Meeting the Goddess

PHOTO: ESA/VIRTIS/INAF-IASF/OBS. DE PARIS-LESIA

A human flyby Venus mission was studied as part of the Apollo programme in 1967 and now experts believe that such an attempt would be an important crew test mission for Mars

A crewed mission to Mars would take a few years and when the Mars spaceship fired its nuclear engines it would be the first time such a long endurance vessel had flown anywhere, but this level of risk can be reduced with a Venus flyby. A mission to Venus could be accomplished in as little as a year. At its nearest point, Venus is 61 million km from Earth while Mars is 225 million km away, on average. Not only could Venus be a test run but as early as 1956, the potential for Venus flybys to save propellant on actual human Mars missions has been understood. In the 1960s, NASA's Future Projects Office's early manned planetary interplanetary roundtrip expeditions' (EMPIRE) studies, examined flybys enroute to Mars and independent Venus missions. Fifty years later, NASA's plan for a crewed Mars mission, design reference 5.0 produced in 2014, once again recognised the potential for a Venus swing-by to reduce the velocity change demands of an opposition-class Mars mission.

Under NASA's Artemis programme human missions to Venus are not part of the baseline exploration architecture. But in 2019, the then NASA Administrator Jim Bridenstine gave a speech at that year's International Astronautical Congress indicating the agency was considering opposition-class Mars missions that would include a Venus flyby. This year, NASA's Moon to Mars objective definition group released a video describing a notional human short-stay mission architecture, with opposition-class missions including Venus flyby opportunities still being studied. But such missions to Venus are still not part of NASA's wider Moon to Mars objectives.

ABOVE

This ultraviolet image of Venus at 380 nanometres was taken by Venus Express' ultraviolet/visible/near-infrared spectrometer on 19 April 2006, during the capture orbit around the planet, from a distance of about 190,000 km.

The Moon to Mars objective definition group Venus flyby opposition-class mission has value because it cuts down the overall duration for a roughly 50-day stay in the Mars vicinity. The Venus fly-by would be on either the outbound or return. At the 73rd International Astronautical Congress held in Paris in September, a session focused on a human Venus flyby and that very month a report had been published from a Venus science symposium held in July. The report included Venus flyby missions and stated there was a "strong argument" one should be in NASA's Moon to Mars strategy. The symposium was held at the California Institute of Technology's Keck Institute for Space Studies.

The Keck Institute's report stated that the flyby mission's reduced risk, compared to a Mars trip, and

the scope for long distance human health research and mitigations testing, presented a robust argument. The report stated that: "Any mission outside of the Earth–Moon system, including to Venus, will test our readiness for long-duration deep space human spaceflight, in particular long-duration spacecraft operations, as well as crew psychology and health." While a Venus mission could be as little as 365 days, or thereabouts, the symposium discussed a 566-day flight with a free-return trajectory called a Venus backflip.

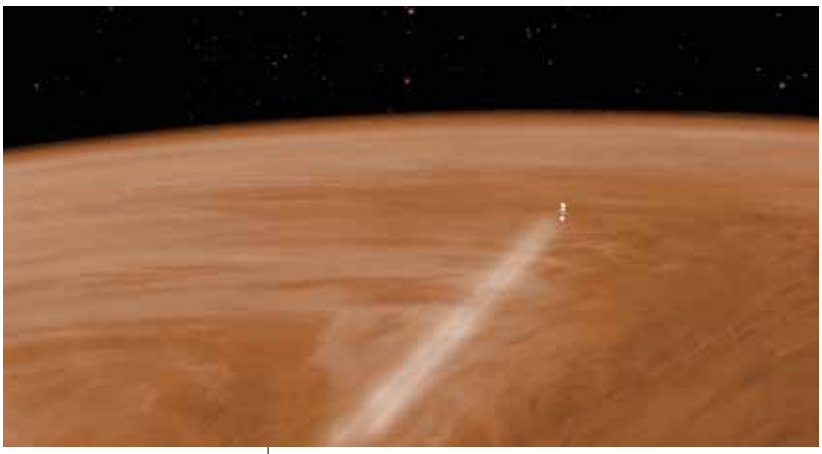
The appeal of the backflip is that it provides more time in the vicinity of Venus to enable teleoperated Venus science. The backflip means two flybys with 176 days within a light-minute of Venus. During the 111-day interval between the two Venus fly-bys the spacecraft would remain over a Venusian pole, enabling continuous teleoperation. The back-flip's benefits are a new flight duration record, science teleoperation, and valuable human performance knowledge all while on a free-return trajectory. This mission's trajectory would see the spacecraft go below, or above the plane of the ecliptic, by about 0.1 AU, or 15 million km, presenting a new view of the Solar System.

