INTERNATIONAL COORDINATION OF SOLAR TERRESTRIAL SCIENCE

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Abstract. A broad, international, cooperative effort is under way to study and develop quantitative understanding of the fundamental electrodynamic processes in the solar-terrestrial environment. Japan, Europe, Russia, the United States, and other countries are providing spacecraft to be placed in key regions with the aim of utilizing coordinated, multipoint spaceflight measurements, ground-based observations, and theory to study the global energy budget of geospace. The U.S. contribution began in the late 1970's as the OPEN program (Origin of Plasmas in Earth's Neighborhood) and was reconstituted in the 1980's as the Global Geospace Science (GGS) program. The international effort, known in the U. S. as the International Solar Terrestrial Physics program (ISTP), began with the launch of the Japanese GEOTAIL in 1992, and will continue with the U. S. spacecraft WIND and POLAR in 1994–1995, and the European four-spacecraft Cluster fleet and its Solar and Heliospheric Observatory (SOHO) in 1995. Russia will launch its Interball set of four spacecraft in 1995. The Inter-Agency Consultative Group (IACG) is promoting the coordination of the spacecraft observations by means of scientific campaigns aimed at addressing scientific questions that can only be answered by observations from the multiple spacecraft. The Solar Terrestrial Energy Program (STEP) is coordinating the involvement of the broad scientific community and especially the correlative ground observations.

1. Solar Terrestrial Science

1.1. THE OPEN PROGRAM

In 1977, NASA formed an *ad hoc* science study group – a Science Definition Working Group (SDWG) – that was charged with defining a program in space plasma physics that would complement other programs in solar terrestrial science and that would respond to recent recommendations by the National Academy of Sciences.

Its first task was to assess the next logical scientific thrust in understanding the near-Earth space environment, and to define the most important problem areas that could be addressed by an effort of realistic scope. This task was to reflect the recommendations of the Study Committee on Space Plasma Physics of the National Academy of Science's Space Studies Board (Colgate, 1978) and the Committee

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on Solar-Terrestrial Physics of the National Academy of Science's Geophysics Research Board (Friedman, 1977). The second task was to define the program in sufficient detail to identify technology drivers and resource requirements and to permit design studies that would lead to solicitations for scientific investigations.

The result of that study, described in the final report of the SDWG, 'Origins of Plasmas in the Earth's Neighborhood' (OPEN), (Alexander and Williams, 1979) was the definition of a program that would utilize coordinated, multipoint, spaceflight measurements, ground-based observations, and theory to study the global energy budget of geospace.

The OPEN program was designed to undertake a quantitative study of the overall geospace system. In doing so, it had three major goals:

- To assess the mass, momentum, and energy flows through the geospace system and their time variability.
- To improve understanding of plasma processes that are important in controlling the collective behavior of the geospace components and for the first time to trace their cause-and-effect relationship throughout the system.
- To assess the importance to the terrestrial environment of variations in energy input to the Earth's atmosphere caused by geospace processes.

The state of scientific understanding had matured to a point where an observational program designed to observe simultaneously all key geospace regions was required to provide such a cause-and-effect understanding of the overall system. In addition, spacecraft and instrumentation development had advanced far enough to allow measurements of a complete set of key physical parameters.

Four critical regions were identified in geospace: (i) the solar wind, upstream of the Earth, which is a source of the plasma and energy input to geospace; (ii) the polar magnetosphere, at high latitudes where plasma and energy are deposited into the auroral upper atmosphere; (iii) the equatorial magnetosphere, where energy and plasma are stored and where magnetic substorms may be triggered; and (iv) the Earth's magnetotail, where plasma and energy are transported and stored. The objective was to obtain and analyze simultaneous measurements taken by spacecraft in these four regions, together, of course, with ground-based measurements, and theoretical modelling.

