Multi-probe In-situ Detection of GasEous Species (MIDGES):
A Low Cost Mission to Detect PH_3 in the Venusian Atmosphere

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Abstract

With recent excitement over the apparent detection of phosphine gas (PH_3) in the atmosphere of Venus, a low-cost mission is proposed to confirm its existence. Utilising multiple femtoprobes with miniaturised instruments, this mission will allow for in-situ measurements to respond quickly to contested science. A minimum concentration is obtainable from a simple yes/no detection flag, avoiding the need to download data packets from the sensor.

This poster presents an overview of the mission and the technology proposed to achieve the scientific goals.

Mission Concept

In this poster, a minimum mission concept is proposed to deliver in-situ measurements of the Venusian atmosphere. Using a CubeSat design philosophy, with low-costs and a short development cycle, a dedicated 20 kg spacecraft called orbital relay is envisaged to deliver an entry probe (Fig. 1) carrying a large swarm of smaller femtoprobes directly from a Venus fly-by trajectory. After deceleration, the entry probe releases 64 femtoprobes (Fig. 2, 60 g femtosatellites equipped with an aeroshell providing thermal protection and aerodynamic stability) to perform massively parallel in-situ measurements of the atmosphere using simple gas sensors. The proposed mission architecture would provide multi-point measurements which can then provide information on the spatial distribution of phosphine (if detected) as the femtosatellites slowly drift down through the cloud layer at 50-60km.

Trajectory Design

The CubeSat of this mission will be launched directly onto a Venus intersection trajectory from the Earth. Upon arrival in the Venusian system, the entry probe is deployed and the orbital relay uses its onboard propulsion system to raise its trajectory to a Venus flyby, while the entry probe enters the Venusian atmosphere.

In a first approximation, the Earth-Venus trajectory is modelled as two coast arcs which are connected with a Deep Space Manoeuvre (DSM). The launch vehicle at Earth provides the Earth departure excess velocity $v_{\infty E}$. To perform the DSM and arrival burn, the on board propulsion system can provide a total Δv = 130 m/s. The arrival condition ($v_{\infty V}$) is highly dependent on the magnitude of the DSM. As such, a multi-objective Genetic Algorithm (GA) is given the objectives, $J = v_{\infty V}$ and $J = \Delta v_{DSM}$.

