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SCIENCE GOALS AND PAYLOADS FOR COMMON PROBE MISSIONS TO VENUS AND THE GIANT PLANETS

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Science Justification for Planet Entry Probes

"Comparative planetology of well-mixed atmospheres of the outer planets is key to the origin and evolution of the Solar System, and, by extension, extrasolar systems."

S.K. Atreya, et al. "Multiprobe exploration of the giant planets – Shallow probes", Proceedings of the 3rd International Planetary Probes Workshop, Anavyssos, Greece, 2005.

There is only one Rosetta Stone in the Solar System; it's in the British Museum. We cannot understand the inner planets by simply studying the Earth, nor can we apprehend the giants by examining only Jupiter.

Despite the stunning successes of previous probes to Venus and the Galileo probe to Jupiter, our knowledge of the atmospheres of even these two planets remains tantalizingly incomplete. We must therefore return to Venus and consider the challenge of exploring all of the outer planets with a family of identical probes, a project that could commemorate the vision of multiple worlds championed by Giordano Bruno."*

T. Owen "Atmospheric Probes: Needs and Probspects," Proceedings of the 1st International Planetary Probes Workshop, Lisbon, 2003.

** A.A. Martinez* "Giordano Bruno and the heresy of many worlds," Annals of Science, Vol. 73, p345-37, 2016

Remote Sensing

Remote sensing has made profound contributions to current understanding of the solar system.

However, remote sensing:

- Cannot provide noble gas abundances and isotope ratios
- Cannot provide abundances of many condensable species. For example, presence of sulfur strongly suspected on Jupiter as H_2S. Only from Galileo probe was this gas detected.
- Is of limited usefulness in determining thermal structure, radiative energy balance, cloud location, composition, and microphysics, and dynamics (deep winds, waves, tides, etc.).

Planetary Science Decadal Survey
Giant Planet Science Objectives

Saturn Probe

Tier-1:

1. Determine noble gas abundances & isotopic ratios in Saturn's atmosphere.
2. Determine atmospheric structure (temperature & pressure vs height) at probe location.

Tier-2:

3. Determine vertical profile of zonal winds as function of depth at probe descent location(s).
4. Determine location, density, and composition of clouds as function of depth in atmosphere.
5. Determine variability of atmospheric structure and presence of clouds *in two locations*.
6. Determine vertical water abundance profile at probe descent location(s).
7. Determine isotope abundances for light elements such as C, S, N, and O.

Uranus Probe

3. Determine the noble gas abundances (He, Ne, Ar, Kr, and Xe) and isotopic ratios of H, C, N, & O in the planet's atmosphere and the atmospheric structure at the probe descent location
9. Determine the vertical profile of zonal winds as a function of depth in the atmosphere, in addition to the presence of clouds as a function of depth in the atmosphere.

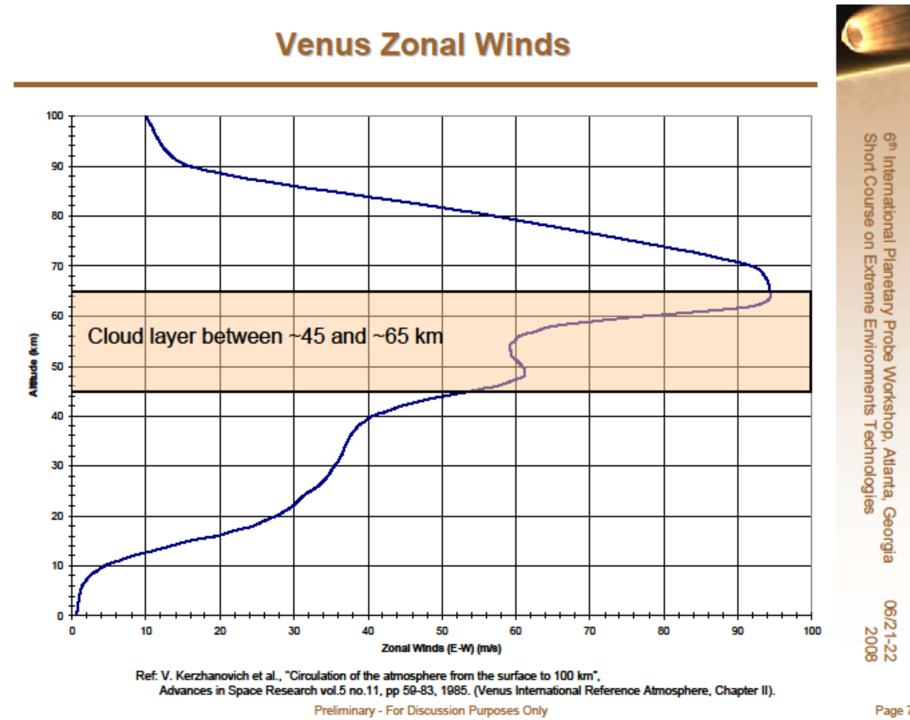
Venus In Situ Explorer Science Objectives

The Planetary Science Decadal Survey (PSDS) science mission objectives for VISE most relevant to probe missions are:

- Understand the physics and chemistry of Venus's atmosphere, especially the abundances of trace gases, sulfur, light stable isotopes, and noble gas isotopes;
- Constrain the coupling of thermochemical, photochemical, and dynamical processes in Venus's atmosphere and between the surface and atmosphere to understand radiative balance, climate, dynamics, and chemical cycles;
- Understand the properties of Venus's atmosphere down to the surface and improve our understanding of Venus's zonal cloud-level winds;
- Look for planetary scale evidence of past hydrological cycles, oceans, and life and for constraints on the evolution of the atmosphere of Venus.

