V3NUS Mission Impact on VEXAG Goals, Objectives, and Investigations (GOI)

and

What Humans In The Loop Can Bring to Venus Science

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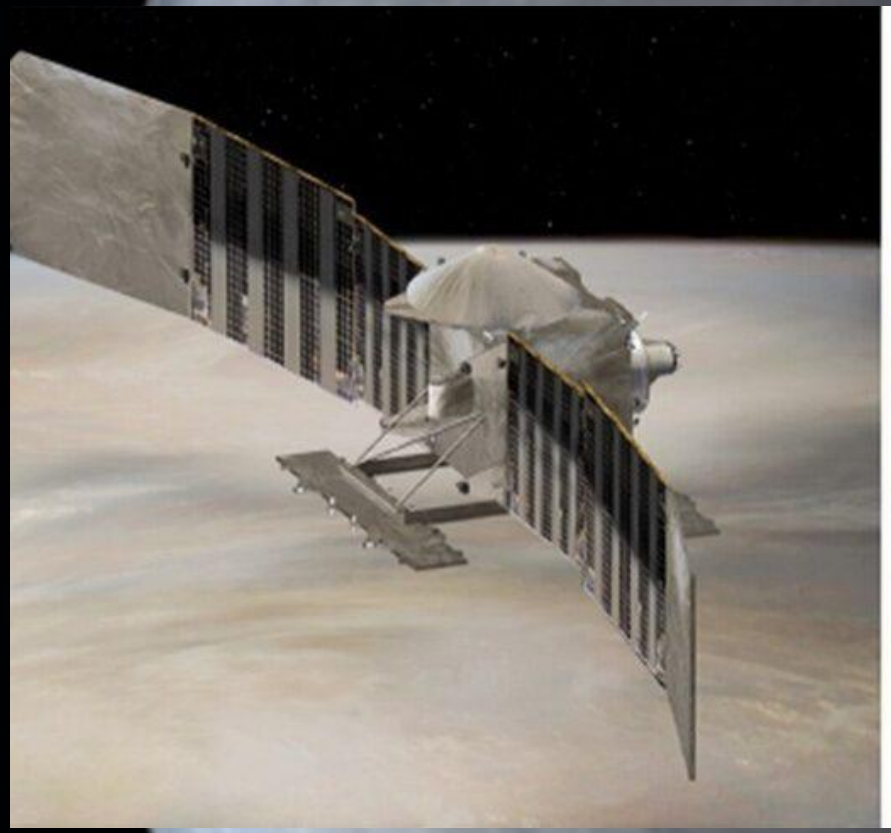
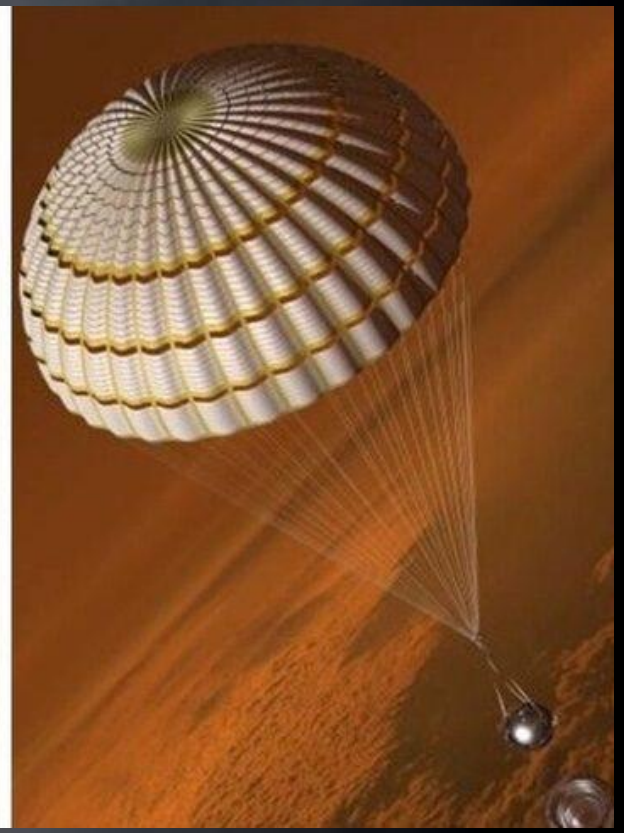
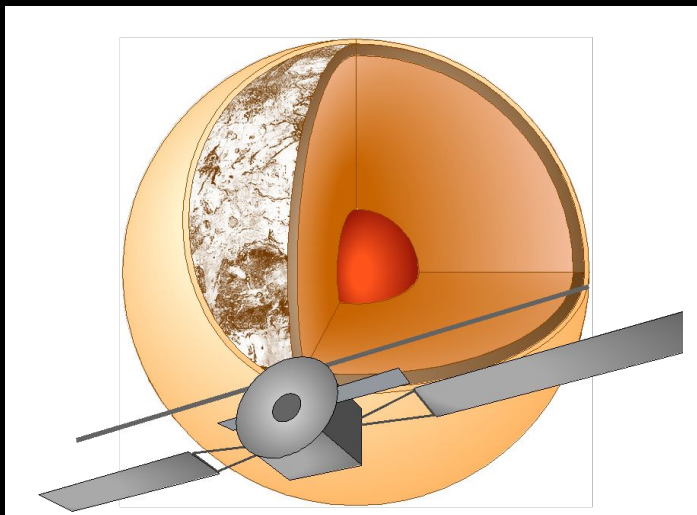
V3NUS = VERITAS, DAVINCI, EnVision





