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KITSAT-1 COSMIC RAY EXPERIMENT - INITIAL RESULTS

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ABSTRACT

The KITSAT-1 was successfully launched on August 11, 1992, into a near circular, 1300-km-high orbit with an 66° inclination. The satellite carries a solid state detector module to measure the high energy particle flux originating mostly from the inner radiation belt. We describe here the objectives of the experiment, the detector structure, and the preliminary result.

1. INTRODUCTION

On August 11, 1992, the first Korean satellite (KITSAT-1) was launched from Kourou, French Guiana, by the Ariane 42P rocket as an auxiliary payload to the TOPEX/POSEIDON together with the S80/T of the Matra Marconi. The spacecraft body is constructed as a rectangular box ($a \times b \times c$; $35.2 \times 35.6 \times 67.0 cm$). Navigation Magnetometers, Earth Horizon Sensor, and the Analog Sun Sensor reside on the top of the satellite, while two CCD cameras and antennas are attached to the bottom of it. Four side walls are attached by the solar cell panels. The satellite is mainly stabilized by gravity gradient forces, although magnetic torque could be employed as an active attitude control. The whole spacecraft weighs about 48.6kg. Details of the satellite system are summarized in Table 1.

The spacecraft carries four major payloads, two of which are related to the communication experiments. The rest are the earth imaging experiment with CCD cameras and the cosmic ray measurement using solid state detectors. We will concentrate in this paper on the last payload, the Cosmic Ray Experiment (CRE).

The purpose of the Cosmic Ray Experiment is to study the space radiation environment at 1300km altitude as encountered by the earth-orbiting KITSAT-1 over both short-term and long-term time-scales. The KITSAT-1 orbit resides just inside the inner Van Allen radiation belt. This region has a large population of high

Table 1. KITSAT-1 characteristics

Orbital Elements	
Altitude	1300km
Period	110 minutes
Inclination	66°
Mechanical Structure	
Spacecraft Type	modular structure
Weight	48.6 kg
Size	$35.2 \times 35.6 \times 67.0 cm$
Power Subsystem	
Batteries	14V, 6AH NiCd
Solar Cell Array	GaAs, 30W
Power Conditioning	+ 5V, + 10V, -10V
Attitude Control Subsystem	
Stabilization	Gravity Gradient Forces, Magnetorquer
Navigation Magnetometer	$\pm 60\mu$T (8nT resolution)
Earth Horizon Sensor	±14° field of view
Analog Sun Sensor	±60° field of view
Pointing Accuracy	$< 5°$
Telecommunications Subsystem	
Uplink	145 MHz
Downlink	435 MHz
Data Transmission Rate	FSK/9600 bps, AFSK/1200bps
On-Board Computer	80C186, Z80
Data Storage Capacity	13 Mbytes
Payloads	
DSFC	Digital Store and Forward Communication
CEIE	CCD Earth Imaging Experiment wide angle camera 2300km x 2300km (4km/pixel) high resolution camera 230km x 230km (400m/pixel)
DSPE	Digital Signal Processing Experiment
CRE	Cosmic Ray Experiment

energy protons (Tascione 1988) which contribute significantly to both long-term and transient radiation effects. The system also detects Galactic Cosmic Rays coming from deep space, and Solar Cosmic Rays associated with solar flares. The payload occupies one half of a payload module, as shown in Figure 1, and consists of two subsystems: the Cosmic Particle Experiment (CPE) and the Total Dose Experiment (TDE). The CPE provides a mechanism for measuring the Linear Energy Transfer (LET) spectrum (in a silicon detector) of ionizing radiation particles passing through the spacecraft over short intervals of time. The TDE provides a mechanism for measuring the long-term total accumulated ionizing radiation dose (in SiO_2) for various locations in and around the spacecraft. The radiation sensors are solid-state RADFET/MOSFET dosimeters, which are monitored for changes in threshold voltage. Details of the hardware are described in §2.

