KITSAT-3 Development and Initial Operations Results

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Abstract: The development of a low earth orbit microsatellite is recognized as a good means of enhancing the technological capability, to gain experience and to train engineers to acquire knowledge and experience in space systems. Most developed countries in space technology do not allow the transfer of critical space technologies such as technology involved in attitude determination and control systems. And the export of critical components and equipment such as high precision attitude sensors is tightly controlled. Therefore it is inevitable to independently acquire self-design and manufacturing capability to implement a satellite mission. The KITSAT-3 program was aimed at verifying the capability to design, develop and operate an indigenous microsatellite system, which includes such critical technologies and associated components and equipment, as well as train engineers.

KITSAT-3 was launched on May 26, 1999 using the Indian launcher PSLV-C2. The operations team has successfully performed a full functional checkout during the launch and early operations phase and the satellite is presently in a normal operations mode. This paper introduces the KITSAT-3 program and the results of the initial operations.

1. Introduction

KITSAT-3, which was launched on May 26, 1999 by the Indian PSLV-C2 launcher as a piggyback payload into a 730km sun-synchronous orbit, is successfully operating and has produced excellent quality multispectral images.

The main goal of the KITSAT-3 program was to develop and perform the in-orbit test of an indigenous satellite system. KITSAT-3 was designed using the knowledge and experience acquired from the previous KITSAT programs(Park et.al., 1995; Park et.al., 1997). The KITSAT-3 spacecraft bus can accommodate different payloads for various missions using a common standard interface.

Figure 1 and Table 1 show the configuration and specifications of the KITSAT-3, respectively.

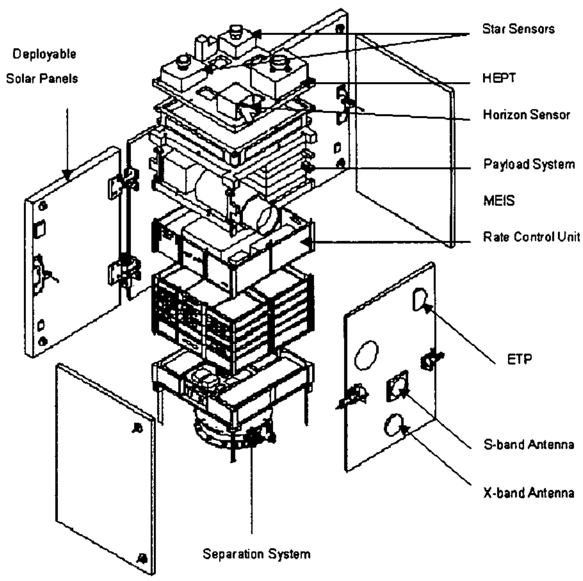

Figure 1. Structural Configuration

The mission objectives for the KITSAT-3 program can be summarized as follows: to develop a 3-axis stabilized satellite; to develop a low cost remote sensing satellite system; to acquire scientific data for space plasma research; and to continue the education and training of satellite engineers. In order to achieve these objectives the KITSAT-3 satellite was designed to perform engineering tests in the following key technologies: 3-axis stabilized attitude control; common bus architecture; deployable solar panels; high speed data transmission system; and solid state mass memory system. The above tests were performed successfully during the initial operations and functional checkout.

Table 1. Specifications

Dimension	495 × 604 × 852 mm
Weight	~ 110 kg
Power	150 Watt (@EOL)
Attitude Control	3-axis Stabilized
Pointing Accuracy	< 0.5 deg
Frequency Bands	U/L : VHF D/L : UHF, S/X-band
Main Computer	Intel i80960 (KASCOM)
Payloads Multispectral Earth Imaging System (MEIS) Space Environment Scientific Experiment (SENSE) + Radiation Effects on Micro-Electronics (REME) + High Energy Particle Telescope (HEPT) + Electron Temperature Probe (ETP) + Scientific Magnetometer (SMAG)	

2. KITSAT-3 System

KITSAT-3 can be classified as a technology demonstration satellite as it performs engineering tests in new technologies for satellite systems. However it also carries payloads which provide valuable data for research in remote sensing and space science. The details of the payloads will be described in the following subsections.

KITSAT-3 was originally planned for launch in mid 1997, but was delayed for 2 years due to difficulties in the launcher selection process. This delay, though, allowed a longer integration and test period, which resulted in a notable improvement in the system reliability.

