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], M. Raguso[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 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. Current interactions among the interior, surface, and atmosphere include exchange of volatiles.

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. To validate and extend models of habitability [e.g., 5], the causes underlying divergence of Venus and Earth must be identified. Such models require 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 continent formation, both of which have played an important role in Earth' habitability. However, our current understanding of Venus' geodynamic evolution is severely hampered by limited resolution and quality of existing datasets, which are orders of magnitude lower in resolution than those for the other terrestrial planets, as well by a dearth of global composition information.

Mission Overview: VERITAS is a proposed Discovery Mission concept. It would launch and arrive at Venus in 2026. Data acquisition would begin in 2027. The final orbit is achieved in 2028, post aerobraking. The nominal science mission spans four Venus rotations (~2.5 Earth yrs).

Payload: VERITAS would carry two instruments, the Venus Interferometric Synthetic Aperture Radar (VISAR) and the 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 and 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. This configuration offers significant advantages over systems like Visible and Infrared Thermal Imaging Spectrometer (VIRTIS) instrument on the European Space Agency Venus Express mission. Specifically VEM has significantly enhanced SNR and higher wavelength stability, providing the ability to ratio band intensities and use slopes between bands.

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 155 km resolution – a 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 the tessera plateaus and larger inliers. Tessera plateaus may be analogous to Earth's continents, which form when basalt melts in the presence of water. VEM will determine if tesserae are globally felsic or mafic, and thus analogous to continental crust or not [8,9,10].

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, outgassing, if observed, would require several % water in the magma and would thus be an extremely valuable constraint on Venus' interior volatile content.

Current Activity: Multiple datasets yield evidence for current or recent volcanism. Both Venus Express VIRTIS [11] and Magellan emissivity data [12] provide evidence of incomplete chemical weathering and thus recent volcanism. Venus Express also observed SO_2 variations likely due to volcanic outgassing [13].

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, 5) near-surface water vapor, and 6) comparisons to past mission data sets including Magellan radar images and Venus Express NIR spectra at 1.02 µm. We will compare the VISAR X-band to Magellan S-band imaging after accounting for look and wavelength differences. This approach requires that new features, such as lava flows, have 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, with limited radar backscatter variation. Flows with the same backscatter as prior flows are invisible in SAR images. Significant flows can be mapped using the VISAR DEM.

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 their 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 [14]. VERITAS data, with a global resolution of 160 km (degree and order >100), will enable estimation of elastic thickness (a proxy for thermal gradient) and density differences due to subsurface processes (e.g., rifts, small plumes) [15]. VERITAS will also constrain interior structure, including core size and state [15, 16].

Targeting approach: *SAR Imaging.* VERITAS will obtain imaging at 30 m and 15 m, global and targeted (>25%) respectively. This level of coverage is enabled by onboard processing of the radar data. Throughout the mission, community input will be requested via both workshops and online. An extended mission would increase this 15 m coverage.

RPI Targeting. This resource is primarily limited by a) data volume because it requires full resolution raw data be downlinked, and by b) fuel to maneuver into position for the 2nd observation. The minimum RPI requirement is for twelve 200 × 200 km targets. Initial RPI targets will focus on regions proposed to be active, again assessed with community input.

VERITAS, Shukrayaan, & EnVision. The Indian and European Space Agencies are considering Venus orbiters with S-band radars. Few details are public, but the Indian Space Agency announced possible plans to launch an orbiter carrying an S-band radar and numerous other instruments as early as 2024. EnVision is a proposed ESA mission competing to be the 5th M-class mission. VERITAS and EnVision have complementary instrument capabilities and measurement objectives [6]. VERITAS conducts RPI; EnVision collects polarimetry. VERITAS' global SAR imagery at 30-m, plus >25% coverage at 15-m, provides important context for targeting EnVisions' 10-m S-band imaging. Similarly VERITAS' global high resolution topography would provide data needed for clutter removal for EnVision's ground penetrating radar. 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 would create foundational data sets of high resolution topography, imaging, spectroscopy, and gravity. These co-registered data are on par with those available for Mercury, Mars, and the Moon, which have revolutionized our understanding of these bodies. VERITAS would answer outstanding fundamental questions such as whether catastrophic resurfacing occurred, what types of geologic processes are active, whether tessera record the chemical history of water, and core size and state. VERITAS would lay the groundwork for future Venus missions, providing data to optimize the science return of probe or lander missions. The motivation for this mission in the context of planetary habitability is described in a Decadal Survey white paper [17].

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