

# POTENTIAL ORBITAL RELAY CAPABILITIES FOR SURFACE AND AERIAL PLATFORMS AT VENUS, James Cutts<sup>1</sup>, Charles Lee<sup>1</sup>, Joseph Lazio<sup>1</sup>, Archit Arora<sup>2</sup>, Leonard Dorsky<sup>1</sup>, Kevin Baines<sup>1</sup>, Sarag Saikia<sup>2</sup>, Kar Ming Cheung<sup>1</sup>, Sami Asmar<sup>1</sup>, William Frazier<sup>1</sup> and Mark Wallace<sup>1</sup>.

<sup>1</sup>NASA Jet Propulsion Laboratory, California Institute of Technology (4800 Oak Grove Drive, Pasadena, CA 91109)

<sup>2</sup>Purdue University, School of Aeronautics and Astronautics, (701 W Stadium Ave. West Lafayette, IN 47907-2045)

**Introduction:** In June 2021 three Venus missions were selected for flight later in this decade and early in the next one (VERITAS and DAVINCI by NASA and EnVision by ESA). All three missions include spacecraft with the potential to operate for a decade or more at Venus. Orbital relay communications capabilities are a long-standing capability for Mars exploration [1]. There are now five Mars orbiters (three from NASA and two from ESA) equipped with proximity telecom systems for relaying data from surface assets including landers such as InSight and rovers such as Mars 2020 and the ExoMars 2022, which make major contributions to scientific data return. In this study, we are exploring the benefits to future Venus in situ missions with entry probes, aerial platforms and landers of relay communications. Only one spacecraft, DAVINCI, currently includes a relay capability.

**Approach:** We have focused initially on the benefits of incorporating a relay on VERITAS not necessarily because this is the most suitable platform but because we have access to detailed information on its orbit. The VERITAS spacecraft will be placed in a near-circular near-polar orbit at an average altitude of 217.6 km and orbital period of 91.2 minutes. The Telecom Orbit Analysis and Simulation Tool (TOAST), which was developed for Mars orbital relay analyses, was used to assess the performance of a proximity relay on VERITAS [2]. Performance at both UHF (390 MHz) and S band (2.2GHz) frequencies is being evaluated. Key metrics in this analysis are peak data rates, the total volume of data that can be returned, the energy efficiency of communications in bits per joule and range-Doppler tracking capabilities.

**Lander Relay Performance:** Because of the low altitude of VERITAS, the duration of communication links with a lander will be measured in minutes but the possible data rates exceed 1 Mbps for transmitter radiated powers of ~10W. Because of the slow rotation rate of Venus, successive orbital overflights by VERITAS of a Venus Lander will migrate only 10km to the East. As a result, overflights will remain in range for many Earth days. However, once the orbital track has moved such that its elevation is less than 15° as viewed from the location of the lander, VERITAS would be unable to communicate with the lander for

half a Venus sidereal day (122 Earth days). Landers with sophisticated geochemical instruments are projected to have lifetimes of no more than 24 hours. Ensuring that the VERITAS overflies the lander within an hour of its arrival would constrain the lander trajectory design unless there is considerable flexibility in the location of the lander on Venus.

**Aerial Platform Performance:** If the aerial platform is equipped with a similar transmitter to a lander, peak data rates will be comparable and in excess of 1 Mbps. However, because the aerial platform is traveling with the superrotating atmospheric flow, the platform will be in range for less than 10 successive orbits. However, for the same reason, the time until the next window opens is much shorter, less than 3 day. Since aerial platforms are expected to operate for time periods of the order of 100 days, there is the potential for several hundred overflights during the lifetime of the mission.

**Comparison with other orbital data relays:** A key advantage of this type of orbital relay is the high data rates that are possible enabling the energy cost of returning data from the *in situ* asset to be dramatically reduced. Using less energy for communications and hence less power dissipation as heat can also extend the lifetime of Venus landed missions.

A disadvantage of relays from orbiters such as VERITAS or EnVision, which are in low altitude circular polar orbits, is that they can only be in communication with in situ assets for a small fraction of the time, limiting their value for tracking aerial platforms and radioscience. A combination of relay orbiters in high altitude for continuous tracking and polar low altitude circular orbits for efficient data transmission would be optimal.

**Acknowledgments:** The research described in this paper was funded by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

## References:

- [1] Edwards, Charles, *Relay Communications for Mars Exploration*, International Journal of Satellite Communications and Networking, DOI: 10.1002/sat.871
- [2] C. H. Lee, K-M. Cheung, C. Edwards, and A. Vaisnys, "Orbit Design Based on Global Maps of Telecom Metrics," IEEE Aerospace Conference Proceedings, Big Sky, MT, March, 2005