Session XXXX

Design a fixed-wing drone for Titan exploration

Micaela Olivas, Mostafa Hassanalian
Mechanical Engineering Department
New Mexico Tech

Abstract

Planetary exploration can reach new heights through the use of space drones; particularly when comparing the mapping capabilities to those of a rover or satellites and orbiters. A drone is capable of reaching greater distances than a rover while maintaining a higher resolution than orbiters. In studying Titan, Saturn's largest moon, the employment of space drones is worth investigation due to its Earth-like atmosphere. A fixed-wing drone with a tapered wing shape, an aspect ratio of 4, a wingspan of 5.2 m, and a total weight of 30 N is designed for Titan exploration. A possible method for exploring Titan is utilizing a liquid methane propelled drone that is designed to perform low-altitude dynamic soaring with the capability to refuel from the moon's methane oceans. The opportunity to utilize the methane from Titan's oceans will diminish the drawback of large energy consumption and allow for a lengthier exploration of the moon.

Introduction

Scientists have been interested in the application of various modes of flight to search for complex organic molecules on the surface of Titan [1]. The moon has a substantial atmosphere, much like that of the Earth, and is the only moon that contains liquid lakes, rivers, and seas. Scientists believe that it is possible that life can be found among the sub-surface water with prebiotic chemical processes. This belief has driven researchers to create a vehicle with the capability to travel to Titan, and explore the moon's life, geography, and atmosphere, among other countless research topics [2]. Previous NASA mission concepts included balloon applications that evolved into the discussion and design of drones for further exploration. A possible method for exploring Titan is utilizing a gas propulsion drone that is designed to soar from lower to higher altitudes with capabilities to perform methane ocean landings. This will allow for the drone to land on Titan's methane ocean and float while replenishing its fuel supply. The opportunity to utilize the methane from Titan's oceans will diminish the drawback of large energy consumption and allow for a lengthier exploration of the moon.

Novel Drone Design

Titan's atmosphere is ideal for a fixed-wing unmanned aerial vehicle due to its high density and low gravity. Given the characteristics of Titan's atmosphere, constraint analysis was performed for an aspect ratio of 4. In order to identify the optimized altitude for flying, constraint analysis was performed on steady, cruising flight at various altitudes[3-4]. According to Figure 1(a), as altitude increases so does the thrust required for a given wing loading. Keeping in mind that lower altitudes are more ideal for planetary exploration, an altitude of 5km was chosen for further analysis. Figure 1(b) presents the constraint analysis and solution space of the system at an altitude of 5 km. The solution space in Figure 1(b) provides the wing loading necessary for flight to be 30N/m^2. Through analysis of the weight distributions of various gliders with similar flight capabilities trying to be achieved such as the AAI RQ-7 Shadow [3], the estimated total weight of the drone is 30 N, with a structural, equipment, and fuel weight of 135 N, 67.5 N, and 67.5 N, respectively. With the wing loading and estimated weight of the aircraft, the planform area, wingspan, and mean area chord were determined to be 6.67 m^2, 5.2 m, and 1.3 m, respectively. In studying different types of wings, a tapered wing with a ratio of 0.3 was chosen based on its high efficiency and low induced drag. Therefore, a root chord of 1.97 m and a tip chord of 0.596 m was identified.

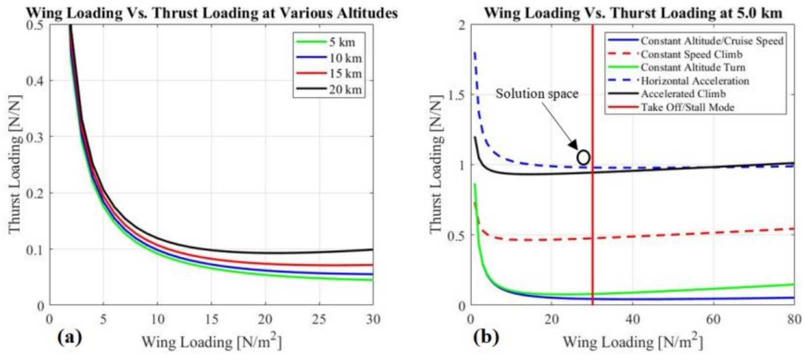

Figure 1. Constraint analysis of (a) cruising flight at various altitudes and (b) six different flight modes at a 5 km altitude that provides the solution space for the optimal wing loading.

The next step in the design is to identify the airfoil of the wing [4]. Airfoils were chosen for analysis based on their max thickness percentage and max camber percentage. The airfoils were analyzed in the aircraft analysis software, XFLR5, to determine the optimal airfoil. S4310 is finally selected as the optimum airfoil. A view of the designed fixed-wing drone for titan exploration is shown in Figure 2.

Figure 2. Schematic view of Titan-based fixed-wing drone.

Summary and Conclusions

Having a similar atmosphere to Earth's, the possibilities of employing a space drone for further exploration of Saturn's largest moon, Titan, is explored. Through studying the atmospheric characteristics and other related concepts, a conceptual drone that utilizes Titan's methane oceans as a fuel supply for repeatable flight will be designed. The proposed methane fuel supply may be applied to future drones and even in larger-scaled aircrafts performing research missions on Titan. Future work for this project includes further investigation of the liquid methane refueling system, the liquid methane/liquid oxygen propulsion system, control mechanisms, and structural analysis and material integrity in the environments of Titan. A prototype of this exploration drone could be developed in as soon as 2 years.

References

[1] Hassanalian, M., Rice, D. and Abdelkefi, A., "Evolution of space drones for planetary exploration: a review", *Progress in Aerospace Sciences*, Vol. 97, pp.61-105, 2018.
[2] https://solarsystem.nasa.gov/moons/saturn-moons/titan/overview/
[3] https://en.wikipedia.org/wiki/AAI_RQ-7_Shadow
[4] Hassanalian, M., Khaki, H., Khosrawi, M., "A new method for design of fixed wing micro air vehicle", *Proceedings of the institution of mechanical engineers, Part G*, Vol. 229, pp. 837-850, 2014.