TOBIAS: Tethered Observatory for Balloon-based Imaging & Atmospheric Sampling

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NASA Innovative Advanced Concepts

Project Objective: To investigate the feasibility of using a tethered towbody suspended below a high-altitude balloon in the Venusian atmosphere to penetrate below the cloud layer for surface imaging and atmospheric sampling .

Mission: A basketball-sized **towbody** containing an IR imager, atmospheric sampling instruments, and support hardware is suspended on a **multi-kilometer tether** from a high-altitude balloon in the Venusian atmosphere, allowing it to **peer beneath the dense cloud layer and image the surface at high resolution.** The towbody harvests energy from the relative wind shear to power onboard instruments and active cooling system. Aerodynamic surfaces allow the towbody to maintain stable pointing for imaging. An optical fiber in tether provides communication to gondola.

Innovation: A tethered towbody presents a game changing capability for a sustained low-altitude observing platform in the Venusian atmosphere below the dense obscuring cloud layer (< 47 km)—an altitude not achievable by variable-altitude balloons (due to temperature and pressure), and only briefly achievable by dropped probes, gliders, and rotorcraft. A tether spool allows for precise control of the towbody altitude for surface imaging and atmospheric sampling.

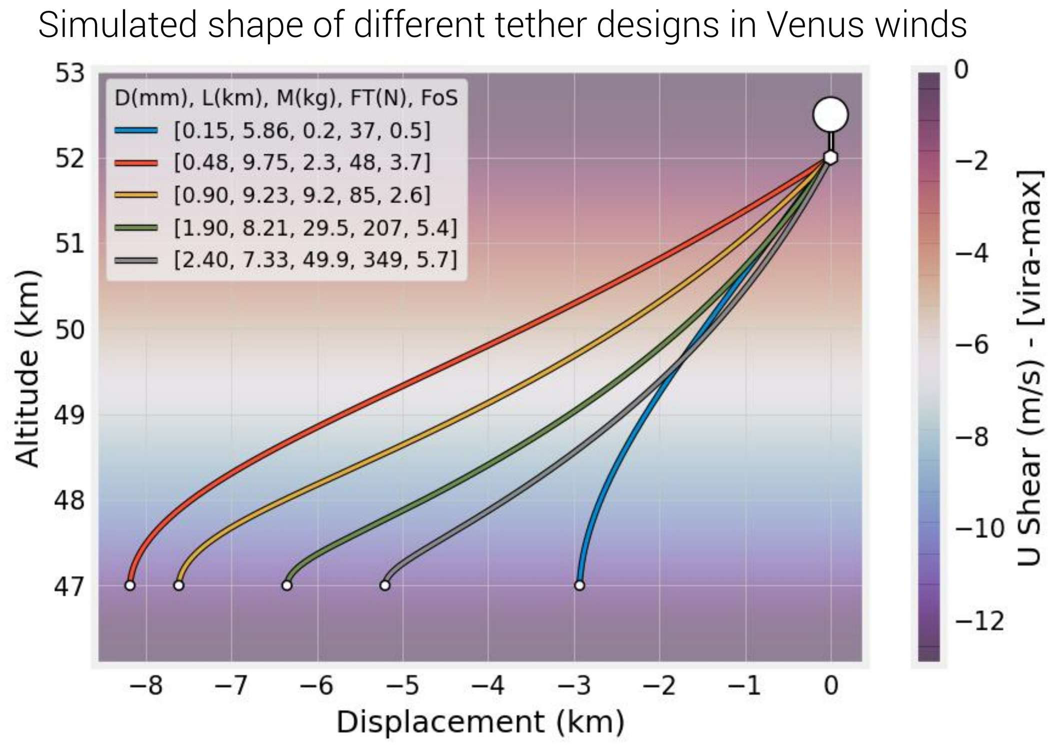
Impact: Night-time IR imaging of the Venusian surface at high resolution and spatial coverage would transform our understanding of the nature and evolution of Venus, including active and past volcanism and other geologic processes. The small size of a towbody platform allows for easy accommodation on upcoming (Discovery- or New Frontiers-class) balloon missions (which are thermally precluded from descending below the cloud layer), dramatically enhancing their science return.

