THE GLOBAL GEOSPACE SCIENCE PROGRAM AND ITS INVESTIGATIONS

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(Received 7 October, 1993)

Abstract. The detailed study of the solar-terrestrial energy chain will be greatly enhanced with the launch and simultaneous operation of several spacecraft during the current decade. These programs are being coordinates in the United States under the umbrella of the International Solar Terrestrial Physics Program (ISTP) and include fundamental contributions from Japan (GEOTAIL Program) and Europe (SOHO and CLUSTER Programs). The principal United States contribution to this effort is the Global Geospace Science Program (GGS) described in this overview paper. Two spacecraft, WIND and POLAR, carrying an advanced complement of field, particle and imaging instruments, will conduct investigations of several key regions of 'geospace'. This paper provides a general overview of the science objectives of the missions, the spacecraft orbits and the ground elements that have been developed to process and analyze the instrument observations.

1. Introduction

The Global Geospace Science Program (GGS) is designed to improve greatly the understanding of the flow of energy, mass, and momentum in the solar-terrestrial environment with particular emphasis on 'geospace'. GGS has as its primary scientific objectives:

(a) Measure the mass, momentum and energy flow and their time variability throughout the solar wind-magnetosphere-ionosphere system that comprises the geospace environment.

(b) Improve the understanding of plasma processes that control the collective behavior of various components of geospace and trace their cause and effect relationships through the system.

(c) Assess the importance to the terrestrial environment of variations in energy input to the atmosphere caused by geospace plasma processes.

Early space probes like the Explorer and IMP series of satellites and more recently ISEE (International Sun Earth Explorers), Dynamics Explorer and AMPTE (Active Magnetospheric Particle Tracer Explorer) carried out *localized* studies of these regions but without the global emphasis of GGS. Geospace is defined as the near-Earth space environment and it encompasses the regions toward the Sun where the heliosphere is disturbed by the Earth's magnetic field, as illustrated in Figure 1.

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Space Science Reviews **71:** 5–21, 1995.

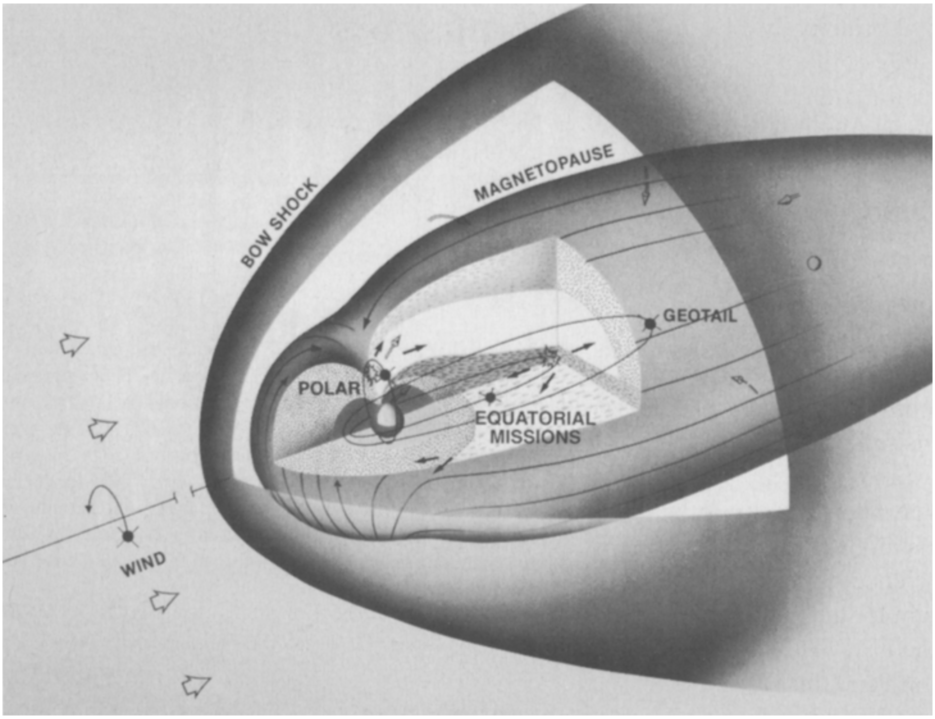

Fig. 1. The Earth's geospace environment. The interaction of the solar wind with the Earth's magnetic field creates a supersonic shock wave and a magnetospheric cavity bounded by the indicated surfaces. The orbits of the GGS spacecraft are designed to provide coverage of key regions of geospace.

