The background of the slide is a collage of scientific images. At the top left is a close-up of the sun's surface. To its right are four circular panels showing blue-toned solar magnetic field lines. Below the sun is a large, bright orange sun. To the left of the sun is a satellite with solar panels. To the right is a colorful spiral galaxy. At the bottom left is a diagram of magnetic field lines around a sun-like object. At the bottom right is a large radio telescope dish.

Solar Terrestrial Physics in the UK: Scientific Goals and Projects for the Next Millennium

**Community Report to
PPARC Astronomy Committee**

April 1998

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0. Executive Summary

Solar Terrestrial Physics (STP) combines the study of the outer solar atmosphere/corona, its extension via the solar wind into interplanetary space, and its impact on the ionised regions which form the Earth's magnetosphere and ionosphere. The UK STP community has taken stock of recent achievements. This report lays out clear objectives and plans for future endeavours. The community notes the following key points:

1. STP is poised to make the important jump from establishing quasi-static morphology to explaining dynamic chains of events which progress from the surface of the Sun through interplanetary space all the way to the Earth's atmosphere.
2. STP studies fundamental astrophysical processes, such as particle acceleration and magnetic reconnection, in a multi-disciplinary approach which, unique to STP, includes direct in situ measurement of all relevant aspects.
3. STP research is necessary to understand processes which impact on terrestrial technical systems, including power lines and satellite performance.
4. The UK is internationally strong in STP. It participates in major international projects and has gained world-wide recognition for scientific investigations involving theoretical work, modelling, instrumentation, and data analysis. Several measures of this strength are presented.
5. The overall strategy for the next decade requires a co-ordinated, multi-disciplinary approach to reveal the chain of events from solar origin through to terrestrial response and manifestation of dynamic and fundamental processes.
6. This strategy requires a range of ongoing and new projects to make the vital measurements, together with a vigorous programme of modelling and theory. It will also be essential to continue to operate key existing facilities and maintain unique long-term monitoring projects.
7. In view of the complex interplay required between various ground-based and space-based activities, theory/modelling, and the multitude of agencies and funding councils, the formal UK decision-making bodies (PPARC and BNSC) together with NERC representation are recommended to establish a UK STP Advisory Panel to monitor, co-ordinate discussion, and advise on the detailed STP agenda for the next millennium.

The present report is the result of an extensive consultation process over ~ one year involving all UK University STP groups with input from the major UK establishments (see Appendix 7).

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1. Background and Purpose

1.1 Solar Terrestrial Physics - a Working Definition

The boundaries defining Solar Terrestrial Physics (STP) are not precise. For the present purposes, this report focuses on processes in the solar atmosphere, the interplanetary medium, and the Earth's upper atmosphere, with particular emphasis on connected sequences of events originating at the Sun through to their impact on the Earth. At the solar end, this definition of Solar Terrestrial Physics excludes studies of the solar interior (including most work in the area of helioseismology and on sub-photospheric magnetic fields) although there is a strong interest and overlap linking either side of the solar surface. At the terrestrial end, weather systems, climate and other topics involving primarily the lower atmosphere are excluded, although again there are important links involving processes and scientific efforts across this artificially-drawn boundary. STP does not encompass the geological and planetological communities, although studies of the solar interaction with other bodies possessing ionised atmospheres (e.g., comets and planetary magnetospheres) provides useful comparative studies undertaken by essentially the same community.

1.2 Background

The Particle Physics and Astronomy Research Council (PPARC) set up a panel which reported in October, 1996 on the ground-based UK STP programme. The Panel's thorough report, entitled PPARC's Ground-Based Solar Terrestrial Physics Programme - A Review, quantified the size and international esteem for the PPARC-supported ground-based UK STP efforts, and drew attention to the very significant decline in support over the preceding 5 year period. The report focused on the range of ground-based projects in operation, the relative priorities for their maintenance, and opportunities for enhancement. The panel also drew attention to the need for theory and modelling efforts, restricted to roughly that portion of geospace accessible to ground-based observations. Acting on the recommendation of the Panel, PPARC established a UK Solar Terrestrial Physics National Facilities Committee with a part-time funded chair to monitor and advise on the running of national facilities, including the services and data provided to the community, the development of new facilities, the scientific return, and an overall strategy for the UK.

In February 1997, the UK STP community began to establish a series of meetings to discuss the future needs for STP in its broader sense within the UK. These grass-roots meetings revealed a variety of creative, UK proposals which would maintain the UK's international standing in this subject. The discussions underlined the diversity of the STP community in terms of regions of the heliosphere and geospace, experimental techniques, theory/modelling efforts, and funding arrangements, and the increased need to co-ordinate activities across this diversity in order to address key STP science goals.

1.3 Purpose of This Report

The PPARC Report described above was commissioned specifically with regard to the ground-based PPARC-supported STP programme in order to provide input into PPARC's overall ground-based strategy. However, STP covers a much wider range of activities, including a significant space-based component and theory/modelling efforts involving the solar atmosphere, the interplanetary medium and the outer magnetosphere. As the understanding of relatively isolated regions or phenomena has matured, so too has the realisation that this isolation is fictitious; the solar terrestrial system is a highly-coupled dynamic one in which processes and events in one region control and drive those in other regions. Thus, the shift over the last few years from studies of localised, steady physics to global dynamic processes requires a combination of techniques, including co-ordinated space-based and ground-based observations of the Sun, interplanetary medium, and terrestrial atmosphere, together with supporting theory and modelling.

The purpose of the present report is:

- to lay out clearly the objectives of STP in order to promote a better appreciation of the relevance of the subject to the general public and to PPARC's mission
- to take stock of the present range of STP activities within the UK
- to delineate the subject areas embraced by STP, the structure of PPARC and BNSC research support, and the relationship to NERC activities
- to assess the over-riding questions which STP must address in the near future
- to provide a framework for UK efforts in STP
- to propose possible medium and large scale projects led by the UK to address key STP issues as we approach the maximum in the solar cycle of magnetic activity
- to establish a forum for the continued co-ordination of ground-based, space-based, theory, and modelling STP activities

2. Solar Terrestrial Physics - Science

2.1 Solar Terrestrial Physics: Objectives

Solar Terrestrial Physics has three main objectives:

1. To explain those natural phenomena observed at the Sun, in interplanetary space, and within the near-Earth environment, with particular attention to the cause-and-effect relationships between the various stages in the chain from Sun to Earth;
2. To study fundamental physical processes, such as atomic radiation, particle acceleration, magnetic reconnection, and collisionless shock waves, found throughout the astrophysical universe and important for terrestrial experiments and applications;
3. To understand solar terrestrial phenomena so as to begin to predict their occurrence and their significance for technical systems (power line faults, radiation damage to spacecraft, satellite drag, communications and navigation failures, etc.).

2.1.1 Natural Phenomena

At perhaps its most fundamental level, the role of science is to explain, understand, and predict natural phenomena. Human curiosity about phenomena "observed" through our senses (extended by our technological advances) demands answers to the ensuing "why?", "how?" questions we pose to ourselves. From this perspective, STP began with the realisation that the occurrence of sunspots and the appearance of spectacular auroral displays were correlated. More sophisticated observations, aided, for example, by in situ data from spacecraft, revealed the variety and complexity of the intervening processes which are responsible for this correlation.

The two ends of STP serve to illustrate the natural drama demanding understanding. Large fractions of the solar corona, apparently stable structures, suddenly accelerate and break away from the Sun as Coronal Mass Ejections (CMEs) at daily intervals. CMEs represent the most massive, energetic transients within the heliosphere, yet this has only been relatively recently acknowledged. These and other interplanetary disturbances accelerate particles and deposit energy in the Earth's atmosphere. How is this accomplished? Spectacular dynamic aurorae dance in fine curtains over the polar skies, inspiring us to gather clues which may someday reveal the key features and physical processes governing their structure.

Uniquely, the observations and ensuing questions posed by STP represent an arena where the astrophysical universe touches our everyday lives. Experiencing an aurora adds an immediacy to the astrophysical question of particle acceleration, and provides a dramatic visualisation of the consequences.

Thus STP occupies an invaluable niche in the scientific world. As humans turn their attentions increasingly to space, be it for communications, the search for extraterrestrial life, or manned exploration, the natural desire to observe and explain will push us to seek greater understanding of our corner of the universe and the physical processes which control and influence geospace.



A spectacular auroral display

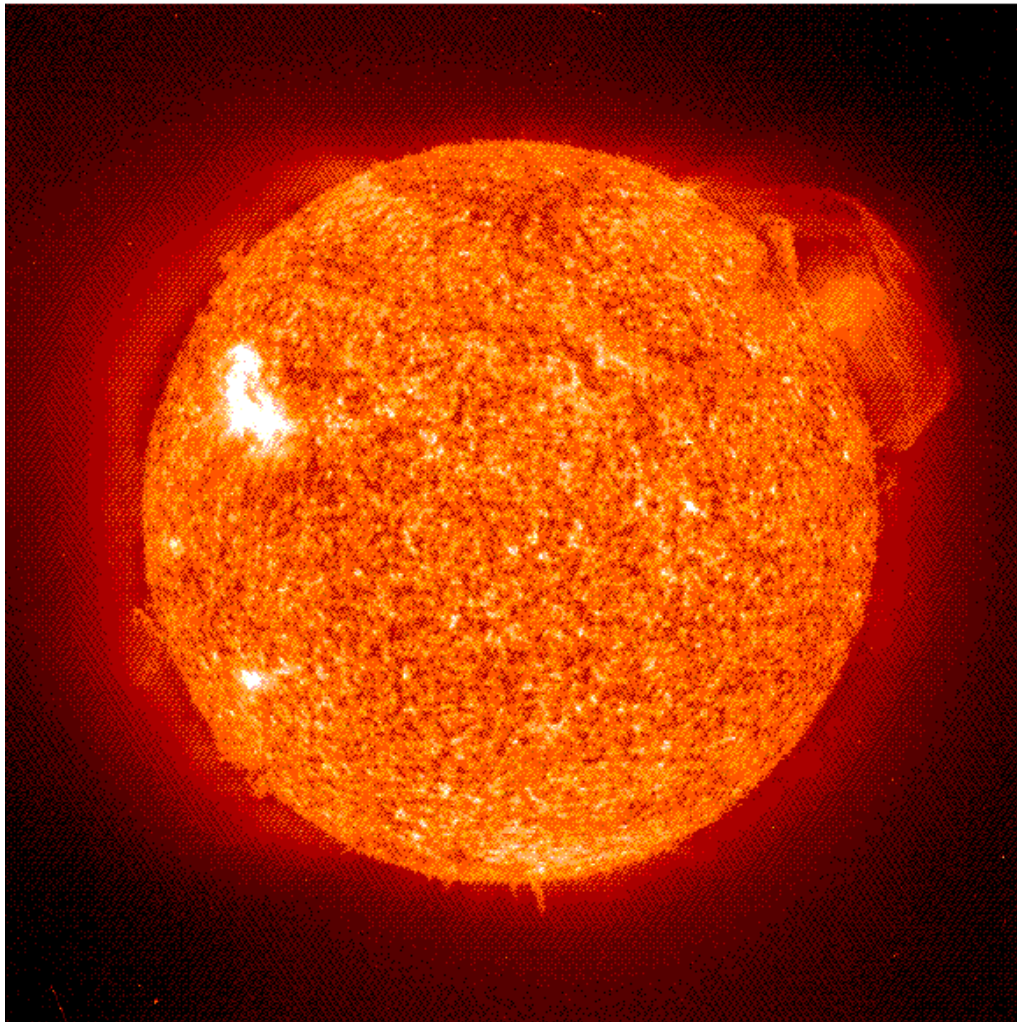
2.1.2 Fundamental Physical Processes - From Astrophysics to Laboratory Physics

The Sun is a star; the only star, in fact, in which we can readily resolve and study processes such as mass loss, flaring, acceleration, atmospheric and internal structure. The Sun's behaviour and that of the interplanetary medium are manifestations of astrophysical plasmas. The study of solar terrestrial physics is therefore a study of a nearby piece of the astrophysical universe.

