European Cooperation in the field of Scientific and Technical Research - COST -

Secretariat

Brussels, 10 July 2002

COST 248/02

DRAFT MEMORANDUM OF UNDERSTANDING

Subject : Draft Memorandum of Understanding for the implementation of a European Concerted Research Action designated as COST Action 724 "Developing the Basis for Monitoring, Modelling and Predicting Space Weather"

The abovementioned draft Memorandum of Understanding is attached.

DRAFT

MEMORANDUM OF UNDERSTANDING

FOR THE IMPLEMENTATION OF A EUROPEAN CONCERTED RESEARCH ACTION DESIGNATED AS

COST 724

"DEVELOPING THE SCIENTIFIC BASIS FOR MONITORING, MODELLING AND PREDICTING SPACE WEATHER"

The Signatories to this Memorandum of Understanding, declaring their common intention to participate in the concerted Action referred to above and described in the Technical Annex to the Memorandum, have reached the following understanding:

1. The Action will be carried out in accordance with the provisions of document COST 400/01 "Rules and Procedures for Implementing COST Actions", the contents of which the Signatories are fully aware of.

2. The main objective of the Action is to develop further within a European framework the science underpinning space weather applications, as well as exploring methods for providing a comprehensive range of space weather services to a variety of users, based on modelling and monitoring of the sun-Earth system.

3. The economic dimension of the activities carried out under the Action has been estimated, on the basis of information available during the planning of the Action, at Euro 15 million in 2002 prices.

4. The Memorandum of Understanding will take effect on being signed by at least five Signatories.

5. The Memorandum of Understanding will remain in force for a period of four years, calculated from the date of first meeting of the Management Committee, unless the duration of the Action is modified according to the provisions of Chapter 6 of the document referred to in Point 1 above.

COST 724
"DEVELOPING THE SCIENTIFIC BASIS FOR MONITORING, MODELLING AND PREDICTING SPACE WEATHER"

A. BACKGROUND

Space Weather is succinctly defined as: "*conditions on the sun and in the solar wind, magnetosphere, ionosphere, and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems and can endanger human life or health*" (definition used by the US National Space Weather Plan). The impact of space weather ranges from technical problems on satellites arising from charged particles, through the effects of radiation on humans both in space and in high altitude aircraft, to problems experienced by power transmission grid operators on the ground during geomagnetic storms. A recent study for the European Space Agency (ESA) reckoned that space weather accounts for annual costs of 55 million Euro to users throughout Europe.

At present users of Space Weather information rely heavily on the US Space Environment Centre (SEC), which is the only source of comprehensive Space Weather data. There is a need for more than one source of comprehensive Space Weather products to ensure a robust supply of data critical for some applications. For instance if communication links to SEC fail, or if for political reasons the supply of services from SEC should in future become restricted this could leave European users of Space Weather services at risk. There is capability in Europe to provide a comprehensive space weather service, and also to provide data products which complement the services provided by the SEC, thereby providing a better global Space Weather service.

The main elements of a coordinated space weather programme consist of monitoring the solar-terrestrial environment, and the use of models to specify and predict the state of the sun-Earth system from limited measurements. Examples of the types of measurement required include: monitoring solar emissions in x-ray and radio frequencies; emissions of energetic electrons and protons; images of solar active regions and coronal holes; in-situ measurements of the solar wind speed, density, composition and embedded magnetic field; in-situ measurements of the Earth's radiation environment; ground based measurement of magnetic field variations; ground-based measurement of ionospheric parameters; and ground-based measurement of cosmic rays.

The types of models required for specifying and predicting the solar-terrestrial environment include: models of the development of solar active regions; the onset of coronal mass ejections; the propagation of coronal mass ejections through interplanetary space; the propagation of energetic particle radiation through interplanetary space; the interaction between the interplanetary medium and the Earth's magnetosphere via the reconnection process; the onset of magnetic substorms; the filling and depleting of the radiation belts; ionospheric composition and density; diffusion and convection of ionospheric plasma and induction of ionospheric electric fields and currents. All the above-mentioned models are essentially scientific models, and further development is necessary to provide outputs useful for specific users such as electricity utilities concerned about the induction of currents in power grids. Furthermore, development is necessary to enable the coupling of these models in order to provide the capability for modelling the complete solar-terrestrial environment.

