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SPACE TRANSPORTATION SOLUTIONS AND INNOVATIONS (D2)
Small Launchers: Concepts and Operations (7)

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THRUST OPTIMIZATION AND OPERATIONAL STRATEGY FOR LOW EARTH ORBIT LAUNCH VEHICLE

Abstract

An operational strategy for launch vehicle's propulsion via multi-stage launch vehicle trajectory optimization is presented. The thrust profile from complex trajectory optimization is analyzed to obtain a tendency which gives an idea for effective organization of propulsion configuration. During most of the operation time, the launch vehicle for low earth orbit is affected continuously by the aerodynamic effect. In the atmosphere, the aerodynamic effect causes a significant change in vehicle's coupled motion dynamics with respect to the altitude or air density level.

Over the decades, although there are extensive researches about the launch vehicle propulsion (thrust), there are no more consequences about detail thrust shaping and curve characteristics. That is about the notion to change the thrust curve; not to just determine the thrust level for each stage of the launch vehicle. To obtain a better performance for a launch vehicle, a thrust optimization is essential. With fixed quantity of propellant and the ratio of propellant to gross weight, there are few options to get a remarkable improvement in launch vehicle's efficiency.

In this paper, a conceptual research for the thrust profile is accomplished for a multi-stage launch vehicle system. The launch vehicle experiences different aerodynamic effects as altitude changes, and it is shown that each stage of the vehicle has a distinguished operational strategy, which is referred to the thrust shape or curve, to have a better performance. In case of the study of the aerodynamics in parts with altitude, a multi-stage launch vehicle is appropriate. The result of the thrust optimization for each stage of the launch vehicle gives a conceptual idea for the effective thrust allocation according to atmospheric environment.

The thrust curve to be optimized is set to be a 1st order polynomial as a function of time. It is more realistic to define the thrust curve as a low order polynomial, since it is difficult for a real application to make grain shape (solid) or to control propulsion (liquid) which results in the designated thrust from the optimization.