EXPERIMENTAL MUTILMISSION MICROSATELLITES - KITSAT SERIES

Impyeong Lee, Dan Keun Sung, Soon Dal Choi

Satellite Technology Research Center(SaTReC)
Korea Advanced Institute of Science and Technology(KAIST)
373-1, Kusung-dong, Yusung-gu, Taejon, 305-701, Republic of KOREA

ABSTRACT

This paper is to report the result of the first Korean satellite, KITSAT-OSCAR 23 (KITSAT-1) and to introduce the KITSAT-B to be launched in September 1993.

INTRODUCTION

The KITSAT-1 had been developed by KAIST graduate student engineers through a collaborative educational program with UoSAT Research Unit at the University of Surrey, U.K, and was launched successfully by ARIANE V52 into a circular orbit with altitude of 1300km, inclination of 66 degrees and orbital period of about 110 minutes.

The primary missions of the KITSAT-1 project are to acquire satellite development technology and to educate a number of engineers on spacecraft engineering. In addition, it has also provided opportunities for academic research, in-orbit technology demonstration, and communications.

The KITSAT-1 has performed its missions very successfully without any subsystem's failure, producing some interesting results such as especially CCD earth images.

Following the success of the KITSAT-1, the SaTReC has developed another microsatellite, KITSAT-B in Korea. It will be launched by ARIANE V59 in September 1993 into a circular sun-synchronous orbit with altitude of 820 Km, inclination of 99 degrees and orbital period of about 101 minutes.

The bus system of the KITSAT-B is modified to improve the performance of the KITSAT-1, and most of the payloads are newly designed and implemented.

The KITSAT-B includes six payloads, KAIST Satellite Computer (KASCOM), CCD Earth Imaging System (CEIS), Digital Signal Processing Experiment (DSPE), Digital Store and Forward Communications (DSFC), Low Energy Electron Detector (LEED), IR Sensor Experiment (IREX).

KITSAT-1 RESULTS

Attitude Control

During the initial stage of KITSAT-1 in orbit after the separation from ARIANE Structure for Auxiliary Payload (ASAP), the satellite had shown a complex random motion with spinning, tumbling and precession modes in very fast rates. The attitude control program was loaded and executed to stabilize the satellite using magnetoquers in 3 axes.

When the tumbling rate and the spin rate had been properly adjusted for boom deployment by magnetoquers, the gravity gradient boom was finally deployed. After the boom deployment, the tumbling period was about 110 minutes. Therefore, the tumbling period was the same as the orbit period, so that -Z facet of the satellite could face the earth all over the orbit. Since then for the most of time up to now, the pointing error has been maintained below five degrees

The spin rate of the satellite has been controlled between four minutes and ten minutes, considering the CCD imaging system and thermal control.

Thermal Control

Since KITSAT-1 has no active thermal control mechanism, the mechanical structure and the thermal surface had been very considerably designed by taking a very accurate thermal analysis in consideration.

Since the satellite is not in sun-synchronous orbit, the eclipse ratio is variable in range between

about 0 and about 31 percent. Nevertheless, the whole orbit data of the satellite has shown that the satellite was safely designed in view of thermal control.

Especially, the battery temperate is most critical and should be in range between 0°C and +40°C. Figure 1 shows the whole orbit data of the battery temperature in maximum eclipse ratio and assures that the battery is in appropriate temperature range.

Earth Image from KITSAT-1

The KITSAT-1 has two CCD cameras, a low resolution camera to provide a panoramic view and a high resolution camera to show the details in small areas, 200Km×200Km.

The imaging system has provided about 180 earth images up to now. Figure 2 and Figure 3 show some examples of earth images, which are nearly raw, not processed in ground.

Voice Broadcasting

Broadcasting voice signal from the space is one of the most exciting missions of the KITSAT-1. Broadcasting about 5 minute message were successfully performed many times. Very clear voice was recognized by many amateur hams.

Radiation Monitoring

The KITSAT-1 has two radiation monitoring payloads, Total Dose Experiment (TDE) and Cosmic Particle Experiment (CPE). At the moment, the payloads provide the radiation information of nearly whole of the earth. They are continuously collecting the information to monitor the radiation with season's change. Figure 4 shows the radiation distribution at the altitude of 1300Km based on the KITSAT-1 CPE data.

Electric Mail Service

The KITSAT-1 provides the electrical mail service using the store-and-forward packet communication function of the on-board computer. Since the electrical mail service was opened to world-wide amateur hams on 15 January 1993, more than five hundred users have utilized this service. Especially, it is very helpful to communicate with users at very remote areas such as the antarctic region.