Approach: This Phase I study will focus on four key aspects of the TOBIAS system:
1. **Tether system**: design, deployment, and models for drag-induced shape deflection under expected wind shear profiles.
2. **Towbody stability**: design trades for attitude stability under wind shears and turbulence.
3. **Power and Thermal system**: wind power harvesting, cooling strategies, insulation, etc.
4. **Mission Architecture**: study key interfaces between the towbody and balloon/gondola (e.g. mechanical, comm.) and broader mission profile.

Tether Analysis

A key challenge for a suspended towbody is overcoming the high relative wind shears expected below the balloon, which tend to "blow" the towbody laterally instead of down vertically. A multi-kilometer tether, even at sub-mm diameter, presents a very large surface area for induced drag. We are developing physics based simulations to study the static and dynamic behaviors of tether-towbody systems subject to Venus' atmospheric wind conditions.

Simulated shape of different tether designs in Venus winds

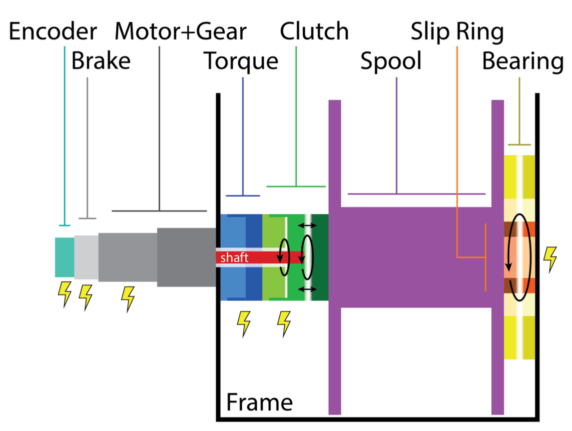


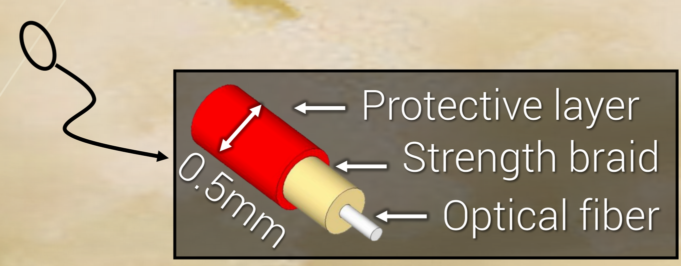
Preliminary results indicate that vertical penetration is feasible with modest downwind drift with a realistic tether design. Towbody drag is negligible compared to the tether.