The observable universe is almost entirely in the state of plasma. Plasmas are gases ionised to the extent that electromagnetic fields are the primary influence on the overall behaviour. Many important fundamental physical processes operate in the plasma between the Sun and the Earth. The most notable include the formation of a thin collisionless shock wave upstream from the Earth's magnetopause; magnetic reconnection on the dayside magnetopause and in the geomagnetic tail; and the acceleration of charged particles to high energies within a few seconds near the solar surface and in the Earth's radiation belts. Such processes are known to be important in many other contexts, some as remote as in supernovae and pulsar magnetospheres; others close at hand such as in the interior of plasma fusion and laboratory devices. Investigations in near-Earth space have the unique advantage that complete in-situ measurements can be made. The complete velocity distribution function of all species can be measured on spatial scales less than an ion gyroradius; electric and magnetic fields over a wide frequency range can be measured; and it can be done without the walls of the system having an effect. This ensures that solar terrestrial physics has a key role in the development of fundamental plasma (astro)physics.

The Sun, interplanetary space, the magnetosphere and ionosphere are 'laboratories' for us to exploit. Our observations of the solar atmosphere and in space reveal plasma environments (temperatures, densities and scale sizes) which we cannot create on Earth. Observations of the electromagnetic spectrum emitted by solar plasmas have been used to refine our understanding of atomic physics, through the discovery of new emission characteristics and through the

absolute and relative intensities of emission 'lines'. In the most profound case, such observations were responsible for the discovery of helium. Space instrumentation provides numerous technical spin-offs which find their way into terrestrial experiments and applications. The nonlinear aspects of space plasmas also provide a testbed for emerging concepts in the subject of nonlinear systems.



The dynamic Sun as seen by SOHO

2.1.3 Terrestrial Impact - the Human Connection

Magnetospheric and ionospheric plasmas, driven by solar processes and transients, have had effects on human technology for centuries. One of the first was the effect of magnetic storms on what was then the basic navigation instrument - the magnetic compass. Later came the effect of ionospheric absorption due to precipitating electrons on long-distance High Frequency radio communications.

The Sun ejects matter into space, as the so-called solar wind and as discrete clouds. The solar wind carries about 1 million tonnes per second into space. Our planetary magnetic field is buffeted by this outflow. Clouds, which can carry 1 thousand million tonnes in one go, are ejected on average twice a day and can occasionally engulf completely the Earth-system. On top of this, huge explosions in the solar atmosphere, known as solar flares, send streams of highly energetic particles through space. All of these interplanetary phenomena and transients initiate energy storage, release and acceleration processes which dramatically reconfigure and energise

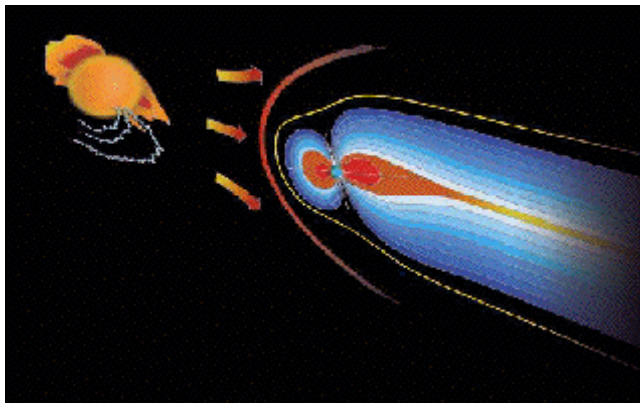
the magnetosphere and ionosphere. Disruption to the Earth's magnetic field can drive electric pulses in power distribution circuits and pipelines, causing failure. Present concerns include the induced currents in electric power lines, surface charging of spacecraft, radiation damage to large scale integrated electronic components in spacecraft electronics, and health hazards of high-altitude flying aircraft. The tasks for scientists include diagnosing the cause of the problems, finding ways of preventing or avoiding damage and, perhaps in the future, anticipating the occurrence of dangerous conditions. If solutions are found for present problems, the increasing sophistication and sensitivity of the technology being developed implies that new difficulties will certainly be encountered in the future as we become more and more reliant on space technology for our everyday lives. The present level of damage is tens of million pounds per annum (or more).

Finally, the active atmosphere of the Sun is responsible for highly variable amounts of ultraviolet and extreme ultraviolet radiation which drive processes in the upper atmosphere of the Earth. There is growing recognition that solar activity may have an impact on weather and climate, but quantitative understanding is only at a primitive stage.

Despite all of these effects, we cannot presently predict mass ejections or flares. We cannot presently predict their effect when they arrive at the Earth. We cannot presently predict the radiation dose over reasonable periods. The Sun's influence on our climate and on climate change is far from understood. The 'transient' behaviour of the Sun is potentially disruptive to industry as well as our private lives, yet we are only at the beginnings of understanding the solar-terrestrial connection.

2.2 The STP Chain at Work: An Example

To understand how to meet the STP Objectives outlined above, let us look at an example of events which begin at the Sun and influence the terrestrial environment:



Impression of a coronal mass ejection heading towards the Earth's magnetosphere.

Geomagnetic Storms

Major geomagnetic storms are the most dramatic manifestation of solar terrestrial coupling. They involve the injection of large amounts of energy from the solar wind into the Earth's magnetosphere, ionosphere and thermosphere. Storms also have major effects on technical systems in space. Expansion of the atmosphere during storms can result in loss of altitude of Low Earth Orbiting (LEO) satellites, difficulties in tracking satellites, major perturbations in ionospheric conditions that affect communications and copious numbers of energetic particles that affect the performance of satellites in geosynchronous orbit. Thus major magnetic storms are not only events of significant scientific interest, but of all the phenomena in space impact most directly on everyday life on Earth.

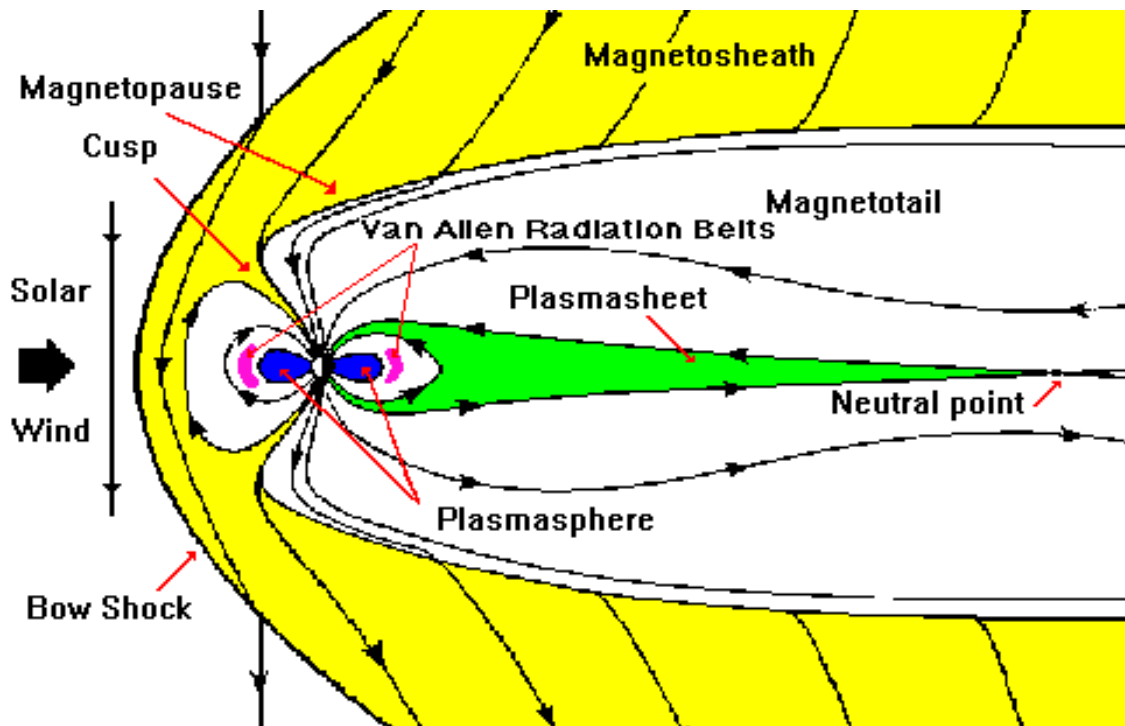
2.2.1 First Link: Coronal Mass Ejections

The story of magnetic storms begins on the Sun. It is now established that they are well associated with a class of solar eruptions called coronal mass ejections (CMEs). CMEs are the most energetic class of solar eruptive events, and throw massive volumes of plasma and magnetic field into space. To follow the complete cause and effect of magnetic storms, we need to understand how, where and when CMEs occur. CMEs are undoubtedly driven by forces associated with the Sun's magnetic field. They move away from the Sun at speeds anywhere between 100 and 2000 km/s. Yet we do not know what produces this range of ejection speeds, whether it reflects different physical processes at work, or corresponds to more subtle changes in the background solar conditions. CMEs also come in all shapes and sizes, presumably corresponding to different magnetic field topologies. Again, whether these differences are fundamental or are more cosmetic is unknown.

Efforts need to be directed to studies of the CME source regions. This can be accomplished by multi-instrument campaigns (using the advanced instrumentation on SOHO) that detect the CME itself (with coronagraphs), provide diagnostic information on the plasma in the CME source-regions (EUV/UV spectrometers), and magnetic field information (magnetograms). Theory and modelling of the interaction of plasmas and magnetic fields are also required, as are accurate observations of the velocities and magnetic fields in the visible Sun from space, where "seeing" is better. It is expected that such studies will reveal the processes by which CMEs are initiated, and distinguish between possible causes such as the evolution of large-scale magnetic structures due to shearing of field lines, loop-loop interactions due to emerging or interacting magnetic flux, or the onset of sudden heating or density enhancements within large loops.

2.2.2 Second Link: Travelling Through Interplanetary Space

Once a CME is launched away from the Sun, what determines its course through the solar wind? Recent eruptions observed by SOHO have shown that we do not do a very good job in predicting whether or when a given CME seen at the Sun will hit the Earth. This may appear surprising, but the solar wind is not a uniform medium. Instead, the interplanetary medium is made up of many different solar wind streams that buffet the CME, changing its course. Also, current observations of Earthward-headed CMEs are limited in their accuracy: thus small errors in the inferred direction at the Sun translate into large errors at the Earth. Determination of the direction of motion of CMEs moving out from the Sun would be greatly helped by spacecraft observing from 45 degrees to the Sun-Earth line, or better yet, a pair of spacecraft doing stereo observations. Finally, CMEs at the Earth can be very organised magnetically (these cause the largest storms), or turbulent. It is not known if this reflects the initial structure of the CME or is just its response to the interaction with the solar wind. Pressing problems are to understand how CMEs move through the solar wind and how their structure is changed by interaction with the wind.



