ALOS-2 AUTONOMOUS ORBIT CONTROL - ONE-YEAR EXPERIENCE OF FLIGHT DYNAMICS OPERATION

Toru Yamamoto[(1)], Yoshihisa Arikawa[(2)], Yasushi Ueda[(3)], Hiroyuki Itoh[(4)], Yoshitaka Nishida[(5)], Hiroyoshi Tsuru[(6)], Shinichi Ukawa[(7)], and Masayuki Yamamoto[(8)]

[(1)(2)(3)(4)]*Japan Aerospace Exploration Agency, Tsukuba, 305-8505, Japan, +81-50-3362-4356, yamamoto.toru@jaxa.jp*

[(5)(6)(7)]*Mitsubishi Electric Co., Ltd., Kamakura, 247-8520, Japan*

[(8)]*Mitsubishi Space Software Co., Ltd., Tsukuba, 305-0032, Japan*

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ABSTRACT

Advanced Land Observing Satellite-2 (ALOS-2), which is a Japanese Earth observation satellite with the state-of-the-art L-band SAR instrument, has an autonomous orbit control functionality for precision keeping of its flight path within the 500 m radius tube-shaped corridor defined in the Earth-fixed coordinate system. The autonomous orbit control of the ALOS-2 has been in practical use since its activation on August 2014, and it has been great help for precision orbit keeping and efficient daily ground operations. Following the detailed explanation of the autonomous orbit control concept, the evaluation results of its performance, and lessons-learned from the one-year flight dynamics operation experience will be reported in the paper.

Some Earth observation satellites carrying synthetic aperture radar (SAR) instruments have more stringent requirements on precision orbit control of Earth-fixed repeating orbits rather than conventional Earth observation satellites. This requirement arises from the geometric constraints for effective repeat-pass SAR interferometry. Tight maintenance of Earth-fixed repeating orbits ensures good coherence between repeat-pass SAR image pairs. For this purpose, the SAR satellite must fly through within a tube-shaped corridor, the center of which is the Earth-fixed reference flight path. The greater any increase in orbit control accuracy requirement, the higher the frequency of orbital maneuvers required. In particular, the frequency significantly increases during the active solar period due to dense atmospheric density. An orbit control operation, which consists of many tasks: orbit determination, maneuver planning, maneuver commanding and maneuver execution, requires considerable workload, hence frequent maneuvers become a burden for daily ground operations. Autonomous orbit control can be a solution for this problem. The workloads and costs of orbit control operations can be reduced by sophisticated on-board software which can handle a series of necessary tasks of orbit control operations. Fully automatic decisions of maneuvers by on-board software causes a new problem when the autonomous orbit control approach is applied for practical Earth observation missions. The problem is unexpected timing conflicts between maneuver executions and mission observations. If the on-board software determines the time of a maneuver without considering mission observations, automatic orbital maneuver may spoil the opportunities of the important observations. Therefore the time of a maneuver should be placed carefully so that the maneuver does not interfere with the planned mission observation.

With the above issues in mind, the authors applied the autonomous orbit control approach for the ALOS-2 mission. The applied method can achieve autonomous operations of orbit determination, maneuver prediction, maneuver planning, and maneuver executions. Both in-plane and out-of-plane maneuvers are planned and executed autonomously so that the satellite fly through within a tube-shaped corridor, the center of which is the Earth-fixed reference flight path. The maneuver planning algorithms can place the time of a maneuver so that it does not spoil the observations by the proposed “maneuver slot” concept.

ALOS-2 was successfully launched on 24th May 2014. Its orbit is 628 km sun-synchronous repeating orbit with 14 days repeat cycle. The orbit control requirement for the radius of the tube-shaped corridor is 500 m (95%).

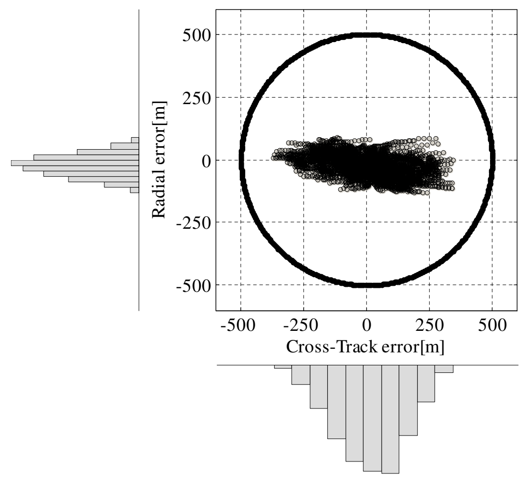

Figure 1. Orbit error in cross-track and radial directions as well as its statistical distributions for 40 days. Errors evaluated at each 10 deg argument of latitude are folded into this single plot. It is clearly seen that the actual flight path is controlled within the 500 m tube-shaped corridor by the ALOS-2 autonomous orbit control.

The applied method has been demonstrated and in practical use since its activation on August 2014. The author believes that this is the world’s first attempt to apply autonomous precision orbit control within a tube-shaped corridor for a regular-basis operation of an Earth observation satellite. The in-plane maneuvers were executed three times per a week in the average during the most solar active period. The automatic operations of such frequent in-plane maneuvers greatly helps efficient ground-operations of the ALOS-2. The “maneuver slot” concept has been working well to prevent conflicts between mission observations and maneuver timings, as well as achieving a flexible mission observation planning even an autonomous maneuver planing approach is taken. The out-of-plane maneuver was also performed autonomously. The orbit control error with respect to the reference trajectory was evaluated. The most of piercing points of the actual flight path are inside the required 500 m radius circle regardless of its argument of latitudes as shown in Fig. 1. The computed probability of success for 200 days since the activation of the autonomous orbit control is 99.7 % and it is far more than the required 95 %. This performance contributes the good coherence between repeat-pass SAR image pairs of the ALOS-2 data products.

In the paper, the practical aspect of the ALOS-2 flight dynamics operations is mainly discussed. The lessons-learned from the one-year actual flight dynamics operations, such as reactions to solar activity change, emergency observation requests, and debris avoidance maneuvers and so on, will be reported.