The EUSO Instrument onboard the International Space Station

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Abstract

The Phase A conceptual study of the *Extreme Universe Space Observatory* (EUSO) mission on-board the International Space Station (ISS) is expected to be completed in September 2003. In this paper we describe the architectural and technological design of the EUSO Instrument as resulting from the one year phase A activity performed by the EUSO Consortium. The design was optimized to fulfill the scientific requirements while meeting the ISS resources and constrains.

1. Introduction

The possibility to detect from space Extreme Energy Cosmic Rays (EECR), (charged particles, photons and neutrinos with energy $E \geq 10^{19}$ eV) was originally suggested in the '70s by J. Linsley [1]. In the middle of '90s, thanks to Y. Takahashi [2], conceptual studies such as the OWL and AIRWATCH projects were carried out. Based on the AIRWATCH concept and following a successfull accomodation study on the ISS, the EUSO project was eventually approved by ESA for a Phase A conceptual study jointly conducted by the SCIENCE and MSM directorates of ESA [3]. The EUSO Instrument mainly consists of an UV telescope on-board the external facility of the ISS Columbus module, looking to Nadir at nighttime, with a total Field of View of 60°, from a 430 km, orbiting altitude (see Fig. 1). With this figures and assuming 10% for the duty cycle, an effective geometric factor of more than $5 \times 10^4\ km^2 sr$ is reached. EUSO will detect the (330-400 nm) UV tracks associated to the relativistic shower of particles, induced by a cosmic ray primary penetrating the Earth atmosphere for 10-100 km, depending on the zenith angle. As shown in Fig. 1, the longitudinal development of the EAS (Extensive Air Shower) in the atmosphere will be reconstructed, at a certain height and slant depth, by observing the spatial and temporal development of the UV fluorescence light, isotropically emitted along the path of the cosmic ray and by detecting the isotropic diffusely reflected Cherenkov signal produced by the impact of the Cherenkov beam hitting the ground, the sea or the top of

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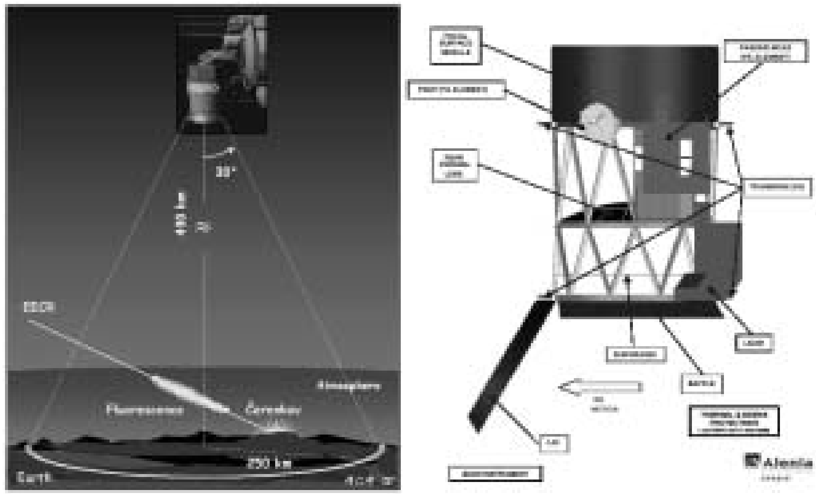

Fig. 1. *left)* The instantaneous EUSO Field of View *right)*pictorial view of the EUSO Instrument

a cloud. The EUSO instrument, conceived as a monocular stand-alone telescope, will therefore convert the fluorescence and diffusely-reflected Cherenkov photons in a number of photoelectrons depending on atmospheric transmissivity, optics collection efficiency and overall detection efficiency of the focal surface detectors. The main instrument is assisted by atmospheric sounding devices, a LIDAR and an IR camera, that will provide real time atmosphere transparency measurements.

The expected performances of the instrument as well as the details of each single part constituting the instrument are reported in the proceedings of this conference. We summarize the main characteristics of the Instrument in its principal parts.

2. The EUSO Instrument

The EUSO Instrument architecture, summarized in Fig. 1, is described in what follows.

