National Aeronautics and Space Administration

A Tethered Towbody for Subcloud Sensing from a Venus Balloon

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Project Statement: The Tethered Observatory for Balloon-based Imaging & Atmospheric Sampling (TOBIAS) has the potential to enhance future Venus balloon missions by enabling in-cloud sampling and direct imaging of the surface below the planet's dense cloud layer, over a vast spatial area (100's km) at resolutions (~10 m/pixel) four orders of magnitude greater than from orbit.

Background: Determining the nature and formation history of Venus, including its potential to harbor life in the atmosphere and active volcanism at the surface is limited due to the lack of in-situ exploration technologies. Venus poses a tremendous engineering challenge resulting from its extreme environment, e.g., surface temperatures of 470 C, atmospheric pressures nearly 100 times that of Earth, and sulfuric clouds and haze. Past approaches to observe Venus have relied primarily on orbital observation and even several short-lived landers. As evidenced by these landers, long-duration, surface missions (especially mobile ones) are broadly considered impractical given the thermal challenges imposed on present-day electronics and flight systems. However, recent advances at JPL in robust balloon-borne observatories, deployed within the cloud layer, provide the safest means to study Venus in the near term at a resolution far greater than from orbit and within a region where recently detected phosphine, a building block for life, may exist. For safety, a balloon observatory would need to maintain a mid-range altitude of 52-62 km to avoid potential exposure to extreme temperatures (>100 C) while also gaining access to viable solar power. Yet, due to cloud scattering and atmospheric attenuation through the lower, turbulent cloud layer, direct, sub-cloud imaging would be limited. The feasibility of subcloud (<47 km) IR imaging of the nighttime surface appears favorable according to a study by Co-I Davis (Davis et al., 2020). Several concepts for reaching these altitudes from a balloon at 52km include dropped payloads, rotorcraft, and tethered towbodies.

Objectives:
- Establishing requirements for a sub-cloud IR imaging payload
- Study tow-body aerodynamics, mass, power, thermal requirements
- Perform tether system analysis
- Determine integration strategy with future Venus balloons
- Outline a technology roadmap for follow-on, increment development

