ENVISION M5 VENUS ORBITER PROPOSAL: OPPORTUNITIES AND CHALLENGES. R. C. Ghail[1], C. F. Wilson[2] and T. Widemann[3,4], [1]Department of Civil and Environmental Engineering, Imperial College London, London, SW15 3HA, UK, *r.ghail@imperial.ac.uk*, [2]Department of Atmospheric, Oceanic and Planetary Physics, Oxford University, Oxford, OX1 3PU, UK, *Colin.Wilson@physics.ox.ac.uk* [3]Observatoire de Paris – LESIA UMR CNRS 8109, 92190 Meudon, France, [4]Université Versailles St-Quentin - DYPAC EA 2449, France, *thomas.widemann@obspm.fr*.

Introduction: In geological terms, Venus is the most Earth-like planet in the Solar System. Mars may have had a past environment favourable for life but at one tenth the mass, it was unable to sustain its early benign environment. Being so similar to Earth, Venus may also have had a habitable past, possibly even sustaining a living biosphere. Why has it not turned out more like Earth? The key question for Venus surface science is how active is the planet? The next stage of exploration must therefore focus on its geology and geochemical cycles, seeking evidence for present and past activity. With its unparalleled radar, IR and UV instruments based on a long European heritage in change detection and monitoring, EnVision will revolutionise our understanding of Venus and enable us to understand why our closest neighbour is so different.

Background: ESA's M5 call, expected in April 2016, is a more conventional Medium-class mission call than M4. Cost-at-Completion is expected to be more restrictive than either Euclid (M2) or Plato (M3) but higher than M4. A nominal 2029/2030 launch date on Ariane 6.2 removes the mass/volume constraints of Soyuz, resulting in truly cost-limited design. The Envision proposal being developed for M5 is therefore different in several key aspects compared to that proposed for M4, while addressing the same science themes. Here we explore the implications of these constraints and opportunities for EnVision at M5.

Science Observations: What lessons can be learned from Venus 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 answered many questions about our nearest planetary neighbour and discovered tantalising hints of current volcanic activity including a tenfold changes in mesospheric SO_2, 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.The core goal of EnVision is to detect activity and measure rates of change on Venus, including geological and geochemical cycles involving the interior, surface and atmosphere. Many natural phenomena follow the Pareto relationship [1]; recently [2] showed that the rate of volcanic activity can be very well constrained by observations at one in ten volcanoes on Venus. Hence rather than aiming for global coverage, the mission will repeatedly observe specific targets with the widest possible range of measurements to fully characterise these areas, in effect trading quantity for quality to maximize the science return. EnVision will observe >20% of the surface with all instruments, exceeding the Pareto threshold, and will obtain gravity and emissivity data globally. Core science measurements are:

Surface change:	$< \pm 1$ cm a^{-1} at <35 m spatial
Geomorphology:	multipolar images at <35 m spatial
	topography at <35 m vertical, <350 m spatial
High-resolution mapping:	<10 m spatial
Spotlight (50 km^2 areas):	~1 m spatial
Subsurface:	50 m vertical, <1 km spatial
0.8-1.2 μm thermal emission:	s/n >100, 50 km spatial
SO_2:	±1% at <300 km spatial and 30–40 km altitude
H_2O:	< ±10% at <300 km spatial and <15 altitude
D/H:	< ±10% at <300 km spatial and <15 altitude
Gravity:	Spherical harmonic degree and order >90
Spin rate:	$< \pm 10^{-8}$ (1 minute in one Venus day)
Spin axis:	< ±0·001° in RA and Dec

Instruments: The instrument suite for M5 is under review but will likely comprise the same three instruments as at M4: VenSAR, VEM and SRS.

VenSAR. The largest payload instrument is a phased array S-band radar, developed from the UK's low-cost NovaSAR-S instrument, with ERS, ENVISAT and Sentinel-1 heritage, optimized for Venus, and essentially unchanged from the instrument proposed at M4. Use of spacecraft pointing for side-looking, instead of a fixed slant, simplifies the observation strategy (Fig 1) to three pairs of ~9 minute/orbit (~36° latitude, ~3800 km) pass-to-pass InSAR swaths (or opposite-look swaths after Cycle 1), two ~9 minute/orbit multipolar (HH-HV-VV) swath at lower incidence angle for stereo mapping, two ~3 minute/orbit (~12° latitude, ~1300 km) high resolution swath and 1 to 2 S-band emissivity swaths per day.

