Mission Overview of Engineering Test Satellite, KITSAT-3

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Abstract

SaTReC has developed and operated two micro-satellites, KITSAT-1 and 2 successfully. Since middle of 1994, the third satellite, KITSAT-3, has been being developed. Its main mission is to perform on-orbit engineering tests of core technologies for high performance small satellite. This includes 3-axis stabilization, high speed data transmission and solar panel deployment. In addition to engineering tests, there are 3 payloads; Earth Observation System(EOS) using a linear CCD camera with 17m resolution and 3 spectral bands, Space ENvironment Scientific Experiment (SENSE) and KITSAT Data Collection System (KDCS). KITSAT-3 is planned to be launched in middle of 1997. This paper briefly describes its mission, system configuration and operation plans for payloads and bus system of KITSAT-3.

1. Introduction

Satellite Technology Research Center (SaTReC) launched two micro-satellites, KITSAT-1 and KITSAT-2, in 1992 and 1993, respectively. KITSAT-1 was developed under a collaborative project with University of Surrey in UK. KITSAT-2 was developed and tested in Korea with major changes on payloads and the corresponding bus systems. Both satellites are carrying Earth imaging system, store and forward packet communication system and several experimental modules. They are still operating in normal condition.

KITSAT-3 has been defined as an engineering test satellite. Its main mission is to provide an opportunity to develop various technologies toward high performance microsatellite and test them on the LEO orbit for practical qualifications. At the same time, the system should meet the requirements of low cost, low power and small size. Technologies used in KITSAT-1/2 are enhanced to develop much higher performance subsystems for engineering test purposes.

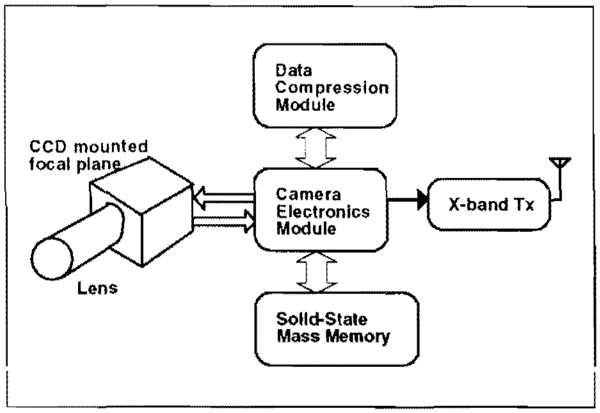
The design life time of KITSAT-3 is to be more than 2 years. For the initial 3 months after launch, the performance of bus system will be tested thoroughly. After the initial intensive test process, the bus system will be tested by the long-term test process and the mission payloads will be operated to maximize the use of whole bus system in order to evaluate the performance of the system.

2. Mission Payloads

There are three major payloads for KITSAT-3. The primary payload is Earth Observation System with multispectral band CCD camera. Secondary payloads are Space Environment Scientific Experiment (SENSE) and KITSAT Data Collection System(KDCS).

2.1 Earth Observation System.

The primary mission of KITSAT-3 is to develop and demonstrate satellite remote sensing technologies. It is to provide test images for monitoring lands, vegetation, environment, etc. The system is comprised of five major parts; Optics Assembly, Camera Electronics Module, Data Compression Module, Solid-State Mass Memory Module and X-band Transmitter. The Optics Assembly and part of the Camera Electronics Module are currently being developed by a collaboration program between University of Stellenbosch, South Africa and SaTReC, Korea. The rest of the system is developed in SaTReC. The system configuration is shown in Figure 1.



< Fig.1 System Configuration of EOS>

The Optics Assembly consists of Lenses, Color splitter and mounted CCD's. Incoming light will be splitted into 3 spectral bands. For each band, a linear CCD of 3456 pixel is to be used. The design specifications of the Optics Assembly are shown in Table 1. The parameters in Table 1 have been selected to make a small and light lens system for this microsatellite. With the fulfillment of this design specifications, it provides the image with swath width of 57 km and resolution of 17 m from the altitude of 870 km.

