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EUSO - Extreme Universe Space Observatory: Ground data handling and outreach.

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Abstract. The Extreme Universe Space Observatory *EUSO*, to be accommodated on board the International Space Station, will observe the Earth atmosphere where Extreme Energy Comic Rays (EECR) interact with. *EUSO* will collect a statistically significant number of EECR and Neutrino events together with atmosphere physics and meteoroid events. In this sense, *EUSO* can be considered as a multi-discipline space mission: it involves scientists from different application fields together with different know-how and tools. Aim of this presentation is to give a first overview of the critical points that must be taken into account in the definition of an efficient data handling for *EUSO*. The calibration of the telescope, the scientific data reduction and analysis, and the essential parts of the *EUSO* Ground Segment are considered.

1 Introduction

The "Extreme Universe Space Observatory - *EUSO*" is an experiment that will be accommodated as external payload on the ESA Columbus module of the International Space Station (ISS).

EUSO, described elsewhere in these Proceedings (Scarsi et al., 2001; Sacco et al., 2001; Catalano et al., 2001), is devoted to the imaging analysis of the Ultraviolet (UV) fluorescence induced by the Extreme Energy Cosmic Ray (EECR) radiation when the EECR particles interact with the Earth atmosphere: its main objective is to obtain a detailed description of the Cosmic Ray energy spectrum above 10^{19} eV together with a map of the arrival directions.

EUSO will observe the fluorescence signal looking downward from Space the dark Earth's atmosphere. The signal seen by *EUSO* looks like a narrow track whose duration, position, and intensity are related to the arrival direction and energy of the primary EECR particle. The tracks are observed in presence of the intrinsic background (Giarrusso et al., 2001; Kostadinov et al., 2001) produced by any event giving light in the same UV band of interest for *EUSO*. The level of background depends on various parameters related to the observation boundaries as, for example, moon phase, geographical position, and meteorological conditions.

A co-aligned atmosphere-sounding telescope will be part of the *EUSO* instrumentation for “in situ/real time” measurements of the properties of the atmosphere (e.g. clouds, transparency) to correctly “certify” an EECR event.

Additionally, *EUSO* will detect data from phenomena intrinsic to the atmosphere (aurora, lightning) or induced by the flux of meteoroids incoming from space.

EUSO is the first experiment from Space devoted to the investigation of the EECRs and it is a challenge under several points of view:

- the calibration of the telescope must be performed taking into account the variable and not-modifiable interaction medium (the atmosphere),
- “certified events” must be recognized, classified and collected to achieve an unique global result (the spectrum, a map of the arrival directions),
- constraints related to the *EUSO* accommodation on the ISS can be present,
- different scientific communities (astrophysics, atmosphere and particle physics) with different know-how and tools are involved in.

Aim of this presentation is to give a first general overview of those critical points that, as those listed above, must be taken into account in the definition of an efficient data handling for *EUSO* both for what concerns the scientific data analysis and the Ground Segment in itself.

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2 The EUSO Ground Segment

The *EUSO* Ground Segment (GS) can be considered made up of a set of components devoted to perform the main functions/operations at ground level to manage the mission both in terms of control and data.

As for other experiments on board the ISS, telemetry from *EUSO* would be received at the Ground Station of the ISS Payload Operation Centre (located at the Marshall MSFC in Huntsville, Alabama) and then forwarded to the European *EUSO* Operation-Scientific Centre, which will constitute essential part of the *EUSO*-GS. A Mission Operations Centre (MOC), a Science Operations Centre (SOC) and a Science Data Centre (SDC) should compose the *EUSO*-GS.

The MOC acts as a data-receiver/command-transmitter and as interface to the ISS operations ensuring the effects of ISS operations on *EUSO* are fully taken into account. It would be located together with the Ground Station while SOC and SDC should be located at the European *EUSO* Centre.

2.1 *EUSO* Operations and SOC

The SOC should have the main role to generate *EUSO* specific commands (to be sent to MOC), to receive telemetry data (from MOC), to monitor instrument health, its functional status, performance and trend (Quick-Look), and to notify any relevant scientific/monitoring event.

EUSO is essentially a fixed nadir-pointing observatory, with no possibility of roto-translation movements on the ISS. Two main modes of operations are foreseeable: "observing" and "protection". In the "observing mode" *EUSO* will observe the atmosphere during night time; different levels of trigger will be implemented for different types of events such as cosmic rays, upward neutrinos, meteoroids and atmospheric phenomena. During the segment of the "day" orbital periods (affected by the Sun), or when the light intensity is above acceptable limits, the *EUSO* aperture will be closed by a cover to protect its focal surface detector. This "default protection mode" should be monitored by two parallel systems: the first driven by ground through tele-commands, and the second one from an on-board light intensity controller. Additional intervals where the ISS external contamination levels are high (as when the Shuttle is docked) will result in the *EUSO* cover being closed.