There are many organisations widely distributed around Europe actively engaged in research in space physics, both through gathering observations and development of models. In addition many of these organisations are actively engaged in developing Space Weather services to address user needs. There is a need to maximize synergy arising from the variety of scientific activity and expertise that exists in Europe, and to coordinate the European effort in development of space weather services to minimize duplication of effort.

Although a title referring to “Space Weather” suggests that ESA may be a suitable funding agency, many of the activities are outside the scope of ESA science (eg. effects of magnetic storms on power grids). ESA is regarded as a contributing institute and its Spacegrid project will play an important role in the development of a European Space Weather service. Additionally, the science of space weather is not addressed explicitly in the Framework Programmes of the EU.

Thus, as a gathering forum enabling coordination of existing national activities in research institutes, academia and industry by cooperation in aiming towards common goals, COST is the most appropriate framework. Furthermore, the analogy of providing information and forecasts of the state of the Sun-Earth system with the services provided by meteorological organisations suggest that an Action concerning space weather aligns closely with the COST Meteorology domain.

One aspect of Space Weather is already addressed by COST Action 271 in the Telecommunication domain, entitled “Effects of the upper atmosphere on terrestrial and Earth-space communications”. Dedicated connections will be set up to liaise with COST Action 271 to incorporate results from COST Action 271 in the European Space Weather Network, which addresses wider issues in modelling the sun-Earth system. Improved solar-terrestrial models developed under the European Space Weather Network may also be of benefit to COST Action 271.

B. OBJECTIVES AND BENEFITS

The main objective of the Action is to develop further within a European framework the science underpinning space weather applications, as well as exploring methods for providing a comprehensive range of space weather services to a variety of users, based on modelling and monitoring of the sun-Earth system.

The general aims of the Space Weather Action will be:

- To coordinate European research into modelling and prediction of space weather;
- To promote where necessary the deployment of new instrumentation to satisfy data requirements, and the development of new models;
- To educate potential users of space weather data;
- To gather feedback from users which may be used to improve services;
- To create a forum for exchanging “best practice” among users and providers of space weather services;
- To set standards on data exchange.

The main benefit of a concerted European Space Weather programme is that organisations which face hazards from space weather in their day-to-day operations will have a resource which will enable them to manage the risk, and which will have traceable quality standards.

C. SCIENTIFIC PROGRAMME

The scientific programme has two main elements:

Research into modelling and predicting the space environment.

Practical space weather services, required by users who have to manage risk associated with space weather, need to rely on the timely supply of relevant space weather data (eg. X-ray flux, energetic particle events, solar wind speed, and geomagnetic variations) and on the ability of models to specify key parameters which describe the Earth’s space environment in near real-time (eg. particle fluxes, ionospheric electron densities, and geomagnetic indices). From this combined information, it is necessary to provide forecasts and real-time specification of the particle radiation environment, ionospheric parameters, and levels of geomagnetic activity. There are currently a sufficient number of relevant data sources and prototype models of constituent parts of the sun-Earth system to make this a realistic goal. For example images of active regions and coronal mass ejections are available from the Solar and Heliospheric Observatory (SOHO), measurements of the solar wind parameters are available from NASA’s Advanced Composition Explorer (ACE), some particle measurements are available from the US Geosynchronous Operational Environmental Satellites (GOES). A number of approaches are possible to achieve this modelling goal, ranging from models based on the underlying physics of the complete sun-Earth system, (eg. the Grand Unified Magnetosphere Ionosphere Coupling Simulation of the Finnish Meteorological Institute) to models which use empirical relationships between certain key parameters (eg. the use of neural networks at the Lund Space Weather Centre).

Development of a coordinated European space weather network

Europe is host to World Data Centres relevant to space weather in Denmark, Belgium, France and the UK, as well as institutes responsible for producing geomagnetic indices, in Germany, France and Spain. Additionally there are Regional Warning Centres of the International Space Environment Service in Belgium, Czech Republic, Poland and Sweden. Examples of other formal networks relevant to space weather include the INTERMAGNET programme for magnetic observatories, the European Incoherent Scatter Radar for studying the high latitude ionosphere, and the IMAGE (International Monitor for Auroral Geomagnetic Effects) magnetometer network in Scandinavia.