Thus, the OPEN program recommended by the SDWG consisted of four suitably instrumented spacecraft placed to observe simultaneously each of the major geospace plasma source regions (solar wind, ionosphere) and storage regions (ring current, plasma sheet and tail). Significant orbit adjustment was included on each OPEN spacecraft to provide the flexibility necessary to realize a variety of observational configurations. The four spacecraft in the OPEN program were the Interplanetary Physics Laboratory (IPL), the Geomagnetic Tail Laboratory (GTL), the Polar Plasma Laboratory (PPL), and the Equatorial Magnetosphere Laboratory (EML).

A theoretical studies and modeling effort and a vigorous data analysis program, using an easily accessible centralized data system containing data from all OPEN spacecraft, were also included in the program. In addition, a coordinated series of ground-based observations was planned to provide correlative measurements of ionospheric electric fields, currents, and conductivities, and Joule heating of the neutral atmosphere.

The Interplanetary Physics Laboratory was to be stationed in the upstream solar wind near the sunward libration point. Its objectives were to:

– determine the characteristics of the solar wind source plasma;

– provide the complete plasma, energetic particle, and magnetic field input for magnetospheric and ionospheric studies;

– determine the loss of particles from the magnetosphere into interplanetary space in the upstream region.

The Geomagnetic Tail Laboratory was to utilize lunar swing-by orbit adjustments in order to maintain a distant apogee (80–250 R_e) in the magnetotail. This spacecraft would:

– determine for the first time the characteristics of the distant magnetic tail;

– with complementary magnetospheric satellites, help determine the role of the distant tail in substorm phenomena and in overall energy balance (energization, transport, storage, and dissipation);

– separate out the ionospheric and solar wind contribution to geomagnetic tail plasma;

– search for acceleration processes (reconnection, parallel electric fields, induction, etc.).

The Polar Plasma Laboratory was to be placed in a highly eccentric polar orbit, with an orbit adjust capability to vary apogee radius in the 4–15 R_e. The spacecraft would:

– help determine the role of the ionosphere in substorm phenomena and in the overall magnetospheric energy balance;

– measure energy input through the dayside cusp and mantle regions;

– determine characteristics of ionospheric plasma outflow;

– study characteristics of the auroral acceleration regions;

– provide global multispectral auroral images of the footprint of magnetospheric energy deposition into the ionosphere and atmosphere.

The Equatorial Magnetosphere Laboratory was to be located in an equatorial 2 x 12 R_e orbit with an orbit-adjust capability to provide a later deep tail orbit, thereby allowing, with GTL, simultaneous 2-point samples of the distant tail. The EML was to:

– help determine the substorm trigger mechanism and the overall magnetospheric energy balance;

– provide direct observations of the interactions of geomagnetic tail and ionospheric plasmas in the equatorial magnetosphere;

– measure the transport and storage of ionospheric and tail plasma in the near-Earth plasma sheet and ring current;

– measure the coupling of the solar wind to the magnetosphere at the subsolar magnetopause.

The SDWG report stated that if any of these four satellites were not included in the OPEN program, the overall goal of assessing energy flow and balance throughout the geospace system could not be attacked.

The OPEN program concept was subsequently reviewed and endorsed by the NASA Space Science Advisory Committee, the SCOSTEP (Scientific Committee on Solar-Terrestrial Physics) Steering Group for the International Magnetospheric Study, the Committee on Solar and Space Physics of the Space Science Board, and the Committee on Solar-Terrestrial Research of the Geophysics Research Board.

In 1979, a NASA Announcement of Opportunity was issued inviting participation in the OPEN scientific investigations. In 1981, investigations were selected and a Science Working Group (SWG) representing participating scientists from the U.S., Canada, and Europe was formed to conduct detailed science investigation definition studies. The SWG worked with the Goddard Space Flight Center to refine the requirements and mission plan for both the space flight and ground segments of the OPEN program.

1.2. THE GGS PROGRAM

Concurrent with the NASA studies, scientists at the Japanese Institute of Space and Astronautical Science (ISAS) were planning two complementary flight missions called EXOS-D and OPEN-J, and space scientists in Europe were conducting studies of possible future European Space Agency (ESA) missions in solar-terrestrial physics. In 1983, a proposal was put forward to merge the U.S. OPEN program and the Japanese and European efforts into a coordinated endeavor.

