GAMMA-RAY SPECTROMETERS ON LAUNCHED AND PLANNED MSU CUBESATS FOR SOLAR-TERRESTRIAL RESEARCH

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- Fields of space research with MSU small satellites
- Parameters of MSU cubesates
- Design of gamma-ray spectrometers of DeCoR family
- Results of space experiments with DeCoR devices
- Design and parameters of advanced gamma-ray spectrometer TGS

Irkutsk, 11.09.2024

Space program of M.V.Lomonosov Moscow State University

A lot of space phenomena are studied by MSU scientists and students:

- Cosmic rays
- Solar activity
- Gamma ray bursts
- Light transients in high atmosphere
- Space weather

Start of the cubesat program of MSU

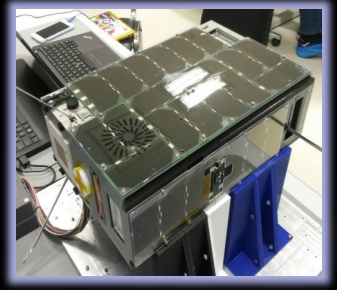
In 2018, the SiriusSat-1 and SiriusSat-2 satellites in the 1U+ CubeSat format with multilayer scintillation detector onboard were launched from the International Space Station.

Similar detectors with increased area were installed on a number of scientific and educational small spacecraft launched into low polar orbit in 2019 (VDNH-80, AmurSat, both CubeSats 3U) and in 2020 (Norby, Descartes, both CubeSats 6U)

