LAUNCH AND EARLY OPERATIONAL PHASE FLIGHT DYNAMICS MISSION ANALYSIS AND OPERATIONS FOR GALILEO IN-ORBIT VALIDATION SATELLITES: ORBITAL MANEUVERS STRATEGY DESIGN AND PERFORMANCES

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ABSTRACT

Galileo will be Europe’s own global navigation satellite system, providing a highly accurate, guaranteed global positioning service under civilian control. It will be inter-operable with the two other global satellite navigation systems: the American GPS (Global Positioning System) and the Russian GLONASS (GLObal NAvigation Satellite System).

The first four operational satellites, launched in 2011 and 2012, will validate the Galileo concept with both segments: space and related ground infrastructure. Once this In-Orbit Validation (IOV) phase will be completed, additional satellites will be launched to build-up the constellation, consisting of 30 satellites (27 operational and 3 spares), positioned in three circular Medium Earth Orbit (MEO) planes at an altitude of 23 222 km, and a 56 degrees inclination of the orbital planes with reference to the equatorial plane.

This paper presents part a of the IOV LEOP (Launch and Early Operations) generic mission analysis and the operational phase after launch. The objective of the LEOP phase is to move the injected satellites onto their final operational position. This implies orbital maneuvers to correct the injection orbit errors and phasing corrections to reach the final in orbit position. At the end of the LEOP, a

very accurate positioning (mainly the semi-major axis) is required, meaning several days for precise orbit determination and corrections. This very accurate positioning is needed in order to keep for 12 years the satellites within an argument of latitude deadband of ±1.5° with regard to their reference orbit, with only one station keeping maneuver.
This paper is relevant for all IOV LEOPs, and will address only flight dynamics aspects of the mission related to the orbital maneuver strategy.

First, the timeline of the maneuver strategy is detailed. This analysis allows to determine a fixed canvas for maneuver planning, calculating slots allocated to maneuver during LEOP. The maneuver strategy proved its robustness in adjusting this timeline during operations due to unexpected events. This canvas considers a maximal number of maneuvers needed to achieve the required accuracy on final orbit. Maneuvers slots have been defined to cope with all known system constraints (LEOP maximal duration, In-Orbit Tests activities, injection dispersions, separation, orbit determination, and thrusters activation, satellites capabilities and constraints, operational computations and managements, double launch, ground station visibilities, etc).

Then, the maneuver strategy itself is described. All sources of dispersions (injection, separation, maneuver achievement, orbit determination) are taken into account. Therefore, this strategy can be considered as generic for all scenarios (limited to 3σ dispersions), including any kind of phasing angles (angle between injection point and target point on orbit, being launch date dependant). The method for rendezvous optimization is also explained as well as the strategies adopted to get around some difficulties due to system constraints. The required accuracy for all possible scenarios (limited to 3σ dispersions and including all possible phasing angles) can then be reached. This maneuver strategy has been elaborated using the DRAGON software, developed at CNES, whose ATV (Automatic Transfer Vehicle) maneuver strategy tool is also based on for analysis and operations.
This paper presents the performances, in terms of targeted point accuracy and total consumption achievement, thanks to Monte-Carlo analyses performed on 3 representative configurations of phasing angles. Those “End-To-End” simulations campaigns have been realized with the help of the OSCAR tool, also developed at CNES, and that can compute several runs of DRAGON in “closed looped” with ground segments activities, with a random shooting of all the dispersed parameters.

At last, a post mission report is presented for IOV launches, with lessons learned for next GALILEO satellites LEOP about the orbital maneuver strategy, and with real performances achieved on targeted point accuracy and propulsion.