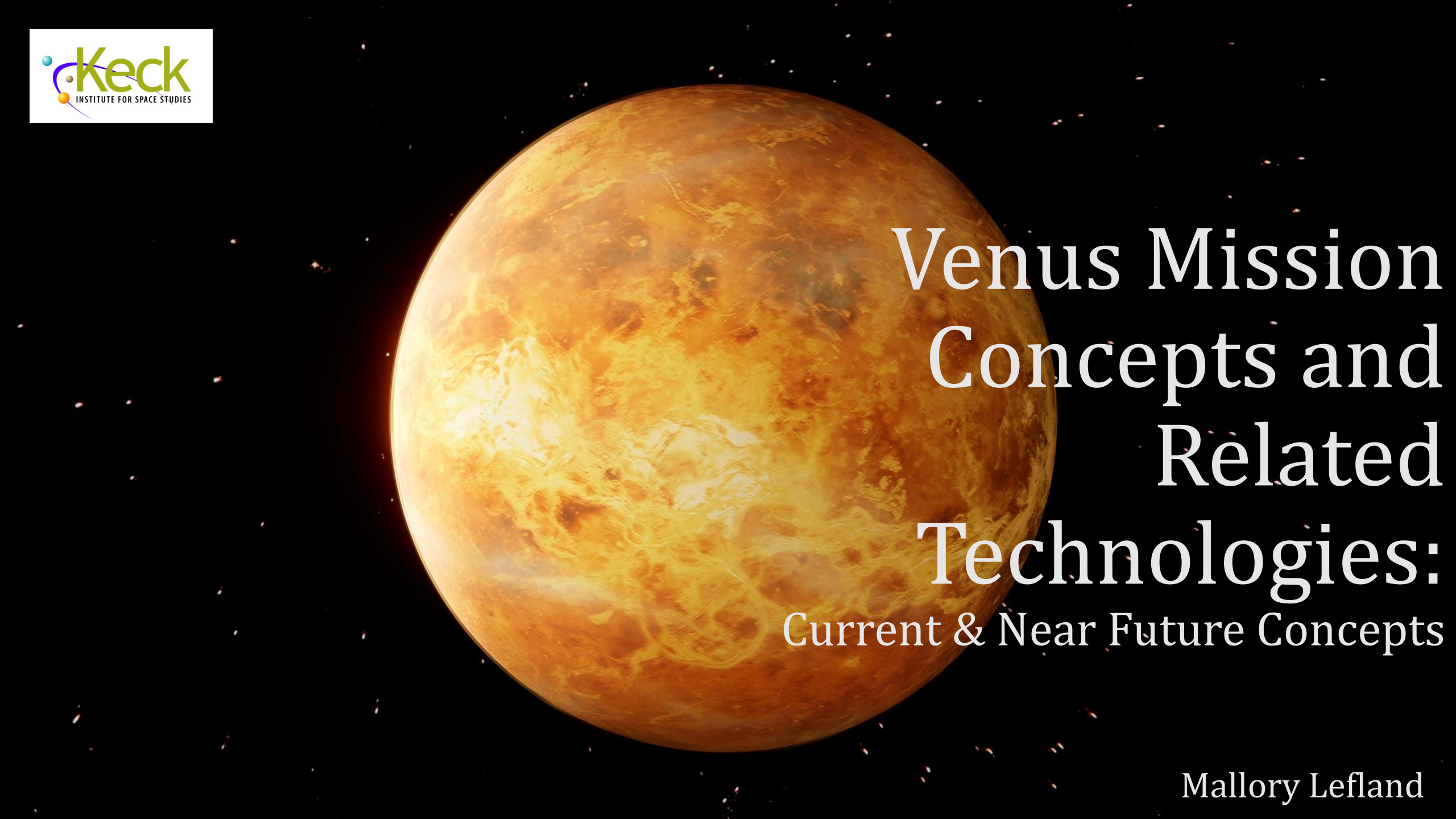


Venus Mission Concepts and Related Technologies:

Current & Near Future Concepts

Mallory Lefland

"A new era in the exploration of our closest, yet wildly different, Solar System neighbour awaits us. Together with the newly announced NASA-led Venus missions, we will have an extremely comprehensive science programme at this enigmatic planet well into the next decade."
- Günther Hasinger, ESA Director of Science

"It is astounding how little we know about Venus, but the combined results of these missions will tell us about the planet from the clouds in its sky through the volcanoes on its surface all the way down to its very core. It will be as if we have rediscovered the planet."
- Tom Wagner, NASA's Discovery program scientist

Current Venus Missions in Development

Venus is about to get crowded!

