02 – Martian Explorer for Astrobiological and Lithological Studies (MEALS)

In humanity's efforts to find alien life on the Red Planet, scientists look towards the geological composition of Mars with particular interest. By mapping the surface and collecting rock samples, it is possible to gain a deeper understanding of the composition and history of specific areas of interest. Currently, the mapping of the Martian surface primarily relies on planetary orbiters, which suffer from limited resolution; whereas the geological sampling has been performed by rovers which are constrained by velocity and range. Recently, NASA's Ingenuity has proven the concept of propelled aerial navigation on Mars, opening possibilities for faster and more detailed exploration at longer distances.

Mission Objective

Martian Explorer for Astrobiological and Lithological Studies (MEALS) is an aerial drone which aims to autonomously identify and acquire rock samples as heavy as 3 kg for transport. It shall be capable of flying over a range of 20 km, alongside a maximum endurance of 30 min, allowing for versatile operations windows. During a mission cycle, MEALS will perform surface scanning over an area of interest of 1 km × 1 km, from which it will determine a target rock sample based on the results. The drone will then land over the sample, pick it up using the integrated robotic arm and perform Visible and Near InfraRed (VNIR) spectrometry on the rock to further detail its composition. Finally, it will stow the arm with the sample and fly it back to a designated ground station, where the sample will be further analyzed and sealed for sample return.

System Design

Multiple concepts were initially explored for MEALS due to the broad constraints given for the mission. After an extensive trade-off, a hexacopter configuration was selected for detailed design. This given configuration raised important concerns regarding the propeller aerodynamics due to the atmospheric properties of the Red Planet, characterized by its thin and highly viscous air. For the design, thin airfoils developed by NASA targeting Martian conditions were taken into consideration, and a optimal design was achieved by varying numerous propeller parameters. Motor heating is also an important limiting factor for propelled flight on Mars, due to the low convectivity of the atmosphere. Cooling fins exploiting the rotor downwash were designed to address this issue, allowing the motors to reach a steady-state temperature during flight.

Regarding the scientific payload, a 6 Degrees of Freedom (DoF) robotic arm was developed, enabling MEALS to pick up samples from the surface with high precision. Furthermore, its claw design allows for excavation on a surface level, further enhancing the sampling capabilities of the arm. For scanning, MEALS is equipped with a high-resolution RGB camera, paired with a multi-spectral camera tuned for four specific wavelengths, chosen to match with the minerals of interest of the scientific community. Additionally, MEALS is also mounted with a spectrometer which enables the detailing of collected samples in the (VNIR) spectrum. In combination, the subsystems will work together enabling MEALS to be a fully-fledged autonomous aerial drone capable of exploring the Martian surface and acquire valuable scientific samples.