MicroDragon: a Vietnamese Ocean-observation Microsatellite Based on Hodoyoshi Architecture

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MicroDragon (MDG) is a 50-kg microsatellite currently under development as a part of a collaborative space education program between Japan and Vietnam. This education program is aimed at providing students, who have no background in aerospace engineering, with an opportunity of design, assembly, integration, testing, and operations through a development of the satellite with ocean color remote sensing mission. The satellite architecture is based on technologies developed in Hodoyoshi project. In this paper the current development status of MDG is reported.

Key Words: Microsatellite, Hodoyoshi, International Collaboration

1. Introduction

Hodoyoshi project started in 2010 with the aim of creating a new paradigm for space technology development and utilization 1). By the end of the project in 2014 four microsatellites were developed to realize the concept of “reasonably reliable” mission capabilities, consisting of components and payloads design, and development and operations philosophy. The mission capabilities of Hodoyoshi architectural design 2) were demonstrated through successful operations of microsatellites UNIFORM-1, HODOYOSHI-1, 3, 4, and a space probe PROCYON 3-5).

In 2013 Vietnam and Japan started working together on a space education program. The four-year capacity building program is aimed at providing young Vietnamese engineers with knowledge and experience on satellite development. In this program a total of 36 engineers from VNSC enter the Japanese universities as graduate students to study aerospace engineering. A 50-kg class microsatellite Microdragon (MDG), as one of the product of the program, is currently being developed by the team of student engineers from VNSC and faculty members of five Japanese Universities: Hokkaido University, Tohoku University, The University of Tokyo, Keio University, and Kyushu Institute of Technology. The MDG project tries to achieve both satellite development and capacity building within a short time period by effectively leveraging technologies developed under Hodoyoshi project.

This paper introduces the overview of MDG project and its satellite, and reports the current development status.

2. Overview

MDG Project consists of six participant organizations: Vietnam National Satellite Center (VNSC), Hokkaido University, Tohoku University, The University of Tokyo, Keio University, and Kyushu Institute of Technology. Fig. 1 illustrates roles of each organization in the project. VNSC sends young technical staff members to five Japanese universities to enter graduate programs in which they study and research topics related to satellite development. Each university plays specific roles based on their expertise and satellite development experience. Hokkaido University, with its heritage of imager payloads development, contributes to mission subsystem. Tohoku University takes part in development of store & forward mission payloads and attitude determination and control technology. The University of Tokyo provides an assembly, integration, and testing (AIT) environment, for its development. Keio University is responsible for systems engineering and project management, as well as rocket interface with JAXA. Kyushu institute of Technology contributes to development of structure, thermal, and sub missions, as well as conducting environment testing such as vibration, thermal cycle, and thermal vacuum, etc.

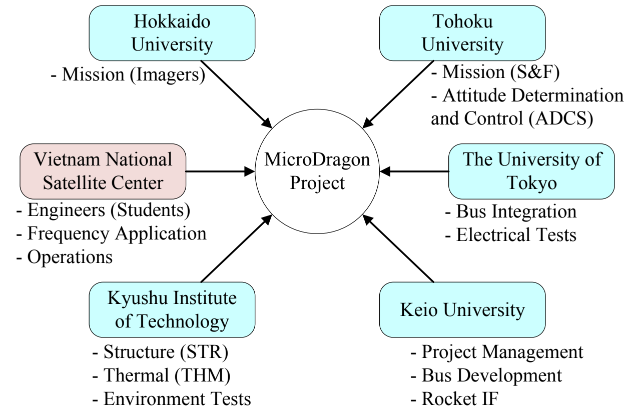

Fig. 1. Project Context

In February 2016 MDG was selected as one of the payloads for Epsilon Rocket launch in 2018, under the innovative satellite technology demonstration program of Japan. As MDG project ends in September 2017, with the student members graduating from respective schools and returning to Vietnam, it is essential that all the development activities be completed by then. A brief summary of the project milestones is shown in Table 1.