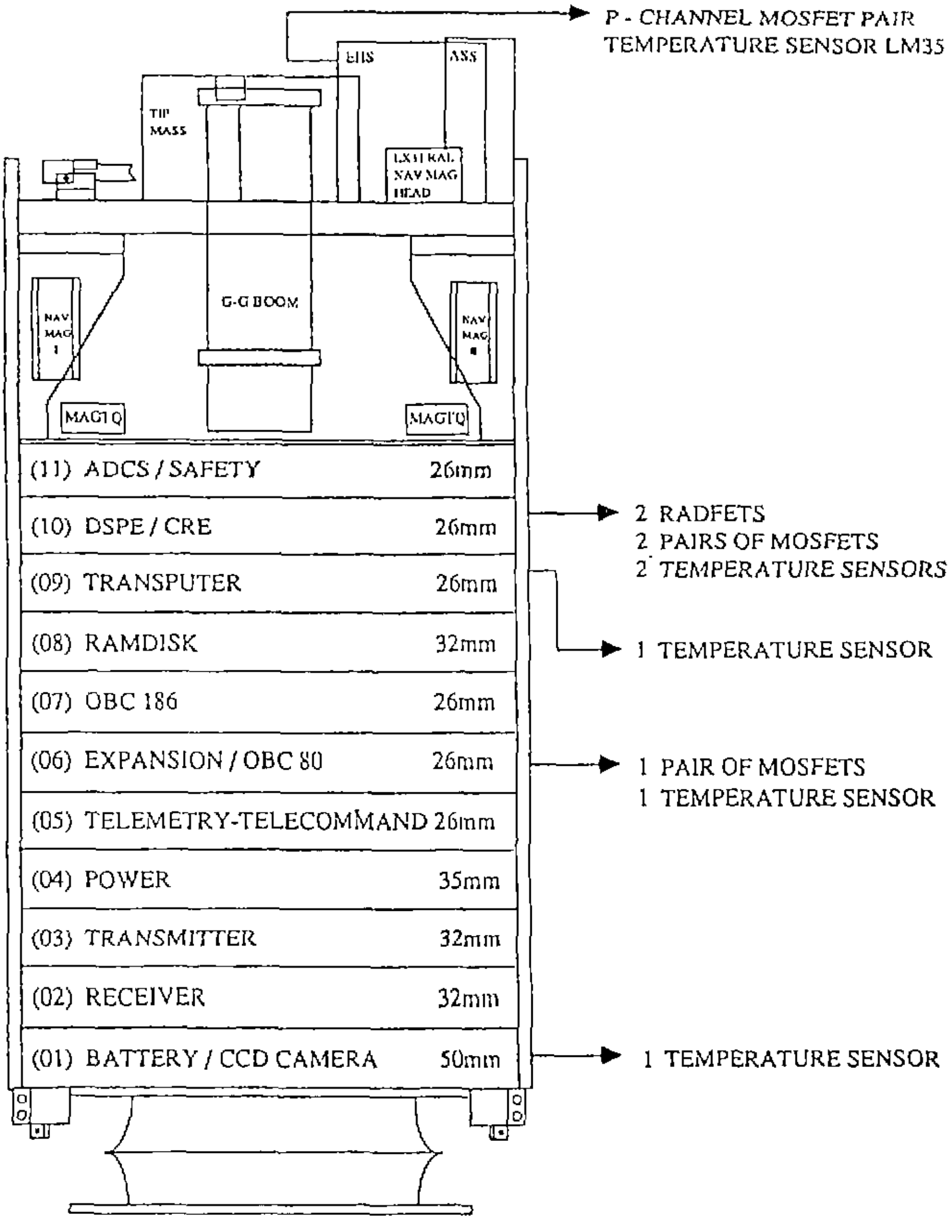

Figure 1. Modular structure of the KITSAT-1. Locations of the TDE dosimeters as well as the CRE board are also shown

