SPACE PROPULSION SYMPOSIUM (C4)
Electric Propulsion (4)

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INTEREST OF STAGED ARCHITECTURES WITH DROP TANKS FOR SPACE VEHICLES USING ELECTRIC PROPULSION

Abstract

The aim of this paper is to investigate the interest and performance of staged architectures with drop tanks for a space vehicule using electric propulsion, or, generally speaking, using a power-limited propulsion system made of a thruster and a power source, characterized by its specific weight (mass-to-power ratio). The minimum specific weight achievable with current and even medium-term power source technologies is a show-stopper for missions that are very demanding in terms of transfer time and/or payload mass ratio, such as manned Mars missions with short transfer time. As shown in previous work, the optimum specific weight requirement for a mission with a given payload mass ratio and a given transfer time can be estimated as a function of the tank structural index and the "trajectory characteristic parameter" (integral of the squared thrust acceleration), first introduced by Irving and Blum. In this new study, we use the same type of approach with simplified performance equations, in order to get a global answer to the question: up to which extent can we reduce the specific weight requirement if the propellant mass is optimally divided into separate tanks that are jettissoned once empty ? The results obtained give a global view of the relative specific weight reduction that can be achieved with an optimized 2-stage or 3-stage architecture (i.e. with 2 or 3 tanks), compared to an optimized single-stage architecture. They are function of the tanks structural index and the payload mass ratio. The main conclusion of the study is that the specific weight reduction is significant but moderate for missions with a "comfortable" payload mass ratio (for instance, 10-13 % with a 0.1 payload mass ratio, assuming a 0.1 tank structural index), while it is much more interesting as long as we accept a small payload mass ratio (24-31 % reduction with a 0.01 payload mass ratio). As demonstrated in the paper, a powerful feature of these results is that they hold for any mission and any type of thruster (no Isp assumption is needed explicitely). This feature stems from the particular properties of Irving & Blum's "trajectory characteric parameter" and from some simplifying assumptions that are discussed in the paper.