Precise Calibration of Multi-Segment Maneuvers for EUMETSAT Polar System (EPS) Operations Planning

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The EUMETSAT Polar System (EPS) comprises a series of three polar orbiting meteorological satellites, Metop, and is the European contribution to the EUMETSAT/NOAA Initial Joint Polar System (IJPS) in providing “morning” service for operational meteorology. Within the European framework, the Metop program is a joint undertaking between the European Space Agency (ESA) and EUMETSAT in which EUMETSAT is responsible for the development and operations of the ground segment, and routine operation of the space segment. Two of the three Metop satellites are currently in orbit with Metop-A close to its end-of-life operation. The three satellites are foreseen to provide polar data for climate monitoring over a minimum period of 14 years.

The Metop satellite is designed to fly in a sun-synchronous orbit with the local time at the descending node occurring at 09:30 ± 2 minutes and a repeat cycle of 29 days. In satisfying the scientific requirements for optimum observation collection, the ground track is kept within a dead band of ±5 km with respect to the reference and the frozen eccentricity condition is maintained. The orbit maintenance of Metop consists of three types of maneuvers: short in-plane (SIP), long in-plane (LIP) and out-of-plane (OOP). In-plane (IP) maneuvers are considered short if the burn duration is less than 30 seconds at the beginning of life and less than 1 minute at the end of life. All SIP maneuvers are performed in the yaw-steering attitude pointing mode (YSM) whereas the long IP and OOP maneuvers are in fine pointing attitude mode (FPM).

In order to accurately characterize the in-orbit thruster performance for planning of future operations, precise maneuver calibration is performed in the precise orbit determination (POD) processing using GPS observations collected by the GNSS Receiver for Atmospheric Sounding (GRAS) instrument onboard Metop. GRAS provides dual frequency navigation and occultation observations for precise positioning and atmospheric sounding, respectively. In view of the ground and space segment operational conditions and limitations, precise maneuver calibration of the Metop satellites is not a straight forward process. One of the crucial knowledge required in the POD for precise maneuver calibration is the availability of accurate spacecraft pointing information throughout the duration of the maneuver. This information is not readily available for POD and requires some form of post-processing of the spacecraft telemetry data. Reconstruction of the attitude knowledge on ground without telemetry data is not possible for the OOP maneuvers as part of the multi-segment burns is automatically commanded by the onboard Attitude and Orbit Control System (AOCS).

For IP maneuvers, the onboard AOCS activates a series of small thruster pulses to correct for the attitude pointing after the main burn. These pulses typically last for approximately 2-3 seconds and their impact cannot be neglected for short IP maneuvers. The profile of the pulses is extracted from telemetry data on the flight dynamics system and then modeled as a single averaged thrust in the POD process. On the other hand, the OOP maneuver comprises five thrusting phases; start slew, stop slew, main burn, start anti-slew and stop anti-slew. The 90° slew and anti-slew maneuvers are also performed by thrusters and the by-product of the IP acceleration contribution is taken into account in planning the OOP maneuver.

Since the beginning of the Metop-A mission, the OOP maneuvers have been calibrated without accurate attitude knowledge in the POD. The main OOP thrust estimate obtained is sufficient for operations planning and the IP acceleration contribution from the slew and anti-slew has stayed close to the theoretical values. Thus there is never a need to precisely calibrate each segment of the maneuvers for routine flight dynamics operations. However, in the last three OOP maneuvers for Metop-B an unexpected along-track acceleration bias has been observed that is never seen on Metop-A. Given the situation and the need to better understand the thruster performance on Metop-B, the need for precise calibration of the multi-segment OOP maneuver arises.

The precisely calibrated SIP maneuvers thus far have helped improve maneuver planning for orbit maintenance since 2012. The LIP maneuvers are only calibrated as a single segment entity in the POD as the effect from the stabilization pulses, which is about 2 orders of magnitude smaller, is considered negligible. It is foreseen that the effort to establish the capability to calibrate multi-segment OOP maneuver for Metop-B will help resolve the unexpected along-track acceleration bias besides it being highly beneficial for future OOP maneuver planning especially for Metop-C and EPS-Second Generation (SG).

The details of the work in retrieving satellite attitude information from the telemetry data in constructing a continuous attitude profile for POD, the POD process and maneuver calibration will be thoroughly described in this paper. A more detailed explanation of each of the maneuver profile will also be presented, followed by the results from the multi-segment calibration performance from the POD process. In conclusion, a short discussion will be included that relates the outcome to the thruster performance, as well as a summary of the importance of this work for flight dynamics routine operations, and for future EPS and EPS-SG operations planning.