ESA SPACE WEATHER INITIATIVES IN THE SPACE ENVIRONMENTS AND EFFECTS ANALYSIS SECTION (TOS-EMA)

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ABSTRACT

Understanding the dynamic space environment is important for optimizing space technologies. Space environments and their effects have been studied for many years, but only relatively recently has the term Space Weather been attached to the subject. This paper presents some of the Space Weather related activities that the Space Environments and Effects Analysis Section (TOS-EMA) at ESTEC/ESA has initiated both technically and in outreach activities. Ways in which the Section might collaborate with the European Space Weather community are suggested.

Key words: Space Weather; Space environment; Spacecraft.

1. INTRODUCTION

The term 'Space Weather' refers to the time dependent space environment and its impact on space and ground systems (technological and biological). Much of this time dependence is due to the Sun-Earth connection (chain of events and their consequences; e.g., coronal mass ejections, solar energetic particle events, geomagnetic storms, radiation belt refilling, etc.) The Space Environments and Effects Analysis Section (TOS-EMA) at ESTEC has responsibility for supporting ESA programmes and European industry by providing quantitative evaluation of space environments and their effects, and related risk assessments [cf, TOS-EMA server, www.estec.esa.nl/wmwww/wma/]. A broad class of these effects is due to the dynamics of the space environment. Thus, TOS-EMA can be said to be the main ESA entity active in the Space Weather field and this paper will present some of its activities. Other recent reviews on TOS-EMA activities can be found in *Daly et al.*, [1996] or *Hilgers and Daly* [1997]. Section 2 introduces the technical activities that TOS-EMA is involved in, followed by Section 3 that concerns the section's outreach activities in this field. The paper ends by examining the international importance of this subject and future Space Weather collaboration envisioned by the Section.

2. TECHNICAL ACTIVITIES

Some examples of analyses performed by TOS-EMA of the space environment and the possible impacts it may have on technological systems are listed in Table 1. Examples of more in-depth analyses of specific space environment-induced problems are listed in the bottom part of this Table. As can be seen the "cause" in the space environment and the effects are very wide-ranging and thus a great challenge for modellers.

Table 1. Support to Projects

Examples of Routine Analyses.
Energetic particle mission flux and dose calculations.
Microparticle (meteroid, debris) impact risk assesment.
Evaluation of electrostatic charging levels.
Calculation of atomic oxygen fluences.
Outgassing contamination analyses.
Single-Event Upset rate prediction.
In-Depth Analysis of Specific Environmentally-Induced Problems.
Analysis of environment-induced noise in detectors.
Analysis of the electrostatic environment of bodies in space plasmas.
Deep-dielectric and surface electrostatic charging risk assessment.
Reflectance models of the atmosphere.
Analysis of environments related to in-flight anomalies or events.

For a long time the space environment effects analysis tools were limited by the small amount of data that were available or that could be processed on a reasonable time scale by the current computer technology. New data sets together with advanced computer and data processing technology can now give access to more detailed information on the space environment and its dynamics. The TOS-EMA Section has initiated various studies in the frame of the TR&D programmes of ESA (e.g., Space Environments and Effects Major Axis of ESA's Technology Research Programme, TRP; General Support Technology Programme, GSTP) to utilize the new data sets in the generation of new models. Currently three main themes are common to many of these studies: time dependence, multi-parameter consistency, and updating.

A key improvement needed in most space environment models is the implementation of time-dependence. Many models available are either empirical or statistical and take into account only the temporal variation due to the solar cycle or the typical 'average' duration of the events of interest. They also rely on long-time averaged parameters or extreme case values.

Refined models using very large data bases may take into account the variability over a broad range of time scales. This approach is currently being used for solar particle events [e.g., Hilgers and Crosby, 1998] and radiation belt models (TREND), see [www.magnet.oma.be/trend4]. For multi-parameter value prediction (e.g. spectra), these models must include possible consistent correlation values between those parameters.

Physical models are also being investigated for, e.g., optimizing the statistical models (cf e.g., Bourdarie, these proceedings) or to provide engineering databases, e.g., the Mars environment Model that is generated via a Global Circulation Model (GCM) [*Hourdin et al.*, 1996].

More and more data are becoming available on a routine basis and are easily accessible via the internet, e.g., GOES data, OMNIWEB, etc. New approaches should be used in order that engineering model updates can also be performed on a routine basis. This is one of the objectives of the Space Environment Database and Analysis Tools (SEDAT), see [www.wdc.rl.ac.uk/sedat].