MSU cubesat program Sozvezdie-270

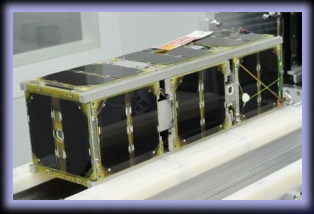
SiriusSat-1,2

SOKRAT



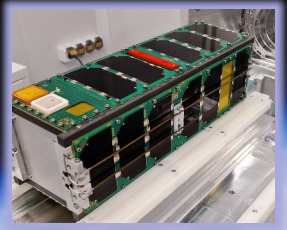
DEKART

Avion

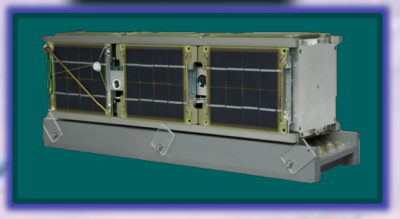


Monitor-1

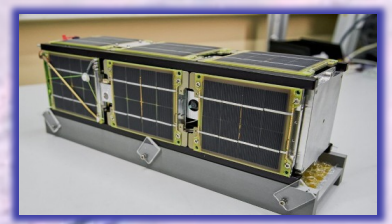
Монитор-2



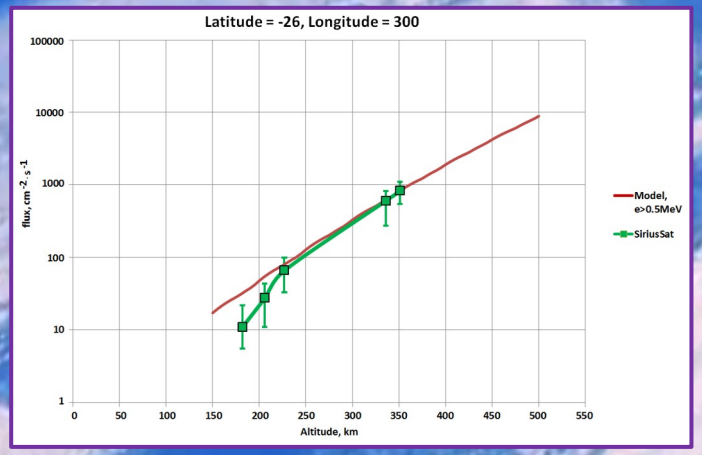
Monitor-3

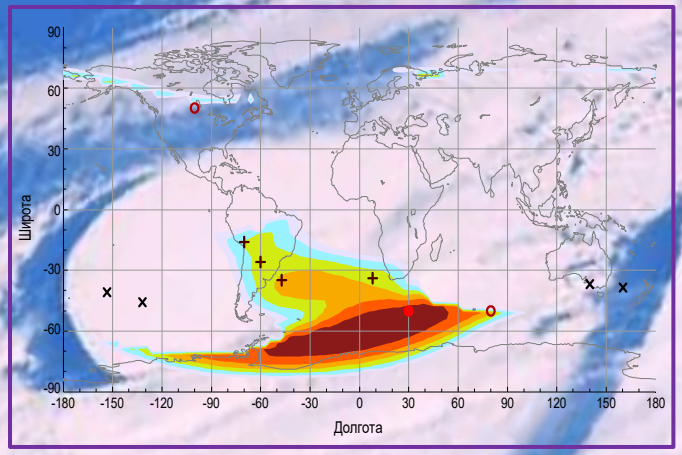


Monitor-4



One of the important results of the MSU cubesate program is the measurement of the radiation level in SAA region at low altitude





Principles of the gamma-ray and electron detector design

- Scintillation detector with enough sensitive area: not less than 20 см^2. Optimal value >50 см^2
- Combination of plastic scintillator and crystal one for separate registration of gamma-quanta and electrons on the Earth orbit
- Storage of the collected data in the internal memory of the device. The stored data can be transferred after the correspondent request command.
- Combination of monitoring and event-by-event data

DeCoR instrument

The DeCoR spectrometer of space radiation was primarily designed to study fast variations of near-Earth electron fluxes such as micro-bursts observed in the experiment on the FIREBIRD-II satellite

Detector: combination of ~4 mm of plastic scintillator and ~10 mm of CsI(Tl)

Energy range: 0.05-2 MeV

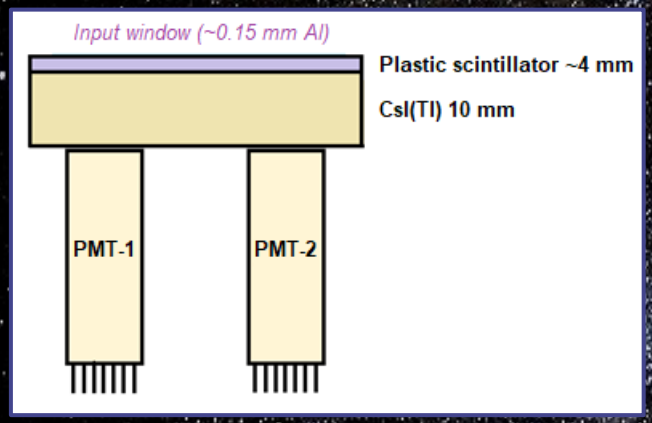
Effective area – 18 cm^2

3-axe magnetometer is placed inside the instrument

Size: 99x91x29 mm

Mass: < 480 g

Power consumption: 1.2 W

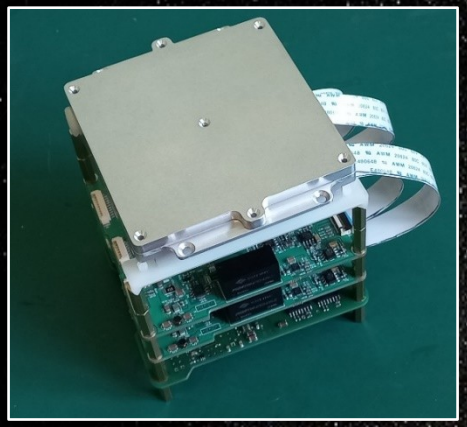


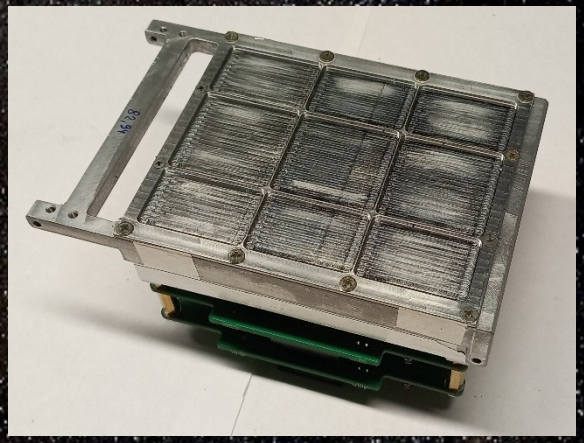
Pulse shape analysis is used to determine the scintillator where the interaction took place