No specific observation plan is required and therefore the commands required are essentially those related to the protection of the focal surface.

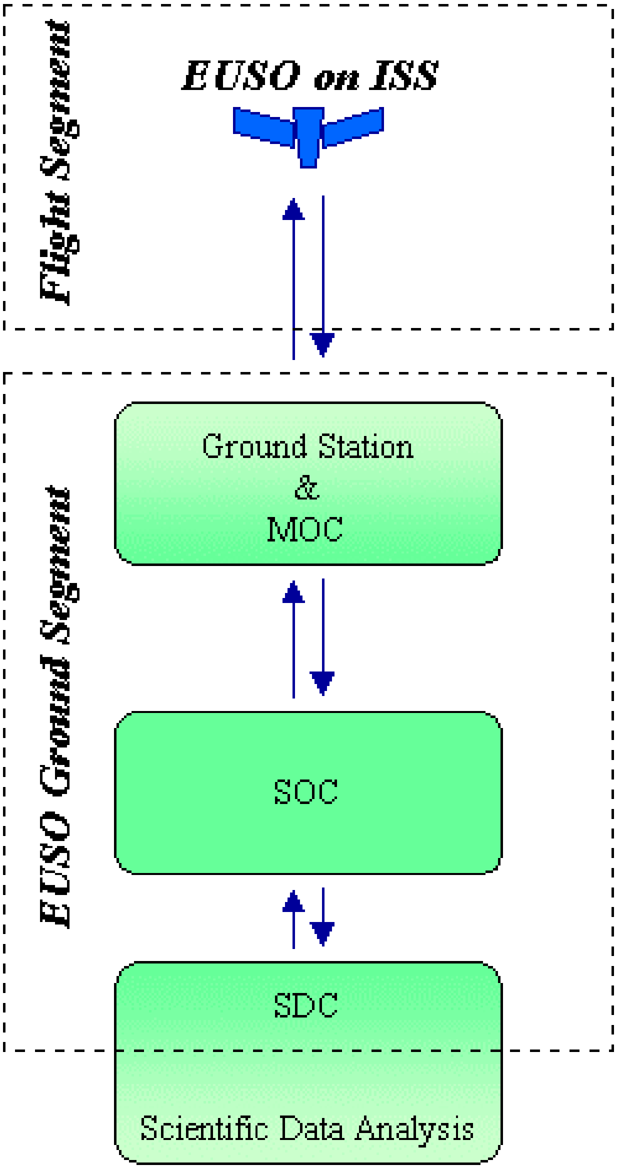
The Quick-Look (QL) Analysis component is foreseen to perform the following tasks:

- checking of the functional status and performance of the scientific payload, accomplished by monitoring the relevant housekeeping,

- monitoring of the ambient backdrop: atmospheric response, transparency, scattering, clouds type and distribution.

- first analysis of scientific data: a rapid alert system to notify any relevant scientific/monitoring event should be implemented,

- production of an on-line QL database containing the output results of the QL Analysis, accessible and retrievable by involved authorized users.



2.2 The Science Data Centre

The SDC will be responsible for the calibration of the *EUSO* instruments, establishing the *EUSO* archive, and providing data to users together with a dedicated *EUSO* data analysis system.

EUSO data will be rapidly collected, processed into standard formats, distributed to the Science Teams and made available to the scientific community in accordance with the ESA-EUSO rules. Products include *EUSO* scientific data, ISS relevant housekeeping and other ancillary information.

The main scientific objectives of *EUSO* (spectrum and arrival directions map) require the establishment of a complete and homogeneous database of EECR events. An organized structure provided by a *EUSO* Archive should then be implemented for storing all mission data, including both telemetry (science/housekeeping) and ancillary data (attitude, time-conversion data, etc.). The *EUSO* Archive shall contain both raw and reduced data, the last ones reformatted in a standard format. To provide long-term and secure data archiving, the system should be based on modular and flexible concepts, supporting evolving user requirements and new operational needs.

3 Data Handling – Scientific Data Analysis

EUSO data handling will face with several problems to be taken into account during the calibration of the telescope as well as during the scientific data analysis; among all, the description of the atmosphere and the background discrimination, both involving the different scientific communities present in *EUSO*.

For what concerns the calibration of the telescope, we recall here the principle of operation: *EUSO* uses the Earth's atmosphere as the interaction region of a Gas Counter where UV fluorescence light is produced. But, differently from an experimental Gas Scintillation Counter produced in lab, all the atmosphere parameters can only be measured: they cannot be modified!!! Moreover, *EUSO* will detect (and use it to improve the determination of arrival direction and energy of the shower) the diffuse optical-UV signal emitted when the Čerenkov beam, accompanying the shower, impacts on top of clouds, land or sea. Basic environmental parameters that can influence the response of the instrument are:

- the ozone level, responsible for the UV absorption,
- the presence of clouds, that can hide the UV fluorescence track or the Čerenkov signal,
- the Earth surface, land, sea, ice-region, desert, that can influence the Čerenkov signal itself,
- the atmospheric temperature and pressure, responsible for variations in the fluorescence yield,
- the winds, although in a smaller measure, that can transport dusts, aerosol and micro particles.

