ROBI a Robust Integrating Proton Fluence Counter based on COTS GaAs LED: Results of a recent near equatorial LEO Space Mission

ID 1308

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EXPANDING THE SCOPE OF RADIATION PROTECTION

SEA WORLD RESORT CONFERENCE CENTRE

GOLD COAST QUEENSLAND I 29 OCTOBER - 2 NOVEMBER 2023

Motivation and Scope of this Research

Radiation (Displacement) Damage induced in Commercial Off The Shelf (COTS) Gallium Arsenide (GaAs) Light Emitting Diodes (LED) was utilised to develop a Proton Dosimeter for Clinical Applications.

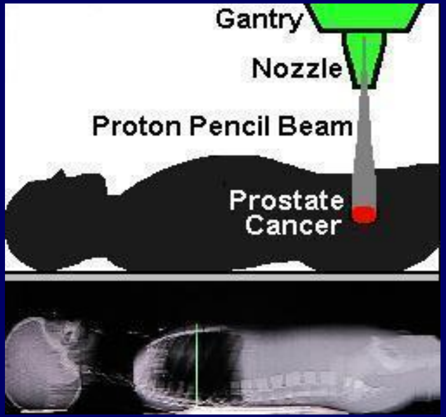
The LED Dosimeters were calibrated using High-Energy Proton beam from a Proton Therapy Medical Cyclotron at West German Proton Therapy Centre Essen (WPE) Germany also used for Space Radiation Dosimetry related research.

The cross calibrated (Proton) Dosimeters (ROBI) were housed in the PSLV Orbital Platform Experiment Module (POEM) and launched into a Low-Earth near Equatorial Circular Orbit using the Polar Satellite Launch Vehicle (PSLV) of ISRO India.

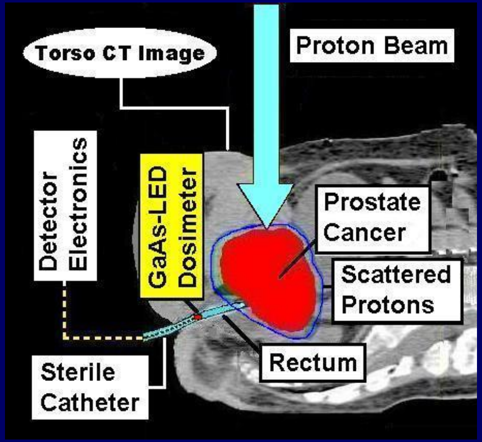
The operation and results of a recent Space Mission (1-31 July 2022) will be disucussed in this Presentation.

From Clinical (Proton Therapy) Dosimetry to Space Dosimetry

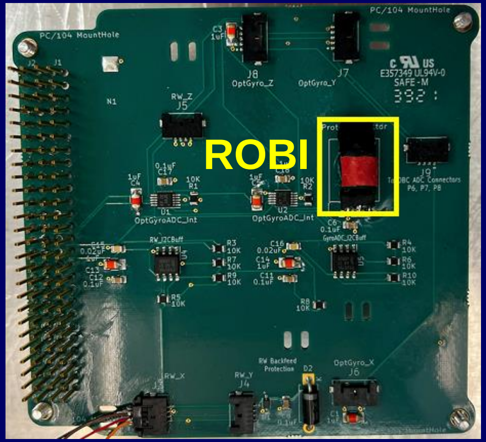
Proton Beam Delivery Nozzle



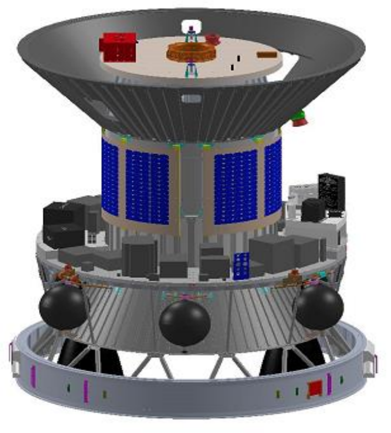
Prostate Cancer Irradiation Procedure



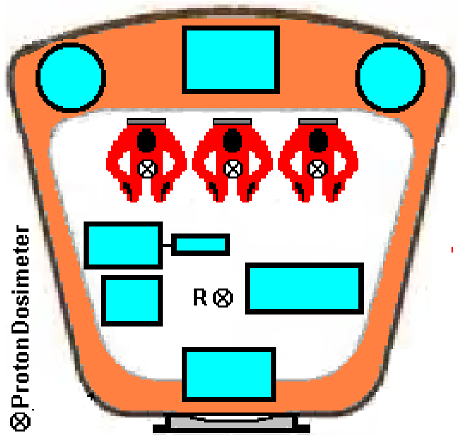
O-O-F Proton Dosimetry



GaAs-LED Dosimeter* on PCB



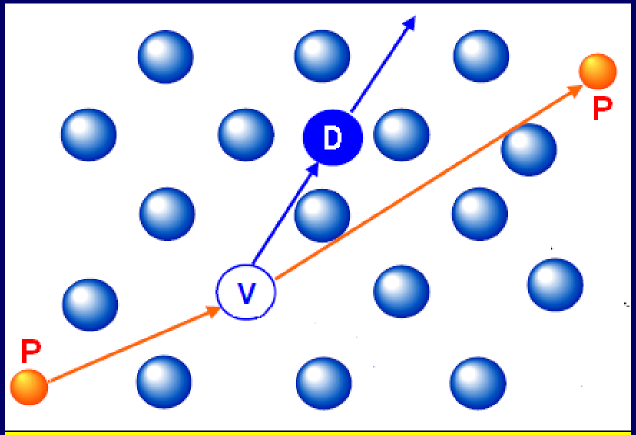
POEM (PSLV-Orbital-Experiment-Module)



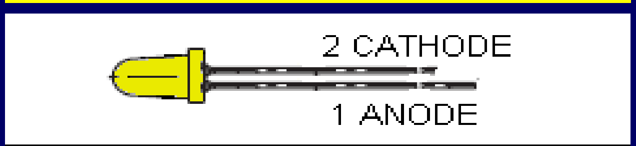
Gaganyaan Crew Module

* ROBI (ROBust Integrating) Proton Fluence Counter for Space Applications

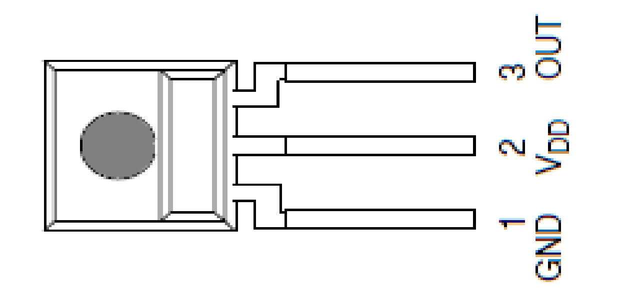
Displacement Damage - GaAsLED - Detection Principle