Data are stored in the device memory in monitoring mode (count rates in several channels, continuously) and in event-by-event mode (exact energy and time data for every interaction for a number of events, starts by command)

DeCoR-2 and DeCoR-3 instruments

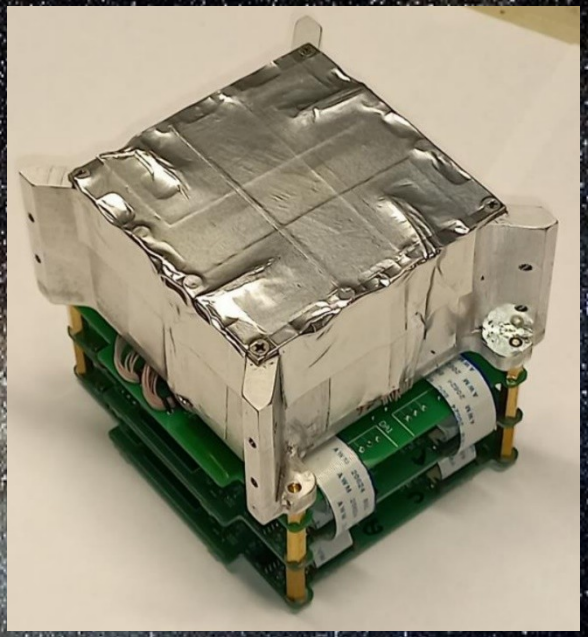
The DeCoR-2 is the gamma-ray detector unit of DeCoR family with large sensitive area which makes it possible to study weak gamma-ray bursts of various nature





Detector: ~4 mm of plastic scintillator and ~10 mm of CsI(Tl)
Energy range: 0.05-2 MeV
Effective area – 2 parts of 32 cm^2
Mass: 750 g
Power consumption: 1.6 W

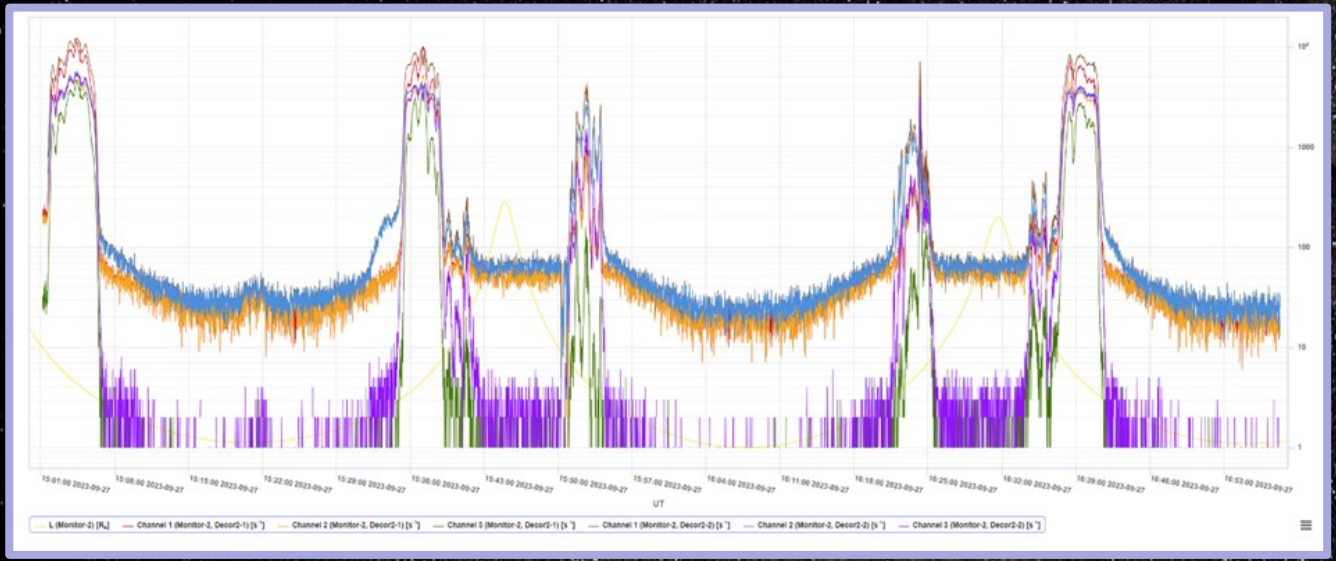
The DeCoR-3 is a large volume gamma-ray spectrometer for measure of gamma-ray spectra of solar flares and GRBs up to 10 MeV