2. CPE AND TDE HARDWARE

The CPE consists of a $30mm \times 30mm$ PIN diode detector ($900mm^2$ active area), $300\mu m$ in depth, housed in a separate screened aluminum box within the CRE module box(Figure 2). The sensor element, thus, is shielded by 10mm thick aluminum walls, preventing most primary electrons and all low-energy ions from contributing to the LET spectrum. This leaves the high-energy proton, alpha and heavy-ion content of the cosmic ray flux to be detected. The silicon detector is connected to a charge amplifier and a pulse-shaping circuit which in turn is connected to a pulse-height multi-channel analyzer. The experiment is controlled autonomously by a 87C51 microcontroller with its own data-storage RAM. The data are sent to the primary on-board computer via the spacecraft's serial data network - the DASH interface. The multi-channel analyzer has 512 channels, each of equal width equivalent to approximately 0.05pC of charge deposited in the detector (i.e., an equivalent normal-incidence LET of $16\text{MeVcm}^2\text{g}^{-1}$). However, the first 4 channels are sub-threshold, and the remaining 508 channels which are linearly weighted from $64\text{MeVcm}^2\text{g}^{-1}$ to $8230\text{MeVcm}^2\text{g}^{-1}$ are used. The detector deadtime determined by the hardware used is less than $10\mu s$, so that the count rate up to 10^5 particles per second can be handled.

The pulse-height is recorded by a fast semi-flash 10-bit analog-to-digital converter (ADC). The output of the ADC is used to address self-incrementing memory locations. For simplicity of design, the three bytes of count-data per channel are stored in four bytes of data memory. Thus, the memory can hold a count of up to $2^{24} - 1$. These counts are integrated over a fixed period of 600 seconds-internally sub-divided into four periods of 150 seconds to improve orbit-position/time resolution. The fourth byte is used to store a fixed bit-pattern for examination of any possible single-event upsets (SEUs).

The purpose of the TDE is to measure the accumulated ionizing radiation dose at various locations on board the KITSAT-1 spacecraft (Figure 1). This is done by a series of solid-state 'RADFET' dosimeters (modified power MOSFETs) which have a thick ($> 0.1\mu m$) gate-oxide to make them especially sensitive to ionizing radiation. The TDE is based on the AEA Technology design originally flown on-board UOSAT-3 as part of the Cosmic-Ray Effects and Dosimetry (CREDO) payload (Dyer *et al.* 1990). The detection mechanism of TDE is as follows.

Exposure to radiation causes the formation of trapped holes (positive charge) in the gate oxide, which in turn causes a gradual shift in the threshold voltage with accumulated dose. Each RADFET sensor consists of a matched pair of p-channel MOSFETs, one of which is biased during exposure (MEASURE MODE), while the other remains unbiased. In READ MODE, a constant current (6μA) is switched to each RADFET in turn, and the threshold voltage is measured. This voltage is a function of temperature as well as dose, but the temperature effect can be largely compensated for by noting the difference in threshold voltage change