The purpose of the European space weather network is to pool European expertise in space physics and space weather in order to develop an efficient means of communicating information about the space weather environment to users. The network will ensure that those institutes engaged in research into space physics models applicable to space weather will have timely supply of relevant data, and it will ensure that the output of operational models is available to interested users in a timely manner and in a form which is useful for the user. The network will also provide means for feedback from the users to the modellers to target research directly at user needs.

In both of the above elements of the Technical Programme, European institutes will cooperate and collaborate with institutes outside of Europe, primarily in the USA.

Improving the capability to model, monitor and predict variations in space weather, and improving the exchange of data and models between researchers and users in Europe will result in benefits in the following areas of application:

Satellites, Launchers and Aircraft

Satellites are obviously technological systems affected by space weather, the principal effects being electrostatic charging, single event upsets, latch-up, degradation of solar cells, and increased atmospheric drag. To cope with these problems, high margins are allowed for in the design of space systems leading to over-design of spacecraft. The availability of more accurate models of the space environment would permit more rigorous specification for future space devices and would help space insurers (an industry which is dominated by European companies) to better master their premium policy.

Prediction of atmospheric drag on satellites and space debris is important in tracking, predicting orbits, and in mitigating collision risk. Research on the atmospheric response to variations in solar EUV radiation and geomagnetic activity is needed to improve the prediction of atmospheric drag, particularly for satellites that require to be maintained in a very precise orbit like Envisat. This will be achieved by a combination of using various atmospheric models and gathering of observational data from satellite orbits

The probability of launch failure during a Solar Energetic Particle (SEP) event is estimated to increase by a factor of 10 to 200 depending on the target orbit. During the last few days before a launch, SEP events should be carefully monitored in order to authorize or postpone it. Special attention, via the validation of model output and forecasts, should be given to minimize the risk of false alarms.

The trends to use miniaturized electronic parts for avionics and to open new polar routes, which are more exposed to energetic particles, suggest that space weather issues should be taken into account for specification and operation, in the same way as for spacecraft. Problems to be addressed are: how often can significant events be expected at aircraft altitudes? Can they be predicted? How are electronic components affected and can they be designed to cope with the expected space weather events?

Radiation effects on Humans

Astronauts in low Earth orbit can be subjected to harmful radiation from trapped protons, galactic cosmic rays, solar energetic particle events, and energetic outer belt electrons. Reliable methods of predicting the radiation environment following different types of solar activity are important in managing the risk, but current models are not very satisfactory for this purpose and further research is needed.

Airline passengers on high altitude routes, particularly in high latitude regions, may be subjected to higher than normal doses of radiation following certain types of solar activity. This problem is more important for aircrews who are likely to be exposed more often, and has been recognised in EU Council Directive 96/29/EURATOM on radiation safety standards. Reliable methods of modelling the radiation environment in the atmosphere are required to manage this risk. The main problems to be addressed are the neutron component, related to galactic cosmic rays, and solar particle events. The provision of real-time information to enable rerouting of flights on high risk routes is also an important consideration.

Ground-based Technology

The effects of space weather on ground-based technology are mostly due to the varying geomagnetic field. This can affect technology which depends on direct measurement of the geomagnetic field, for example geophysical surveying in geological studies, or directional drilling techniques which rely on the geomagnetic field as a direction reference. In addition the rapidly varying geomagnetic field may induce electric fields and currents in the ground that can affect power transmission grids, the most severe example being the widespread blackout in Quebec in March 1989. Geomagnetically induced currents have been observed in European power grids, and operators need to understand their effects on the grid systems. Pipelines protected from corrosion by active cathodic protection may also be at risk due to space weather, and operators of long distance telecommunication cables may experience problems during magnetic storms. It has been suggested that some types of railway signalling can be affected by magnetic storms, and this is a topic that requires more research to understand.