Mission	Organization	Proposed Launch	Science Target	Element(s)
VERITAS*	NASA - JPL	2028	**Surface**: to map the surface in high resolution	Orbiter
DAVINCI	NASA - GSFC	2029	**Atmosphere**: to measure the composition of the atmosphere of Venus	Orbiter, Atmospheric Probe
Venera-D	Russian Federal Space Agency	2029	**Atmosphere**: to measure composition of of the atmosphere of Venus with orbiter instruments and atmospheric probes	Orbiter, Lander Balloons (?) Microprobes (?)
EnVision*	ESA	2031	**Surface**: to map regions of the surface in high resolution	Orbiter

*In addition to primary objectives, telecom systems on the spacecraft and Earth will be used for gravity investigations

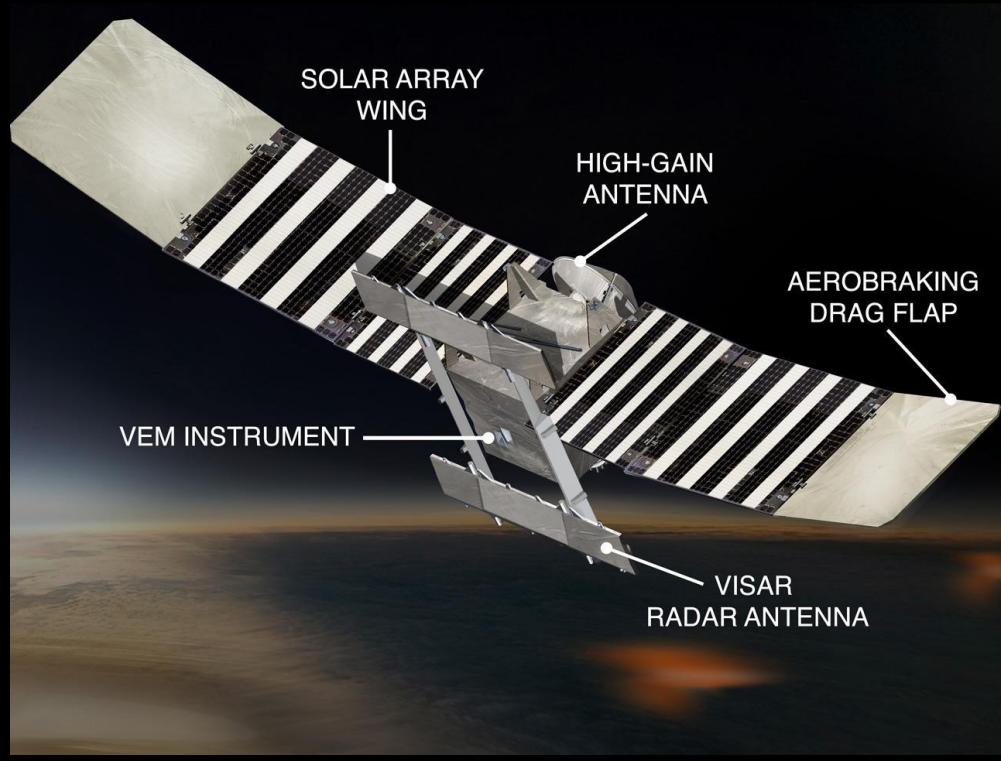
VERITAS

NASA JPL, 2028

Venus Emissivity, Radio Science, InSAR, Topography, and Spectroscopy

Mission Design:

- Six month cruise
- Enters polar orbit after an orbit insertion maneuver
- One phase of aerobraking lasting 5 months
- 4.5 months of science
- Second phase of aerobraking lasting 5 months which puts VERITAS into its final science orbit
- Nominal science mission is ~2.7 Earth years



