SSC14-II-1

UNIFORM-1 Ground System: Mission Planning, Scheduling, Control, and Data Processing

Takashi Hiramatsu
Japan Association for Satellite Technology Cooperation
KBIC, 7-7 Shin-Kawasaki, Saiwai-ku, Kawasaki, Kanagawa 212-0032 Japan; +81-44-280-6199
hiramatsu@jastc.jp

Shusaku Yamaura
Graduate School of System Design and Management, Keio University
4-1-1 Hiyoshi, Kohoku-ku, Yokohama, Kanagawa 223-8526 Japan; +81-44-280-6199
Shusaku.yamaura@sdm.keio.ac.jp

Tomomi Otani, Naoko Sato, and Katsumi Morita
Wakayama University
930 Sakaedani Wakayama, 640-8441 Japan; +81-73-457-8503
totani@center.wakayama-u.ac.jp

Toru Koyama
National Institute of Advanced Industrial Science and Technology
t.kouyama@aist.go.jp

Kikuko Miyata
Nagoya University
Furo-cho, Chikusa-ku, Nagoya, Aichi 464-8603 Japan
kikuko.miyata@gmail.com

ABSTRACT

Mission planning and scheduling is an essential part of satellite operations, and traditional satellites have a big, complex ground system which takes care of their operations planning, resource allocation, scheduling, and so on. As small satellites become more and more complex, their capability have been increased and so has the need of proper planning and control; it is necessary to have a good planning system in order to maximize the functionality of a small satellite by effectively and efficiently utilize its resource. This paper discusses the ground software developed for UNIFORM-1 satellite. The ground software consists of mission planning/scheduling, mission control center, and operations data distribution. All the downlinked operations data are stored in a database and will be used for analyzing the satellite conditions as well as extracting information necessary for addressing when/how much mission data acquisition is available. Combined with the request from the end-user (i.e., those who need to monitor specific target area on Earth for wildfire surveillance), achievable mission plans will be generated. Those operations plans include when image capture will take place, when those data will be downlinked to the ground, etc., and will be automatically converted to operations procedures which is comprehensible by the TT&C software at the control center (MCC). This paper also presents the actual operations plans and the corresponding data obtained from the early-phase operations of UNIFORM-1.

INTRODUCTION

UNIFORM (UNiversity International FORmation Mission) is a program funded by the Ministry of Education, Culture, Sports, Science & Transportation in Japan (MEXT) and is aimed at through international collaboration creating a constellation of microsatellites [1]. The main idea is to broaden the horizons of small satellites capabilities by increasing both the number of small satellites for real utilities and engineers with hands-on experiences in small satellites, particularly by training young engineers from participating countries to the program. The program's first satellite UNIFORM-1, a 50-kg microsatellite for wildfire monitoring, was launched from Tanegashima Space Center (TNSC), Japan via an H-IIA rocket on 24 May 2014. It was delivered to an approximately 628km altitude near-circular orbit and has been in operation since then. Table 1 summarizes basic information of UNIFORM-1.

Table 1: UNIFORM-1 Specifications

Type	Values
NORAD Catalog #	39767
Orbit	628km SSO
Mass/Size	50kg, 50x50x50cm
Mission Payloads	Microbolometer Array Sensor x 1 Visible Light Camera x 1
Communication	S-band Transmitter S-band Receiver X-band Transmitter
Attitude Control	Magnetic Torquers Reaction Wheels

UNIFORM-1 orbits around the earth and captures infrared images of ground using a microbolometer camera. The data is downlinked to the ground and analyzed to find possible heat anomalies of the ground surface, leading to detect wildfire [2]. A basic flow of mission operations is as follows;

(1) scientists request images of a region of interest on the ground (i.e., a region which has a high risk of wildfire during certain period of time).

(2) mission planners calculate the ground access, downlink resource (i.e., how much data can be acquired to the ground) based on the length of each pass, to generate satellite operations procedures (SOP).