The OPEN program was renamed the Global Geospace Science (GGS) program as NASA's contribution to this international effort, with ESA providing the CLUSTER and SOHO spacecraft as part of its Solar Terrestrial Science Program (STSP). CLUSTER is a fleet of four spacecraft designed to fly in close formation to study boundary layer regions and the cusp regions of the magnetosphere (Schmidt, 1988). It is planned to be launched in late 1995 into an orbit inclined at 90° with an apogee of 20 R_e. SOHO is a spacecraft to carry out solar and heliospheric observations (Domingo, 1989), to be launched into a halo orbit about the L1 libration point in mid 1995. Thus was born a program of international solar-terrestrial physics missions (known in the U.S. as ISTP) that would provide a cost-effective and scientifically vigorous international collaboration in solar, heliospheric, and space plasma physics in the 1990's.

The four original spacecraft in the OPEN program were renamed WIND (replacing IPL), POLAR (replacing PPL), and EQUATOR (replacing EML) – these three to be provided by NASA – and GEOTAIL (in place of GTL), to be provided by ISAS. Ground-based and theoretical investigations were continued as an integral part of the program. The program at this stage was described in the NASA Report, 'Science Plan for the Global Geospace Science Mission' (Alexander and Nishida, 1984). Further information is contained in an article by Parks *et al.* (1988).

In 1986 the EQUATOR spacecraft was cancelled for budgetary reasons. Instead, the CRRES satellite (Combined Release and Radiation Effects Satellite), a joint NASA/Air Force satellite planned for launch in 1990, was brought into the GGS program to provide equatorial data. CRRES was to be in a low inclination, elliptical orbit with perigee at a few hundred km and apogee at geosynchronous altitude. CRRES was successfully launched in July, 1990 and completed its primary mission objectives, but the spacecraft failed in the fall of 1991 before the launches of the other GGS spacecraft (Vampola, 1992).

Because of the importance of the equatorial observations to the GGS program, other methods of acquiring equatorial data have been explored. In addition, the principal investigators selected for the original EQUATOR spacecraft were continued in the program as an equatorial science team to advise on ways to obtain equatorial data and to participate in eventual data analysis efforts. In 1987–1988 the suggestion that one of the CLUSTER spacecraft could be launched early into an equatorial orbit and then later join up with the other three was explored, but this plan did not prove possible. Russia proposed in 1990 that one of their Regatta spacecraft could carry out an equatorial mission, but this program has been delayed indefinitely.

Beginning in 1991, Memoranda of Agreement were established between NASA and NOAA (National Oceanic and Atmospheric Administration) and between NASA and LANL (Los Alamos National Laboratory) to bring equatorial data from geostationary spacecraft into the GGS Program. Magnetic field data will be supplied from two NOAA GOES (Geostationary Operational Environmental Satellite) spacecraft, and plasma and energetic particle data from three LANL spacecraft. Because of the importance of the equatorial tail region beyond synchronous orbit (6.6 R_e) out to about 12 R_e, where it is thought that magnetospheric substorms may be triggered, an effort has been underway to add a small spacecraft, known as Equator-S (S for Small) to the ISTP program. This spacecraft will be built by Germany and will carry five or six particle and field experiments, with a launch date expected for early 1996. It will be placed in an elliptic, equatorial orbit with an apogee at about 10 R_e.

GEOTAIL was launched in July, 1992, and is at present (February, 1994) in the deep tail orbit phase with apogee at some 200 R_e. It will be repositioned later in 1994, using a lunar swing-by, into a near-Earth orbit with an apogee of approximately 30 R_e. WIND will be launched late in 1994 into a figure-eight orbit around the Earth and the Moon on the Sun side of the Earth with an apogee as far as 250 R_e and a perigee of at least 5 R_e. It will later use a lunar gravity assist to go into a small circular orbit about the L_1 libration point. POLAR is expected to be launched into a 90° inclination orbit with apogee at $9R_e$ and perigee at about 2 R_e.