VERITAS

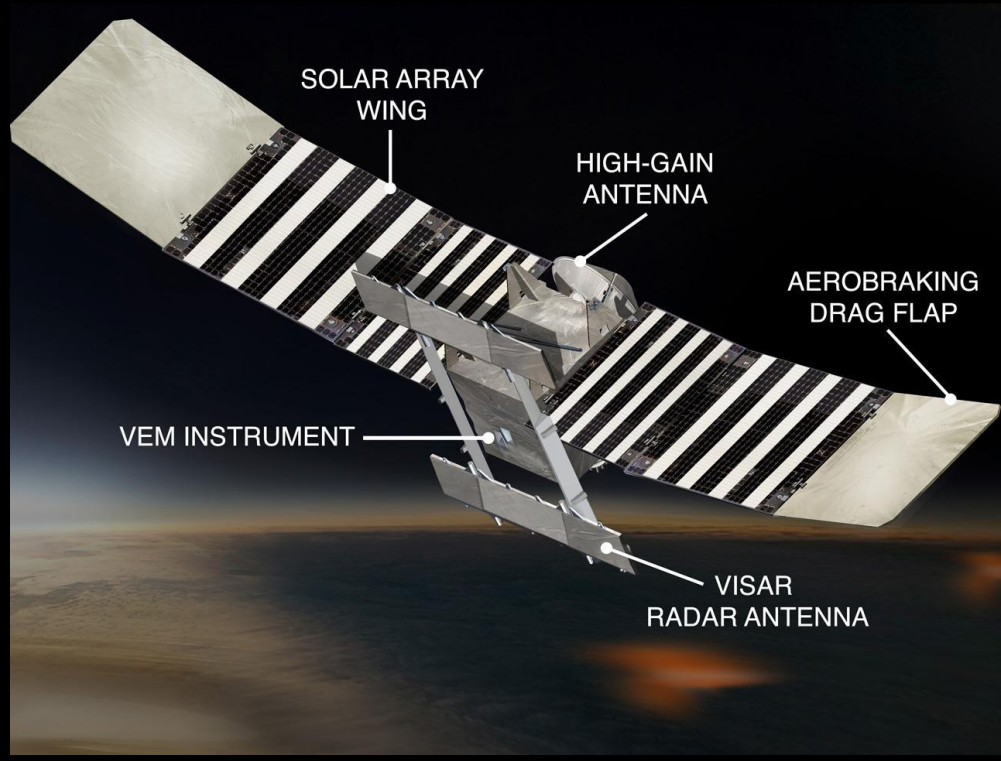
NASA JPL, 2028

Venus Emissivity, Radio Science, InSAR, Topography, and Spectroscopy

What processes shape rocky planets? And what processes are currently active?
Is there evidence of past or present water?

Payloads:

- Emissivity mapper: an infrared imaging spectrometer that will map surface emissivity using spectral bands in atmospheric bands that see through the clouds
- Interferometric Synthetic Aperture Radar: produce the first planetary active surface deformation map and high resolution topography
- Deep Space Atomic Clock-2



Gravity Science:

Will provide data to help answer questions about the interior of Venus:

- Is the core liquid or solid?
- What is the temperature of the mantel?
- Provide a map of gravity strength

DAVINCI

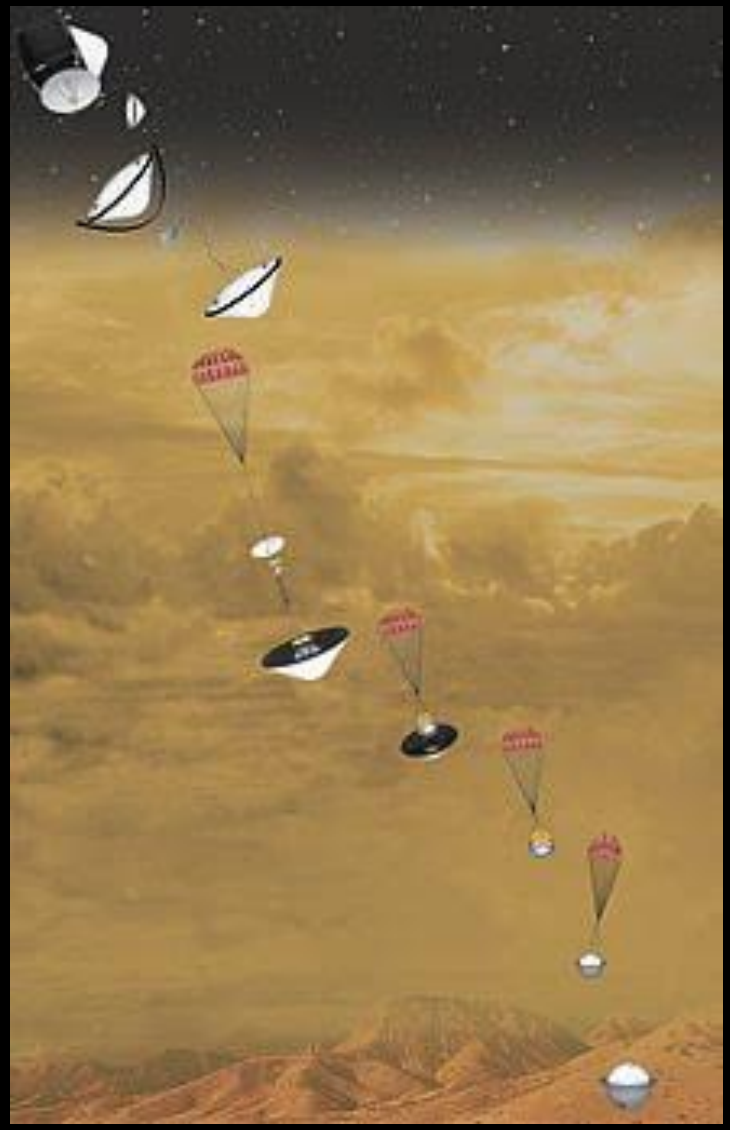
The first probe to enter the atmosphere of Venus since Soviet VeGa in 1985!