Table 1. Project Milestones

Year	Month	Event
2013	September	Project Start
2014	December	Mission Definition Review
2015	September	Preliminary Design Review
2016	September	Critical Design Review
2017	September	Launch Readiness Review Project End
2018	TBD	Launch by Epsilon Rocket
		Operations (Japan & Vietnam)

2.1. Mission Overview

The main mission of MDG satellite is ocean color remote sensing to acquire maritime information of Vietnamese coastal seas, which will be contributed to the local fishery and environmental conservations. For a 50-kg microsatellite class, it will be the first time in the world to demonstrate ocean color remote sensing. Fig. 2 illustrates an example mission scenario where MDG continuously observes along with Vietnamese coastlines.

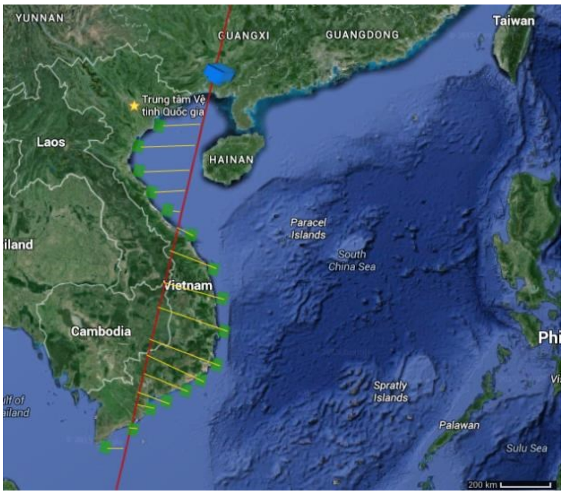

Fig. 2. A mission scenario: coastal scanning

There are two submissions as parts of research activities of student members: evaluation of Antimony Tin Oxide Coating Solar Cell (ATOCSC) charging mitigation capabilities and characterization of influence of Atomic Oxygen on sample materials (AOS).

2.2. MDG Satellite Overview

MDG satellite is a 50-kg class microsatellite. The satellite design is based on Hodoyoshi architecture and has similar bus configuration with its predecessor satellites such as HODOYOSHI-3 & 4, UNIFORM-1, and PROCYON. Fig. 3 shows the exterior view of its current design, and Table 2 summarizes basic specifications.

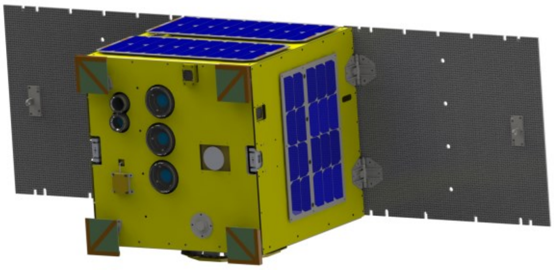

Fig. 3. MDG satellite overview (SAP deployed)

The architecture conforms to Hodoyoshi concept, which comes from a Japanese term "hodoyoshi" (which can be loosely translated to "adequate" or "good enough") that a microsatellite shall be built in a "reasonably reliable" manner instead of pursuing the same reliability as traditional large satellites.

The operational orbit is planned to be a sun-synchronous sub-recurrent orbit (SSO) of approximately 500 km altitude, with expected local time in the morning. The choice of local time is due to the avoidance of sunglint around noon and clouds in the afternoon. Maximum of 100 W power is acquired from two deployable solar array paddle (SAP) wings and body-mounted cells on five panels. Three-axis attitude control is enabled by reaction wheels for nominal operations. S-band communication (4 kbps command uplink, up to 64 kbps telemetry downlink) is used for satellite operations, and X-band communication (up to 10Mbps downlink) is used for mission data downlink. Also, UHF is used for receiving S&F data from ground.

