Paper ID: 65361
student

IAF ASTRODYNAMICS SYMPOSIUM (C1)
Mission Design, Operations & Optimization (1) (4)

Author: Mr. Nicola Marmo
Sapienza University of Rome, Italy, nicola.marmo@uniroma1.it

Dr. Alessandro Zavoli
Sapienza Università di Roma, Italy, alessandro.zavoli@uniroma1.it
Dr. Diogene Alessandro Dei Tos
Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency (JAXA), Japan, diogenealessandro.deitos@ac.jaxa.jp
Dr. Hitoshi Ikeda
Japan Aerospace Exploration Agency (JAXA), Japan, ikeda.hitoshi@jaxa.jp
Prof. Yasuhiro Kawakatsu
Japan Aerospace Exploration Agency (JAXA), ISAS, Japan, Kawakatsu.Yasuhiro@jaxa.jp

DESIGN OF ROBUST MANEUVERS FOR THE MMX MISSION, A CHANCE-CONSTRAINT OPTIMIZATION PERSPECTIVE

Abstract

The design of spacecraft trajectories in nonlinear dynamical systems subject to model uncertainty and disturbances is a complex and demanding task. Traditional methods used for mission design proved to be rather effective when dealing with deterministic problems, where the spacecraft environment is well known and free of major disturbances. However, in practical scenarios, time-consuming iterative procedures are commonly employed to check and correct the obtained solutions to account for the presence of various source of uncertainty, such as phases of poor orbital determination or missed thrust events. This process often results into the definition of sub-optimal control strategies and over-conservative margins.

A different approach, loosely referred as robust optimization, consists in accounting directly within the optimization process for the possibility of having an imperfect knowledge of state and control variables. This allows to obtain a solution in which, *a priori*, a small amount of propellant is traded for reduced sensitivity to (bounded norm) uncertainties and state errors. This feature is extremely desirable in order to mitigate risk of partial or complete mission failure, as large deviation from the expected trajectory may require expensive ground-commanded maneuvers, that might be difficult, or even impossible, to be carried out.

In this manuscript, a chance-constrained optimization method is considered to design a robust impulsive approaching trajectory for a spacecraft aimed at the Martian moon Phobos. The trajectory starts at the end of the heliocentric journey from the Earth with given uncertainty on initial conditions. Spacecraft states and control are regarded as probability distributions over time. Unscented transformation is used for efficient propagation of probability distributions of states and controls, through nonlinear stochastic system dynamics, without therefore having to rely on linearization about a nominal solution. Terminal and path constraints are thus enforced in a probabilistic sense and must be satisfied within a prescribed confidence level. The resulting joint probability constraints, which are of general intractability, are relaxed by using Boole's inequality, allowing for a fast solution.

Numerical results are presented for a case study related to the future sample return mission MMX of the Japanese Aerospace Explorations Agency (JAXA). The effect of various source of uncertainty on the robust solution, as well as the additional propellant consumption, is investigated by means of Monte Carlo simulations.