Self-Configurable Flight Software Architecture with Goal-Oriented Operation for CubeSats

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In recent year, CubeSats have been developed in different universities, research organizations, and industrial sectors around the world. To successfully perform a space mission, a good coordination of the ground segment and space segment is needed. Sending a sequence of time-based commands from ground segment to space segment is the most popular method for space mission operation. However, for CubeSat operation, the limitation of communication bandwidth and the short coverage duration in low-earth orbit (LEO), the time-based commands may not be efficient especially when the mission becomes more complicated. In the paper, the use of goal-oriented operation is proposed and discussed as an alternative in ground segment operation. A self-configurable flight software architecture is proposed to facilitate goal-oriented operation for CubeSats.

The concept of goal-oriented operation has been investigated in 1999. Instead of sending a sequence of time-based commands, such an operation sends goals from ground segment to space segment. When the space segment receives the goal, the flight software decomposes the goal into different subtasks in different hierarchy. With respect to each subtask, the software selects, organizes, and executes a series of lower-level functions corresponding to the subtask to fulfill the goal. A challenge in this goal-oriented operation is the self-configurability. Owing to the fact that there are alternative ways of decomposing a task, an efficient decomposition needs to be determined. In the paper, an innovative design of self-configurable flight software architecture is proposed to facilitate goal-oriented operation. Under this architecture, the system parameters which are used to control the behavior of CubeSat are updated in an iterative manner so that the efficiency of the task decomposition task can be incrementally improved. Moreover, in this self-configurable architecture, a margin library is used to limit the system parameters in reasonable boundary to prevent the CubeSat to keep the CubeSat within the safety requirements and eliminate the redundant way of decomposing tasks. Thus, with goal-oriented operation and a well-designed self-configurable flight software architecture, it can adapt to the unpredictable and harsh environment in space and also can enhance the performance of CubeSats.

If needed, the proposed architecture can be switched into non-goal-oriented operation mode as the prevalent operational paradigm of command sequencing. For the proposed architecture, there is the need to determine how to exploit the update algorithm with limited resource in CubeSats, and the implementation of the proposed architecture also needs to be validated. However, the improvement of space technology and semiconductor industry make this architecture possible. Consequently, the proposed architecture would allow CubeSats to conduct more complicated missions and enable much better utilization of CubeSats.