The Earth's Magnetosphere, showing the incident solar wind flow and embedded magnetic field together with the major plasma regions and boundaries.

2.2.3 Third Link: Hitting the Magnetosphere

The third step in this chain of events is the interaction of a large CME with the Earth's magnetosphere. The Earth's bow shock responds rapidly, deforming and re-structuring in ways which are not well-understood. Behind this front line defence, when the magnetic field in the CME is southward, magnetic reconnection must occur at the dayside magnetopause. This reconfiguration of the Earth's magnetic field topology permits an enormous amount of energy ($\sim 10^{13}$ W) to access the magnetosphere and subsequently the ionosphere through the cusp regions. The process of magnetic reconnection is pivotal to understanding the response of the entire magnetosphere-ionosphere system to solar disturbances, yet we do not understand the fundamental physical processes that permit and regulate reconnection in a collisionless plasma.

Inside the magnetosphere, the flow of energy from the solar wind to the ionosphere follows a complex path: some flows directly to the ionosphere; another portion travels through the magnetotail, causing significant disruptions there. Tracking this energy flow requires in-situ measurements at many places in space, such as can be achieved by a large number of satellites, as well as theory and modelling that permits us to follow energy flows through "model" magnetospheric fields.

2.2.4 Fourth Link: Energising the Ionosphere

In near-Earth space, this energy input is especially manifest in the Van Allen belts and ionosphere. During large storms the Van Allen belts become energised significantly, leading to changes in the magnetic field measured at the Earth's surface. There are also major enhancements of energetic O^+ during major storms. How O^+ is extracted from the ionosphere and heated from $<1\text{eV}$ to energies $>10\text{keV}$ is a major unresolved question. Satellite observations also show dramatic variations in the relativistic electron fluxes. Typically, the electron flux at energies of a few MeV first decreases for a period of a few hours and then increases over a period of days to levels much higher than the pre-storm level. There is no generally accepted explanation for the flux increase, but current evidence suggests that acceleration takes place inside the magnetosphere. Yet the cross-tail electric field can only

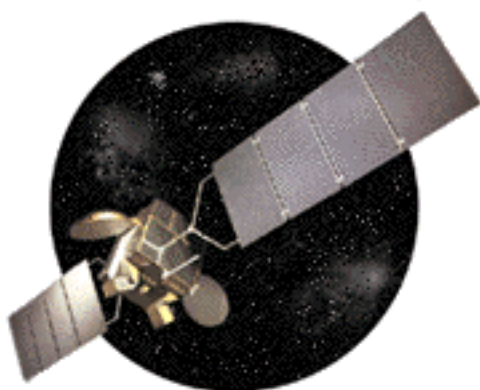
accelerate electrons to a few hundred keV, so some other mechanism(s) must be responsible for electron energisation.

This energy input can be disastrous for technical systems in space. Relativistic electrons can cause significant damage to spacecraft. For example, a 2MeV electron can penetrate up to 5mm of aluminium. If the electron flux is sufficiently high for an extended period then these 'killer' electrons can penetrate insulating material and cause deep dielectric charging. The failure of the two Canadian communication satellites ANIK E1 and E2 in 1994, each costing \$300M, is believed to have been caused by discharges resulting from deep dielectric charging. Similarly, it has been noted that the complete loss of the Telstar 401 communications satellite during the January 1997 magnetic storm occurred when the relativistic electron flux was enhanced significantly. Storm-induced changes in the atmosphere can result in a ten-fold increase in the drag forces on satellites, significantly affecting operational lifetimes.

One of the most spectacular manifestations of this STP chain is the energy input into the ionosphere seen in high latitude auroral displays. The aurorae have several scale sizes, from systems of arc-like structures covering hundreds of kilometres in latitude and thousands of kilometres in longitude, to elemental structures only tens of metres wide. These are the footprints of processes above the ionosphere which accelerate particles and cause them to precipitate into the atmosphere where their energy is deposited. By measuring the dynamic auroral emissions to high resolution in space, time and wavelength, and combining these measurements with theory and modelling, the energy distribution within the precipitating flux of electrons and protons can be determined. This is important information for theoretical studies of how the highly structured and dynamic aurorae are formed, and critical to understand particle acceleration processes.

2.2.5 Final Link: Coupling to the Biosphere

Finally the energy from this chain of processes is deposited in the Earth's upper neutral atmosphere. This results in heating and the production of large-scale wind motions which can carry the energy away from the auroral zone down to mid- and low-latitudes. Waves can be excited; the reflectance properties of the storm-time atmosphere can be significantly modified; nonlinear wave interactions occur. The combined effect on gravity waves and tides propagating up from the lower atmosphere has subtle effects on atmospheric circulation and weather. A range of ground-based optical instrumentation can follow this chain of energy and momentum processes. Global and local modelling investigate the importance of the different processes invoked.



Communications satellite similar to the AT&T Telstar 401 which was rendered inoperative during a geomagnetic storm on 11 January 1997.

3. UK Strong in STP Research

The UK has established a world-wide reputation for excellence in STP research, built upon the vision of early UK pioneers in the subject such as Chapman, Ferraro, Cowling, Dungey, and Sweet. More recent years have seen this leadership in theoretical concepts expanded further and matched by novel experimental facilities, instruments, and participation in and exploitation of satellite missions.

3.1 UK Lead Roles in International STP Projects

For example, projects since 1990 in which the UK has won lead roles (i.e., Principal Investigator status or equivalent) in the design, construction, and operation of experiments include:

- Solar Atmosphere Space Missions: Yohkoh, SOHO
- Interplanetary and Cometary Physics Missions: ICE, Giotto, Ulysses, Mars-96, Cassini
- Magnetospheric Space Missions: CRRES, GGS, Cluster, STRV-1A
- Active Space Plasma Missions: STS-46, STS-75, OEDIPUS-C
- Ground-based Ionospheric Radars: EISCAT, SABRE, CUTLASS, ESR, SHARE

In many other international projects, the UK has played important roles in both experiment design/construction and scientific analysis. Additionally, the UK is playing important roles in the present development of new, approved missions, including ESA's Cluster II (on which the UK provides 3 Principal Investigators of the 11 in total for the mission). A list of these projects and the UK involvement therein can be found in Appendix 1. Implicit in all these lead roles is a recognition of the technological expertise, innovation, scientific exploitation, and leadership of the UK groups involved.

3.2 UK Leadership in STP Theory, Modelling and Simulation

The long-standing international esteem toward UK contributions to the theoretical framework for understanding STP processes continues to the present epoch. Areas of particular excellence and international leadership include:

- Magnetic Reconnection - both as a generic plasma process and specifically with regard to the "open magnetosphere" notion which, despite decades of study, continues to pervade and perplex the subject of solar-terrestrial interactions
- Microscale kinetic plasma processes, including waves and instabilities in fully and partially ionised plasmas, collisionless shocks, and particle energisation
- Scientific exploitation of global modelling of the Earth's thermosphere and ionosphere
- Atomic physics calculations which underpin the use of spectroscopy in inferring physical conditions in the solar atmosphere and solar wind
- MHD modelling of structures and processes in the solar atmosphere

3.3 UK Presentations at International Meetings

A more quantitative measure of the UK's scientific standing at international level is the number of invited papers given by UK scientists at major international conferences. The PPARC Ground-based STP Review Report considered the meetings of the International Association of Geomagnetism and Aeronomy as the most representative for work relating to geospace. The

results presented there have been augmented by the inclusion of Division IV activities, which cover the solar wind and interplanetary medium. Additionally, those results have been up-dated by inclusion of the 1997 IAGA Assembly. While no single conference embraces the entire solar community, a collection of solar physics meetings has been similarly surveyed.

The detailed results, comparing the UK against other major scientific nations, is presented in Appendix 2. The IAGA results show that the UK leads all other countries, with the exception of the USA, in the number of invited papers. UK solar physicists account for 14% of all invited talks at four recent international conferences. These results confirm the high international recognition of UK contributions to STP and its continued leadership.

3.4 UK-led Scientific Highlights

The UK standing within the international community can also be judged by the outstanding scientific contributions led by UK researchers. Such outstanding contributions may be defined as those which

- have caused the international STP research community to stop working on the topic because the contribution essentially solved the remaining significant problems, or
- caused the international STP research community to adopt very new concepts, owing to the importance of the new results, or
- opened up a significant new area of study.

In many cases, the highlight may be a collection of work, contained in several papers. After careful consideration of activities over the last ~5 years, the community regarded the following list of topics as meeting the stringent criteria given above. A brief description of each topic is given in Appendix 3. The Appendix also lists several other areas and studies where UK scientists have made contributions of major international importance.

1. Magnetic reconnection
2. Seasonal storm effects: Coupling of the thermosphere and ionosphere
3. New horizons: The Ulysses 3-D heliosphere
4. The properties and dynamics of the solar atmosphere
5. Numerical and experimental studies of collisionless shocks and particles

4. Solar Terrestrial Physics: The Future

4.1 Themes for the Next Millennium

Detailed investigations of local structures and physics, from solar prominences and flares through interplanetary discontinuities to microscale processes in the auroral regions, will continue to play an important role in STP research, particularly with regard to the many fundamental physical processes STP can uniquely pursue. The next millennium will see an increased emphasis on the more global processes which effect the transfer of material and energy from one region to another. Such a global perspective itself encompasses a range of scales from the structure and evolution of a coronal mass ejection with significant variation over scales larger than a solar radius to the ionospheric footprint, measured in kilometres, of reconnection and dynamic processes affecting the Earth's magnetosphere over scales of several Earth radii.

Pursuing these complementary themes of local physics and global processes will enable STP scientists to answer numerous outstanding and vital questions, including

- What is the sequence of events in geomagnetic substorms and storms? What is the physical size and location of each of these events?
- How is the location and strength of a geomagnetic storm related to and controlled by changes in the solar atmosphere and in the interplanetary medium? How does the Earth's atmosphere respond, in terms of ionospheric and thermospheric flows, densities and composition, and magnetic disturbances, to interplanetary pressure pulses and geomagnetic storms?
- What are the dynamics of the plasmapause? What is the distribution of ionization in the outer plasmasphere/inner magnetosphere?
- What are the effects of the mesosphere on the thermosphere above it?
- Do solar cycle variations have an energetically disproportionate effect on lower atmosphere behaviour (weather and climate)? If so, what mechanism(s) amplify the inputs to the terrestrial system?
- How does the Earth's bow shock and transient reconnection over the dayside portions of the magnetosphere mediate and filter the interplanetary input to the terrestrial system?
- How are particles accelerated in the Earth's auroral regions?
- Why and how do Coronal Mass Ejections occur? What is the physical size of CMEs as they propagate out into interplanetary space? (How) Are CMEs related to solar flares? What, where and when are the processes of energy release and particle acceleration in solar flares?
- What is the location and mechanism of solar wind acceleration, and how does this influence the composition of the solar wind? How are the different types of structure in the solar corona heated? What is the three-dimensional structure of the solar atmosphere and heliosphere? How does this structure, and its interplanetary/terrestrial consequences, change with the solar cycle?
- What are the principles which govern real plasma turbulence (as found, e.g., in the interplanetary medium, the Earth's magnetosheath, and within the central regions of the geomagnetic tail)?
- What are the detailed mechanisms by which magnetic fields may reconnect in three dimensions?

