THE ENVISION MISSION TO VENUS. T. Widemann[1], R.C. Ghail[2], C. F. Wilson[3,4], D. V. Titov[4], A.G. Straume[4], A. Ocampo[5], T. Bocanegra-Bahamon[6], L.Bruzzone[7], B. Campbell[8], L. Carter[9], C. Dumoulin[10], G. Gilli[11], J. Helbert[12], S. Hensley[6], W. S. Kiefer[13], E. Marcq[14], P. Mason[15], A. Moreira[16], A. C. Vandaele[17]; [1]Paris Observatory, Meudon, France; [2]Royal Holloway, University of London, UK; [3]University of Oxford, UK; [4]ESA-ESTEC, Noordwijk, Netherlands; [5]NASA HQ, Washington, DC; [6]Jet Propulsion Laboratory, Pasadena, CA; [7]Università di Trento, Italy; [8]Smithsonian Institution, Washington, DC; [9]Lunar and Planetary Laboratory, University of Arizona, AZ; [10]LPG, Université de Nantes, France; [11]Instituto de Astrofísica de Andalucía (IAA-CSIC), Granada, Spain; [12]DLR Institute of Planetary Research, Berlin, Germany; [13]Lunar and Planetary Institute, Houston, TX; [14]LATMOS, IPSL, Guyancourt, France; [15]Imperial College London, UK; [16]DLR Microwaves and Radar Institute, Oberpfaffenhofen, Germany; [17]Royal Belgian Institute for Space Aeronomy (BIRA-IASB), Brussels, Belgium.

Introduction: On June 10, 2021, the European Space Agency (ESA) announced the selection of EnVision as its newest medium-class science mission. EnVision's overarching science questions are to explore the full range of geoscientific processes operating on Venus [1, 2, 3]. It will investigate Venus from its inner core to its atmosphere at an unprecedented scale of resolution, characterising in particular core and mantle structure, signs of past geologic processes, and looking for evidence of past liquid water. Recent modeling studies strongly suggest that the evolution of the atmosphere and interior of Venus are coupled [4, 5], emphasizing the need to study the atmosphere, surface, and interior of Venus as a system. The nominal science phase of the mission will last six Venus sidereal days (four Earth years). EnVision will downlink 210 Tbits of science data, using a Ka-/X-band comms system with a 2.5 m diameter fixed high-gain antenna. As a key partner in the mission, NASA provides the Synthetic Aperture Radar, VenSAR.

EnVision B/L mission scenario: The mission will launch in 2031 on Ariane 62. Following orbit insertion and periapsis walk-down, orbit circularisation will be achieved by aerobraking over a period of several months, followed by a nominal science phase lasting at least 6 Venus sidereal days (4 Earth years).

EnVision payload: The EnVision payload consists of five instruments provided by European and US institutions. The five instruments comprise a comprehensive measurement suite spanning infrared, ultraviolet-visible, microwave and high frequency wavelengths. This suite is complemented by the Radio Science investigation exploiting the spacecraft TT&C system. All instruments in the payload have substantial heritage and robust margins relative to the requirements with designs suitable for operation in the Venus environment. This suite of instruments was chosen to meet the broad spectrum of measurement requirements needed to support EnVision science investigations.

VenSAR: the Venus Synthetic Aperture Radar (VenSAR) will image pre-selected regions of interest at a resolution of 30 m/pixel, and subregions at 10 m/pixel. An order of magnitude better than Magellan and with a better sensitivity, these images are key to understanding geological processes from the local to global scale, discriminating relationships between units of different age, and identifying the changes caused by geological activity. Topographic information at 300 m spatial and 20 m vertical resolution across these regions, derived from stereo imaging at two different incidence angles, is complemented by a global network of altimetry mode tracks with a vertical resolution of 2.5 m, essential for resolving the geometry of faults, folds and other features, and enabling the quantitative analysis of geological processes. Surface properties such as roughness will be derived from active imaging in both HH and HV polarizations and passive radiometry at a range of angles, which also permits the detection of surface temperature anomalies. Repeated observations and comparisons with Magellan and VERITAS VISAR imagery [6] will allow for the detection of volcanic, tectonic and geomorphic changes over periods of months, years and decades.

SRS: the Subsurface Radar Sounder (SRS) will be the first instrument to profile the subsurface of Venus and thus will acquire fundamental information on subsurface geology by mapping the vertical structure (mechanical and dielectric interfaces) and properties of tesserae and their edges, plains, lava flows and impact craters and debris, thus providing useful data for inferring the genesis of these features. It also provides information on the surface in terms of roughness, composition and permittivity (dielectric) properties at wavelengths much longer than those of VenSAR, thus allowing a better understanding of the surface properties. SRS also obtains altimetry measurements by providing low-resolution profiles of the topography that can be integrated with the altimetric data of VenSAR.

VenSpec: the Spectrometer suite (VenSpec) will obtain global maps of surface emissivity in six wavelength bands using five near-infrared spectral transparency windows in the nightside atmosphere, to constrain surface mineralogy and inform evolutionary scenarios; and measure variations of SO2, SO and linked gases in the mesosphere, to link these variations to tropospheric variations and volcanism [7].

