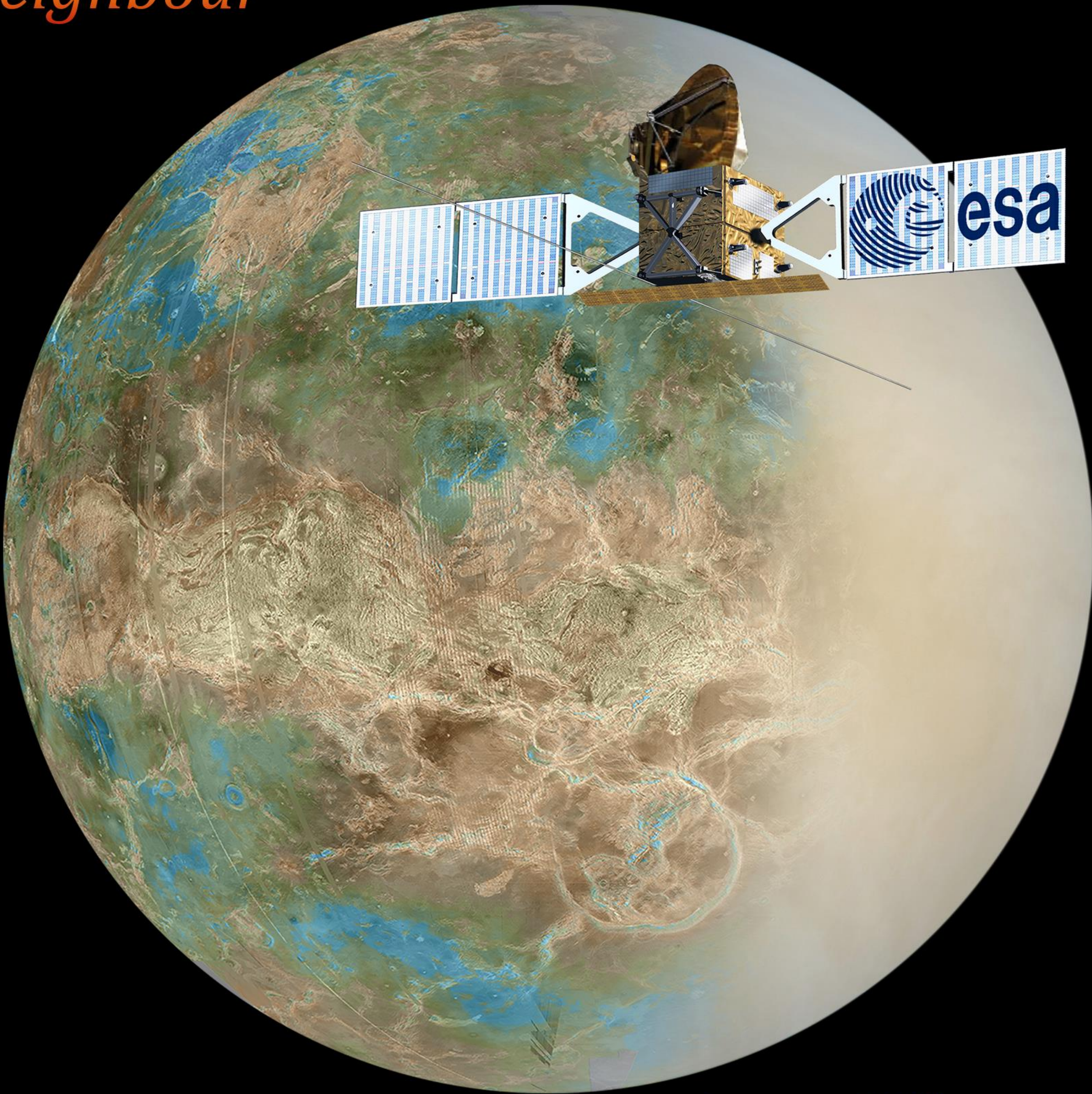
EnVision

Understanding why our most Earth-like neighbour



is so different

Executive Summary

Why are the terrestrial planets so different? Venus should be the most Earth-like of all our planetary neighbours: its size, bulk composition and distance from the Sun are very similar to those of Earth. Its original atmosphere was probably similar to that of early Earth, with abundant water that would have been liquid under the young sun's fainter output. Even today, with its global cloud cover, the surface of Venus receives less solar energy than does Earth, so why did a moderate climate ensue here but a catastrophic runaway greenhouse on Venus? How and why did it all go wrong for Venus? What lessons can be learned about the life story of terrestrial planets in general, in this era of discovery of Earth-like exoplanets? Were the radically different evolutionary paths of Earth and Venus driven solely by distance from the Sun, or do internal dynamics, geological activity, volcanic outgassing and weathering also play an important part?