Main OBC Error Log Analysis

The comic radiation is one of most influential factors to make hardware fail and to change data stored in RAM or ROM. Figure 5 shows the errors generated from RAMDISK and program memory of main OBC. Almost all errors were corrected by error correction coding method.

It is much noted that the errors are more often generated in the South America, where relatively much radiation is observed.

Communication Interference Analysis

Figure 6 shows the noise or interference level in amateur frequency band (145MHz) used by KITSAT-1. According to this information, the noise level of 145MHz band experienced by the KITSAT-1 is too large in East Asia relatively.

KITSAT-B BUS SYSTEM

A block diagram of the KITSAT-B is shown in Figure 7.

Power Subsystem

The primary power of the KITSAT-B is generated from solar panels on four facets of the body. Each solar panel comprises four strings of solar cells in parallel. Each string consists of 42 GaAs/GaAs cells in series.

Nickel Cadmium rechargeable battery provides power during eclipse period. Ten cells are connected in series, and they generates about 14.2V at 20°C.

The power system consists of mainly Battery Charge Regulator (BCR), Power Conditioning Module (PCM), and Power Distribution Module (PDM). Most of important parts are duplicated so that when any fault in a unit is detected, the active unit can be replaced by a stand-by unit automatically.

The BCR is to convert the raw fluctuating solar power into regulated power, tracking the maximum power of the solar panels and to charge the battery, protecting the battery from overcharge.

The PCM is to provide regulated +5V and ±10V power from raw +14V battery power. Then, the regulated power and the raw +14V power are

distributed by PDM comprising various electric switches and fuses.

RF Subsystem

The uplink system of the KITSAT-B comprises three separate VHF radio receivers: Rx0, Rx1 and Rx2 to employ 1200 baud AFSK and 9600 baud FSK modulation schemes. The radio signal is received through a monopole VHF antenna and a low pass filter, and the base-band signal is extracted and passed to corresponding demodulator.

Rx0 is dedicated for commanding the satellite by the command station in SaTReC, KAIST while the other two receivers (Rx1, Rx2) are designed for packet communication. Uplink frequencies for packet communication are 145.870MHz and 145.980MHz.

The downlink system includes two UHF transmitters: Tx0 and Tx1. Tx0 is a low power transmitter with RF output power of 2W. Tx1 features a nominally high RF output of 5W to support the Digital Signal Processing Experiment payload, and can be used as back-up of Tx0. The downlink frequencies are 436.500MHz and 435.175MHz.

The transmitters are of a modular design. Each chain consists of a frequency synthesizer and an RF amplifier. Each synthesizer is dedicated to a single amplifier without any cross switching. One of outputs from two amplifiers is then switched to the antenna system via a latching relay.

The UHF antenna system consists of an array of four monopole antennas. Impedance matching is performed using transmission line transformers and power splitters.

OBDH Subsystem

The On Board Data Handling System of KITSAT-B consists of a primary on-board computer (OBC186), a secondary on-board computer (OBC80) and a telemetry and telecommand system(TTC).

The primary On-Board Computer is based upon an 80C186 microprocessor. It features parallel interfaces for telemetry system, DSPE, BCR and RAMDISK and serial interfaces for telecommand system, DASH (Data Sharing) network and radio communication. The multitasking operating system enables to execute separate programs to control different tasks.

The OBC186 has 512KBytes EDAC (Error Detection and Correction) memory to store programs. For Digital Store & Forward Communication Experiment, a RAMDISK of 12MBytes is provided. The RAMDISK is a block-addressable data storage device comprising three 4MBytes SRAM banks.

The secondary on-board-computer is a backup computer in case of the failure of the primary computer. It is based upon a Zilog Z84C00 microprocessor and its family peripherals. It has a simple architecture to achieve high reliability.

The Telemetry and Telecommand system is provided to control and monitor the satellite by receiving command from a ground station or on-board computers. The Telecommand system has 130 command channels. The Telemetry system is to support 64 analogue channels and 192 digital status channels. The Telemetry and Telecommand system is fully duplicated to avoid single point failure of the satellite.

Attitude Control Subsystem

The attitude of the KITSAT-B can be stabilised with pointing error of less than five degrees in order to take sharp pictures of the earth surface. The satellite also has to spin with appropriate period of 4 to 10 minutes for thermal control.

Most of the attitude determination and control are performed by a Gravity-Gradient boom, 3-axis magnetoquers, two 3-axis magnetometers. The boom passively enables the satellite to be stabilized. According to the attitude information from the magnetometers, the magnetoquers are suitably fired to correct the attitude by on-board program.