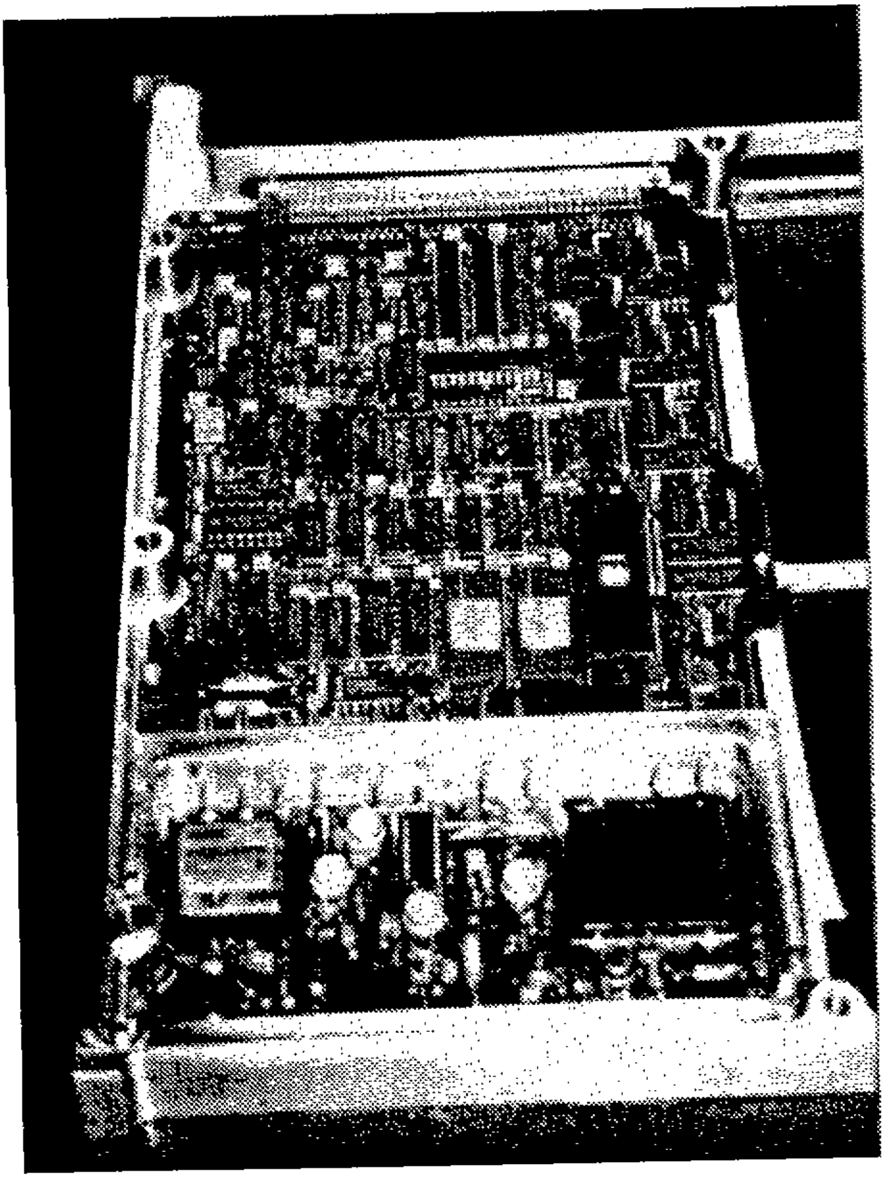

Figure 2. CPE board. The large rectangle in the lower right corner is the PIN diode detector

between the biased and un-biased RADFETs on a particular sensor. The gradual shift in this voltage difference is approximately proportional to the accumulated ionizing radiation dose.

To maintain the correct biasing conditions, the TDE part of the CRE payload must be kept powered-up and the system held in MEASURE MODE. During READ MODE, the data from the RADFETs and associated temperature and current sensors are passed to the telemetry system by multiplexing the 24 analog outputs onto a single analog telemetry input. These are then read by 'random-access' from the primary on-board computer.

3. INITIAL RESULT

The importance of the space environment and its effects on space technologies is well understood from the beginning of the space age, and it is now a necessary procedure to study the environmental effect on the spacecraft at its designing stage. The pioneering work in this area was the CREME code developed by Adams (1981). The code has now advanced to the stage that one can compute the high energy proton environment, geomagnetic and spacecraft shielding, and the radiation dose as well as the single event upsets. Nevertheless, there has been very little validation against flight data and a lack of simultaneous measurement of effects and environment on the same spacecraft. Only recently, we can have some results : upper atmospheric measurement on the supersonic Concorde (Dyer *et al.* 1989); the CREDO system on board the UOSAT-3 (Dyer *et al.* 1990); and the RDM on board the AKEBONO (Takagi *et al.* 1992). All these measurements are done in different orbit conditions and the KITSAT-1, being at 1300km altitude, can have a unique opportunity for studying the effects of the inner radiation belt.

Figure 3 shows the result of the CPE during the period of March 10, 1993 through March 24, 1993. Three flare eruptions were recorded during this period : M2 flare on March 12, 1993, and two M1 flares on March 16, 1993 and March 24, 1993. The grey scale at the bottom represents the total count of the whole channels over 150 second period. The South Atlantic Anomaly is clearly seen with its high count rates. The peak value $6.5 \times 10^4/150$s is a bit higher than the expectations probably due to the solar flares, although the exact comparison is difficult because of the complicated shielding geometry. Figure 4 shows the changes of the LET counts at the South Atlantic Anomaly after the major solar flare on March 12, 1993. The three curves are for March 15, March 17, and March 24, 1993, respectively. It is clear that the LET counts decrease as time passes by. However, it should be noted that the shape of the spectrum (hardness) is not affected much by the solar flare.

