Geostationary **RA**diation **SP**ectrometer

GRASP

An Instrument to Study the Energetic Particle Environment in GEO Orbit

An Executive Summary

Submitted by

Space Astronomy Group

URSC

Executive Summary:

The following document gives the executive summary of a Radiation Spectrometer that is flown on the GSAT-19 mission. Aspects such as science goals, detector configuration and instrumentation are addressed in the sections that follow.

Prelude:

The particle environment in space is highly dynamic, filled with energetic particles from solar events, trapped radiation belts and high energy cosmic rays originating from galactic and extra-galactic sources. Charged particles cause a variety of undesirable effects in spacecraft, electronic components and biological systems. They are known to induce gradual material degradation and malfunction of critical electronic components in satellites. Therefore, a Radiation Spectrometer is proposed on GSAT 19 to monitor the nature of the particle and its characteristics.

The proposed radiation spectrometer is a two detector system capable of measuring the flux and energy spectrum of particles (electrons, protons and alphas) in the Geo orbit. The special feature of this instrument is its ability to distinguish between the particles that are incident on it. It is also capable of measuring the time of occurrence, temporal evolution of the particles and also the total dose absorbed by the detector.

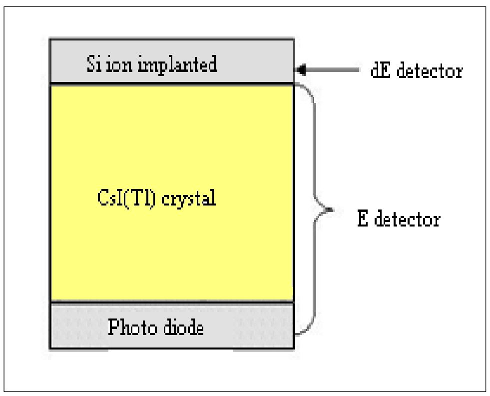
Science Objectives:

- Measure flux and energy spectrum of electrons, protons and alphas in energy range of interest (refer instrument specifications)
- Incident particle identification and its flux (e.g. electrons, protons and alphas particles) - required for designing optimum shielding.
- Carry out continuous long-term monitoring of the radiation environment to derive the basis for engineering guidelines which help for
    - Satellite design
    - Analyzing failure(s) if any onboard and
    - Anomalous behavior of spacecraft sub-systems.
- Improve upon the existing models (for ISRO missions) of the radiation environment.
- Study the effects of solar energetic particles, solar flares, and coronal mass ejections (CMEs) on the outer radiation belt.
- Understand the complex dynamical plasma phenomena in the earth's magnetosphere viz., particle acceleration, magnetic reconnection, and charge-exchange with neutrals.

The instrument is fundamentally designed as a generic radiation spectrometer and is now tailored & optimized for incorporation into GEO missions. This instrument in its full capacity is not limited just for GEO missions, but also can be extended to other types of missions – LEO, Interplanetary, and human space programmes.

A brief description of the Instrument:

In order to identify the particles that are incident on the detector, several techniques like pulse shape discrimination, time of flight and E-ΔE method are in use today. We propose to use the E-ΔE technique which achieves particle identification on the basis of distribution of energy loss in multiple detectors.

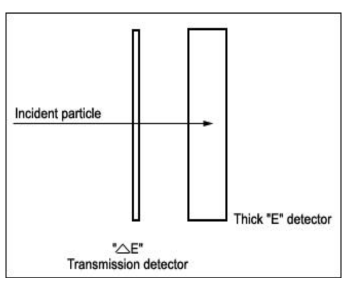


The instrument is a two detector system. The top thin detector, called the dE detector, is an ion implanted Silicon (Si) wafer placed above a thick crystal, called E detector which is a CsI (Tl) scintillator. The crystal is optically coupled with a photodiode for reading out the light produced in it. The charge output from each detector is fed to the electronics to measure the energy of the incoming particles using the pulse height measurement technique. (Details in Annexure IV)

Principle of Operation:

This instrument uses the well-known E-dE technique for particle identification and pulse height measurement for measuring the energy of the incoming particles.