Mechanical Structure

Figure 8 shows the mechanical structure of the KITSAT-B. The dimension of the fully assembled satellite is 352mm × 356mm × 670mm and the total mass is about 49Kg.
Each electronic subsystem is mounted on an aluminium box with external dimension of 330mm by 330mm and a height ranging from 26mm to 35mm. A stack of eleven module boxes is the main body of the satellite.

The attach fitting and separation assembly are at the bottom of the body. The +Z structure is on the top. Several sensors, boom and tip mass are mounted on the +Z structure.

The solar panels are mounted on the four sides of the satellite. They consist of rectangular honeycomb plates, which hold the solar cells and the magnetorquer windings.

KITSAT-B PAYLOAD SYSTEM

CCD Earth Imaging System (CEIS)

This payload is to take pictures of the earth surface and to process the image for better quality of image itself and higher efficiency on transmission.

The CEIS includes two CCD image sensors, a wide-view color one and a narrow-view B/W one with the ground resolution of 2Km and 200m, respectively. It also two camera controllers and two image processing systems implemented with transputers (T800) for on-board image processing.

KAIST Satellite Computer (KASCOM)

The KASCOM is the next generation experimental on-board computer based on 8MHz 32bit Intel 80960 microprocessor with 10MBytes CMOS SRAM.

The KASCOM is designed to improve the performance of the main OBC based on a 80C186 in the KITSAT series in terms of instruction speed and memory management.

Digital Signal Processing Experiment (DSPE)

The DSPE is to experiment various kinds of high speed software modems. It also provides speech processing applications, such as voice store-and-broadcasting and voice telemetry broadcasting.

The DSPE implements the high speed modem in software using digital signal processors such as TMS320 C30 and TMS320 C25. The software modem is very useful to change the transmission speed and to swap the way of modulation. It is to experiment the high speed FSK modem of up to 38.4Kbps.

Digital Store and Forward Communication (DSFC)

The DSFC provides open access store-and-forward communication for amateur hams with basic amateur digital communication equipment. This system uses the standard PACSAT amateur protocol in 9600bps speed. The satellite has 12 MBytes of CMOS SRAM for this purpose.

Low Energy Electron Detector (LEED)

The LEED is to monitor low energy electrons (less than 6 KeV) in polar circular orbit with altitude of 820 Km.

The LEED consists of mainly four parts, Energy Analyzer to monitor incoming electron's energy, Spiraltron to detect electrons and to amplify the signal of electrons, High Voltage Supplier to provide about 3000V power to the Spiraltron, Signal Processor to convert the detected analog signal into digital information, to store it, and to transfer it to the main computer of the satellite.

IR Sensor Experiment (IREX)

The IREX is designed to monitor the performance of infrared sensor under the hard radiation in orbit. The experimental results will provide IR sensor characteristics under space radiation for future IR imaging system.

The IREX comprises three types of infrared sensors. They are respectively reactive to light of different wave length. It also includes radiation and temperature monitoring circuitry in order to observe the environment of the sensors.

CONCLUSION

The primary mission to train engineers in the field of space technology has been fulfilled through the KITSAT project. The KITSAT-1, the first Korean satellite was launched successfully and a number of good results have been obtained.

The KITSAT-B comprises newly developed interesting payloads described in last section. Also, to meet the requirements of the payloads, the bus system was thoughtfully modified. The KITSAT-B is to offer very useful results from its payloads, and to give an invaluable opportunity of operating a satellite to many students and reseachers in KAIST.

