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ExoFly: a flapping wing aerobot for planetary survey and exploration

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Introduction

ExoFly is a light-weight (20 to 200 g.) flapping-wing robotic fly, capable of exploration and scientific observations of the surface and lower atmosphere of planets. It is only in the last years that flapping wing insect flight is fully understood, and the step to robotic flapping-wing concept is very recent [1,2,3]. The concept of ExoFly is based on the DelFly, which has successfully been developed in the last years by the Technical University Delft, Wageningen University and TNO. Flapping winged flight is well suited to the low density and highly viscous Martian atmosphere, but may also be used in a denser atmosphere such as Titan. In any planetary mission, ExoFly would be a highly innovative mission element, technically part of the mission infrastructure, but enabling scientific breakthrough observations with the imaging system and micro-payload.

Characteristics of ExoFly

A demonstrator has been implemented for use in Earth atmosphere, capable of autonomous, stable and robust straight-line flight and hovering, as well as take-off and landing capabilities. This demonstrator has a total weight of 17 grams and is able to fly for 12 minutes with onboard energy storage and a pinhole camera payload. The characteristics are listed below.

Wingspan	350mm
Length	400mm
Mass	17g
Flying speed	1.8 ms^{-1}
Flapping frequency	6 Hz
Flying Time	12 min
Wing Material	Mylar foil
Structure	balsawood
Motor	2g pager motor
Camera	1.2g pinhole camera
Energy storage	3g Li Polymer cell
Actuators	shape memory alloy wires
Base station	3GHz PC
Software	C++
Sensors	pinhole camera

While adaptation to Mars conditions would require different physical characteristics, initial studies have found that this should not be an impediment to feasibility [3]. The studies have identified a potential mission with a MarsFly of 20 grams and range of 10-15 km with onboard solar cell recharging of the energy storage subsystem, and a similar scientific payload.

For the use of the ExoFly concept in a Titan mission, the aerobot could be larger (denser atmosphere), possibly up to 200 gr, but would have to be adapted to the very cold conditions (100 K).

Figure . Delfly demonstration in ESTEC rover test bed

Science and exploration with ExoFly

The concept of being able to fly, hover, land, and takeoff in an insect-like manner on other planets is so new that we are only beginning to realize the enormous scientific and exploration potential of

ExoFly. One of the most important aspects of ExoFly is that it will provide outcrop scale visual information from a mobile platform. The importance of such observations on the planetary surface can not be overemphasized: most of the clues about the current environmental conditions (e.g. wind, chemical erosion) or the past environment, though geological studies of the rock record (e.g. sedimentary structures, volcanic flow features indicative of water depth, particle size in fans and deltas) are between 1mm and 1 m in size. To avoid misinterpretations, such features need to be analysed in 3D, such as commonly done during field expeditions on Earth. Current planetary data sources, from orbit or from a rover, can not provide such observations, due to a combination of lack of visual resolution, atmospheric haze, and limitations in mobility and viewing angles. The image information taken by ExoFly during flight (optical flow), and used initially for navigation purposes, can be processed to the critical combination of image data + digital terrain model (DTM). The outcrop scale features can subsequently be analysed in a simulated environment on Earth, in analogy to 3D immersive environment techniques, in order to derive information on the (paleo) environment.

Depending on the potential for additional micro-payload, other scientific observations can be envisaged. For Mars the most important geophysical observation would include an aerial magnetic survey. At low elevation, the true pattern of remanent magnetization of early Martian terrains can be deciphered, and similar to the magnetic anomaly pattern on the Earth’s oceanic crust, will provide breakthroughs in our understanding of early crustal dynamics of Mars.

In terms of atmospheric sciences and meteorology there may be interesting possibilities. The lower 300 m of the atmospheres of planets such as Mars and Titan are not well constrained. ExoFly could provide important observations with a specifically designed micro-payload for temperature, pressure, and specific atmospheric components. An important goal would be to detect specific atmospheric components which provide information on the interaction between the atmosphere and solid planet. On Mars, the localization of the sources of methane would be a prime target with important implications for potential life detection.

Conclusions.

The potential for science and exploration, and the inherently small size and mass of ExoFly makes it a suitable mission element for any mission to Mars, Titan, or possibly Venus. Further development of the concept will have to take into account the miniaturization and integration of the sensors, navigation system and instruments to a high degree.

References

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