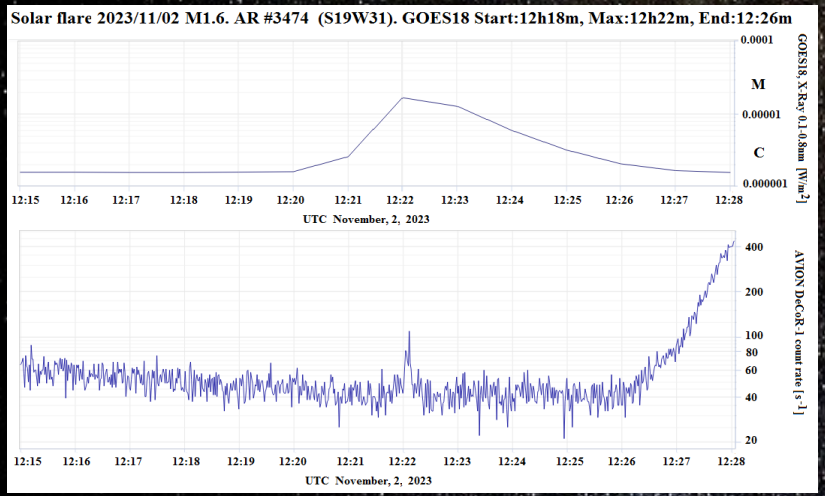
Detector: 40 mm of CsI(Tl)
Energy range: 0.05 - 8 MeV
Effective area – 36 cm^2
Mass: 1000 g
Power consumption: 1.6 W

DeCoR-2 and DeCoR-3 devices use SiPM photodetectors

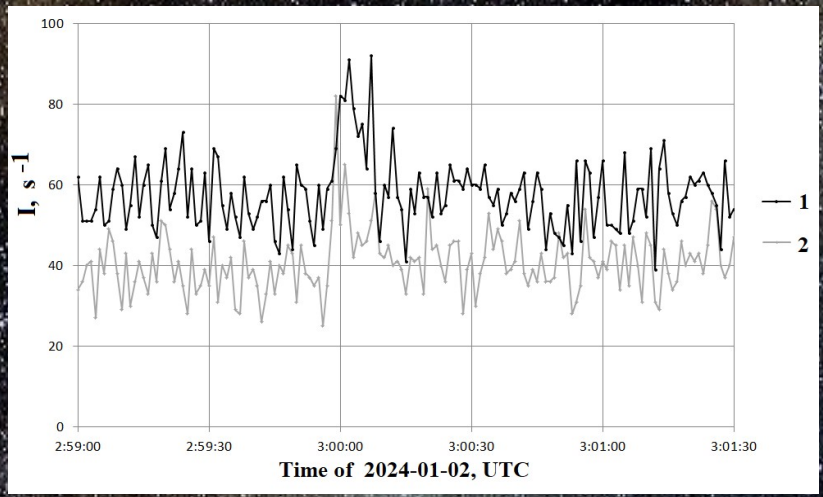
Examples of DeCoR data



Behavior of near-Earth electrons.

