1.13 POD improvements of GNSS satellites through the measurements of their non-gravitational accelerations by means of an onboard accelerometer

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The Precise Orbit Determination (POD) of the satellites of the Global Navigation Satellite Systems (GNSSs) represents the basic prerequisite in order to provide refined ephemerides for their orbit aimed at providing a precise and accurate positioning on the Earth (namely in a well-defined reference frame). Two important factors that impact negatively in the POD of these satellites are the orbital maneuvers and the non-refined modeling of the accelerations produced by the surface (non-conservative) forces, i.e., by the non-gravitational accelerations. Indeed, the non-gravitational perturbations (NGPs) are subtle and generally complex to model properly, also in the case of a passive and spherical in shape satellite. Not more to say in the case of the increasing difficulties in the modeling for a complex in shape satellite, with solar panels and antennae for microwave link with ground stations or for intersatellite tracking and the consequent (not so easy to consider) mutual shadowing effects among the many surfaces involved. These NGPs are mainly generated by radiation pressure forces, both in the visible and in the infrared part of the spectrum. Generally, a careful modeling requires the knowledge of the physical and also chemical properties of the various spacecraft surfaces, as well as of its attitude in inertial space. Moreover, such perturbations are further modulated by the eclipses, along with the change of the illumination conditions and the consequent appearance of unbalanced effects in acceleration which are produced by the thermal inertia of the various surfaces of the spacecraft. In the case of GNSS satellites, the main NGP acceleration is the one produced by the direct solar radiation pressure, with non-negligible contributions due to Earth's albedo, thermal effects and power radiated by the antennae. Indeed, the models developed so far for the NGPs acting on the GNSSs spacecraft have shown many limits, as pointed out in the scientific literature since the beginning of this era with the first satellites of the Global Positioning System (GPS). Currently, the models developed for the NGPs are mainly based on empirical blind models (with the goal of absorb unknowns quantities) and more recently with the use of wind-box models, that try to provide a finite elements approach to the modeling. Moreover, and very importantly, a refined modeling of the NGPs is also significant for the geophysical applications of the GNSSs satellites in the future. Indeed, a poor modeling will impact negatively in the determination of a number of geophysical parameters of interest, such as for the stations coordinates, the Earth's geocenter and orientation parameters. Such aspects are also very important for the laser tracking to these satellites. Indeed, the Satellite Laser Ranging (SLR) tracking is currently used for calibration purposes of the GNSS orbits. However, the possibility of a deeper use of SLR data for GNSS spacecrafts equipped with Cube Corner Retroreflectors (CCRs) can enhance many implications in the field of geophysics. The European Space Agency (ESA) — because of its efforts to provide a new constellation of GNSS satellites, called GALILEO, and especially in view of the next generation of GALILEO satellites — beside being interested in possible improvements of the NGPs models, especially for the direct solar radiation pressure, is also envisaging to use an onboard accelerometer to directly measure their accelerations and finally improve the POD of each spacecraft of the GALILEO constellation. By the way, the possibility to exploit the readings from an accelerometer was highlighted by Ash in 2002 in the case of GPS satellites. We have been involved in this study by means of a proposal to ESA denominated GALileo and ACcelerometry (GALAC) led by the Space Research Centre (SRC) of the Polish Academy of Sciences (PAS) of Warsaw. The GALAC main objective is to provide the characteristics and performance of an onboard accelerometer able to improve the POD with respect to the current best results obtained through the modeling of the NGPs. The starting point of our activities has been the ISA accelerometer developed for the ESA cornerstone mission to Mercury denominated BepiColombo. We present our results of a preparatory work for GALAC concerning the order-of-magnitude for the main NGPs accelerations acting on the GALILEO spacecraft of second generation and on their (main) spectral content. We used such results to preliminary fix the accelerometer measurement band, its sensitivity and physical characteristics in order to fit with the GALILEO spacecraft environment.