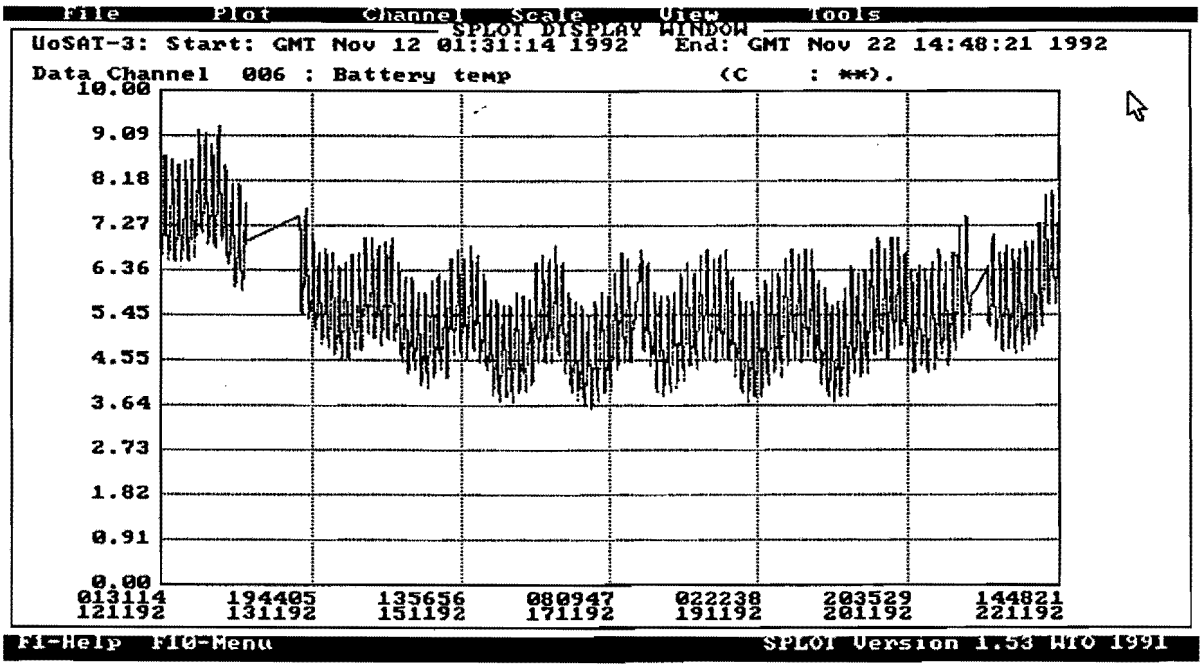
The KITSAT project has stimulated the interest of school and industry in Korea and provided a valuable experience in spacecraft engineering from design to operation. This project also shows a very useful example of multi-mission microsatellites.

REFERENCE

1. S.H. Kim, D.K. Sung, S.D. Choi, "A Korean Experimental Microsatellite, KITSAT-1 System", The Asia-Pacific Workshop on Multilateral Cooperation in Space Technology and Applications, Beijing, 1992

ACKNOWLEDGEMENT

The authors wish to thank the Ministry of Communications, the Ministry of Science and Technology and Korean Science and Engineering Foundation who has supported the KITSAT project so far. The authors also appreciate all research engineers participating in this project with their own best.



This graph shows that the period from Nov. 15 to nov. 20 (6 days) has the lowest temperature range.