Establishment of networks of in-orbit monitors of the space environment is an important element of any Space Weather activity. The section participates in the development of the Standard Radiation Environment Monitors (SREM) which can be found at [www.estec.esa.nl/wmwww/wma/srem/index.html]. SREM is a standard piece of equipment and ideal for continous monitoring of the radiation enviroment. It will also be included on the International Space System (ISS), see [www.estec.esa.nl/wmwww/wma/creep/index.html].

TOS-EMA also has a contract with industry for the development of a standard meteoroid and space debris in-situ detector known as DEBIE. The detector will actively monitor sub-millimeter sized particles which impact its surface.

Future space environment monitors should also include plasma sensors since low energy electrons (below or equal to 10 keV) and processes related to their dynamics can lead to spacecraft operational anomalies.

3. OUTREACH ACTIVITIES

The Section has initiated various outreach activities concerning Space Weather relying strongly on the efficiency of the internet. Basically the activities can be grouped as: (i) of web servers, (ii) electronic newsletter, (iii) workshops etc.

3.1. Web Servers

Internet technology is seen as an important mean for space weather activity since it potentially provides a quick access to various types of data in a distributed environment.

Table 2. WWW Site Names and Addresses

SPace ENVironment Information Service (SPENVIS) www.spenvis.oma.be
Time-Dependent Radiation ENvironment Development (TREND) www.magnet.oma.be/trend4
Space Environments and Effects Analysis Section www.estec.esa.nl/wmwww/wma
ESA Space Weather Web Server www.estec.esa.nl/wmwww/spweather
Study of Plasma and Energetic Electron Environment and Effects (SPEE) www.geo.fmi.fi/spee
The ECSS Space Environment Standard www.estec.esa.nl/wmwww/wma/ECSS.html
Space Environment Database and Analysis Tools (SEDAT) www.wdc.rl.ac.uk/sedat
Standard Radiation Environment Monitors (SREM) www.estec.esa.nl/wmwww/wma/srem/index.html

TOS-EMA is sponsoring several activies that have resulted in WWW based tools that are easy to handle for the users. For example SPENVIS (the SPace ENVironment Information System) provides information on the space environment and its likely effects on space systems, and models describing the environments and effects. Specifically it allows easy quantitative analysis of environments and effects, including generation of spacecraft orbits. The system is continuously updated. The project SEDAT is devoted to refined data analysis of space environment effects making use of extensive database and flexible interrogation tools.

Besides several information servers have been developed in the frame of contractor studies or by the section itself (cf Table 2).

3.2. Electronic Newsletter

The Space Weather Euro News (SWEN) is an initiative taken by the Section to create a communication tool for the European Space Weather community via internet. SWEN is an electronic newsletter which offers news of interest for the Space Weather community in Europe, for example information about events such as conferences and workshops, news about on-going research and new results, tender opportunities, offers and requests of services, resource and trainee opportunities, job opportunities, etc. Previous SWEN issues are available on the ESA Space Weather Web Server (see Table 2) and are furthermore archived at www.astro.lu.se/~henrik/spweuro.html.

New registration on the SWEN mailing list can be made by sending an e-mail to swen@wm.estec.esa.nl requesting to be added to the list.

3.3. Workshops, Conferences, etc.

The section has organised and co-sponsored various workshops on Space Environmental Effects on Spacecraft and Space Weather related subjects which are listed in Table 3. This includes the "ESA Workshop on Space Weather" where this work was presented in which the emphasis was being placed on Space Weather services.

Table 3. Workshops and Conferences

"ESA Workshop on Space Weather", ESTEC, NL, November 1998
"The 6th Spacecraft Charging Technology Conference", Hanscom AFB, USA, November 1998
"Artificial Intelligence Applications in Solar-Terrestrial Physics", Lund, Sweden, July 1997
"Environment Modelling for Space-Based Applications", September, ESTEC, NL, 1996
"Round Table on Space Weather: European Needs and Capabilities", ESTEC, NL, March 1996
"Radiation Belt Models and Standards", BIRA/IASB, Belgium, October 1995
"Space Environment Analysis Workshop", ESTEC, October 1990

4. CONCLUSION

It is certain that the number of space missions will increase in the future and their higher sensitivity to space environment effects will be unavoidable due to developments in technology. This includes aspects such as sensitive payloads, sending man to space, high performance requirements and low cost/light weight objectives. Bearing this in mind and the fact that the next solar maximum is approaching, it has become apparent that the understanding of the dynamic space environment must be given priority, but studied in the context of effects such as electrostatic charging, background, SEU and health hazards. TOS-EMA stresses the importance of international collaborative efforts involving historical data, models, near real-time data from spacecraft, ground-based observatories and simulations. There is also an importance for continuous in-orbit environments and effects monitoring including monitors such as SREM. This is essential if one wishes to establish an advanced form of space environment assessment and prediction system that would be useful for the whole Space Weather community, which must include the engineering community.

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