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Extreme Universe Space Observatory – EUSO: present status and perspectives.

The EUSO Collaboration
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The “Extreme Universe Space Observatory – EUSO” is an international, multi-agency mission aimed at measuring from a Low Altitude Earth Orbiting Space Platform the flux of the UHECR particles with energy above the conventional value $E_{GZK} \approx 5x10^{19}$ eV. EUSO, which uses sensitive surface and mass/volume target values far greater than those achievable from ground based experiments , was proposed to ESA on 1999 in response to an Announcement of Opportunity issued to complement the “ Science Mandatory Program“. The Mission has been selected for implementation as “External Payload“ for the Columbus Module contributed by ESA as a segment of the International Space Station and the Phase A Study has been successfully completed in 2004; however, the ESA Executive has put on hold the follow-on into Phase B requiring that programmatic issues related to the fundamental changes and reorientation lately occurred in the international “Space Panorama” be preliminarily addressed and clarified. This process is ongoing and its conclusion expected within year end; if positive, the reconfigured Mission should be on not later than 2012, as a forerunner of the “Cosmic Vision” Space Science Program now under consideration by ESA to cover the decade 2015-20255.

1. Introduction.

The Science Goals of the *“Extreme Universe Space Observatory – EUSO”* address basic problems of Fundamental Physics and High Energy Astrophysics by the investigation of the highest energy processes present and accessible in the Universe through the detection of the Extreme Energy Component of the Cosmic Radiation UHECRs with E> 5×10^{19} eV, where the GZK effect is predicted to strongly attenuate cosmic ray protons).; contextually EUSO aims to open the Channel of High Energy Neutrino Astronomy to probe the boundaries of the Extreme Universe and to investigate nature and distribution of the UHECR sources. The systematic surveillance of Atmospheric Phenomena (Atmosphere as a Physical System, Meteors, and Electrical Discharges) is the secondary goal.

-The Observational Heritage

The knowledge derived from past Experiments is mainly due to AGASA (now closed down) and HiRes (operational for few more years). The observational panorama is framed by the size limitations of the experiments which have a maximum effective aperture of about 10^3 km^{2}sr (HiRes) and a substantial gain of orders of magnitude is needed in the Acceptance Factor.

It can be summarized as: a)-Cosmic Ray particles with E>10^{20} eV have been reported to exist, with a rate of arrival at Earth of the order of 1 event / km^2 x100 yr; b) -The distribution of their arrival direction is apparently isotropic on the large scale, with an indication of clustering on the small scale (outside statistical expectation) suggesting the existence of compact sources; c)-A signature of the GZK effect at E = $5x10^{19}$ eV is a matter of dispute between the AGASA and HiRes; d)-No UHE Cosmic Neutrinos have been identified to date.

The Pierre Auger Experiment is providing the first steps forward. It is under construction in Argentina (today it has reached about ½ of its final size) and it will reach, when completed in 2005/6, an aperture of 7×10^3km^{2}sr (and ~10^3km^{2}sr for the hybrid configuration) . The gain of a factor of 10 above HiRes will be crucial in answering to some of the outstanding questions open like those concerning the GZK Effect and the reality of the clustering in the arrival directions for the UHECRs in the southern hemisphere. Auger will provide tens of events /year for E>10^{20} eV (depending on the shape of the energy spectrum). Auger, which is foreseen to operate for a decade (2006 – 2015), represents the limit reachable for ground based Experiments of its class.

To proceed further and cope with the very low flux levels UHECRs the coupled to the very low interaction cross section of Neutrinos a Gigantic detector at planetary scale is required: the Earth Atmosphere viewed from Space (EUSO) offers an acceptance aperture of $\sim10^6$ km^2 sr and a target mass of $\sim2\times10^{12}$ tons, constituting an ideal absorber/detector for UHECRs and Cosmic Neutrinos.

