Enhancing the Science Value from Venus Aerial and Surface Platforms with Relays on Venus Orbital Spacecraft

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THE CHALLENGE

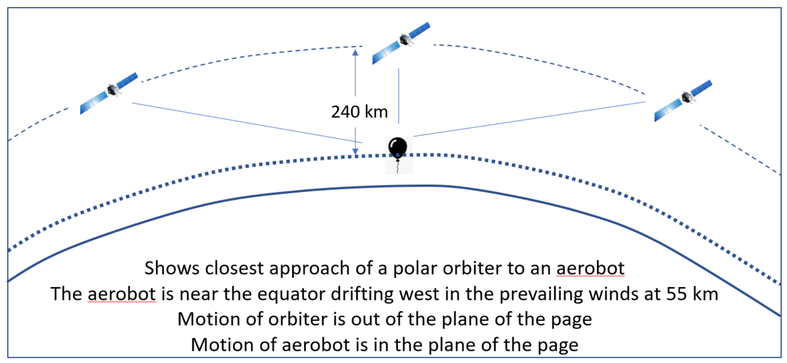
Future missions to Venus with surface and aerial platforms may generate large volumes of imaging and multispectral data on the Venus surface in addition to extensive geophysical and atmospheric data. Since it is impractical to equip surface and aerial platforms with large antennas, and point them precisely to Earth, communications direct to Earth may be limited to data rates of less than 1 kbps and this is only achievable when Venus and Earth are near opposition. A solution is for the mission to include an orbiter or multiple orbiters as in the Venus Flagship mission (Ref 1) but that may be prohibitively expensive.

THE SOLUTION

The solution proposed here is modeled on the Mars Relay Network. At Mars, landers, rovers and helicopters can take advantage of an established orbital relay infrastructure. The network enables the return of much more data that would otherwise be possible and with minimal power on the in situ platforms. The selection of three Venus missions by NASA and ESA in July 2021 **DAVINCI, VERITAS** and **EnVision** raises the possibility of establishing a similar communications capability at Venus that could relay data from future Venus aerial and surface platforms.

ORBITAL RELAY GEOMETRY -VENUS VS MARS

Because it is a very slowly rotating planet, the orbital relay geometry for a Venus surface platform is very different from that for Mars. The ground track of a low altitude polar orbiter such as VERITAS or EnVisions is displaced by only 10 km per orbit on Venus and 1600km on Mars. However, for an aerial platform moving 20X the rotation rate of Venus, the ground track is displaced by 200 km (see chart below). A lander on Mars is visible to an orbiter on a single pass but on Venus it is visible for more than 100 successive passes and an aerial platform for about 10 passes. This fact can be exploited to enhance data return.



Shows closest approach of a polar orbiter to an aerobot
The aerobot is near the equator drifting west in the prevailing winds at 55 km
Motion of orbiter is out of the plane of the page
Motion of aerobot is in the plane of the page

WHAT IS REQUIRED FOR A VENUS RELAY NETWORK?