The following figures show the system block diagram and the external view of KITSAT-3, before and after the solar panels are deployed.

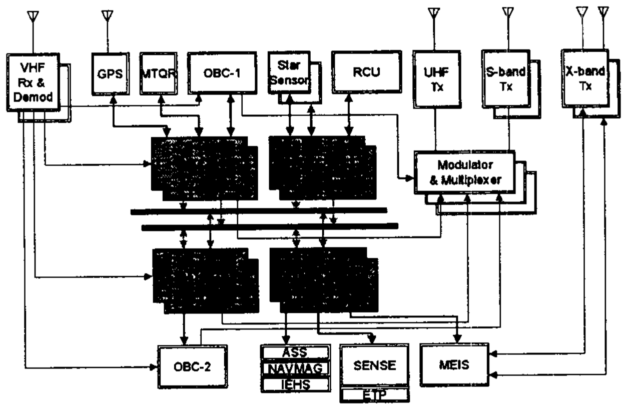

Figure 2. System Block Diagram

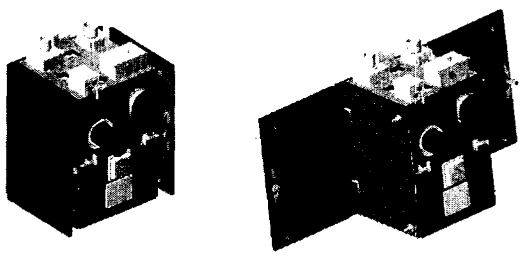

Figure 3. External View of KITSAT-3

2.1 Payloads

1) Multispectral Earth Imaging System (MEIS)

The Multi-Spectral Earth Imaging System (MEIS) is a pushbroom type linear scanner providing multispectral images with a swathwidth of about 50 km and a Ground Sampling Distance (GSD) of 13.8m at an operational altitude of 730 km(Yoo et.al., 1996).

Spectral bands similar to the SPOT XS and the Landsat TM (B2, B3 and B4) were chosen for practical use of the MEIS data in existing applications as well as for measurement of the quality of the MEIS data compared to the commercial systems. The radiometric performance was improved by using low noise CCDs and analog readout electronics. The offset and gain controls allow a wide dynamic range for different levels of target brightness. The SNR is greater than 100 for a target reflectance of 25% at a sun elevation angle of 65 degree in all spectral bands. The system MTF value is better than 15% at the Nyquist sampling frequency.

The MEIS consists of the optical subsystem, camera electronics subsystem including the focal plane assembly, analog signal processing unit, high speed digital interface unit, power distribution and survival heater unit, and the payload data transmission subsystem.

Except for the optical subsystem, which was designed and assembled in cooperation with the CSIR (Center for Scientific and Industrial Research) in South Africa, all subsystems were developed at SaTReC.

An X-band transmission scheme was used for downloading imagery with a solid state recorder used for the on-board storage of the imagery. The solid state recorder was jointly developed with Samsung Electronics using SRAM and Flash memories specially packaged for the KITSAT-3 program.

2) Space Environment Scientific Experiment (SENSE)

The Space Environment Scientific Experiment (SENSE) was developed for the *in-situ* measurements of the space environment(Shin et.al., 1996).

The SENSE consists of four small experiment modules: the High Energy Particle Telescope (HEPT), Radiation Effects on Micro-Electronics (REME), Electron Temperature Probe (ETP), and Scientific Magnetometer (SMAG).

The HEPT measures the energy of electrons, protons, and alpha particles in the 0.25 MeV to 60 MeV range and also determines the incident angle of incoming particles. The REME monitors the effects of radiation on microelectronics using a dosimeter. The SMAG is an improved version of the magnetometer used for attitude determination. The resolution has been improved from 30 nT to 5 nT. The flux gate type sensor is positioned outside the satellite to reduce magnetic field disturbance caused by the satellite electronics. The ETP is designed to measure the density and variation of low energy electrons at the 1eV level. The ETP can also measure the floating potential so as to monitor the spacecraft charging status and its effects.

2.2 Spacecraft

Table 2 summarizes the key features of KITSAT-3 at the subsystem level.