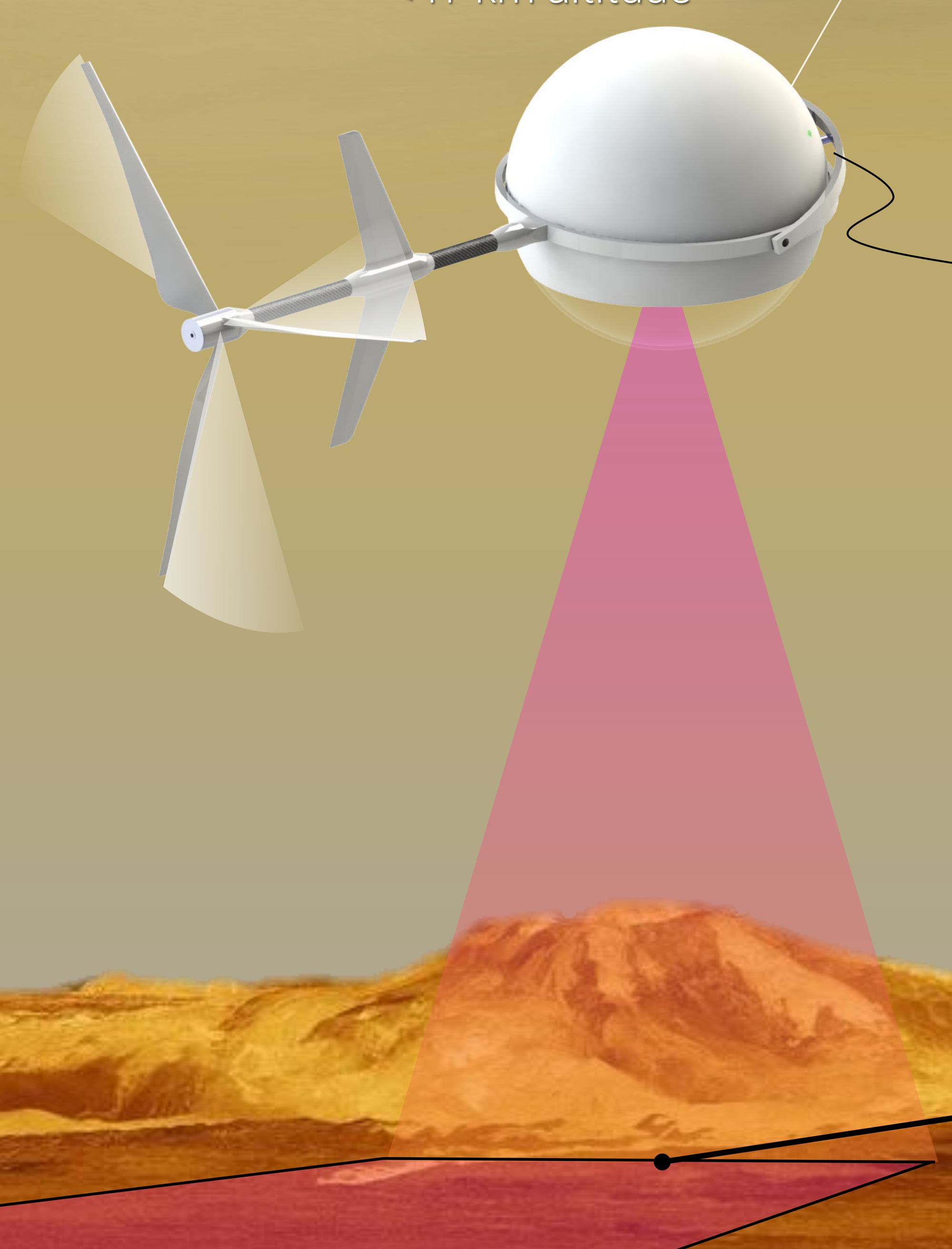
Mission Operations

After balloon inflation, the tether is payed out from a spool on the Gondola. Power, thermal, and communications dictate altitude cycling. Our baseline is to retract the towbody to a higher/ colder altitude, charge batteries, and refreeze a phase change material before the next nighttime deployment. An alternate option uses onboard (solar or wind) power generation on the towbody to power an active cooling system and remain deployed. Communication to gondola is through an optical fiber in the tether (baseline) or RF link.

