DESIGN AND OPERATIONAL IMPLEMENTATION OF SWARM ORBIT INSERTION PHASE AND ROUTINE ORBIT CONTROL

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ABSTRACT

Swarm is a three spacecraft ESA Earth Explorer mission which is to be launched in the second half of 2012. The spacecraft will be launched together onboard a Rockot-Briz launcher into a common orbit with inclination 87.55 degrees, altitude 490 km and frozen eccentricity. The spacecraft are then manoeuvred into their operational constellation during the first three months after launch.

The operational constellation consists of a lower pair and an upper spacecraft. The lower pair flies in a side by side formation with their ascending nodes separated by 1.4 degrees in right ascension and with an initial altitude of around 460 km. The lower pair should decay to an altitude of 300 km after four years and must be maintained such that their node crossing times are within 10 seconds of each other and such that collisions are avoided even in the case of a safe mode. The upper spacecraft has an inclination of 88 degrees, 0.6 degrees greater than the lower pair and an altitude of 530 km.

The satellites use a cold gas propulsion system with pairs of 50mN orbit control thrusters. This low thrust requires that each spacecraft must perform around 150 manoeuvres of around 20 minutes duration to reach its operational orbit. The manoeuvres simultaneously change the semi major axis and inclination as well as correcting eccentricity dispersions. The manoeuvres are commanded in advance and inserted on the on board timeline as batches of up to three days duration, twice per orbit manoeuvres along with associated slews.

The design of the orbit insertion phase has been performed in order to simplify these operations as much as possible. The spacecraft are manoeuvred one at a time with a single batch of manoeuvres being commanded per week. The manoeuvre schedule has been implemented such that manoeuvre batch failures due to spacecraft problems can be corrected for by a replan of the remaining sequence without the need for a rapid response. The challenge here is to keep simultaneous along track and relative node drift rates in sync.

The commanding in advance of large numbers of manoeuvres is new for the flight dynamics team and this has meant significant software changes in the orbit control and telecommand

generation areas. The approach followed has been to re-use some flexible orbit control software already in use for planetary missions.

On the routine phase, orbit control of the lower pair is required to maintain the constellation, with manoeuvres performed at regular intervals to simplify operations. The manoeuvres may be implemented to lower, leave unchanged or raise the altitude of the spacecraft. Which mode is used depends on whether long term predictions of the orbit decay show that the initial altitude is too high, about right or too low for the requirement that the spacecraft shall be at 300 km after 4 years. The required delta-v, manoeuvre frequency and rate of orbit decay depend on the difference in spacecraft ballistic coefficient and the atmospheric density experienced. A simulation tool has been developed to test the sensitivity of the orbit control implementation to these unpredictable aspects and to demonstrate the robustness of the implemented approach.

The paper will present the Swarm operational orbit insertion phase in detail, concentrating on how the design and software implementation of this complex mission phase has been performed minimizing mission risk, complexity and cost. The constellation maintenance phase implementation will also be presented along with the results of simulations to determine the likely manoeuvre size and frequency.