VERITAS (VENUS EMISSIVITY, RADIO SCIENCE, INSAR, TOPOGRAPHY AND SPECTROSCOPY): A PROPOSED DISCOVERY MISSION

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Introduction: VERITAS addresses one of the most fundamental questions in planetary evolution: How Earth-like is Venus? These two twin planets diverged down different evolutionary paths, yet Venus may hold lessons for past and future Earth. Venus' has a hot lithosphere, which may limit the development of plate tectonics [1]. Determining the factors that permit and preclude the initiation of plate tectonics would inform our predictions for rocky Earth-sized exoplanets. The conditions leading to Venus' greenhouse atmosphere may also inform our understanding of Earth's future. VERITAS would answer key questions about Venus' geologic evolution, determine what processes are currently active, and search for evidence for past or present water.

Mission Overview: VERITAS accomplishes its 2.4 [Earth] year mission over the course of three Venus rotations, or cycles. The slow rotation of Venus allows data swaths to be acquired sequentially, with overlap from orbit to orbit. Most of the planet will be mapped in cycle 1, with gaps filled in cycles 2 and 3. Cycles 2 and 3 also permit (RPI) pass interferometry for change detection and repeat VEM coverage. VERITAS carries two instruments: 1) Venus Interferometric Synthetic Aperture Radar (VISAR) and 2) Venus Emissivity Mapper (VEM, plus a gravity science investigation.

Payload: The VISAR X-band [2] 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 RPI at 2 mm precision for targeted, potentially active areas.

VEM [3] will produce surface coverage of ~88% of the surface in six NIR bands located within five atmospheric windows and of eight atmospheric bands for calibration and water vapor measurements.

VERITAS will use Ka-band uplink and downlink to create a global gravity field with 3 mgal accuracy / 145 km resolution (130 spherical harmonic degree and order or d&o) and providing a significantly higher resolution field with much more uniform resolution than that available from Magellan.

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 for evidence of prior features buried by volcanism, and 4) determining the links between interior convection and surface geology. In particular, VERITAS will examine the stratigraphy and nature of tesserae deformation features, determine the processes modifying impact craters, search for evidence of pre-existing features such as buried impact basins, and determine the origin of tectonic features such as huge arcuate troughs that have been compared to Earth's subduction zones.

Water and Surface Composition: VERITAS looks for the chemical fingerprint of past water in the form of low Fe, high Si rock in the tessera plateaus and larger tesserae inliers, and for present day volcanic outgassing of volatiles in the form of near surface water variability associated with recent or active volcanism. The thick cloud layer on Venus does not allow for classic spectroscopy methods. But the five atmospheric adsorption windows in the CO_2 atmosphere near 1 μm allow the Fe mineralogy to be investigated [3-5]. In comparison, the VIRTIS instrument mapped <50% of the surface using broader spectral windows. To date only one band at 1.02 microns has been successfully reduced over the southern hemisphere. VIRTIS was not designed with surface spectroscopy in mind, whereas VEM is optimized for this purpose [3].

VEM will address key scientific questions by providing a near global map at six spectral bands sensitive to iron mineralogy. This data set can be used to discriminate between weathered and unweathered basalt, search for recent volcanism, and distinguish between different hypotheses for surface weathering processes and products. VEM will also determine if tesserae plateaus have compositions distinct from the plains. Tessera plateaus are proposed to be equivalent to Earth's continents, which may require basalt to be melted in the presence of water to form. VEM will determine if tesserae globally are more felsic or mafic, and thus analogous to continental crust or not.

In addition to surface mineralogy, specific VEM bands are dedicated to detecting near-surface water vapor [3]. Venus Express has found the distribution of water vapor in the atmosphere to be quite uniform. Thus any new near-surface variations are highly likely to 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 significant interior water and thus be an extremely valuable constraint on Venus' overall evolution.

Current Activity: Several studies have found evidence of current or recent volcanism on Venus. [6] used Magellan emissivity data to argue for active volcanism. [7] found bright regions interpreted as active volcanism using Venus Monitoring Camera data. Several studies [8,9] used atmospherically corrected near NIR data near 1 μm from the VIRTIS spectrometer identify regions with iron mineralogy different from typical plains basalt. Regions with high NIR surface emissivity have been interpreted as unweathered and thus geologically recent volcanism [10].

VERITAS uses a variety of approaches to search for present day activity, including 1) tectonic and cm-scale volcanic surface deformation, 2) chemical weathering, 3) thermal emission from recent or active volcanism, 4) topographic or surface roughness changes, and 5) comparisons to past mission data sets including Magellan radar images and Venus Express surface imaging. VERITAS has numerous means of identifying surface activity. VERITAS can compare X-band to Magellan S-band SAR imaging after accounting for look and wavelength differences. This methodology will be validated using Tandem-X X-band and S-band data acquired simultaneously in Iceland. This approach further requires that new features such as lava flows have a different radar backscatter than the pre-existing flows. VEM data at 1.02 μm will also be compared with VIRTIS data acquired at that wavelength. Again, instrument characteristics will need to be accounted for to permit accurate comparisons.

VERITAS can also detect very small changes in surface elevation using targeted RPI. Larger variations, such as new lava flows, could be seen in topography data or surface correlation of radar images. These detection methods are key to obtaining a more global view of surface activity because ~40% of the surface consists of 'featureless' plains – areas where radar backscatter does not reveal specific flows. New flows in these areas might resemble prior flows in backscatter, but could be detected based on their unweathered composition with VEM or as a different elevation or surface correlation with VISAR.

Gravity Science: The Magellan spherical harmonic gravity field was expanded to d&o 180 [11] to ~d&o d&o 100, available only over very limited equatorial regions. The average resolution is only d&o 70. These long wavelengths contain no information on elastic thickness [12]. Similarly methods such as gravity gradieometry are not viable at the average resolution [13]. VERITAS data, with an avg. resolution of 145 km, will enable estimation of elastic thickness (a proxy for thermal gradient) and resolution of tectonic features indicative of specific processes [13].

Targeting approach: *Imaging.* VERITAS will obtain global imaging at 30 m, and ~23% of the surface at 15m resolution. The high resolution images are limited only by downlink volume. Thus an extended mission would provide an opportunity to obtain extended, possibly global 15 m coverage. Initial targets will be proposed by science team members responsible for assuring each level 1 science objective. This list will be expanded through community input acquired via both workshops and a target suggestion website, similar to that developed for HiRISE images of Mars.

RPI Targeting. This resource is also limited only by data volume, as it requires full resolution data, and by delta-V needed to maneuver into position for the 2nd pass [x]. Thus the initial allocation is for 12 200km × 200 km targets. The exact dimension and number of possible targets will be assessed during Step II. Mission design considerations that could enhance the delta-V budget will be considered. Initial RPI targets will focus on those regions proposed to be currently or recently active based on Venus Express data. These targets will very likely expand as VERITAS discovers active regions using the methods described above.

Conclusions: VERITAS will create a rich data set of high resolution topography, imaging, spectroscopy, and gravity. These co-registered data [x] will be on par with those acquired for Mercury, Mars and the Moon that have revolutionized our understanding of these bodies. VERITAS would be an extremely value asset for future Venus missions, providing a very accurate topography plus surface composition map to optimize targeting of probe or lander missions as well as for later investigations of surface change.

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