Table 2. MDG Satellite Specifications

Size	approx. 50 cm cube (stowed)
Mass	approx. 50 kg
Orbit (Planned)	SSO, 500 km LT(AN or DN) 9:30
Attitude Control	Three-axis Earth Pointing
Power	Solar Cells Solar Array Paddles x2 Body mount Cells x5
	Generation 100 W (max) Consumption 50 W (avg) Bus Voltage 28 V unregulated 5 V Battery 5.8AH Li-ion
Communication	S-band 4kbps Command Uplink S-band 4/16/32/64 kbps Telemetry Downlink X-band 10Mbps Mission Data Downlink
Mission	Ocean Color Remote Sensing Store & Forward (UHF) ATO Coting Demonstration AOS Degradation Characterization

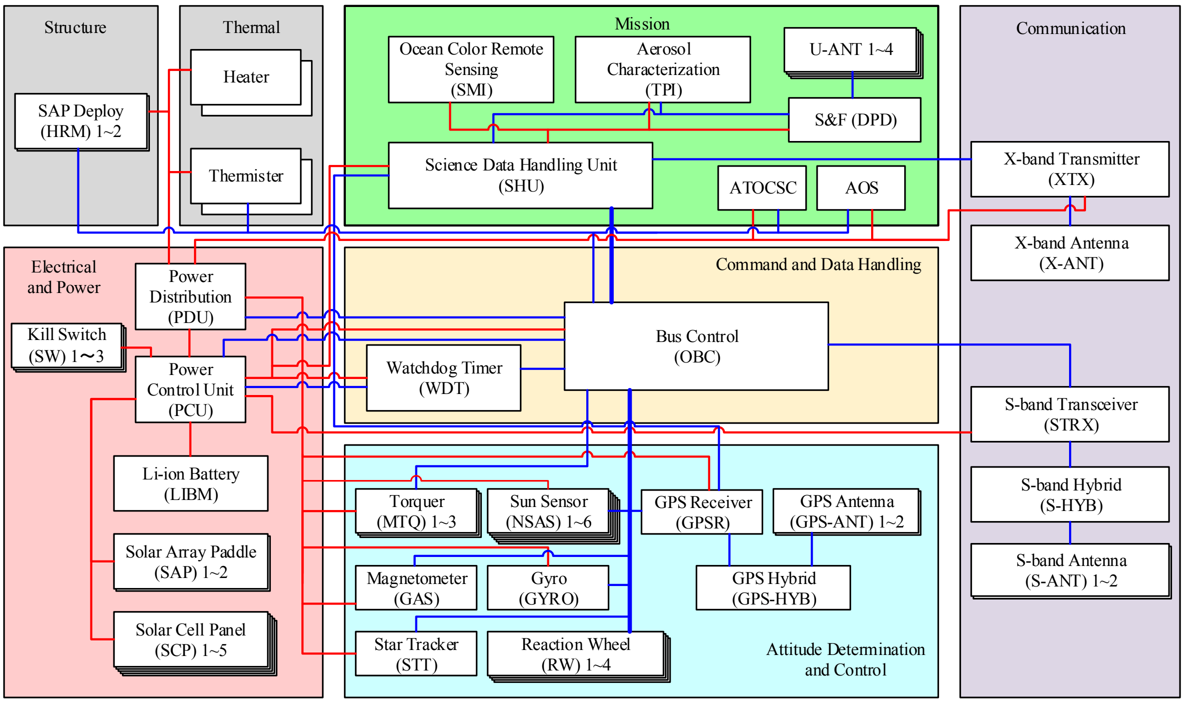

Fig. 4. Simplified MDG system block diagram (red: power, blue: data)

3. MDG Design

A simplified system block diagram of MDG is shown in Fig. 4. The satellite is composed of one mission and six bus subsystems: Mission, Communication (COM), Command and Data Handling (C&DH), Attitude Determination and Control (ADCS), Electrical and Power (EPS), Structure, and Thermal. While mission payloads are newly designed for MDG missions, bus design is based on HODOYOSHI-3,4 and UNIFORM-1, and thus most of the bus components are almost identical. Major differences include structural design, which shall conform to Epsilon rocket requirements, and software design, which is newly developed by the students. Several hardware and software designs of MDG are briefly introduced in 3.1 and 3.2.

