

Mission Design



- A 5600 kg carrier with 2 balloons and 2 landers launches to Venus on an Atlas 551.
- A 5600 kg orbiter launches later, on a separate Atlas 551.
- Orbiter arrives first and enters a 300 x 40000 km near-polar orbit
- Entry vehicles arrive 13 hours apart with simultaneous balloon-lander entries
- 1 month balloon missions at 50-70 km
- 10 hour lander missions
- Orbiter aerobrakes to a 230 km circular orbit for a 2 year science mission phase

Payload Summary

- Orbiter
 - InSAR
 - INMS
 - Vis-IR-UV imaging spectrometer
 - Submm sounder
 - Magnetometer
 - Langmuir probe
 - Radio subsystem

170 kg instruments
- Balloon
 - Mass spectrometer
 - Nephelometer
 - Net flux radiometer
 - Atmospheric structure
 - Optical lightning detector
 - Radio subsystem
 - Magnetometer

23 kg instruments
- Lander
 - Mass spectrometer
 - Nephelometer
 - Net flux radiometer
 - Atmospheric structure
- Descent and panoramic cameras
 - Radio subsystem
 - Magnetometer
 - Sample handling and acquisition
 - XRD/XRF
 - Microscopic imager
 - Intrinsic g-ray spectrometer
 - Microwave corner reflector
 - Heat flux plate

105 kg instruments

 - Long duration package:
 - Seismometer
 - Meteorological station
 - Radio subsystem

Venus STDT Final Report

Fact Sheet

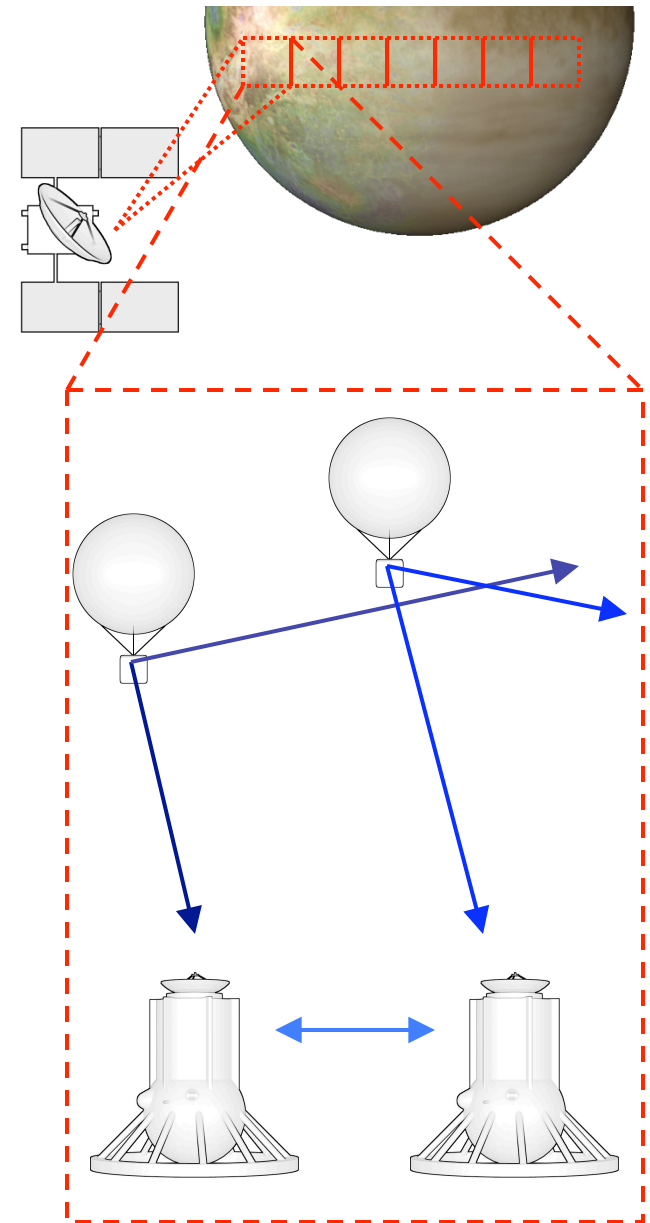
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- 2 Venus Science Goals and Objectives
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New Frontiers and Discovery science and technology to enable the Venus flagship mission

- Science
 - Descent imaging
 - High resolution topography in selected areas (e.g. tessera). And roughness for landing site characterization.
 - Optimized mapping of the surface and lower atmosphere in the near-IR from orbit (VCO may contribute data).
 - Entry into Venus atmosphere with any in situ science
- Demonstration Technology Experiments
 - Test of high temperature electronics (sensors, telecom, data storage)
 - Improved lifetime with passive T control
 - Test high temperature power generation and storage - RPS and high T batteries
 - Palette of different materials for testing
 - Flotation device under high T,P
 - Lander lifetime information

Venus Flagship Science Synergies

- **Deployment** of in-situ elements:
 - 2 landers + 2 balloons deployed at the same time
 - Probe descents to be targeted to go near balloon paths
- **Measurement synergies** for atmospheric science
 - 2 landers give **vertical** slices of the atmosphere during descent
 - 2 balloons give **zonal and meridional** slices roughly **intersecting** balloon paths
- **Science synergies** between **geochemistry and atmosphere**
 - Simultaneous geochemical and mineralogical analysis
 - Spatial and temporal atmospheric gas analysis
 - Two disparate locations at the same time
- **Science synergies** between **geology and geochemistry**
 - Landings on tessera and volcanic plains
 - for comparative geology and geochemistry



Venus STDT Conclusions

- A flagship mission to Venus with a 2020-2025 launch would revolutionize understanding of rocky planets and would cost less than \$3B FY09.
- A flagship mission to Venus would be the first deep exploration of another planet with the explicit intent of understanding our own.
- Such a mission would consist of one highly capable orbiter, two balloons capable of circumnavigating the planet up to 7 times, and two passively cooled landers lasting for up to 10 hours each.
- A technology development program specifically for Venus exploration must begin now for achieving necessary TRL levels for a 2020-2025 launch.