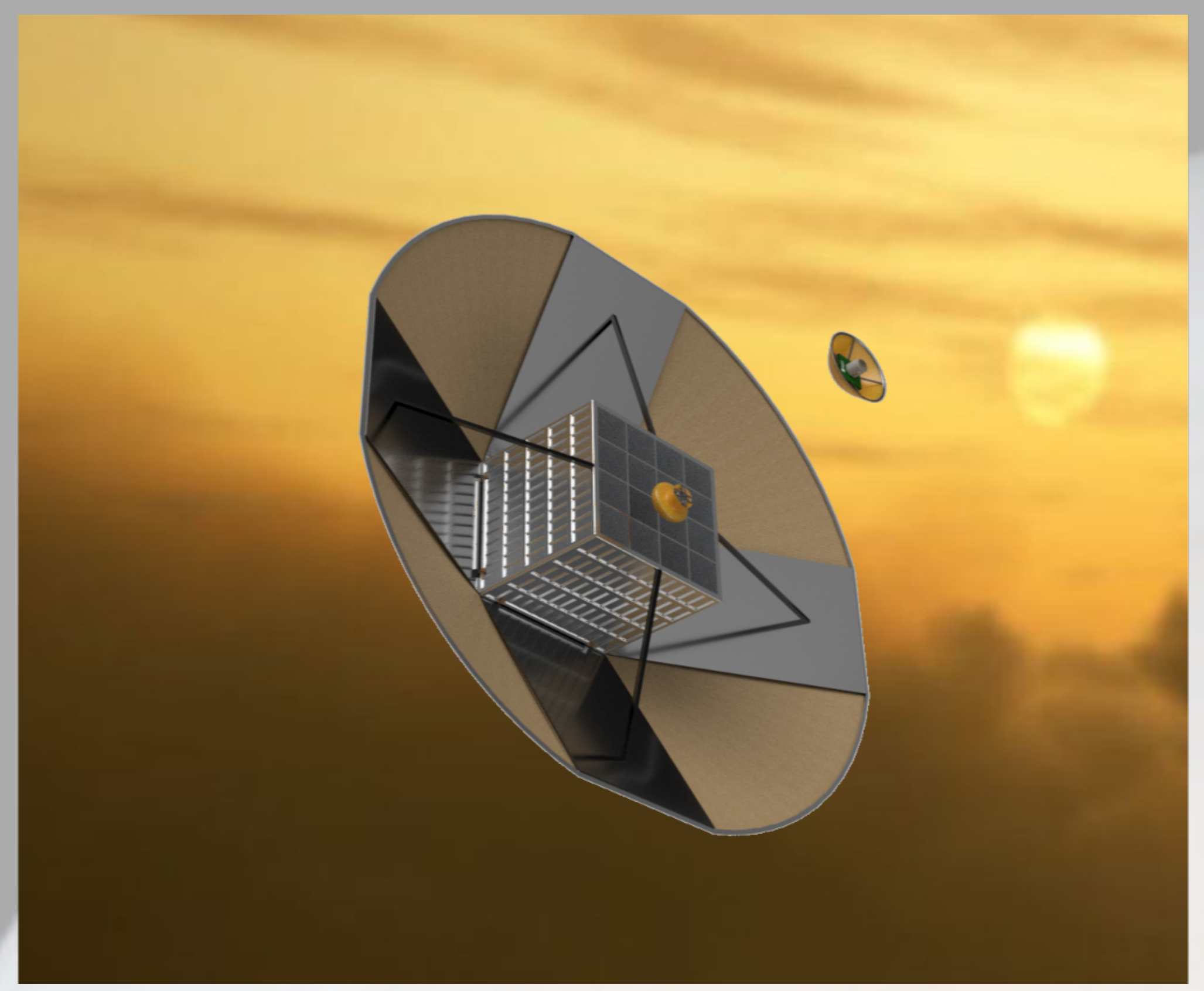

Figure 1: Femtoprobe deployment from main entry probe

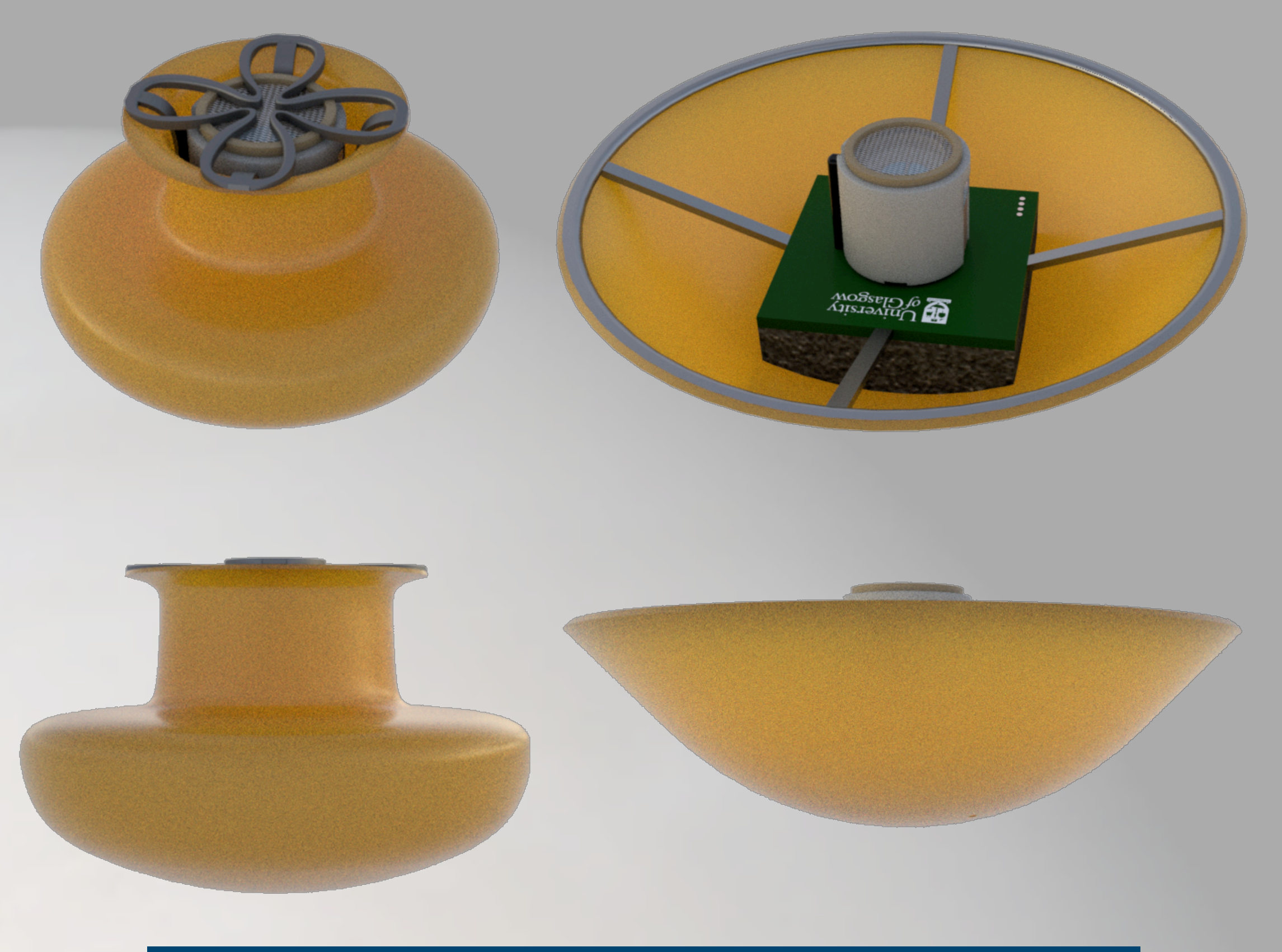

Figure 2: Femtoprobe (Left: packed, Right: deployed)

Figure 3 shows the results of this multi-objective optimisation. The Pareto front indicates that a smaller DSM results in a larger arrival velocity at Venus. As the onboard propulsion system is only capable of providing a small impulse, a solution is chosen which favours a lower DSM. The chosen solution departs Earth with a departure excess velocity of $v_{\infty E}$ = 4.26 km/s, a DSM of Δv_{DSM} = 9.80 m/s, leaving Δv = 129 m/s available for arrival at Venus, and an arrival velocity in the Venusian system of $v_{\infty V}$ = 3.95 km/s. The trajectory is shown in Fig. 3.