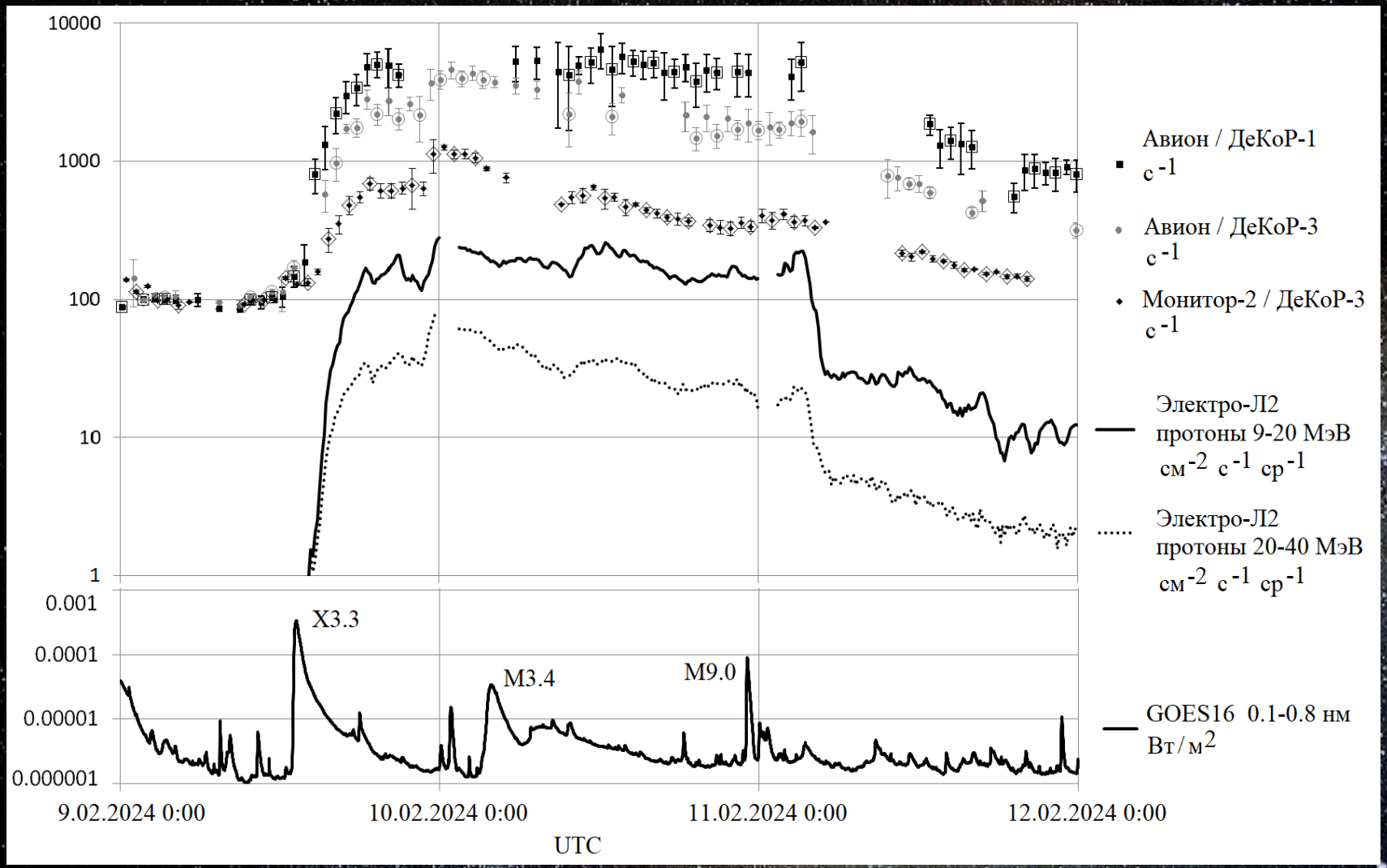


Gamma-rays from Solar Flare (M1.6)