Altitudes of Interest - Venus

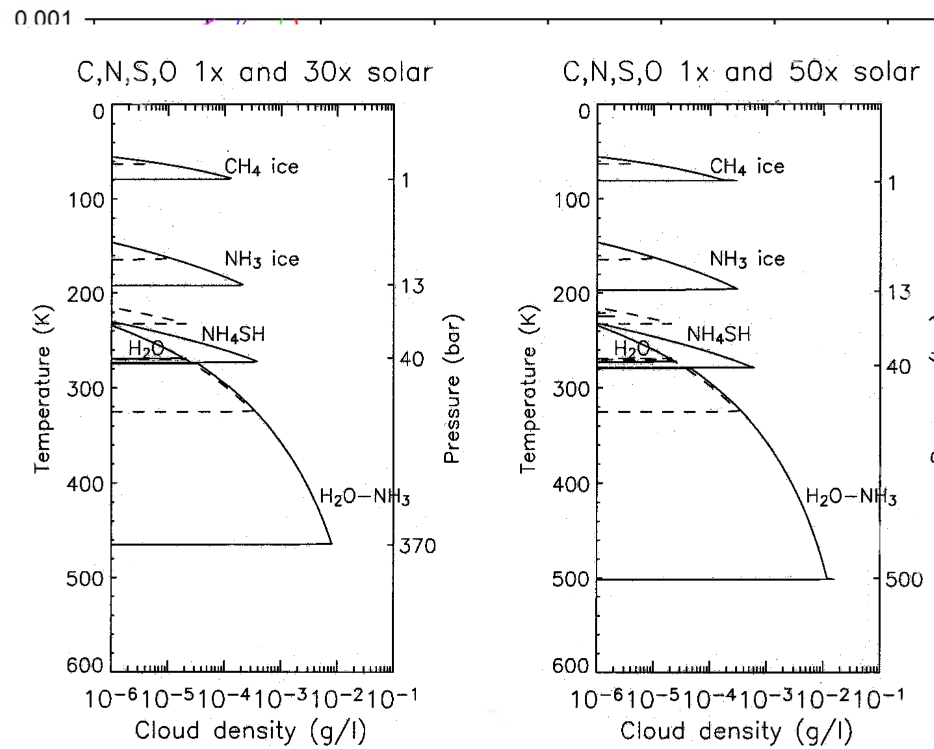
- To the surface!
- Noble gases in upper atmosphere
- Three cloud layers, 65 km – 45 km
- Failure of all Pioneer Venus probes to measure temperatures below 12 km
- ~5-8 km: Atmospheric dynamics in “acceleration region”
- Near surface stability and dynamics, outgassing and surface-interior interactions, atmospheric composition&compositional gradients



Altitudes of Interest - Giant Planets

- As deep as possible…!
- Descent science start near tropopause ~100 mb
- Noble gases: ~1-2 bars
- Cloud locations: depends on total abundances of N, S, & O

Neptune



Equilibrium Cloud Condensation Models (Atreya, Wong 2005)

Probe Science Instrument Payloads

	Instrument	Measurement
Tier 1	Mass Spectrometer	Elemental and chemical composition, especially noble gases and key isotopes
	Atmospheric Structure Instrument (ASI)	Pressure and Temperature → Thermal structure, density, stability Entry Accelerations → Density
Tier 2	Radio Science Experiment	Atmospheric dynamics: winds and waves; Atmospheric absorption → composition
	Nephelometer	Cloud structure, aerosol number densities & characteristics
	Net Flux Radiometer	Net radiative fluxes: Thermal IR, solar visible

Target Specific Instruments

Venus

- Cameras for surface imaging, planetary context of landing site;
  Complement Doppler wind measurements in Planetary Boundary Layer

- Acoustic Instruments
  Speed of Sound → Composition or Temperature
  Microphone → Thunder (but more likely aeroacoustic noise), Surface winds

Giant Planets

- Helium Abundance Detector

- Acoustic Instruments / Speed of Sound → Composition or Temperature

- Ortho/Para Hydrogen: Conversion may affect thermal structure, dynamics;
  Thermal equilibrium reached slowly → measure convective upwelling from hot deeper atmosphere

SUMMARY

- Although each planet has individual science priorities, there are common overarching science goals for all planetary atmospheres.
- Commonality of overarching science goals leads to certain common payload elements.
- Highest priority: Composition (esp. noble gases and key isotopes), thermal structure, and dynamics.

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