Design and Implementation of the MetOp-B Orbit Positioning Strategy

Javier Sánchez [1], Miguel Ángel Martín Serrano[2], Dirk Kuijper[3] and Isidro Muñoz[4]

[1]*GMV at ESA/ESOC, Robert-Bosch straße 5, 64293 Darmstadt, Germany*
email: javier.sanchez@esa.int, fjsmartin@gmv.com
phone: +496151902416
[2] *SCISYS Deutschland GmbH at ESA/ESOC, Robert-Bosch straße 5, 64293 Darmstadt, Germany*
email: miguel.angel.martin.serrano@esa.int
phone: +496151902273
[3] *Logica Deutschland GmbH at ESA/ESOC, Robert-Bosch straße 5, 64293 Darmstadt, Germany*
email: dirk.kuijper@esa.int
phone: +496151902376
[4] *ESA/ESOC, Robert-Bosch-Straße 5, 64293 Darmstadt Germany*
email: isidro.munoz@esa.int
phone: +496151902108

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ABSTRACT

MetOp-B is the second of a series of three spacecraft comprising the space segment of the EUMETSAT Polar System (EPS) programme, which constitutes a joint initiative in collaboration with the United States National Oceanic and Atmospheric Administration (NOAA) for weather and climate monitoring. The first MetOp satellite, MetOp-A, launched on October 19th 2006, has successfully provided valuable operational meteorological observations from the beginning of its mission. An extension of its activities beyond the nominal five years lifetime has been granted thanks to its excellent performance, leading to an overlap with the operational life of MetOp-B. This period of dual operations will have associated a substantial increase on the wealth and quality of the data gathered by the MetOp mission.

The MetOp-B satellite is to be launched from the Baikonour cosmodrome with a Soyuz/Fregat rocket (launch scheduled for July 2012). The MetOp-B orbit is controlled around a sun-synchronous reference orbit, with local time of descending node at 9:30 hours and a repeat pattern of 412 orbits in 29 days. The final in-orbit position of MetOp-B shall ensure the over-flight of the same equatorial nodes as MetOp-A with a revisit time of either 12 or 17 days, leading to two possible phasing targets with respect to MetOp-A.

Launch and Early Orbit Phase (LEOP) operations are conducted at the European Space Operations Centre (ESOC). During LEOP manoeuvres are performed to correct the injection errors and to comply to a number of Hand-Over criteria defined beforehand by the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT). The main drivers included in these Hand-Over criteria are the following:

- The final position of MetOp-B shall be acquired between 5 and 14 days after Hand-Over of operations from ESOC to EUMETSAT. The drift-stop manoeuvre(s) will be implemented by EUMETSAT.
- No manoeuvres shall be executed during the drift phase.
- Interferences with MetOp-A are to be avoided if possible.
- Local Time of Descending Node (LTDN) shall be kept within a dead-band of +/- 2 min with respect to the reference for at least 45 days after Hand-Over.

Due to the tight schedule of activities the manoeuvre opportunities are constrained to only two slots on the last day of a three-day LEOP (nominal duration). The baseline is to perform an out-of-plane (OOP) and an in-plane (IP) manoeuvre in the two available slots, in that order. OOP manoeuvres aim at changing the inclination and the evolution of the LTDN, whilst IP manoeuvres correct the semi-major axis and the eccentricity vector. Additional constrains to the optimization of the manoeuvre sequence are introduced by the MetOp-B AOCS, since the maximum achievable delta-V does not suffice to correct the maximum expected injection errors. These constraints together with the large amount of possible scenarios due to the variability of the launch day and the injection conditions make the positioning of MetOp-B a very challenging task. The present paper describes the Mission Analysis study carried out by the Flight Dynamics Orbit Determination and Control team at ESOC to illustrate the positioning problem of MetOp-B. The objectives of the study have been the following:

- Evaluation of feasibility to comply to the Hand-Over conditions established by EUMETSAT under all possible injection scenarios.
- Identification of injection scenarios that would require an extension of LEOP operations.
- Design of a positioning strategy with the ultimate goal of providing a guideline to be used during LEOP.

Relative positioning of sun-synchronous satellites is a challenging practical problem fairly frequent in LEOP operations. Similar orbital contexts will be faced in future missions due to the numerous advantages in science return of multiple spacecraft following the same reference orbit (e.g. MetOp-C, Sentinels). Both IP and OOP problems concerning respectively the relative positioning with respect to MetOp-A and the evolution of the LTDN, have been treated using analytical models. The reasons behind this choice are essentially its capability to analyse a large amount of different scenarios and its swiftness, the latter being crucial in view of the tight schedule for the preparation of the manoeuvre strategy during LEOP. When comparing this approach with numerical full-force models, quite accurate results are obtained. This allows the results to be used as first guess in the manoeuvre optimization processes.
Finally, the experience of implementing this methodology in the LEOP simulation campaign and LEOP operations is addressed in this paper.