- How do we quantify and predict the impact solar and space plasma processes have on mankind, including both on natural phenomena (weather and climate) and also on technological aspects (satellite communications and power lines)?

4.2 Strategy to Meet STP Objectives

Studying the example chain of STP phenomena described earlier in this report reveals the complexity of the task. At the macroscopic end is a sequence of large-scale momentum and energy storage, violent release, and transport. Often, such as the CME-driven example, one such sequence occurs near/within the Sun, another as it impacts on the Earth's outer magnetosphere, and yet another as the energy is stored, e.g., in the geomagnetic tail, and subsequently deposited into the near-Earth environment. Moreover, each stage in these sequences is controlled by microscale, often collisionless, processes.

4.2.1 Co-ordinated Approach

Thus meeting the STP objectives requires a co-ordinated approach. High-resolution solar images and spectra are required to capture and understand the initiation of the chain. Interplanetary transport and local processes require in situ data stations; at a minimum some continuous monitoring of the region immediately upstream of the Earth is essential to pin down the input disturbances to the terrestrial environment. The time-dependent, highly structured nature of the Earth's magnetosphere demands a global, 3-D perspective through the use of many satellites (in at least the outer magnetosphere) and wide ground-based coverage of the auroral regions. The approach involves a high level of co-ordination to ensure that the entire sequence is captured in the data.

4.2.2 Multi-Discipline

It is clear that no one mission or facility can meet these requirements. It has been noticeable over recent years that STP researchers have striven to make use of information and data from several sources. However, while such data are becoming more readily available, their availability for any particular study relies on serendipity, and often only the most basic information (i.e., gross parameter behaviour) is sufficiently reliable, available, and suitably matched across sources to be included in such studies. The range of data and analysis required cuts across many disciplines, from atomic spectral analysis through a plethora of in situ particle and fields experiments to inference of ionospheric flows based on scattered radar signals. Active space plasma experiments complement passive experiments by providing well described perturbations via injected particles or waves to better understand the physics of natural processes. Modelling and theory play an integral part in the data selection and interpretation.

4.2.3 Portfolio of Projects

Thus, the strategy for significant and necessary progress in STP requires a portfolio of projects. These projects must be designed and operated so as to resolve and understand chosen links in the chains of STP processes. In some cases, study and understanding of the basic physical processes in such single links must be advanced prior to a study of the complete chain. Equally, the projects must be co-ordinated well, thus allowing intercomparison between them to understand the complex sequences as they evolve. Such a portfolio is put forward in the following section.

4.3 STP Projects to Meet Scientific Challenges

A range of national and international projects are envisaged to meet the scientific challenges posed above. These projects vary in timescale, cost, level of current specification, and degree of international co-operation required. Proposed new projects (and extensions of some existing ones) are summarised in the following table. More detailed descriptions are provided in Appendix 4. Projects shown in italics have been peer reviewed by PPARC and are proceeding through PPARC's planning phases. None of these projects on its own can address the pressing outstanding questions within Solar Terrestrial Physics; each provides a particular perspective

on the underlying physical processes and coupling between them. These projects complement approved and funded missions listed in Appendix 1.

The proposed projects are internationally competitive and lead, rather than duplicate, international strategic planning. They include regular access to in situ and remotely-sensed data from spacecraft, a comprehensive ground-based programme, and a supporting theory/modelling effort. Crucially, the programme builds on UK international excellence in instrumentation, data exploitation, and theory.

Table 1 Proposed STP Projects for the Next Millennium

Timescale	1 Year	3 years	> 5 years
Cost			
< £1M	EISCAT Scintillation Modelling Res. Init. SOHO Ground Fac.	IPS SuperDARN Tomography	
£1-5M		EISCAT <i>MAGPIES*</i> <i>SPEAR*</i> <i>Svalbard Observatory*</i>	
£5-10M			<i>FARADAY*</i> IMPACT <i>MOLNIYA*</i> <i>Solar-B*</i> STORMS
> £10M			HIREX GIME Solar Probe STEREO <i>SWARM*</i>

* *Projects in italics are proceeding through the PPARC planning stages at present, following initial peer review.*

4.4 Maintenance of Existing Facilities and Infrastructure

For new projects to be successful as part of a co-ordinated, multi-disciplinary approach, it will be important to maintain some existing infrastructure and facilities, including

- **Ground-based facilities: EISCAT/ESR, IRIS, CUTLASS, Ionosondes, SAMNET** in order to study the physics of the polar cap and characterise the ionospheric response to transient inputs to the terrestrial environment. In some cases, these facilities provide continuous datasets for long-term monitoring. These are world-class facilities and will remain competitive. They represent excellent scientific return for the UK investment.
- **Space-based missions: Yohkoh, SOHO, Ulysses, ClusterII** to study the Sun, the interplanetary medium, and the microscale processes in the magnetosphere during the coming epoch of solar maximum activity. These missions have finite lifetimes, and provide unrivalled capabilities. The UK has an enviably large degree of participation in instrumentation and data rights for the national investment made in these international missions.
- **Data Centres: Yohkoh Data Archive Centre, World Data Centre, Co-ordinated Data Handling Facility for STP** to ensure maximal data access, exchange and preservation. In recent years, the UK has developed these highly successful repositories containing a rich variety of datasets. The key to global, multi-

mission, multi-disciplinary studies lies in ready, user-friendly and long-term access to the data.

- **Theory, Modelling, and Simulations** are at present supported entirely by individual research grants. The UK boasts several important efforts, including the Sheffield/UCL Coupled Thermosphere-Ionosphere-Plasmasphere, solar MHD, and several major kinetic simulational efforts. These models are vital for providing contextual and parametric support for data interpretation.

These facilities and projects are described briefly in Appendix 5.

4.5 Relationship to NERC Activities

The National Environmental Research Council (NERC) supports a modest amount of STP work through the British Geological Survey, which operates and maintains a magnetometer network, and the British Antarctic Survey, which carry out all UK STP research in Antarctica in collaboration with university groups. There is excellent cooperation in these areas which readily transcend the funding boundary; no changes in this arrangement are recommended at present. However, there is increasing evidence that solar terrestrial processes can have a very significant effect on processes in the lower atmosphere (troposphere and stratosphere) which are firmly in the remit of NERC. Thus the current funding structure may begin to inhibit some important scientific advances.

5. Recommendations

1. A range of creative and ambitious projects are underway or envisaged for the next millennium which build on the UK's longstanding reputation for excellence in Solar Terrestrial Physics. We need to build and support a co-ordinated multi-disciplinary and global approach to the future endeavours. This approach requires three strands of experimental activities: (i) continued participation in key facilities, missions and long-term monitoring, (ii) leadership in new ventures and (iii) an effective infrastructure to facilitate the multi-mission perspective.
2. Such a portfolio of projects requires a vigorous programme of theory and modelling to provide contextual and diagnostic information necessary to interpret the experimental results and to consolidate and test our understanding of the underlying physical processes.
3. This report highlights the vital interplay between ground-based, space-based, and theory/modelling activities, and the diversity of agencies and national funding councils which need to be involved in a successful STP programme. To monitor, co-ordinate discussion, and advise on the detailed agenda for STP in the next millennium, we recommend that a UK STP Advisory Panel be established by PPARC and BNSC and include representatives of UK STP groups and NERC. Draft terms of reference are given in Appendix 6.

Appendix 1 UK Participation in International Projects

Over recent years, the UK has played a major role in numerous missions and experiments. This participation at international level is a testament to the UK's international standing. Some of these involvements from circa 1990 onwards are listed below, including fully approved and funded projects not yet onstream. The division of the Space-based activities into subjects is somewhat arbitrary, and dictated more by presentation limitations than science objectives. All participation is at official project level, broken down into Principal Investigators (PIs), CoInvestigators (CoIs), Associated Scientists (AS), and Guest Investigators (GI). For brevity, CoIs and GIs at PI sites, and GIs at CoI sites, are not listed separately. Some of these facilities and projects, particularly those which need to be maintained for co-ordinated science involving the proposed new activities, are described briefly in Appendix 5.

Table 2 Ground-based Facilities

Project	Principal Country	Time Frame	UK Groups Involved	
SESAME	UK	1996-Present	PIs	BAS
Optical Interferometry	UK	1981-Present	PIs	UCL
Magnetic Activity	UK	1841-Present	PIs	BGS
EISCAT ESR	Europe (incl UK)	1981-Present 1996-Present	Central Support Users	RAL Many
SAMNET	UK	1987-Present	PIs	York
SHARE	UK	1988-Present	PIs	BAS
Cambridge IPS	UK	1989-1993	PIs Others	MRAO BAS RAL
SABRE	UK	1981-1994	PIs	Leicester
IRIS	UK	1994-Present	PIs	Lancaster
CUTLASS	UK	1995-Present	PIs	Leicester

Table 3 Space-based Activities - Solar

Project	Agency	Time Frame	UK Groups Involved	
Yohkoh	ISAS	1991-present	PIs CoIs AS	MSSL RAL Birmingham Cambridge Glasgow St. Andrews
SOHO	ESA/NASA	1995-present	PIs CoIs AS	RAL Birmingham Cambridge MSSL Oxford QMW St. Andrews Armagh UCLan Glasgow IC (& GI) Queens Belfast
SERTS	NASA	1996-Present	CoIs AS	RAL Cambridge Queen's Belfast
TRACE	NASA	1998-	CoIs	RAL St. Andrews
SMEI	NASA		CoIs	Birmingham
HESSI	NASA	2000-	CoIs	Glasgow
Solar-B	ISAS	2004-	PIs CoIs	MSSL Birmingham Cambridge IC RAL St. Andrews

Table 4 Space-based Activities - Interplanetary

Project	Agency	Time Frame	UK Groups Involved	
Giotto	ESA	1986-1993	PIs CoIs	MSSL Kent RAL
Galileo	NASA/FRG	1990-present	CoIs	IC
Ulysses	ESA/NASA	1990-present	PIs CoIs GIs	IC Birmingham Leicester QMW
WIND	NASA	1994-present	AS	QMW
Mars-96	IKI	1996	PIs CoIs	MSSL Sussex IC Sheffield UCL
Cassini	NASA/ESA	1997-2008	PIs CoIs	IC Kent Leicester MSSL Oxford QMW RAL Sheffield
ACE	NASA	1997-present	CoIs Gnd Stn	Birmingham RAL
Rosetta	ESA	2003-	PIs CoIs	Open University IC Kent Leicester MSSL Oxford QMW RAL