Figure 1. Battery Temperature Survey in Maximum Eclipse

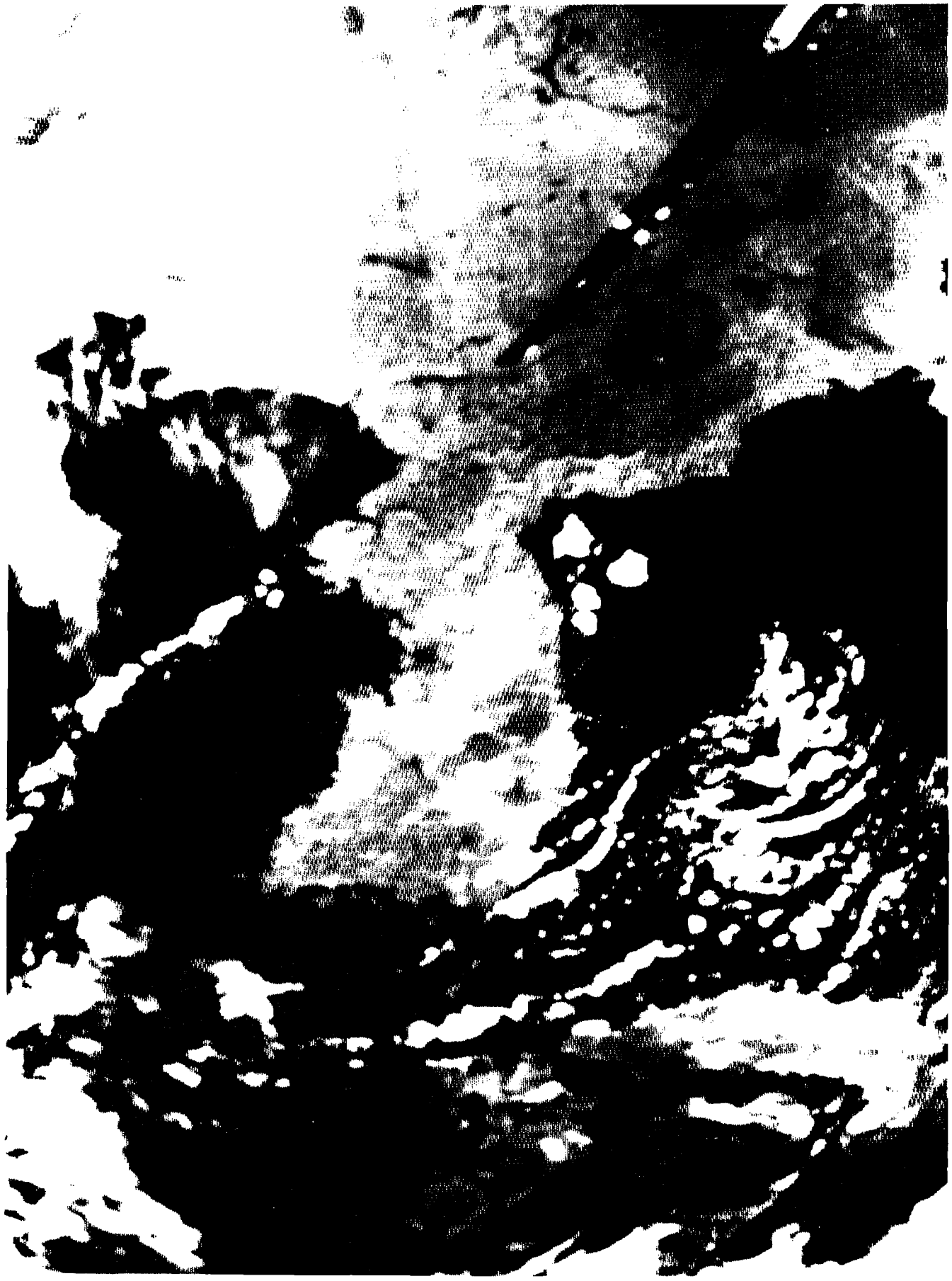


Figure 2. CCD Image of Korean Peninsular

Figure 3. CCD Image of the Mediterranean Sea

