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# PRINCIPLES FROM 2 SMALL SRM-BASED LAUNCHER DESIGN/DEVELOPMENTS

**Abstract**

Two solid rocket motor based launch vehicles are in design and development at MSFC, a 4-stage Earth-to-Orbit vehicle cube-satellite launcher, and the 2-stage Mars Ascent Vehicle for the Mars sample return mission. Trade studies that refined these designs have benefited from the following developments in understanding sensitivities and approximate modeling: 1. Propulsion system dry mass fraction as a function of propellant mass, motor geometry, nozzle geometry, construction methods, and other mission considerations. Key to this is an iterative approach that builds fidelity as different design decisions need to be made. Initially, focusing on just propellant mass and construction method effects roughly sizes the vehicle. Later, trading mass for Specific Impulse in the nozzle becomes important. And after approximately sizing, refining with a scaling law for just lengthening under constant acceleration limit was important for one of the stages. 2. Non-propulsion system masses that may be sensitive to propulsion and vehicle choices. Examples of this are: vehicle skins that scale with stage diameter and heavy guidance systems that perhaps can be moved down from the terminal stage. 3. The integrated optimization of stage properties when considering both propulsion and non-propulsion effects together. Examples of this are: reaction control system used during the coast phase being strongly linked to first stage motor burn time, and vehicle interstage skin mass changing the optimum nozzle length-Isp trade. 4. Trajectory effects due to architecture choices - many of these can be understood and traded by reduced-order flight modeling to adjust the delta-V split and ensure orbit is achieved while all the combinations of the above parameters are explored. For example, small vehicles with rail-launched solid boost stages often have long coast times between stages. The stages can then be modeled as elliptical orbit transfers, at least for trajectory design purposes. This automatically covers a large amount of the sensitivity of delta-V losses to vehicle design trades, so that a large number of vehicle variants can be run with only a few validating trajectory integrations required.