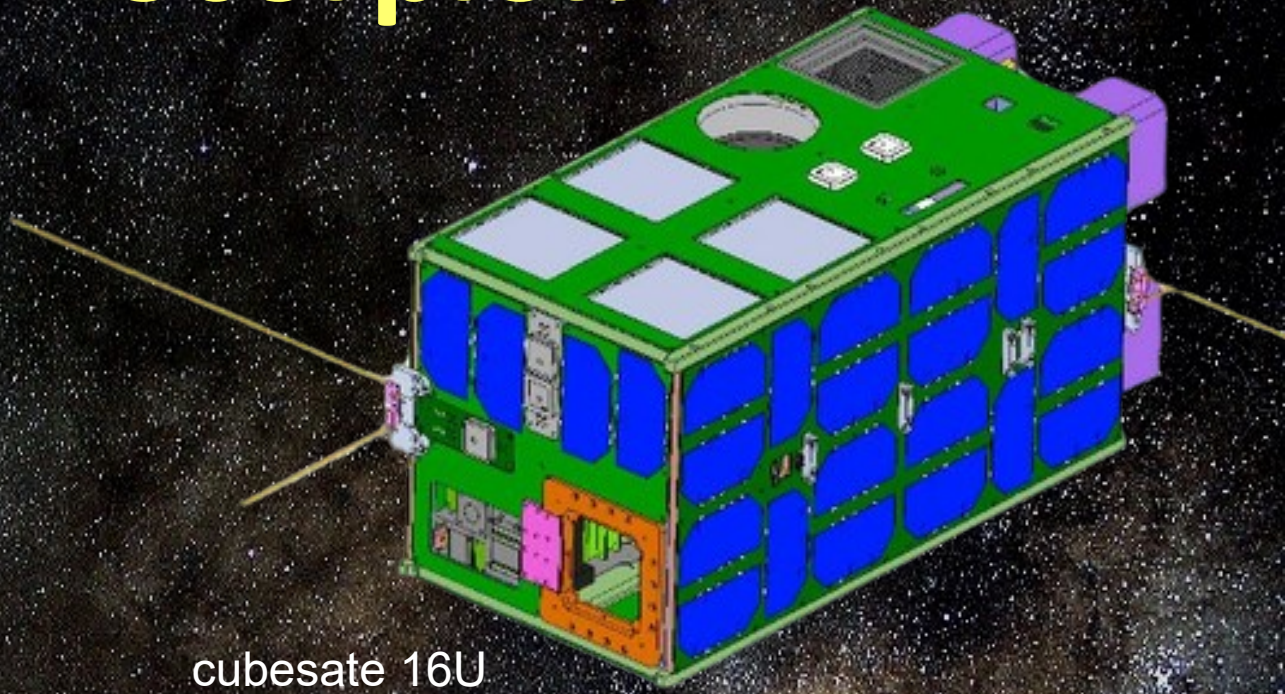


GRB-detection

Example of observation of solar cosmic rays by MSU cubesates



Satellite «Scorpion»



Parameters:

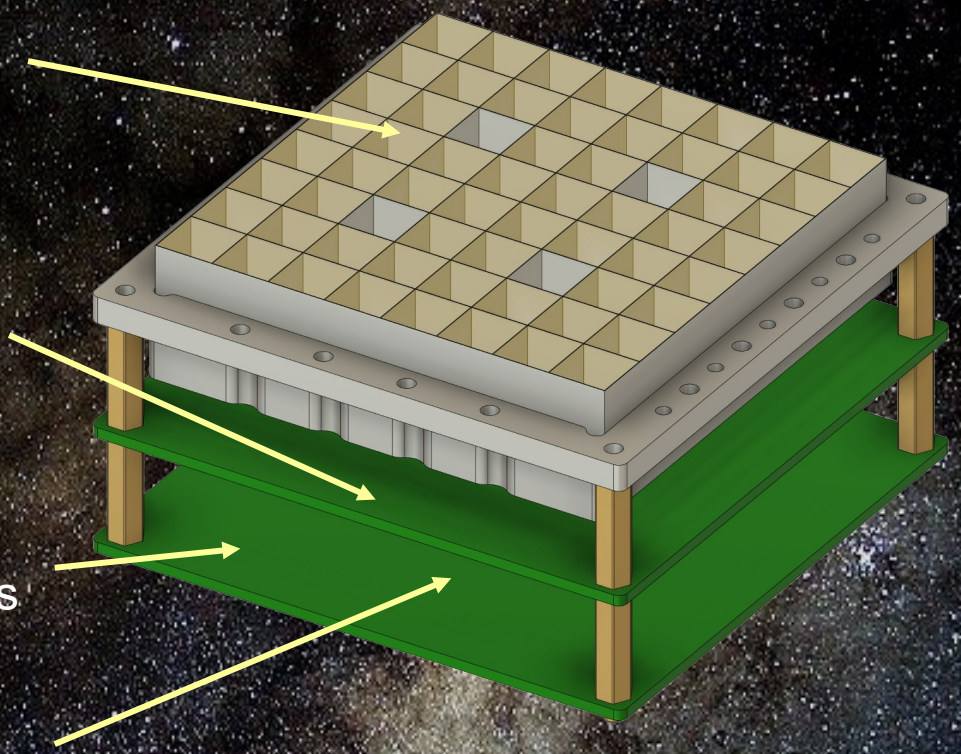
Design	cubesate 16U
Platform mass	16 kg
Payload mass	8 kg
Volume for the payload	12U
Mean power for the payload	10 W
Communication	Control ~146 MHz, Telemetry~435 MHz, Scientific data ~2400 MHz
Scientific data transfer rate	500 kbod -2000 kbod