Liaison with COST Action 271

COST Action 271 is aimed at research into "effects of the upper atmosphere on terrestrial and Earth-space communications". This incorporates high frequency radio communications which use the Earth's ionosphere to communicate over long distances, and the effects on radio signals transmitted and received from satellites. Of particular importance are the effects on performance and reliability of navigation systems such as GPS and Galileo. The effects of the ionosphere on these radio signals is very closely tied in with the wider field of space weather. The aims of this Action, which include the large scale modelling of the sun-Earth system (including the ionosphere) and the development of infrastructure to deliver space weather services to users, are closely aligned with COST Action 271. There will need to be a liaison between COST Action 271 and the modelling work and service delivery developed under this Action.

European Space Weather Network

It is expected that the main method for delivering space weather information to users will be via the Internet, in particular via a web site. This will incorporate links to the distributed centres around Europe which provide specialised space weather products and services addressing the needs of users. Research and development activity will be required to ensure that models of the space environment developed primarily for academic study can be run reliably in an operational mode in real time, using adequate input data. For example the use of grid technology in service delivery will be investigated.

Cooperation with researchers in climate research

There is growing interest in understanding how solar-terrestrial physics (STP) may account for energy input into the neutral atmosphere and how solar-terrestrial processes may influence tropospheric climate. Of particular interest is whether long-term changes identified in the solar-terrestrial environment may be related to long-term changes in tropospheric climate. This topic is not intended to be the subject of deliberate study by the participants of this Action. However, monitoring and modelling work carried out under this Action may be relevant to the STP-climate interface, and links will be fostered with the main international initiatives in this field: the European Science Foundation Network SPECIAL (Space Processes and Electrical Changes Influencing Atmospheric Layers); and a new programme CAWSES (Climate and Weather of the Sun-Earth System) sponsored by SCOSTEP (Scientific Committee on Solar-Terrestrial Physics). Liaison with these initiatives will be managed through the Management Committee.

D. ORGANISATION

Reflecting the above description of the scientific programme, but concentrating on the main scientific areas to be addressed, the Action is organised into four Working Groups (WG) with the following aims:

Working Group 1 – Monitoring and predicting solar activity for Space Weather

- To research the use of solar observations (eg. extreme ultraviolet images, X-ray observations, radio emissions) and models (eg. magneto-hydrodynamic models of flux tubes) for predicting energetic particle events;
- To research the use of solar observations and models (as above) for predicting coronal mass ejections;
- To research the modelling and prediction of solar extreme ultraviolet radiation (EUV) which affects atmospheric density and hence drag on satellites at low Earth orbit altitudes.
- To liaise with COST Action 271 where monitoring and modelling of solar activity is relevant to ionospheric radio propagation;
- Liaise with WG4 to ensure relevant data and models are incorporated in a European Space Weather Network.

Working Group 2 – The radiation environment of the Earth

- To develop a quantitative model of the interaction of solar energetic particle events with the Earth's magnetosphere;
- To develop a quantitative model of the development of trapped radiation in the Earth's magnetosphere during geomagnetic storms;
- To develop a quantitative model of the variation of galactic cosmic radiation in response to solar activity;
- To study how electronic technology in satellites, launchers and aircraft is affected by the Earth's radiation environment;
- To study how humans are affected by solar and cosmic radiation in different activities (eg. astronauts, aircrew, air passengers, on the ground).
- To set up and maintain a database of recorded effects on electronic technology and human health;
- Liaise with WG4 to ensure relevant data and models are incorporated in a European Space Weather Network.

Working Group 3 - Interaction of solar wind disturbances with the Earth

- To develop a quantitative model of the propagation of observed coronal mass ejections (CME) through the interplanetary medium to predict their arrival at Earth;
- To develop a quantitative model to predict geomagnetic storms and ionospheric current systems from observations of the solar wind made by ACE;
- To liaise with COST Action 271 where modelling of the ionospheric response to geomagnetic storms is relevant to ionospheric radio propagation;
- To develop the capability to model electric fields induced in the ground by geomagnetic storms;
- To set up and maintain a database of recorded effects of geomagnetic storms on technological systems;
- Liaise with WG4 to ensure relevant data and models are incorporated in a European Space Weather Network.

Working Group 4 – Space Weather Observations and Services

- Coordinate a network of European websites relevant to data, models, prediction and public outreach;
- Develop methods and standards for data exchange to enable coupling of different space weather models (eg. using Spacegrid) and to disseminate relevant information to users;
- Liaise with COST Action 271 to let COST 271 benefit from space weather model development and to incorporate COST 271 output where it will be of benefit to other space weather services;
- Maintain databases of users and statistics about the service.