The experiment has two detectors, of which the top detector is thin and the bottom detector is thick. Each detector is associated with a preamplifier and associated electronics that will derive the energy loss by the particle in that detector.



E-dE telescope

When an energetic particle passes through the 2 detector stack, it will deposit a fraction of its energy in the thin dE detector and the remaining energy in the thick E detector.

The charged particle passes completely through the dE detector retaining most of its initial energy and a signal proportional to the specific energy loss (dE/dx) is observed. The particle then interacts with the E detector which is sufficiently thick to completely stop the charged particle within its active volume. The charged particle produces an output signal in each detector whose amplitude is proportional to the specific energy loss (dE/dx) of that particle in the detector. In this case, the number of charge carriers produced is proportional to the total energy of incident particles.

Since the specific energy loss in the thin detector is a function of the particle type and its energy, a plot of the energy measured in thin detector (dE) versus the total energy lost in both detectors (dE+E) will show a distribution based on the particle type and its energy. Using this method, both the particle identification and the particle spectrum can be obtained.

Payload Specifications:

Element	**Parameter**	**Specifications**
Data Rate in GEO	kbits/sec	4
No of electronic cards	No	3
Telecommand	No	1
Total Raw Power	Watts	< 5W
Weight	kg	1.5
Overall size	mm^3	(L x W x H) 190mm x 180mm x 110mm
Collimator FOV	degrees	30^0
Collimator material		Copper

Detector Specifications:

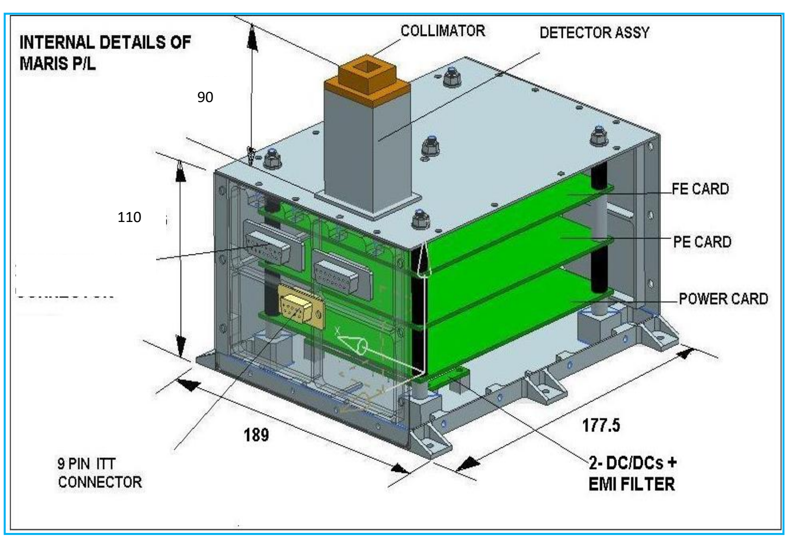
Element	**Parameter**	**Specifications**
Instrument type		Spectrometer
dE detector	Make	Ion implanted detectors –MSX03-140 (FM)
	Active area	10mm x 10mm
	Detector thickness	130 micron
	Full depletion depth	15V
	Window	<0.5 micron

	Leakage current	< 50 nA
	Mode of use :	in transmission –no dead layer
E Detector(Scintillator CsI(Tl) & Photodiode for Scintillator Readout	Dimensions	Scintillator CsI(Tl): 10 X 10 X 25 mm^3
		Photodiode for Scintillator Readout: 10 X 10 mm^2
	Reverse Bias Voltage (Max)	75V
Energy Range of particles	MeV	Electrons : 0.3 -10 MeV Protons : 4 -85 MeV Alphas : 17 -85 MeV
Det.Operating Temperature	^{0} C	dE det : +10 to +30 E det : +10 to +30
Det.Storage Temperature	^{0} C	dE det : -20 to +80 E det : -20 to +80

Instrument Specifications:

Parameter	Specifications
Mass	1.5kg
Power	< 5W (raw power)
Volume (LxWxH)	190mm x 180mm x 110mm
Data rate in GEO orbit	4 Kbits/s
Preferred Mounting	AEV /East/West panel
Energy of particles	Electrons : 0.3 -10 MeV Protons : 4 -85 MeV Alphas : 17 -85 MeV

Mechanical Configuration:



ΔE Detector:

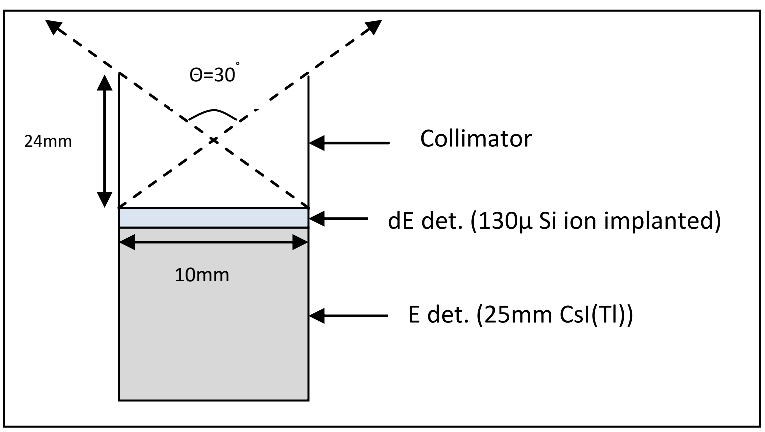
The ΔE detector is a 130 micron thick ion implanted Si detector. The scintillator crystal is placed directly below the ΔE detector. Incident protons of energies > 4 MeV will pass through the top detector and enter the E detector. A time coincidence window of ~2 μs is defined and all coincident events (E and ΔE) are recorded and used for generating the E -ΔE plot.

E Detector:

The E detector is a CsI (Tl) scintillator with dimensions 10 x 10 x 25 mm^3. The thickness of this crystal is chosen such that 85 MeV protons will be fully absorbed within its active volume. The scintillator is packaged in reflective material and one side of it is used for scintillation light readout of energy loss of energetic particles in the crystal. A photodiode that is optically coupled to the crystal, with approximate dimensions of the active area of 10×10 mm^2 will be used for read out of the scintillation light of the crystal. The photodiode signal is then amplified by a pre-amplifier to provide the analog output.

Collimator:

A collimation of +/- 15^0 is achieved by placing a mechanical collimator of height 24mm. The main condition that has been used for the calculation of the FOV is that the incident particle must pass through both detectors (condition of coincidence). (See fig below).



Detector Window: A six micron aluminized mylar sheet will be used as a thin entrance window. This window will make the package light tight and also serve as a protection for the topmost detector.