Table 2. Key Features of the KITSAT-3 Spacecraft

Subsystems	Key Features
Attitude Determination & Control Subsystem	Three-axis stabilization based on four reaction wheels Pointing Accuracy : < 0.5° (2 σ) Stability : 0.014 °/sec Pointing Knowledge : 1 arcmin (1 σ)
Electrical Power Subsystem	GaAs/Ge solar cells on honeycomb substrate NiCd batteries (8 Ahr) Peak Power Tracking (PPT) Approach Solar power > 150 W @ EOL
Command & Data Handling Subsystem	Two on-board computers (32/16 bits) Modular telemetry control network Data network : 38.4 kbps Analog Telemetry channels : upto 192 Digital Telemetry channels : upto 114
RF Subsystem	9600 bps / 1200 bps VHF TT&C uplink 38.4 kbps / 9600 bps / 1200 bps UHF and S-band TT&C downlink
Structure & Thermal	Modular structure Aluminum honeycomb panels Passive thermal control design

KITSAT-3 is 3-axis stabilized using reaction wheels in zero momentum bias, which provides accurate and agile attitude control for imaging operations. The Attitude Determination and Control Subsystem is operated in a closed-loop manner using the on-board computers. The attitude is determined using a magnetometer, a sun sensor, fiber optic gyros and a star sensor(Kim et.al., 1995; Kim et.al., 1997).

The Electrical Power Subsystem is designed to provide high reliability and sufficient power to operate the spacecraft and the payloads for a 3 years mission lifetime. KITSAT-3 uses deployable solar panels, which can generate more than 150 Watts during the sunlit period by controlling the satellite attitude into a position where the solar panels point toward the Sun.

The Command and Data Handling Subsystem processes telemetry and telecommands and provides an on-board data handling network for the spacecraft bus and payloads. The C&DH subsystem of the platform consists of one primary on-board computer, one secondary on-board computer, four Modular Telemetry and Command modules and two Modular Command, Data Handling networks and a GPS based Satellite Navigator.

The RF Subsystem provides the TT&C communications for the spacecraft. It consists of two VHF uplink channels, one UHF and two S-band downlink channels. All communication antennas were designed as omni-directional for reliable communications even with an unstable attitude or during attitude maneuvers.

The structure was designed based on a modular concept to encompass not only the current KITSAT-3 mission, but also a diverse possibility of future missions. The modular design allows the reconfiguration of the payload modules with minimum impact on the spacecraft. KITSAT-3 has a rectangular shape structure, stacked-type with separate spacing for the bus system, payload module and sensor platform. As shown in figure 1, the payload modules are located between the sensor platform and the rate control unit.

KITSAT-3 uses a passive thermal control scheme to maintain the temperature of all equipment and components of the satellite within an allowable temperature range. The Thermal Control Subsystem was designed using various thermal coating materials with certain absorptivity and emissivity ratios, which allow the control of the incoming and radiating heat flux at the external surfaces. The KITSAT-3 thermal model was developed using an in-house built program. The data acquired from the in-orbit telemetry confirmed the accuracy of the thermal model and program.

3. Launch and Initial Operations

3.1 Launch and Early Operations

KITSAT-3 was shipped to the launch site 26 days before actual launch. Five engineers performed the final checkout and the installation for three weeks at the launch site. KITSAT-3 was launched at 15:22 of May 26, 1999 (in KST) by the Indian PSLV-C2 and was separated from the launcher 17 minutes 46.34 seconds after lift off.

As KITSAT-3 does not carry an on-board propulsion subsystem, the mission orbit was determined by the moment of separation from the launcher. The KITSAT-3 orbit has a 67day repeat cycle. For imaging operations however, by using the attitude control system, the revisit period can be shortened to 2 days in the short term and 34 days in the long term.

The spacecraft attitude was first captured and 3-axis stabilized on May 30 and the solar panels were deployed on June 24. The first imaging was performed on May 31, which was only 5 days after launch.

Most of the functional checkout was carried out within two months and all the subsystems were found to be functioning normal.

3.2 Operations

During the normal operations mode, the spacecraft attitude is controlled to generate maximum power. When an imaging task is scheduled, the ADCS controls the attitude to point the camera toward the target area. As soon as the programmed imaging task is completed, the spacecraft attitude returns to the normal operations mode. During nighttime passes, the attitude is controlled to an Earth pointing position for better communications.