MISSION 2034

The report sets out a mission with a launch date of 7 August 2034. After the Earth departure, the crew will be on a free-return trajectory, only needing to carry out some small trajectory corrections. The first Venus flyby would occur on 18 November 2034 and the second would be on 9 March 2035, both at 500 km altitude. The crew would have roughly 177 days for scientific studies and of those 177 days, 111 are between the fly-bys, but still with a view of the southern hemisphere. After the second fly-by, the crew would return to Earth on 24 February 2036. An Earth-Venus opportunity occurs every 19 months compared to 26 months for Earth to Mars.

Each Earth-Venus opportunity can differ significantly in terms of departure and arrival velocities. A high return velocity cannot be higher than the design constraints of the Orion spacecraft's heat shield and parachute system. Another difference between each opportunity is which hemisphere is available. For a backflip this varies depending on where Venus is in its orbit at the first encounter. The symposium report found that the simplest possible back-of-the-envelope analysis suggests that a vehicle conducting a Venus backflip mission would have about 80% of the total galactic cosmic ray environment exposure of the very best-case Mars conjunction class mission. This Mars conjunction mission was analysed by NASA's strategic analysis cycle 2021 and it assumed nuclear electric propulsion.

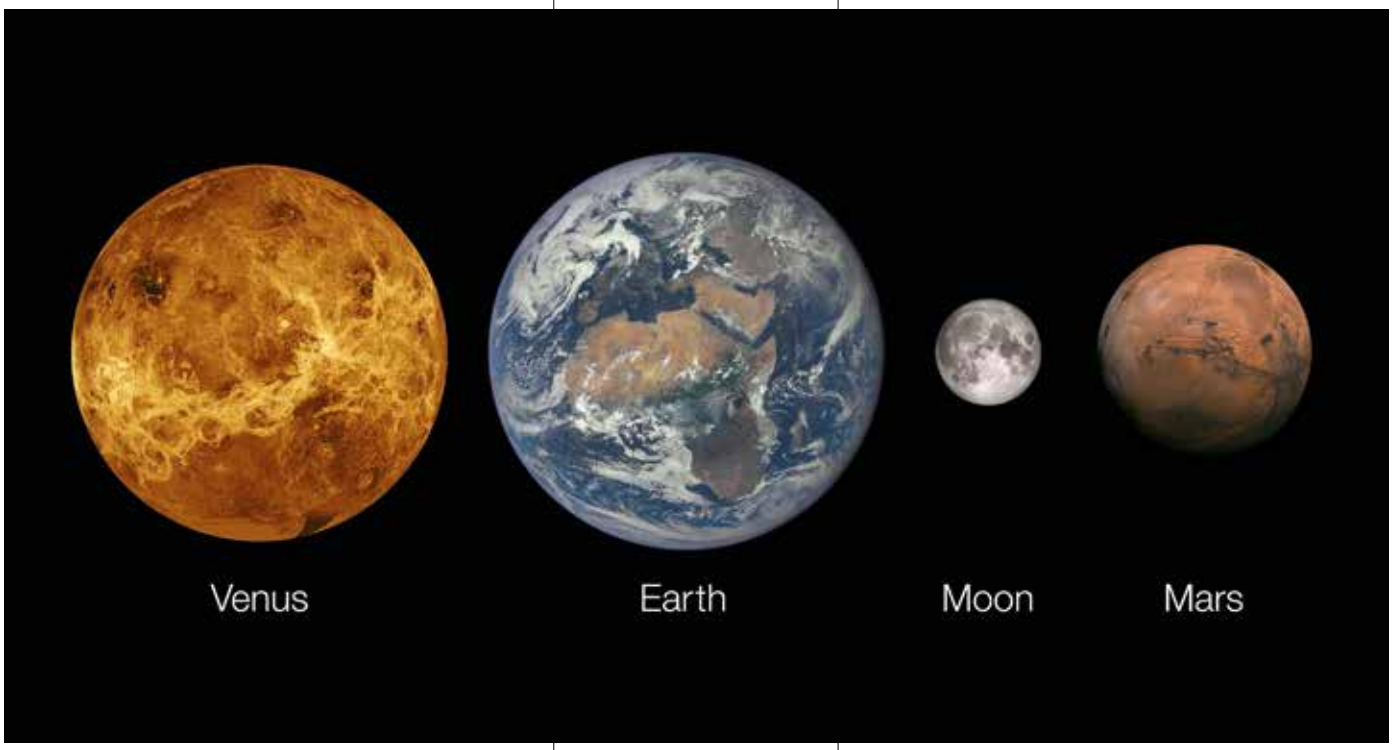
The report spells out that human missions have additional opportunities compared to robotic ones, increasing the science return. They are significantly increased communications capabilities and the opportunity to carry multiple ride-along payloads. These can be sent down to explore the Venusian atmosphere and surface and can be teleoperated. High data and communications bandwidths are often required for crewed missions, including for mission »



