Sentinel-1B Flight Dynamics operations during LEOP and acquisition of its reference orbit: achieving the Sentinel-1 constellation

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Approximately two years after the launch of Sentinel-1A, its twin satellite Sentinel-1B was launched on the 25th of April 2016 at 21:02:13 UTC by a Russian Soyuz-ST launcher equipped with a Fregat upper stage from Europe's Space port in French Guiana. The Sentinel-1 Mission is a two-satellite System each carrying a C-band Synthetic Aperture Radar (SAR) as well as a laser communication payload to transmit data to the geostationary European Data Relay System for continual data delivery. Sentinel-1 is the first in-orbit complete constellation part of the Sentinels fleet developed for the European Earth observation Copernicus Programme. The Sentinel-1 constellation is operated from the European Space Operations Centre (ESOC) in Darmstadt, Germany.

Sentinel-1A and B are controlled around dusk-dawn Sun-synchronous reference orbits with a 12-day repeat cycle, frozen eccentricity and a 180 deg argument of latitude separation between the two satellites. The two reference orbits share the same ground-track with a revisit time of 6 days.

The Sentinel-1 Flight Dynamics (FD) Team as part of the Mission Control Team working at ESOC was tasked with the following principal activities during the Sentinel-1B three-day LEOP: perform the first orbit determination after separation and assess the injection achieved by the launcher vehicle, monitor the AOCS telemetry during the deployment of the SAR and the Solar Array Wings (SAW), generate AOCS commands for the on-board propagator configuration and design an optimal manoeuvre strategy to bring Sentinel-1B to its reference orbit, achieving this way the Sentinel-1 constellation. This activity required a mission analysis study during the Launch Preparation Phase, due to the complexity of the task. The initial phase offset between the two satellites and the initial phase drift rate were depending respectively on the Sentinel-1B launch date and the injection state vector achieved by Soyuz. A parametric analysis accounting for the 12 possible initial phase offsets and a range of initial phase drift rates based on the Soyuz expected injection errors was carried out. The Propulsion System added some complexity to the analysis. The Sentinel-1 satellites are equipped with three sets of 1N thrusters, each set made up of a prime and a redundant unit. These three sets of thrusters are mounted on the satellite faces which are aligned (when flying in Normal Pointing Mode) with the velocity direction, the anti-velocity direction and anti-orbit-angular-momentum direction. Nominally the first two thruster sets are dedicated to the execution of in-plane corrections, while the third thruster set is dedicated to the execution of out-of-plane corrections. In Sentinel-1A the first two thruster sets are affected by plume impingement (plume interaction with the SAR and SAW), which implies a drastic limitation of their maximum activation time (35 seconds instead of 300 seconds). The same behaviour was expected in Sentinel-1B; therefore it was agreed before the Sentinel-1B launch to prepare for execution of semi-major axis corrections using the third set of thrusters (nominally aligned with the anti-orbit-angular-momentum direction) since they are not affected by plume impingement and can perform larger orbit corrections. The execution of such manoeuvres involves slewing the satellite by +/-90 degrees around the zenith direction, making the SAW almost parallel to the Sun direction and bringing the satellite into eclipse conditions. This type of manoeuvres implied a non-negligible risk and had never been tested on Sentinel-1A.

This paper provides a summary of the work performed by the Sentinel-1 FD Team during Sentinel-1B LEOP as well as the preparation, design and implementation of the manoeuvre campaign which led to the successful acquisition of the Sentinel-1 constellation on June the 16th 2016.