3.1. Mission Payloads

MDG has five payloads: a space-borne multispectral imager (SMI) for ocean color observation, a triple polarization imager (TPI) for aerosol characteristic retrieval and atmospheric correction, a UHF data packet decoder (DPD), an atomic oxygen degradation measurement sample (AOS), and an Antimony Tin Oxide (ATO)-coated solar cell (ATOCSC) for demonstration of AO degradation mitigation.

Three main mission payloads are located on the surface of the panel facing toward the Earth during nominal operations, as shown in Fig. 5. SMI and TPI constitute ocean color remote sensing mission, and DPD and four UHF antennae (U-ANT) constitute store & forward mission. These main mission payloads are controlled by science data handling unit (SHU). Both SMI and TPI use liquid crystal tunable filters (LCTFs) which electronically control a wavelength to transmit, allowing for an observation of a target area in multiple wavelengths with an imager while target tracking maneuver.

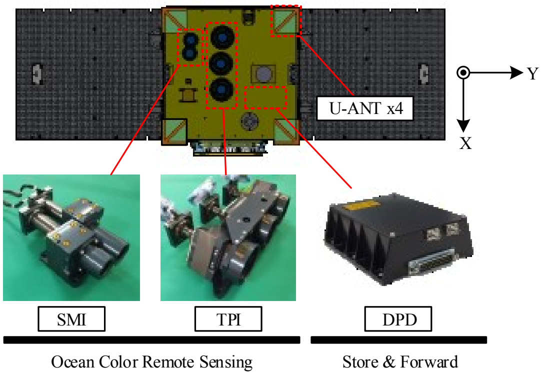

Fig. 5. +Z Panel: main mission payloads

Two sub mission payloads, AOS and ATOCSC, are located on the opposite side of main mission payloads as shown in Fig. 6, as these payloads need to be exposed to sunlight.

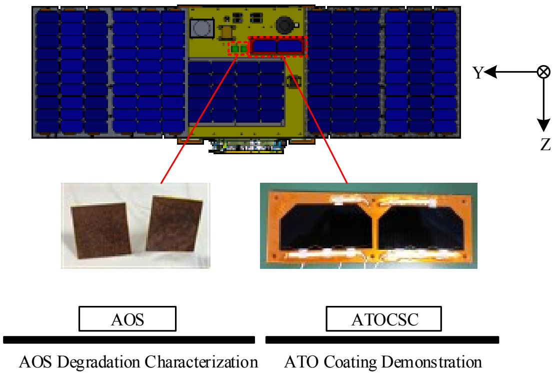

Fig. 6. -Z Panel: sub mission payloads

3.2. Bus Components

MDG bus components are basically identical to HODOYOSHI-3,4 and UNIFORM-1 except for updated structural design (e.g., S-band antenna, S-ANT) and improved radiation tolerance (e.g., gyro). Other differences include the number of onboard computer (i.e., one OBC is used in MDG while two OBCs are used in HODOYOSHI-3,4 and UNIFORM-1) and sun sensors (six NSASs in MDG, three in the previous satellites).

Structural design is also based on Hodoyoshi bus; the body has a cubic shape, and inside there are two panels in placed in T-shape to house main bus components and mission payloads as well as to improve the structural strength. Fig. 7 shows an interior view of the structural and thermal model (STM) of MDG.

