The Venus Emissivity Mapper - getting ready for flight. J. Helbert[1], G. Alemanno[1], D. Dyar[2,3], S. Adeli[1], M. Pertenais[4], T. Hagelschuer[4], T. Säuberlich[4], A. Pohl[4], A. Maturilli[1], S. Del Togno[1], A. Fitzner[1], K. Westerdorff[4], T. Widemann[5], G. Peter[4], E. Pechevis[5], J. Carron[6], N. Müller[7,1], A. Das[7,1], H. Rauer[1,7], S. Smrekar[8] [1] Institute for Planetary Research, DLR, 12489 Berlin, Germany; [2] Mount Holyoke College, USA, [3]Planetary Science Institute, USA, [4]Institute of Optical Sensor Systems, DLR, 12489 Berlin, Germany [5]LESIA, Observatoire du Meudon, Meudon, France [6]CNES, Paris, France, [7]Freie Universität Berlin, Germany, [8]Jet Propulsion Laboratory, Pasadena, USA.

Introduction: The NASA VERITAS (Venus Emissivity, Radio Science, InSAR, Topography, And Spectroscopy) mission studies the surface and interior of Venus with a powerful new generation of scientific tools – the first NASA mission to return there since the 1990s. The mission was selected for flight in 2021 as part of NASA's Discovery program. NASA's Jet Propulsion Laboratory is responsible for mission design, management, operations, and navigation.

How did Venus become a sulfurous inferno, while our home planet, Earth, evolving to become the only known abode for life? Of all known planets, moons, and newly discovered exoplanets, Venus is the most Earth-like in terms of size, overall composition, and energy from its star. Although not currently habitable, Venus lies within the Sun's "Goldilocks zone," and was likely habitable before Earth. What caused Venus to evolve into its present hostile state, devoid of the ocean, magnetic field, and plate tectonics that have enabled Earth to become so hospitable for life in the long-term?

VERITAS addresses these compelling questions by determining how Earth's twin diverged, enabling breakthroughs in our understanding of terrestrial planet evolution and habitability in our own solar system and beyond. It will be followed by NASA's DAVINCI mission and ESA's EnVision mission, leading the way into a period of intense focus on Earth's next-door neighbor planet. VERITAS will return richly detailed radar maps of the Venus surface, vastly improving the resolution of maps made by the Magellan mission in the 1990s. Scientists will make the first global, high-resolution maps of radar imagery and topography and the first maps of regions where geologic processes are actively deforming the surface in the present day.

With the Venus Emissivity Mapper (VEM) provided by DLR as a contribution, VERITAS will also produce the first maps of surface rock composition and constrain surface weathering by peering through the planet's dense atmosphere using spectral windows in the infrared portion of the EM spectrum. VERITAS will search for the thermal signatures of active volcanism and the chemical signatures of recent volcanism.

The Venus Emissivity Mapper: VEM and the VISAR radar system provided by JPL constitute the core payload of the VERITAS mission. VEM is the first flight instrument designed with a focus on mapping the surface of Venus using multiple atmospheric windows around 1 μm wavelength. Its global map of surface composition will be based on observations with six narrow band filters from 0.86 to 1.18 μm [1-4]. Continuous observation of Venus' thermal emission will place tight constraints on current day volcanic activity. Eight additional channels will measure atmospheric water vapor abundance and cloud microphysics/dynamics and permit accurate correction of atmospheric interference on the surface data.

After several years of pre-development including the setup of a VEM laboratory prototype, the implementation for flight has begun with qualification of flight detectors, review of all requirements flowdowns, and finalizing of spacecraft interfaces.

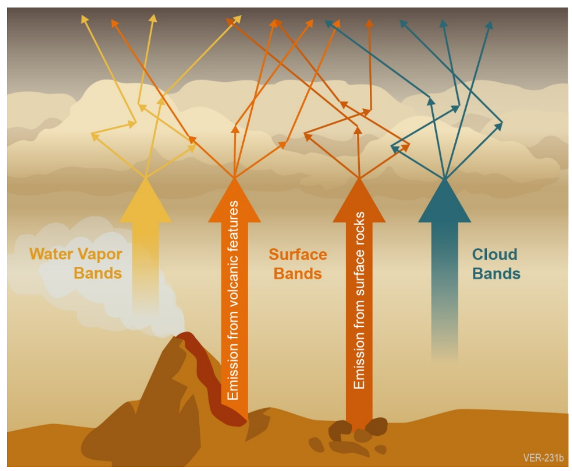

Figure 1 VEM maps surface rock type and search for evidence of volcanic activity by its thermal signature and by an enhancement of water vapor near the surface. A dedicated set of bands is used to correct for the effect of clouds.

VEM Design: VEM design and performance evaluation are discussed in previous publications[5, 6]. VEM is a pushbroom multispectral imaging system; its optics (VEMO) consists of three lens elements in a telecentric configuration. A single-element objective relays the image onto the filter array in the intermediary focal plane. This multilayer-dielectric-coated, bandpass filter array filters light into 14 bands. Each band is imaged by a two-element relay optic onto the FPA.

Those 14 bands fall in four categories depending on where the radiation is originating (Figure 1). Radiation for the six surface bands originates at the surface; those bands are used to determine rock types as well as monitor for the thermal signature of active volcanism.

Radiation in the two water vapor bands originates in a layer close to the surface and is sensitive to the abundance of water vapor which may see changes due to volcanic exhalations. In the three cloud bands, radiation originates at an atmospheric layer above the surface but below the clouds. Because the signal in the cloud bands has no surface or water vapor contributions, measurements in these bands can be used to remove cloud-induced contrast variability from the other bands. Finally, the three background bands (not shown in Figure 1) are sensitive in spectral regions where the atmosphere is opaque, facilitating removal of background signal on the detector. The high density of cloud particles results in multiple scattering of the radiation, reducing the spatial resolution to 50–100 km.