VenSpec-M is a pushbroom multispectral imager optimised to map thermal emission from Venus' surface using six narrow bands ranging from 0.86 to 1.18 µm, and three bands to study cloud microphysics and dynamics. This allows mapping of surface composition, constrained by its emissivity spectrum, as well as searching for thermal anomalies associated with volcanic activity.

VenSpec-H will focus on the volcanic and cloud forming gases and search for composition anomalies potentially related to the volcanic activity. VenSpec-H will include four spectral bands: 1.165 - 1.180 µm (B#1), 2.34 - 2.48 µm (B#2), 1.72 - 1.75 µm (B#3) and 1.37 - 1.39 µm (B#4) that cover the infrared spectral transparency "windows". In order to reduce the instrument complexity, B#2 will be further subdivided in two ranges: 2.34 -2.42 µm (2a) and 2.45 - 2.48 µm (2b). Bands 1, 2a, 2b and 3 will be observed on the night side, bands 2a, 2b and 4 on the dayside. In the IR range, the high spectral resolution (R ~ 8000) along with the high sensitivity of the instrument will allow to clearly identify the absorption features of the targeted species.

VenSpec-U will investigate the upper atmosphere using the following wavelength ranges and resolutions: (1) 205-235 nm at 0.2 nm spectral resolution (SO_2 and SO separately at 70-80 km); (2) 190-380 nm at 2 nm spectral resolution (UV absorber, total SO+SO_2 at 70-80 km); (3) 1.36–1.409 µm (H_2O, HDO at 70-90 km); (4) 2.29–2.48 µm (H_2O, HDO, CO, COS, SO_2 at 70–90 km).

Variable trace atmospheric species on Venus - SO_2, SO, H_2O, CO, COS, H_2SO_4 - are often associated with volcanic activity. In combination, VenSpec will provide unprecedented insights into the current state of Venus and its past evolution. The goal of EnVision is to understand the intrinsic atmospheric variability, and to establish to what extent it can be associated with surface activity. Several key gases have been studied & mapped below the cloud deck, at 0-50 km altitude, such as water vapour (H_2O and HDO) [8], sulphur compounds (SO_2, COS) and carbon monoxide (CO) [9, 10]; these are all potential volcanic volatile gases. In particular, spatial variability of the D/H ratio – whether associated with volcanic plumes or other fractionating processes – would be fundamental for understanding the history of the water on Venus.

RSE: Radio Science Experiment uses the spacecraft-Earth radio link for gravity mapping and atmospheric profiling. Magellan gravity data are consistent with an organised pattern of mantle convection broadly similar to Earth but lack the resolution necessary to understand its connection with geological-scale features, such as individual coronae or mountain belts. Higher spatial resolution is needed to better constrain the crustal and lithospheric structure variations; EnVision will obtain higher resolution globally, allowing better constraints on the geodynamic evolution of the planet. EnVision's gravity measurements also will allow calculation of the tidal Love number *k2* with an accuracy of 0.01; this increased precision will constrain the distribution of internal mass, and the size and state of the core. Furthermore, the refraction of EnVision's radio signal in the neutral atmosphere and ionosphere of Venus will be used to obtain high-resolution vertical profiles of temperature, pressure, and sulphuric acid vapour and liquid profiles at 55-45 km, and total electron content in the ionosphere.

EnVision bridging phase B0: following selection of EnVision by ESA in June, a bridging phase B0 has been started immediately after selection to address key Mission Selection Review (MSR) recommendations: (1) the technical and schedule feasibility of a launch date in 2031; (2) the technical feasibility of a back-up launch in 2033, including High Elliptical Orbit (HEO) escape; (3) overall EnVision spacecraft optimization (thermal, aerobraking). Final B0 progress meeting was held end of October.

EnVision Definition Phase B1 kickoff: Two parallel competitive industrial studies will continue in the Definition Phase B1, to complete trade-offs, consolidate requirements and interfaces, produce system specifications, support development of the science operations, calibration strategies, science products definition under the responsibility of the Future Missions Department (SCI-F) and under the authority of the EnVision Study Manager until Mission Adoption Review (MAR) scheduled in 2024.

References: [1] Ghail R. C., Wilson, C., Widemann, T., Bruzzone, L., Dumoulin, C., Helbert, J., Herrick, R., Marcq, E., Mason, P., Rosenblatt, P., Vandaele, A. C., Burtz, L. J. The EnVision mission (2016) https://arxiv.org/abs/1703.09010. [2] EnVision mission website: www.envisionvenus.eu. [3] ESA's EnVision Assessment Study Report: sci.esa.int/web/cosmic-vision/envision-assessment-study-report-yellow-book. [4] Way, M.J. & A.D. Del Genio, *JGR Planets,* 125, (2020) [5] Weller, M.B. and Kiefer, W.S., *J. Geophys. Res.* Planets, 125, 1 (2020). [6] Smrekar, S. E. et al., 51st LPSC 2020, id.1449. [7] Helbert, J. et al., Proc. SPIE 11128, A1112804, (2019). [8] Bézard, B., C. C. C. Tsang, R. W. Carlson, G. Piccioni, E. Marcq, and P. Drossart, J. Geophys. Res., 114, E00B39 (2009). [9] Marcq, E. et al., J. Geophys. Res., Volume 113, E00B07 (2008). [10] Arney, G. et al., J. Geophys. Res. Planets, Vol. 119, Issue 8, pp. 1860-1891 (2014).