Single spacecraft missions have suffered in the past from the disadvantage that it is extremely difficult to separate time dependent phenomena (i.e., transient disturbances), from the spatial structures encountered along the spacecraft trajectory (e.g., magnetospheric boundaries). The spatial boundaries define several characteristic regions in geospace which play different roles in the transport, storage and evolution of mass, momentum and energy in the system. Moreover, the integrated magnetospheric system responds with poorly known cause-effect relationships to perturbations induced by solar activity (see for example, Akasofu and Chapman, 1972; Kamide and Slavin, 1986; Hargreaves, 1992).

Mass, momentum, and energy are carried by the charged particles that comprise the solar wind and some of these particles can enter the Earth's magnetosphere. This coupling between the Sun and the Earth has been known for many years as it is best evidenced by the spectacular auroral phenomena which are visible at high latitudes in the southern and northern hemispheres (see Frank and Craven, 1988; Meng, Rycroft, and Frank, 1989). This complex energy chain, from the Sun's interior through the corona, the interplanetary medium and the magnetosphere, and its ultimate deposition in the Earth's atmosphere is illustrated in Figure 2. Several spacecraft names are associated with the blocks in the figure to indicate the missions that principally address the particular region of solar-terrestrial space. The overall study of this energy chain is a daunting task which cannot be undertaken by a single nation alone. The recognition of this fact led to the concept and development of the International Solar Terrestrial Physics Program (ISTP), an international effort designed to coordinate solar-terrestrial research in a synergistic manner, taking advantages of the unique resources and already planned space missions by the United States, Europe, and Japan.

The Global Geospace Science Program is the US contribution to the ISTP Science Initiative. It was designed to address the goal of *detailed understanding* of the global features of the geospace system by integrating a number of key elements in its planning. First, the acquisition of coordinated and concurrent data from spacecraft placed in key orbits that allow the synergistically selected onboard instruments to sample simultaneously the principal regions of geospace where energy and momentum are transported and stored. These key regions are the upstream interplanetary medium (WIND), the geomagnetic tail (GEOTAIL, provided by Japan), the polar regions (POLAR) and the equatorial magnetosphere (equatorial science, originally covered by the EQUATOR spacecraft). Second, the incorporation for the first time of theory and global models as an integral part of the program, to allow the prompt and ready interpretation of the spacecraft measurements. The third and final component of the GGS Program is the development of a Central Data Handling Facility (CDHF) for the purpose of processing, storing and distributing the GGS data sets to the investigators in a rapid and cost effective manner. This concept makes use of advanced data processing, management and visualization tools which address the problems experienced with previous mission data sets in this area. The fundamental objective of obtaining a detailed understanding of the global geospace system is therefore facilitated as never before.

The US GGS Program is thus made up of the WIND and POLAR spacecraft and instruments, theory and ground-based investigations and data sets obtained from equatorial spacecraft operated by the National Oceanics and Atmospheric Administration (NOAA) and the Los Alamos National Laboratory (LNAL). The NASA GGS Program, the Solar Terrestrial Science Program (STSP) of the European Space Agency (CLUSTER and SOHO spacecraft) and the Japanese Institute of Space and Astronautical Science (ISAS), (GEOTAIL spacecraft), are all part of the ISTP effort. Additional contributions are planned from the former InterCosmos organization (IKI) of Russia, and other international efforts coordinated through the Inter-Agency Consultative Group (IACG). The IACG was formed by NASA, ESA, ISAS, and IKI to coordinate the space missions to comet Halley in 1986. After successfully accomplishing this task, the IACG selected the coordination of solar-terrestrial research as its next objective (see article by E. Whipple, this issue). The Max Planck Institute for Extraterrestrial Physics in Germany is also planning to build and launch a small spacecraft (EQUATOR-S) designed to support *in-situ* equatorial measurements and recover some of the objectives originally

