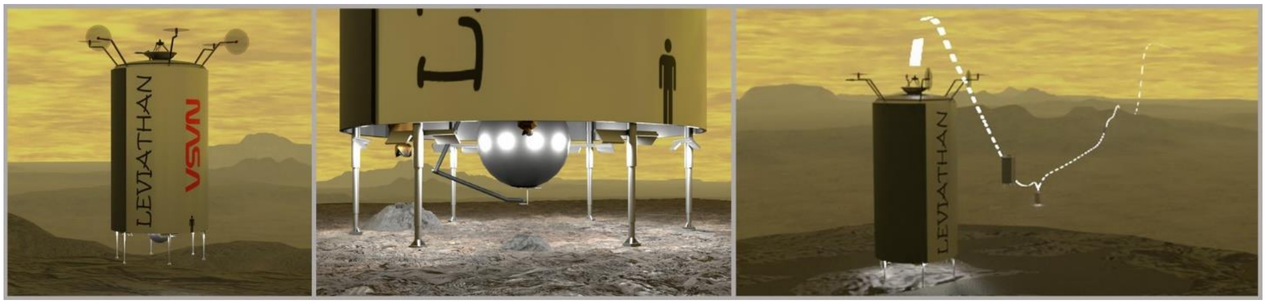
LEVIATHAN: A STARSHIP-BASED VENUS AEROBOT FOR LOW-ALTITUDE AND SURFACE EXPLORATIONS. J. T. Vistica, Leviathan Explorations (jvistica@leviathanexplorations.com).



Introduction: Over the years numerous missions have been proposed to explore the lower altitudes and surface of Venus; however, due to the unforgiving environment, mission designs have been exceedingly limited in mass, duration, and power thus severely restricting scientific return. The Leviathan is a next-generation lander and near-surface explorer that can revolutionize our approach to exploring Venus.

The Leviathan Venus Explorer is a long-lived 30-ton nuclear-powered stainless-steel methane-filled aerobot with operational altitudes from -2 km to 4 km capable of landing and taking off almost anywhere while circumnavigating Venus for possibly years.

For a rigid superpressure balloon the larger the tank size the greater the payload capacity and the potential for more scientific return. In this mission a 17 m section of Starship itself is used as the methane tank giving a lift capacity of 30 tons. This mission would be delivered by a customized SpaceX Starship on a one-way journey.

This mission is designed to take maximum advantage of standard SpaceX Starship[1] components (Figure 1) allowing development costs to focus on aerobot control systems and scientific instruments.

Aerobot Shell: The aerobot shell consists of a methane lift tank composed of eight standard Starship segment rings, two end caps, and a lower skirt segment (**Figure 2**). The shell mass is 15 tons leaving a payload and systems mass allowance of 15 tons. Scientific payload allowance is about two tons.

Altitude Control System: The key to the usefulness of the aerobot is its ability to control its altitude[2]. **Figure 2** shows a conceptual 3-cell vertically hung bladder almost the full height of the methane tank. Blowers use outside air to inflate the bladder to reduce lift causing the aerobot to descend. Vent valves release the air to ascend. Internal pressure is 1 bar above ambient.

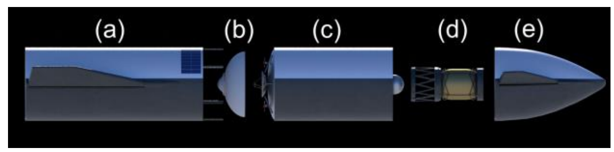


Figure 1: (a) engines and fuel tanks (50% standard size) and interstage disconnect (b) backshell with parachutes (c) Aerobot (d) cryogenic liquid methane tank (e) nose cone with interstage disconnect

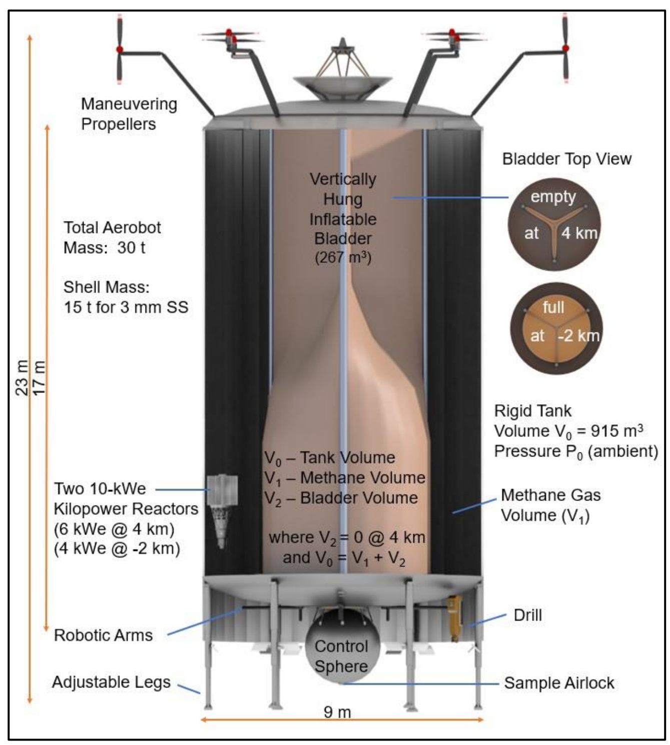


Figure 2: Leviathan aerobot cross section showing a partially filled bladder which compresses the methane space thus reducing buoyancy causing the Leviathan to descend.