Table 5 Space-based Activities - Magnetospheric

Project	Agency	Time Frame	UK Groups Involved	
Meteosat-3	ESA	1988-1995	PIs	MSSL
CRRES	USAF/ NASA	1990-1991	CoIs	MSSL RAL Sussex
Geotail	ISAS/NASA	1992-present	GIs	Warwick
STS-46, -75	NASA	1992, 1996	AS	Sussex
STRV-1a, 1c	DERA	1994-Present, 1999	PIs	MSSL
Interball	IKI	1995-Present	CoIs	MSSL Sheffield
Polar	NASA	1996-present	CoIs AS	MSSL RAL Leicester
Pulsaur	Norway	1996	CoIs	MSSL RAL Sussex
Mugin	NASA	1997	CoIs	RAL Sussex
Equator-S	FRG	1997-Present	CoIs	IC Leicester
Variant	Ukraine	1999-	PIs (nom)	Sheffield
Warning	Ukraine	2000-	PIs (nom)	Sheffield
Image	NASA	2000-2003	CoIs	RAL
ClusterII	ESA/NASA	2000-	PIs CoIs	IC MSSL Sheffield BAS Leicester QMW RAL Sussex Warwick

Table 6 Theory/Modelling

Project	UK Groups Involved
MHD Modelling	Armagh BAS UCLan Glasgow IC UMIST MSSL St. Andrews
Magnetic Reconnection	Glasgow RAL St. Andrews Sussex Warwick
Kinetic Simulations	BAS Glasgow IC QMW RAL Southampton Warwick
Plasma Waves and Particles	BAS Glasgow Leicester MSSL QMW RAL Sussex Warwick
Thermosphere, Mesosphere, Ionosphere Plasmasphere Modelling (CTIP, SUPIM, ...)	Leicester Sheffield UCL
Auroral Excitation & Structure	Southampton
Cusp Particle Dispersion	RAL
Atomic Physics/Modelling	Armagh Cambridge Glasgow MSSL Oxford Queen's Belfast RAL Strathclyde UCL

Appendix 2 UK Invited Presentations at International Meetings

UK Invited Presentations at International Meetings - IAGA

A quantitative indicator of the UK's scientific contributions at international level is the number of invited papers given by UK scientists at major international conferences. The PPARC Ground-based STP Review Panel, which reported in October of 1996, considered the meetings of the International Association of Geomagnetism and Aeronomy as the most representative for magnetospheric work, as it provides no bias towards ground versus space activities. That table has been augmented by the inclusion of Division IV activities, which cover solar wind and interplanetary subjects not considered by that review panel, and by the inclusion of the 1997 IAGA Assembly.

The table compares the number of invited speakers from the USA and Japan (the largest spenders on STP research), the UK, Germany and France (similar in size and spend to the UK) and all others. After the USA, the UK leads all other countries in this measure of acknowledged leadership.

Table 7 Number (%) Invited Papers at IAGA 1993, 1995, and 1997 Conferences

Country	Ground-based work		Space-based work		Theory, modelling, etc.		Total	
USA	51	34.0%	129	60.8%	90	59.2%	270	52.5%
UK	19	12.7%	11	5.2%	11	7.2%	41	8.0%
Japan	9	6.0%	26	12.3%	4	2.6%	39	7.6%
Germany	12	8.0%	9	4.2%	15	9.9%	36	7.0%
France	5	3.3%	2	0.9%	8	5.3%	15	2.9%
Other	54	36.0%	35	16.5%	24	15.8%	113	22.0%
Total	150	100.0%	212	100.0%	152	100.0%	514	100.0%
% of Total	29.2%		41.2%		29.6%		100.0%	

UK Presentations at International Meetings - Solar Physics

There is not a single comprehensive and representative venue for solar physics. However, a good way to assess the UK's contribution to solar physics is to look at the statistics for the last four large international conferences or symposia on:

- YOHKOH (Bath, March 1996, Magnetic Reconnection in the Solar Atmosphere)
- COSPAR (31st Scientific Assembly, Birmingham, July 1996, E2.1: The Sun and its Atmosphere)
- Fifth SOHO Workshop (Oslo, June 1997, dedicated to the memory of Bruce Patchett, PI on CDS from its inception until 1992)
- 31st ESLAB Symposium (ESTEC, September 1997, Correlated Phenomena at the Sun, in the Heliosphere and in Geospace)

All of these conferences had world wide participation from Europe (East and West), USA, Japan and elsewhere.

Table 8 Comparison of UK Participation in Solar Physics Conferences/Symposia

	YOHKOH	COSPAR	SOHO	ESLAB	TOTAL
Invited reviews	20	17	20	13	70
Number (%) from UK	4 20%	1 6%	3 15%	2 15%	10 14%
Contributed Papers	62	49	141	49	301
UK Lead Author Number. (%)	10 16%	8 13%	13 9%	7 14%	38 13%

In addition, there have been two special issues of Solar Physics devoted entirely to SOHO results (Vol 171, 1997 and October 1997). There are a total of 42 papers in these two issues, of which 10 (i.e., 24%) are led by the UK.

Appendix 3 UK STP Highlights

Magnetic reconnection

Fundamental Theory

The 2D theory of reconnection has been put on a firm foundation by the development within the UK of a new generation of models, for which the classical regimes of Sweet-Parker and Petschek are special cases. In addition, the three-dimensional theory of this fundamental process has been developed along several lines, including:

- the properties of null points, their structure and the ways they may collapse;
- the nature of highly complex magnetic fields by studying the skeletons of the distinct different topologies that are possible;
- the nature of the bifurcations in magnetic topology, both local and global;
- the nature of the three main types of reconnection at a null point, namely spine reconnection, fan reconnection and separator reconnection.

Magnetopause Reconnection

Reconnection of the Earth's and Sun's magnetic fields is the principal mechanism by which energy is transferred from the solar wind to the magnetosphere and ionosphere. This reconnection drives large-scale convection of plasma and magnetic flux within the Earth's magnetosphere. UK scientists have shown experimentally how the convection pattern evolves from one state to another. Until recently, reconnection at the magnetopause and in the geomagnetic tail had been largely considered time independent, but observations on time scales shorter than an hour have led to a very different view.

The UK has played a key role in the development of time-dependent reconnection models and their use to explain "flux transfer event" (FTE) signatures and other magnetopause structure (e.g., shock features). UK scientists' initial exploitation of EISCAT and SABRE radars with AMPTE satellites predicted a number of features that would be seen in the ionosphere if the magnetopause reconnection rate was pulsed. These included poleward-moving auroral events, transient bursts of plasma motion in the high latitude ionosphere, and steps in the dispersion of "cusp" ions which enter the magnetosphere from the solar wind by flowing along the open field lines produced by the reconnection. UK scientists subsequently identified all these signatures using mainly EISCAT data with low altitude satellites, confirming the predictions of the time-varying reconnection model. The combined observations allowed the first ever determination of:

- the location of the reconnection site on the magnetopause,
- the reconnection rate variation, and
- the plasma and field conditions prevailing at the reconnection site.

This work has opened up new methods for remote sensing the reconnection processes on the magnetopause and for studying some of the related processes quantitatively.

Seasonal storm effects: Coupling of the thermosphere and ionosphere

CTIP, developed primarily in the UK, is the most comprehensive Coupled model of the Thermosphere, Ionosphere and Plasmasphere in the world. CTIP has been used to explain for the first time the different annual and semi-annual variations of the F-region ionospheric concentration. It transpires that the regional differences in the observations result from the complex interplay of the effects of solar illumination, neutral winds, composition and the displacement of the geographic and geomagnetic poles. CTIP has also been used to explain the variations with latitude and longitude of F-region plasma concentration caused by significant geomagnetic storms, thus essentially solving a major problem of over 50 years standing.

New horizons: Ulysses 3-D heliosphere

The Ulysses mission carried out the first ever exploration of the heliosphere over the polar regions of the Sun. The magnetic field investigation, led by the UK, and the low energy particle instrument, with UK Co-Investigator, have made several important discoveries in these regions which have substantially altered our view of the three-dimensional heliosphere. The following are particularly noteworthy:

- The radial component of the magnetic field, contrary to expectations, is independent of heliolatitude. This discovery has placed fundamental constraints on the configuration of open magnetic field regions in the corona as well as on the acceleration of the solar wind.
- Large amplitude, low frequency, transverse fluctuations dominate the magnetic field over the Sun's polar regions, at least at solar minimum. This is considered to be the cause of the unexpectedly high level of modulation of cosmic rays in these regions; the discovery of the waves has changed some of the fundamental assumptions of the theory of cosmic ray modulation.
- The study of the fluctuations in the magnetic field observed by Ulysses has shown that the development and decay of turbulence is significantly delayed over the solar polar regions, compared to previous observations in the ecliptic plane. The characteristics of the turbulence have been found to follow more closely the Kolmogorov model, rather than MHD models. In addition, studies of the intermittency and anisotropy of the turbulence have contributed to validate several competing models of these phenomena.
- Electrons and ions accelerated by low latitude co-rotating interaction regions are observed up to the polar regions. These observations are quite incompatible with the Parker model of the interplanetary magnetic field and have led to a substantial revision of our view of the heliospheric magnetic field.

The properties and dynamics of the solar atmosphere

Atomic transitions in trace elements in the Sun's atmosphere radiate UV/X-ray emission lines, the analyses of which can be used to probe the solar atmosphere to reveal plasma properties (temperature, density, flow velocity, abundance) as well as topology and evolution. The interpretation of UV/X-ray intensities relies critically on knowledge of the atomic processes at work. The UK has a long history of excellence in atomic physics research and has been particularly active in applying this work to the study emission lines from the solar atmosphere. Defining the physical parameters of different solar features is of prime importance to all models of heating and energy transport. Through UV diagnostic studies, it is now known that the transition region between the chromosphere and corona is highly structured and dynamic in nature. This has completely changed our early concept of a quiescent plane parallel solar atmosphere.

UK scientists have exploited UK-led instrumentation on the Solar and Heliospheric Observatory (SOHO). They have discovered transient brightenings ('blinkers'), which are distributed throughout the Sun's atmosphere, and which perhaps relate to the merging of small magnetic flux elements which, in turn, may be closely linked to the basic processes leading to heating and acceleration. They have also investigated the anomalously high fluxes from lines of HeI and HeII, which give the best indication that simple models of the solar transition region are inadequate. Diagnostic studies of UV emission from active regions show that transient brightenings, with high electron densities and photospheric abundances, are apparently associated with emergent magnetic flux. The relationship between small active region brightenings and the continuous expansion of the corona in X-rays (YOHKOH) and in the UV (SOHO) may be fundamental to understanding the origin of the slow solar wind. UK scientists have identified dynamic features in the polar regions which could possibly be one source of the fast solar wind. They have taken a leading role in CME research, based on a heritage going back to the mid-1980's when the UK took the lead in rejecting the opinion that the CME and flare onset were the same.

