THE INSERTION OF GCOM-W1 INTO THE A-TRAIN CONSTELLATION

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ABSTRACT

The Afternoon Constellation, or "A-Train" is an Earth observation satellite constellation organized by NASA. The A-Train consists of multiple satellites flying in close proximity in a 705 km sun-synchronous orbit, and crossing the equator at around 1:30 p.m. mean solar time. The orbits of the satellites in the A-Train are controlled so that the satellites follow the same ground-track and observe the same locations on the Earth nearly simultaneously.

JAXA runs a program called Global Change Observation Mission (GCOM) to observe the global environment, global water cycle mechanisms, and long-term climate change. The GCOM-W1 is the first satellite in the program and it was launched on 18th May 2012. Its main sensor payload is AMSR2 which is a successor of AMSR-E installed on Aqua, which is one of the A-Train constellation. The GCOM-W1 will join the A-Train constellation in terms of data continuity from the AMSR-E on the Aqua and enhancement of scientific research by simultaneous measurements with various kinds of sensors on distinct satellites.

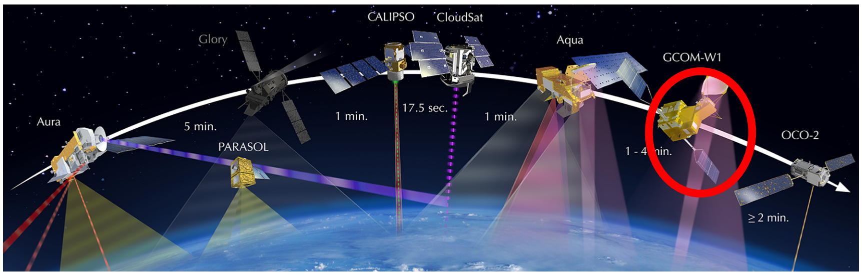

Figure 1. Location of GCOM-W1 in A-Train constellation

The design of GCOM-W1 ascent plan from launch to the A-Train constellation is the main topic of this paper. Satellites in the A-Train fly in a sun-synchronous orbit with 16 days repeat cycle. Therefore initial relative phase angle of GCOM-W1 with respect to the target location in the A-Train has also 16 patterns, and it changes depending on launch date. GCOM-W1 should absorb this date-dependent initial relative phase angle, initial difference of other orbital parameters, rocket injection errors, and relative perturbations due to difference of orbital parameters to reach the target location in A-Train. The following guidelines are considered to be important for the design of the GCOM-W1 ascent plan to the A-Train constellation:

(a) Risk of collision with other A-Train satellites should be minimized.
(b) Dates of orbital maneuvers should be determined before the launch date regardless of launch injection errors.
(c) An ascent operation should be completed as soon as possible.

(d) Fuel consumption should be minimized.
(e) Deceleration maneuvers should be avoided.

Minimization of collision risk is the top priority issue for design of ascent trajectory and its error analysis. The GCOM-W1 should not violate specified box-shaped regions centered at positions of each A-Train satellite even if a malfunction occurs on the GCOM-W1. The dates of orbital maneuver operations should be determined before the launch date regardless of rocket injection errors so all tasks of operations and key personnel can be allocated in the pre-planned timeline. A shorter ascent operation contributes quick start of mission operation in the A-Train and lower costs. Fuel consumption should be minimized since onboard fuel of GCOM-W1 is limited and is the key factor in extension of mission life. Deceleration maneuvers should be avoided since they require an attitude maneuver around its yaw axis by 180 degrees, which potentially causes undesired velocity increments. The ascent plan is designed with these guidelines taken into account. It consists of three parts, called Steps one, two, and three, as shown below.

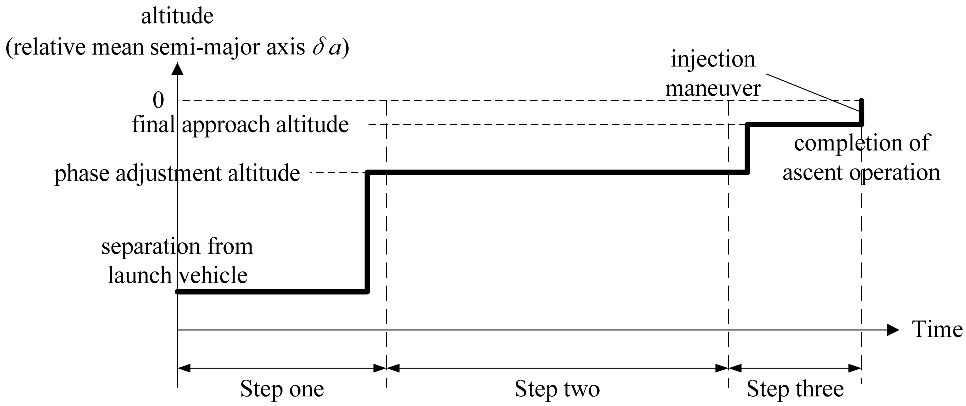

Figure 2. Basic structure of GCOM-W1 ascent plan to A-Train constellation

In Step one, test maneuvers, plane adjustment maneuvers and ascent maneuvers to phase adjustment altitude are performed. Step two is "phase adjustment" timeframe to absorb initial relative phase angle. During this step no maneuver is planned. The duration of Step two depends on the launch date and is basically unaffected by rocket injection errors since they are absorbed by selecting the proper phase adjustment altitude. In Step three the GCOM-W1 performs an in-plane maneuver to raise its orbit from the phase adjustment altitude to final approach altitude. A relative eccentricity vector to the A-Train orbit is kept small by conducting pairs of in-plane maneuvers when GCOM-W1 approaches to the target position on this altitude. Finally GCOM-W1 is injected to the target position by a final injection maneuver. The important point is that the timeline of maneuver operations in Step one and three is fixed regardless of launch date and rocket injection errors. Only duration of Step two changes depending on the launch date. This feature can greatly help pre-launch preparation of operations and allocation of key personnel for important critical events.

In this paper, the concept of the GCOM-W1 ascent plan design, collision safety issues, the detailed ascent plan, and results of pre-launch analysis are described. In addition, the actual ascent operation has already started from 18th May 2012 and it is expected to be completed within 60 days. Therefore, some results of actual ascent operation are expected to be shown, and lessons learned from the actual experiences will be discussed.