Flight Dynamics Challenges for the GRACE Follow-On Mission

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Keywords: *GRACE Follow-On Mission, Flight Dynamics Operations, Formation Flying, Laser Ranging Interferometer.*

1. Abstract

The GRACE Follow-On mission is a partnership between NASA and the German Research Centre for Geosciences (GFZ) and will be operated by the German Space Operations Centre (GSOC) / DLR. The baseline launch date is in August, 2017. It is a follow on mission for the successful GRACE (Gravity Recovery and Climate Experiment) mission [1]. GRACE consists of twin satellites launched together in March, 2002. They are flying approximately 220 kilometers apart in a polar, nearly circular orbit that started at an altitude of 500 kilometers and has slowly degraded during the mission. Collecting and providing detailed measurements of Earth's gravity field, the mission supports an understanding of the distribution and flow of mass on and within the Earth.

The GRACE Follow-On (GRACE-FO) mission is designed to continue this exceptional task to consistently and uninterruptedly provide extraordinary data to the science community beyond the GRACE mission. Hence another set of twin satellites—GRACE-FO1 & GRACE-FO2—will by placed into a polar, nearly circular, 500 km altitude orbit using a single launch of a Dnepr rocket in August, 2017. The formation again foresees an along-track separation of about 220 kilometers. After separation from the rocket the satellites are in slightly different sized orbits that cause them to drift apart with a nominal drift rate of about 200 km/day. A conservative assumption that the spacecraft will be ready for maneuvering after 5 days results in an along-track distance of about 1000 kilometers at the time of the first maneuver. At this time the basic idea for getting the satellites into formation is to reduce the size of the higher satellite's orbit and raise the lower satellite's orbit above that, so the two spacecraft begin to drift toward each other. As soon as the desired distance of about 220 kilometers is achieved, the lower satellite (which was originally higher) would have its orbit raised to match the other satellite's altitude and thereby the drift is stopped.

The implementation of this basic idea is constrained by the limited acceleration available from the propulsion subsystem—about 0.00017 m/s^2. An extensive maneuver strategy has been developed to bring the satellites into the required target formation. The boundary conditions and rationales for the strategy will be presented in detail within this paper. Experiences in formation flying are taken from the GRACE mission [2] and the TanDEM-X mission [3].

The GRACE-FO satellites are very similar to their GRACE precursors, but carry a Laser-Ranging Interferometer (LRI) as a technology demonstration. Like the primary microwave instrument the LRI measures fluctuations in the inter-spacecraft separation but with greater precision using laser interferometry. The LRI requires a pointing accuracy which cannot be

achieved by the originally implemented (on GRACE) pointing direction computation. Here, the two-line elements (TLEs) of both spacecraft are provided by ground command to both satellites, so that each of them can propagate the positions of both satellites and therefore compute a coarse pointing direction. Then the on-board available GPS data is used to estimate the local vertical, local horizontal coordinate frame in which to apply the pointing direction.
This corrected pointing still is not accurate enough for LRI operations, though. Hence, a parametric model was developed at JPL [4] to estimate the differences between the pointing angles based on corrected TLEs and the pointing angles derived from the high precision orbits based on GPS data of both spacecraft. The resulting fit parameters are computed on the ground and sent to both spacecraft with each set of TLEs, which allows a final pointing adjustment within the LRI to enable a more accurate over all pointing (cf. Fig. 1). The parametric fit method and its implementation at GSOC will be described within this paper. The analysis results will be presented and depicted in detail.

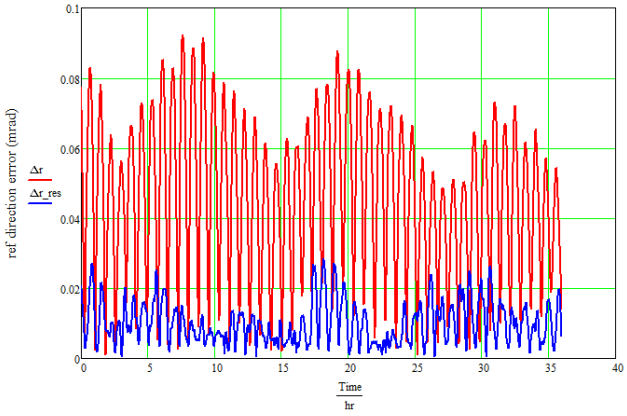

Figure 1. Residual pointing errors between predicted pointing based on TLEs and GPS data; red: frame-corrected, blue: frame- & fit-corrected.

This paper provides an overview about the GRACE Follow-On mission and the new Flight Dynamics tasks with respect to the GRACE mission. The main focus is on the maneuver strategy for formation acquisition and the LRI operations support.

2. References

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