Numerical and experimental studies of collisionless shocks and particle acceleration

Landmark numerical self-consistent simulations of particles and fields revealed the intrinsic cyclic reformation of collisionless shocks under certain "quasi-parallel" geometries for which the unshocked magnetic field is nearly aligned with the shock normal. This UK work underpinned and explained observations of the Earth's bow shock, described as a pulsation shock under these conditions. Follow-on investigations, both numerical and observational, showed further that the unsteady behaviour is directly related both to high levels of coherent, transient phenomena, and via a feedback mechanism to the acceleration of particles through first order Fermi acceleration. Again using the in situ data as a testbed, studies of this acceleration demonstrated how particles are injected into the acceleration process directly out of the thermal population, and how the acceleration efficiency scales with various physical parameters, thereby confirming and quantifying a process believed to be a dominant source of energetic cosmic rays throughout the Galaxy. This UK work was at the forefront of an international campaign, inspired numerous investigations, and solved one of the major problems in astrophysical particle acceleration.

Other UK studies of major significance

1. Coronal heating: X-ray bright points and turbulent reconnection
2. Observations and theory of ion pick-up, excited plasma turbulence, and dynamical influence at comets
3. Instrumentation, theory and analysis of the solar atmosphere and flare plasma
4. Non-thermal processes, transport and acceleration in solar flares
5. Acceleration and evolution of the solar wind
6. Waves and tides in the mesosphere, thermosphere, and ionosphere
7. Coupled thermosphere mesosphere modelling linking global climate to STP processes
8. Nonlinear plasma wave phenomena, including naturally occurring instabilities and turbulence as well as those induced by man-made high power electromagnetic waves in the ionosphere
9. Chaos in particle dynamics with application to wave particle interactions and substorm processes

Note: Several of these are described in "PPARC's ground-based solar terrestrial physics programme - A review" dated October 1996.

Appendix 4 New Project Descriptions

The STP Projects for the Next Millennium shown in Table 1 within the text are described, in alphabetical order, below.

EISCAT Developments and Scintillation

There are numerous developments to the existing EISCAT facilities which could significantly enhance the scientific return of the project. These include:

- **Adding a third antenna at the ESR site** to enable vector velocities to be measured without temporal ambiguity, to improve signal to noise and give higher resolution multi-point measurements of the plasma.
- **Refurbishing the Tromso transmitters** would allow higher duty-cycle operations, which could include the addition of stratosphere and middle atmosphere capabilities, enhancing the value of the radars to a wider community. Refurbishment of the VHF would extend the lifetime of the facility, enabling the continuation of important studies of coupling and inflow/outflow phenomena involving the low altitude (D-region) and high altitude (topside) ionosphere.
- **Adding a high-gain receiver** to enable the Tromso heating array to function as a magnetospheric radar. This would open up a new observational capability in a very important altitude region.
- **Further reducing the system noise** to increase the number of possible interplanetary scintillation sources and the time resolution of such scintillation measurements, thereby facilitating direct measurements of solar wind acceleration in the corona.
- **Increasing the number of remote site antennae** to extend the range and availability of tristatic measurements, enabling vector velocities to be measured over this increased range, thereby disentangling spatial and temporal ambiguities.

FARADAY

A pair of satellites measuring ion and electron fluxes for co-ordinated measurements with radars, using magnetic torquing to maintain pointing, enabling very fast ion and electron observations in the field-aligned direction (looking up) whilst monitoring optically the consequent aurora (looking down). A small microsatellite is sufficient to identify the position, motion, and orientation of the open/closed field line boundary and so reconnection voltages can be measured by combination with ground-based radars. The ion data give remote sensing of the magnetopause reconnection site and the cameras provide auroral tomography with ground-based observations.

GIME

Global Imaging of Magnetospheric Electrodynamics would measure directly the electric fields and currents in the ionosphere with a fleet of 50 microsatellites whose orbits provided good coverage of moderately high latitudes (50-70 degrees) at altitudes of 500-600km. Global scale physical models of the ionosphere and thermosphere currently incorporate the major physical and chemical processes which occur there, but are limited by the lack of electrodynamic inputs from the magnetosphere on a spatial scale and time resolution commensurate with magnetospheric and auroral substorm activity. This crucial input would be supplied at a time resolution of fifteen minutes by GIME.

HIREX

The High-Resolution X-Ray Explorer will be a NASA MIDEX mission (launch 2002-2003) with the aims of trying to understand interactions of magnetic fields and hot plasmas in the solar atmosphere on spatial scales approaching plasma and kinetic scale lengths. It will have two co-aligned soft X-ray/EUV high-resolution imaging telescopes which will image the solar corona with a spatial resolution of 0.01" or 20 km. This should allow us to understand:

- the origin of coronal heating
- the relation between small-scale instabilities and global scale coronal disruptions
- the sites of magnetic reconnection
- the role played by resonant absorption of Alfvén waves

IMPACT/IBIZA

This is a dual-spacecraft mission to carry out the next major new step in auroral magnetospheric research. It will employ two spacecraft, equipped with state-of-the-art instrumentation and oriented carefully along or perpendicular to (at different times) the ambient magnetic field, in order to investigate the basic processes which lead to the acceleration of particles in the auroral regions and which generate electromagnetic radiation. These processes are now known to be highly localised in space and variable in time, requiring such dual-spacecraft high resolution measurements. Specific scientific questions to be addressed include:

- the way in which a plasma can support significant quasi-static parallel electric fields
- the nature of electrostatic shocks and "double layers"
- the role, if any, of wave turbulence in particle acceleration
- the process(es) responsible for perpendicular ion heating
- the processes responsible for the generation of observed wave modes (e.g., auroral kilometric radiation and lower hybrid waves)
- the extent to which the ionosphere controls the dynamics of the energy exchange with the outer magnetosphere
- the relationship and mapping of processes observed in the outer cusp to the low altitude dayside regions
- the nature of the nightside magnetosphere-ionosphere coupling processes which occur during substorms

Interplanetary Scintillation

This pilot investigation would apply new radio astronomy techniques capable of imaging the solar wind rapidly and identify a suitable site (both electromagnetically and ionospherically quiet) where a full array, approximately ten times the size of the pilot, can be constructed.

At present our only view of the large-scale structure of the inner heliosphere is provided by low-frequency interplanetary scintillation. A projection of the density and velocity structure of the solar wind can be obtained from the scintillation of compact extragalactic radio sources shining through this turbulent plasma. Trials have shown it to be capable of both accurately tracing the evolution of density transients approaching the Earth, and of being a potentially powerful predictor of geomagnetic activity. Interplanetary scintillation offers an inexpensive, ground-based technique capable of imaging the entire inner heliosphere. However, its development depends on both an improved understanding of the physics behind the scintillation process and on the construction of a new breed of radio telescope capable of measuring scintillation over the entire sky quasi-simultaneously.

The science objectives of this development project are:

- To identify the solar progenitors of large-scale interplanetary transients affecting the Earth by projecting the structures seen back to the Sun.
- To monitor the solar wind from the ground in near real-time to identify the characteristics of geomagnetically relevant transients.
- To investigate the relationship between white-light coronal mass ejections and density structures in the solar wind around 1 AU from the Sun.
- To use tomographic techniques to image the large-scale structure of the solar wind in three dimensions.
- To reveal the relationship between scintillation and the turbulent characteristics of high-speed streams and shock-compressed solar wind.

MAGPIES

This project will obtain global images of the plasmasphere and magnetosphere by observing sunlight at 30.4nm resonantly scattered from singly-ionised Helium. The observations will be made from a pair of microsatellites in geostationary transfer orbit, and the images will enable the community to study the dynamics of cold plasma in the magnetosphere. In particular, it will enable investigations of

- the global electric field variations during magnetic storms and substorms
- the mechanisms by which magnetic flux tubes are filled with plasma
- the effect of the cold plasma distribution on wave-particle interactions, in particular on trapping lifetimes in the radiation belts and the source of SAR arcs
- the dynamical behaviour of the magnetosphere as a CME plasma cloud impacts the magnetosphere

MODELLING RESOURCE INITIATIVE

This project would support several long-term personnel to provide the infrastructure, expertise and permanency for

- further development of numerical models of the coupled solar-wind, magnetosphere, ionosphere, thermosphere, lower atmosphere system
- better coupling between individual models to allow small-scale models to run in better background conditions
- maintenance, integration, and extension of atomic modelling packages
- availability of theoretical and computational expertise to the smaller groups
- development of theoretical and computational techniques that may benefit multiple groups

The need for a Modelling Resource Initiative has arisen out of the UK's recognised expertise in physics-based models together with the increasingly sophisticated and complex codes. These demand a high level of continuity and expertise which cannot be provided by short-term staff and research students.

MOLNIYA

Magnetosphere Ionosphere Coupling Satellite (MICS) will fly in a Molniya orbit to hang over the cusp/auroral regions for long periods, for co-ordinated studies with ground based instrumentation, specifically radars, magnetometer chains and all-sky cameras. The minimum payload would consist of a wave instrument, low energy ion spectrometer, energetic particle/neutral atom monitors and UV imager.

The prime objective is to make use of the ability of a spacecraft in a Molniya orbit to "hover" near or over a single high latitude location, in this case EISCAT and Svalbard, for periods of 6 to 8 hours in every 24. These locations will then sample cusp and auroral regions.

The specific aims of the mission are:

- To establish the conjugacy of the field lines at the spacecraft to those at the radar, by detecting the effects of heating by the radar.
- To then understand in detail the nature of the precipitation into the radar field of view.
- To perform novel science using detailed measurements of high resolution wave and particle time series, looking for non-linear effects.
- To test theories of auroral acceleration.
- To explore upflow mechanisms, using radar to study the base of the field line, and the spacecraft to measure higher altitudes.
- To investigate cusp reconnection signatures.
- To relate in situ measurements to the overall cusp and auroral oval morphology.

SOHO Ground-based Facility

The SOHO UK Ground Based Facility would ensure that the tremendous stimulus and focus in the UK do not dissipate in the future when the main SOHO instruments are no longer operational. In particular, the leading UK role in CDS and LASCO has opened up new opportunities for collaborations with colleagues in Europe, the USA and Japan.

A SOHO facility would provide:

- a European SOHO data archive for both raw data and, as appropriate, additional pre-processed data products
- expert help in analysis and interpretation of data from all SOHO instruments
- help with the software requirements of the user community
- solar helpline for ionospheric and solar wind researchers
- workstation facilities to access and analyse SOHO data
- regular workshops (10-15 participants)
- interface with other solar data centres (YDAC, MEDOC, GSFC)
- interface with terrestrial data centres (WDC, ionosphere, Cluster)
- PR/schools resources and support

The facility would operate for 5 years in the first instance and include several staff members, computer hardware, and meeting rooms/office space. By providing the means for a vigorous interchange of data and ideas, the facility would allow the UK solar community to address fully the needs of the whole STP community.

Solar-B

Solar-B, the successor to Yohkoh, is a joint Japanese/US/UK mission to observe the Sun. It will carry three instruments: an optical telescope, an X-ray telescope, and an EUV imaging spectrometer - the latter of these is being built by a UK consortium. Solar-B will be launched in February 2004.

The primary goal of the Solar-B mission is to advance our understanding on the origin of the outer solar atmosphere, the corona, and of the coupling between the fine magnetic structure at the photosphere and the dynamic processes occurring in the corona. The 0.5m, diffraction limited optical telescope will image the photosphere and chromosphere providing vector magnetograms, Dopplergrams and filtergrams. The X-ray telescope will image 0.5 to 10 MK plasma, and the EUV Imaging Spectrometer (EIS) will permit highly accurate measurements of mass flows and other plasma parameters in the outer solar atmosphere.