2. Coordination through the Inter-Agency Consultative Group (IACG)

Early in the development of this program it was recognized that coordination of these missions must be maintained through their flight phases in order to make most effective use of these resources and to optimize research results. Other spaceflight missions being planned by other countries were recognized as potentially valuable additions that could complement the solar-terrestrial effort. An international coordinating body had been previously formed to informally coordinate the space missions to Halley's Comet, the Inter-Agency Consultative Group (IACG). Four space agencies – ESA, InterCosmos of the former USSR and Eastern European countries, ISAS, and NASA – make up the IACG, with the goal of increasing the overall scientific return from their respective missions through cooperation among the agencies. The success of the Comet Halley activities led each agency to recognize the value of maintaining close international collaboration within the IACG framework. The IACG determined that its second major international collaborative effort should focus on solar-terrestrial research (Reinhard, 1987).

Serious efforts began in the late 1980's to stimulate such cooperation. The focus of the IACG joint-mission planning activity is the science working group (WG-1, Chairman: E. Whipple*, U.S.). Consisting of scientists representing each agency, its projects, and its scientific community, this group interacts at the working level to define crucial science objectives that require multiple spacecraft measurements; to identify the data sets needed for progress towards those objectives; to identify appropriate models of the solar-terrestrial environment, which can be used for mission planning and for data interpretation; and to formulate policies for the exchange of data, which must be done in a way that optimizes the research results while protecting the data rights of the principal investigators appropriately. The science working group, which consists of four or five scientists from each agency, meets periodically and, most importantly, organizes symposia and workshops to involve the larger community in defining specific campaigns, which will focus maximum effort and resources toward the accomplishment of the scientific objectives.

Working Group 2 (Data Exchange, Chairman: J. Green, U.S.) studies the technical aspects of implementing efficient data exchange between different projects. It includes members with extensive experience in data acquisition, reduction, and analysis in cooperative research programs. One of its important functions is the definition of 'Rules of the Road' to be followed by scientists in the exchange and use of data from the various projects.

Working Group 3 (Mission Design and Planning, Chairman: K. Uesugi, Japan) is composed primarily of spacecraft and mission-design engineers who are expert in the operational aspects of multi-mission coordination. They are supported by project satellite situation centers which can help identify and explore combinations of trajectory options which would allow the optimum return of scientific data, especially during the campaign periods.

* Succeeded by A. Pedersen, September 1994.

The IACG has also established panels to consider potential future space science disciplines that would benefit from inter-agency coordination. There are panels on Very Long Baseline Interferometry, on Planetary and Primitive Bodies, and on High Energy Astrophysics.

3. IACG Campaigns

In 1990 the IACG decided to focus its coordination activities by planning and conducting scientific campaigns. Each campaign addresses a set of specific questions on the solar-terrestrial environment and will be accomplished over several periods when spacecraft positions are particularly favorable. As it is difficult to predict spacecraft constellations far in advance (e.g. due to ongoing orbit optimizations) a period of several months per campaign is assumed for planning purposes. The multi-mission data taking will occur in one or more short intervals (days to weeks) within the longer period.

Four campaigns have so far been identified:

- Solar Sources of Heliospheric Structure Observed Out of the Ecliptic (beginning with the first Ulysses polar pass in May, 1994).
- Magnetotail Energy Flow and the Role of Nonlinear Dynamics (beginning in 1995).
- Boundaries in Collisionless Plasmas (beginning in 1996).
- Solar Events and their Manifestations in Interplanetary Space and in Geospace (beginning in 1996).

3.1. SOLAR SOURCES OF HELIOSPHERIC STRUCTURE OBSERVED OUT OF THE ECLIPTIC

In 1993, the IACG specifically recommended that the membership and activities of the IACG Science Working Group be expanded to include study of the three-dimensional heliosphere. This new heliosphere thrust recognizes the unique opportunity presented during the next several years by the simultaneous operation of an international fleet of solar and heliospheric missions to achieve maximum understanding of the global heliosphere from its solar sources to its detailed interaction with the interstellar medium.