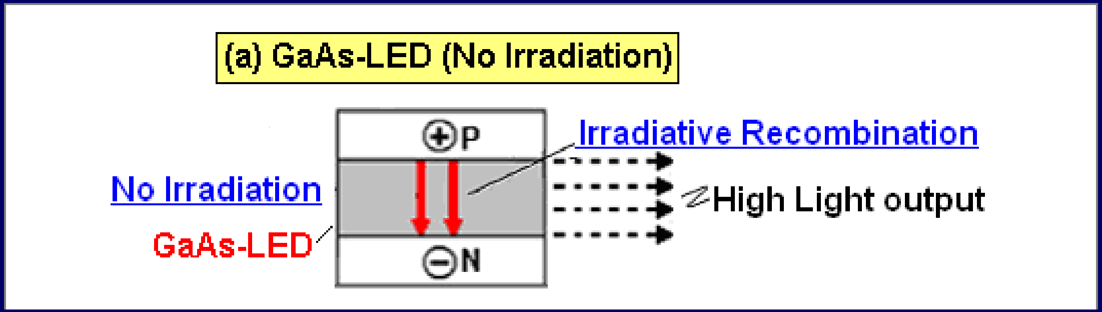
P: Impinging Particle, V: Vacancy, D: Displaced Atom

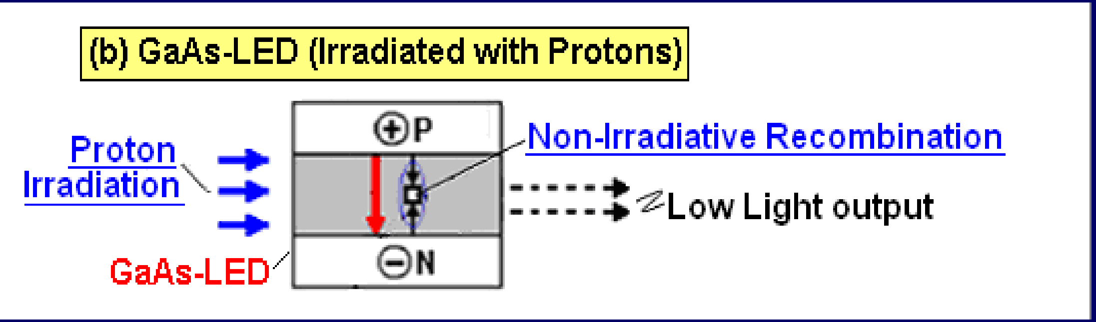


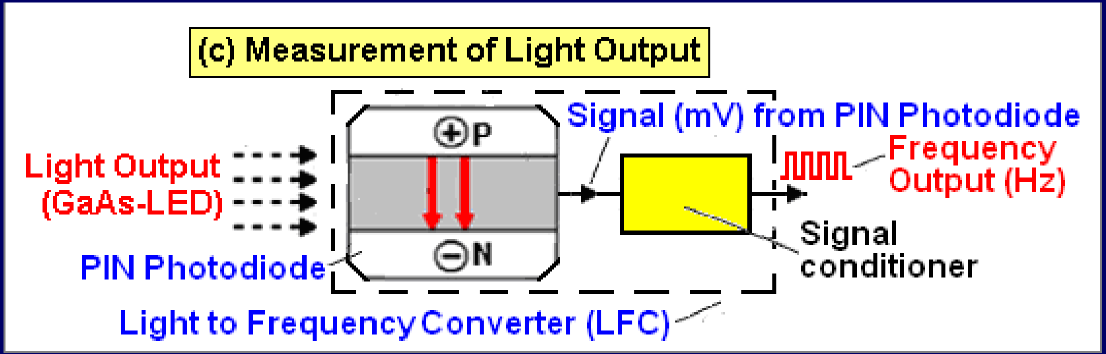
GaAs-LED (Amber)



Light-Freq Converter (LFC)

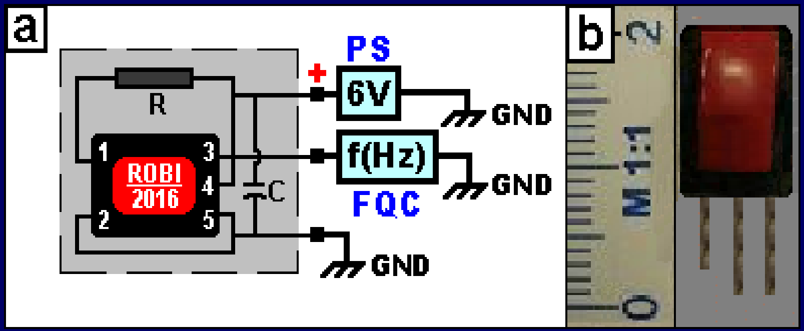






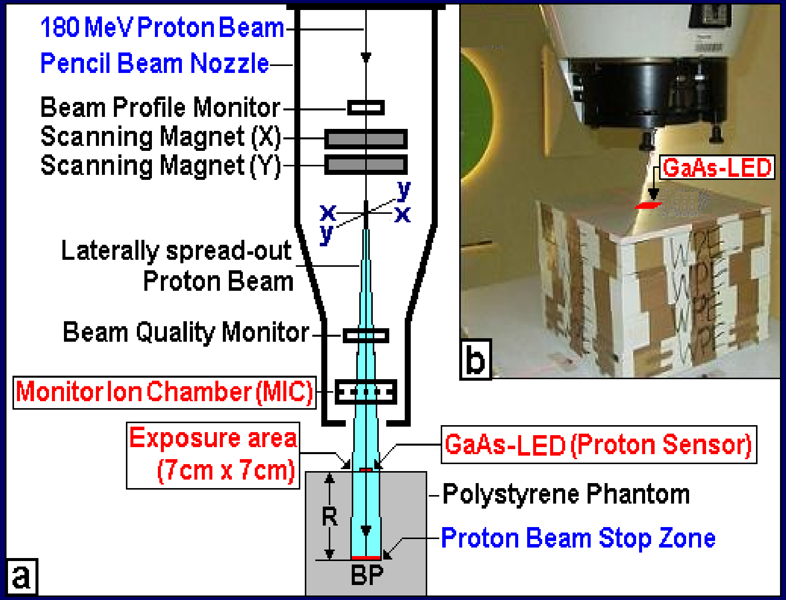
B. Mukherjee et al. Application of low-cost Gallium Arsenide Light-Emitting Diodes as Kerma Dosemeter and Fluence Monitor for High-Energy Neutrons, *Radiation Protection Dosimetry 126 (2007) 256-260.*

Dosimeter Fabrication - Calibation using a Proton Therapy Cyclotron



(a) **Fabrication**: Showing the 6V stabilised power supply and a Frequency counter attached to the proton irradiated GaAs-LED dosimeter.