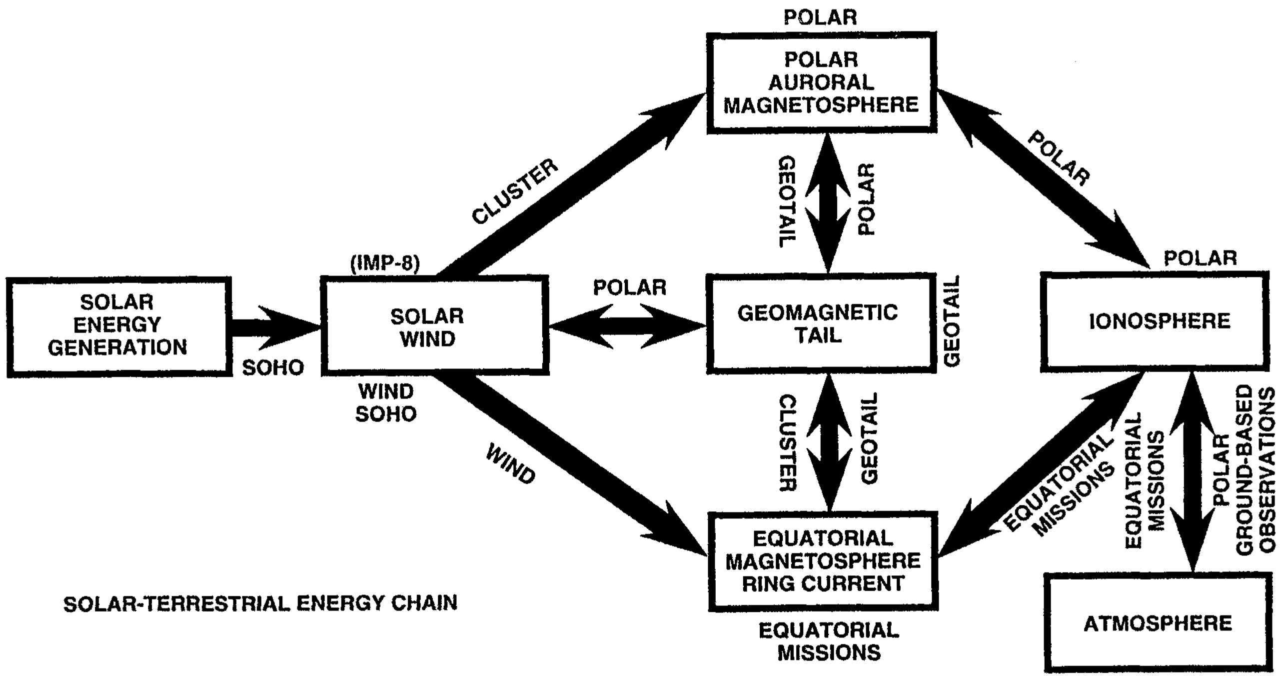

Fig. 2. The solar-terrestrial energy chain. The Sun's energy flows from the interior through the photosphere, corona and interplanetary medium to the vicinity of the Earth where it interacts with the geomagnetic field and atmosphere.

assigned to the EQUATOR spacecraft. Finally, and although not a formal part of ISTP, significant data sets and scientific contributions are also expected from the Solar Terrestrial Energy Program (STEP), a program of the Scientific Committee on Solar Terrestrial Physics endorsed by the International Council of Scientific Unions (ICSU).

This issue describes the WIND and POLAR spacecraft, the scientific experiments carried onboard, the Theoretical and Ground Based investigations which constitute the US Global Geospace Science Program and the ISTP Data Systems which support the data acquisition and analysis effort. The scientific instruments carried aboard the GEOTAIL spacecraft, an integral part of the ISTP/GGS program supported by Japan and which was launched on 24 July, 1992, are described in the 'Geotail Prelaunch Report' (1992), while complete descriptions of the experiments and investigator teams for the CLUSTER and SOHO spacecraft are given in 'CLUSTER: Mission Payload and Supporting Activities' (1993) and 'The SOHO Mission: Scientific and Technical Aspects of the Instruments' (1988). Tables I–V summarize the investigations, Principal Investigators and Institutions associated with the GGS Science Teams.