Furthermore, mostly of these parameters are variable with the seasons and with the geographical coordinates (longitude, latitude, altitude).

The background discrimination is one of the more important points to classify a *EUSO* event as "certified". The sources of UV background for *EUSO*, i.e. anything that can produce light in the UV band of interest for *EUSO*, are numerous; they can be roughly divided into three broad categories, namely man-made sources, transient natural phenomena, and constant sources.

- Man-made sources consist of city lights, and lights from ships and airplanes. City lights produce emission at several orders of magnitude above the "natural" background; however, the regions of city lights are well known and identifiable through the correlation between the attitude ISS information and geographical databases and maps. Lights from moving ships and airplanes cannot be avoided but they will be very slow moving sources compared to actual events.
- Transient natural phenomena are mainly aurora, lightning, meteoroids. Aurora produces extremely bright UV emissions, confined to high northern and southern latitudes; even if aurora is not in the direct field of view of the instrument, the light produced in the aurora region can still be scattered off the atmosphere and could contribute to a general increase in the background light level. Lightning produces very intense near-UV emission, travels at the speed of light, can extend over many tens of kilometres, and it could mimic an actual EECR particle event; fortunately, lightning strikes mainly occur from cloud-to-cloud and cloud-to-ground and then a correlation between the observation time and attitude and meteorological information can be very useful to discriminate lightning from the events of interest for *EUSO*.
- Constant sources can be identified in reflected starlight and moonlight, atmospheric near-UV emission light from chemical reactions, low energy cosmic ray air showers. Reflected moonlight is always present, except around the new moon. Atmospheric near-UV emission light from chemical reactions is produced by atom-atom collision excitations and ionic recombination; it depends on the local oxygen density, and is comparable to the reflected starlight component of the UV background. Low energy cosmic ray air showers produce Nitrogen fluorescence as well, although the individual showers are too weak to be seen from orbit; but, in any case, this effect contributes to increase the average level of UV background.

Part of the information needed for the calibration and scientific data analysis will be measured on-board;

nevertheless, external distributed information (atmospheric, meteorological, geographic databases and maps, and more) would be necessary to complete the knowledge of the observation conditions.

Moreover, astrophysical catalogues would be used to correlate EECR events seen by *EUSO* with astronomical phenomena, as GRBs.

In summary, different heterogeneous information and data are necessary to simulate *EUSO* behaviour, to optimise its design, to calibrate its response function, and then to properly analyse and certify *EUSO* observational data.

4 Communication and Outreach

As a scientific experiment, *EUSO* will use very specific tools and methods to observe, detect and study the extreme energy universe, mainly cosmic rays and neutrinos. These tools and methodologies when applied in processing the information (retrieval and archiving, data analysis, data mining, information fusion with atmospheric, meteorological and astrophysical data) are part of the *EUSO* communication potential.

As a space mission, the many aspects of science and technology related to *EUSO* have to be included in its communication potential too. Moreover, *EUSO* will be accommodated on board the International Space Station: this fact brings the wealth of interest and excitement of manned space flight together to the exciting science of *EUSO* – the most energetic particles ever observed!

The communication potential of the *EUSO* mission is therefore very high and immediate. The interest both in the exploration of the "Extremes" of the Universe and of the atmospheric phenomena is large and widespread, capturing the imagination of scientists as well as of the public.

In this sense, a dedicated *EUSO* team will take care of activating and maintaining the Educational and Public Outreach (EPO) program. The science community active in the *EUSO* mission will play an essential role in providing content and promoting outreach. Dissemination of the *EUSO*-EPO products will be facilitated by the help of professional educators, teachers, media professionals, science journalists, and facilitators which would also provide access to the relevant expertise, necessary to ensure quality products reach the greatest number of people.

Furthermore, a dedicated Web site will serve as the "face of *EUSO* to the world": it will be the main portal to *EUSO* activities and constitute the means to disseminate scientific information. A preliminary version of the Web site is located at *http://www.ifcai.pa.cnr.it/ ~EUSO*.

5 Conclusion

The main *EUSO* science exploitation resides in the overall body of the EECR detected events and in the availability of all the useful scientific and ancillary data. It is therefore necessary that the entire *EUSO* Archive is made available to the scientific community as soon as possible, after a suitable data property time to the dedicated *EUSO* team charged with the certification of data. Several aspects that must be taken into account to calibrate *EUSO* and to achieve "certified events" have been considered in this presentation.

References

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