(b) A prototype of fully fabricated Robust Integratiing (ROBI) Proron Fluence Counter (Proton Dosimeter).



(a) **Calibration**: The 235 MeV Proton Therapy Cyclotron of WPE was used for the calibration of ROBI Proton Dosimeter. The standard proton therapy QA procedure was taken into account.

(b) Showing a GaAs-LED dosimeter placed on a 35 x 35 x 30 cm^3 polystyrene phantiom under the proton beam delivery nozzle.

$$\text{Proton Dose} \sim (\text{LED Light Output})^{-1} \sim (\text{Frequency Counts})^{-1}$$

B. Mukherjee. Feasibility study of a proton fluence monitor for LEO-Nanosatellite missions based on displacement damage induced in GaAsLED, *Journal of Instrumnentation Jinst 14(2019)T10002.*

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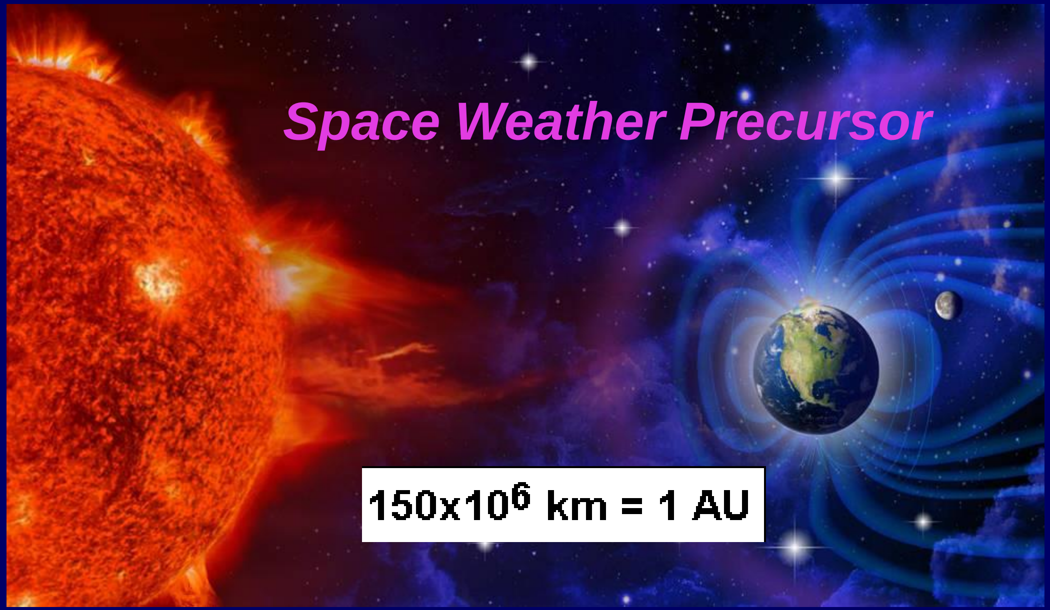
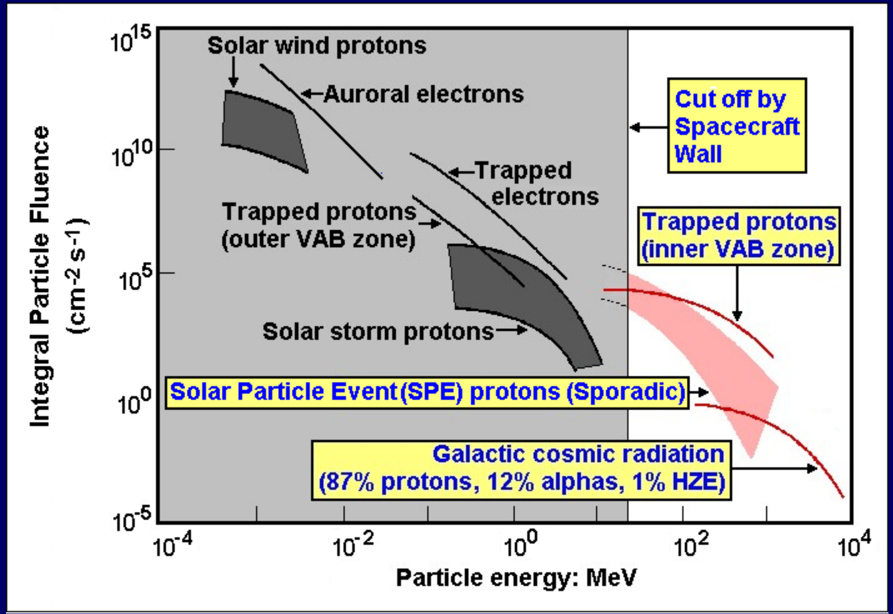
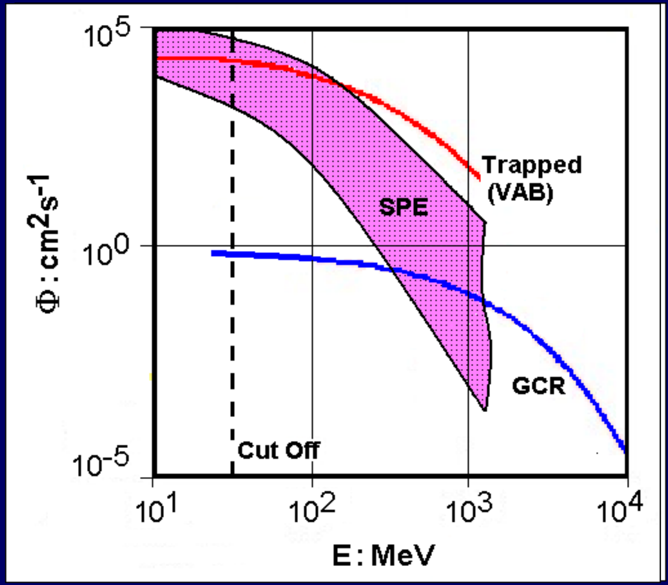
Space Radiation Exposure : Origin and important Characteristics





Spacecrafts operating within Solar system (inter- planetory space) are predominantly exposed to radiations from the Sun.

Whereas, the contribution of Galactic Cosmic Rays (GCR) is 5 orders of magnitude lower than the above. The radiation cut off zone is highligthed.



