A REVIEW OF SWARM FLIGHT DYNAMICS OPERATIONS FROM LAUNCH TO ROUTINE PHASE

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ABSTRACT

Swarm is a three spacecraft ESA Earth explorer mission which will measure the Earth's magnetic field with unprecedented accuracy. The spacecraft were launched together on 22nd November 2013 aboard a Rockot with a Breeze-KM upper stage. The spacecraft are injected into the same near polar orbit with altitude 490 km before being inserted into their operational constellation. The spacecraft use a low thrust cold gas propulsion system and so a sequence of around 150 manoeuvres per spacecraft are needed to achieve the final constellation in which two satellites fly side-by-side, decaying naturally from an initial altitude of 462 km while the third orbits at about 530 km. The lower pair has an inclination some 0.6 degrees lower than the upper spacecraft so that their planes separate over the course of the mission due to precession. For routine operations the lower pair will be maintained such that their node crossing times are with 10 seconds of each other.

The flight dynamics operations challenges for this mission start at launch when the orbits of all three spacecraft need to be quickly determined and using the same number of ground stations as would usually be attributed to a single spacecraft. Furthermore using this limited data there is a need to determine as early as possible whether the upper stage has safely separated the spacecraft orbits as expected. These two aspects of the early orbit determination are achieved by applying artificial observations to constrain the initial state vectors relative to one another according to the nominal insertion by the upper stage. Using this technique tracking any single spacecraft will provide information on all three spacecraft orbits. In addition, if the relative state vector constraints are not consistent with the tracking data, because of a non-nominal injection, this will be detectable in the orbit determination.

The insertion of the spacecraft into their operational constellation involves many manoeuvres so to be done in a reasonable time (and at a reasonable cost) the manoeuvres are commanded together in batches of up to 90 at a time. Commanding such a large number of manoeuvres to be

executed over several days, with limited station availability and with visibility gaps of 12 hours each day must be handled carefully. For example, careful planning was implemented to ensure that thruster misperformance and manoeuvre sequence interruption do not result in problems either with later station acquisition or the need for major sequence replanning.

The transition into routine where relative orbit control is performed will follow.

This paper will review these and other challenges and how they were handled by the flight dynamics team at ESOC.