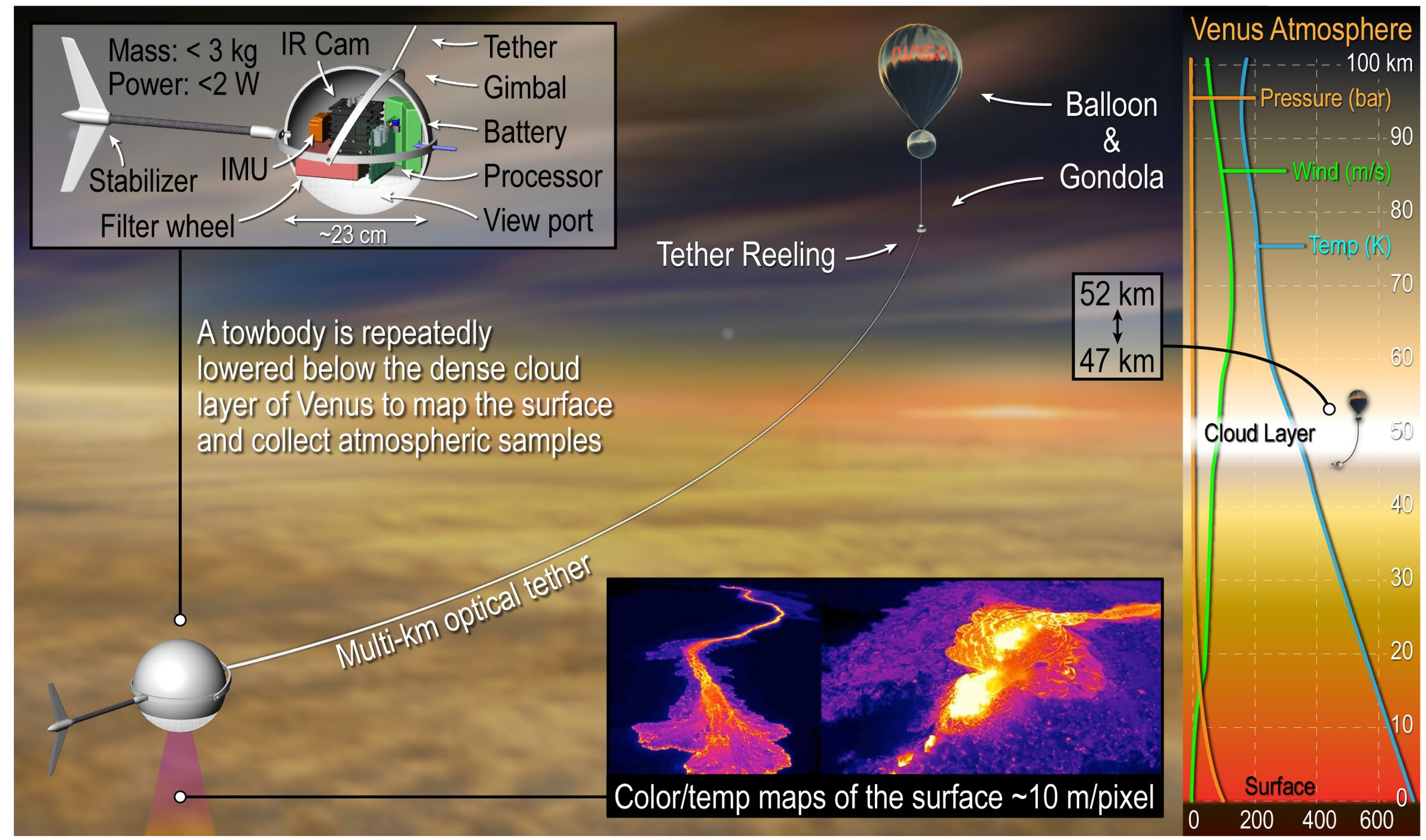
Approach and Results: We conducted a trade study to look into objectives above and determined the concept was not only feasible but provided 'game-changing' imaging capabilities to support future Venus balloon missions under development at both JPL and other NASA centers. Some results from the study are shown via illustrations and figures *(see right)*.

