VERITAS (VENUS EMISSIVITY, RADIO SCIENCE, INSAR, TOPOGRAPHY AND SPECTROSCOPY): A PROPOSED DISCOVERY MISSION, S.E. Smrekar[1], S. Hensley[1], M.D. Dyar[2], J. Helbert[3], J. Andrews-Hanna[4], D. Breuer[3], D. Buczkowski[5], B. Campbell[6], A. Davaille[7], G. DiAchille[8], C. Fassett[9], M. Gilmore[10], R. Herrick[11], L. Iess[12], L. Jozwiak[5], A. Konopliv[1], M. Mastrogiuseppe[12], E. Mazerico[13], N. Mueller[3], D. Nunes[1], J. Stock[14], C. Tsang[15], J. Whitten[16], T. Widemann[17], H. Zebker[18]; [1]Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr., Pasadena, CA 91109, ssmrekar@jpl.nasa.gov; [2]Mt. Holyoke Coll., MA, USA; [3]Inst. Planetary Research, DLR, Berlin, Germany; [4]U. AZ, Tucson, USA; [5]John Hopkins U./APL, USA; [6]Smithsonian Inst,. DC, USA; [7]CNRS/FAST, Paris, France; [8]Inst. Natl. Astrophys., Italy; [9]NASA Marshall, USA, [10]Wesleyan U., USA, [11]U. AK Fairbanks, USA; [12]U. Roma La Sapienza, Italy, 13 NASA Goddard, USA, [14]Caltech, USA, [15]SWRI, Boulder, [16]Tulane U., USA, [17]Observ. De Paris/LESIA, France. [18]Stanford U., USA.

Introduction: A deep understanding of planetary habitability requires identifying the key factors that govern the environment over time. Venus is the ultimate control case for understanding how Earth developed and maintained conditions suited to life. Venus is very likely to have had elements essential to habitability [1,2] such as (past) surface water and even a dynamo. Tectonism and volcanism, with associated outgassing and driven by a robust internal energy budget, very likely persist today. There is current interaction, including exchange of volatiles, between the interior, surface, and atmosphere.

Most of the 100s of rocky exoplanets are more like Venus than Earth in terms of radiation budget [3]. The ultimate question is whether any of them are habitable. Without understanding the ultimate causes underlying the divergence of Venus and Earth, we cannot validate and extend models of habitability [e.g., 5]. Such models demand a better understanding of Venus' geodynamics. Venus offers a unique opportunity to study the conditions that do (or do not) lead to the initiation of plate tectonics and the formation of continents, both of which have played an important role in Earth' habitability. However, our current understanding of Venus and ability to answer these questions are severely hampered by the limited resolution and quality of existing geophysical datasets, which are vastly inferior to comparable datasets for the other terrestrial bodies.

Mission Overview: VERITAS is a proposed Discovery Mission concept. VERITAS would launch and arrive at Venus in 2026. It would begin acquiring data in 2027, reach its final orbit in 2028 post aerobraking, and then conduct its nominal science mission over four Venus days (~2.5 Earth yrs).

Payload: VERITAS would carry two instruments: 1) Venus Interferometric Synthetic Aperture Radar (VISAR) and 2) Venus Emissivity Mapper (VEM), plus a gravity science investigation. The VISAR X-band [6] measurements include: 1) a global digital elevation model (DEM) with 250 m postings, 5 m height accuracy, 2) Synthetic aperture radar (SAR) imaging at 30 m horizontal resolution globally, 3) SAR imaging at 15 m resolution for targeted areas, and 4) surface deformation from repeat pass interferometry (RPI) at 2 cm precision for targeted areas.

VEM [7] covers >80% of the surface in six NIR bands located within five atmospheric windows sensitive to Fe mineralogy, plus eight atmospheric bands for calibration and water vapor measurements, all with significantly enhanced SNR relative to the VIRTIS instrument on the European Space Agency (ESA) Venus Express mission.

VERITAS will use a low circular orbit (< 250 km) and Ka-band uplink and downlink to create a global gravity field with 3 mGal accuracy at 160 km resolution - significantly higher and more uniform resolution than available from Magellan.

Science Overview: *Past and Present Water:* VERITAS looks for the chemical fingerprint of past water in low Fe, high Si rocks in the tessera plateaus and larger inliers. Tessera plateaus are proposed to be equivalent to Earth's continents, which require basalt to be melted in the presence of water to form. VEM will determine if tesserae are globally felsic or mafic, and thus analogous to continental crust or not [8,9].