Scientific instruments onboard «Scorpion»

- Gamma-ray spectrometer for the study of solar, astrophysical and atmospheric gamma-ray bursts
- Spectrometer-photometer for the study of atmospheric UV and optical flashes
- The device for registration of charged particles and neutrons
- Biocontainer for the study of the behavior of microorganisms under the influence of cosmic factors

Gamma-ray spectrometer TGS (1 of 4 units)

- 64 scintillator elements of 2 kinds (GAGG:Ce and plastic) and silicon PMTs (SiPM) are placed in array 8x8
- Preamps (32 * 2) that convert a weak current pulse into a voltage pulse
- Amplifiers that summarize signals by rows and columns
- Two 8-channel ADCs that simultaneously convert analog signals into digital pulses with an amplitude of 1-5 V and a duration of 5 microseconds
- An MCU that reads digitized values over a parallel interface and generates output data



Scintillation crystals GAGG:Ce are used as detecting elements having a high density of 6.6 g/cm3, a relatively short illumination time of ~90 ns and an energy resolution of 5%-6% for an energy of 662 keV

Data of TGS gamma-ray spectrometer

The day amount of data for one TGS device module is 5-10 MB: (there are 4 independent modules in the device)

Two main types of data will be generated:

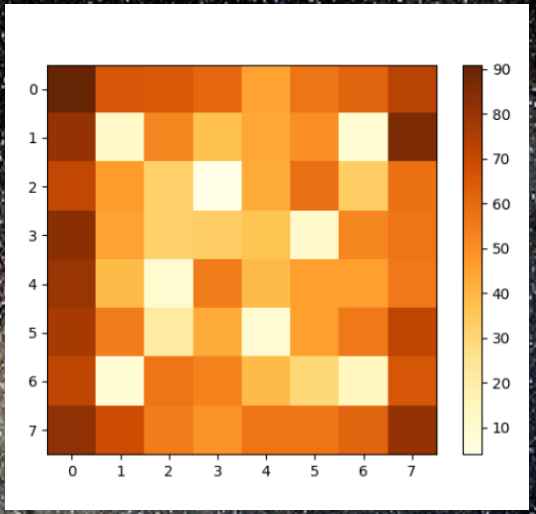
- - Monitoring (counting rate in multiple channels)
- - Array (an event-by-event record containing for each act of interaction the exact time (accuracy of 1 microsecond) and a set of amplitudes and coordinates of the brightest pixels)

The expected speed of data generation of the type ”Monitoring" is 1.3 Mbytes per day (for 8 channels)

The expected speed of data generation of the type “Array”:

- At the equator: 1 kbyte per second
- In polar caps: 2-3 kbytes per second

The data will be stored in the device’s memory. The flash memory capacity of each module is at least 128 MB



Modeling of the brightness distribution over the surface of the PSD for E=1 MeV and an angle of incidence of 60°

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Thank You!

This work was supported by
MSU Program of Development,
Project № 23-SCH №23A-Ш01-02.

Irkutsk, 11.09.2024