These missions cover a unique combination of observations of the Sun from near-Earth space, along with in situ observations of particles and fields emanating from or modulated by the Sun from platforms near Earth as well as at both high helio-latitudes and at great distances from the Sun. The imminent and unique pole-to-pole passage of Ulysses around the Sun during solar cycle minimum in 1994-1995 makes this heliospheric campaign particularly timely.

A workshop to plan the campaign was held at Easton, Maryland, U.S.A., January 27–29, 1994, and a report will be available soon (Forman, 1994). The campaign is planned to begin in mid-1994 and extend through 1996, covering the prime mission

TABLE I

The IACG mission set

Mission	Number of spacecraft	Agency	Launch
Part I. Core missions			
Geotail	1	ISAS/NASA	July 1992
Wind	1	NASA	1994
Polar	1	NASA	1994
Interball	4	Intercosmos	1994
Solar and Heliospheric Observatory (SOHO)	1	ESA/NASA	July 1995
Cluster	4	ESA/NASA	Dec. 1995
Part II. Complementary Missions			
Interplanetary Monitoring Platform (IMP-8)	1	NASA	Oct. 1973
Geostationary Operational Environmental Satellite (GOES)	2 in orbit	NOAA	D-H: 1980–87 I-M: 1993
Los Alamos National Laboratory (LANL)	3 in orbit	DOE	
Akebono (formerlyEXOS-D)	1	ISAS	Feb. 1989
Relict-2	1	Intercosmos	1995
Yokhoh (formerly Solar-A)	1	ISAS	Aug. 1991
Upper Atmospheric Research Satellite (UARS)	1	NASA	Sept. 1991
CORONAS-I	1	IZMIRAN	1994
Sampex	1	NASA	June 1992
SPARTAN	1	NASA	April 1993
FAST	1	NASA	Aug. 1995
CORONAS-F	1	IZMIRAN	1996
ACE	1	NASA	1997
Part III. Spacecraft in Heliocentric Orbits			
Pioneers 10 and 11	2	NASA	1972
Voyagers	2	NASA	Aug./Sept. 1978
International Cometary Explorer (ICE)	1	NASA	Aug. 1978
Suisei	1	ISAS	Aug. 1985
Galileo	1	NASA/FRG	Oct. 1989
Ulysses	1	ESA/NASA	Oct. 1990
Mars-94	1	Intercosmos	1994

period during solar minimum when Ulysses will be traversing from south to north solar pole and then down to northern solar mid-latitudes. Solar missions Yohkoh, CORONAS, Spartan 201, and SOHO will be operating during this time, as will other particles and fields missions in different parts of the heliosphere, particularly IMP-8, SAMPEX, Wind, Pioneer, and Voyager.

The fundamental science question discussed at this workshop is one of the most basic questions of solar-heliospheric physics. How does the Sun control the structure and temporal variations of the interplanetary medium over the full range of solar latitudes through the coronal structures associated with active regions and helmet streamer regions as well as through coronal holes? The workshop participants identified four themes around which the campaign will be organized:

(i) The large-scale heliosphere and its dependence on solar photospheric and coronal phenomena.

(ii) The topology of and boundaries between fast and slow solar wind streams.

(iii) The three-dimensional shape of coronal hole boundaries.

(iv) Solar wind source regions and acceleration mechanism.

3.2. MAGNETOTAIL ENERGY FLOW AND THE ROLE OF NONLINEAR DYNAMICS

This campaign was planned at a workshop at Airlie House, Warrenton, Virginia, June 1–3, 1992. The goals of this workshop were to devise a strategy and to prepare an implementation plan for answering several science questions, focused on three topics: plasma dynamics of the distant tail; equilibrium tail structure; and tail dynamics and the interplanetary magnetic field.