EUSO represents the culmination of a line of thought for a space based experiment started in 1979 with "SOCRAS" (a first suggestion by J.Linsley) to the " MASS " concept of Y.Takahashi in 1995, followed by " OWL " sponsored by NASA and " AIRWATCH " in Europe , converged in a joint effort in 1999 .

EUSO is supported by a Consortium involving a total of about 50 institutions and more than 150 scientists in six European countries , the USA , Japan and Brazil

-The EUSO Experiment.

EUSO, shown in figure 1, is very large wide angle UV-camera that will be located on the Columbus module of the International Space Station. This focal surface is populated with multi-anode photo-multiplier tubes operating in single photon counting mode. From its berth on the ISS, EUSO views a large area in the atmosphere below. An extensive air shower (EAS) initiated by an EECR appears as a thin luminous disk streaking down though the atmosphere at the speed of light. Operating as a high-speed movie camera, EUSO records a video clip of the progress of the EAS shower front and the reflected Čerenkov flash from its foot print at the earth.

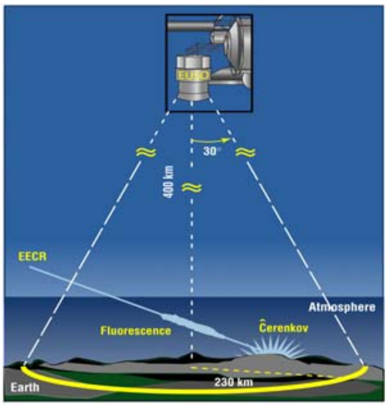
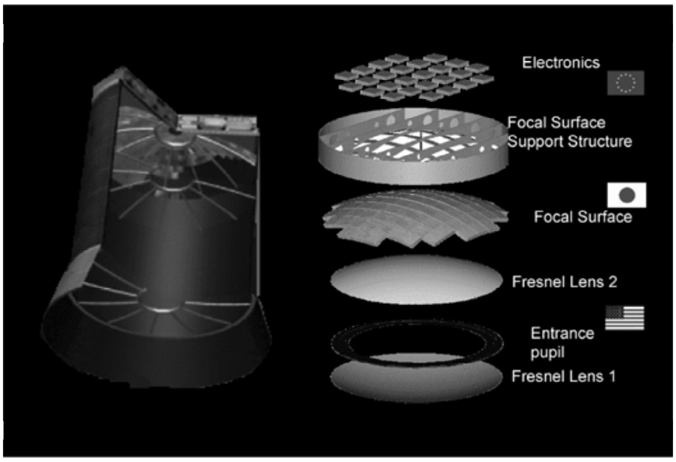


Figure 1: EUSO uses the Earth atmosphere as its detector. Within its field of view of 60' EUSO records both the fluorescence and the reflected Čerenkov light from an EAS



the electronics as schematically shown. In the Phase A design the angular resolution of the optics is at the order of 0.1°.

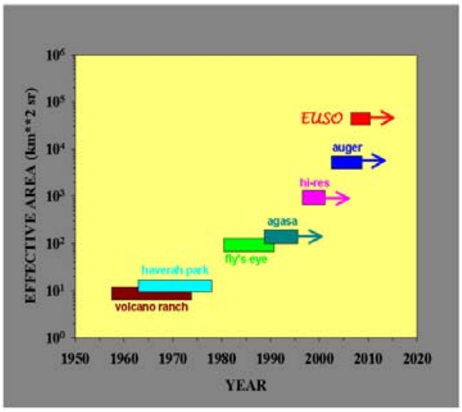
The EUSO Instrument sub-systems.

Optical Module-A double Fresnel lenses module with 2.5 m external diameter (made of radiation hard light weight plastic material) is the baseline optics for the EUSO Telescope. *The Photo-Detector on the Focal Surface* -The UV light, focused by the large collecting area of the optics, is imaged onto the FS made of highly pixelized single photon sensitive sensors based on a modular structure. *Atmosphere Sounding Device*- The real time knowledge of the properties of the local atmosphere where the EAS occurred 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 baseline is based on a Nd-YAG laser operating as a stand-alone device associated to a wide FoV IR Camera.

