Aerospace Europe Conference 2023
Joint 10th EUCASS – 9th CEAS Conference

Abstract #XXX *(to be filled by the organizers)*
Preferred Topics: AEROFLIPHY / SUSTAV / *SYSINT (3 maximum from the list of topics)*
Corresponding author: Vishal Youhanna
e-mail of the corresponding author: vishal.youhanna@cranfield.ac.uk
Type: Oral
Status of the corresponding author: Student
For student corresponding author: student member of one of the following: RAeS (3006160)
3AF / AAAR / AIAE / AIDAA / CzAeS / DGLR / FTF / NVvL / PSAA / RAeS / SVFW / EUROAVIA

Title
Possible Design Configurations for Martian VTOL Aerobots

Authors
Vishal Youhanna [1], Leonard Felicetti [2], Dmitry Ignatyev [3]*

** Corresponding author*
[1] PhD Researcher, Centre for Autonomous and Cyber-Physical Systems. Cranfield University, Cranfield, UK
Vishal.Youhanna@cranfield.ac.uk
[2] Lecturer, Centre for Autonomous and Cyber-Physical Systems. Cranfield University, Cranfield, UK
Leonard.Felicetti@cranfield.ac.uk
[3] Senior Research Fellow, Centre for Autonomous and Cyber-Physical Systems. Cranfield University, Cranfield, UK
D.Ignatyev@cranfield.ac.uk

Abstract
Inspired by the success of the first Mars Helicopter - Ingenuity, this paper proposes a new design study of the next-generation Martian drone based on aerodynamic parametric analysis of electric rotary VTOL aircraft configurations. Mars offers a few design challenges for a rotorcraft, mainly because its atmospheric density is about 100 times lower, and the speed of sound is about 32% lower than that of Earth. Therefore, the rotors operate at tremendously low Reynolds numbers, but at higher Mach numbers because of the higher tip speed required, imposing severe constraints on the rotor design and heat evacuation mechanism of the propulsion system during flight. NASA's Ingenuity has overcome most challenges for flying a rotating wing aerobot on Mars by landing and flying on the planet in the year 2021 and currently is Operations Demonstration phase [1]. However, the design of the helicopter has limitations such that it lacks the endurance, range, and science payload capacity due to its small size and elementary design. These limitations reduce its ability to perform science exploration missions that would require long-distance flights, higher scientific payload, a sophisticated communication system, or a powerful propulsion system for high-altitude flights. Using a system engineering approach, we propose optimized rotorcraft design configuration/s for a set of more challenging requirements for a Martian aerobot mission, sized to fit into the maximum aeroshell limit of 4.5 m diameter and to land at the Valles Marineris canyon system on Mars. An aerobot will aim to generate a high-resolution aerial mapping of the area and can mark potential experimental/sample collection points for future rover missions.

One possible solution is to use low Reynolds number specialized airfoils to design and study a VTOL fixed-winged Mars drone. Winged aircraft have better endurance due to increased lift per power unit, which in return prolongs the range of the mission. This would increase the size of the aerobot, which could benefit in terms of carrying larger science payloads and in providing increased surface area for solar panels. But contrarily, wings also add complexity (if requiring a folding mechanism) and extra weight during VTOL. Therefore, a generic parametric study is deemed necessary to answer the question of whether the addition of wings to the Martian rotorcraft is beneficial overall, and if so, then in what configurations. In Martian environment settings, a relationship analysis between the coefficient of lift, forward speed, the power required, and wing reference area of a fixed-wing aircraft in cruise has been developed. Also, relationships between rotor disk area, forward/vertical-climb speed, and power required of a rotorcraft have been calculated based on momentum theory. Hence, the sizing of a combination of fixed wing and rotorcraft is considered to analyse the pros and cons of such a hybrid design. For the final paper, we aim to produce a thorough analysis of the

rotor aerodynamic performance of the shortlisted aerobot design/s, based on the blade-element/simplified-momentum model.

References

[1] Information about Mars Helicopter [Internet]. [Cited 12/01/2023]
Available From: https://mars.nasa.gov/technology/helicopter/