Feasibility Study and Preliminary Design of Lunar Reconnaissance Drone. T. Pfeiffer[1], E. Uythoven[2], D. Rodríguez-Martínez[3], J-P. Kneib[4], and H. Koizumi[5], [1]Faculty of Mechanical Engineering, EPFL, thomas.pfeiffer@epfl.ch, [2]Faculty of Mechanical Engineering, EPFL, erik.uythoven@epfl.ch, [3]eSpace, EPFL, david.rodriguez@epfl.ch, [4]eSpace, EPFL for second author, jean-paul.kneib@epfl.ch, [5]Department of Aeronautics and Astronautics, University of Tokyo, hiro.koizumi@epfl.ch.
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Introduction: More than 50 years after humans first landed on the Moon, our neighbouring natural satellite has become the primary target of human exploration, scientific discovery, and commercialization in space for the upcoming decade.

The problem: With orbiting stations and ground bases planned to be built, we are yet to master the ability to explore long term and long range over areas of the Moon often characterised by an extreme topography, dauntingly low temperatures, and wedged with what are known as Permanently Shadowed Regions (PSRs). This represents significant challenges for traditional ground exploration approaches, often relying on individual, limited-range, slow, wheeled rovers. Precise knowledge about the terrain for an optimised route planning is crucial and often relies on limited-resolution satellite data from lunar orbiters, data that are even more limited in PSRs. The need for a long-range yet simple and lightweight scouting method is becoming more and more apparent.

Our solution: The goal of this project is to study the feasibility of a compact, lightweight, and versatile lunar reconnaissance drone that can be quickly deployed and refuelled from a ground vehicle or a rover. The drone will be capable of producing high-resolution maps (~10cm/px) that can be used to optimise mission planning and assist robotic assets on the ground. This innovative mission design was developed using established Systems Engineering tools and approaches. It highlights the main challenges of such a system and sets the baseline for future developments.

The main aspects defining the mission (i.e., propulsion, thermal, and mapping systems) have been addressed and analysed with reasonable assumptions. The study shows that a lightweight drone (15 to 20 kg) combined with a refuelling and recharging base on the rover is a promising concept.

The drone has an interchangeable payload in the form of a 3D mapping Lidar. Its propulsion uses 4 fixed green monopropellant thrusters. With one tank containing 1 kg of propellant (HPGP and He pressurant, for a total of ~5% of drone mass), a preliminary analysis shows the drone can complete a 1 km horizontal flight profile at 50 m AGL in about 10 minutes. A preliminary design of the drone's propulsion system is shown on Figure 1.

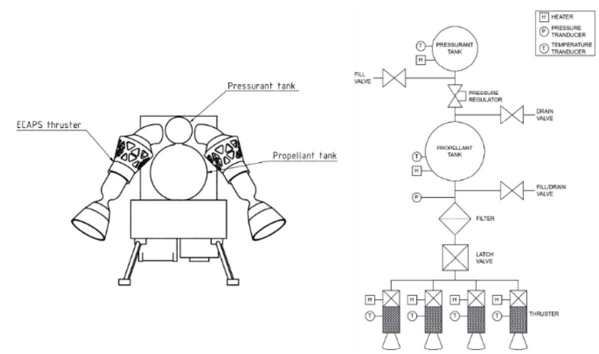

Figure 1: Preliminary design of the propulsion system of the drone allowing an unobstructed view of the ground from the payload.

The drone is refuelled and recharged on its base, which includes a take-off and landing (TOL) structure, a hold-down mechanism, a thermal and radiation protection cover, and the required electrical and data interfaces. A preliminary Concept of Operations (ConOps) is illustrated on Figure 2. At this stage, the results obtained suggest that the mission is feasible with currently or soon-to-be available technology.

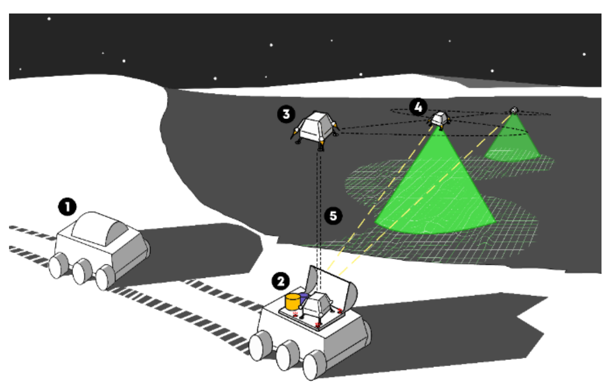

Figure 2: Illustration of the ConOps: 0. Launch and landing on the Moon (not shown); 1. Stand-by mode; 2. Flight preparation and deployment; 3. Take-off and vertical ascent; 4. Horizontal flight and mapping of the lunar surface; 5. Vertical descent and landing for data transmission, refuelling and standby.