Executive Summary

Introduction

As space missions become more technically sophisticated, they are increasingly sensitive to the space environment. "Space Weather" describes the state of the environment as a result of dynamic solar, heliospheric and magnetospheric phenomena in the context of potential impacts on technological systems. The Space Weather field includes observational, modelling and effects aspects. It is a rapidly growing subject worldwide, although European Space Weather activities are fragmented in different groups and European-wide initiatives are in an embryonic state. Progress in space environment analysis is expected from extensive collaborative efforts with near real-time data from spacecraft, ground-based and theoretical simulations with the aim of establishing predictive systems relating the cause (solar activity) to the effect on technological systems and human activity. At the same time it has become evident for the scientific community that it also needs input from potential users of future Space Weather services.
As a support unit, ESA's Space Environments and Effects Analysis Section is particularly concerned with how the Space Weather concept can lead to products which enhance the performance and reliability of space systems.

Workshop Overview

The workshop was highly successful in meeting its goals to have comprehensive reviews both of the status of European efforts across the various Space Weather areas of activity and of technical and non-technical implications of Space Weather. It was hoped that this would all be done in the context of users of a possible space weather programme, and this was achieved both through appropriate invited talks and through working-groups.

The working groups met after two days of invited talks covering the diverse areas from the various user aspects to the scientific problems. The working groups were:

- Users and Needs
- Forecasting Space Weather - Scientific Road-map
- Organisational Issues

The results of their deliberations are contained in the Working Group Report sections of these proceedings.

Feedback from attendees was very positive concerning the content of the workshop and the initiative it represented for a European space weather activity. From the point of view of ESA's Space Environments and Effects Analysis Section, the initiating group for the workshop, it was also highly successful. It allowed valuable exchanges of experiences and view between groups who have in the past not been closely associated. For example, while the solar terrestrial community often refers to space weather, there is often not enough appreciation of the real engineering problems that space weather causes and the methods which are needed to cope with them. Another good example was the perspective of space flight risks from the point of view of the insurance sector. The workshop also provided a good forum for "taking stock" of the maturity of the various component fields involved in space weather. Since ultimately a space weather service has to draw on solar, heliospheric and magnetospheric physics, on data processing and computing, on instrumentation, and on effects quantification, it is important to assess and fix weak links. Finally from the Agency's point of view, it is crucial to involve potential partners from throughout Europe and beyond. The fact that so many presentations were made in a very positive spirit on national initiatives and activities was very gratifying.

As a result of the workshop, it is clear that there is a broad consensus that ESA should move forward rapidly in this field and that communications channels and collaborations should be established. It is also clear that more work on the "user definition" end of the problem is necessary. The enthusiasm and maturity of the science community needs to be matched by work on defining and producing products of real practical value to users.

The following sections briefly review the results of the individual sessions.

Effects and Users

This session set the scene for the later discussion of details of the environment. Effects on spacecraft and aircraft electronics were presented by Clive Dyer. Spacecraft electronics and detectors are becoming increasing susceptible to radiation and electrostatic charging problems and aircraft systems are also beginning to show effects due to cosmic ray induced secondary radiation. Space weather also influences the atmosphere and Hans-Heinrich Klinkrad presented orbit and attitude perturbations due to the neutral atmosphere. Nicolas Picot presented effects on the ionosphere, which affects electromagnetic signal propagation. On the ground the effects of space weather perturbations are due to magnetic field effects, particularly at high latitude, and Risto Pirjola presented the effects on power lines and pipelines. With increasing manned presence in space it was also important to look at effects on biological systems. This was done by Günther Reitz who stressed the problems of quantifying the effects, and need for monitoring. Air crew are also becoming increasingly concerned. The last presentation in this session, by José Da Costa Lopes gave an over perspective on risks in space activities. From the point of view of insurance companies, the risk on in-orbit failure is small and the most serious risk is presently related to launch and commissioning phases.

The poster session complemented these presentations very well, containing details of activities related to a variety of effects, and some monitoring aspects. Computer tools for effects evaluation were also presented.

