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ASSESSMENT OF HYBRID PROPULSION FOR GEOSTATIONARY TRANSFER ORBITS: A MISSION DESIGN APPROACH

Abstract

The classic strategy to place a satellite in the geostationary orbit (GEO) relies on chemical propulsion. Starting from a low-Earth orbit, this solution allows acquiring the final GEO by applying, ideally, only two impulses. This option has proven to be effective, and grants short transfer times. On the other hand, the increase of power levels required by payloads in GEO satellites has paved the way to the all-electric solutions. In these satellites, the GEO is achieved by a low-thrust transfer, typically starting from a geostationary transfer o rbit. This strategy involves designing more efficient satellites (that is, less propellant is used in the transfer phase) at the cost of accounting for longer transfer times, which can be on the order of up to six months, depending on the thrust-to-mass authority [Kluever, 2010].

The two options available give rise to platforms having divergent features. On the one hand we have the fully chemical satellite, with short transfer times but large propellant masses, on the other hand, the fully electric satellite, with low propellant mass fractions but long transfer times. This dichotomy is too firm, and forbids widening the trade space in preliminary design of GEO satellites. A way to account for intermediate design solutions consists in allowing the two propulsion systems to coexist on the GEO platform [Kluever, 2015]. In principle, a hybrid propulsion system may lead to a family of design solutions that fill the gap between the two boundary solutions. Recent studies have shown that hybrid spacecraft have peculiar features when applied to missions to Mars, Moon, and NEOs [Mingotti, Topputo, Massari 2013]. However, a methodology to preliminary assess this kind of solutions is not established yet, and requires non-trivial procedure.

In this paper we elaborate on the concept of hybrid propelled satellite for GEO applications. A preliminary design procedure is derived, which allows evaluating the usefulness of hybrid platforms for given payload. Elements of preliminary system design are combined to those of preliminary trajectory optimization. These involve power subsystem sizing, electric and chemical propulsion modeling, and multi-spiral, long-duration, low-thrust trajectory optimization. The overall benefits of hybrid GEO satellites are evaluated by using economical models as well. The results show that hybrid platforms may be conceived as a viable option to widen the trade space for the next generation of GEO satellites.