2.1. Optical module

A double Fresnel lens configuration (Fig. 2), with 2.5 meters external diameter and f# ~ 1, has been chosen to achieve an angular resolution of $\sim 0.1°$ and a full aperture of 60°. Lightweight polymer material with an (330-400 nm) UV transmittance of ~90% fulfills the requirements imposed by the in orbit operating condition. A Lid mechanism prevents reflected/diffused light entering the focal surface detector during the diurnal orbit phase and protects the instrument from the environmental pollution during flight and Shuttle docking.

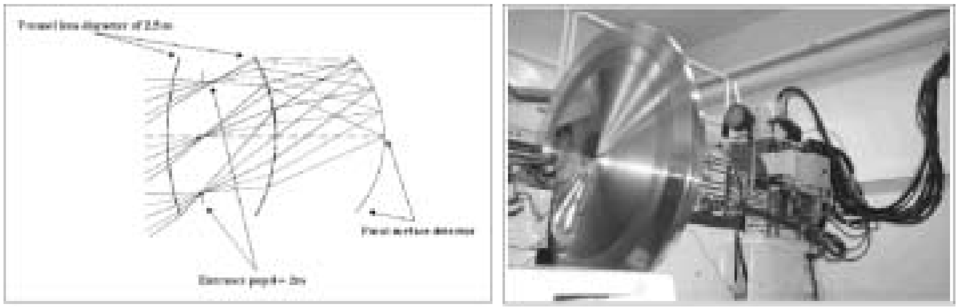

Fig. 2. Reduced scale prototype unit of the EUSO Fresnel lenses produced at the Optics Centre of the University of Alabama.

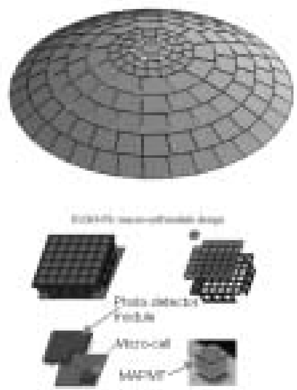

Fig. 3. The EUSO Focal Surface: the modular approach is shown.

2.2. Focal Surface

To adapt the detector unit to the curved shape resulting from the Fresnel lenses a "tiled" focal surface has been designed. A conceptual configuration, together with the modular "bottom-up" scheme, is shown in Fig. 3. The MAPMT unit is currently the Hamamatsu R8900. Micro-cells are constituted by 2x2 MAPMTs and the intermediate assembly unit, the Photo-detector module geneally consists of 3x3 micro-cells. Suitable photo-detectors for EUSO require (330-400 nm) single photon sensitivity, fast response, low noise and cross-talk and good signal to noise ratio.

2.3. System electronics

Signal to noise ratio optimisation, image segmentation and "free running" method are at the core of the EUSO system electronics. A special method devoted to enhance the signal-to-noise ratio has been developed and implemented in a specific of the front-end electronics design. The specific functions of the Analog Fron-End Electronics (AFEE) and the Digital Fron-End Electronics (DFEE) at pixel level are integrated in an ASIC. Independent stand-alone module operations and reduction of the total number of read-out channels are also other important aspects of the design. Channel reduction has been accomplished connecting adjacent pixels (respectively by rows and columns) belonging to a module, called “macrocell”, OR-ing them together. The characteristics of the design of the macrocells and associated read-out are part of the TCU (Trigger & Contrlol Unit) system. The ’free running’ method adopted is based on the continuously writing of information into ring memories until a stop signal, derived from a specialized trigger unit, freezes the writing operation. At the stop signal, a reading operation is started enabling to access the information recorded in the memories.

2.4. Atmosphere Sounding Device

The “in situ / real time” knowledge of the scattering and light absorption properties of the “local” atmosphere is provided by means of a LIDAR. The LIDAR essentially provides accurate profiles of the atmosphere, sounding the presence and nature of clouds and aerosol and evaluating the transparency and scattering properties. The LIDAR is based on a space qualified three harmonics Nd-YAG laser.

2.5. Structure and Thermal Control

The structure holds together all subsystems, providing the necessary stiffness for the relative alignment among subsystems and the strength to withstand all mechanical environments (on ground and on orbit). It also protects the Instrument from debris/meteoroids and assures light tightness in daylight orbit phases while providing the connection with the Payload. Proper thermal hardware is being designed to maintain the instrument parts within their operating temperature ranges and in all mission conditions.

3. Conclusion

The EUSO Mission is expected to proceed into phase B early next year. According to the present schedule launch is foreseen within 2009.

4. References

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