All LEO spacecrafts are exposed to: (a) <u>Strong</u> radiation field of Trapped Protons from the Van Allen Belt (b) <u>Weaker</u> Galactic Cosmic Rays (GCR)

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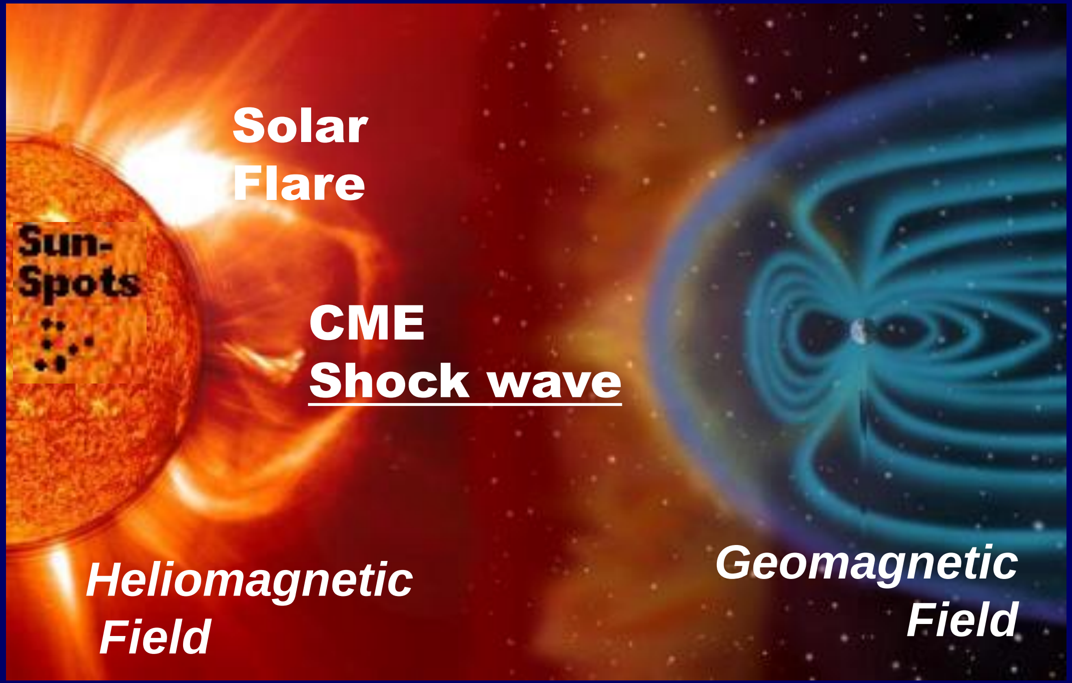
(c) <u>Sporadic</u> Solar Particle Events (SPE)

Space Weather : Occurance

Vast amount of energy is produced in suns´s core from Nuclear Fusion process



Solar- Magnetic field (*Heliomagnetic Field*) is generated by Solar Dynamo effect

Heliomagnetic Field is governed by the shape and number of *Sunspots*

Geomagnetic Field (Magnetosphere) *is* originated from molten magma in earth´s interior

Sporadic Incidence of

Coronal Mass Ejection (CME)/Shock wave

Solar Flare

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Space Weather : Sporadic effects - Aftermaths

Coronal Mass Ejection (CME)

=> Release of Solar Magnetic Plasma as ***Shock Wave***

=> ***Geomagnetic Storm*** => Faults in Electrical Powerlines, GPS and Satellite-Comunictions

=> ***Radiation Storm*** => Damage in Space electronics, High radiation exposure to Astronauts

Solar Flare

=> Sporadic Intense eruption of Electromagnetic radiation from solar atmosphere

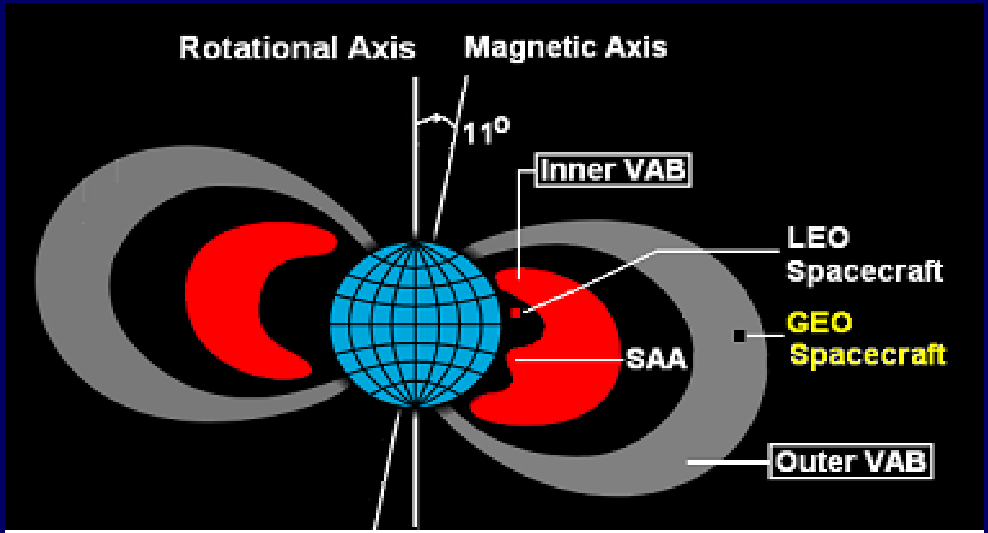
=> Highly localized, EUV-to-Visible spectrum including high-energy X-rays (100s of keV)

=> ***Radio Blackout*** => Severe disturbance in radio-telecommunications on earth and in space

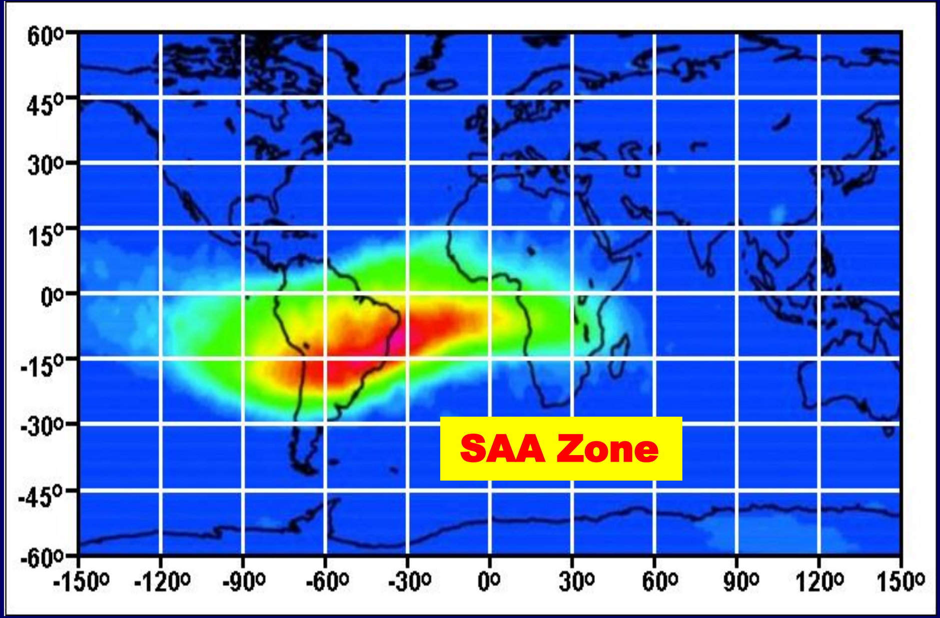
NOAA Space Weather Prediction Center

www.swpc.noaa.gov/NASAscales

Van Allen Radiation Belt (VAB) - Space Weather



Structure and Features of Van Allen Belt (VAB)