KITSAT-3 can take at maximum an image 360 km long every two days. The amount of data taken is limited by the downlink capability. The SENSE can be operated in a 100 % duty cycle.

Figure 4 describes the different operation modes.

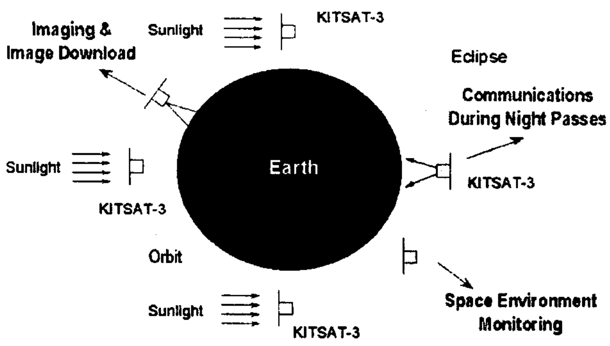

Figure 4. Operation Mode

3.3 Operations Results

Figure 5 shows the sub-sampled full scene image over Cairo, Egypt taken on June 14, 1999 with a 10degree cross-track tilt. Figure 6 shows a full resolution sub-scene image over Cairo international airport.

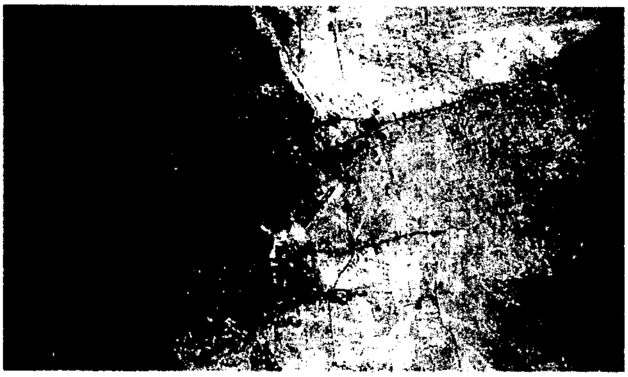

Figure 5. Image of Cairo (3456 x 2048 pixels)

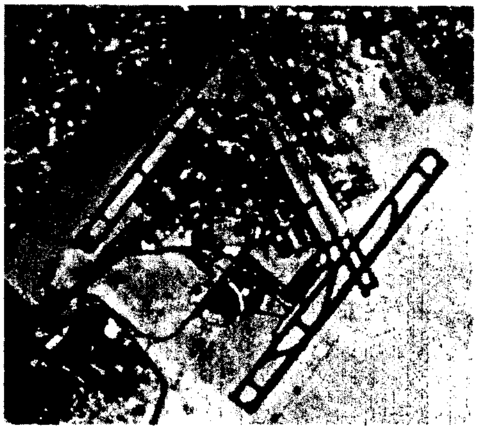

Figure 6. Sub-Scene Image of Cairo International Airport in Full Resolution (400 x 360 pixels)

The quality level of the KITSAT-3 imagery data requires evaluation by remote sensing scientists, however the functionality of the MEIS has been proved.

In order acquire any scientific meaning from the SENSE data, data must be gathered and analyzed for a long period. However, during the test period of the SENSE, the HEPT could detect high energy particles in the polar region, the SMAG could measure the geomagnetic field which is compliant with the conventional IGRF model, the REME could detect total dose variation, and the ETP could measure electron density.

4. Conclusion

The development of a low Earth orbit microsatellite is recognized as a good means of enhancing the technological capability, to gain experience, and to train engineers with knowledge and experience in space systems.

The successful operations of KITSAT-3 verified not only the mission operations procedures, but it also showed that all the subsystems including attitude control, electrical power, command and data handling, RF, structure, thermal control as well as ground stations were functioning as designed. The KITSAT-3 program provided SaTReC with critical space technologies in precision attitude control, Earth imaging instruments, solar panel deployment, high speed image downlink and so on.

The success of KITSAT-3 shows the unlimited possibilities of microsatellites including high resolution earth observation. The KITSAT-3 program has also contributed to the enhancement of the national space development capability. KITSAT-3 can be marked as one of the best microsatellites for Earth observation. It is expected that the KITSAT-3 system and the experience and technology gained though the program can provide the basis for SaTReC to take part in the international space market with technological competence in the near future.

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