Improved Reference Orbits for the Repeat-Ground-Track Missions EnMAP and Tandem-L

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DLR's German Space Operations Center prepares for two upcoming Earth observation missions: EnMAP with a hyperspectral instrument for environmental mapping and Tandem-L – a formation flying mission with L-Band radar – aiming on the global observation of dynamic processes on the Earth's surface. Apart from the different payloads, these missions and the flying TerraSAR-X satellite (TSX) have the usage of a reference orbit in common. Such an orbit can be formulated for any Sun-synchronous repeat-ground-track mission and is typically applied for orbit control and instrument planning purposes.

This paper is motivated by a phenomenon that we are observing since the early operations phase of TSX. The TSX orbit is controlled to stay within a 250 m radius tube surrounding the Earth-fixed reference orbit, while the along-track motion is not controlled [1, 2]. The variation of the TSX-REF along-track distance in-between two drag make-up maneuvers is typically below ±15 km as depicted in Fig. 1. However, the fall back and catch up phases are not always symmetric, building up to an oscillation with one-year period and an overlaid secular drift. After almost 10 years in orbit -450 km of along-track distance have accumulated, which corresponds to 60 seconds of flight time and hence change in the ascending node crossing time.

The along-track variation can be explained by J2-induced change of the ascending node drift rate, where size and direction depend on semi-major axis and inclination deviations from the reference orbit. The sinusoidal behaviour in Fig. 1 follows from the luni-solar perturbation of the orbit's inclination. Its amplitude might be reduced by lowering the control band for the relative inclination, which however would drastically increase the number of required out-of-plane maneuvers. But, the secular variation goes back to an inclination offset being smaller than 0.0001 deg in the reference orbit. Treating this finding in the reference orbit generation process, the secular effect can be cancelled out for future repeat-ground track missions.

Our improved process for the generation of reference orbits features three additional steps: (1) a one-year simulation of inclination correction maneuvers in order to estimate the expected yearly RAAN drift with sufficient accuracy, (2) an adjustment of the reference orbit inclination, and (3) a one-year maneuver simulation comprising drag make-up and inclination maneuvers to validate the refined reference orbit. The paper will describe the improved process in detail and results for TSX as well as for EnMAP and Tandem-L are presented.

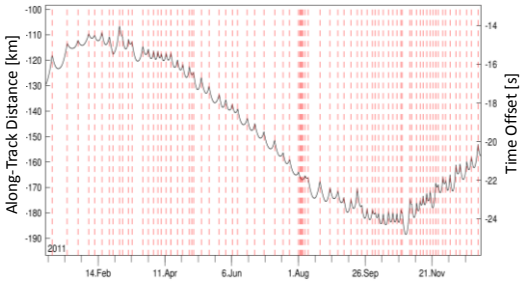

Fig. 1. TSX-REF along-track distance (left) and corresponding time off-set (right) in year 2011. Vertical red lines indicate orbit control maneuvers.

Table 1. Repeat-ground-track characteristics and mean orbital elements.

	TerraSAR-X	EnMAP	Tandem-L
Launch	2007	2019	2023
Repeat period	11 days	27 days	16 days
Orbits per repeat cycle	167 orbits	398 orbits	231 orbits
Orbits per day	15 + 2/11	14 + 20/27	14 + 7/16
Local time of ascend. node	18:00	23:00	18:00
Eccentricity	0.00125	0.00120	0.00117
Inclination	97.446°	97.979°	98.378°
Semi-major axis	6883.513 km	7020.447 km	7118.619 km

References

[1] S. D'Amico *et al.*, Generation of an Optimum Target Trajectory for the TerraSAR-X Repeat Observation Satellite, 18th International Symposium on Space Flight Dynamics, Munich, Germany (2004).
[2] R. Kahle and S. D'Amico, The Terrasar-X Precise Orbit Control – Concept and Flight Results, 24th International Symposium on Space Flight Dynamics, Laurel, Maryland (2014).