CALYPSO VENUS SCOUT. Horzempa, Philip, LeMoyne College (Syracuse, New York; horzempa45@gmail.com).

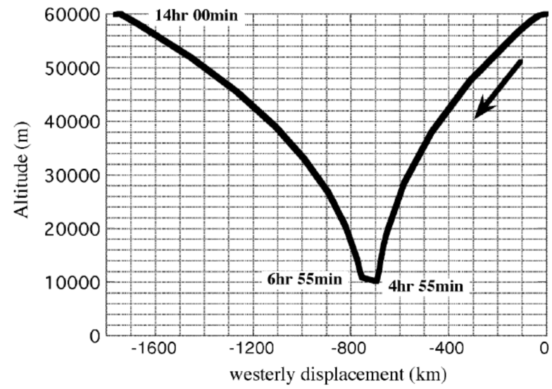
Introduction: The Calypso Venus Scout is a mobile, low-altitude survey and mapping mission. A unique design allows the science payload to view a significant amount of the surface of Venus from an altitude of 10-25 km. The harsh environment of the planet makes a surface rover or a low-altitude balloon untenable. Venus presents 4X the continental surface area of the Earth, a vast territory which would take centuries to explore by landers. Calypso acts as an "aerial rover" that can provide Global Access to all crustal units on the planet.

Mission Overview: Venus is not an easy place to explore. The key to the viability of the Calypso architecture is the separation of hardware elements. They operate in environments that do not require leaps in technology. The Anchor Balloon stays at high altitude (50-55 km) where the ambient temperature is 25C (75F). This obviates the need for metallic bellows, as proposed by the Venus Mobile Explorer (VME), built to survive at the surface temperature of 450C (900F). Even with such heroic measures, the VME would only have explored 2 sites on the planet.

Credit: Sam Zaref

Calypso's Descent Module ("Bathysphere") will descend on a tether, "skimming" over the terrain below. The deployment gondola is suspended a few meters below the balloon, and reels out the tether to a length of 20-40 kilometers. Solar panels are located along the upper rim of the gondola. At the flotation altitude of 50-55 km, sunshine will provide ample power.

The Anchor Balloon will be traveling with the winds of Venus. The Descent Module will also be carried along at that velocity, allowing it to conduct a transect of the ground below. The temperature at an altitude of 10 kilometers is 380C (720F).



Gilmore et al 2005

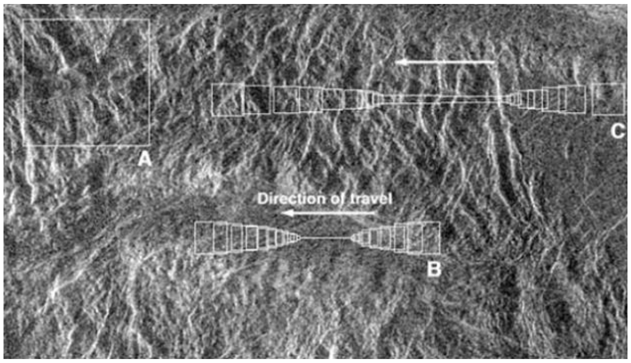
The Bathysphere will be well insulated, but the duration of its "dive" is limited by the time required for its interior to reach 150C (300F), the limit of state-of-the-art electronics. Calypso aims to limit technology development and will use available avionics. Allowance needs to be made to guard against the effects of droplets of sulfuric acid. This, however, is a well understood technology challenge.

After being reeled in to the Anchor Balloon, the Descent Module will cool to 50C (120F), followed by another deep dive.

Calypso will demonstrate control of the module during deployment, aerodynamic stability at various altitudes, and the ability to collect meaningful science data.

Payload: Calypso's Bathysphere will carry a High-Resolution Imager and a wide-angle Context Camera. Both are crucial to conducting aerial Field Trips. Below the haze layers, the atmosphere is clear. However, Rayleigh scattering will be a factor. As the Bathysphere reaches greater depths, the visible-light cameras will get a clearer view of the terrain below. The Context Camera will provide images with 1-10-meter resolution, while the narrow-angle Hi-Res camera will produce images with a resolution of 10 cm - 1 meter.