Lens Focal Length	570 mm
Aperture Diameter	100 mm
Relative Aperture	F/5.7
MTF (at Nyquist Frequency of 47 cycles/min)	35 %
Lens Transmission	83 %
Filter Peak Transmission	83 %
Spectral Bands (50% Transmission)	520 - 620 nm 620 - 690 nm 730 - 900 nm

<Table 1, Preliminary Design Specifications of Lens>

Since the image data output rate from this CCD camera with 3 spectral bands is about 32 Mbps, a very high speed transmitter with high power is required for transmitting all data in real time. In order to avoid using such a high speed transmitter and a large ground station for our microsatellite, we employ a Data Compression Module and a Solid State Mass Momery Module.

The Data Compression Module has adjustable compression rate. Since it is lossy compression, higher compression rate may result in coarse image quality. For normal operation, it is proposed to provide approximately 3:1 data compression with negligible loss.

The Solid State Mass Memory Module consists of specially packed SRAM Module and Flash Memory Module. In this packaging, 8 memory chips are stacked up in one package to achieve high capacity in small size. It allows to have a complete mass memory system with 2 Gbits of SRAM and 8 Gbits of Flash Memory in a box of 400 x 200 x 90 mm.

The mass memory module can store the raw image data of around 300 seconds with overheads of file system and frame format. During 300 seconds, the camera sweeps about 1959 km with swath width of 57 km on ground. For flexible on-orbit operation, the memory is sectored to store several scenes of a certain unit length.

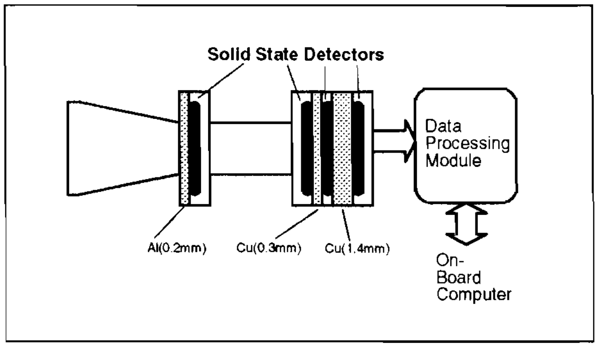
The module is protected from radiation damage by means of shielding and software error corrections. Radiation tests on ground will be conducted to qualify the system and to obtain the reference data for the future analysis. It will be very interesting to monitor single event upsets in this 3-dimensional memory modules.

The stored image data are downloaded through the X-band Transmission Module. QPSK modulation scheme is employed. The data rate is 2.65 Mbps. A microstrip fetch antenna is used with shaped radiation pattern to increase the link margin at low elevation angles.

2.2 Space ENvironment Scientific Experiment (SENSE)

Both KITSAT-1 and 2 had carried simple experimental modules to measure radiation particle distributions on low Earth orbits. They have been significantly improved for KITSAT-3 and named Space ENvironment Scientific Experiment(SENSE). It consists of two modules; High Energy Particle Telescope(HEPT) and Radiation Effects on Micro Electronics(REME).

HEPT is to measure the distribution of radiation particles near Van Allen Belt and its variation of energy spectrum for various solar activities. It is also to measure the pitch angle distribution of incident particles to analyze the dynamical process of particles. Figure 2 shows a configuration of the particle telescope.



<Fig. 2, Configuration of Particle Telescope>

As shown above, it has a mechanical structure of cone shape to limit the incident angle of particles. Four silicon detectors are used with blocking materials, such as aluminum and copper, between each other to control the energy transferred to each sensor. Signals from four sensors are combined and processed to identify the energy and type of particle. It consists of 7 measurement channels shown in Table 2.

Channel	Particle Type	Energy(MeV)
pE1	Proton	30 - 38
pE2	Proton	15 - 30
pE3	Proton	6.4 - 15
eE1	Electron	2.0 <
eE2	Electron	0.72 - 2.0
eE3	Electron	0.25 - 0.7
AA	Alpha Particle	15 - 60

<Table 2, HEPT Measurement Channels>

The REME is designed to test non-space qualified electronic components, such as memory IC's and discrete components. For memory chips, it performs a series of test dedicated to measure SEU characteristics. Discrete components are connected to appropriate measurement circuits, and variations of their characteristics are monitored together with the total dose measurement.

2.3 KITSAT Data Collection System(KDCS)

The KDCS receives the data from small ground terminals and stores these received data, and then forward them to the system ground station. If both the system ground station and DCS ground terminals are within the same communication coverage, the received data are simultaneously retransmitted in real-time. It is not supporting location service.