The result was the definition of two overarching science research themes, and a two-phase campaign plan, described in the workshop report (Whipple and Lancaster, 1992), focusing on: (i) the structure of the global magnetotail system, especially during quiet periods; and (ii) magnetotail effects of the global solar wind-magnetosphere interaction, especially during active periods.

The first of these themes recognizes that despite decades of magnetospheric research, our spacecraft have systematically explored only the relatively near- Earth region of space. An immense amount remains to be learned about the quiescent structure of the distant tail, about the evolution of the tail plasma regions, about the relative contributions of the sources of the tail plasma population, and about the ultimate fate of these plasmas as they convect toward, and away from, the Earth. Thus, the prime objective of this campaign phase will be to use the widely-spaced IACG satellites – along with ground-based data, other spacecraft, and modeling tools – to gain a true understanding of the large-scale configuration of the magnetotail system.

The second dominant research theme concerns the time-dependent behavior of the coupled solar wind-magnetosphere system. Time variations can arise very naturally in this system owing to major solar wind perturbations, including interplanetary shock waves, large pressure pulses, and changes in the interplanetary magnetic field. But significant internal magnetospheric instabilities can also cause profound, global changes throughout the magnetosphere. Thus, the second phase of the campaign will deal with the storage and release of energy within the magnetotail, especially during both substorm and storm conditions, and with the many large-scale manifestations of these energy transfer processes in the near-Earth and distant-tail regions. The IACG suite of spacecraft is ideally suited for such studies.

A prototypical spacecraft arrangement for this campaign would have WIND or IMP-8 in the upstream solar wind to monitor the interplanetary conditions and sense the kind of changes that will induce global dynamical responses in the magnetosphere. INTERBALL-AURORA, AKEBONO, and/or FREJA should be in the polar regions to image the polar cap and monitor the low-altitude plasma population. Ground-magnetometer chains, all-sky camera stations, and HF radar facilities will be used to provide correlative data. A set of geostationary spacecraft at several different local times will also provide important data.

A key component of the configuration strategy is to have INTERBALL-TAIL in the mid-magnetotail during this campaign, optimally being relatively near the midnight meridian, and probably near apogee ($\sim 30 R_e$). However, INTERBALL-TAIL could be at any local time in the tail – including near the flanks – and still return very useful information.

The GEOTAIL spacecraft is the cornerstone of this campaign, spending most of its time near apogee in the relatively distant tail region. Apogee can range from $\sim 80\ R_e$ for 1-month period orbits to $\sim 220\ R_e$ for 4-month orbits. A wide range of INTERBALL–GEOTAIL separation strategies are possible. Moreover, if IMP-8 is in the magnetotail along with INTERBALL and GEOTAIL, there are a very wide variety of 3-spacecraft location possibilities available to study how disturbances propagate in the tail after their initiation.

The general campaign starts when INTERBALL-TAIL enters the magnetotail from the dawn boundary. When GEOTAIL reaches a distance of 220 R_e in the magnetotail a number of campaign sub-intervals will occur in which measurements in the distant tail are possible. Intervals will be selected (i) either in retrospect by referring to appropriate signatures in the solar wind or inside the magnetosphere, or (ii) according to orbit predictions when INTERBALL-TAIL (or IMP-8) crossings of key physical regions (e.g. flanks of the magnetotail, inner edge of the plasma sheet) are identified.

3.3. BOUNDARIES IN COLLISIONLESS PLASMAS

Another campaign workshop was held in Graz, Austria, in April 1993 on the subject of boundaries in collisionless plasmas (Schmidt and Paschmann, 1993). The campaign is planned to start in late 1996, but with a number of preliminary campaign tasks to begin earlier.