NASA JPL, 2028

Deep Atmosphere Venus Investigation of Noble gases, Chemistry and Imaging

Mission Design:

- Orbiter will study atmosphere during two flybys
- After seven months, orbiter will release descent probe, the probe will take an hour to fall through atmosphere where it will take measurements and images.
- The probe is not required to survive landing but could last up to 17 minutes on the surface
- During the descent and any additional time on the surface, the orbiter will serve as a communication asset for the probe



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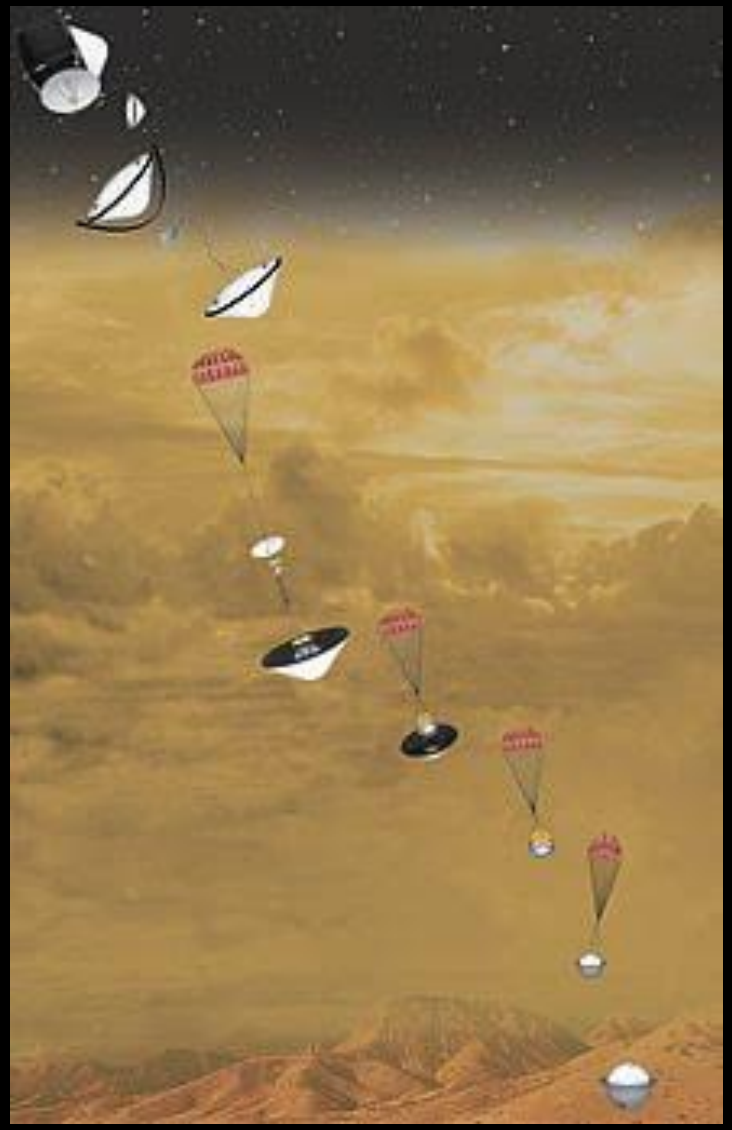


Designed to address Decadal science objectives regarding the atmospheric makeup of Venus:

Understand origin of Venus's atmosphere

Investigate chemical processes in work in the lower atmosphere

Obtain high resolution images

Orbiter Payloads

- Mass spectral camera to image in UV
- Remote sensing after release of descent probe