Figure 5 shows the TDE results obtained during January, 1993. The two curves are from the two RADFETs in the CRE module. The figure shows smooth linear changes in the threshold voltage, although two occasions of the system failure are also seen. The upper curve, which has a higher slope than the lower one, plots

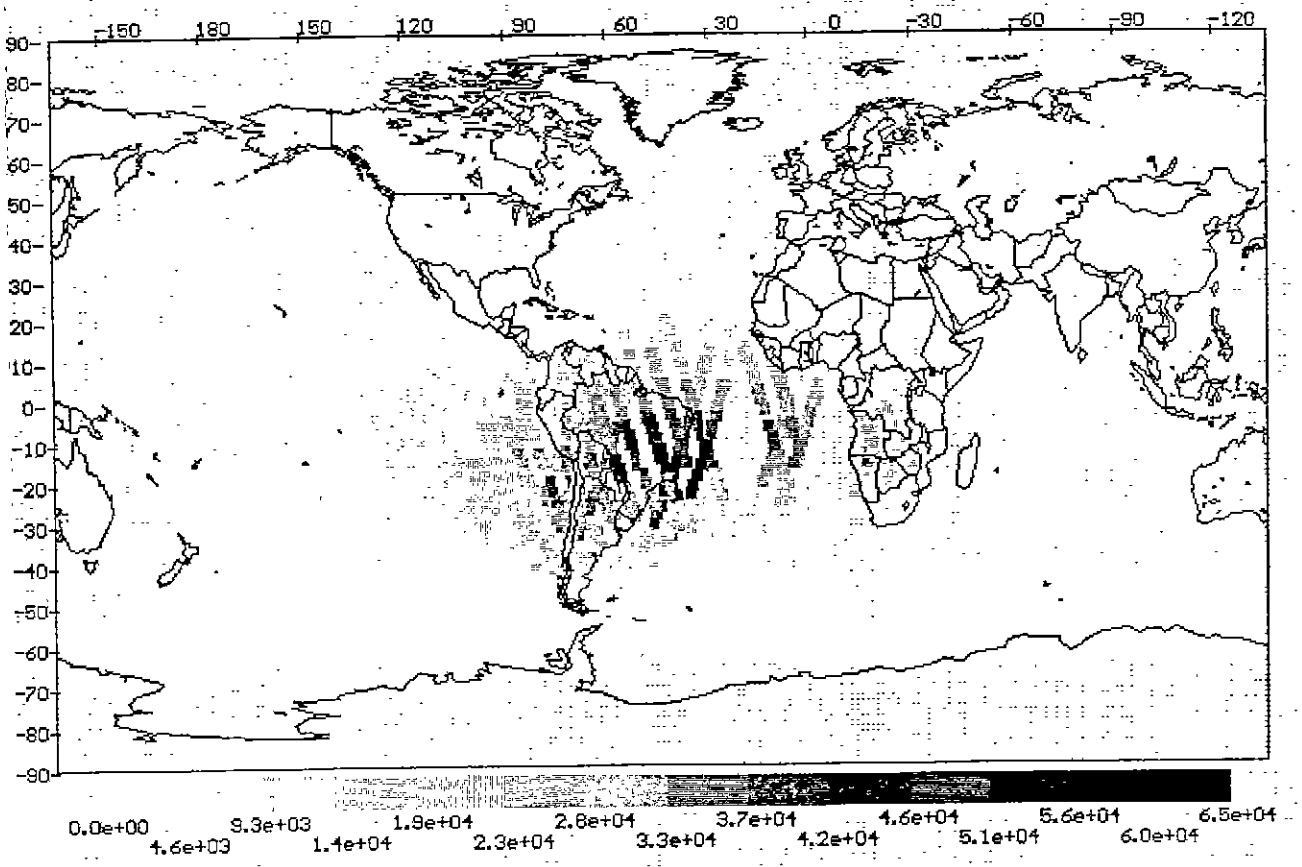

Figure 3. Global map of the CPE result. The South Atlantic Anomaly is clearly seen