Baseline values assumed, for the simulation studies, during phase A:

EUSO altitude	430 km;	Active diameter (EPD)	Ø 2.3 m;	Field of View (FoV)	30°;
Observ. duty cycle	(18- 25)% (E dep.);	Overall pho.-detect. eff.	0.12;	Optics PSF diam.	5 mm ;
Trigger parameters	$(N_{thre} : N_{pers}) = 4 : 4$;	Bkd noise level	500 ph/m^2/nsec/sr;	GTU	2.5 µs;
FS pixel size	.8 x .8 km^2 at nadir;	Cloud description	ISCCP / TOVs;	ISS lat. (min to max)	± 51°.

Under these conditions the EUSO Trigger efficiency reaches ≈50% at $5x10^{19}$eV and ≈90% at 10^{20}eV.
Figure 3 shows a comparison of the EUSO effective area with ground-based experiments



2. EUSO "Odissea" and present situation.

EUSO has been proposed to ESA on Oct. 1999 as a "Free Flyer**"** in response to the Announcement of Opportunity issued by the Directorate for Science for "2 Flexi Missions (F2 -F3)" to complement the "ESA Science Mandatory Program" in course of definition to cover the time period up to 2010/12 ; the A.O. was extended to cover also the exploitation of the Space Station facilities beside the Free Flyer concept.

The proposal was the joint effort of a Consortium of Research Groups from Europe (Italy, France, Germany, U.K.) , USA and Japan , with involvement of the three major space Agencies ESA , NASA and NASDA (today JAXA). The Consortium in the following years was joined by other members and today it includes also Groups from Portugal, Switzerland, Spain and Brazil.

In June 2000, EUSO has been selected by the "Science Program Committee SPC" of ESA for implementation as "External Payload" for the Columbus Module contributed by ESA as a segment of the International Space Station . To evaluate the feasibility of the conversion from Free Flyer to the Space Station platform , ESA carried out in 2000 for EUSO an "Accommodation Study "on shared responsibility between the Directorates for "Science" and " Manned Space Flight and Microgravity, MSM ". The Study was successfully concluded with the recommendation, endorsed by both the "Science Program Committee– and the "Manned Space Program Board ", to proceed to a normal Phase A Study.

A Phase A Study has been carried out in 2002 – 2004 sub-dived in two sections:

"Instrument" defined as the Hardware and the Scientific Ground Segment (simulations, science data analysis and Science Operation Centre), under the responsibility of the EUSO Consortium and funded by the National Space Agencies or Institutions referring to the Research Groups involved in the Mission ;

"Payload" defined as the activity and specific hardware concerning the transportation from ground to the ISS of the EUSO total package including beside the "Instrument" itself , the Platform and other hardware necessary to interface to the carrier, the robotically handled accommodation on the Columbus External Payload Facility (CEPF), the operation in orbit, under the shared responsibility and funding by ESA D-Science and D-MSM.

The two Studies ended in June 2004 with an extension from October 2003 to consider transportation systems alternative to the Shuttle because of the Columbia accident and they were jointly reviewed by an ESA appointed Panel**.** In their meeting at ESTeC on 15 July 2004 the Panel considered the EUSO Phase A Study successful ,concluding: :…*"With the completion of Mission and Instrument Phase A Extension, the EUSO Project could technically proceed to Phase B"….*

However, with a Letter dated 29 July 2004 the ESA D-Sci Dr. D.Southwood informed the EUSO P.I.:

