SPACECRAFT RECOVERY OPERATIONS CONDUCTED TO THE GALILEO FOC-1 L3

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Abstract: *This paper presents the highlights of the spacecraft recovery operations conducted by Spaceopal to the FOC-1 (Full Operational Capability) spacecraft's which were injected in a severely non-nominal eccentric orbit due to a launcher anomaly August 22nd 2014.*

Spaceopal which is a joint venture of DLR GfR mbH and Telespazio, is the operations prime contractor for the European Galileo Satellite Navigation System. As such Spaceopal carried out the technical and organizational coordination across the recovery participants which involved:

- *DLR-GfR: Flight operations preparation and execution conducted from the Galileo Control Centre in Oberpfaffenhofen.*
- *ESOC: mission analysis and flight dynamics support*
- *CNES: external ground station support*

Post launch analysis evidenced that the injection orbit was so far off from target that the nominal operational orbit could not be reached, with the fuel available on-board. The prime objective of the mission soon shifted to evaluating the in-orbit performance of the FOC-1 spacecraft´s in a manner, configuration and timescale sufficient to allow an assessment of the design implementation prior to subsequent launches.

In the recovery phase, the spacecraft´s were safely handed over from the LEOP centers to the GCC-D (Galileo Control Centre Germany) in sun pointing mode after which they underwent degraded routine contacts in a babysitting configuration. Soon after a series of orbit control manoeuvers were performed to each spacecraft in order to increase the perigee altitude to allow continuous use of nominal spacecraft AOCS configuration (Earth-pointing, Normal mode), targeting an orbit suitable for the Galileo constellation in terms of resonance and ground coverage. This was followed by limited in orbit tests sufficient to characterize the spacecraft platform and payload design implementation in line with the mission objectives.

Mission Recovery was thoroughly analyzed and prepared to ensure the spacecraft operability in an orbit far from the design specification. Ground segment operational software and procedures were duly developed, validated and installed in order for the spacecraft avionics software to be able to cope with a variable angular rate in the non-nominal elliptical orbit. This was

compensated by inhibiting the Earth Sensors during the perigee crossings as the model was not designed to detect the Earth at such low altitudes. The angular rate manual correction was performed until the perigee raising manoeuvers had increased the altitude of the perigee sufficiently in order for the Earth Sensors to operate nominally. Two different methods were developed and proposed as detailed in the paper (spacecraft biases and on board propagator values) which were subsequently simulated and validated by Operations using local simulators..

The FOC-1 Recovery Campaign results will be summarized and outlined throughout the paper in terms of target orbit achieved and in orbit spacecraft behavior and status.