Inner VAB: Space Weather Relevance

1000-12000 km from Earth surface

Trapped Protons predominate

Magnetic Axis tilted by 11°

=> South Altantic Anomaly (SAA)

=> Proton Exposure to LEO Spacecrafts

Outer VAB: Space Weather Relevance

13000 - 60000 km from Earth surface

Trapped Electrons (E ~ 7 to 10 MeV) predominate

Spacecraft Surface charging effect

No severe Radiation Damage in Space-electronics

=> Critical to GEO Spacecrafts

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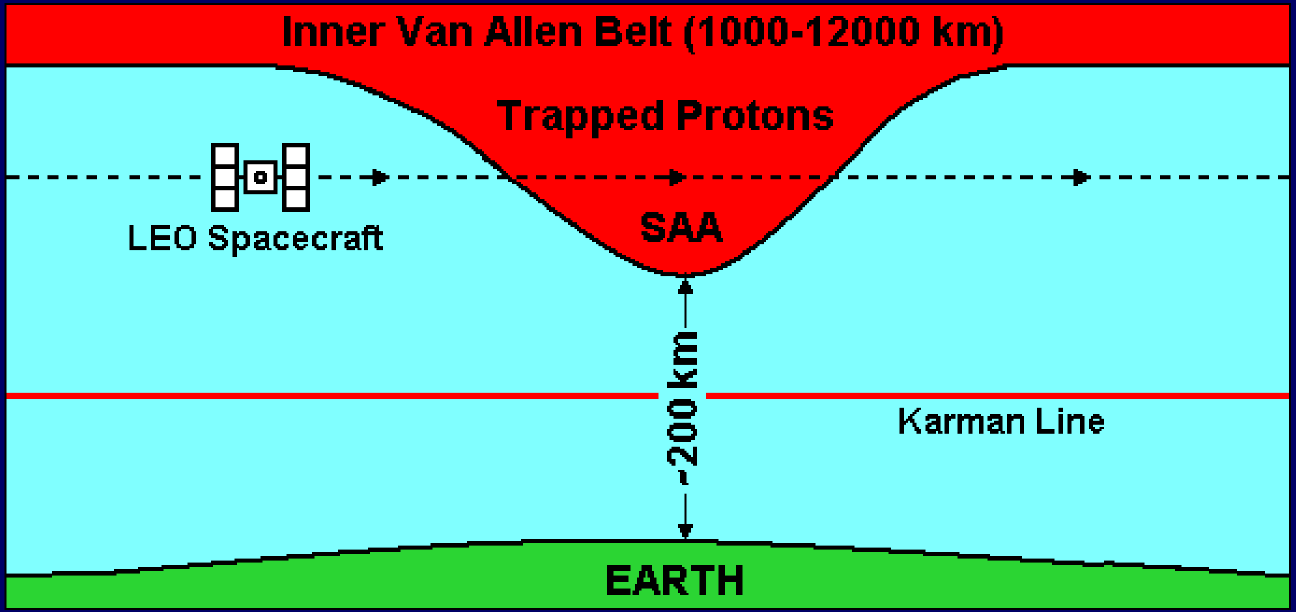
Van Allen Radiation Belt (VAB) - Proton Exposure - LEO Spacecraft



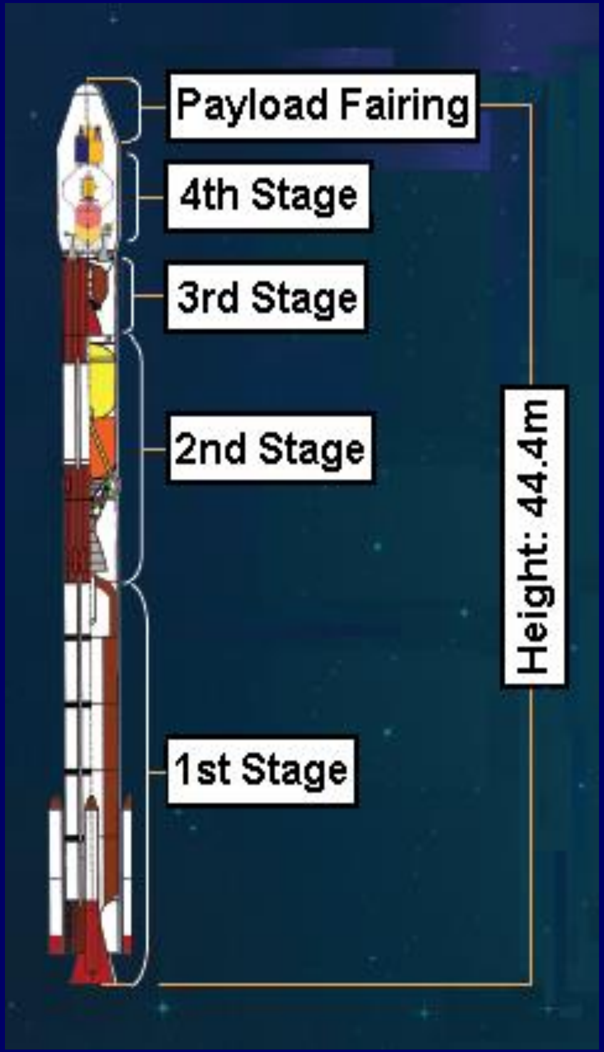
Throughout the South Atlantic Anomaly (SAA) Zone the Trapped-Proton field from the Inner Van Allen Belt drops substantially at an altitude of approx. 200 km from the Earth surface.

LEO Spacecrafts are exposed to Trapped protons during their passage through SAA Zone lasting only 10-12 minutes out of total orbital period of 100 minutes.

Therefore, a Sudden Rise of the Proton Fluence Rate Forecasts a Solar Proton Event (SPE).

Hence, the GaAs LED based Proton Fluence Counter (ROBI) înstalled in POEM spacecraft could serve to monitor the Space Weather Status.