Small ground terminal equipments are designed to consume low power and each ternimal equipment has a 3W transmitter with an omnidirectional antenna. They transmit short data frames according to different time intervals which are arranged to minimize collisions of transmitted packets on uplink. A ground terminal consists of some measurement sensors, a controller and a transmitter.

The KDCS is comprised of one receiver chain and a data processing unit. The uplink frequency is around 400MHz and the data rate is 400 bps. The receiver is particularly designed to work under the Doppler shift in LEO environment. The data processing unit validates the received data and the on-board computer forward them to the system ground station.

The system ground station receives the collected data from satellite and distributes them to users. Since KITSAT-3 is on 870 km sun synchronous orbit, a ground terminal equipment, located in any place of the world, can see the satellite more than 6 times a day. Therefore, the KDCS could be utilized to provide daily data collection services for various applications. For the initial test, ground terminals will be mounted on observation buoys. They will be used to monitor the environments of sea surrounding the Korean peninsular.

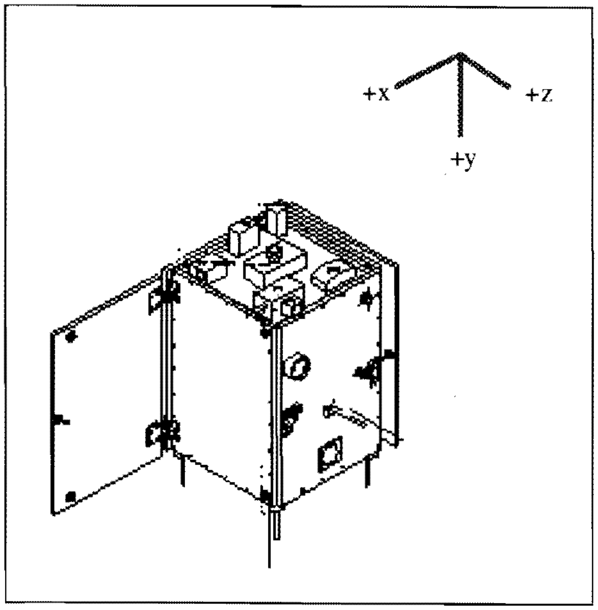
3. Satellite Bus System

Technology developments of the proposed bus system are carefully tailored to accommodate mission payloads. Many components developed for this bus system could be regarded as engineering test items. On-board test results will be very useful information for future missions.

3.1 Mechanical Structure

The external configuration of mechanical structure is largely based on that of KITSAT-1/2. But internally it is modified to accommodate reaction wheels, gyros and CCD camera. Two solar panels are designed to be deployed. One quarter of upper space is allocated as a dedicated payload compartment. It is considered to easily assemble and disassemble the whole payload compartment together with the satellite bus system.

Figure 3 is a schetch of KITSAT-3 mechanical structure with one panel deployed. During launch, both panels will be folded.

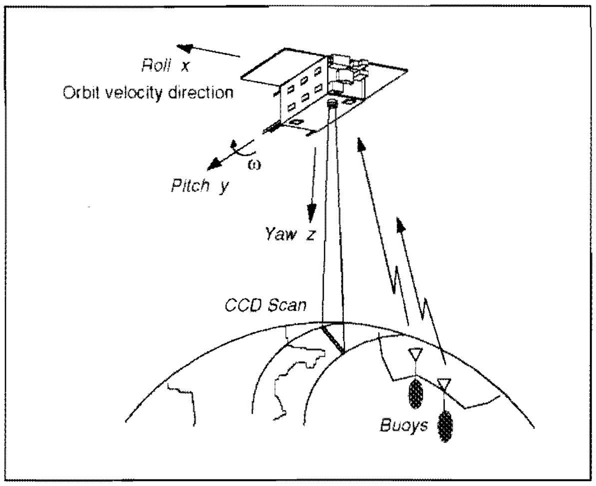


<Fig. 3, Deployed view of KITSAT-3>

Since the satellite coordinate system is defined for on-orbit operations, z-axis is not vertical direction during launch. After the launch, the attitude of the satellite is stabilized to have the x-axis on flight direction normally. Two panels on +/-X facets will be deployed. Three solar panels are designed to point the Sun in normal condition.