Descent Payloads

- Mass Spectrometer: first comprehensive surveys of noble and trace gases at Venus, and capability to discover new gas species
- Tunable Laser Spectrometer: measurements of trace gases and isotope ratios to study chemical processes
- Atmospheric Structure Investigation: measure structure and dynamics of atmosphere during entry and descent
- Descent Imager

Venera-D

Russian Federal Space Agency, 2029

- Orbiter in polar orbit for ~3 years
  - Study the nature of the greenhouse effect
  - Characterize thermal structure of atmosphere, winds, thermal tides
  - Measure composition of atmosphere, investigate upper atmosphere, ionosphere, and the gas escape rate

- Lander: operational life time on the surface planned to be ~3 hours
  - Elemental composition of the surface
  - Interaction between surface and atmosphere

EnVision

ESA, 2031

Mission Design:

- 15-month cruise followed by 15-month aerobreaking to reach science orbit
- Will spend 4 Earth years in science orbit

How have surface and interior of Venus evolved?
How tectonically active is Venus today? What about past activity?
Did Venus have oceans?
How does Venus lose heat? Why did greenhouse effect begin?

Payloads:

- Synthetic Aperture Radar: provides targeted surface mapping, global topography and altimetry, stereo imaging
- Subsurface Radar Sounder: provides stratigraphic relationships
- Spectroscopy Suite: uses three different channels to produce compositional data on rock types, atmospheric measurements, and sulphured minor species, and UV absorption

Radio Science:

- EnVision's orbit will allow for radio science to obtain gravity resolution at each longitude and latitude of the planet

Future Venus Technology Developments

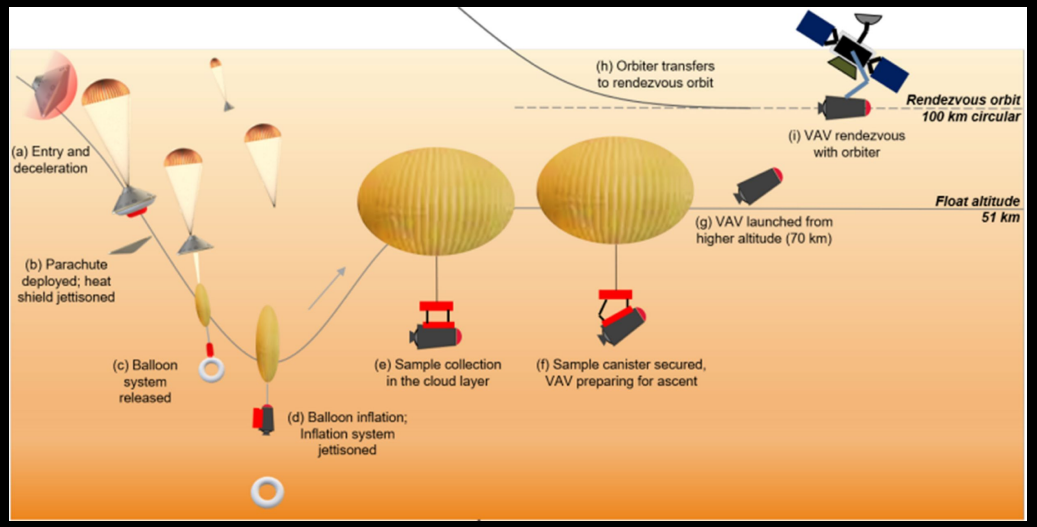
- Pressure & Thermal Control:
  - Titanium pressure vessel is space qualified; New lightweight materials need development. If pressure vessel mass is decreased, more payload can be carried for the same entry mass
  - Aerogels, MLI: Improvements in passive thermal control could extend surface survival to up to 5 hours, potentially longer
  - Refrigeration: long duration missions will require some refrigeration Adopt Stirling conversion based coolers for Venus surface conditions

- Power generation & storage:
  - High temperature cell and battery designs
  - Generation: Demonstrated single Stirling convertor for long life operation

- Unique Mission architectures that utilize the environment on Venus to operate

NASA Innovative Advanced Concepts (NAIC) Program Selections:

