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DESIGN OF A LIFTING-BODY EARTH RETURN ORBITER FOR MARS EXPEDITION MISSIONS

Abstract

Mars has been the primary target for deep space expedition for decades, with nations such as the USA, Europe, and China unveiling their own plans for expedition. Among the most common earth return orbiter (ERO) designs are blunt-headed return capsules (e.g. Soyuz, Apollo, Dragon, Shenzhou), as well as winged multi-trip vehicles (e.g. Space Shuttle and Buran). Each of these spacecrafts has its own set of advantages and disadvantages depending on the mission. During the Earth re-entry phase of a Mars expedition ERO, the blunt-head return capsule has a low lift-to-drag ratio (L/D) of K=0.2. . . 0.5, resulting in high velocity upon arrival back on Earth. This could lead to an overload exceeding 8g, which poses a significant health risk for astronauts who have experienced prolonged weightlessness. Meanwhile, the Space Shuttle's L/D is too high, ranging from 1 to 4.5, leading to a longer return time to Earth that could be detrimental in an emergency situation. To address these issues, this paper proposes a lifting-body ERO design with a L/D ranging from 0.8 to 2.5. Its unique aeroballistic, aerothermodynamic, and mass properties make it appropriate for a Martian expedition system. As a result, the lifting-body ERO has the potential to extend the re-entry corridor Rc=2500km, reduce waiting time in orbit, and land in a designated area at any time of day. Additionally, the lifting-body ERO could descend at a lower overload of G= 2. . . 3g compared to the 4. . . 8g overload of gliding or ballistic descent orbiters, which is particularly important for astronauts prolonged exposure to weightlessness. In order to design the lifting body ERO for a Martian expedition system, the mass characteristics of the lifting-body ERO are determined based on its intended purpose, overall dimensions, and aerodynamic shape. Using Newtonian theory, the aerodynamic characteristics of the ERO during the hypersonic descent phase are calculated. To determine the ballistic characteristics of the vehicle, the system of equations of motion is used, treating the ERO as a material point with the roll angle as a control parameter. The problem of optimal control is formulated and solved using a sequential linearisation method. In summary, the resulting design parameters for the lifting body ERO include a nominal overload of G=6g, K=1.5 (Mach=6), and Rc=2000km. Graphs are presented showing the overload, speed, temperature, and altitude of the ERO over time.