DEVELOPMENT OF ENGINEERING MODEL OF MEDIUM-SIZED APERTURE CAMERA SYSTEM

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ABSTRACT

As an international collaborative program, SaTReC*i* and ATSB are developing the Medium-sized Aperture Camera (MAC) for earth observation. The bus system for MAC is also being developed between SaTReC*i* and ATSB. Following the first model, the development of the Engineering Model (EM) of MAC was completed. The optical subsystem of EM incorporates a conventional approach of using low-expansion optical and structural materials. It is a 300-mm on-axis system with two aspheric mirrors and two spherical correction lenses. It has five linear detectors aligned on its focal plane together with proximity electronics. The electronics subsystem of EM consists of five modules; two for management and control in cold redundancy, two for mass storage and one for power supply. It was developed to have mass storage of 16 Gbits, which can be easily increased to 32 Gbits by adding memory packs for following models. EM weighs about 42 kg and consumes about 55 W of peak power including heaters.

1. INTRODUCTION

SaTReC*i* and ATSB have been developing a high-resolution imaging system, the Medium-sized Aperture Camera (MAC), as an international collaborative program since 2000. Development of four models is planned for the MAC program for risk minimization, system verification and technology absorption. Following the successful development of the first model, Test Model (TM), its Engineering Model (EM) was developed.

In 2001, the development program of its satellite bus system, MACSAT program, was kicked off between the two organizations. MAC is the primary payload of MACSAT. The launch of MACSAT is planned in 2004 into a circular near-equatorial low-earth orbit (NEqO) with inclination between 7.5 and 9 ° and altitude of 685 km.

MAC EM was integrated with MACSAT Electrical Test Bed (ETB) and Structural Model (STM) and various tests were performed. The features of MAC EM and its test results with ETB and STM are presented. The future plan is also briefly described.

2. SYSTEM OVERVIEW

MAC is a typical pushbroom system with five linear detectors aligned in parallel on its focal plane. Its ground sample distances are 2.5 and 5.0 m in panchromatic and multi-spectral bands respectively at the nominal altitude. Its swath width is greater than 20 km at this altitude. MAC consists of two subsystems: Electro-Optical Subsystem (EOS) and Payload Management Subsystem (PMS).

MACSAT is a three-axis stabilized small satellite that has a hexagonal shape. It weighs about 200 kg including MAC and provides more than 330 W at the end of life from three deployable solar panels. Its attitude control and determination accuracy and off-nadir imaging capability allow generation of stereo images and image maps of 1:25,000 scales. Key features of MAC and MACSAT are summarized in Table 1 and 2 respectively.

Imaging channels	1 panchromatic (PAN) 4 multi-spectral (MS)	
GSD (m)	PAN MS	2.5 5.0
Swath width	≥ 20 km	
MTF (%)	PAN MS	≥ 8 ≥ 15
SNR	≥ 70	
Signal quantization	8 bits	
Signal gain	Programmable	
Mass storage	32 Gbits (16 for EM)	
Mass	≤ 50 kg	
Peak power consumption	≤ 60 W (all heaters on)	

[Table 1] Key Features of MAC

Orbit	Near-Equatorial
Nominal altitude	685 km
Inclination	7.5 ~ 9 °
Mass	≤ 200 kg
Envelope	ϕ1200 mm × 1200 mm
Power generation	≥ 330 W @ EOL
Battery	NiCd, ≥ 6Ah × 3
Attitude control accuracy	0.2 °
Off-axis imaging	Up to ± 30 °
Communication	1.2, 9.6 & 38.4 kbps (S-band)
Image Data D/L	30 Mbps (X-band)
Mission lifetime	≥ 3 years

[Table 2] Key Features of MACSAT

3. ENGINEERING MODEL (EM) DEVELOPMENT

3.1 Design Modifications from TM

Two major design modifications were made since the program kick-off. The first one is the telescope configuration. Unlike TM of all-Aluminum design approach, EM telescope is a conventional low-expansion system [1]. During TM development, it was found that advantages of Aluminum mirrors in terms of fabrication time and cost were not significant compared with traditional low-expansion glass mirrors. In addition, an all-Aluminum optical system requires a rigorous active thermal control for athermalization [2].

The second one is the implementation of heaters. Since the MACSAT program kick-off, trade-off studies and analyses showed that the maximum-sun-tracking orientation is optimum for MACSAT due to power requirement. In this orientation, the telescope aperture is exposed to deep space and its average temperature is much lower than the target assembly temperature of the telescope. To raise its average temperature and to minimize the temperature gradient, heaters at three different locations were implemented. They are controlled by PMS and their average power consumption is about 9.0 W.

3.2 Electro-Optical Subsystem (EOS)

EOS includes telescope, focal plane assembly (FPA) and signal processing unit (SPU). The telescope is made of two aspheric mirrors and two corrections lenses. Mirrors are made of the low-expansion glass, AstroSitall, and lenses are made of BK7. Its structural elements are made of different materials such as Super Invar, Invar, Aluminum, Stainless Steel and Titanium to protect optical elements during launch and to maintain the optical performance during operation.