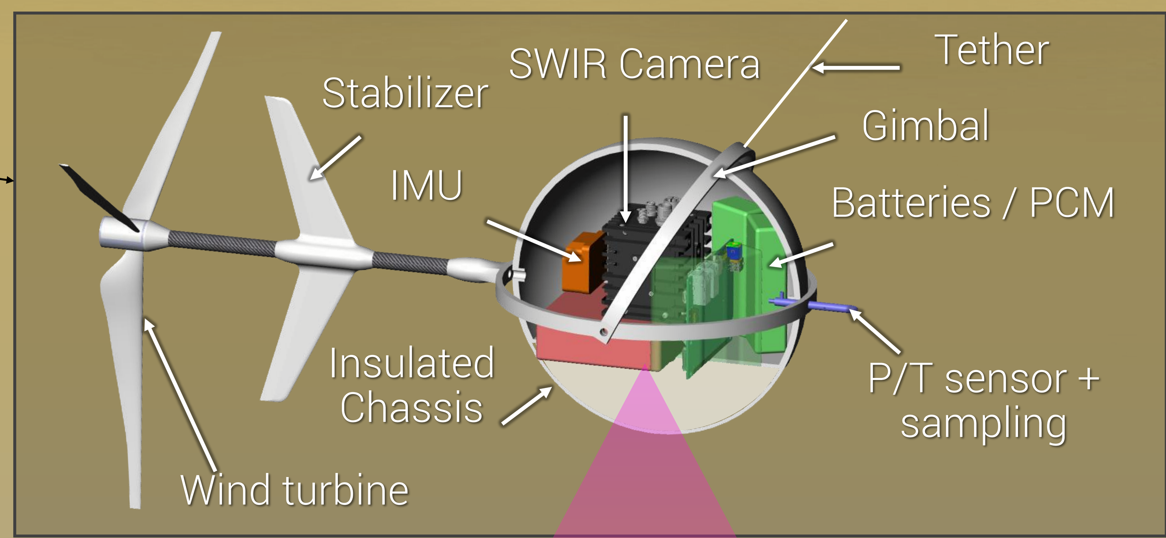
Notional spool design





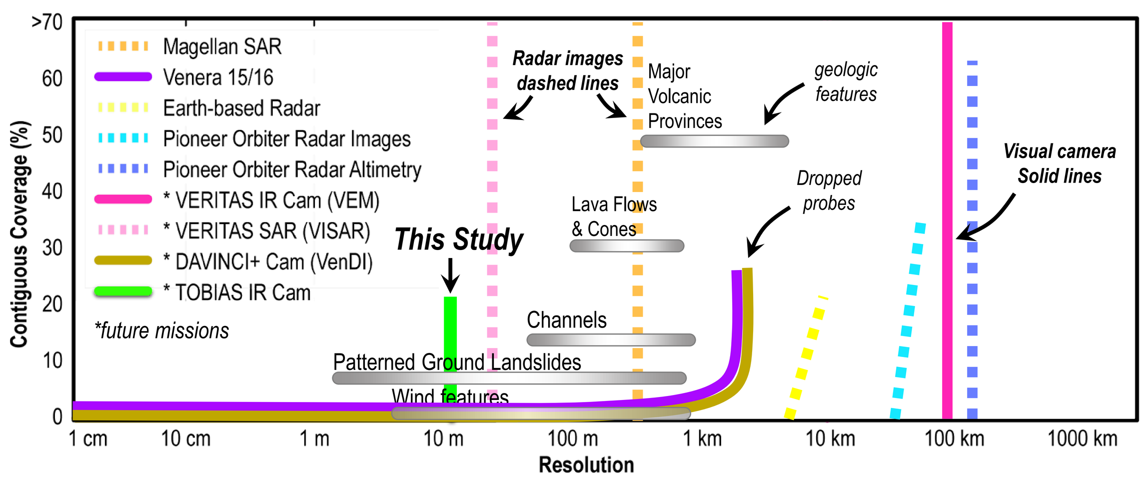


Notional System Design



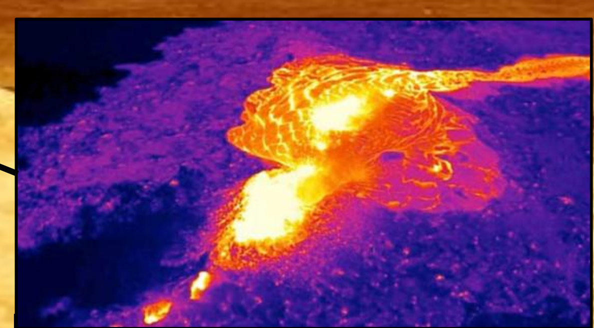
Comparison to other methods

Night-time IR imaging is fundamentally different than traditional Radar imaging, and would allow us to resolve key compositional information of a variety of geologic features and even active (hot) volcanism.



Getting below the clouds is the only way to observe in the near-IR and a towbody would provide orders of magnitude greater spatial coverage than dropped probes or short-lived daughter vehicles.

Three filter bands (1.01, 1.1, 1.18 µm) help to discriminate rock with different composition/emissivity signatures. Repeated band provides stereo for 3D topography.



High-resolution IR imaging