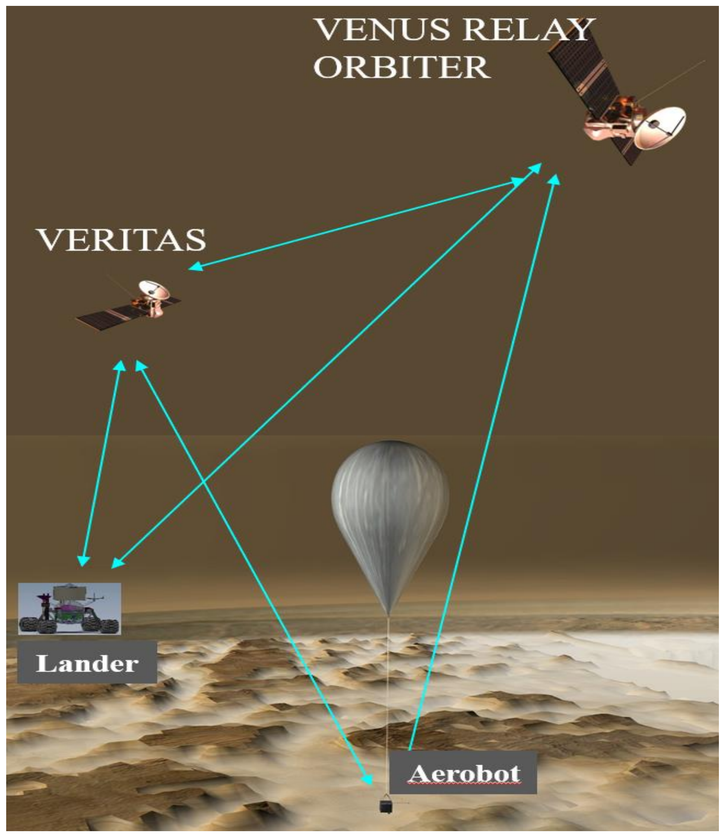
The DAVINCI Carrier Relay Imaging Spacecraft (CRIS) which delivers the DAVINCI probe is equipped with an S band communications system for relaying data from the probe. The 2m diameter S-band antenna on the CRIS will be pointed at the DAVINCI probe to enhance data return which lasts for the lifetime of the probe. THE CRIS has the capability to enter Venus orbit but this is not part of the PI led mission (Ref 2. resent there are no plans for it to do so Venus orbit. EnVision and VERITAS are in low circular orbits.

Electra radio which flew on MAVEN

Currently, they are not planned to be equipped with radios that could communicate with in situ platforms. For these low altitude orbiters UHF proximity relay systems such as the Electra radio which flew on MAVEN, do not require antenna pointing and would be preferred to S-band because they would place no pointing requirements on the orbiters

MARS RELAY NETWORK

Communications with Mars surface landers, rovers and aerial assets is facilitated by the Mars Relay Network. Currently, there are five orbiters in the Mars relay network – three from NASA () and two from ESA. Each is able to transmit commands to in situ assets and receive data from them and return it to Earth. Telecom hardware and protocols developed for Mars are directly applicable to Venus.



Venus Telecom links analyzed

Aerobot Telecom Performance

Key Telecom Parameter	0°N	30°N	60°N
VERITAS			
Maximum data rate (kbps)	*21,443*	*20,660*	*19,479*
Max data return per pass (Mb)	*2,010*	*1,965*	*1,922*
Data return per Earth Day (Mb)	*3,000*	*4,000*	*5,000*
Efficiency (Bits per Joule)	*62,500*	*80,000*	*90,000*
Venus Relay Orbiter			
Maximum data rate (kbps)	*5.7*	*5.4*	*4.6*
Max data return per pass (Mb)	*2X73 =144*[1]	*155*	*127*
Data return per Earth Day (Mb)	*144*	*155*	*127*
Efficiency (Bits per Joule)	*100*	*110*	*90*

[1]On equatorial passes the balloon blocks coverage near the zenith

CONCLUSIONS

Scientific data return and tracking of future landers and aerial platforms at Venus can be enhanced by data relay through orbiters already approved for flight to Venus

Polar orbiters with low circular orbits,VERITAS and EnVision, if equipped with UHF relay equipment, can provide both high rates of data return and communication energy efficiency but aerial platforms will only be visible for limited tracking

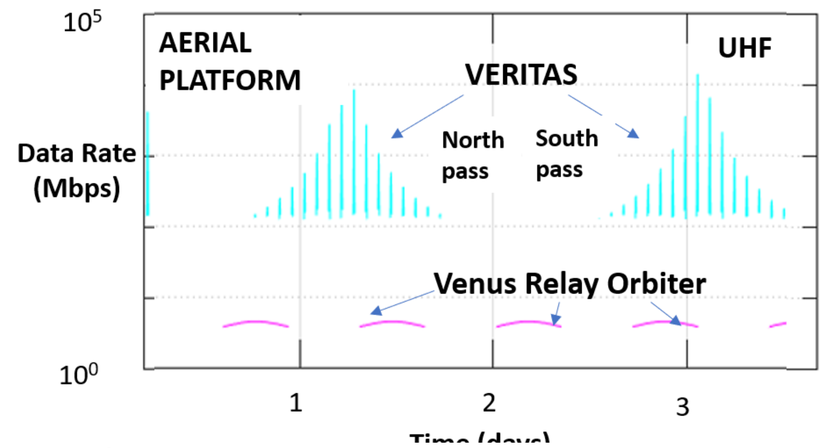
Spacecraft in high orbits, such as DAVINCI-CRIS, if it were to enter Venus orbit or a hypothetical Venus Relay Orbiter, would have less data return capability and lower energy efficiency but would enable aerial platform tracking for long periods.