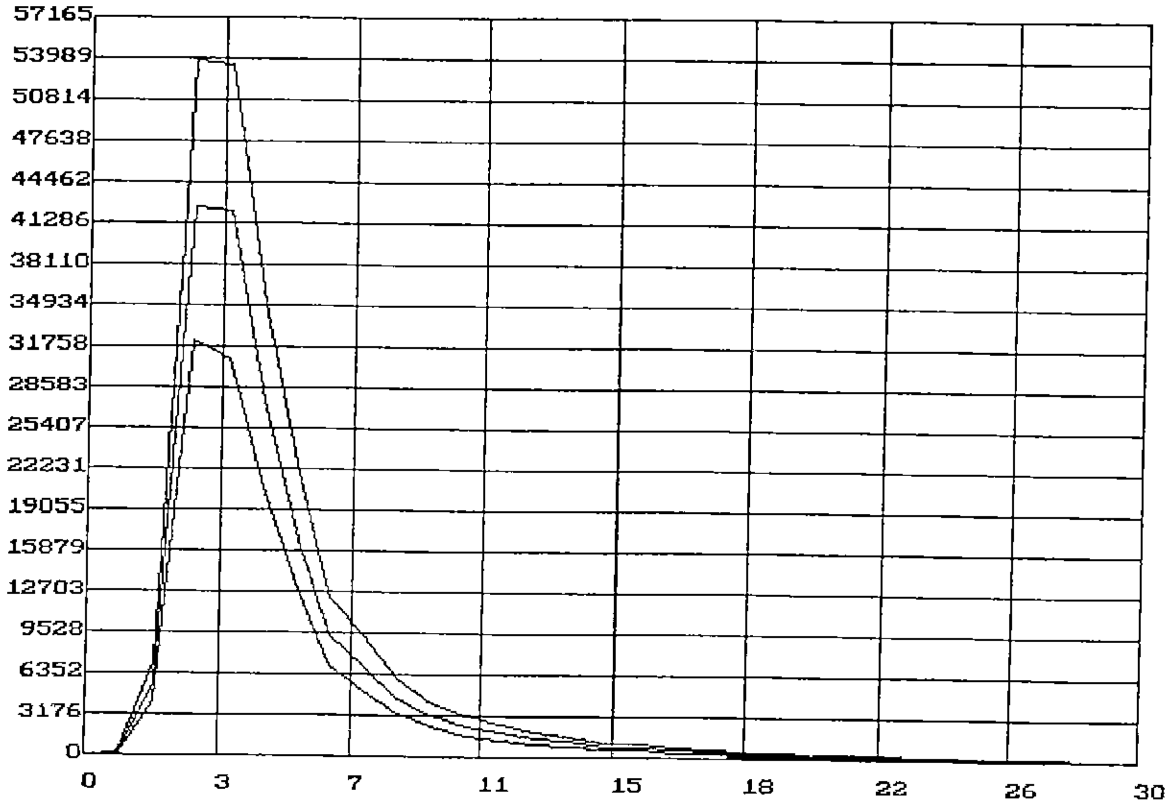

Figure 4. Changes of the LET counts after the solar flare. The three curves represent the counts/150s at the South Atlantic Anomaly on March 15, March 17, and March 24, 1993, from the top, respectively. Three solar flare events were recorded during this period : M2 flare on March 12, 1993, and two M1 flares on March 16, 1993 and March 24, 1993