The experience of the DLR team with VIRTIS on Venus Express [7-13], as well as the advantage of having the only laboratory dedicated to Venus surface-analog emissivity measurements, enables DLR to lead the investigation on emission spectroscopy of Venus. This is supported by the expertise of the FU Berlin in atmospheric modeling and of the Planetary Science Institute in calibration and machine learning analyses.

Development status: The schedule for the VEM development is based on a Launch Readiness Date for VERITAS in 2029 and is currently on track for the instrument Preliminary Design Review (PDR) early in 2025. The VEM filter array has already recently passed its subsystem PDR. The Xenics XSW-640 InGaAs detector is currently undergoing a radiation test campaign as part of the flight qualification [14]. The design of the main electronics is finalized and an Electrical Interface Model (EIM) will be set-up early in 2025.

In parallel to the instrument design consolidation the work on the laboratory analog studies have been intensified [2, 15, 16] with the goal of having a minimal database containing at least 300 samples ready by the time of the qualification campaign for the VEM Qualification Model – currently planned for the beginning of 2026.

References: [1] Gilmore M. S., et al. (2023) *Space Science Reviews, 219,* 10.1007/s11214-023-00988-6. [2] Alemanno G., et al.(2023), 10.1117/12.2678683. [3] Helbert J., et al. (2021) *Science Advances, 7,* 10.1126/sciadv.aba9428. [4] Dyar M. D., et al. (2020) *Geophysical Research Letters,* 10.1029/2020gl090497. [5] Helbert J., et al.(2022), 10.1117/12.2634263. [6] Helbert J., et al.(2020), 10.1117/12.2567634. [7] D'Incecco P., et al. (2017) *Planetary and Space Science, 136,* 25-33 10.1016/j.pss.2016.12.002. [8] Mueller N. T., et al. (2017) *Journal of Geophysical Research-Planets, 122,* 1021-1045 10.1002/2016je005211. [9] Stofan E. R., et al. (2016) *Icarus, 271,* 375-386 10.1016/j.icarus.2016.01.034. [10] Gilmore M. S., et al. (2015) *Icarus, 254,* 350-361 10.1016/j.icarus.2015.04.008. [11] Mueller N. T., et al. (2012) *Icarus, 217,* 474-483 10.1016/j.icarus.2011.09.026. [12] Helbert J., et al. (2008) *Geophysical Research Letters, 35,* 10.1029/2008gl033609. [13] Mueller N., et al. (2008) *Journal of Geophysical Research, 113,* 10.1029/2008je003118. [14] Pohl A., et al.(2023), 10.1117/12.2677393. [15] Adeli S., et al.(2023), 10.1117/12.2677369. [16] Helbert J., et al.(2023), 10.1117/12.2676635.

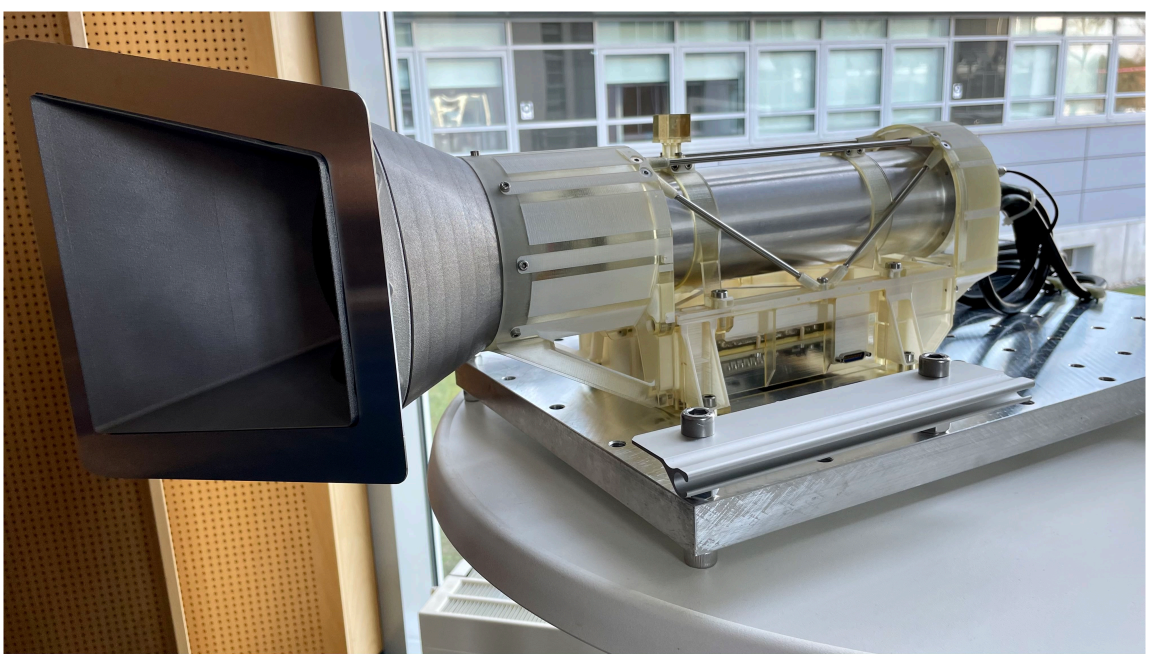

Figure 2 VEM prototype with flight like optics, flight like baffle (without coating), flight-like detector and updated mechanical design including stiffener - housing is replaced by representative 3D print for visualization