Paper ID: 39547
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24th IAA SYMPOSIUM ON SMALL SATELLITE MISSIONS (B4)
Small Spacecraft for Deep-Space Exploration (8)

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EXPERIMENTAL DESIGN OF SMALL PRACTICAL MARS ROTORCRAFT

Abstract

As in many terrestrial applications, there are good reasons to believe that small (<5kg), highly manoeuvrable rotorcraft would be valuable to human explorers on Mars (Young, Aiken and Briggs, 2004). They could be used for scouting difficult or dangerous terrain, aerial photography for EVA safety and maintenance inspection purposes, hoisting antenna wires, fast location of small science targets and rapid transportation of small tools, instruments, circuit boards or regolith samples. In recent field trials of Mars astronaut-assistance robots, a small rotorcraft performed equal to or better than most ground robots in many tasks (Mann, et.al 2014). Low atmospheric density (approx. 0.020 kg/m3), temperatures (-89 to -31 degrees C) (Williams, 2016) and windblown fines (1.52 to 1.85 0.3 μm) (Pollack, et al., 1995) near the surface present severe challenges for rotorcraft. To provide sufficient lift, even allowing for lower gravitational acceleration (3.71m/s2), rotors need to be larger and turn faster than their terrestrial counterparts (Young and Aiken, 2002), imposing high mechanical stresses on the rotors. This, combined with poor battery efficiency at low temperatures, could impose serious restrictions on the endurance of such aircraft. Fine abrasive particulate matter would also problematic for exposed bearings, sensors and cameras. We studied modified low pressure propellers computationally, showing the need for a thrust of approximately 5N per motor for a 4kg quadrotor at Mars, achievable according to blade element theory calculations. As a baseline, conventional propeller designs were tested in a vacuum chamber down to 6 mbar. As the pressure was reduced the thrust dropped significantly from approximately 6N to 0.05N. However, the power consumption also dropped from 120W to 16W due to the much lower drag on the propeller. While this system is not yet optimised, it also demonstrated only a 60% decrease in thrust which compares favourably with conventional propellers, with a 40% reduction in power consumption. This suggests that correctly optimised propellers may indeed be able to be used as propulsion for lightweight multirotor aircraft on Mars. Since vacuum chamber tests are complicated by ground effects and limited freedom to move, we intend to drop a 4kg test vehicle from a balloon at 120,000 feet, where atmospheric conditions approximate those at Mars, and record performance data on-board during programmed manoeuvres. The decent of the rotorcraft could also be used to correct the results for the greater acceleration due to gravity near Earth.