TABLE II

Missions contributing to campaign on boundaries in collisionless plasmas

Mission	Launch	Orbit	Data coverage	Spin rate
IMP-8	10/17	35 R_e; circular	50–75%	
Geotail[a]	7/92	8×30 R_e; equatorial; 116 h	~100%	20 rpm
Interball-Tail	1995	1.1×32; $i = 65°$	~100%	0.5 rpm
Interball-Aurora	1995	1.1×4; $i = 65°$	~100%	0.5 rpm
Wind	1994	(upstream)	100%	
Polar	1995	1.9×9; $i = 90°$; 17.6 h	~100%	10rpm
SOHO	7/95	$L1$	~100%	
Cluster	12/95	4×20; $i = 90°$; 66 h	~50%	15 rpm
Relict-2	late 95	$L2$	~100%	60 rpm (no booms)
Equator-S	2/96	1.1×11; equatorial; ~20 h	50–100%	1 rps
GOES, LANL	...	Geostationary	~100%	
DMSP	...	840 km circular; polar	~100%	
FAST	8/94	800 × 4200 km; polar	(Auroral zone)	12 rpm

[a] Near-tail phase, commencing in late 94.

The physics of boundaries in collisionless plasmas is a long-standing and challenging scientific problem. Such boundaries provide an interface between different plasma regimes or cells. Plasma behavior within a cell may be described by the fluid equations known as magnetohydrodynamics. However, the small-scale kinetic processes which take place within these boundaries could control the overall dynamics of the magnetospheric system. The characteristic narrowness of these boundaries and their mobility in space impose rather severe restrictions on their experimental study. The high time resolution data obtained simultaneously by a set of spacecraft crossing these boundaries would provide deeper insight into the physics of these small-scale kinetic processes. The report examines questions relating to the bow shock, the magnetopause, current sheets, and particle acceleration, requiring coordinated observations from SOHO, WIND, INTERBALL, CLUSTER, POLAR, FAST and GEOTAIL. Observations from Equator-S were also felt to be critical in answering many questions.

3.4. SOLAR EVENTS AND THEIR MANIFESTATIONS IN INTERPLANETARY SPACE AND IN GEOSPACE

This campaign was planned at a fourth workshop held at ISAS, Tokyo, May 31–June 2, 1994. The campaign will start in 1996 and will involve the following spacecraft: CLUSTER, SOHO, WIND, MARS-94, CORONAS, GEOTAIL, POLAR, INTERBALL, UARS, IMP-8, ULYSSES, YOHKOH, and SAMPEX, to the extent that spacecraft operations continue.

The goals of the workshop are to devise a strategy for answering the following questions: (i) What are the sources of solar events which influence geospace? What is the coronal and solar wind structure, and how do they evolve on different spatial scales? What solar atmospheric conditions lead to coronal mass ejections (CME's) and what are their physical conditions and structure? (ii) How do physical disturbances propagate through interplanetary space from the Sun to Earth's magnetosphere? (iii) What are the effects of disturbances in geospace?

Solar-terrestrial physics is concerned with the effects of the Sun's radiative and corpuscular output on the Earth and its environment. So-called 'solar events' are transient disturbances of the solar atmosphere and radiation that are caused by the Sun's magnetic activity. They originate in the solar corona and then propagate through interplanetary space to the Earth's orbit and beyond into the outer realms of the heliosphere. They manifest themselves as changes in the background solar wind and its particles, fields, and waves. Since the Earth's magnetosphere and ionosphere are the results of the interaction between the Sun's radiation and wind and the Earth's magnetic field and atmosphere, it is clear that solar events produce magnetospheric disturbances (storms) and changes in geospace.

Therefore solar events and associated interplanetary phenomena provide a useful tool to investigate and reveal the causes and effects of solar-terrestrial relationships. They can be used to improve, extend, and corroborate our knowledge of the physics of the solar atmosphere, corona, and wind, and of the Earth's magnetosphere and its atmospheric couplings.

The precise schedule of the campaign, especially allowing for the study of the magnetospheric/ionospheric effects, will have to be based mainly on the orbital characteristics of the POLAR, CLUSTER, and INTERBALL spacecraft.