Physical Processes/Presentation of Data

Following this complete review of space weather effects, the workshop moved on to consider the physical processes in the sun-earth system which generate space weather. The source of much of the variability in the environment is the sun and Nicole Vilmer reviewed Solar Activity, discussing solar flares, coronal mass ejections, solar energetic particles, co-rotating interaction regions and the solar wind. Tuija Pulkkinen followed this by discussing what is observed close to the earth following some solar transient phenomena. Geomagnetic storms, sub-storms and auroras are often the result and related magnetospheric electrodynamics and energetic plasma phenomena were presented. One of the most hazardous features of the near-earth environment (and of environments of the large planets) is the presence of trapped "radiation belts". Paul Bühler presented a review of radiation belt phenomena and physics and included discussion of energisation and transport processes. Energetic particles entering the earth's environment from outside include particles energised close to the sun - solar energetic particles, and particles from outside the heliosphere - galactic cosmic rays. In finishing the session, Stephen Gabriel presented a review of these phenomena and also how the particles enter the near earth environment in the presence of the geomagnetic field.

A very extensive poster session accompanied the review talks. The results from SOHO were well represented, and solar and heliospheric phenomena seemed the most common topic.

Models and Data

The session on models and data began with a presentation from Daniel Heynderickx on data

processing, databases and tools. This was based on work using several satellite data sets to construct empirical models of the radiation environment. With this experience, he was able to make recommendations for future approaches. There followed presentations on models of specific environments. Volker Bothmer presented theoretical models of solar corona and solar wind structure, including recent observations, and discussed additional observations needed in future. Models of the magnetosphere and radiation belts were discussed by Sebastien Bourdarie. He reviewed model types and activities at various institutes in this field. The important issues of Model coupling and application were also discussed. Ljiljana Cander discussed ionospheric Models, emphasising models used for practical application in communications. The application of modern numerical methods such as neural networks, filters and analogue models was reviewed by Henrik Lundstedt, who gave examples of problems and successes. The session was completed with a different but important view point. In assessing space weather effects, characterisation of these effects is done in ground testing and Manola Romero presented a review of the methods and problems to link these methods and effects models to environmental measurements.

The poster session for this session was the largest. Posters augmented the review talks very well and presented several complementary initiatives. There was, however, a lack of posters on effects modelling and data.

Various World Wide Space Weather Initiatives

The final session provided the opportunity for attendees to see what was being done in the space weather field in various countries and organisations. It started with a presentation by Hannu Koskinen on a report prepared for ESA on Space Weather. He discussed the needs for a programme and the possible role of ESA. This was followed by presentation of Czech (Marian Karlicky), Danish (Eigil Friis-Christensen), Finnish (Tuija Pulkkinen), French (Jacques Breton), German (Wolfgang Baumjohann), Italian (Maurizio Candidi), Norwegian (Pal Brekke), Russian (Aleksey Dmitriev), Swedish (Henrik Lundstedt) and U.K. (Andrew Coates) initiatives. The reader is referred to the submitted papers for details. Some states are clearly quite advanced in the domain compared to others and there seemed a general desire for international collaboration. These national initiatives were followed by a presentation of the AGONET Antarctic geospace observatory network by Maurizio Candidi. US progress in implementing real space weather services was demonstrated by the following two presentations. In the context of the International Space Station, it is crucial to have warning of hazardous radiation levels for astronaut protection. Michael Golightly presented the approach of NASA to manage exposures from space weather events. This made use of services provided by NOAA and Ernest Hildner presented NOAA's role in providing products for space weather evaluation and the context of NOAA's establishment and development of these services. The session ended with a presentation from Richard Thompson on the international space environment service (ISES), a collaboration of 10 regional warning centres collecting and distributing data on solar terrestrial conditions.

Further information on initiatives related to space weather was presented in the associated poster session.

Workshop Conclusion

The Sessions described above were followed by working group activities, the reports of which are to be found elsewhere in these proceedings. The results were presented to the workshop in a final session, which also included a panel discussion. Several points came out of the deliberations and discussions. There was general support for the idea of a

European Space Weather Programme. This support was well-elaborated by those involved in solar terrestrial physics (in its broadest sense). There was also support for co-ordination of European effects. This introduces better use of national resources, promotes international collaboration, reaches the public and demonstrates the benefits of space physics research. There was a cautionary note, however. The user community: the engineers and technologists who will make use of space weather products, have to be more involved. Several actions were suggested to achieve this and it was stressed that Space Weather should not be just a scientific topic.

The reader will find a lot of provocative ideas in the summaries of the working group activities and in the submitted papers in these proceedings. The enthusiasm with which people participated was very encouraging. Another workshop will be held in the not-to-distant future and by then many of the embryonic activities will hopefully have reached maturity.