PSLV-C53/DS-E0 Mission on 30 June 2022 - Launch Vehicle



Stages	Length (m)	Diameter (m)	Propellant	Propellant mass (T)
1st	22.0	2.6	Solid: (HTPB)	139
2nd	12.8	2.8	Liquid: (UH25 + N_2O_4)	41
3rd	3.6	2.0	Solid: (HTPB)	7.7
4th	3.0	1.34	Liquid: (UH25 + N_2O_4)	0.8
Payload Faring	3.0	1.34	none	none

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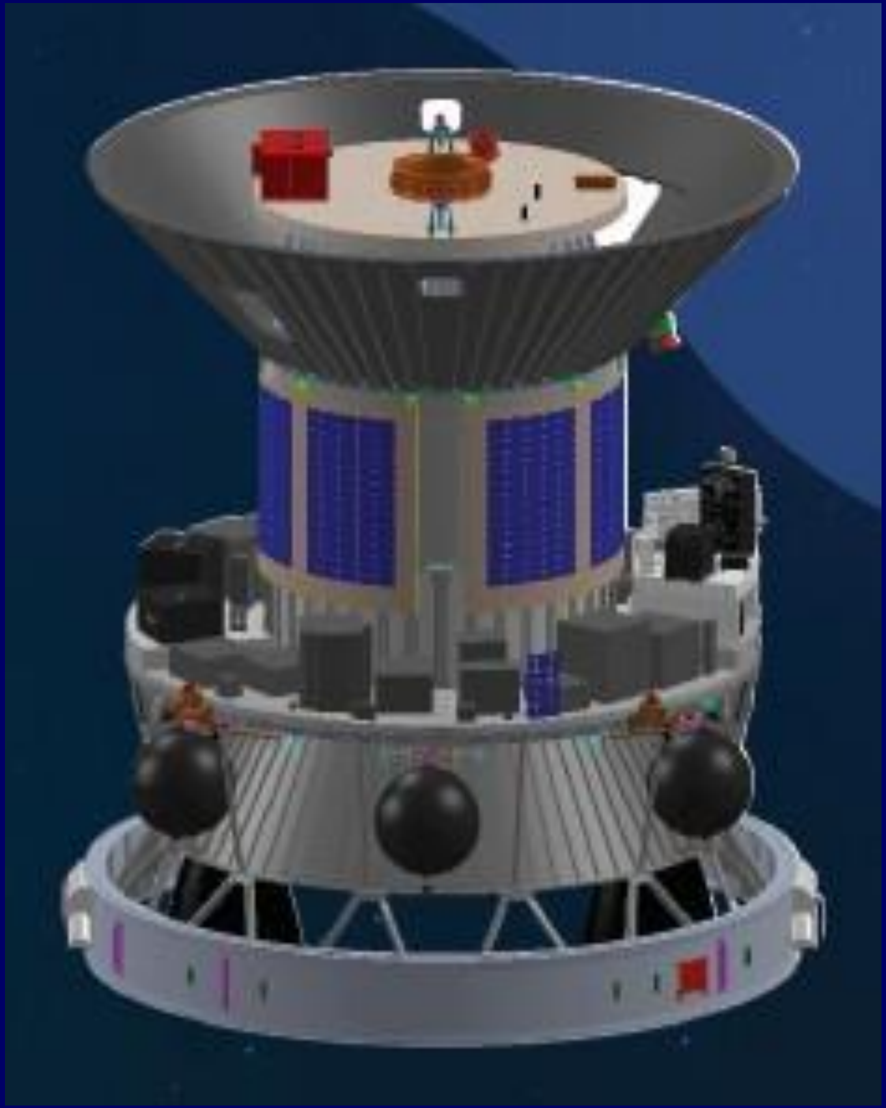
PSLV Orbital Platform Experiment Module (POEM) - Configuration

By using the spent 4th stage of the PSLV Rocket ISRO has developed the PSLV ORBITAL Experiment Module (POEM).

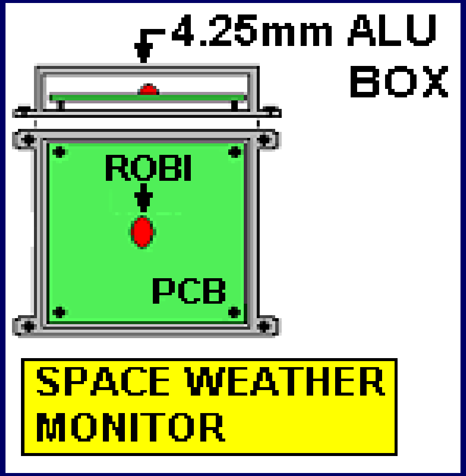
Power for POEM was derived from dedicated Solar panels mounted around the Fuel tank and a LiIon battery.

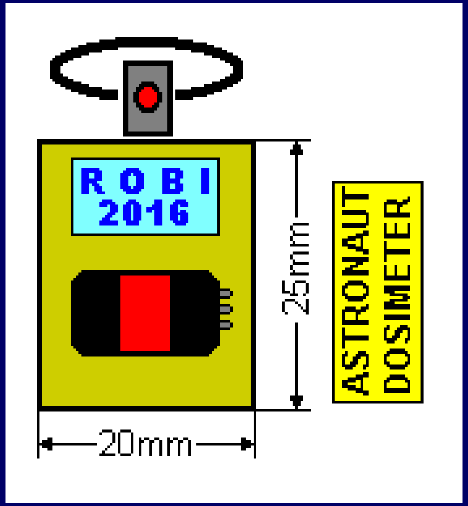
The POEM navigation system was supported by a set of 4x Sun sensors, 1x Magnetometer and NAVIC GPS module.

He-Gas Thursters (x8) were deployed for orbit stability and altitude control of POEM.