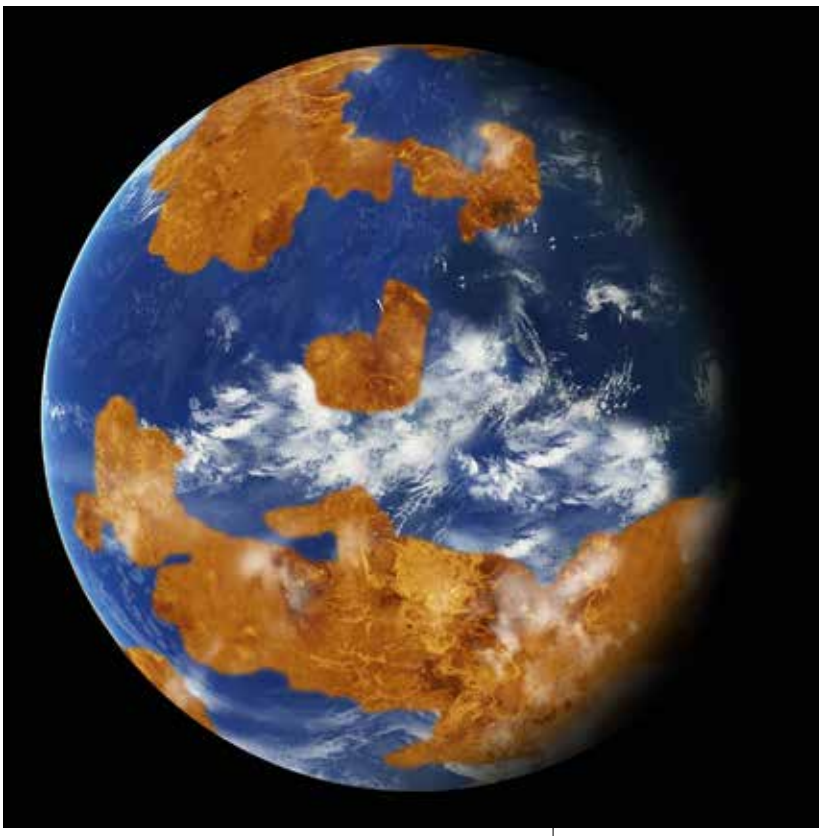
FROM ABOVE

A visualisation of the European Venus Express spacecraft aerobraking in the planet's atmosphere. Like the payloads carried by a human mission, a Venus Express-like probe could orbit the planet at an altitude of just 130 km.

This graphic shows Venus, Earth and its Moon, and Mars.



PHOTOS FROM TOP: ESA–C. CARREAU / NASA/JPL-CALTECH/ESA



« operations, personal communications home, and for public engagement purposes. These communications capabilities are significantly more than what robotic missions have. As such, more science data can be returned to Earth.

As set out in a previous edition of SpaceFlight (*SpaceFlight* Vol 64 No. 8 August p42), the symposium report agrees that the high mass of human mission spacecraft means substantial science payloads can accompany the mission at small additional cost. Multiple robotic probes can accompany a human-class mission to Venus, where it can be a challenge to obtain funding for a single robotic mission. Another advantage human missions have over robotic ones is that the mission's goals do not have to be prescriptive with a predefined set of targets. The crew has the ability to make spontaneous decisions in real time.

An example of this real time decision making would be reaching Venus and being able to determine that a location previously deemed important is not as high a priority as another location. This would ensure the highest possible scientific return. A crew can use infra-red (IR) telescope data, targeted radar emissivity images, or even flyover drone footage for real-time analysis of a volcano, for example. The substantial communications capabilities of a crew mission also mean significant amounts of data can be sent back to Earth for analysis by experts there.

There is also a psychological benefit for the crew in having this role. The crew are onsite, and they are, arguably, bar the Earth based scientists, in the best position to make immediate decisions. This decision-making capability also increases crew autonomy, which generally enhances the sense of agency and improves the team's psychological outlook. A priority for a Venus mission would be to seek evidence of active tectonics. Tectonic activity has played a major role in life on Earth and could do also on Venus. In the search for evidence of active tectonics, a human crew can identify areas of interest after cursory observations of potentially active faults.

CLOCKWISE FROM ABOVE

Observations suggest Venus may have had water oceans in its distant past. A land-ocean pattern like that above was used in a climate model to show how storm clouds could have shielded ancient Venus from strong sunlight and made the planet habitable.

This artist's concept of Venus suggests the presence of lightning in the atmosphere.