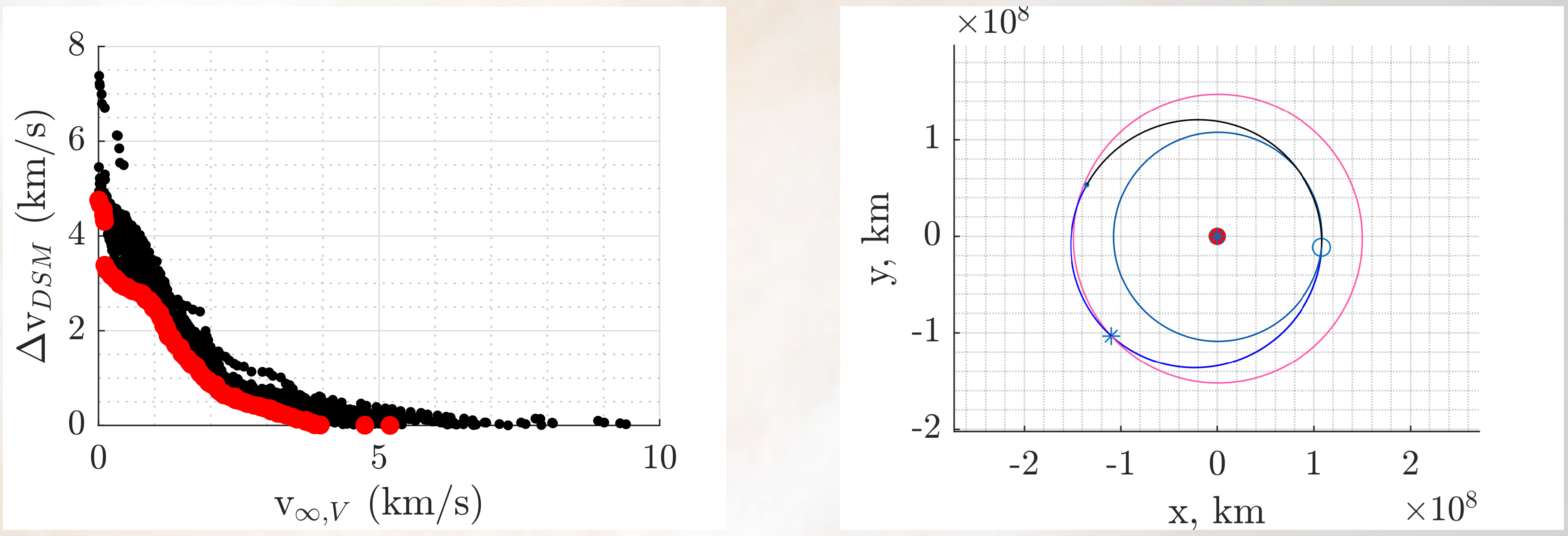

Figure 3: Interplanetary Trajectory Design

Spacecraft Design

Orbital Relay

The orbital relay spacecraft also acts as carrier to the entry probe during the interplanetary phase of the mission. Upon release of the probe at Venus, the relay is then required to transmit all data received from the entry probe to the Earth. The proposed design benefits from the flight heritage of the MarCO spacecraft [2], given the similar functionality. Using the same onboard instrumentation, this also has the advantage of Deep Space Network (DSN) compatibility. Inclusion of the AAC ClydeSpace PULSAR-SANT S-band antenna compliments the X-band antenna to allow for communication in both bands.

In order to provide maneuvering capability, the orbital relay is equipped with four 0.25U Micro Propulsion System (MiPS) thrusters. These can also be used to de-saturate the reaction wheels.

Entry Probe

The main entry probe is responsible for delivering the femtoprobes into the Venusian atmosphere. As such, it is required to withstand the considerable heating during entry into the atmosphere. The velocity of the probe at interface with the atmosphere is around 10.5 km/s. Based around a femtoprobe deployer, the probe will be equipped with a deployable heatshield utilising the FTP A6 thermal protection material (TPS) developed by the ArianeGroup [3]. The entry probe design is shown in Fig. 1.

Femtoprobes

The femtoprobe is a 10 g board equipped with an aeroshell which provides thermal protection and aerodynamic stability (Fig. 2). The scientific package is based around the phosphine gas sensor, with the data down-linked via the main entry probe and the orbital relay. The 8 cm diameter aeroshell is using a Kapton TPS tensioned by a substructure made out of shape memory alloy.

Conclusion

This poster presents an overview of the mission and technology proposed for a low-cost phosphine detection mission in the atmosphere of Venus. The choice of trajectory favours a lower DSM due to the available propulsion system. Upon arrival at Venus, the main entry probe detaches from the orbital relay and enters the Venusian atmosphere. After entry, the femtoprobes are deployed. The femtoprobes relay a simple yes/no detection flag to the entry probe which transmits this to the orbital relay for relay to the Earth.

This low-cost mission can provide a valuable pre-cursor to a more expansive mission, should the phosphine levels prove to be such as may indicate biological processes at work in the clouds of Venus.

Acknowledgments

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