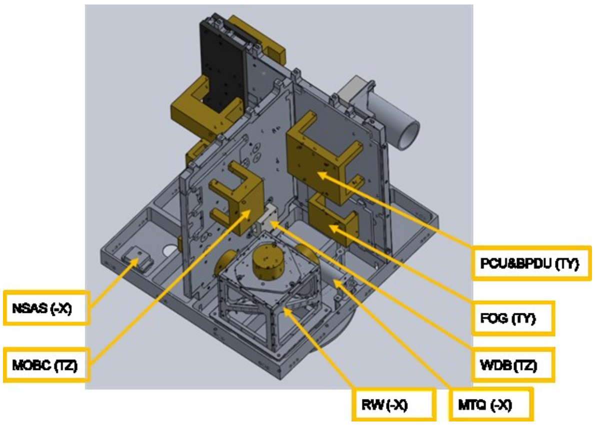

Fig. 7. An interior view of MDG STM

3.2. Software Design

From separation to mission observation, there are several stages of operations and corresponding attitudes. MDG has nine operational modes to ensure safety and operability at each stage. Fig. 8 shows a sequence diagram of MDG modes. For example, mission operations are conducted during “Earth Pointing” modes (e.g., coastal scanning as shown in Fig. 2 is achieved by changing the offset angle during offset pointing mode). Outside mission operations, MDG stays at coarse sun pointing mode, where –Z panel is directed toward the Sun, to maximize power generation. When three-axis attitude control should not be maintained due to battery conditions, it is changed to spin sun pointing mode via ground operator’s commands, or to safe mode automatically if the battery level is more critical.

Fault detection, isolation, and recovery (FDIR) is a part of the safety design of MDG flight software. For each mode, fault tree analysis is conducted to identify and prioritize failures, from which detection, isolation, and recovery algorithms are designed.

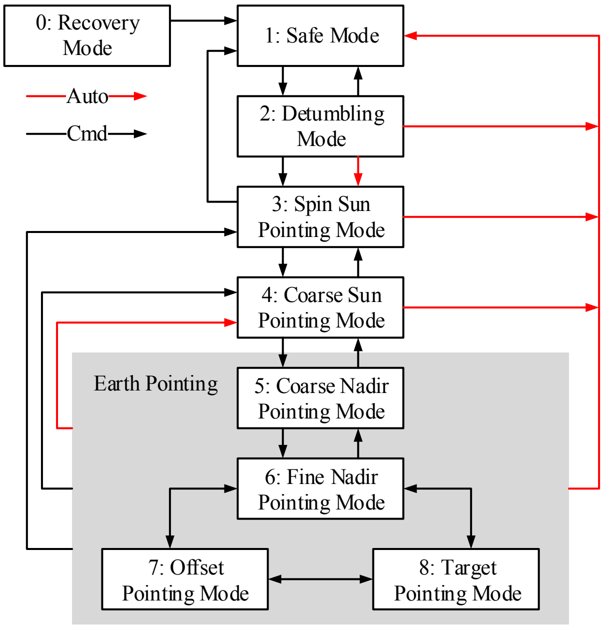

Fig. 8. MDG mode sequence

4. MDG Satellite Development

MDG was initially designed to meet requirements of H-IIA rocket. STM was developed, and vibration test and thermal balance test were conducted to evaluate structural and thermal mathematical modeling. In February 2016 MDG was selected for Epsilon launch, and new sets of requirements, such as vibration level, characteristics of a separation system, and a stowage orientation were provided. With updated rocket requirements of Epsilon, the structural design has been updated. An updated structural model is under development, and a vibration test is scheduled at the end of 2016.

An engineering model (EM) of each mission payload was developed, and their designs were verified through electrical tests both on individual and system levels. Toward the development of flight models (FMs) the design will be updated, if necessary, depending on the updated structural design.

Bus components design including harness wires was fixed, and almost all the FM components were procured. Software development for both CDH and ADCS is still at an early stage. CDH has been designing telemetry and command, and ADCS has been developing attitude determination and control algorithms for different operational modes using model in the loop simulations (MILS) and software in the loop simulations (SILS).

6. Conclusion

This paper introduced the project overview of an international collaboration program on space education between Japan and Vietnam, and reported the specifications and the current development status of the microsatellite MicroDragon (MDG). MDG completed its preliminary design and as of September 2016 the detailed design is almost finished with several parts under revision in order to satisfy

Epsilon rocket requirements. Utilization of Hodoyoshi satellite architecture provided a baseline understanding of microsatellite design to young Vietnamese engineers with no prior experience in aerospace engineering and has enabled development of MDG satellite within relatively a short period of time. A flight model of MDG is to be completed by September 2017, the end of the project, and is expected to be launched in 2018 via Japanese Epsilon rocket. By successful development completion and in-orbit operations, it is expected that this program will become a model case of a Japanese international collaboration program on space technologies applicable to emerging countries.

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