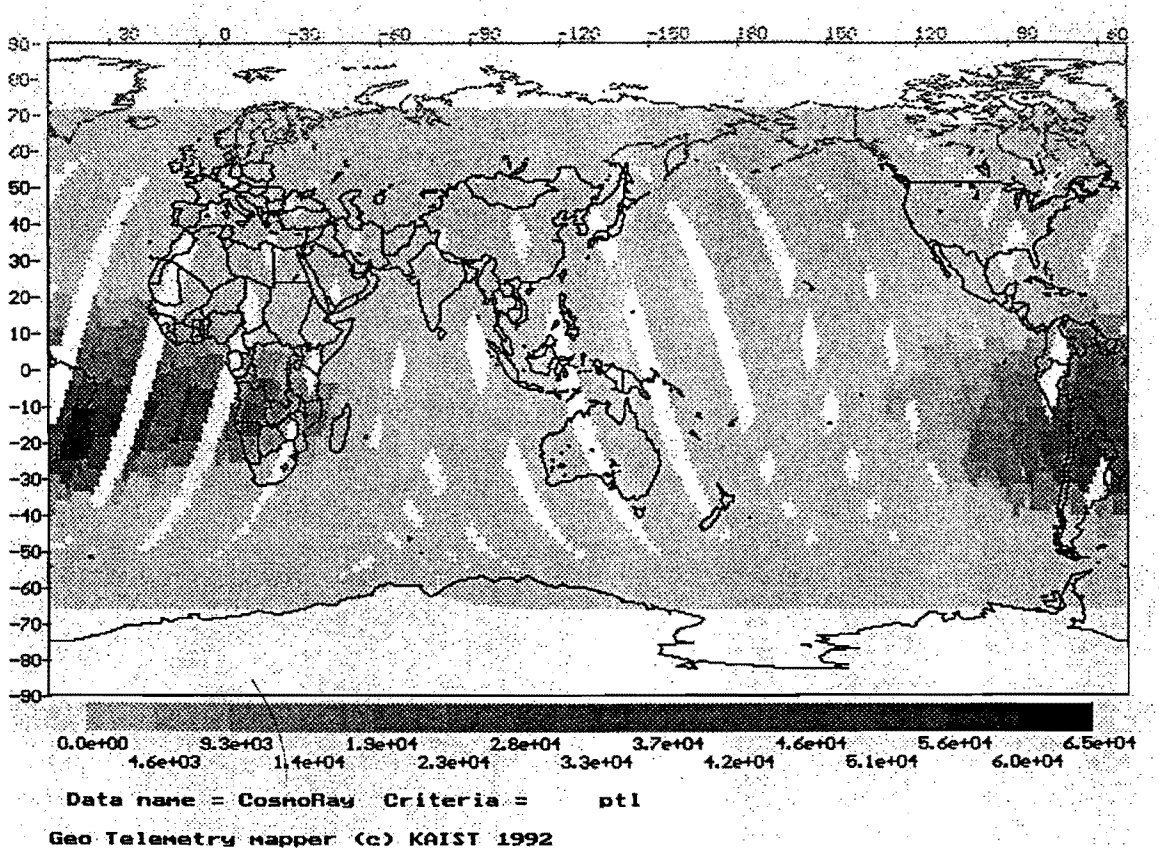


Figure 4. Earth Radation Distribution from Cosmic Paticle Experiment

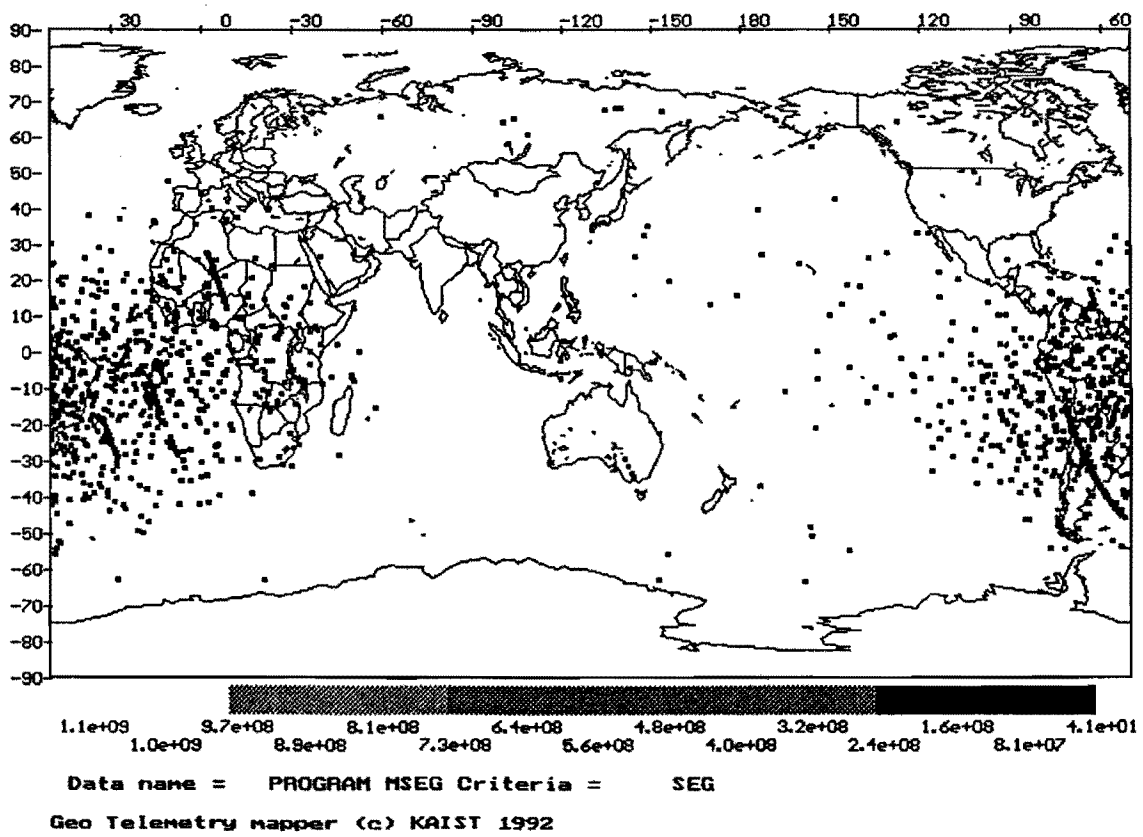