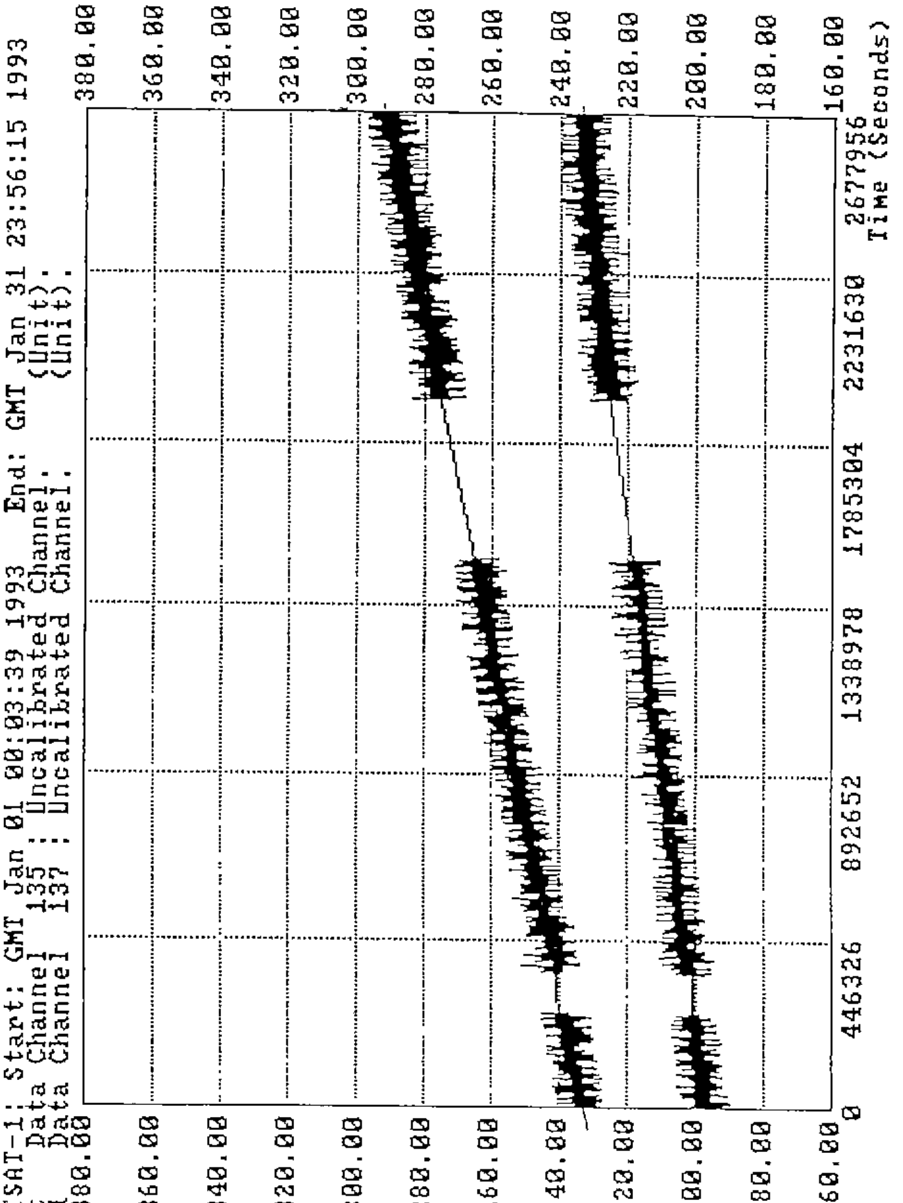

Figure 5. TDE data obtained during January, 1993. These two curves are from the two RADFETs in the CRE module

the data from the RADFET 1 located in the corner of the CRE module, while the lower curve corresponds to the RADFET 2 located more or less in the center of the module. The difference in the slope of two curves can be regarded due to the different amount of shielding since the boom is mounted in the central top of the module, which causes more shielding to the RADFET 2 than to the RADFET 1.

4. DISCUSSIONS

The Cosmic Particle Experiment on board the first Korean satellite, KITSAT-1, was reviewed in this paper. The detection mechanism was decribed rather in detail, and the brief initial results are presented. The preliminary results show good agreements with the previous models, and moreover, we expect good scientific results due to the unique orbital conditions of the KITSAT-1. Long term measurement of the Total Dose Experiment is being carried out, and the correlation studies of the LET flux, the SEUs, and the solar flare are planned.

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