IAF SPACE PROPULSION SYMPOSIUM (C4)
New Missions Enabled by New Propulsion Technology and Systems (6)

Author: Mr. Dorian Hargarten
DLR (German Aerospace Center), Germany

Dr. Karl Wieland Naumann
Bayern Chemie, Germany
Mr. Josef Ettl
German Aerospace Center (DLR), Germany

TRAJECTORY AND CONTROL SYSTEMS DESIGN FOR A HOVERING MESOPAUSE PROBE

Abstract

Owing to the difficulty in reaching and maintaining the altitude of upper atmosphere layers such as the mesopause, performing in-situ experiments is typically limited in scope. Generally, atmospheric physics missions use either balloons, specially adapted aircraft or ballistic sounding rockets. Examples include the ENRICHED program, the NASA X-15 Hypersonic Research Program, or the sounding rocket missions PMWE and WADIS, respectively. This paper presents a novel approach to overcome both the altitude limitations of balloons and conventional aircraft as well as the limitations of ballistic sounding rocket flight profiles by employing a hovering probe. A throttleable rocket engine burning a storable monopropellant allows the probe to follow a desired trajectory and to perform science experiments and measurements during its burn phase. Scientific mission objectives include taking samples of noctilucent clouds as well as of various particles. In this paper, the different development aspects required to successfully and safely perform such a mission are examined, focusing on trajectory optimization and trajectory and attitude control system aspects, while also presenting mission design and launch vehicle design. The probe constitutes the upper stage of a two-stage sounding rocket, with an unguided, fin-stabilized solid rocket engine for the first stage. Before liftoff, the target flight profile is chosen using ground-based measurements such as radar echoes. Variation in first stage performance and atmospheric conditions influence the apogee following first stage burnout, thus the probe needs to correct and maintain its apogee to follow the target trajectory. The primary target of the trajectory optimization is to maximize the distance traveled on the target altitude while respecting vehicle parameter limits (including weight, thrust, and propellant mass fraction), payload requirements (including speed, angle of attack), and flight safety considerations. Parameter variation simulations are employed to demonstrate robustness of mission design and control algorithms against varying vehicle parameters and perturbations. The latter stem from external sources which include atmospheric conditions, or internal sources such as imprecise thrust control in both direction and dimension, or imprecise sensor inputs, respectively. Given empirically determined boundary conditions for vehicle parameters, flight performance calculations yield measurement distances on the order of 10 to 50 km while maintaining a target altitude in the range of 80 to 90 km.