Figure 5. Errors of RAMDISK and Program Memory

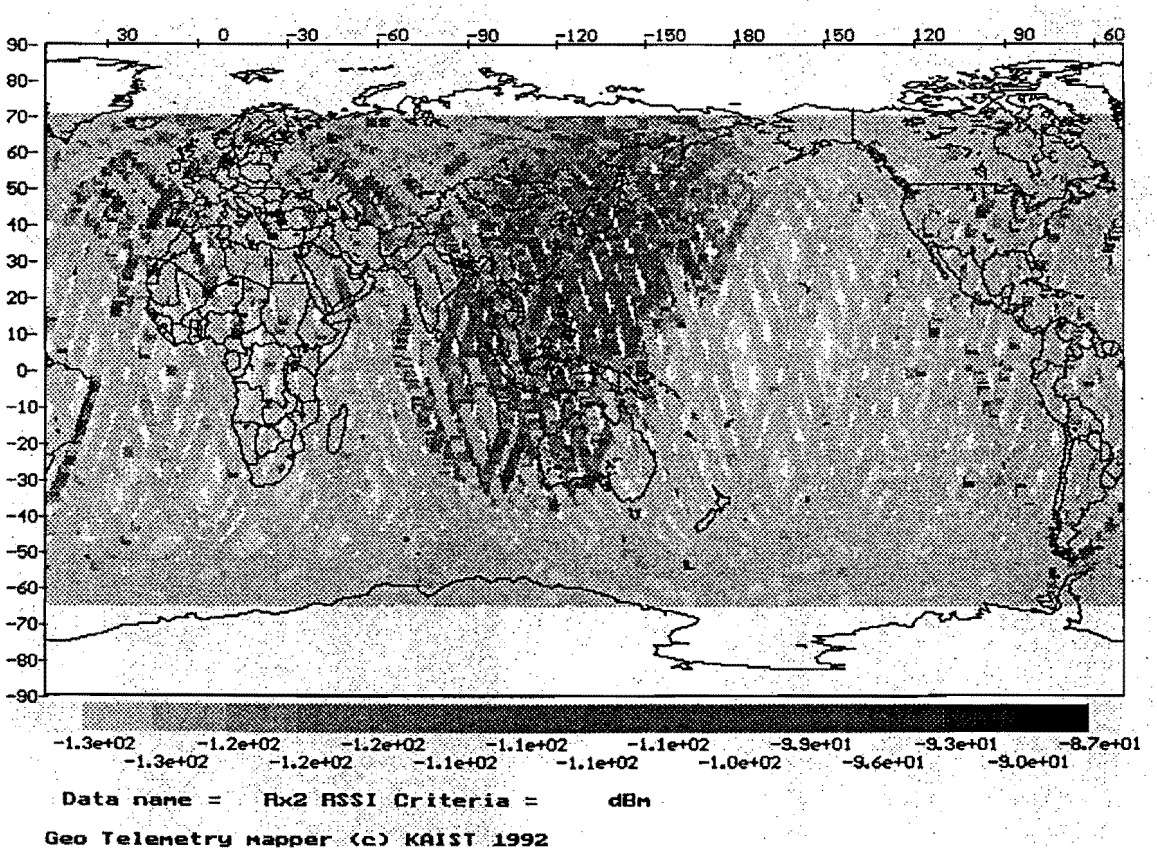


Figure 6. Noise/Interference Distribution in 145MHz Band Experienced by the KITSAT-1