Five identical linear detector dies with 8,192 active pixels are used for five spectral bands. Two adjacent pixels are aggregated for multi-spectral bands. These detector dies were aligned and bonded on a ceramic substrate that has proximity electronics. Five spectral filters were bonded to the ceramic substrate in front of detector dies.

SPU is responsible for power provision to FPA, operation of detectors, processing and formatting of video signals and transmission of digital image data. It consists of four small modules that are assembled together and integrated to the telescope directly.

3.3 Payload Management Subsystem (PMS)

PMS includes Thermal and Power Unit (TPU) and Management and Memory Unit (MMU). TPU provides power to different electrical units generated from MACSAT primary power. It also includes switches for heater on/off control by MMU and it supports MMU in telemetry collection.

MMU has two control modules (MCM1, 2) in cold redundancy and two memory modules (MSM1, 2). MCM1 and 2 are responsible for overall management of MAC, image data storage, maintenance and transmission and communication with the MACSAT bus system. Two different processors are used for each MCM: TS68EN360 and XPC860. It synchronizes its imaging operation to the pulse-per-second signal from MACSAT GPS.

Each MSM was designed to provide a total storage capacity of 16 Gbits. It contains four memory packs made of 64 Mbits SDRAM devices. It was designed with a multiple level of tolerance to bypass damaged memory blocks or memory packs. Transmission of stored image and real-time quick-look data is supported at a speed of 30 Mbps.

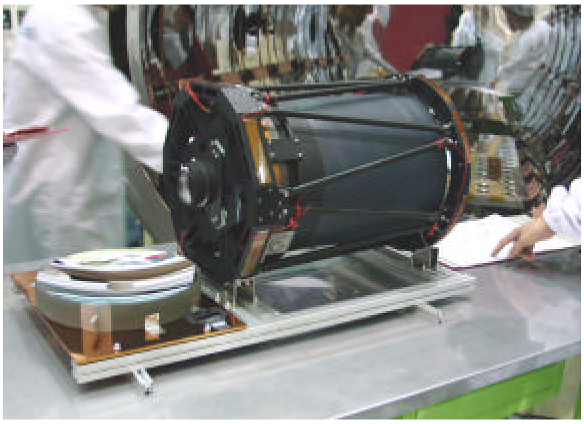
4. EM INTEGRATION & TESTING

EM PMS was integrated with MACSAT ETM and its electrical interface and functionality was verified. Dummy loads were used for SPU and heaters during this test. The electrical interface between PMS and SPU and functionality of SPU was verified using a PCI-based interface card.

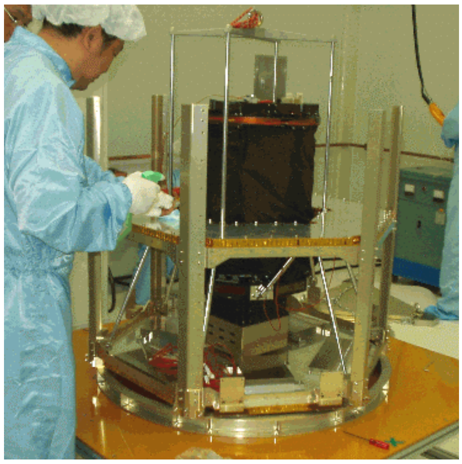
A thermal vacuum test of EM telescope and a thermal cycling test of EM FPA were performed. No degradation of its optical performance or damage of detector dies was observed from these tests. Figure 1 shows EM telescope in bake-out preparation. EM EOS with a dummy SPU load was integrated with MACSAT STM and a random/sine vibration test was performed. Figure 2 shows EM EOS being integrated with MACSAT STM.

After vibration test, EM EOS was disintegrated from MACSAT STM for MTF measurement of telescope. Some degradation of MTF was observed from this measurement. From an analysis of the measured data, it was concluded that the secondary mirror slipped during the vibration test. The design modification of the secondary mirror assembly is in progress. Flexures will be used for the secondary mirror as for the primary mirror.

The total mass of MAC EM was measured at about 41.9 kg (EOS 35.5 kg and PMS 6.4 kg). The peak power consumption was measured about 55.4 W when all heaters are operational. In normal operation, the peak power consumption will be less than 50 W.



[Figure 1] EM Telescope in Test Preparation



[Figure 2] Integration of EM EOS with MACSAT STM

5. FUTURE PLAN

In addition to design modification of the secondary mirror assembly, some additional design modifications, design optimization and refinement of assembly methodology are being conducted for the development of MAC Qualification Model (QM) and Flight Model (FM). A vibration test of the new secondary mirror assembly is planned in February 2003.

For the MACSAT bus system, QM manufacturing of electrical modules is in progress both in Korea and in Malaysia by SaTReC*i* and ATSB engineers. According to the current plan, the QM development will be completed by mid 2003 and MACSAT FM will be ready for launch by early 2004.

6. REFERENCES

1. E. Kim and *et al*, A high-resolution multi-spectral imaging system for small satellites, *3rd IAA Symposium on Small Satellites for Earth Observation*, Apr. (2001)
2. H. S. Yang and *et al*, Aluminum-based high-resolution camera for a small satellite, *SPIE Int. Symp. On Optical Science and Tech.*, *Airborne Reconnaissance XXVI*, Jul. (2002)