(3) mission control operator perform TT&C using the SOP to get mission data and operations data.

(4) the mission data is sent to scientists for analysis, and the operations data is stored in database for monitoring the satellite health.

Successful mission operations require that the ground system can achieve the above steps. To ensure this, ground software has been developed by the project members with the goal of simplifying the planning and operations processes as much as possible and making it semi-automatic so that it is easy for new operators to get used to it quickly, and that hopefully it will become a good entry-level satellite operations software to be distributed to future members of UNIFORM program.

This paper introduces the ground software developed and used at Wakayama GS for UNIFORM-1 mission operations.

GROUND SYSTEM

A dedicated ground station (GS) for UNIFORM-1 operations has been built in Wakayama University, Japan. Figure 1 shows a small cabin next to a 12m antenna for mission data downlink. Currently this is where the entire satellite operations are performed. There is also a 3m antenna for S-band uplink/downlink, which is located adjacent to the 12m antenna.

Figure 1: Wakayama Ground Station with 12m Antenna (Top, X-band) and 3m Antenna (Bottom, S-band).

Architecture

Figure 2 shows the four segments of UNIFORM-1 with the functional block diagram of the UNIFORM-1 ground station emphasized in the center. The planning

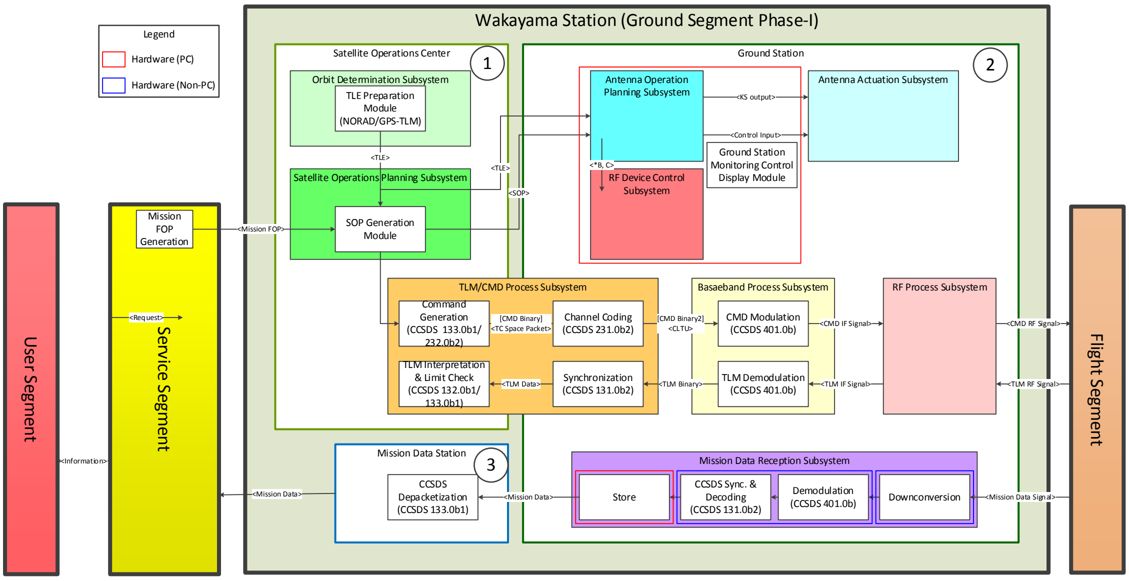

Figure 2: UNIFORM-1 Ground Segment (and Flight, Service, and User Segments).

Planning

Mission operations plans are created to satisfy both satellite-bus and mission requirements. First, pass resources are prepared by obtaining a TLE and calculating the satellite accesses to the ground station (passes). An example of pass resource information is shown in Fig. 2, where the available operations time and duration as well as azimuth, elevation, and possible loss of signals near the zenith are provided.

