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A COMPARATIVE ANALYSIS OF RECOVERY MODES FOR REUSABLE LAUNCH VEHICLES (RLVS) WITH AN OVERVIEW OF OPTIMAL TECHNOLOGIES SUPPORTING REUSABILITY OF A SMALL SATELLITE LAUNCHER

Abstract

The quest for a fully reusable launch vehicle (RLV) began shortly after the beginning of the commercial space race. Expendable launch vehicles such as Delta and Titan were originally derived from military ICBMs (Intercontinental Ballistic Missiles). With an ever-increasing market demand for commercial access to space, the need for low-cost launch operations arose and this in turn, imposed a demand for Reusable Launch Vehicles (RLVs). The Space Shuttle program was initiated by NASA in recognition that fully reusable launch vehicles will reduce the cost of access to space and increase the reliability and flight integrity of the launch vehicle through reuse. While the Shuttle program was a triumph of engineering, the high-operations cost is a major drawback. This paper gives a brief overview of Reusable Launch Vehicles (RLVs): their merits, dis-advantages, complexities involved; first stage recovery modes using; Retro-Propulsion, Mid-Air Recovery using Parachutes and a Helicopter; and Air-Launch using an Airplane. The author compares the most optimal recovery modes based on Cost, Environmental effects, and technology Readiness levels (TRLs). Current trends in recovery used by SpaceX's Falcon 9, RocketLab Electron and Virgin Orbit's Launcher One are compared and analyzed in detail. Based on the analysis, an optimal recovery technique is devised for a small satellite launcher capable of deploying up to 500 kg payload to LEO, launched from the UK. This research takes into account various losses encountered by the launch vehicle during the ascent trajectory such as, Gravity losses, atmospheric drag losses, vehicle steering losses, etc. and provides an optimal trajectory analysis for a Gravity Turn.