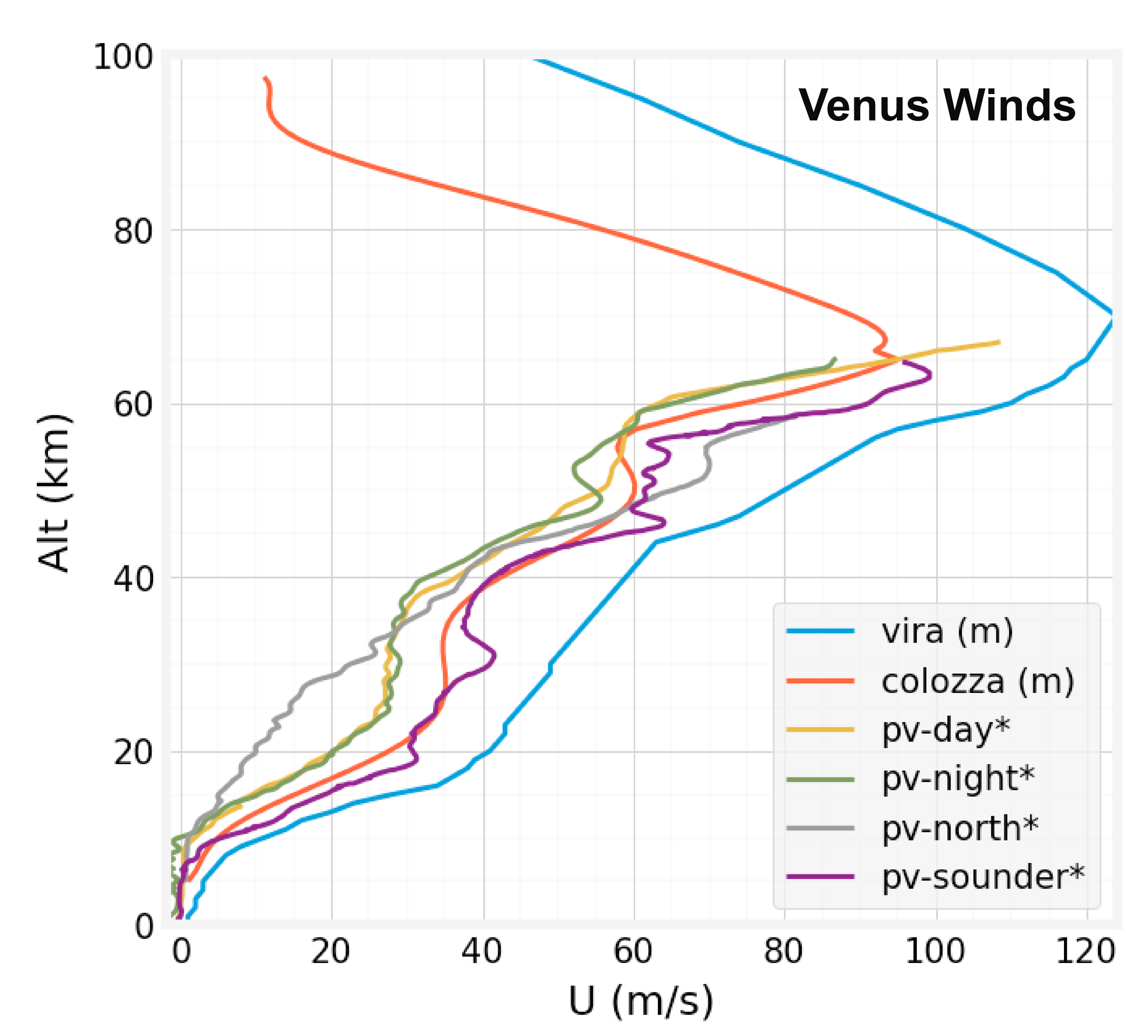
Significance/Benefits to JPL and NASA: Resolving features on the surface of Venus would require a probe to be placed at or below 47 km in altitude, where sharp, near-infrared spectral imagery can be obtained (Davis et al., 2020; Baines et al., 2021). Above the cloud layer, an imager will achieve no better than 50-100 km/pixel resolution due to light scattering/diffusion in the clouds. Over a thousand-fold improvement in resolution, down to ~10 m/pixel, appears possible over state-of-the-art, orbit-based approaches.

Publications:

[1] McGarey, P., Hockman, B., Sutin, B., Izraelevitz, J., Davis, A., Cutts, J., Dorsky, L., Baines, K. (2021, July). A Tethered Towbody Payload for In- and Sub-Cloud Sensing on Venus. In 18th International Planetary Probe Workshop (Vol. 2021). IPPW.

[2] Baines, K. H., Cutts, J. A., McGarey, P., Sutin, B. M., & Davis, A. B. (2021, March). High Spatial Resolution Imaging of the Surface of Venus via a Balloon-Borne Tow-Body Camera System. In Lunar and Planetary Science Conference (No. 2548, p. 2498).





