INTEGRAL End-Of-Life Disposal Manoeuvre Campaign

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EXTENDED ABSTRACT

ESA's INTErnational Gamma-Ray Astrophysics Laboratory (INTEGRAL) is the most sensitive gamma-ray observatory ever launched and is operated from the European Space Operations Centre (ESOC) in Darmstadt, Germany. The spacecraft was launched from Baikonur, Kazakhstan, in October 2002 into a highly eccentric orbit of 9,050 x 153,660 km (perigee x apogee) altitude with an inclination of 52.25 deg. The 72-hour orbit has provided long periods of uninterrupted observation and ensured continuous ground station tracking support outside of Earth's radiation belts. The mission was designed for a nominal lifetime of 2.5 years with a possible extension of another 2.5 years. Due to the flawless performance of the platform and instruments as well as continued high scientific interest, the mission has regularly been extended, currently up to end of 2018 (subject to a mid-term review in 2016).

The natural orbit evolution, mainly influenced by lunar and solar perturbations, causes a variation of the perigee altitude of the spacecraft that will lead to repeated crossings of the protected GEO and LEO regions in the next 200 years. Therefore, ESA's Space Debris Office (SDO) analysed options for a disposal by an atmospheric re-entry of the spacecraft with the available fuel and ideally maximizing the period of remaining science operations. The outcome of this analysis was to perform an apogee-lowering manoeuvre in 2015 that would lead to a re-entry in early 2029 due to the effects of third body perturbations. This is the first time that a spacecraft's orbit has been adjusted after 12 years in operations to achieve a safe re-entry 15 years in the future, while still continuing the mission after the de-orbit manoeuvre. It is also the first time that a targeted disposal for a mission in such a highly elliptical orbit has been carried out.

In the course of 2014 the Flight Dynamics (FD) team at ESOC performed an analysis to determine a target orbit that would be acceptable for future operations, would fulfil SDO's requirements and would maximize ground station coverage outside Earth's radiation belts. FD then designed a manoeuvre campaign to achieve this target orbit, considering all requirements regarding operations, maximizing time for science observations, and spacecraft safety. The manoeuvre campaign lasted one month and was executed beginning of 2015.

It was mandatory that the post-manoeuvre orbit avoided non-repetitive and/or incomplete ground station coverage patterns as INTEGRAL science operations require continuous TM/TC coverage. A final apogee height leading to a repeat orbit of 8 revolutions in 3 sidereal

days was chosen. This significantly eases mission planning in the future, especially when compared to non-repeat orbits in which slews and reaction wheel biases would have to be planned individually for each revolution. Additionally, full ground station coverage outside the Van Allen belts was achieved.

Reaching the desired 3:8 resonance orbit was compliant with the required lowering of the apogee height by SDO. Ideally, the orbit change would be implemented by an impulsive manoeuvre executed exactly at perigee and in early 2015 due to increasing delta-v requirements. However, in reality the manoeuvre would last for several minutes and could not be executed at perigee due to lack of station visibility. These two constraints would make any manoeuvre significantly less efficient. Therefore, the disposal manoeuvre was divided into three manoeuvres in order to reduce individual manoeuvre's duration and improve station visibility at perigee for the second and third manoeuvres, thus mitigating performance losses. The manoeuvres were planned in a joint effort of FD, the FCT (Flight Control Team) and ISOC (INTEGRAL Science Operations Centre) in order to optimize the manoeuvre placement while respecting operational constraints. The go-ahead for the disposal was only obtained in October 2014, implying a very tight design and execution schedule.

This paper describes the detailed preparatory analyses, gives insight into the successful manoeuvre execution and subsequent operations from FD point of view, and depicts the current status as well.