IAA Study Group Status Report

Responsible Commission: Commission IV

Study Number and Title: 4.22 Through Optimization of Aerospace Trajectories

Short Study Description (repeat from Study Group Proposal):
The analysis and improvement of advanced methods for elaboration of a rigorous approach to the through optimization of branching trajectories of space transportation systems (STS), including injection into an orbit, interplanetary flights, reentry of separated parts and vehicles, emergency trajectories and probability processes.
The methods are supposed to give the possibility of using adjoint variables as sensitivity functions (one of the basic Pontryagin maximum principle properties). Also the possibility to develop methods for global optimization, in particular to estimate the number of local optimal solutions arising in different aerospace problems. These methods may have both analytic and geometric foundations.
Current trends of broad cooperation among specialized scientific institutions as well as geographical expansion of the aerospace corporations have forced development of the new approaches to integrated and multidisciplinary optimization. The new approaches must allow for combining diverse programs intended for detailed single-discipline investigations into a unified framework.

Progress in past six months:

- The problem of through optimization of the reusable aerospace system (RASS) with recoverable winged booster (RWB) was considered on the base of the Pontryagin maximum principle for branching processes. The novelty consists in obtaining by the regular numerical procedure the family of RWB reachability regions (footprints) for a wide range of the orbit inclination at the launch from the Plesetsk cosmodrome. Each the footprint is the envelope of sets of extremals differing in the azimuth of the landing target in the circular range.
- The synthesis of the optimal control of the thrust vector of spacecraft (SC) with air-breathing electric propulsion (ABEP) to provide the fastest change of orbit parameters (apogee altitude and inclination) is obtained. Analytical estimates are confirmed by numerical modeling.
- The optimization problem of SC layout and ABEP is considered to minimize the SC mass. The analytical solution of the problem is obtained with generalized parameters combining SC and ABEP characteristics.
- The problem of the aircraft range maximization is considered. The problem is solved on the Pontryagin maximum principle with the new procedure to avoid the known difficulties caused by the problem degeneration as the total range increases. New analytical solutions, including oscillating ones, are obtained within a framework of the approximate pseudo-conservative model of motion taking into account physical constraints on the path angle rate.
- The new method on the base of the Pontryagin maximum principle was developed for joint optimization of the spacecraft trajectory and main design parameters of the electric propulsion system (EPS) (thrust, specific impulse, electric power). The

purpose of the method is maximization of the spacecraft useful mass minimizing the total mass of the electric propulsion system, filled propellant supply and feeding system, and part of the power supply system providing EPS operations only.

- The necessary optimality conditions were derived and the numerically stable method for optimization of the round-trip low-thrust trajectories was developed. Trajectories of the Mars manned mission were analyzed. It is shown that the duration of the manned Mars mission may not be less than one and a half to two years using the achievable in the foreseeable future technology level in the electric propulsion and onboard power supply systems.

Website Study Information update: (please give any update regarding Study Group Membership, documents, Study Plan and Schedule):
Additional Study Team Members not listed at http://iaaweb.org/content/view/738/970/ are:

Daniel Choukroun, Prof.
Gueorgui Smirnov, Prof.

Issues requiring resolution? (recommend approach):
None

Product Deliveries on Schedule? (If modified explain rationale):
Yes

Study Team Member Changes? (List any Study Team Members that you wish to discontinue, and provide names plus contact coordinates of any Members you wish to add on the second page of this Study Update form.) Note: Complete contact information including email, tel. and fax must be provided for all additions. Only Members with complete contact information will be listed and receive formal appointment letters from the IAA Secretariat.)
Yes

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Status Report Date: 14.09.2018

Study Team Membership Changes

Effectivity Date: 14.09.2018

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