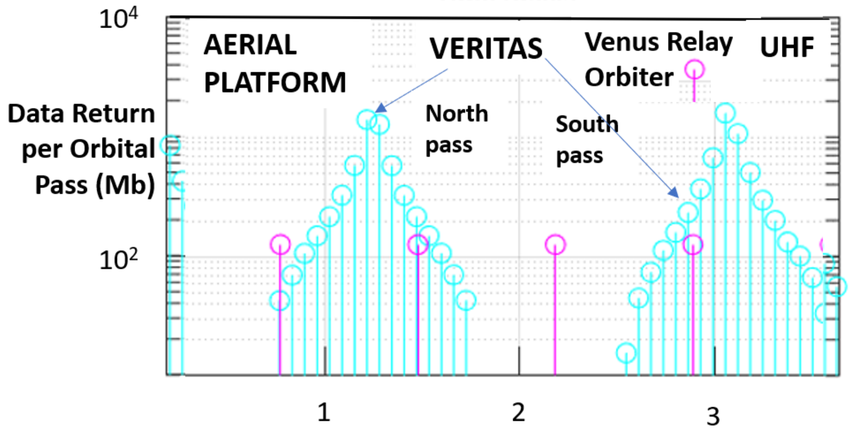
ORBITAL RELAY PERFORMANCE AT VENUS

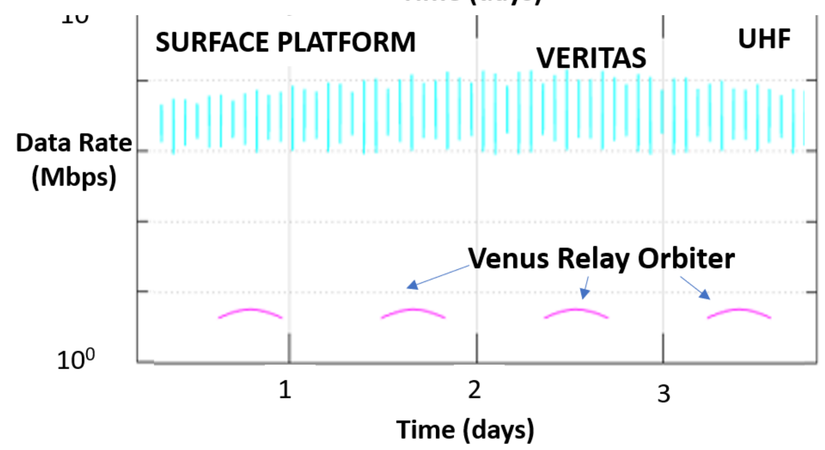
To understand the benefits, we contrast relay performance for relays in two different orbits- See chart at left:

- VERITAS – this is the actual orbit of the Discovery mission selected by NASA in July 2021. It is near-polar circular orbit at an altitude of 240km and orbital period of 91 minutes
- Venus Relay Orbiter – This is a hypothesized mission with an equatorial circular orbit at an altitude of 33,00 km and a period of 24 hours.

The performance of the relays at both UHF (390MHz) and S band (2300MHz) has been analyzed with the **Telecom Orbital Analysis Simulation Tool (TOAST)** for an aerobot and a lander. Radiated power is assumed to be 10W in each case







RELAY PERFORMANCE HIGHLIGHTS:

- Aerial Platform relay performance largely independent of longitude of platform entry. Improves at higher latitudes
- Surface Platform relay performance highly sensitive to longitude of lander location. Less sensitive as that location approaches the poles. Further analysis is needed. .

References:

1. Venus Flagship Mission by Patricia Beauchamp and Martha Gilmore, Proceedings, IEEE Aerospace Conference 2020.
2. DAVINCI CRIS plans, James Garvin to James Cutts, private communication.

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