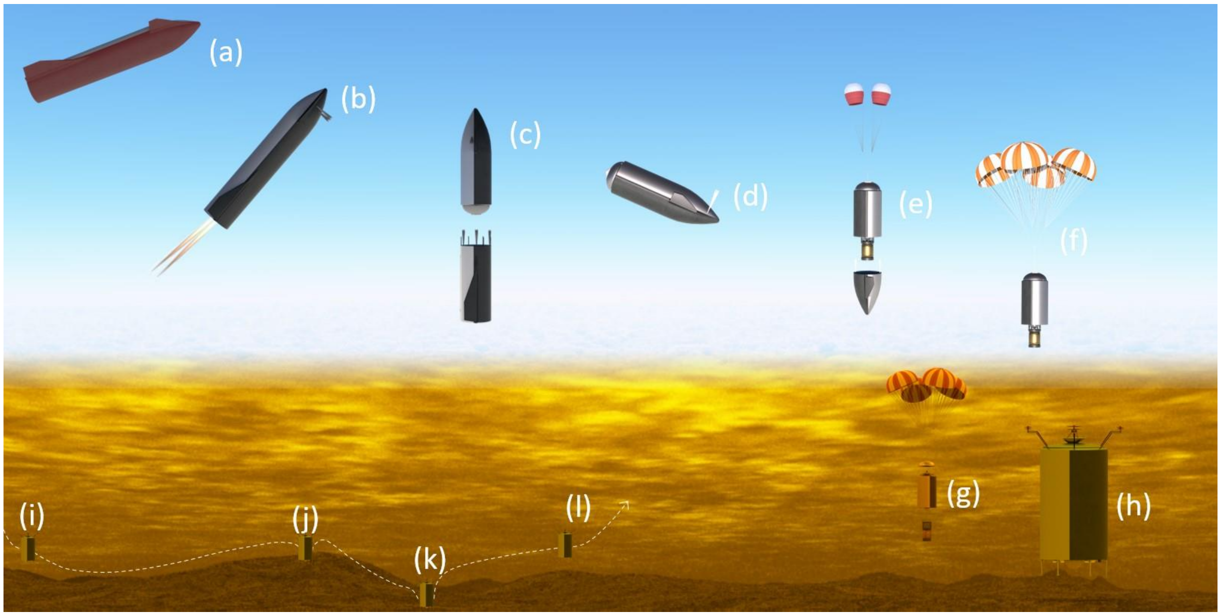


***Figure 3**: Venus Arrival and Mission Operations*
***Disassembly Maneuver:** (a) atmospheric entry (b) flip to vertical (c) engines and tanks disengage (d) forward section flip (e) drogue chutes deploy and nose separation (f) main chutes deploy (g) backshell with chutes and methane tank separations at design altitude (h) system checkouts, landing legs and maneuvering arms deployed.*
***Surface Operations:** (i) survey surface at fixed height above ground (j) powered landing, sampling, photos, etc. (k) powered relocation to another area of interest (l) return to higher altitude to catch faster winds.*

Power System: Power is provided by two self-regulating 10-kWe Kilopower[3] fission reactors located in the methane volume providing power for the cooling system, batteries, instruments, and electronics. External heat exchanger panels dissipate 50 kWt per reactor at full power to the environment.

Lift Gas: Methane was selected as the lift gas to minimize leakage issues to maximize mission duration. 18 tons of liquid methane is transported in an external cryogenic drop tank and is gasified during initial descent to maintain positive pressure in the aerobot.

Maneuvering Propellers: High-temperature electric motors drive maneuvering propellers to assist with obstacle avoidance, landings, takeoffs, and short navigated flights.

Control Sphere: The 1.75 m diameter control sphere's internal temperature is maintained below 75 C using a bank of multi-stage coolers. About 3,200 Watts of electric power for the cooling system will be needed to continually remove the projected 1,200 Watts of heat from all thermal sources. Cooling, vacuum, thermal isolation, and insulation blankets ensure that control systems maintain nominal operational temperatures.

Scientific Instruments: The Leviathan can accommodate the entire list of geological and atmospheric instruments in VEXAG's Venus Flagship Mission Study[4] along with new instruments such as ground-penetrating radar, robust sample analysis in coordination with drilling activities, and an advanced panoramic camera transmitting high-definition video as the Leviathan cruises over the Venetian landscape.

Conclusion: Previously proposed Venus landers have been limited to a single landing site and extremely limited duration. The Leviathan aerobot could possibly operate for years while circumnavigating Venus and perform surface operations anywhere along its travels. Venus conditions provide many challenges but also a unique opportunity to deliver a true global explorer in a Starship-based Leviathan aerobot.

References:
[1] SpaceX (2021) SpaceX Starship. [Online].
[2] Loon LLC (2021) Loon Library: Lessons from Building Loon's Stratospheric Communications Service
[3] Poston D. I. et al. (2019) Kilopower Reactors for Potential Space Exploration Missions, NETS-2019, ANS.
[4] M. S. Gilmore, et al. (2020) Venus Flagship Mission Decadal Study Final Report, Venus Exploration Analysis Group (VEXAG).