2. The WIND and POLAR Spacecraft and Their Orbits

WIND and POLAR are cylindrical, spinning spacecraft of traditional design which will be launched by DELTA II vehicles from the Cape Canaveral Air Force Station, Florida, and the Western Space and Missile Center in Vandenberg, California, respectively. WIND spins at 20 r.p.m. to allow the instruments to sample the ambient charged particle distribution function with good time resolution while POLAR spins at 10 r.p.m. to accommodate the requirements of a despun platform where visual, ultraviolet and X-ray wavelength imagers and specialized charged particle instruments are mounted (see papers by Frank *et al.*; Torr *et al.*; Imhof *et al.*, this issue). Both spacecraft have been implemented with stringent electrostatic, magnetic and electromagnetic constraints to minimize potential interference with the sensitive measurements carried out by the scientific instruments. The spacecraft record the science and engineering data on magnetic tape recorders which are then played back to the ground during tracking passes. There is no requirement for either spacecraft to provide real time science data; however, they can be operated in this mode for limited periods of time when ground tracking facilities are available. This capability is important if the WIND spacecraft is to be used as an early detection and warning system for disturbances induced by solar activity, a desired objective of the Forecast Center of NOAA's Space Environmental Laboratory. Detailed engineering design features of the WIND and POLAR spacecraft and their subsystems are given in the article by Harten and Clark (this issue).

The initial orbit selected for WIND is based on a general class of orbits commonly called 'double lunar swing-by' (Farquhar, 1991) due to the fact that the

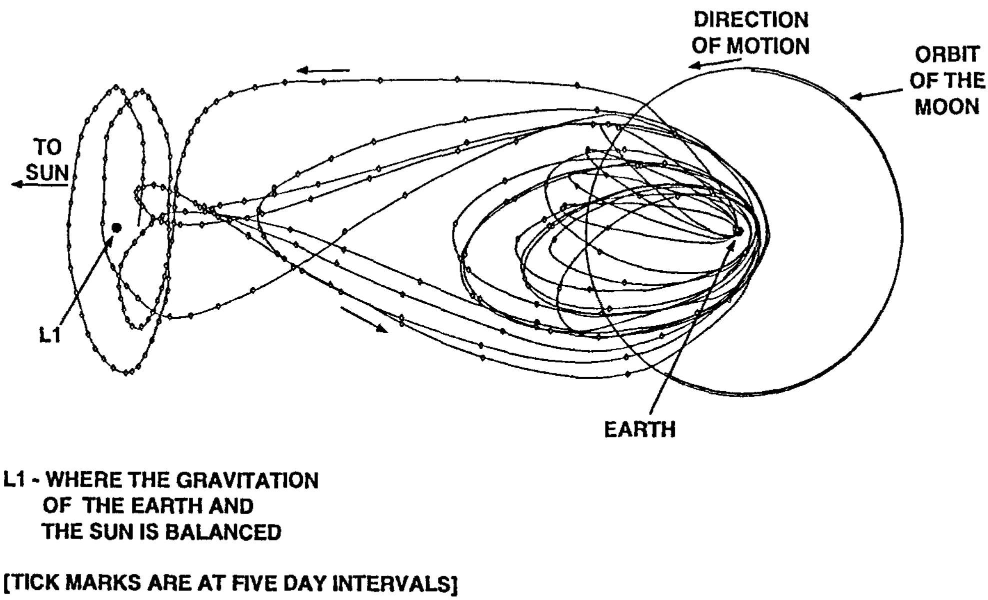

Fig. 3. The selected orbit for the WIND spacecraft. Periodic encounters with the Moon are used to maintain the apogee near the Earth–Sun line ('double lunar swing-by's'). The final orbit is a 'halo' orbit around the $L1$ libration point.

gravitational attraction of the Moon is used through periodic encounters with the spacecraft to maintain the semi-major axis of the orbit roughly aligned with the Earth–Sun direction during the entire mission. The WIND orbit is illustrated in Figure 3 and was selected by the Science Team for the purpose of providing a radial mapping of the interplanetary medium and the Earth's foreshock region by the onboard instruments at the beginning of the WIND mission. After a preselected time has elapsed (6-12 months), the WIND spacecraft will be placed in a 'halo' orbit around the Lagrangian point (L1) between the Earth and the Sun (Farquhar, 1970) utilizing the onboard propulsion system which has a total delta-V capability in excess of 500 m s^{-1}. The halo orbit was used in the recent past to maintain the ISEE-3 spacecraft at the Lagrangian point to act as an upstream monitor of solar wind conditions (Ogilvie *et al.*, 1978) and is intended as well for ESA's SOHO spacecraft since it allows continuous remote sensing of the Sun's corona and photosphere without periodic perturbations induced by the rotation of the Earth as in ground based observatories. The double lunar swingby technique has also been used by the GEOTAIL spacecraft to maintain its orbit apogee continuously in the geomagnetic tail, as shown in Figure 4.