4. The Solar Terrestrial Energy Program (STEP)

STEP is an international program established under the International Council of Scientific Unions (ICSU) for the 1990-1997 time frame. It is administered by the Scientific Committee on Solar Terrestrial Physics (SCOSTEP), as defined in the report, 'STEP: A World-wide Solar Terrestrial Energy Program' (Williams and Shawhan, 1986). The scientific goal of STEP is to advance the quantitative understanding of the coupling processes responsible for the transfer of mass and energy between the various regions of the geospace environment from the Sun to the middle atmosphere, and to the lower atmosphere. All observational modes are included in STEP with special emphasis on improved utilization of ground-based capabilities and integration of these with space-based observations. The distinction between the STEP and IACG coordination efforts is that the IACG consists of representatives from the four lead space agencies with the objective of coordinating the various solar-terrestrial space missions, whereas STEP is made up of representatives from the broader international scientific community, with substantial ground-based and theory components, and the following four broad scientific objectives (Roederer, 1990):

(i) Solar Physics: Solar interior structure and differential rotation; luminosity variations and links to solar oscillations and solar activity; interactions of solar plasmas with strong magnetic fields in active regions; processes determining mass and energy balance in the solar atmosphere.

(ii) Physics of the Heliosphere: Generation, structure and variability of the solar wind; three-dimensional properties; plasma processes regulating solar wind flow and particle acceleration; interactions of material of cometary and meteoritic origins with solar radiation and the terrestrial environment.

(iii) Magnetospheric and Ionospheric Physics: Transport of energy, momentum and mass across the bow shock and magnetopause, through the magnetosphere, ionosphere and into, or out of, the upper atmosphere; storage and release of energy in the magnetospheric tail; local sources and sinks of plasma; physical and chemical processes controlling coupling to the atmosphere.

(iv) Atmospheric Physics: Radiative energy balance and interrelations with chemistry and dynamics of the thermosphere, mesosphere and stratosphere; vertical interactions and energy transport to atmospheric regions below and above; global effects of solar variability on the thermosphere and middle atmosphere; the role of the global electric field in atmospheric transport and chemistry .

A U.S. STEP Steering Committee was formed in 1988, chaired by Dr D. J. Williams, to begin planning this nation's involvement in the international STEP program. One recommendation was the establishment of a STEP coordination office in the U.S. This office has been established and is located at NASA Goddard Space Flight Center, with Dr D. Baker as the U.S. Step Project Scientist and Dr M. Teague as the U.S. STEP Coordinator. An important activity of this office is publication of the U.S. STEP International Newsletter.

STEP has established a number of projects specifically for coordination with IACG and GGS campaigns. STEP Project 2.7 (Leader: S. Curtis, NASA/GSFC) is intended to promote the acquisition of international ground-based data during the IACG Magnetotail Campaign and also to involve the international modeling community in the subsequent data analysis. STEP Project 2.6 (Leader: C. Cattell, University of Minnesota), the International Auroral Study, will involve multiple ground- and space-based observations of the Northern and Southern auroras; key spacecraft missions include POLAR, WIND, and FAST.

5. Conclusions

Since the launch of Sputnik and Explorer I and the beginning of space physics research some 35 years ago, there has been immense progress worldwide in the study of the solar terrestrial environment. The international space research community now stands poised on the threshold of an exciting epoch in which measurements of unprecedented breadth and depth will be available at many points throughout the solar terrestrial system. As was recognized in the early 1980's, such an ambitious program of scientific inquiry can only be undertaken in the framework of close international, multi-mission cooperation such as that established by the four agencies of the IACG. The problems that can now be solved by scientists working together on the satellite programs of the 1990's could not previously have been addressed by any of the individual national or bilateral missions. The mechanisms for cooperation that have been set up have enabled scientists, program managers, engineers, technicians, and senior agency officials from many countries to come together in a single working forum to share their expertise and scientific vision. Thus the groundwork has been laid for a decade of unprecedented scientific achievement in expanding human understanding of the complex processes of the highly interactive system that we call geospace.

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