GALILEO FIRST FOC LAUNCH: RECOVERY MISSION DESIGN

Daniel Navarro-Reyes[(1)], Rubén Castro[(2)], and Pere Ramos Bosch[(3)]

[(1)]*ESA, ESTEC Keplerlaan 1, Noordwijk an Zee, The Netherlands, +31 71 5658313,*
Daniel.Navarro-Reyes@esa.int

[(2)]*CGI, ESTEC Keplerlaan 1, Noordwijk an Zee, The Netherlands, +31 71 5658576,*
Ruben.Castro@esa.int

[(3)]*ESA,ESOC Robert Boschstrasse 5,Darmstadt,Germany, +49 6151 902986,*
Pere.Ramos.Bosch@esa.int

Abstract: *Europe's Galileo satellite navigation system – currently under construction – will provide high-quality positioning, navigation and timing services to users across the whole world. Galileo's Full Operational (FOC) constellation will consist of 24 operational satellites plus six spares circling Earth in three circular medium-Earth orbits, at an altitude of 23222 km and 56 degrees inclination. Galileo is an endeavour of the European Commission, with the European Space Agency as Design Authority in charge as well of its implementation.*

The first two FOC satellites, manufactured by the OHB/SSTL consortium, were launched by Arianespace from Guiana Space Centre on a Soyuz ST-B equipped with a Fregat-M upper stage on 22 August 2014.

As planned, 3.8 hours after lift-off, the two satellites separated from Fregat, and their signals were acquired by the TTC antennas of the LEOP network managed by a joint CNES/ESOC team. An initial orbit determination was done by the ESOC Flight Dynamics team, based on angular and ranging S-band data, and clearly showed that the satellites' orbits were far from the expected nominal injection orbits. Analysis of the achieved orbit indicated that Fregat's second burn, a circularisation manoeuvre from an elliptical transfer orbit to the final one, was performed with the correct magnitude but about 35 degrees away from the nominal direction. This last manoeuvre not only did not circularise the final orbit, leaving the eccentricity at 0.233 and semi-major axis 3700 km below the nominal value, but it also reached the final orbital plane with about 12 degrees error (13.2 degrees in RAAN and 5.35 degrees in inclination). Such orbits were out of the range of orbits that the satellites could recover using the amount of propellant budgeted for a nominal mission (about 170 m/s), and therefore reaching the nominal orbit in the Galileo Constellation was not possible. In addition, due to the low perigee, the satellites could not be able to maintain Earth pointing attitude with the accuracy needed for payload operations and navigation service provision since its main attitude sensor, the Infrared Earth Sensor, could not operate at those low altitudes (13700 km) . Unfortunately, that meant that the satellite could not be used as part of the nominal Galileo constellation under these circumstances.

Nevertheless, work at the Galileo Project Office (GPO) was started right away to design a recovery mission. The objective was to define an so-called recovery orbit that could allow the satellite to provide added value to the Galileo System. The analysis also included the manoeuvre strategy to achieve the recovery orbits, and its later evolution.

This paper presents the mission analysis performed at GPO in collaboration with its subcontractors. The mission design took into account the known capabilities of the satellites (avionics, propulsion constraint, available propellant and the needed reserves for later routine operations, etc.), and operational constraints (non-nominal Earth pointing procedures, station visibility, manoeuvre timing).

Given the high eccentricity and low perigee of the orbit, the mission drivers for this recovery orbit, aiming to provide navigation signal in space, were:
- Reduce the L-power dynamic range between apogee and perigee
- Reduce Doppler as to facilitate L-band ground receivers to lock the signal.
- Increase visibility time for receiver
- Reduce burden on the Earth Sensors operation
- Reduce exposure to the Van Allen belts, and, therefore, reduce satellite equipment degradation
- And, finally, improve contribution to the global constellation performance in case the satellites could be introduced in the Galileo navigation service.