+Z facet is used to mount devices which need to point the Earth. The camera lens is mounted to look down the Earth through +Z facet. S-band Antenna, X-band antenna and DCS antenna are mounted on +Z facet. During flight, the star sensor mounted on -Y facet points the deep space under the proper attitude control.

A flight configuration of KITSAT-3 is drawn in Figure 4. The external dimension of the main body is approximately 500 x 500 x 700 mm when solar panels are folded. The estimated mass is less than 100 kg as shown in Table 3.



<Fig. 4, Flight Configuration of KITSAT-3>

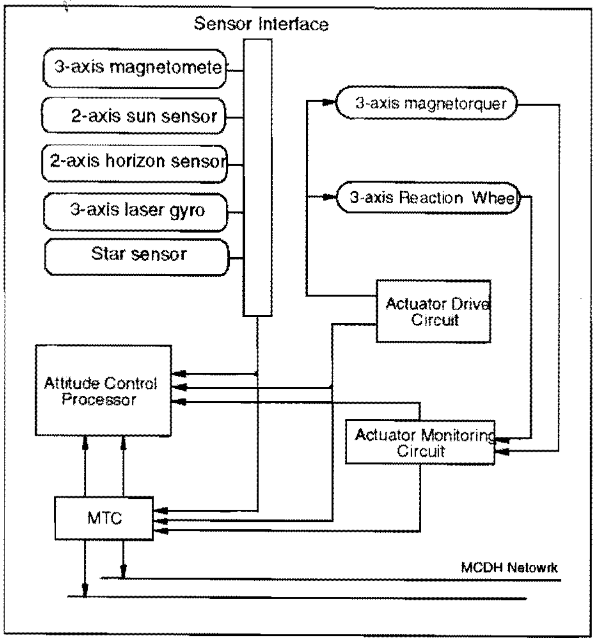
Subsystems	Estimated mass(kg)
Bus System	
Electrical Power System	13
ADCS	15
Command & Data Handling	8
Tx & Rx	7
Structure & Thermal	22
Payloads	
Earth Observation System	17
SENSE	3
KDCS	2
Total	87
System margin	10 %
Estimated total mass	95.7

<Table 3, KITSAT-3 Mass Budget>

3.2 Attitude Determination and Control System

The block diagram of attitude determination and control system is shown in Figure 5. The attitude motion of the satellite is monitored by five different types of sensors; magnetometer, sun sensor, earth horizon sensor, fiber optic gyro and star sensor. The fiber optic gyros are regularly updated from the accurate information provided by the star sensor to compensate drifts.

On-off type magnetorquers were used for KITSAT-1 and 2. They are operated with only one magnetorquer active at one time. For KITSAT-3, magnetorquers are designed to produce a magnetic



<Fig. 5, Block diagram of ADCS>

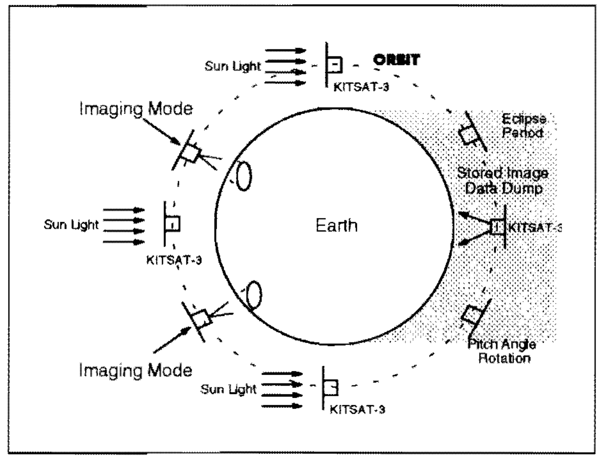
field to any desired direction by driving 3 magnetorquers with 256 levels. The reaction wheel consumes only 1W and weighs about 1kg.

The attitude control processor (KASCOM) is based on an Intel 80960MC CPU. It has been proven to be reliable after one and a half years of operation on board KITSAT-2. All of sensors and actuators are connected to a Modular Telemetry and teleCommand (MTC) module to allow to be attitude-controlled by any other control processor on the satellite.

In normal operation of the satellite, there are three major attitude maneuvering modes. The first one is called normal operation mode. In the normal operation mode, the attitude of the KITSAT-3 is controlled to generate the maximum power from the solar panels(Sun Tracking Mode). During eclipse period, the satellite is maneuvered to keep the best RF link quality with ground control(Earth Pointing Mode). SENSE and KDCS can be operated in this mode.