ESA's Venus Express a landmark in Venus exploration, answered many questions about our nearest planetary neighbour and established European leadership in Venus research. Focussed on atmospheric research, Venus Express nonetheless discovered tantalising hints of current volcanic activity including a tenfold changes in mesospheric sulphur dioxide, anomalously dark lava surrounding volcanoes, and surface temperature changes that all point towards activity which had not been expected from NASA's Magellan mission of the early 1990s. That mission showed that Venus has abundant volcanic and tectonic features but did not have the resolution or technology necessary to detect geological activity.

We therefore propose EnVision, a medium class mission to determine the nature and current state of geological activity on Venus, and its relationship with the atmosphere, to understand how Venus and Earth could have evolved so differently. EnVision will use a world-leading European phased array synthetic aperture radar, VenSAR, to:

- Obtain images at a range of spatial resolutions from 27 m global coverage to 1 m images of selected regions, including the Venera landing sites; an improvement of two orders of magnitude on Magellan images;
- Global topography at 27 m resolution vertical and 135 m spatially from stereo imaging, supplemented by interferometric (InSAR) data at <1 cm vertical and 27 m spatial resolution, of one third of the planet's surface;
- Vertical and longitudinal InSAR change detection of <1 cm per year across areas of probable volcanic and tectonic activity, and estimating rates of weathering and surface alteration from InSAR decoherence data; and
- Characterisation of surface mechanical properties and weathering through multi-polar radar data.

Its RIME-heritage subsurface radar sounder, SRS, will:

- Characterise the vertical structure and stratigraphy of geological units including volcanic flows;
- Determine the depths of weathering and sedimentary deposits; and
- Discover as yet unknown structures buried below the surface.

VEM, an infrared mapper and spectrometer designed specifically for Venus, is able to:

- Search for temporal variations in surface temperatures and tropospheric concentrations of volcanically emitted gases, indicative of volcanic eruptions; and

- Study surface-atmosphere interactions and weathering by mapping surface emissivity and tropospheric gas abundances.

EnVision will also take advantage of its low circular orbit to:

- Provide gravity and geoid data at a geologically-meaningful scale, and
- Measure the spin rate and spin axis variations, to constrain interior structure.

VenSAR, the S-band phased array antenna, has heritage from NovaSAR and Sentinel-1 and is funded by the UK Space Agency. SRS, derived from RIME on board JUICE, has heritage from MARSIS and SHARAD and is funded by the Italian Space Agency. The Venus Emissivity Mapper, VEM, operating in the infrared, builds on the success of VIRTIS and VMC on Venus Express and has heritage from SOIR, NOMAD, and MERTIS. It is funded by a consortium of the German, French, and Belgian Space Agencies.

The proposed baseline mission is ESA-only, with science payloads funded by ESA member states as outlined above; no funding from international partners is required. Envision is launched on a Soyuz-Fregat with a nominal launch date of 27 Dec 2024 (although a 2025 date is possible within the launch window). Following a brief 5-month cruise, the spacecraft will perform a Venus Orbit Insertion manoeuvre using conventional propulsion to enter a capture orbit with a 50 000 km apoapsis. An aerobraking period lasting approximately six months lowers the apoapsis to 258 km, with chemical propulsion again used to raise the periapsis into the final circular 258 km altitude science orbit.

The nominal science mission starts on 1 Feb 2026 and continues for 3½ years. All science investigations are carried out in the nadir direction, with the SAR antenna panel oriented parallel to the orbital track and positioned to look sideways at 32°. No spacecraft repointing is required for the science operations. Communications are achieved by a 3·2 m X-band antenna, steerable in two axes to allow downlink throughout science operations. Envision will generate an unprecedented volume of data for an interplanetary mission and will apply well-established multiple-bit encoding techniques used by Earth-orbiting telecommunications satellites to achieve downlink rates of 10 – 64 Mbps from Venus.

In conclusion, the EnVision mission takes advantage of Europe's world-leading position in both Venus research and in interferometric radar to propose a mission which will address universally relevant questions about the evolution and habitability of terrestrial planets. In doing so, it will provide a range of global image, topographic, and subsurface data at a resolution rivalling those available from Earth and Mars, inspiring the public imagination and the next generation of European scientists and engineers.