PAYLOADS





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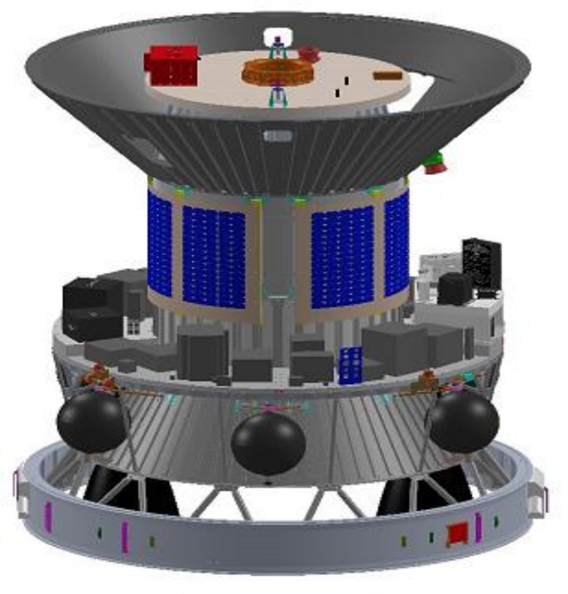
PSLV-C53/DS-E0 Mission on 30 June 2022 - POEM in Orbit



Inclination : 10º (Near- Equatorial)

Eccentricty : 0.00 (Circular)

Apogee height : 570 km (LEO)

Orbits executed per day : 14.94

Launch location : Sri Harikota, INDIA

Launch coordinate : 13.718ºN 80.20ºE

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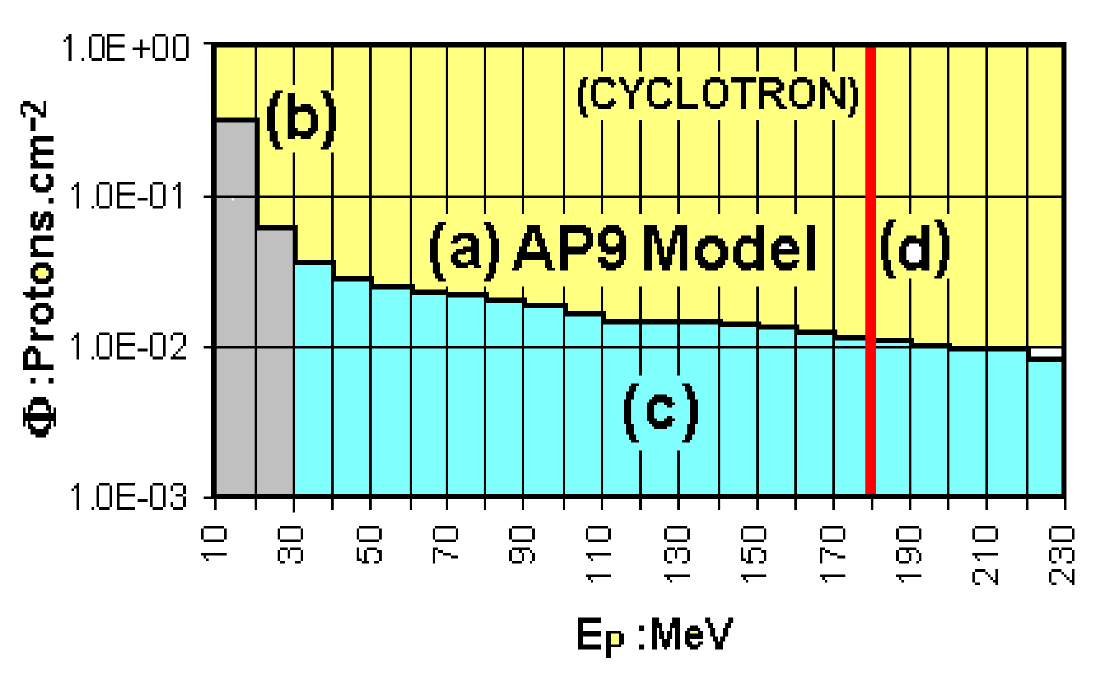
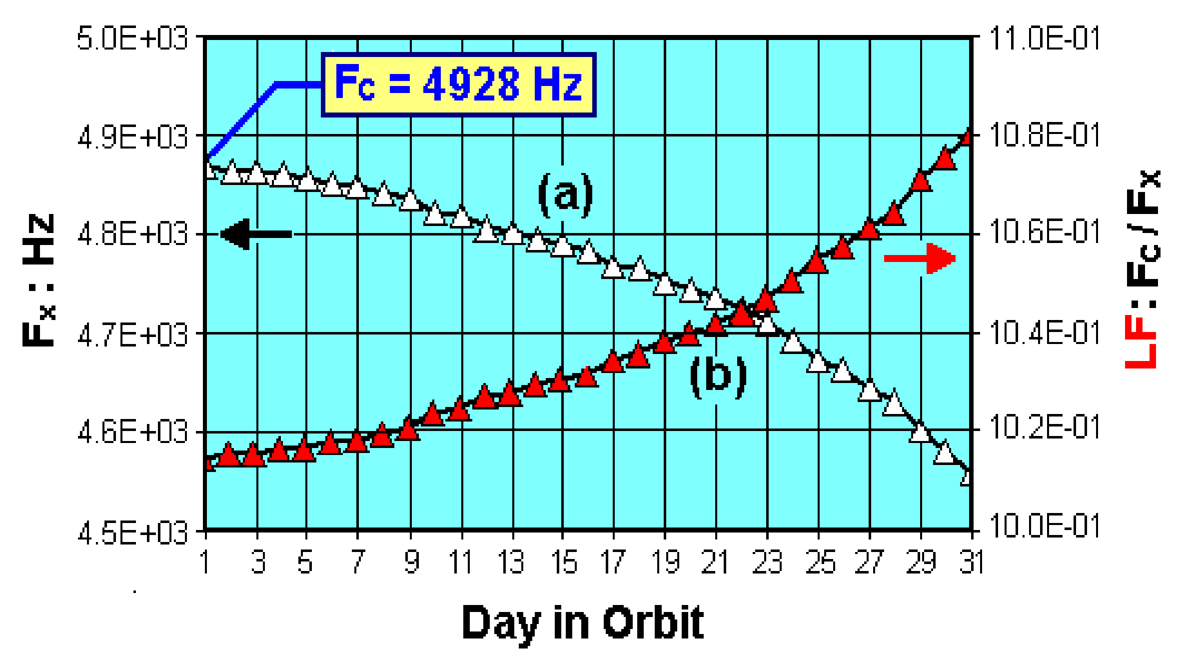
ISRO PSLV-C53/DS-E0 Mission on 30 June 2022 , ISRO web site (www.isro.gov.in)

PSLV-C53/DS-E0 Mission on 30 June 2022 – Core Results (1/2)





(a) AP9 Spectrum (trapped protons)

(b) 30 MeV (cut off) by 4.25 mm ALU-wall

(c) Spectrum inside ROBI contanier (E_{av}= 36MeV)

(d) 180 MeV protons from Cyclotron (Calibration)

(a) GaAs-LED Frequency output F_x (Hz) drops with increasing space radiation exposure. This Data is transmitted to ground station every minute.

(b) Light attenuation factor (LF = F_C/F_X) rises with increasing space radiation exposure. The LF data was used to claculate the integral proton fluence.