The satellite enters the imaging mode for the operation of Earth observation system. It is moved to keep the camera pointing the center of the Earth while image is being taken. After completion of imaging operation, the satellite tracks the Sun again to have maximum incoming power. This operation is described in Figure 6.

Other attitude maneuvering mode is pitch angle rotation mode for SENSE. This mode is used only when the solar activity like solar flares is forecasted. The satellite is spinning with about 10 minute period. SENSE is activated in high resolution mode for detailed monitoring of any big change in space radiation environment.



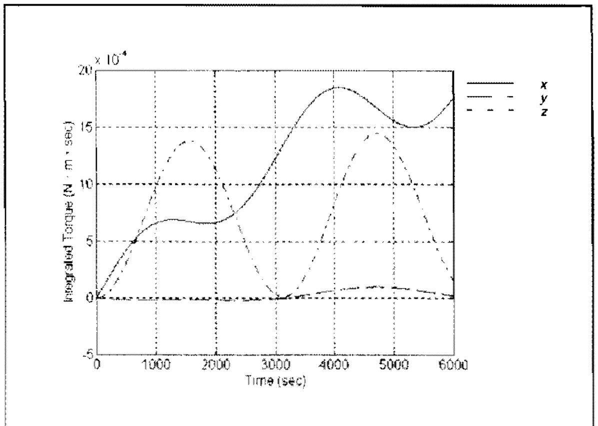
<Fig. 6, Attitude Maneuvering of KITSAT-3>

Coarse control mode and fine control mode are also available. Coarse control mode is used when the satellite is initially in power on state and when it is in safe mode. Coarse control mode is based on sun sensor, magnetometers and magnetorquers. This mode is expected to achieve the pointing control accuracy of about 1 degree(3 σ).

Mission payloads on KITSAT-3 require accurate attitude controls. The Earth Observation system with 17m ground pixel resolution requires the most stringent attitude control requirements in the mission. On the proposed 870km 10:30 sun synchronous orbit, 0.5 degree pointing accuracy with 0.014 deg/sec stability of the platform has to be achieved for good quality images. Fine control mode is applied to this operation.

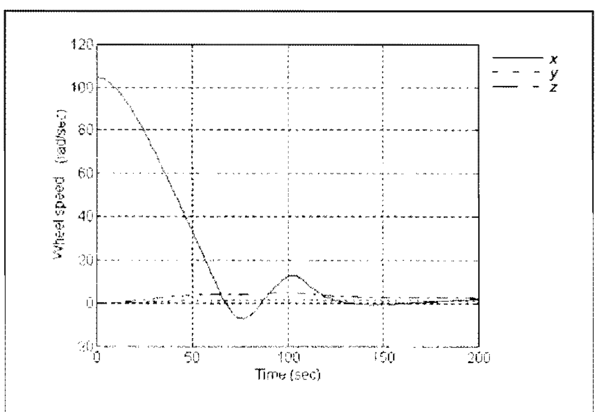
Fine control mode employs all attitude determination sensors and control actuators. Reaction wheels are the main control devices. Due to the small momentum storage capacity of the wheel, the magnetorquers occasionally need to dump the wheel momentum to prevent saturation.

With the initial design of the mechanical structure, a computer simulation has been done to estimate the environmental disturbance to KITSAT-3. The result of simulation for one orbit period is shown in Figure 7. For this simulation, the satellite is assumed to keep pointing the sun for one orbit period.



<Fig. 7, Integrated environmental torque during the sun tracking mode >

As shown in figure, during the sun tracking mode, the momentum of the reaction wheel, especially the x axis one, builds up due to the environmental torque's. Occasional momentum dumping is needed by means of the magnetorquers. For the maximum torque condition, the magnetic dipole vectors have to be controlled carefully. The computer simulation result in Figure 8 demonstrates the momentum dumping capability of magnetorquers.