VERITAS

DAVINCI



EnVision

Understanding why our closest neighbour is so different

V3NUS = VERITAS, DAVINCI, EnVision

Dark blue - "Substantially Addressed"

The Investigation can to be substantially incremented/revised after V3NUS completion.

Medium Blue– "Partially Addressed"

The Investigation might need to be incremented/revised after V3NUS completion.

Light Blue – "First Look"

The Investigation could be incremented/revised after V3NUS completion.

White – "Not substantially addressed"

The V3NUS missions won't affect these Investigations.

Caveats

This quick initial evaluation is from a subset of the VEXAG steering committee, including members of the V3NUS missions, and can't be viewed as an official VEXAG document revision.

Substantially addressed does **not** mean *completed* or *resolved* – the fact the far right column has no blanks emphasizes that point, although some Essential (1) Investigations may evolve to Important (2) or Targeted (3).

The wealth of data in “substantially addressed" areas will without doubt spur calls for new research. To give the most obvious example, “Geological History” will never be completely resolved.

The Big Questions

Goal	Objective	Investigation	Achieved by end of V3NUS	Future Achievement
I. Understand Venus' early evolution and potential habitability to constrain the evolution of Venus-size (exo)planets.	A. Did Venus have temperate surface conditions and liquid water at early times?	**HO. Hydrous Origins (1).**	Near-IR emissivity maps, searching for widespread felsic crust.	Measurement of surface rock composition in situ (e.g. XRF, GRS, LIBS), particularly in tesserae. **LS, SC**
		RE. Recycling (1).	Radar maps, subsurface sounding, Near-IR emissivity maps.	Measurement of surface rock composition in situ (e.g. XRF, GRS, LIBS). Follow-up high-res radar & high res NIR surface imaging. **LS, SC**
		A**L. Atmospheric Losses (2).**	-	Orbital measurements of ionosphere & solar wind interaction; sub-mm sounder to measure winds and transport through lower thermosphere. **SR**
		MA. Magnetism (3).	-	Magnetic fields measured from orbit and/or balloon
	B. How does Venus elucidate possible pathways for planetary evolution in general?	**IS. Isotopes (1).**	Comprehensively addressed by DAVINCI+.	Next generation MS instruments on long-lived cloud platform may be able to achieve even higher sensitivity. [Isotopes in surface materials **LS]**
		LI. Lithosphere (1).	Comprehensively addressed by VERITAS & EnVision's SAR & gravity.	Seismometry; Magnetotelluric sounding; In situ measurements of surface material composition. Follow-up high-res radar & high res NIR surface imaging. **LAG**
		HF. Heat flow (2).	Constraints from gravity/ topography calcs; also from detection & characterization of volcanism & tectonism.	Seismometry; *[in situ heat flow in different provinces].* **LS**
		CO. Core (2).	Strongly constrained by gravity measurements & spin vector variation monitoring.	Seismometry. [*Higher accuracy gravity from e.g. gradiometry*] Magnetic field measurements from orbit and/or aerobot. **LS**

Human In the Loop Science Activities:

LS: Landing Site/Workspace
SC: Sample Choice
SR: Sample Retrieval
LAG: Low Altitude Guidance

