AUTONOMOUS ORBIT CONTROL FOR ROUTINE STATION-KEEPING ON A LEO MISSION

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ABSTRACT

Introduction

LEO spacecraft station-keeping activities have been up to now completely managed by the Ground Segment (orbit determination, maneuver computation and upload, orbit extrapolation for events prediction and operations scheduling). As the station-keeping requirements are getting more and more stringent in terms of both cross-track and in-track windows, the operational workload increases dramatically due to the need of frequent maneuvers. In this context, on-board Automated Orbit Control (AOC) is the answer to meet system requirements and reduce the workload of operational teams. Furthermore, an autonomous orbit control allows to simplify the ground system architecture and interfaces as all components (mission planning, station designation) will use a shared reference orbit.
Up to now, only a few in-flight experiments have been led in Europe such as CNES DEMETER AOC experiment in 2005 which demonstrated the feasibility of in-track autonomous control as a routine feature.

AOC Requirements and Design

Astrium Satellites is now leading the development of a fully operational Autonomous Orbit Control function for a Sun-synchronous Earth Observation mission. Algorithms use techniques inspired by feedback control in order to simplify on-board computations and avoid complex flight dynamics calculations.
The AOC shall be able to manage both cross-track and in-track position errors with a performance target from one to a few km whatever the latitude. It shall be applicable to a wide range of altitudes (typically 450-1000 km) and solar activity levels, meaning that algorithms shall be robust to highly variable levels of drag perturbations.

Constraints

When the main mission of the spacecraft is to perform Earth observations, the automated station-keeping activities should not interrupt it. Maneuvers are thus only allowed on dedicated orbital slots where no mission is required (above oceans for example), which means that the control of the orbit eccentricity is performed in a “best effort” way when the nominal argument of latitude is not available to carry out correction maneuvers.
At low altitudes and with a narrow control window the number of maneuvers can quickly increase and require several corrections per day. It is then necessary to reduce the total number of maneuvers performed during the lifetime of the spacecraft in order to be compliant with the qualification domain of the thrusters. A deltaV threshold has been introduced in the AOC algorithms to avoid too small maneuvers.

AOC Performance Assessment

An analysis of the orbital perturbations and the design of preliminary algorithms were carried out in 2008. The development of an accurate software simulator for performance validation and a prototype of the on-board implementation have been performed during 2010-2012. The satellite on-board software is now being developed and intensive campaigns of functional and performance validation will start in 2012-2013.
Simulations covering a complete satellite lifetime show that the AOC is able to maintain the spacecraft in a typical ±2000 m in-track window and a ±1000 m cross-track window.

Transition orbit

From an operational point of view it is also interesting to start the AOC even if the spacecraft is still out of the station-keeping window, for example after a safe mode or a collision avoidance maneuver. The concept of transition orbit corresponds to a continuous trajectory followed by the AOC to come back to the reference orbit. The in-track and cross-track windows are then centered on the new trajectory so the AOC can be enabled and the mission re-starts immediately.