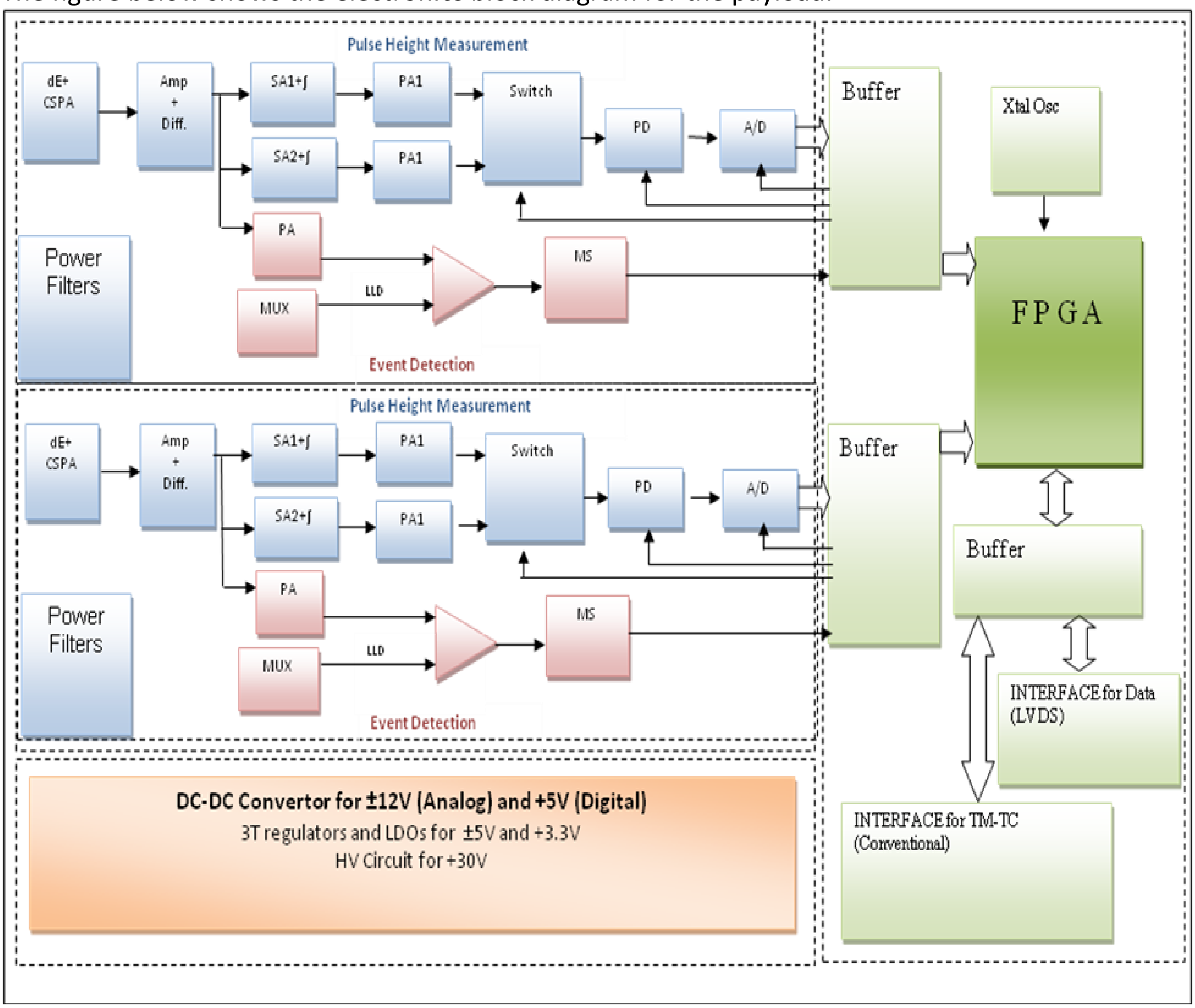
<u>Electronics Configuration:</u>

Detector Electronics and Event processing:

Front End Electronics:

The charge output from the detector is amplified and converted into a voltage signal using a charge sensitive preamplifier (CSPA), which is further shaped and amplified by the post amplifier. Peak detector tracks this analog output and holds the maximum voltage as a peak voltage on its hold capacitance. This peak voltage is then digitized by an 8 bit ADC and interfaced with digital electronics.

The figure below shows the electronics block diagram for the payload.



Processing Electronics:

The digital data is sent to the FPGA for further processing. The main functions of FPGA are generating the timing signals for peak detector and ADC, implementing coincidence logic, formatting data and packet, providing the interface for data and commands and most importantly constructing PHA in EDAC memory.

Readout Modes:

We propose to use two modes of operation and data collection. One is event mode, which will run during the normal quiet phase and the other is matrix mode, which will be used during the bright phase as seen during an SEP event. The transition from the event mode to the matrix mode will be made if the counts exceed a certain threshold, the value of which can be uplinked from ground by telecommand.

