SENTINEL-1: OPERATIONAL APPROACH TO THE ORBIT CONTROL STRATEGY

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ABSTRACT

Sentinel-1 is an ESA satellite system developed in the frame of the Global Monitoring for Environment and Security programme (GMES). Sentinel-1 is designed as a two-satellite system each carrying a C-band Synthetic Aperture Radar (SAR), aimed at providing continuity of crucial data for user services initiated with the ERS and Envisat missions. The launch of the first Sentinel-1 satellite into a Sun-synchronous, dusk-dawn orbit with a 12-day repeat cycle is planned with of a Soyouz from Kourou for summer 2013.

This paper describes the analysis, design and demonstration of a new ESOC Flight Dynamics (FD) operations concept for Sentinel-1 orbit control.

The on-ground orbit control of Sentinel-1 poses a high challenge on the Flight Operations Center and in particular on the Flight Dynamics System due to the high accuracy of the orbit control requirements. The Sentinel-1 osculating Earth Fixed orbit shall be maintained inside a tube-shaped boundary defined around the osculating Earth Fixed reference orbit with a RMS-diameter of 100 m. The maximum allowed absolute deviation in Mean Solar Local Time of the Ascending Node (LTAN) is 5 minutes. The tightness of the orbit control requirements becomes clear when comparing with previous ESA missions like ERS-2 or Envisat (flying at around 800 km altitude), which were controlled within a 1 km dead-band around their reference ground-tracks.

The definition of distance with respect to the reference orbit for Sentinel-1 is a RMS definition that is not practicable from an operational perspective. Thanks to mission analysis studies it is known that the orbit control requirement described above can be translated to an equivalent ground-track dead-band control at the Equator crossings and at the point of maximum latitude in the orbit. The width of the control dead-band around the reference ground-track is 60 m.

Sentinel-1 is equipped with a state-of-the-art mono-propellant propulsion system. The orbit control is achieved by implementing two types of manoeuvre: In-Plane (IP) manoeuvres to control the ground-track deviation at the Equator crossings and the evolution of the eccentricity vector and Out-Of-Plane (OOP) manoeuvres to control the ground-track deviation at maximum latitude as well as the LTAN and its drift.

Depending on the level of solar and geomagnetic activity a maintenance manoeuvre frequency ranging from 2 to 5 manoeuvres per week will be required to keep the Sentinel-1 orbit within the predefined ground-track control-dead band. This high frequency of manoeuvres justifies the implementation of a new FD Orbit Control System that can support a manoeuvre maintenance process with the following two main characteristics:

- Cyclic pre-planned or pre-scheduled uplink opportunities in order to load the manoeuvre execution products on-board the satellite
- Fixed number of manoeuvre execution opportunities per cycle, allowing the selection of the calendar days on which these manoeuvre opportunities occur. This provides the ability to define a deterministic orbit maintenance manoeuvre timetable

A fixed manoeuvre timetable is highly desirable in order to couple the manoeuvre maintenance activities with the working calendar as well as to take into account constraints coming from the payload mission planning. This approach also aims at reaching a high level of automation of the orbit control tasks, which is essential given the expected manoeuvre frequency.

A feasible operational approach has been designed, aiming at maximizing the duration of the manoeuvre optimization cycles (or in other words, minimizing the number of manoeuvre optimizations and uplinks) as well as minimizing the number of manoeuvre execution opportunities per cycle. The computation of the required OOP manoeuvres is deterministic and their frequency is determined by the third body perturbation and the solid tides perturbation. The computation of IP manoeuvres is affected by the well known problem of the orbit prediction accuracy for LEO satellites. IP manoeuvres aim mainly at compensating the permanent decay in semi-major axis due to the atmospheric drag. The optimization of IP manoeuvres relies on the orbit predictions available on the day the optimization takes place. These predictions are affected by the rather unreliable forecast of the air drag force encountered during the prediction period due to the poor predictability of solar and geomagnetic activity.

The selected approach to demonstrate the feasibility of the orbit control strategy based on given manoeuvre optimization and manoeuvre execution frequencies involves reproducing the conditions of unpredictability of the solar and geomagnetic indexes in a simulation. Simulated solar and geomagnetic profiles have been derived extracting information from the previous solar cycle. The extended lifetime of Sentinel-1 is 12 years, which means that in principle the mission will be operated throughout a complete solar cycle. Consequently, the operational orbit control strategy has to cope with different levels of solar and geomagnetic activity, in particular with those representing the maximum and minimum levels within the solar cycle.
It has been a key aspect for the study to use solar and geomagnetic activity profiles that represent realistic atmospheric environments in terms of reference values and expected maximum error in the predictions.

The paper presents the most relevant results that have lead to the final selection of the orbit control concept that will be applied to the Sentinel-1 mission.