DEVELOPMENT OF EARTH OBSERVATION SENSORS FOR SMALL SATELLITES IN SATREC INITIATIVE

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ABSTRACT

Satrec Initiative (SI) has recently completed the Flight Model (FM) of the Medium-sized Aperture Camera (MAC) system. The MAC system produces high-resolution images in one panchromatic and four multi-spectral bands with ground sample distances (GSDs) of 2.5 m and 5.0 m, respectively. The MAC system is scheduled to be launched into a near-equatorial orbit on the Falcon I launch vehicle in 2005 as the primary payload of RazakSAT. SI is developing a smaller electro-optical sensor, the IRIS system for the Singaporean satellite, X-SAT. The IRIS system produces high-resolution images in three multi-spectral bands with a GSD of 10.0 m. Its Engineering & Qualification Model (EQM) is presently under development. SI also performs research for more advanced electro-optical sensors. One example is the development of an off-axis three mirror anastigmatic (TMA) system for various applications. This program was initiated in late 2004 under financial support from the Korean Ministry of Commerce, Industry and Energy.

1. INTRODUCTION

Since its foundation in 2000, SI has provided cost-effective total solutions for Earth observation missions using its experience and expertise in high-performance satellite platforms, high-resolution sensors, and image data receiving and processing systems.

Current activities within SI in the field of electro-optical sensors are the development of the MAC system and the IRIS system. Recently, SI has completed the development of MAC FM successfully with extensive functional tests, characterization, and environmental tests. It can produce high-resolution panchromatic and multi-spectral images with GSDs of 2.5 and 5.0 m, respectively at a nominal altitude of 685 km. The IRIS system is an ideal high-resolution imaging system for micro-satellites. It can produce multi-spectral images with a GSD of 10.0 m at a nominal altitude of 685 km. SI is currently developing IRIS EQM.

SI has vigorously conducted internal and national research programs for electro-optical sensors of better performance. These research programs include the development of a real-time compression and encryption module for high-speed image data, a high-speed phased-array antenna system, storage modules with high capacity, and an off-axis TMA system for next generation sensors. Other activities related to electro-optical sensors include the development of star sensors, test equipment for star sensors, and sophisticated collimators for sensor testing.

SI will continue its research and development activities to provide solutions for electro-optical sensors with better performance and more advanced functions, especially for small and micro-satellites. In this paper, activities within SI are described with recent results from various programs.

2. EARTH OBSERVATION SENSORS

2.1 Medium-sized Aperture Camera System

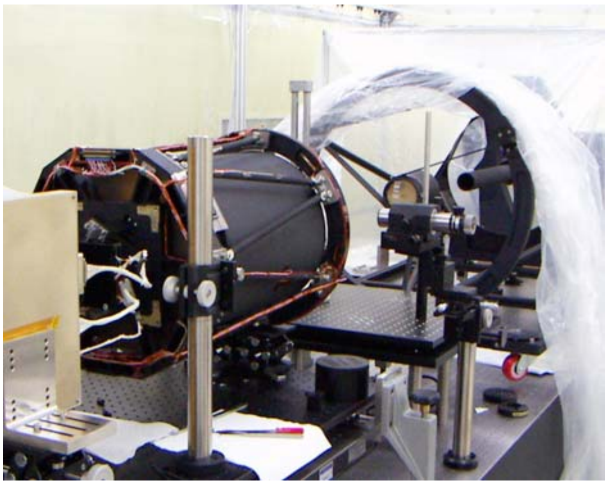
The development of the MAC system was initiated in April 2000. Since the program kick-off, four models were developed until March 2005. The MAC system is the primary payload of the Malaysian small satellite RazakSAT (former MACSAT), which was jointly developed by SI and Astronautic Technology (M) Sdn. Bhd. RazakSAT is planned to be launched into a near equatorial orbit on the Falcon I launch vehicle in 2005.

The MAC system consists of two subsystems of optics and electronics. The optics subsystem includes telescope, focal plane assembly, and signal processing module. The electronics subsystem consists of power supply module, two redundant control modules, and two mass storage modules. Table 1 shows key specifications of the MAC system.