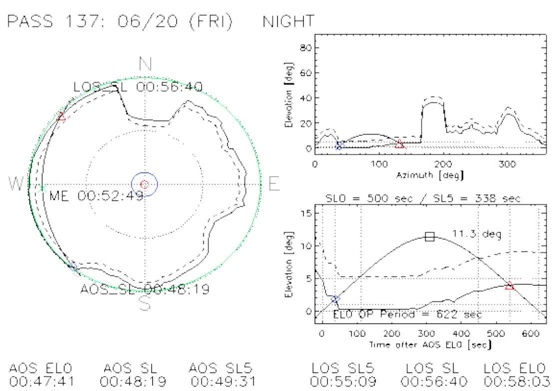

Figure 3: Pass Resource Information

Using the pass resources satellite operations procedures will be created. Figure 3 summarizes a flow of planning a satellite operations procedure (SOP) for each pass. After pass each pass resource is prepared, decisions are made based on the length of visible time combined with overall antenna elevation. If the elevation is high enough over long visible time, full TT&C operations are possible. If the elevation is low, then such pass may be operational for telemetry (TLM) monitoring but not for sending commands (CMD). Table 2 summarizes each operation type based on visibility. Note that the 3m antenna elevation information is included in the visibility (CMD).

Table 2: Visibility and Operation Type

Visibility (TLM)	Visibility (CMD)	Operation Type
No	No	NA
Yes	No	NA
Yes	No	Telemetry Monitoring
Yes	Yes	Command and Telemetry
Yes (long)	Yes (long)	Command and Telemetry Mission Data Downlink

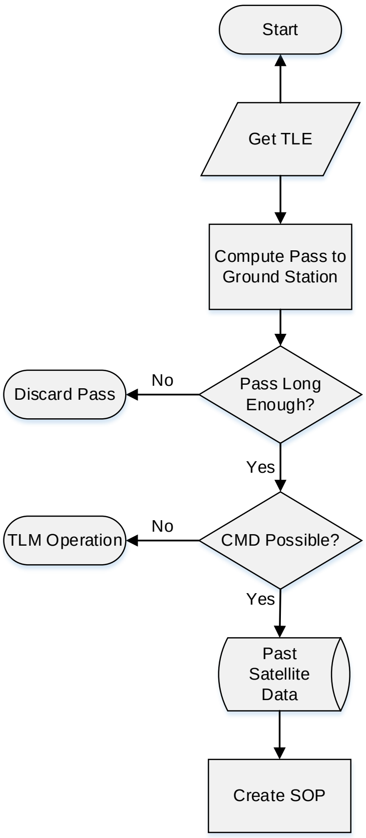

Figure 4: Satellite Operations Procedures (SOP) Generation Flow

Operations

The mission operations consist of ground station operations and satellite operations. The role of the ground station operations is to ensure that the communication line between the ground and the satellite is established and maintained during each pass. The role of the satellite operations is to send appropriate command to the satellite while monitoring its housekeeping (HK) data to ensure that the satellite is fully functional, and that in case of emergency necessary contingency actions can be taken.

The previously obtained pass resource can be used as an input file to the antenna tracking, and each SOP, being a document, does also act as an input file to the TT&C software developed for UNIFORM-1. Therefore once a SOP is made the whole mission operations procedures are defined, and the actual satellite operations will be done by following each line of the SOP, as shown in Fig. 5, where each line indicates comments, telemetry to be checked, and command to be sent. Additionally telemetry information is also monitored through quick look (QL) windows as shown in Figure 6. The command window and telemetry window are separately displayed in different terminals so that one operator focuses on the command window while other members monitor telemetry.