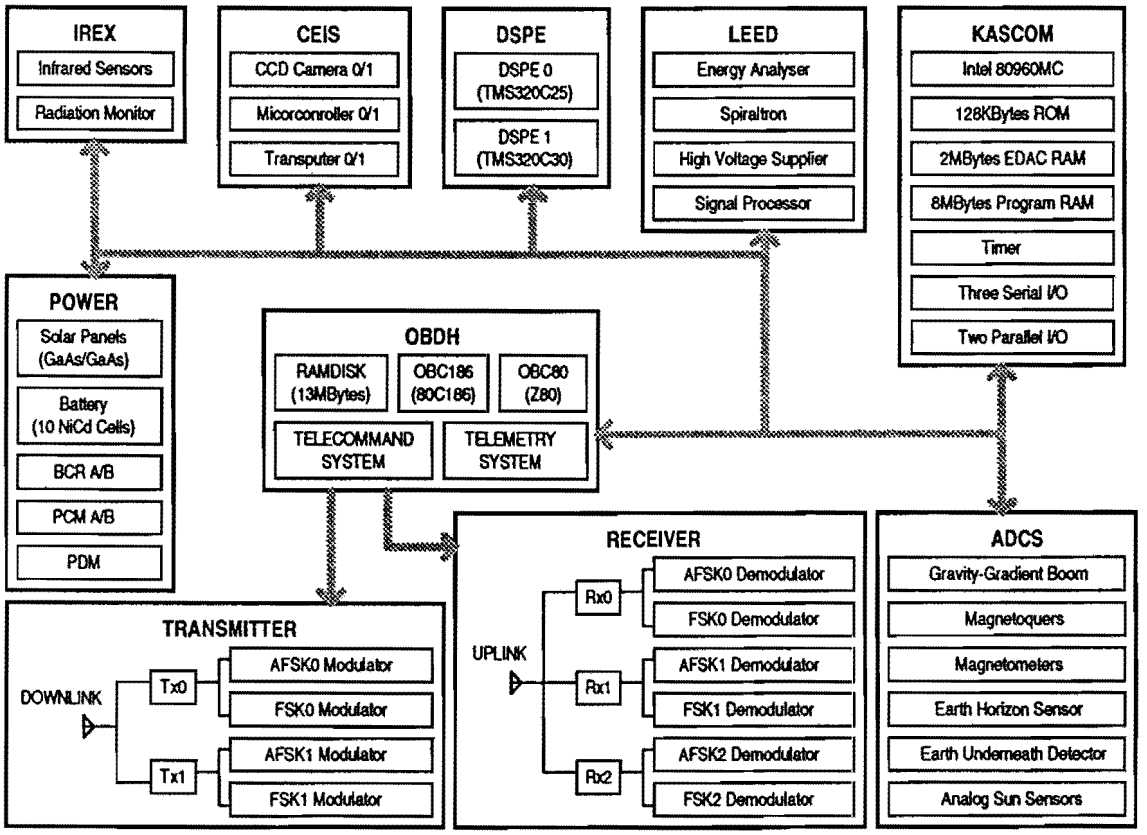


Figure 7. Block Diagram of the KITSAT-B

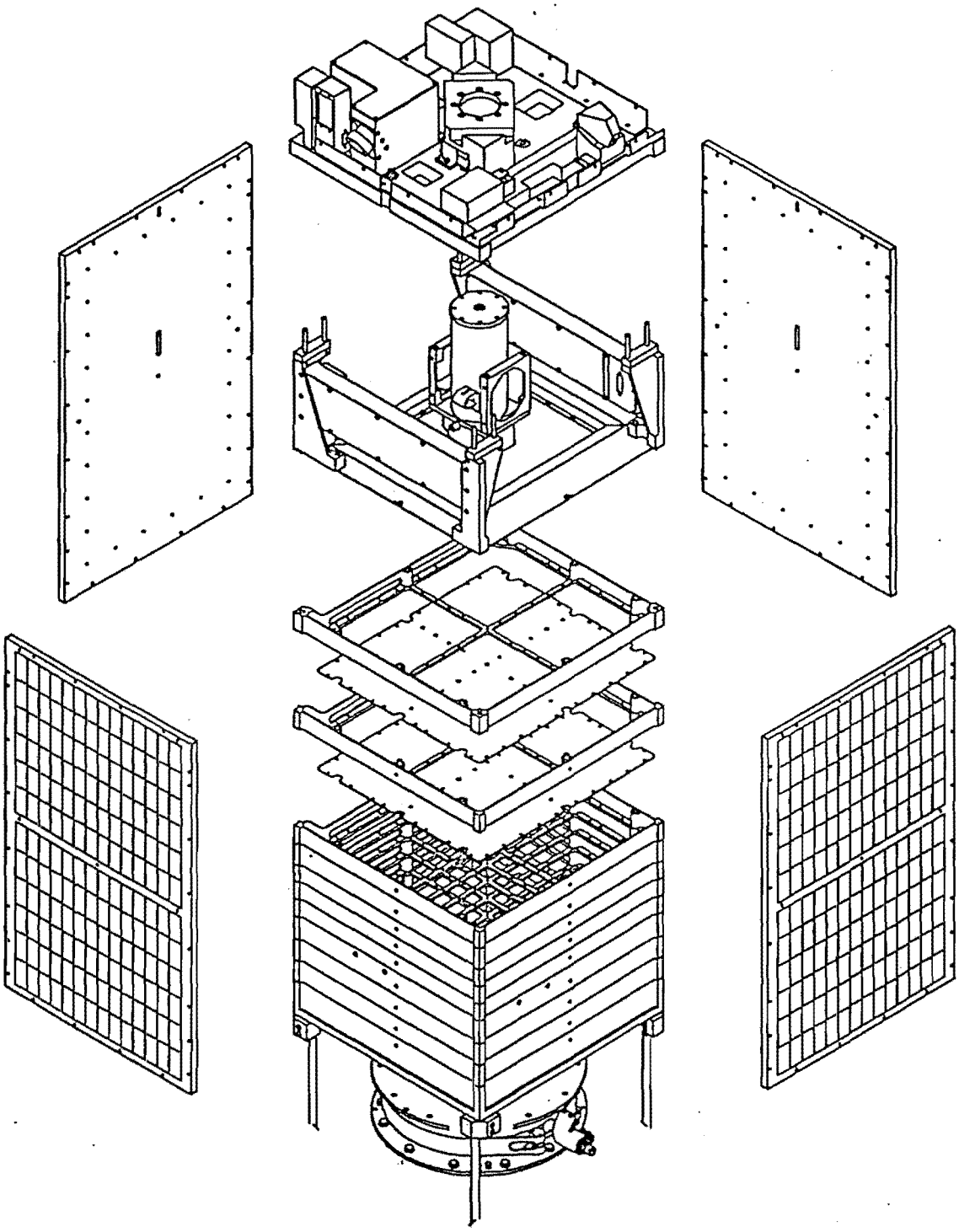


Figure 8. The Mechanical Structure of the KITSAT-B