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II. Understand atmospheric dynamics and composition on Venus.	A. What processes drive the global atmospheric dynamics of Venus?	**DD. Deep Dynamics (1).**	Vertical profile of P, T, wind, from DAVINCI; cloud-level winds & waves from cloud tracking particularly from Akatsuki; gas mapping & radio occultation from EnVision; surface winds from Aeolian features from SAR.	Cloud-level 3-D winds & waves from aerobot. Long-life surface meteorological station. Next-generation cloud tracking from orbit (higher spatial resolution, quasi-geostationary orbit *like HOVER*). Sat-to-Sat radio occultations for frequent T profiles at 40 – 90 km. **HAG**
		UD. Upper Dynamics (1).	-	Ionosphere / magnetosphere / plasma / solar wind interaction orbital measurements. Sub-mm heterodyne to measure winds & transport at 70 – 140 km, or thermal IR sounding of mesosphere (60 – 100 km). **SR**
		MP. Mesoscale Processes (2).	Constraints on winds & waves from Akatsuki & Envision. VERITAS, DAVINCI camera elements.	Cloud-level 3-D winds & waves from aerobot. Simultaneous orbital & in situ atmospheric observations. Long-life meteorological station. **HAG**
	B. What processes determine the baseline and variations in Venus atmospheric composition and global and local radiative balance?	**RB. Radiative Balance (1).**	Radiative flux measurement from DAVINCI+ descent probe. New spectroscopy from orbit by EnVision.	Radiative flux measurements & variations from multiple descent probes over a range of latitudes & solar longitudes. Cloud-level radiative flux measurements from aerobot. Long-life radiometric/meteorological station.
		IN. Interactions (1).	DAVINCI+ chemical profiles, and EnVision's maps of key volatile gases, and links to volcanic activity as studied by VERITAS & EnVision.	In situ characterization of cloud particles, radiation, microphysics. Search for lighting (aerobot, orbiter). Aeolian processes (lander, orbiter). **HAG, LAG**
		AE. Aerosols (2).	VERITAS/VEM, and EnVision/VenSpec will map aerosol distributions. DAVINCI+ will measure the gaseous volatile species which participate in condensational cloud formation.	In situ cloud-level aerobot measuring cloud and gas composition, and particle size & shape. Characterization of dust at surface. **HAG, LAG, SC, SR**
		UA. Unknown Absorber (2).	VenSpec-U and CUVIS will contribute new UV observations. DAVINCI contributes to understanding of chemical inventory in clouds.	In situ cloud-level aerobot measuring cloud, gas, aerosol composition, especially at altitudes > 60 km, and UV/blue fluxes. **LAG, SC**
		OG. Outgassing (3).	DAVINCI+ will obtain a vertical profile of composition including volcanically outgassed volatiles; EnVision-VenSpec will map major outgassed volatile species.	In situ measurements of surface and cloud materials to search for signatures of outgassed volatiles. **LAG, LS, SC** In situ study of sites of active volcanos & vents. **LS**

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III. Understand the geologic history preserved on the surface of Venus and the present-day couplings between the surface and atmosphere	A. What geologic processes have shaped the surface of Venus?	**GH. Geologic History (1).**	global SAR imaging & topography, nIR emissivity, gravity & subsurface mapping including high-res imaging follow-up.	In situ measurement of surface composition (multiple locations?). Follow-up high-res radar & high res NIR surface imaging. **LAG, LS, SC**
		GC. Geochemistry (1).	Constraints from nIR emissivity maps (& SAR & radiometry).	In situ measurement of surface composition. **LS, SC**
		GA. Geologic Activity (1).	Change detection in repeated SAR imagery, nIR & RF thermal anomaly search, volcanic plume search (EnVision), volcanic tracer search (DAVINCI).	Systematic surface monitoring with repeat-pass InSAR & radiometry (NIR & RF). Seismometry (surface aerobot, or orbital). **LAG, LS, SC** In situ study of active areas (flows, faults) **LS**
		CR. Crust (2).	Addressed by VERITAS & EnVision's SAR & gravity, and EnVision's Sub-surface sounding, and DAVINCI descent imaging.	Seismometry; Magnetotelluric sounding; In situ measurements of surface material composition. **LAG, LS, SC**
	B. How do the atmosphere and surface of Venus interact?	**LW. Local Weathering (1).**	Constraints from nIR emissivity maps (& SAR & radiometry). Also DAVINCI measurements of near-surface atmospheric composition.	In situ measurement of surface & atmosphere composition (at multiple localities). **LS, SC**
		GW. Global Weathering (2).	Constraints from nIR emissivity maps (& SAR & radiometry) & SAR imagery.	In situ measurement of surface & atmosphere composition, global patterns . **LAG, LS, SC**
		CI. Chemical Interactions (3).	DAVINCI measurements of near-surface atmospheric composition. EnVision measurements of tropospheric gas abundances. VERITAS & EnVision maps of clouds & low-altitude water vapour. Study of radar anomaly.	Surface landers & meteorological stations. Follow-up high res radar and other surface mapping. **LS, SC**

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Human In the Loop Sceince at Venus

Ionosphere / escape

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Upper Atmosphere

Clouds, Lower Atmosphere

Near Surface

Surface

Subsurface

Deep Interior