The first flight of a solar optical telescope in space promises to provide a vast improvement in the accuracy of photospheric velocity and magnetic fields due to the improved seeing. The combination of instruments provides an unprecedented opportunity to study "cause and effect" on the Sun, i.e., the influence of photospheric magnetic forces on coronal activity such as flares, CMEs and jets.

Solar Probe

This is a mission to explore in situ the near-Sun environment by means of a specially designed spacecraft to travel, after suitable gravity assists, to within 4 solar radii. There are many technological challenges relating to reducing the spacecraft weight, power supply, and providing adequate heat shielding. The spacecraft payload would include plasma and field packages, energetic particle and composition analysers, and dust experiments. High accuracy clocks and radio links are required for fundamental gravity experiments. The scientific goals include:

- Solar wind origin and acceleration
- Coronal plasma physics, energy transport, and heating
- Coronal composition and ionisation state
- Origin, propagation and acceleration of energetic particles
- Distribution of circumstellar and interplanetary dust
- Solar neutrinos
- High-precision tests of general relativity

SPEAR

This is a proposed HF active radar for Svalbard. It is a development of heater science and technology and would provide an excellent complement to the ESR radar and to satellite experiments such as Faraday and Molniya. It has four main aims:

- Generate irregularities around the ESR beam to allow confidence in bistatic vector flows from CUTLASS during key intervals
- Study the effect of heating in the cusp and polar cap
- Excite ULF waves to identify open/closed boundary
- Excite electromagnetic waves which can be identified by satellites and so determine the field-line mapping

STEREO - the first stereoscopic view of a star

Solar remote sensing instruments are limited by line-of-sight integrated intensities resulting in the necessity for assumptions and complex modelling. In addition, present observations of solar ejecta are best suited to the plane of the sky, i.e. a direction which is not directed toward Earth and is thus not suited to the subsequent sampling of ejected plasma.

The plans for a stereoscopic mission aim to provide a major step forward by stationing two or more spacecraft at very different angles to the Sun-Earth line. The most basic concept is for one spacecraft to be between 30-60 degrees off the Sun-Earth line, with another near to the Earth. With a suitable payload this would allow the following new observations:

- observations of Earth-directed CMEs, from outside the Sun-Earth line, allowing better predictions of CME arrivals (i.e. magnetic storms at Earth).
- the opportunity to sample CME plasma directly - i.e. a CME seen in white-light from one platform can be directly sampled by the other, thus helping to identify specific features in the particle and field profiles.
- remote sensing of solar plasmas can be made from several vantage points, allowing better 3-dimensional interpretations of plasma characteristics and magnetic structures - i.e. giving the first stereoscopic view of a star.

The STEREO mission was discussed as a candidate for an ESA cornerstone in the Horizon 2000+ programme. This involved significant UK input. More recently it is being discussed by the European solar community as a strong candidate mission for the F2 or F3 flight opportunities. The discussions include NASA who are considering a similar concept. Considerable effort is being put into marrying the ESA and NASA activities. The UK is involved at all levels in the discussion.

STORMS

Geomagnetic storms are the major disruptive influence on near-Earth space. They are well known to be associated with large scale aurora, communications difficulties, and disrupted satellite operations (including total satellite failure). With the increased commercialisation of space, these issues will only become more important. Accordingly, forecasting geomagnetic storms has become a topic of international interest, and one in which the UK could advance considerably. Resources, mainly in the form of personnel but also including spacecraft, will be involved in

- the analysis of archival solar datasets (e.g., Yohkoh and SOHO) - searching for X-ray and UV proxies for coronal mass ejections
- the modelling of the cause of solar eruptions, their propagation, and interaction with the magnetosphere
- the development of forecasting tools, assimilating the data and developing algorithms for predicting the occurrence, nature, and severity of terrestrial consequences based on solar observations
- the eventual deployment along the Sun-Earth line of satellite(s) to measure the magnetic fields and plasma well in advance of their arrival at Earth for forecasting purposes (needs to be much closer to the Sun than the L1 point)

SuperDARN

The HF radar technique has proved to be a powerful method of investigating the coupling between the solar wind, the magnetosphere and the ionosphere and for studies of the plasma electrodynamic of the auroral ionosphere. Although such radars have large viewing areas, they

generally observe over limited segments of the auroral oval and the polar cap. The objective of the SuperDARN project is to develop a chain of such radars which cover large sectors of the oval both in the northern and southern hemispheres. To date six radars are operating in the northern hemisphere with another four in Antarctica. Plans are well advanced for the construction of further radars to provide improved spatial coverage. Typical examples of the scientific topics to be addressed by these radars are:

- Global Convection Modelling
- Dynamical Studies of Global Convection
- MHD Wave Studies
- Substorm Studies
- Gravity Wave Studies
- High Latitude Plasma Structure Studies
- Ionospheric Irregularities

Svalbard Observatory

This project will create a UK optical facility which would be complementary to the Norwegian centre. It would include photometers, spectrographs, imaging Fabry-Perot interferometers, Doppler Imaging systems, resonance and Rayleigh lidars plus auroral imaging systems. It would also incorporate a radio tomography facility (see separate section below).

As the site of the ESR, and with the coverage of the area afforded by the CUTLASS SuperDARN HF coherent radar, Svalbard is of immense importance to studies of solar-terrestrial coupling, high-latitude phenomena, and middle atmosphere science. Svalbard was chosen for the ESR because of its unique positioning for optical experiments - it is far enough north for it to be dark, even in the F-region, at mid-day in mid-winter, thus affording 24 hours of potential observing time.

Optical techniques are the obvious complement to the science already being carried out on radars, satellites and via radio-based techniques by the UK community, and are at the cutting edge of current experimentation. As such, an optical facility would be a good platform for developing optical science and technology in the UK.

Some of the main scientific objectives include:

- high time-resolution imaging of auroral phenomena
- energy distribution of precipitating particles
- high time-resolution velocity and temperature mapping of the mesopause and thermosphere
- gravity wave structures and tides
- energy and momentum transfer between middle and upper atmosphere
- mapping of "blobs" and large scale electron density structures crossing the Polar Cap

SWARM

This project will employ a large number (30 or more) of minimally-instrumented very small, inexpensive satellites to study the 3-D, time-dependent magnetosphere of the Earth. Specific objectives include:

- Mapping magnetic field configurations throughout a substorm

- Mapping the shape and response to varying solar wind input parameter regimes and transients of key boundary layers (bow shock, dayside magnetopause, cusp, tail current sheet) which mediate the Solar-Terrestrial Interaction
- Simultaneous study of 3-D time dependence over many scales, ranging from micro/gyroscales to global scales
- Studies of naturally occurring turbulence (e.g., magnetosheath, foreshock, and auroral acceleration regions) including study of planarity, coherence, propagation directions and mode identification
- Testing and validating geospace and magnetospheric models

The mission complements that of Cluster II, which will be launched in mid-2000. Cluster II will employ 4 identical highly equipped spacecraft to unravel the detailed local micro-processes which mediate the transport through key regions and boundaries (bow shock, high altitude cusp, geomagnetic tail). By contrast, SWARM is a minimal payload to map and follow large-scale, global processes and transients. By analogy with meteorology, Cluster II will unravel the structure and physics of a hurricane, while SWARM will establish the global weather configurations under which hurricanes form and how they move.

Tomography

(see Svalbard Observatory above) Tomographic imaging using radio signals from satellites is a new ground-based technique for the study of the spatial distribution of ionospheric electron density. The UK has played a leading role in the development of the method and in particular in its application to the investigation of the field-aligned structures in the high-latitude ionosphere that form the signatures of the fundamental processes of solar-terrestrial interactions.

Resources will be needed to maintain the pre-eminent position of UK in the field of radio tomography, with new receivers required to exploit the purpose-built tomography satellites planned for the next decade. Opportunities should be explored for the inexpensive addition of a tomographic radio beacon on future UK satellites to complement other measurements. With its unique ability to image spatial structures, tomography will investigate ionospheric signatures of magnetopause reconnection, cusp and auroral precipitation and signatures of field-aligned currents.

Appendix 5 Present Project Descriptions

Selected present projects, especially those highlighted for continued operation and maintenance in co-ordination with proposed projects, are described briefly below.

ClusterII

ClusterII is part of the first ESA Horizon 2000 cornerstone (with SOHO), rescheduled for launch in mid-2000 following the demise of the original Cluster spacecraft with the failure of Ariane 501. Cluster is a set of 4 identical spacecraft in a highly eccentric, highly inclined orbit. A full complement of 11 fields and particle experiments (three with UK PIs) will separate unambiguously spatial and temporal variations in the key boundary regions of the Earth's magnetosphere. Specific mission targets include the Earth's bow shock, magnetopause, cusp, and geomagnetic tail. The separation strategy for the 4 spacecraft is designed to reveal the basic microphysical processes which ultimately mediate the large-scale transfer of particles, momentum, and energy from the solar wind to the terrestrial environment.

Co-ordinated Data Handling Facility for STP

The Co-ordinated Data Handling Facility (CDHF) for STP is a world wide web-based data archive and access facility provided jointly by establishment and university groups. The CDHF currently holds AMPTE UKS and IRM data together with ISTP Key Parameter data from numerous international missions. Future holdings will include Equator-S and ClusterII. CDHF facilities include quicklook plotting and data retrieval, together with the supply of science analysis tools for more sophisticated local data analysis and display.

CUTLASS

The HF coherent radar technique is an excellent tool for investigating a whole range of STP and plasma physics topics. CUTLASS consists of two HF radars, one at Hankasalmi, Finland and the other at Pykkvibaer, Iceland, which have overlapping fields of view which encompass the EISCAT and ESR fields of view. The radars complement existing systems in this area such as EISCAT, ESR, IRIS and optical instruments and magnetometer networks. As part of the CUTLASS National Facility a vertical ionosonde on Longyearbyen is also operated. CUTLASS forms part of the larger network of HF radars called SuperDARN.

Scientific topics which can be investigated with CUTLASS include:

- Localised response of ionospheric convection to changes in the interplanetary medium
- Convection flows associated with transients in optical signatures
- MHD waves
- Magnetospheric substorms
- Atmospheric gravity waves and planetary waves
- Ionospheric irregularities
- Artificially stimulated ionospheric irregularities

EISCAT/ESR

The EISCAT Scientific Association is an international research organisation of seven countries, whose aim is to study the high-latitude atmosphere, the aurora and the coupling of the solar wind to the Earth's polar ionosphere. These studies are carried out using incoherent scatter radar, the most powerful ground-based technique for studying a wide range of ionospheric parameters. EISCAT operates two radar systems in Northern Scandinavia; a tristatic system at

UHF (931 MHz), with radars at Tromso, Kiruna and Sodankyla, and a monostatic VHF radar (224 MHz) in Tromso. The altitude range covered by these systems extends from 60 to over 1800 km, and the latitude range from 65 to 75 degrees North. In 1996, a new radar was established on Svalbard (the EISCAT Svalbard Radar - ESR), which extends the observing area to higher latitudes and provides information on the cusp region. In addition to the incoherent scatter facilities, EISCAT also operates an ionospheric heating facility at Tromso to support various plasma physics experiments in the high-latitude ionosphere, and an advanced ionospheric sounder (Dynasonde) also at Tromso. UK EISCAT activities are co-ordinated by a support group at RAL which also maintains a data archive and analysis software on behalf of the UK community.