The main task of WG4 will be to implement the basis of the European Space Weather Network. WG4 will consist of representatives of working groups 1-3, as well as experts on the design of web based communication systems.

WG4 will maintain close links with SEC in the USA, and active participation in the development of a European Space Weather Service will be sought from SEC, to ensure the best balance between providing redundancy and complementarity of US and European space weather services. WG4 will promote the science and benefits of Space Weather in COST member states that have not participated in setting up this Action. WG4 will also liaise with Eumetsat and the Global Monitoring for Environment and Security (GMES) initiative of ESA and the EU, both of which may be providers of data for, and users of, a space weather service.

E. TIMETABLE

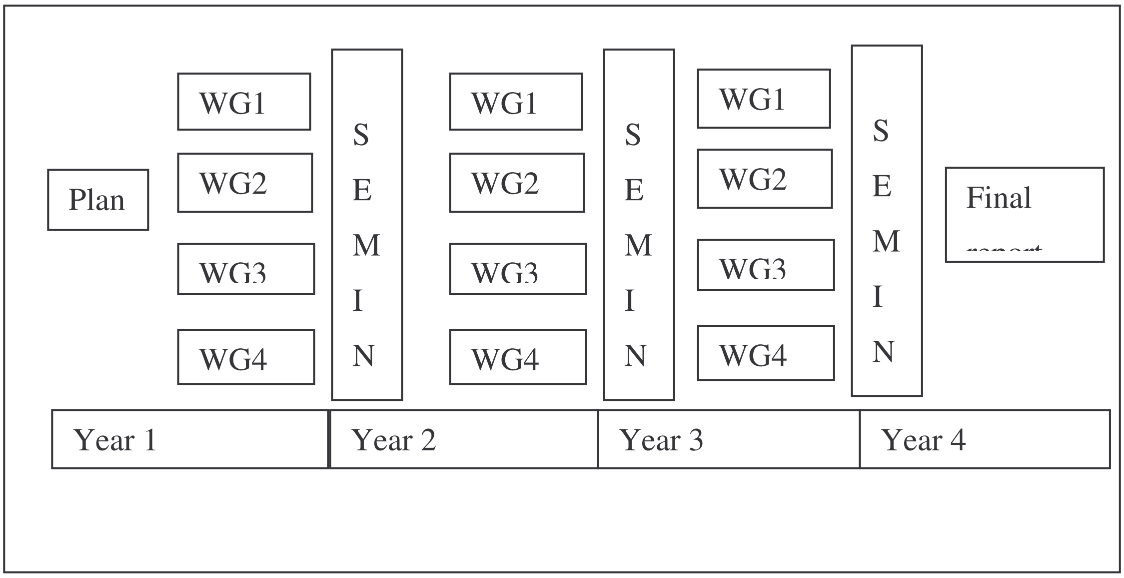
The Action will last for four years. The immediate planning phase, during which the Management Committee (MC) will form and identify the Working Groups and the specific work packages for each WG, will last six months.

Working groups 1, 2 and 3 will initially work to establish the current level of expertise around Europe in their respective fields, and to establish the needs of users in each field. This will build on the published output of the ESA studies on a European Space Weather programme. This work will take six months.

Subsequently, working groups 1, 2 and 3 will coordinate the development of relevant models, including coupling together of models that address different parts of the solar-terrestrial environment. Development will continue in parallel on the provision of reliable and timely data required for running the models. This work will be continuous to the end of the Action. As models become deemed to be operational, each WG will communicate the work to WG4, which will advise on the implementation of service delivery. When prediction models are made operational, each WG will set up a programme to monitor the accuracy of prediction and to measure how well the output meets user needs. This work will be continuous to the end of the Action.

The MC will organise annual workshops to communicate and monitor progress. Dedicated individuals in WG1 and WG4 will liaise with COST Action 271 to channel information between the two communities throughout the course of the Action.

Working Group 4 will commence by evaluating the technology for communicating information between participating institutes and delivering space weather information to users. Coupling of space physics models aimed at different domains of the sun-Earth system may require use of new grid computing technology.