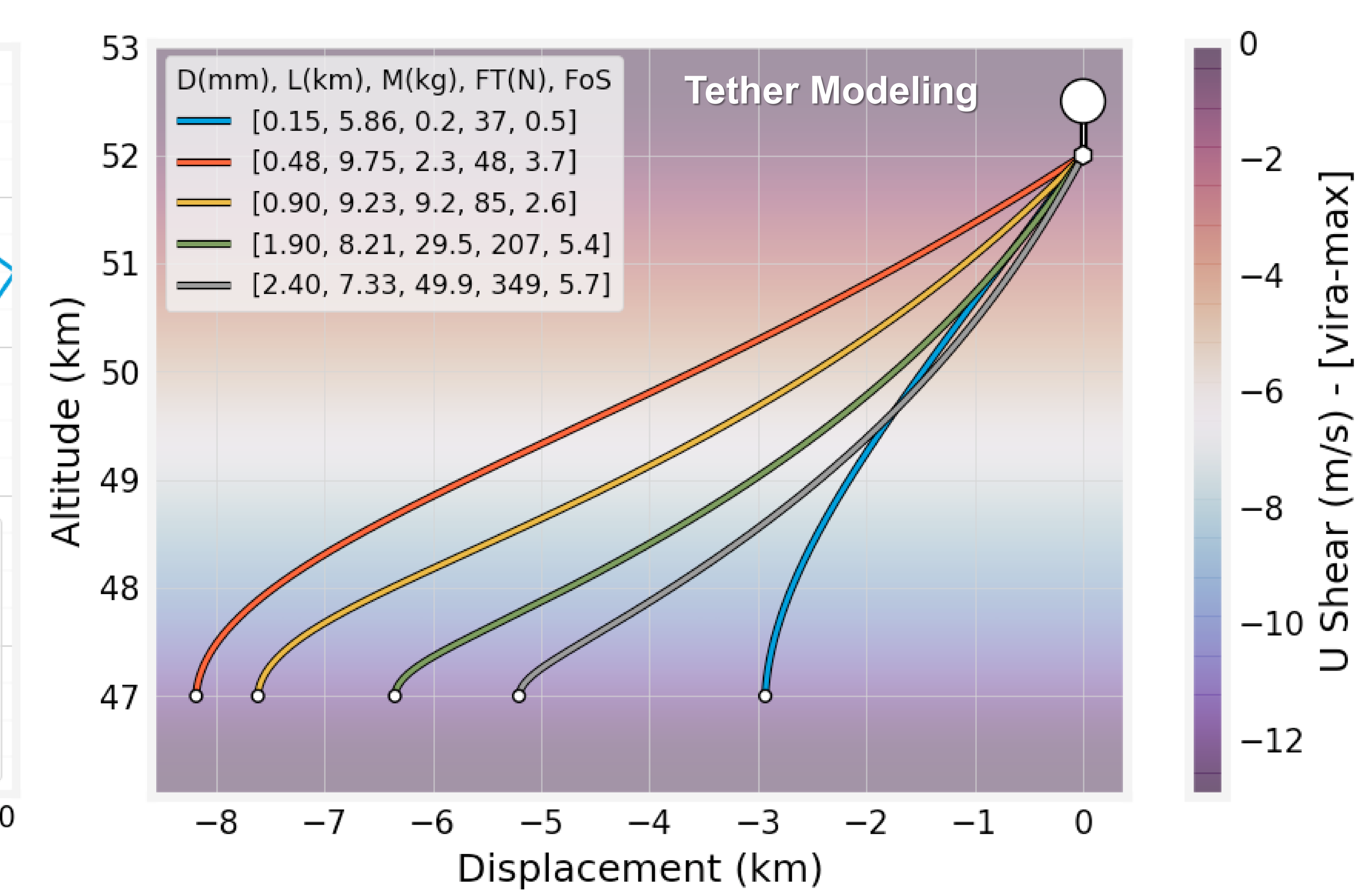


Figure Caption: Models and measured (Pioneer Venus Probes, 1978) wind speed data (U) are shown with respect to altitude on Venus (*left*). We use the VIRA model from *Kliore et al., 1985*, as it represents the maximum expected value for wind shear. We model the tether deployment using models from Triantafyllou et al., 2002, (*right*) to estimate the deployed shape, length (L), and tension (Ft) along thin fiberoptic tethers of varying diameter (D), mass (M), and factors of safety (FoS). In order to minimize mass and volume maximize FoS, a 0.48-mm, 10-km, off-the-shelf tether from *Linden Optics* is assumed as a baseline design.

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