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PRELIMINARY DESIGN ANALYSIS OF A FLY-BACK FIRST STAGE FOR COST EFFECTIVE SPACE LAUNCH

Abstract

A decade of efforts by private companies such as Virgin Galactic, X-Cor Aerospace, Armadillo Aerospace, Space Exploration Technologies and MARCOM Aeronautics & Space to commercialize the transportation of payloads to space have provided a brief glimpse of the future, namely, an expansion of commercial activity with a subsequent overall reduction in launch prices.

However, beyond commercialization will come the demand for truly re-usable space transportation systems. To date, many studies have been conducted on fly-back "strap-on" boosters, however and ultimately, the most promising reduction in costs, particularly for smaller launch systems, will be effected by recovery, by fly-back, of the first stage itself. Further, several attempts at recovery of a first stage booster, by parachute, by Space Exploration Technologies, has yet to result in successful recovery, possibly indicating re-usability may involve a more complicated recovery system (i.e. fly-back).

This reference system study is focussed on a LOX/Hydrocarbon propelled first-stage, winged vehicle and highlights the difficulties associated with the added heating and deceleration environments encountered when recovering at higher re-entry velocities over and above typical strap-on, fly-back boosters and provides a comparison of the advantages and disadvantages of recovery by flight versus recovery by parachute of relatively fragile liquid boosters compared to their solid counterparts.

The primary aspects of this study included 1) longitudinal aerodynamic investigations highlighting the difficulties encountered in ensuring a stable, trimmable re-entry and fly-back platform in all flight environments, hypersonic re-entry, supersonic recovery and subsonic fly-back 2) the development of closed loop control algorithms and trajectory shaping routines to ensure control authority is retained and flight envelope constraints are not violated 3) evaluation and optimization of structural elements to asses gross lift-off weights, center of gravity positions and propellant mass fractions 4) evaluation of the air-breathing propulsion requirements to meet expected fly-back time and range for recovery at the launch site and 5) an economic analysis highlighting the expected reduction in launch costs re-usable fly-back boosters could afford.