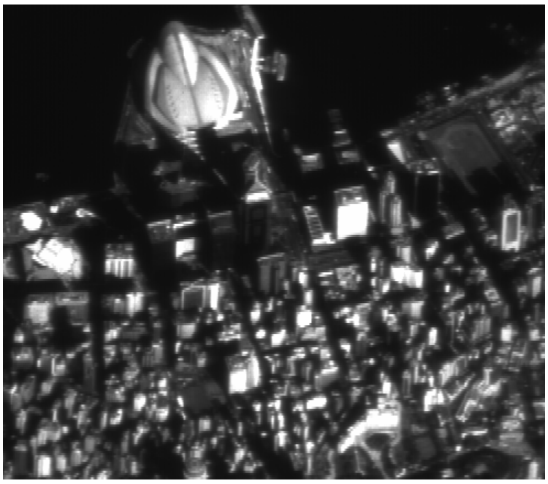
Parameter	Feature	Remark
Imaging bands	One panchromatic (PAN) Four multi-spectral (MS)	Visible & near infrared
Instantaneous field-of-view (μ rad)	PAN : 3.65 MS : 7.30	2.5 m GSD @ 685 km 5.0 m GSD @ 685 km
Field-of-view	1.675 degrees	> 20 km swath @ 685 km
Aperture diameter	300 mm	
Modulation transfer function	PAN ≥ 8 % MS ≥ 15 %	@ Nyquist frequency
Signal-to-noise ratio	≥ 70	
Mass (kg)	42.1	
Volume (mm)	Optics : ϕ450 × 755 Electronics : 320 × 215 × 162	
Power consumption	Peak : 63.3 W Standby : 12.8 W	With all operational heaters
Storage capacity	32 Gbits	
Downlink speed	30 Mbps	QPSK

[Table 1] Key System Specifications of MAC System

Extensive test and characterization was performed during the development of MAC FM. The modulation transfer function (MTF) of the optics subsystem was measured before and after an acoustic test. The line-of-sight difference between panchromatic and multi-spectral bands was measured with accuracy. The radiometric characteristics of focal plane assembly and signal processing module were measured. Functional test and software verification was performed for the electronics subsystem with focal plane assembly and signal processing module of the optics subsystem and electronics modules of the RazakSAT bus. An end-to-end imaging test was performed using the full mass storage capacity. Finally, random vibration, thermal vacuum, and acoustic tests were performed successfully for the complete RazakSAT. Figure 1 shows the FM optics subsystem during MTF measurement and Figure 2 shows a part of an image acquired during the end-to-end imaging test.



[Figure 1] MTF Measurement for MAC FM



[Figure 2] Image from End-to-End Imaging Test with MAC FM

2.2 IRIS System

The development of the IRIS system was initiated in April 2002. The IRIS system is the primary payload of the Singaporean micro-satellite X-SAT. X-SAT is planned to be launched into a sun-synchronous orbit in 2007. Currently, the integration and test at system level is in progress in SI for IRIS EQM.

Parameter	Feature	Remark
Imaging bands	Three multi-spectral	Visible & near infrared
Instantaneous field-of-view (μ rad)	14.60	10.0 m GSD @ 685 km
Field-of-view	4.2 degrees	> 50 km swath @ 685 km
Aperture diameter	120 mm	
Modulation transfer function	≥ 15 %	@ Nyquist frequency
Signal-to-noise ratio	≥ 100	
Mass (kg)	< 12.0	
Volume (mm)	Optics : ϕ180 × 530 Electronics : 320 × 210 × 150	
Power consumption	≤ 25 W	
Storage capacity	8 Gbits	
Downlink speed	12.5 / 25 / 50 Mbps	QPSK, selectable speed

[Table 2] Key System Specifications of IRIS System

The IRIS system also consists of two subsystems of optics and electronics. The optics subsystem includes telescope and focal plane assembly. The electronics subsystem consists of signal processing module, power supply module, two redundant control modules, and a mass storage module. A unique feature of the IRIS system is its configuration flexibility. Two identical optics subsystems can be integrated with one electronics subsystem to enhance its imaging capability with minor modification. Two optics subsystems can be used either to acquire images with wider swath width or to generate in-track stereo images in a single pass. Table 2 shows key specifications of the IRIS system.

2.3 Three-Mirror Anastigmatic System

In November 2004, SI was selected to develop a three mirror anastigmatic (TMA) system by the Korean Ministry of Commerce, Industry, and Energy as a national research program. The development of two prototype models is planned and the optical and opto-mechanical design for the first model is in progress in SI.

This TMA system is an off-axis system with an optical aperture of 120 mm. SI's goal is to acquire the technology for design and precision alignment of off-axis optical systems and to apply this technology for next-generation imaging systems. Hyper-spectral imaging systems and super-swath imaging systems can be examples.

3. OTHER ACTIVITIES

3.1 Development of Star Sensors

SI has successfully developed a prototype star sensor with an attitude determination accuracy of better than 10 arcsec for a Korean defense agency. Along with this star sensor, dynamic test equipment with software was developed and delivered. The dynamic test equipment can be used to perform the functional test and software verification of star sensors and the integrated functional test of attitude determination and control algorithms either in an open loop or in a closed-loop configuration.

Based on this experience, SI is currently developing a miniature commercial star sensor for small satellites with an accuracy of better than 10 arcsec. This star sensor can be configured to use two identical optical heads with a single electronics unit.

3.2 Ground Support Equipment

SI has developed sophisticated large collimators for the testing of electro-optical sensors on ground in collaboration with the Korea Research Institute of Science and Standards (KRISS). The first collimator that has an aperture diameter of 450 mm was installed in SI and used for the alignment and testing of MAC FM. The second collimator that has an aperture diameter of 900 mm was installed in KRISS for the testing of large optical mirrors.

4. REFERENCES

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