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FEASIBILITY ANALYSIS OF AN INNOVATIVE CANNON-BASED LAUNCH SYSTEM FOR ORBITAL INJECTION

Abstract

In recent years, the space sector has witnessed a growing interest for small-payload missions, but few possibilities are available for their fulfillment. SpaceBlast aims to fill this void through the development of a multi-stage launch system, characterized by a light-gas cannon-based ground infrastructure acting as a first stage deploying a liquid-propellant second stage. The cannon features an initial combustion chamber, in which a gaseous fuel-oxidizer mixture is ignited and then expanded against a moving piston. The latter compresses a light gas against a breakable diaphragm: once a pressure threshold is exceeded, the disposable element breaks and the light gas is quickly released against another piston, which launches the second stage into the atmosphere with velocities potentially reaching 4 km/s. After the ejection, the trajectory is driven by a liquid propellant launcher providing 50 kg payloads into medium-to-high LEO orbits.

The combustion and heat exchange in the cannon first chamber are analyzed adopting a chemical equilibrium model assuming infinitely fast kinetics, while the following light-gas expansion and compression are assessed through quasi-1D dynamics. The trajectory of the second stage is developed through a three degrees of freedom approach, featuring a variable thrust profile and an accurate prediction of the aerodynamic loads, computed with a CFD-corroborated panel method. The structural integrity of the launcher in critical phases is granted by a shock-waves analysis, while the trajectory is optimized with an extensive parametric study, featuring variations of the vehicle mass, shape and performance indicators.

This design significantly reduces the cost of small-payload launches: the cannon-based first stage replaces classical rocket boosters, thus diminishing production, operational, and launch costs, paving the way for a more affordable space access. Moreover, the launching frequency is significantly enhanced in light of the reusability and readiness of the first stage cannon, together with the reduced complexity of pre-launch procedures. These only require refueling the ground segment, avoiding extended preparation periods: as a consequence, numerous potential users such as small satellites constellations or replenishment missions could take advantage from this innovative design. The proposed solution offers a remarkably greener alternative to traditional launch systems, since the adoption of an ecological mixture in the cannon-based ground segment strongly reduces the emissions of polluting substances into the troposphere, when compared to classical boosters. The environmental footprint of small space launchers can be substantially improved through this innovative, simple yet promising technology.

Keywords: Cannon, light-gas gun, launch systems, orbital launch.