Specific VEM bands are dedicated to detect near-surface water vapor [7] above background levels that indicate outgassing. Observations would be correlated with other indicators of surface change (see below) to provide convincing evidence of present day outgassing. Due to the high surface pressure on Venus, observable outgassing would require several % water in the magma and would thus be an extremely valuable constraint on Venus' overall evolution.

Current Activity: Multiple datasets yield evidence for current or recent volcanism. Incomplete chemical weathering in the harsh Venusian environment is interpreted to be recent using both Venus Express VIRTIS [10] and Magellan emissivity data [11]. Venus Express also observed SO_2 variaitons likely due to volcanic outgassing [12]

VERITAS' multiple methods to search for activity include 1) cm-scale geologic deformation, 2) recent, chemically unweathered flows, 3) volcanic thermal emission, 4) topographic or surface roughness changes, and 5) comparisons to past mission data sets including Magellan radar images and Venus Express

NIR spectra at 1.02 microns. VERITAS can compare X-band to Magellan S-band SAR imaging after accounting for look and wavelength differences. This approach further requires that new features, such as lava flows, have a different radar backscatter than the pre-existing flows. This suite of analyses is key to investigating global activity because ~40% of the surface consists of 'featureless' plains, where radar backscatter does not reveal specific flows. New flows in these areas might resemble prior flows in backscatter and thus be invisible in SAR images, but could be seen from their emissivity contrast by VEM or as a different elevation or surface correlation by VISAR.

Geologic Evolution: VERITAS answers key science questions via: 1) examining the origin of tesserae plateaus – possible continent-like features, 2) assessing the history of volcanism and how it has shaped Venus' young surface, 3) looking at craters and modifications subsequent to ttheir formation, 4) characterizing possible subduction zones and the processes governing their formation, 5) looking for evidence of prior features buried by volcanism, and 6) determining the links between interior convection and surface geology. VERITAS would create a global inventory of geodynamic processes to understand the alternate evolutionary path of Earth's twin.

Gravity Science: The average Magellan spherical harmonic gravity field resolution is only degree and order 70. Wavelengths longer than degree and order 70 contain little or no information on elastic thickness [12]. VERITAS data, with average resolution of 160 km (degree and order>100), will enable estimation of elastic thickness (a proxy for thermal gradient) and resolution of tectonic features indicative of specific processes [13]. VERITAS will also constrain interior structure, including core size and state [e.g. 14].

Targeting approach: *SAR Imaging.* VERITAS will obtain global and targeted imaging at 30 m and 15 m (>25%), respectively. This level of coverage is only possible by onboard processing of the radar data. Initial targets will focus on level 1 science objectives. Throughout the mission, community input will be requested via both workshops and online. An extended mission could build 15 m coverage globally.

RPI Targeting. This resource is primarily limited by a) data volume because it requires full resolution raw data be downlinked, and by b) ΔV needed to maneuver into position for the 2nd pass. The minimum requirement is for twelve 200 × 200 km targets. The exact number of possible targets will be assessed during Step 2. Initial RPI targets will focus on regions proposed to be currently or recently active, again with community input.

VERITAS and EnVision: EnVision is a proposed ESA mission competing to be the 5th M-class mission. The Step 2 selections for Discovery and M5 are roughly coincident. VERITAS and EnVision have distinctive instrument capabilities and measurement objectives. Global 30-m and regional 15-m SAR imaging at X-band (VERITAS) and targeted 10-m S-band imaging (EnVision) is complementary, and provides additional opportunities for change detection. Targeted high resolution topography via stereo imaging from EnVision is complementary to VERITAS, but the low resolution global topography obtained from EnVision's radar sounder and S-band radar altimetry (3 km x 40 km spacing at equator) is insufficient for many purposes and is 1-2 orders of magnitude lower resolution than VERITAS' 250-m-resolution, geodeticaly controlled global DEM. EnVision's RPI deformation search covers more area than VERITAS' but does not employ Δv to target specific sites. Having both datasets increases the likelihood of detecting surface deformation. Additionally, the timelines for the two missions are highly complementary. EnVision would begin acquiring data > 7 years after the start of VERITAS, and provide a valuable continuity for change detection.

Conclusions: VERITAS will create a rich data set of high resolution topography, imaging, spectroscopy, and gravity. These co-registered data will be on par with those acquired for Mercury, Mars, and the Moon, which have revolutionized our understanding of these bodies. VERITAS would lay the groundwork for future Venus missions, providing very accurate topography and surface composition maps to optimize targeting of probe or lander missions as well as for later investigations of surface change. Motivation for this mission is described in a Decadal Survey white paper on the LPI website. *If you would like to support this mission, please add your name*: https://www.lpi.usra.edu/decadal_whitepaper_proposals/#vn

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