Dear Professor Scarsi,

…..I have been informed about the conclusions of the EUSO Phase A Study Review Board and I want to express

my admiration for the quality of the work that was carried out by everybody involved in this study. The technical maturity of the instrument design as well as of the mission design is very satisfactory. However before proceeding into Phase B several scientific, programmatic and financial issues have to be addressed and clarified.
In the recommendations formulated by the Advisory Bodies of ESA (AWG, FPAG and SSAC) and communicated to you by the respective Executive Secretaries, EUSO has not been identified as one of the top scientific priorities for implementation in the foreseeable future (°).The Science Programme Committee (SPC), at their meeting on 7 and 8 June 2004, has not included EUSO in their priorities for implementation in the Cosmic Vision Programme. As a consequence the SPC has made no decision to allow EUSO to proceed to phase B. Nevertheless the SPC continues to support the joint SPC/PB-HSR Joint Working Group with the mandate to confirm and consolidate the role of ESA, the National Agencies and the International Partners in the development and financing of Space Science payloads for accommodation on the International Space Station.
Although the ESA Science Programme at this moment in time does neither have the authorisation nor the funds available to proceed to phase B it is my intention to monitor closely, to coordinate when necessary and to assist when possible, the further developments and deliberations regarding EUSO.
Yours sincerely, David Southwood Director of Science , European Space Agency.

(°)Recommendation on the Phase A Study of EUSO Fundamental Physics Working Group (FPAG):
At its 25th meeting held on 13th May 2004 at ESA Headquarters Paris, the FPAG heard the presentation of the results of the Phase-A study of the EUSO project given by the Principal Investigator. EUSO is an ISS experiment which will use the Earth's atmosphere to search for extreme-energy cosmic rays. It is specifically aimed at resolving issues regarding the existence, identity, and sources of cosmic rays near and above the GZK cutoff.
EUSO addresses fundamental questions in physics. Observations from ground-based cosmic-ray experiments have suggested that the highest-energy cosmic rays have properties that are not easily explained using the standard model and our present understanding of astrophysics. The FPAG feels that resolving these questions has a high scientific priority.
The Phase-A study has shown that the experimental design is capable of meeting the scientific objectives of the mission within the constraints imposed on experiments attached to the ISS. However, the same scientific questions are being addressed by the Pierre Auger experiment, which is already in partial operation in Argentina. Moreover, the presently available data from ground-based observations show apparently contradictory rates and energy dependence. While EUSO will be able to acquire data of comparable or better quality than Auger at a ten-times higher rate, Auger has a considerable head start and should produce data very soon. It is therefore possible that observations with Auger will show, even before the EUSO launch, that an improved design of the mission objectives will be necessary before actually flying it.The FPAG recommends that the decision to launch a space-based cosmic-ray observatory should wait until the first data from Auger has been assessed and the EUSO design has been confirmed as optimum……

Along similar lines the Recommendation of the Astronomy Working Group (AWG)

On their "Wrap-up and conclusions" the Board Meeting on 15 July 2004 stated:
…….. ESA "MSM" (now "HME-Human flight, Microgravity, Exploration") Directorate could start Phase B on its side provided that : (a) Instrument sponsoring (by D/SCI) and (b) Instrument funding are ensured. Under this conditions, as an option for EUSO to continue, the Instrument Consortium could look for an alternative national Entity / Agency, which can support and sponsor the EUSO instrument directly vis-à-vis ESA for mission implementation; this process should start as soon as possible. …
Actions are ongoing.
- Formal commitment of funding of the Instrument by the Agencies/ Institution involved : the action is closed as far as possible in absence of a final green light on Mission approval.
- Transportation to ISS with a vehicle alternative to the Shuttle: the JAXA HTV is being considered.

3. Conclusions .

Originally planned for operation starting 2008-2010, EUSO has been heavily handicapped by external adverse conditions like subjective recommendations on relative Science priority by Advisory Committees, the Columbia accident and the consequent limitations by NASA to the International Space Station and Shuttle fleet activity, the reorientation of future programs by the major Space Agencies : the Mission needs necessarily a revision in view of a launch not sooner than 2012.

The deepest thanks to all Members of the EUSO Collaboration for their professionalism and attachment to Science values , to J.Knapp , E.Lorentz, D.Treille, A.Watson and A.Parmar of the Science Study Team for their clean, invaluable , "courageous" and unselfish support.