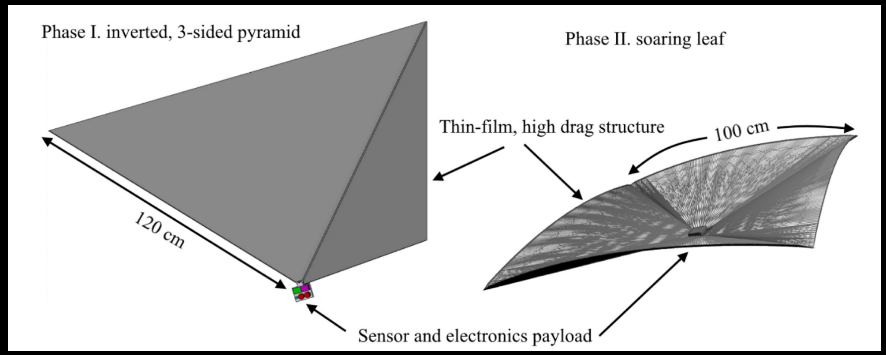
Numerous Venus mission concepts and technology developments have been selected in recent years



2022: Venus Atmosphere and Cloud Particle Sample Return for Astrobiology

- Entry probe and orbiter
- Entry probe is a variable altitude balloon that contains sample capture hardware and an ascent launch vehicle
- Ascent launch vehicle rendezvous with orbiter after capture, then orbiter returns to Earth

2021: Lofted Environmental Venus Sensors



- Swarm approach of ”kite-like” sensor suite
- in-situ atmosphere data for low cost and risk
- Ultra-lightweight sensor package
- Deployed directly into orbit with a passive, drifting body that should allow for ~9 hours of science in the upper and middle atmosphere
- Could be used as a sensory payload or enhancement of other missions orbiting / flying by Venus

NASA Innovative Advanced Concepts (NAIC) Program Selections:

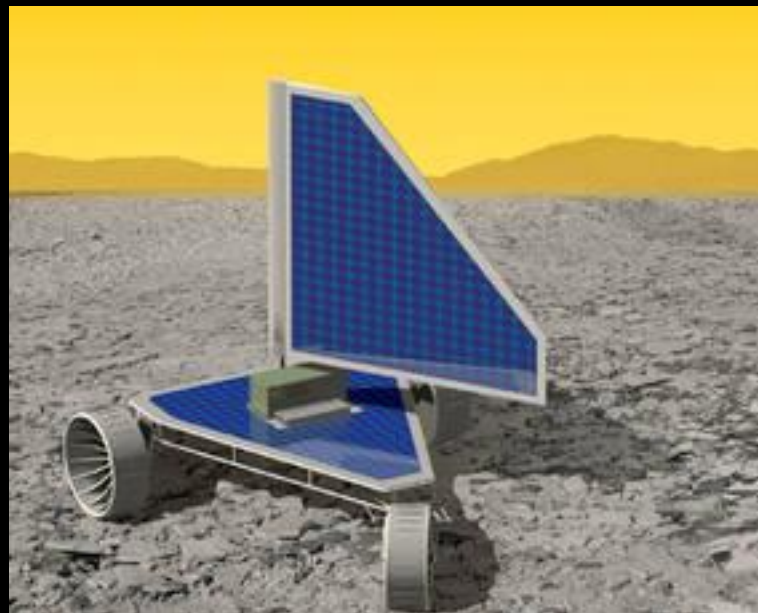
Numerous Venus mission concepts and technology developments have been selected in recent years

2021: Heat Exchange-driven aircraft for Low Altitude and Surface Exploration of Venus

- Fixed wing aircraft capable of flying through the atmosphere
- uses a heat sink material to power the engines and the aircraft using the atmospheric heat
- Dives between low and high altitudes to take advantage of the temperature differences

2019: Venus Landsailing Rover

- NASA Glenn developed electronics that continue to function at a temperature of 450C
- Have also tested solar cells up to Venus surface temperatures, though power density is low
- The combination of wind (even low speed) and surface pressure make Venus an ideal environment for landsailing
- If placed in a flat landscape, as seen by the Venera probes, it is ideal conditions for landscaping



NASA Innovative Advanced Concepts (NAIC) Program Selections:

Numerous Venus mission concepts and technology developments have been selected in recent years

2019: Power Beaming for Long Life Venus Surface Missions

- Use of a dual vehicle architecture, one at a high altitude that provides power generation in the upper atmosphere and moves to the lower atmosphere to transfer energy, and a one a lander that collects, stores and uses the power
- Power is generated in the upper atmosphere, where the solar flux is high, allowing the batteries to recharge
- Power is transferred between the two through power beaming (wireless energy transfer). For Venus, this type of transfer would require transmitting power at radio frequency or microwave wavelength
- The atmospheric vehicle descends to transfer the power to the lander and ascends back into the upper atmosphere after completing the transfer
- Potential for atmospheric vehicle to be used for telecommunication purposes