	Year 1	Year 2	Year 3	Year 4
MC	Identify working groups; allocate specific work packages; Consolidate WG output into annual report	Monitor WG progress; Manage liaisons with external groups; Consolidate WG output into annual report; Organise annual workshop	Monitor WG progress; Manage liaisons with external groups; Consolidate WG output into annual report; Organise annual workshop	Monitor WG progress; Manage liaisons with external groups; Consolidate WG output into annual report; Organise annual workshop
WG 1	Create catalogue of existing sources of data and models; Review of scientific understanding	Recommend scheme for predicting SEP onset; Recommend scheme for predicting CME initiation; Recommend scheme for predicting solar EUV radiation variations	Implement scheme for predicting SEP onset; Implement scheme for predicting CME initiation; Implement scheme for predicting solar EUV radiation variations;	Evaluate scheme for predicting SEP onset; Evaluate scheme for predicting CME initiation; Evaluate scheme for predicting solar EUV radiation variations;
WG 2	Create catalogue of existing sources of data and models; Review of scientific understanding	Recommend scheme for modelling SEP effects, trapped radiation and galactic cosmic radiation at Earth; Create catalogue of reported events when humans, satellite and avionic technology affected	Implement scheme for modelling SEP effects, trapped radiation and galactic cosmic radiation at Earth;	Evaluate scheme for modelling SEP effects, trapped radiation and galactic cosmic radiation at Earth;
WG 3	Create catalogue of existing sources of data and models; Review of scientific understanding	Recommend scheme for modelling CME propagation to, and interaction with, Earth; Recommend scheme for modelling induced ground electric fields; Create catalogue of reported events when ground-based technology affected	Implement scheme for modelling CME propagation to, and interaction with, Earth; Implement scheme for modelling induced ground electric fields;	Evaluate scheme for modelling CME propagation to, and interaction with, Earth; Evaluate scheme for modelling induced ground electric fields;
WG 4	Create and manage website with links to data sources identified by WG1-3; Incorporate outreach material.	Identify where standards on data exchange need to be set, and propose solutions; Implement catalogues of reported events on website;	Manage web links to models implemented by WGs incorporating data exchange standards; Summarise usage statistics; Manage space weather events catalogue	Manage web links to models implemented by WGs incorporating data exchange standards; Summarise usage statistics; Manage space weather events catalogue

Table of suggested annual milestones and deliverables to be achieved in each year of the Action

(subject to change during the planning process by the MC and WGs

An important step will be to launch a pilot coordinated European Space Weather Service in the second year of the Action, initially based on monitored data streams, with real-time specification and forecast models added as they become available through the course of the Action.

F. ECONOMIC DIMENSION

The following COST countries have actively participated in the preparation of the Action or otherwise indicated their interest: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Poland, Spain, Sweden and UK.

On the basis of national estimates provided by the representatives of these countries, the economic dimension of the activities to be carried out under the Action has been estimated, in 2002 prices, at roughly Euro 15 million.

This estimate is valid under the assumption that all the countries mentioned above but no other countries will participate in the Action. Any departure from this will change the total cost accordingly.

G. DISSEMINATION PLAN

The main objective of this Action is dissemination of information to users, and this is the objective of Working Group 4. As well as scientists researching the Earth’s space environment, typical users of a Space Weather service will include satellite operators, requiring information on the radiation environment and atmospheric drag, power grid operators, geophysical prospectors, radio communications operators, airline operators and pipeline operators. There is also an increasing interest by the general public for knowing when and where there may be the chance of seeing the northern lights. Some national weather services already provide coarse forecasts of aurorae.

The dissemination of a Space Weather Service will be achieved primarily via a public website. The design of the website will take into account the needs of users identified in Working Groups 1-3, as well as current web-related technology. Other forms of communication will also be available, for example e-mail alerts and mobile phone text messaging.

Results from research activities related to the development of the Space Weather service will be disseminated among the scientific community in the usual way via refereed journal papers and conferences. The MC will organise an annual workshop for users and providers of Space Weather services, and will coordinate the publication of refereed articles. Additionally the MC will coordinate public outreach, which will raise public awareness of the relevance of Space Weather via the website, media activities, articles and lectures.