SENTINEL-1A FLIGHT DYNAMICS LEOP OPERATIONAL EXPERIENCE

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EXTENDED ABSTRACT

Sentinel-1A was launched by a Russian Soyuz-ST launcher equipped with a Fregat upper stage on the third of April 2014 at 21:02:26 UTC from Europe's Space port in French Guiana. Sentinel-1A is the first in-orbit spacecraft (S/C) from the new ESA Sentinels fleet developed for the European Earth observation Copernicus Programme, previously known as GMES (Global Monitoring for Environment and Security). It is also the first of a two-satellite System (Sentinel-1B currently planned for launch in 2016), 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-1A operations are conducted at the European Space Operations Centre (ESOC) in Darmstadt, Germany.

Sentinel-1A is controlled around a sun-synchronous reference orbit with a repeat pattern of 175 orbital revolutions in 12 days and a Mean Solar Local Time of the Ascending Node (MSLTAN) of 18:00 h. The S/C Attitude and Orbit Control System (AOCS) consists of the following sensors and actuators: fine sun sensors, magnetometers, gyroscopes, star trackers, GPS receivers, magnetic torquers, a reaction wheels assembly and reaction control thrusters.

The main activities of the Flight Dynamics (FD) team as part of the ESOC Mission Control Team (MCT) during the three-day LEOP were:

- Determine the injection orbit achieved by Soyuz/Fregat and support the Ground Station Network in acquiring the S/C signal at every scheduled visibility. Antennas were located in Svalbard (Norway), Alaska, Kiruna (Sweden) and Troll (Antarctica).
- Monitor the AOCS telemetry during the deployment of the SAR wings and the Solar arrays as well as the S/C mode transitions ranging from a Sun pointing mode to its final Normal Pointing Mode required for operating the S/C during the Commissioning and Routine Phases.

- Generate the AOCS commands required to re-initialised the on-board orbit propagation throughout its different accuracy modes to allow the S/C mode transitions.
- Start the preparation of a manoeuvre sequence to acquire the Mission Reference Orbit. The manoeuvre sequence selection was driven by the overall duration of the acquisition period and the fuel consumption.

This paper presents a brief overview of the preparatory work carried out at ESOC by the FD team to achieve readiness to support the activities mentioned above, together with a more extensive description of the actual operations conducted during the three-day LEOP.

Sentinel-1A was injected approximately 8 km lower than nominally predicted. This injection, which was well outside the expected dispersion envelope provided by the launcher, posed a challenge on the FD Orbit Determination team during the first hours of LEOP. Thanks to the preliminary orbit solutions based on ranging and angular data, the Ground Station Network could be provided with time offsets to be applied to the expected visibility start times. This ensured the acquisition of S/C signal at all station passes during the first hours of operations.

At approximately Mission Elapsed Time (MET) 17:00 hours, another unexpected event caused a significant deviation with respect to the nominal operations timeline. The Space Debris Office at ESOC performed a screening of the determined injection orbit against the NORAD TLEs catalogue: a series of high risk conjunctions with the NASA satellite ACRIMSAT were detected, the first one at MET 33:00 hours. These results where confirmed within a few hours by the Joint Space Operations Centre (JSpOC). After getting confirmation from the ACRIMSAT operators that no manoeuvering was possible on their side, the ESOC MCT started working on a new operations timeline which would allow Sentinel-1A to reach its Nominal Pointing Mode and perform a manoeuvre to mitigate the conjunction risk half a revolution before the first predicted potential conjunction at the latest. The paper describes the decision making process that was triggered by this conjunction warning, in particular the contribution of the FD team to the implementation of the first Sentinel-1A collision avoidance manoeuvre.

The execution of this manoeuvre during LEOP led to another unexpected finding. The response of the AOCS to the manoeuvre execution seemed to indicate a change in S/C angular momentum considerably larger than expected. Additionally a performance error of approximately -20% was estimated by the FD Orbit Determination team. This issue led to a thorough investigation, where the FD team could contribute to a large extent. The paper summarises the analysis performed by the FD team during and after the LEOP to try to provide feasible explanations to the observed problem.

Due to this anomalous behaviour of the Sentinel-1A propulsion system, the manoeuvre strategies to acquire the reference orbit that were analysed before launch had to be re-engineered after LEOP. This topic is subject of a separate paper, also submitted to the 25th ISSFD (See A. Vasconcelos et All, *"Sentinel-1A Reference Orbit Acquisition Manoeuvre Campaign"*, *extended abstract*)