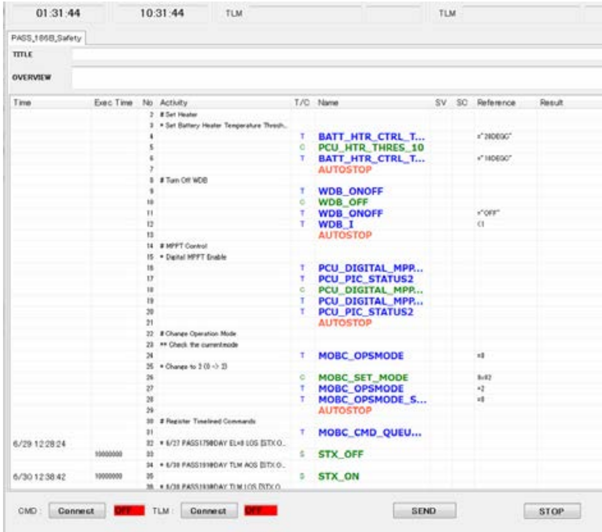

Figure 5: Example of Satellite Operations (TT&C) Terminal.

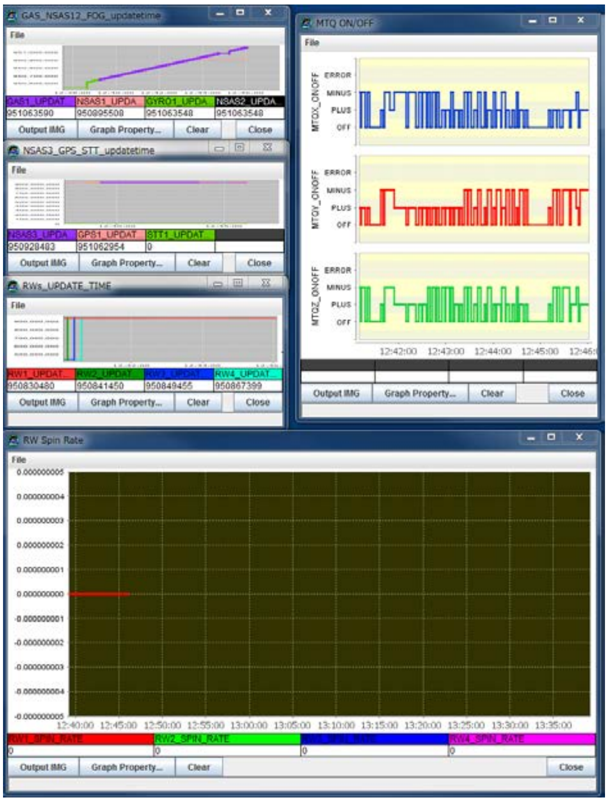

Figure 6: Example of Quick Look (QL).

POST-PROCESSING

Once each pass ends, the downlinked telemetry and mission data are stored in database and processed to generate engineering data which is understandable and analyzable to satellite engineers and mission scientists. The mission data is distributed through an FTP server to designated members, and they will further process the data to apply wildfire-detecting algorithms.

CONCLUSION AND FUTURE WORK

The design architecture of UNIFORM-1ground system was presented, and the software for the mission operations was introduced. Since its launch UNIFORM-1 has been successfully operated from the ground with the system described in this paper.

The software development is still ongoing so that the entire cycle of UNIFORM-1 mission operations, from mission planning to post-processing, can be done more smoothly. There are still lots of rooms to improve, such as automating the process of transferring pass resources to the ground operations, semi-automating SOP generations, etc. In addition, as UNIFORM project is aimed at creating a microsatellite constellation, future work will also include expanding the ground software system to allow for multiple satellite operations as well as ground stations.

ACKNOWLEDGEMENT

UNIFORM program is funded by the Ministry of Education, Culture, Sports, Science & Technology in Japan (MEXT). The authors would also like to thank the past and the present members of the program, as well as all the other experts from the collaborative organizations.

REFERENCES

1. H. Akiyama, "UNIFORM Project," in UN/Japan Nano-Satellite Symposium, Nagoya, Japan, 2012.
2. K. Nakau, et al. "Development of wildfire alert system for efficient fire fighting," International Workshop on Peatland Management, 2013.