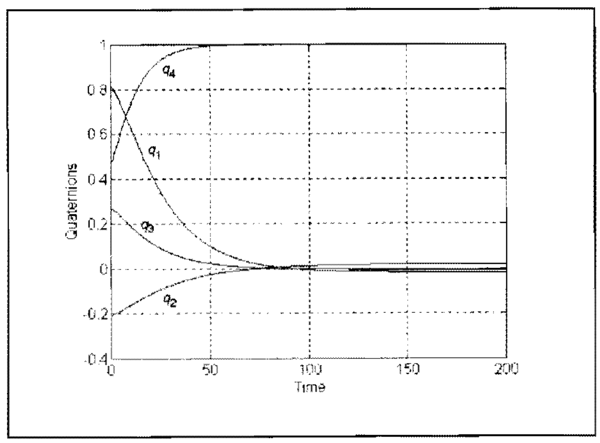


<Fig. 8, Momentum Accumulation/Dumping>

The ADCS controls the attitude of the satellite for the proper operation described in the previous Figure 6. When the satellite is going into eclipse and coming out from it, it makes a large angle maneuvering, such as 120° on y-axis and 22.5° on x-axis. If the satellite is commanded/scheduled for imaging mode, it should make a quick maneuvering before it arrives the target area. After the imaging operation, it is supposed to return to the sun tracking mode again for maximum power supply.

The attitude maneuvering capability of ADCS is studied by computer simulation. A quaternion feedback control scheme with a genetic algorithm for searching gain parameters is employed for the three-axis large angle maneuvers. 120° and 22.5° large angle maneuvers are performed in simultaneous manner about the y and x axes, respectively.

The result of error quaternion history is shown in Figure 9. During the simulation, the wheel speed and torque are within the range of its capability. It clearly demonstrates that the satellite can achieve its desired attitude within 60 seconds.[3]



<Fig. 9, Error quaternion history >

A GPS receiver-based Satellite Navigation system(GSN) is being developed to provide accurate position and time information. The satellite orbit parameters are calculated from several positions and time measurements by a data processing computer. The computer is also used to provide estimated position data from previous measurements when GPS signals are not received or the receiver is power off for power saving.

3.3 Electrical Power System(EPS)

The EPS is comprised of 3 solar panels, NiCd battery packs, Battery Charge Regulator(BCR) and Power Conditioning and Distribution Module (PCDM). The maximum power points of solar panels are tracked to supply as much power as available. Unregulated power of +28V is supplied by BCR. It is regulated into +/- 12V and +5V and then distributed by PCDM. Two of 4.3Ah NiCd battery packs are used in parallel to increase its reliability.

GaAs solar cells with typical efficiency of 17% are mounted on 3 solar panels. When the satellite is in sun tracking mode, three solar panels can generate 110W at the beginning of life(25°C). Since the eclipse ratio of 870 km sun synchronous orbit is about 0.34, the average power is about 73W. It varys depending on operation modes.

Power budgets for different operation modes are shown in Table 4.

(W)

	Sun Tracking Mode	Earth Imaging Mode	Spinning Mode
EPS	8	17	4
ADCS	17	17	5
C&DH	3	3	3
Tx & Rx	10	10	7
EOS	0	60	0
SENSE	1	1	3
KDCS	2	2	0
Total Power	50	110	22
Maximum Input Power	110	101 (on equator)	101
Average Input Power	73	N. A.	24

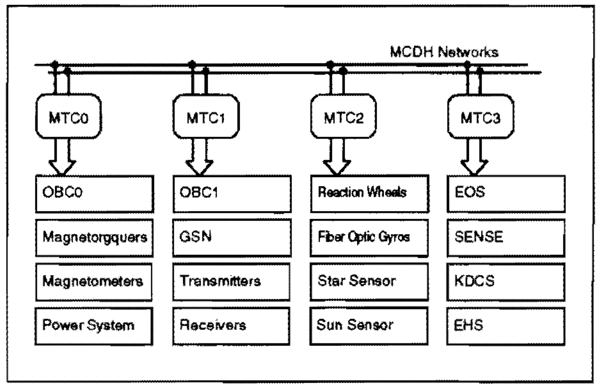
<Table 4, KITSAT-3 Power Budget>

In earth imaging mode, the power consumption is higher than the maximum input power. However, this mode will be operated for less than 5 minutes. Battery discharge for a short period is not very critical. Since the satellite enters sun tracking mode right after the Earth imaging mode, the battery is charged up within few minutes.

During spinning mode, the average incoming power is very low. It is supposed to run this mode for at least 48 hours after solar flares are noticed. Thus the satellite is switched to operate with minimum configuration for low power consumption.