InSAR swaths are contiguous to meet the repeat-pass requirement while gaps in the StereoPolSAR, HiRes and emissivity are filled in during later passes, providing a full suite of data for specific targets totaling ~25% of the surface. ~1 m resolution sliding spotlight images, each ~50 km^2 in area, will also be obtained at the Venera landing sites and other locations identified during the mission. In addition, InSAR will be acquired along a narrow equatorial strip and across the North Pole to measure variability in the spin rate and axis.

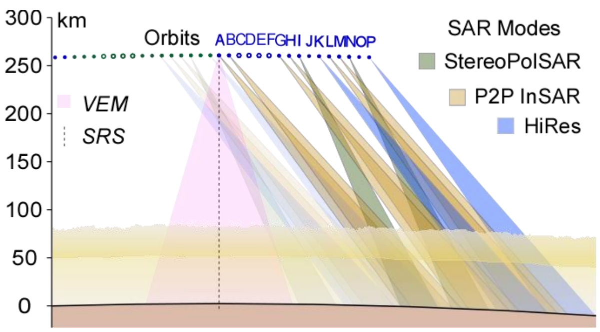

Fig. 1 Example 24-hour observation strategy. Orbits AB, GH, and LM: InSARs; orbits I, N: StereoPolSAR; orbits K, P: HiRes; and orbits J, O: S-band emissivity. VEM and SRS are obtained in each of these orbits. Orbits CDEF have the HGA pointed to Earth for the 6-hour communications link, during which no science operations are planned.

VEM. The Venus Emissivity Mapper suite comprises two UV and IR spectrometer channels in addition to the VEM-M IR mapping. VEM-M global IR-mapper [3] incorporates lessons learned from VEx/VIRTIS: band-center and width-scatter are ~5 × more stable, with decreased scattered light and improved sensitivity; a filter array provides wavelength stability and maximizes signal to the focal plane array (FPA). VEM-H is high-resolution, nadir-pointing, infrared spectrometer, the ideal instrument to enable characterization of volcanic plumes released from the surface of Venus by observing SO_2, H_2O and HDO through the 1 µm, 1.7 µm, and 2-2.3 µm atmospheric windows. Specifically, VEM-H is a redesign of the LNO (Limb, Nadir and Occultation) channel of NOMAD, retaining much heritage from the original with minor modifications to meet the science objectives of the M5 EnVision mission. The third channel, VEM-UV is an upper-atmosphere UV spectrometer dedicated to global SO_2 & sulfur cycles.

SRS. The Subsurface Radar Sounder will image faults, stratigraphy and weathering in the upper ~100 m of the areas mapped by VenSAR, to identify structural relationships and geological history.

Operations: EnVision M5 has a simplified mechanical design to one with a fixed SAR and HGA, with an AOCS capable of several changes in spacecraft pointing during each 90-minute orbit. These principally allow for radiator, power generation, communications, and the 15-minute science operation modes. Daily Earth-pointing communications occur in 6 hour blocks, occupying 4 of the 15½ orbits in every 24 hours, during which science operations are suspended.

The 3-m body-fixed HGA achieves a link rate sufficient for continuous InSAR and for StereoPolSAR and HiRes during closest approach (Fig 2) across ~25% of the surface, for a total of 336 Tbits in the nominal mission.

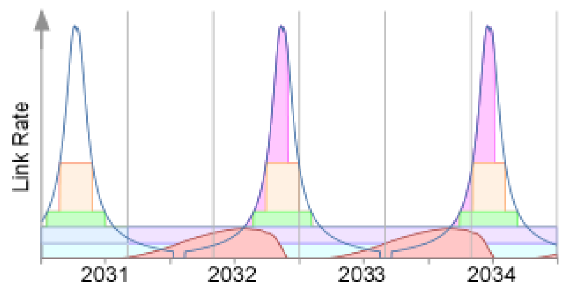

Fig. 2 Graph illustrating possible science observations and data return. Blue shades are InSAR; green is multipolar stereo SAR; orange is high resolution mapping. Data storage is in red and return in pink. Blue line is the achievable data rate (inversely proportional to Earth-Venus distance), vertical grey lines are Venus roational cycles.

Summary: EnVision achieves its science goals within the M5 constraints by focusing on ~25% of the surface with a comprehensive suite of observations, sufficient to identify types and rates of geological activity and characterize its geochemical cycles. The opportunity for the science community is to help define these areas and maximize the value of the science data return.

References: [1] Newman, M. *Contemp. Phys.* **46,** 323–351 (2005). [2] Lorenz, R. D. *Planet. Space Sci.* **117,** 356–361 (2015). [3] Helbert, J. et al. *LPSC* **47**, 1913 (2016) *this meeting*