HESSI

HESSI is an approved NASA SMEX mission for launch in 2000 to observe flares with unprecedented spatial, spectral, and temporal resolution at hard (non-thermal) X-ray and gamma-ray energies (few keV to few MeV). Building on expertise with balloon borne Ge spectrometers and on Yohkoh Fourier imagers, it will allow the first direct probing of flare particle acceleration and propagation problems, and their relation to flare energy release.

Ionosondes

The ionosondes facility provides scaled parameters and true-height profiles from three digital ionosondes located at Lerwick (Shetland Islands, UK), Chilton (Oxfordshire, UK) and Port Stanley (Falkland Islands). Auto-scaled parameters are available in real time and these, along with final scaled parameters are obtained via the World Data Centre's web site. During periods of special interest the sounding programmes of the UK ionosondes can be adjusted to better meet current scientific objectives; e.g., by recording ionograms at higher time resolution or by running special sounding modes which obtain detailed information about the horizontal position and Doppler velocity of each scattering point in a sounding. This information can be used to chart the movement of gravity waves and plasma drifts, and to deconvolve complex ionograms. All three sounders are controlled by GPS timing enabling oblique soundings to be made between these and other similar sounders.

Ionosonde data is used to study:

- Global ionospheric response to solar wind energy extraction
- Global warming
- Gravity waves
- Ionosphere/thermosphere coupling
- Radio propagation
- Turbulence

IRIS

The Imaging Riometer for Ionospheric Studies (IRIS) system has a sophisticated phased-array antenna which produces 49 narrow beams, on the order of 12 degrees beamwidth, all of which are sampled once a second. This system is capable of examining ionospheric electron density perturbations in fine time scale (1 second), as well as small spatial scale (approx. 20km). This enables determination of the structure and dynamics of the energetic particle precipitation over a large field of view with good spatial resolution, not at present obtainable with any other technique. Scientific topics which can be investigated with IRIS include:

- Dynamics and structure of the energetic particle precipitation
- Auroral absorption

- Ionospheric scintillations
- Artificially induced absorption and scintillation

SAMNET

The UK Sub-Auroral Magnetometer NETWORK (SAMNET) is an array of stations in the UK, the Faroe Islands, Sweden, Norway, and Finland to monitor and study changes in the magnetic field at the Earth's surface induced by events and transients in the Earth's magnetosphere and ionosphere. The magnetometer record underpins research into geomagnetic storms and substorms as well as other phenomena, including global magnetospheric oscillations driven by solar wind transients and solar wind interaction with the magnetosphere.

SOHO

The SOLar and Heliospheric Observatory (SOHO) is a joint NASA/ESA mission, launched in 1995 into a halo orbit around the L1 Lagrange point. SOHO has an uninterrupted view of the Sun and carries a suite of experiments to measure solar oscillations, the solar atmosphere, and the solar wind. There is considerable UK involvement, including a PI and numerous CoIs. Scientific objectives include

- Helioseismology studies to infer the structure of the solar interior
- The fine-scale structure of the solar atmosphere
- The source of the solar wind
- Coronal structure and heating, including both the inner and outer corona
- Coronal Mass Ejections and other transient events

Ulysses

Ulysses is a joint ESA/NASA mission launched in 1990 to explore for the first time the solar wind over the poles of the Sun. This was accomplished through a gravitational assist at Jupiter, resulting in polar passes in 1994 and 1995, near solar minimum. A second set of passes will take place in 2001 near solar maximum. Ulysses carries a suite of experiments to measure the electromagnetic fields, thermal plasma, composition and energetic particles as well as X- and gamma-rays and interplanetary dust. UK involvement includes a PI, CoIs and Guest Investigators. At solar minimum, Ulysses measured the nearly uniform, high-speed polar solar wind, unimpeded by streamer interactions which are found in the ecliptic plane. Scientific objectives of the mission include

- The state of the solar wind (bulk parameters, composition) over the poles of the Sun
- Turbulence and energetic particle transport in the interplanetary medium
- The source and acceleration of the solar wind

World Data Centre

The UK World Data Centre (WDC) C1 is part of a worldwide system of geophysical data centres. The WDC holds and archives important datasets, including ionospheric parameters and raw ionosonde data, various geophysical indices which are used in characterising the solar, geomagnetic and auroral activity, standard geophysical models, and international reports/predictions of geophysical and solar conditions. Most of this key data is accessible online through a world wide web interface, and underpins a large bulk of STP research.

Yohkoh/Yohkoh Data Archive Centre

Yohkoh is a satellite of the Japanese Institute of Space and Astronautical Science (ISAS) dedicated to high-energy observations of the Sun, specifically of flares and other coronal disturbances. The spacecraft carries a compliment of four scientific instruments: the Soft X-ray Telescope (SXT), the Hard X-ray Telescope (HXT), the Bragg Crystal Spectrometer (BCS - with UK involvement), and the Wide Band Spectrometer (WBS). The structure within the corona is observed by the SXT; the HXT shows where energy is released; the BCS provides information about the characteristics of the flaring plasma; and the WBS provides an overall energy balance. The principal scientific objectives of Yohkoh are to study:

- Flare-related phenomena
- Dynamic phenomena not necessarily related to flares
- Other forms of coronal activity
- The global coronal structure

Yohkoh was launched in August 1991 and is predicted to remain in orbit until ~2002, with some dependence on solar activity. It has been the practice of ISAS to continue operating a mission while it remains viable and to date Yohkoh remains fully operational.

The Yohkoh Data Archive Centre (YDAC) was established in 1994 to provide access to all of the data from the Yohkoh mission for researchers within the UK. The Centre aims to provide similar facilities to those available to scientists who visit ISAS. Users of the YDAC have free access to all Yohkoh data in the public domain (more than 12 months old), and can gain access to more recent data if collaborating with any member of the Yohkoh Team. A comprehensive, well-documented suite of analysis software is provided - this is updated nightly from Japan and the US. The PPARC grant to operate the YDAC was extended in 1997 and it is now funded until April 2000.

Appendix 6 UK STP Advisory Panel - Draft Terms of Reference

Role

The Panel, convened under the auspices of PPARC and BNSC, shall meet at least once a year and will

1. monitor developments in UK STP research, including instrumentation, data analysis, theory and modelling work
2. co-ordinate and foster discussion within the broad STP community to identify future goals
3. scrutinize and prioritise proposals for new projects, with due consideration for the need for the continuation of some existing STP projects and an overall budgetary profile
4. advise PPARC as to the important key initiatives and opportunities for national, bi-lateral, and international participation
5. ensure that forefront research is not impeded by the artificial boundary between PPARC- and NERC-funded regions of geospace
6. ensure that the range of ground-based, space-based, and theory/modelling activities are balanced in terms of the synergy required for meeting the objectives of STP
7. ensure that data is accessible by the UK community and promote the fullest possible exploitation of the data

Membership

The membership shall consist of the following:

- Six to eight members of the community (one of whom will serve as chair)
- Chair of the STP National Facilities Committee
- A Representative of BNSC
- A Representative of PPARC

Attendees

- A Representative of NERC

Appendix 7 UK STP Groups

University Groups

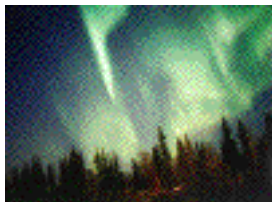
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Cambridge
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Oxford
Queen Mary and Westfield College, London (QMW)
Queen's, Belfast
Sheffield (Automatic Control & Systems Engineering *and* Applied Mathematics)
Sheffield-Hallam
Southampton
St. Andrews
Strathclyde
Sussex
University College London (UCL)
University of Manchester Institute of Science and Technology (UMIST)
Warwick
York

Establishments

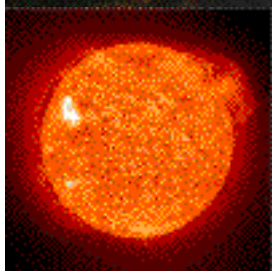
British Antarctic Survey (BAS)
British Geological Survey (BGS)
Rutherford Appleton Laboratory (RAL)

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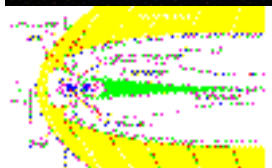
Jan Curtis [<http://www.geo.mtu.edu/weather/aurora/>]



Courtesy SOHO/EIT team



British Antarctic Survey

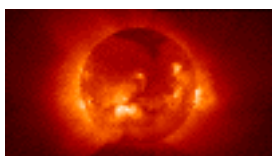


Modified version of an original taken from Space Physics Textbook, Oulo
[<http://www oulu.fi/~spaceweb/textbook/magnetosphere.html>]

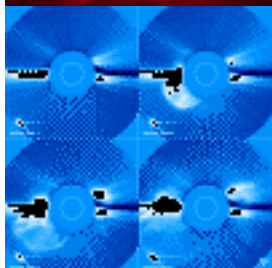


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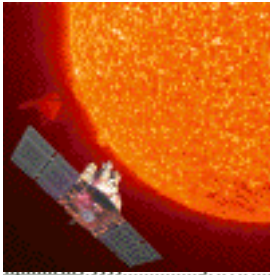
Cover Page Images:



Extended view of the corona in Soft X-rays. Image taken from the Yohkoh Data Archive Centre (YDAC)
[<http://ydac.mssl.ucl.ac.uk/ydac/>]



Sequence of images taken by the LASCO experiment on SOHO showing a Coronal Mass Ejection expanding toward the lower left corner. Image supplied by the LASCO team and taken from the "SOHO Portfolio" held at <http://sohowww.nascom.nasa.gov/>.



Artist's impression of the SOHO spacecraft in flight. Image taken from the "SOHO Portfolio" held at <http://sohowww.nascom.nasa.gov/>.

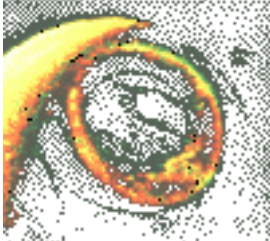
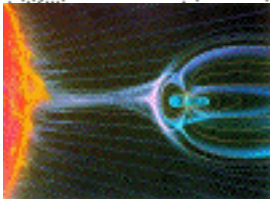
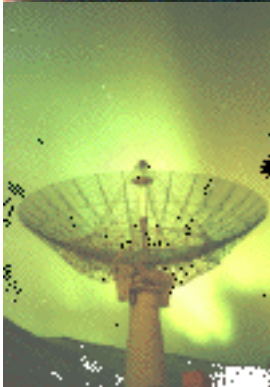


Image of the Earth's auroral oval taken by the DE spacecraft. [Courtesy LA Frank, University of Iowa.]



Artist's impression of the solar wind impact on the Earth's magnetosphere. Image taken from the "SOHO Portfolio" held at <http://sohowww.nascom.nasa.gov/>.



Radar antenna in Scandinavia with an auroral display in the background. [Courtesy Nigel Meredith, MSSL. Image taken from <http://msslsx.mssl.ucl.ac.uk/~npm/aurora/aurora.html>]