Further insight will be provided by the near-IR imager with a spectral range of 0.55–1.0 μm. It will allow first-order estimates to be made of the mineralogy, and by inference, lithology. The power of Calypso is that these measurements will not be confined to one or two landing sites. Rather, a large number of targets will be surveyed, allowing access to most of Venus' major geological provinces. The Gondola will include an engineering camera to monitor the operation of the tether winch. This camera will provide, as a bonus, views of flight within the haze layer. The Gondola could also carry instruments to sample, and analyze, the atmosphere.



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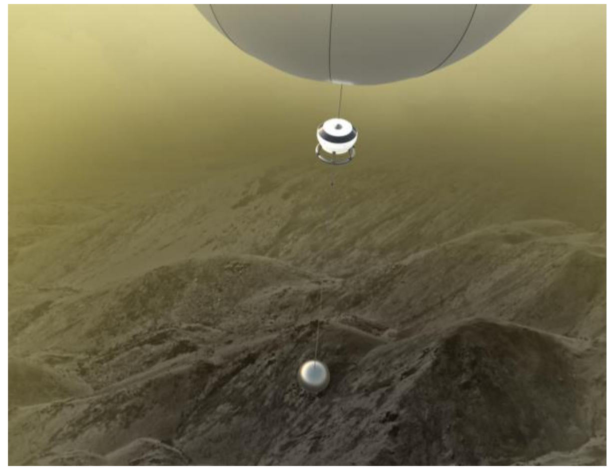
Science Enabled by Global Access: The Calypso Scout will be able to visit all terrain types on Venus. The Bathysphere can conduct low-altitude geologic transects over sites scattered across the planet. (1) When enough experience is gained using this technology, touch-and-go dives can be conducted. Terrain that is out of reach of landers, including the all-important Tesserae, can be viewed from ground level. As shown in this image, strata will be clearly visible, allowing insight into formation sequences and structural geology.

During this brief visit, rapid analyses of rocks at the site can be conducted with a Laser-Induced Breakdown Spectrometer (LIBS). Tests have demonstrated that a Venus-specific LIBS instrument will function on the surface. (2)

Future Missions: Advanced versions of Calypso will have the ability to collect samples during "touch-and-go" landings at dozens of sites. A "dredge net" will scoop up loose rocks and regolith, while a rapid-operation drill (3) will obtain shallow bedrock cores. Once winched back to the Anchor Balloon, these samples can be analyzed by an Aerial Rock Lab **(ARL)**. The ARL is comprised of an automated thin section machine, XRD spectrometer, petrographic microscope and an in-situ geochronology instrument (4), all operating at ambient conditions of 25C (75F) and 1 atm pressure.



Credit: Sam Zaref

This design also provides a pathway for a plausible Venus Sample Return (VSR) mission. Soil and rocks can be delivered to a waiting Earth-return rocket attached to the high-altitude Anchor Balloon. Calypso's tether architecture means that there is no need to launch the vehicle from the surface and no need for a complicated mid-air rendezvous between an ascent vehicle and an aerial platform.

The beauty of this design is that instead of retrieving a sample from a single site, a diversity of lithologies can be obtained from numerous locations for analysis in the ARL or for delivery to Earth.

References: (1) Gilmore et al 2005, "Investigation of the application of aerobot technology at Venus," Acta Astronautica 56

(2) Clegg et al 2010, "Remote Raman – Laser Induced Breakdown Spectroscopy (LIBS) Geochemical Investigation under Venus Atmospheric Conditions," 2010 AGU Meeting

(3) Zacny et al 2020, "Venus Drill and Sample Delivery System," 18th VEXAG Meeting

(4) Cohen et al 2021, "In Situ geochronology for the next decade: Mission Designs for the Moon, Mars and Vesta," Planetary Science Journal

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