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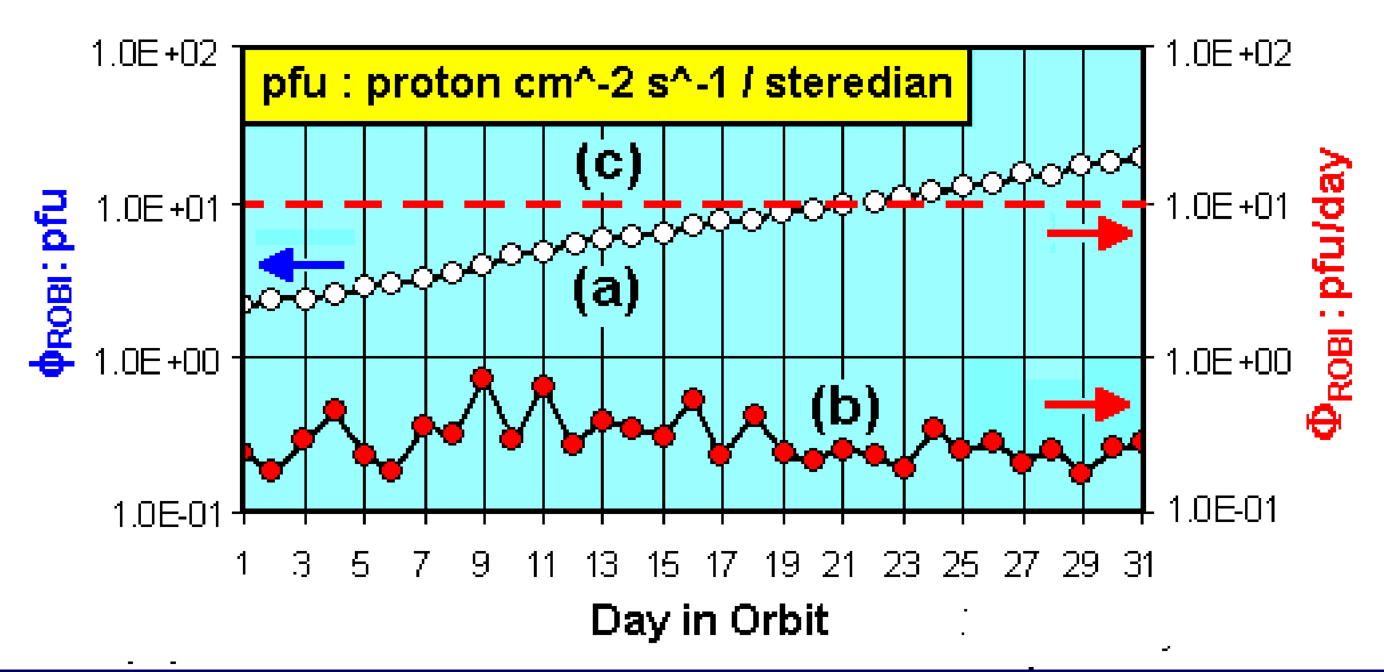
PSLV-C53/DS-E0 Mission on 30 June 2022 – Core Results (2/2)



(a) Integrated proton (SPE) fluence (ϕ_{ROBI} : pfu) was evaluated using the GaAs-LED light attenuation factor LF presented as a function of exposure time (Day in Orbit)

(b) Proton fluence rate (Φ_{ROBI} : pfu/day) during the same exposure time was calculated to be the 1st derivative of ϕ_{ROBI}

(c) Space Weather Predicting Center (SWPC) Warning thresold given as 10 pfu/day

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Φ_{ROBI} below SWPC Threshold > Vindicates NO Escalation of SPE

Summary and Conclusion (1/2)

PROTON FLUENCE COUNTER SPECIFICATIONS

Sensor Mass: 0.5g

Dimension: 10mm (L), 5mm (Dia)

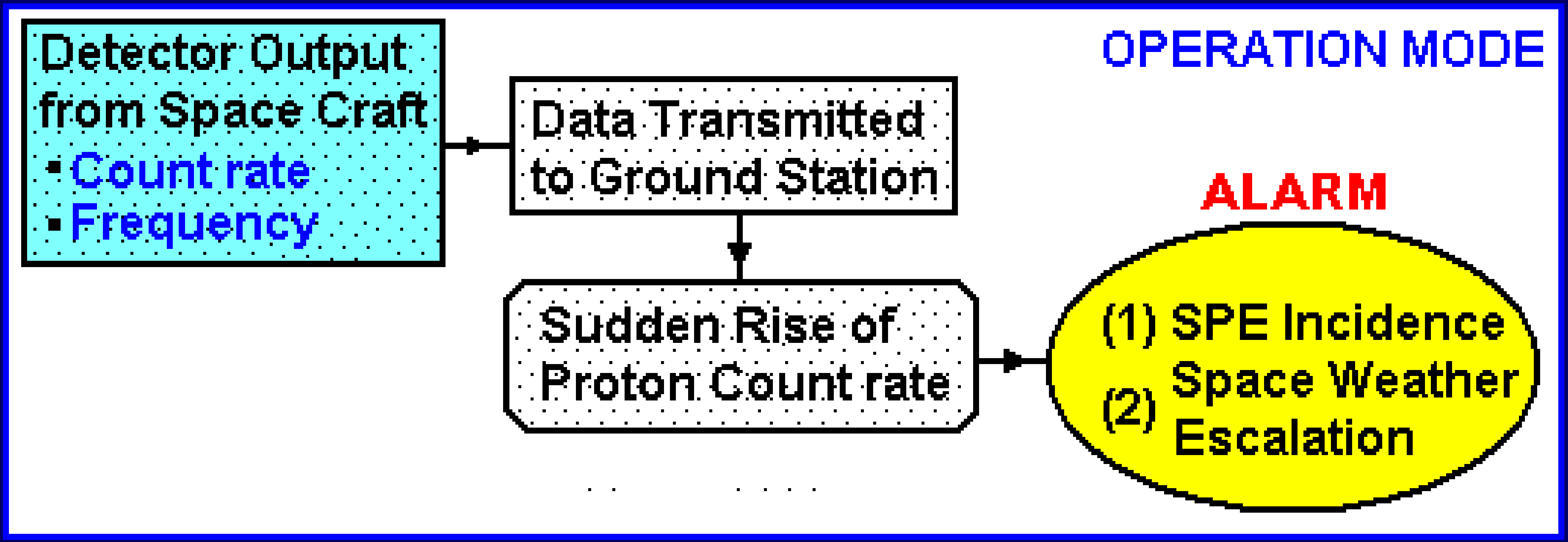
Power consumption: 15mW (3mA at 5V)

Powering mode: Powered via Microcontroller

Switching mode: Quasi-real-time, detector switched on for 1 second every minute (1s/min). Thereby a very high power saving was achieved.

Data Output: Count rate (pulse frequency) Hz

Summary and Conclusion (2/2)



Mission Accomplishment : All Goals achieved (100%)

Thank You for Your Interest

ARPS 2023 – Welcome

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