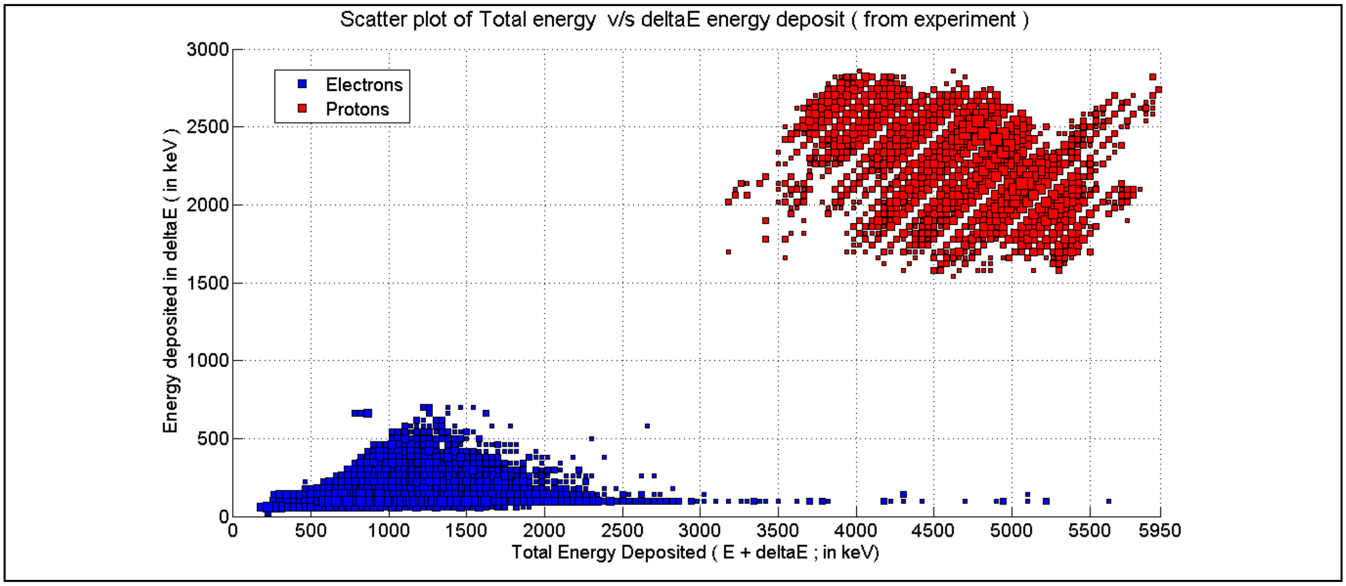
Event Mode:

This mode is event based. During this mode, when a charged particle falls on the detector, the time of incidence, the energy loss in both the detectors (ΔE, E) and a flag indicating coincidence will be generated. The count rate will be generated by a counter which will count all the events that are recorded over the entire energy band. This data is then stored in the onboard memory and then transmitted during data downlink. The coincident events will be used to generate the E-ΔE plot

Matrix Mode

This mode collects raw data and creates a coarsely binned histogram on board, for a certain integration time, the value of which can be uplinked from ground. In this phase, we expect the count rates to be very high (10^5 - 10^6 c/s) because this phase is used when there is a Solar Energetic Particle (SEP) or a very bright solar flare. In order to cope with the high count rates, we intend to separately divide the energy dynamic range of both types (electron and proton) into 128 bins (16 X 8) to make a 2D histogram from E and delta E energy depositions.

The following plot shows the species separation in an E-deltaE particle telescope as obtained from the ground experiments (done at beamline for protons):



From the results shown above, we have demonstrated the concept of the E-dE technique using this instrument.

<u>Conclusion</u>:

As outlined in the science objectives, with this instrument:

1) We have measured the flux and energy spectrum of electrons (of energy 10keV-2.3 MeV) and protons (of energy 4.4-5.3 MeV) that are incident on the detector.

2) Using the E-dE technique, we were able to distinguish between the incident particles.

As mentioned earlier, this instrument is fundamentally designed as a generic radiation spectrometer and is now optimized for incorporation into GEO missions. The instrument in its full capacity is not limited just for GEO missions, but also can be extended to other types of missions – LEO, Interplanetary, and human space programmes.