3.4 Command & Data Handling (C&DH) System

The C&DH system is based on several Modular Telemetry and teleCommand(MTC) modules connected by MCDH (Modular Command & Data Handling) network. Each of MTC modules has binary telecommand latches and digital & analog telemetry channels. 4 MTC modules are used for KITSAT-3. It also provides functions of on-board data communication. Figure 10 shows how KITSAT-3 is configured based on MTC's and MCDH network.



<Fig. 10, Configuration of C&DH System>

The MCDH network is working on dual 38.4 kbps serial links. Any one of MTC modules can be allocated as a master node on network. The master is responsible for distributing the telecommand and collecting the telemetry within specified time. Traffic analysis shows that only 10% of network capacity is occupied by telecommand and telemetry including network overhead. The rest of capacity can be used for on-board data sharing.

Two on-board computers are used to manage the satellite. Only one of them is designed to operate in normal mode. OBC0 is an improved version of KASCOM which has been flown on KITSAT-2. It has been tested for one and a half years since the launch. It is based on Intel 80960 microprocessor. 2 Mbytes of EDAC memory and 4 Mbytes of non-EDAC memory are used. Parallel and serial ports are connected with ADCS sensors and actuators directly. It is used as a primary on-board computer.

The secondary and back-up computer is OBC2 based on Intel 80C186 microprocessor. It has been used as a primary computer on KITSAT-1 and 2 successfully. 512 Kbytes of EDAC memory and 4

Mbytes of non-EDAC memory are used. It is able to control all subsystems of the satellite through MCDH network.

A multi-tasking operating system(ByulGiKi) is developed for both of OBC1 and OBC2. Basic input and output functions related with each hardware are developed to have full compatibility. It allows two OBC's to use same software tasks for house keeping and payload operations.

3.5 Telecommunication System

Initial operations of the satellite are commenced with VHF receivers and UHF transmitters as they were in KITSAT-1 and 2. Both uplink and downlink employ audio frequency shift key(AFSK) modulation with 1200 bps and frequency shift key(FSK) modulation with 9600 bps.

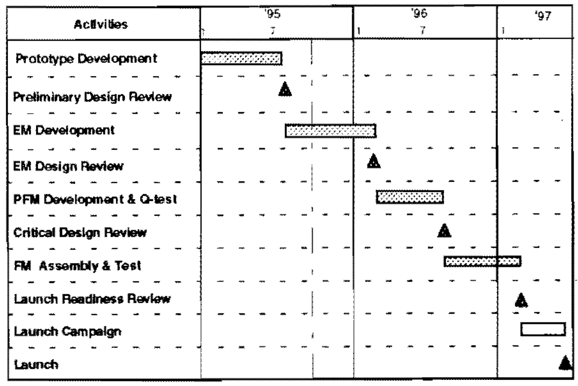
There are two other transmitters for test purposes. One is a S-band transmitter for telemetry and the other one X-band transmitter for image data transmission. During initial operation phase, they are tested in detail to measure their characteristics on orbit. Afterward, they are to be used for normal operation.

The S-band transmitter employs frequency shift key(FSK) modulation scheme. Its output power is 1W. The information bandwidth is 38.4 kbps. The X-band transmitter is described in previous section 3.1. Both S-band transmitter and X-band transmitter use microstrip patch antennas.

4. Mission Timelines

The KITSAT-3 program has been initiated since August, 1994 as a 2.5 year program. It is expected to be launched around May, 1997. A time schedule of the program is shown in Figure 11.

An engineering model will be developed for complete function test and structure qualification test. A protoflight model is to be built for space environment test. It is supposed to be same as the flight model. It will be used as a ground reference system after the launch. After all, the flight model will be carefully assembled and tested at acceptance level.



<Fig. 11, TSAT-3 Mission Timelines>

5. Conclusion

In this paper, mission payloads, important subsystems and baseline system architecture of KITSAT-3 have been introduced. As it was mentioned in the beginning, most of subsystems are built for the purpose of many engineering test items. In-orbit test of the KITSAT-3 will provide invaluable information and experience in space technology.

The bus platform of KITSAT-3 can be a good engineering test bed together with that of KITSAT-1 and 2. Since they can be tailored to other practical missions very easily and can be developed with low cost, many application fields can be found with these platforms.

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