An artist's impression of an active volcano on Venus. Results from a long-term study of Venus find evidence of a clear injection of sulphur dioxide into its upper atmosphere. One possible interpretation is that volcanic activity increased the sulphur dioxide component of the upper atmosphere, although an alternative is that a change in atmospheric circulation dredged up the gas.

TELEOPERATIONS

The very first human Mars mission has been touted as an opportunity for teleoperations using robots on the surface controlled by the crew in Martian orbit. A human Venus mission would also offer this opportunity and teleoperations is only going to be possible with this planet anyway because of its extremely harsh surface conditions. The Keck Institute report outlines how remotely operated rovers and aircraft could be used. A solar-powered semi-autonomous aircraft could have astronauts monitoring its flight and able to identify in real time compelling science objectives.

The aircraft could recharge its batteries using solar power above the clouds at more than 70 km altitude. The aircraft could then fly into the clouds and use its instrumentation to study the cloud composition looking for habitability and biosignatures. A human teleoperator, even with up to a few seconds time delay could actively guide such an aircraft, or powered balloon, through the hazes and clouds. The astronaut operator would be able to guide these instrumented vehicles down to the lower cloud layers where particles from geological, volcanological or even biological processes can be found. Finding the source of the phosphene in the atmosphere would be a priority.

An aircraft with a fully charged battery could also fly into the planet's night side, both within and below the cloud deck. Within the clouds, answers could be found to their temperature variations and the possible effects on potential cloud habitability and haze photochemistry. Below the clouds, using far-optical to near-IR sensors, the aircraft could locate silicate mineralogy and map volcanic hotspots. For the harsh surface environment, the Keck Institute report expects advances in high temperature power sources and electronics to enable weeklong surface missions for rovers.

But it also suggests landing a rover on a mountain top. To escape the Venus' harsh mean surface temperature of about 464 degrees Celsius, a rover could be landed on the Maxwell Montes. Its top is 11 km above the planetary mean surface level and is the highest point on the planet. At this elevation, the temperature is more than 100 degrees cooler, about 377 Celsius, and has an easier pressure level of 45 bar; half that of the mean surface level. On Maxwell Montes a rover could last for longer than a week. As the rover is teleoperated it could travel far faster than the autonomous Mars rovers.

With astronauts a light minute away, the humans can direct the speed and direction of travel, coupled with near-real-time audio, image and video uplink. The rover would only need to stop for geochemical analysis, such as from laser-induced breakdown spectroscopy, Raman spectroscopy, or x-ray diffraction; multispectral stereo imaging would occur during the fast-paced drive, allowing for geomorphometric, topographic, and compositional mapping from the resulting dataset. Astronauts

PHOTOS CLOCKWISE FROM LEFT: NASA / J. WHATMORE / ESA/AOES

would respond almost immediately to serendipitous discoveries and adjust the rover's actions accordingly. The rover could even take samples, its robot arm teleoperated by the crew.

VENUSIAN SAMPLE RETURN

With the backflip mission configuration with two flybys, samples could be launched on both occasions from the surface or mountain top. The sample return vehicle would rendezvous with the crewed ship and the material transferred to a secure onboard laboratory. The crew could perform sophisticated laboratory experiments to determine the presence of or amenability to life. The results from the analysis of the first flyby's sample return could lead to better target collection for the second flyby's sample batch. The samples could be a mixture of atmospheric gases and particles and regolith. A mix of samples from two sample returns would allow for more detailed analyses once the samples are returned to Earth.

More than 50 years ago, NASA's Manned Space Flight office proposed a Venus flyby mission to the Apollo Applications programme. Using a single standard Saturn V, a three-man crew would be sent to the planet in November 1973. The Saturn V would be able to loft 48,432.32 kg, enough for the Command and Service modules to be attached to an environmental support module and a spent S-IVB stage. The S-IVB stage would be used for habitable volume and structural support for a solar array power system. Today, NASA's Mars mission reference architecture, for its ongoing analysis, foresees a crew of four with two going down to the surface. The Mars ship uses nuclear propulsion, and the crewed part of the spacecraft is one large habitat module attached to an Orion spacecraft. The Space Launch System (SLS) rocket would presumably launch the ship and crew separately. An SLS Block 2 Crew, with a 43 t payload capacity, would launch the Orion and perhaps the habitat, which could be expandable. An SLS Block 2 Cargo with a 46 t payload capacity would launch the nuclear electric propulsion part of the ship with additional orbiters, landers, rovers, balloons and fixed wing robot aircraft attached. While Mars is attractive because humans can walk on its surface, the journey will be a long one with many potential hazards. Flying by Venus could reduce substantially the risk of a future multi-year Mars mission. The planet of the Greek goddess is a solution to many possible problems, almost as beautiful as Aphrodite herself. SF