For scientific reasons which are related to the ability to predict conditions at the Earth's orbit based on observations carried out at the $L1$ point, it is desired that the semiaxes of the final halo orbit achieved be as small as possible. However, the minimum distance is bounded by a limit dictated by communications requirements

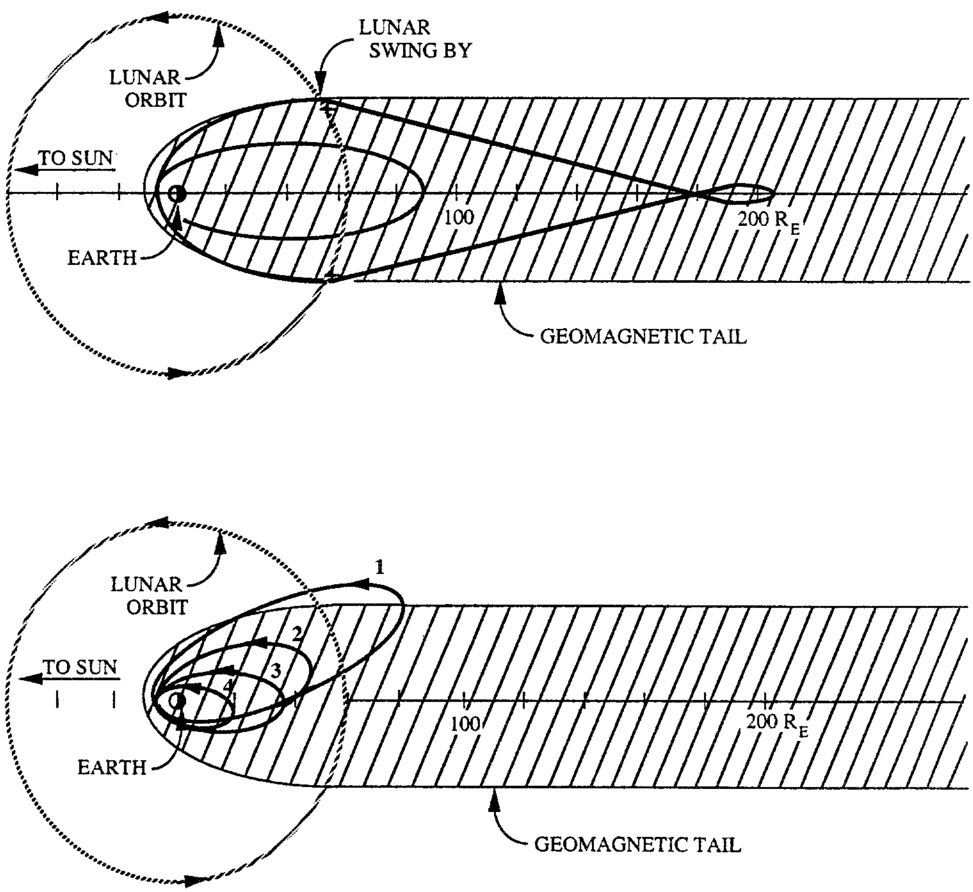

Fig. 4. The GEOTAIL orbit is similar to the WIND orbit except that lunar swingby maneuvers are used to maintain the apogee inside the geomagnetic tail. The initial orbit reached distances in excess of 200 R_E. In the fall of 1994 the apogee of the GEOTAIL orbit will be reduced to approximately 30 R_E.

such that ground-based antennas tracking the spacecraft do not have to point close to the Sun which is a very powerful noise radio source and would interfere with command and data acquisition functions. An additional constraint that must be satisfied by the double lunar swingby orbit is that eclipse-induced shadows must not last for more than 90 min at any time during the prime mission in order to maintain thermal and power design constraints on the GGS instruments and spacecraft. To maximize the performance of the onboard scientific instruments and the communication system, the WIND spin axis will be maintained perpendicular to the ecliptic plane to within ± 1 deg. Particular attention was placed on building a magnetic, electrostatic and electromagnetically clean spacecraft. The accurate measurement of very low energy plasmas and weak electric and magnetic fields imposes significant system level requirements on the spacecraft due to the sensitivity of the science instruments. All exterior surfaces including thermal blankets, solar cells and control paints are conductive to ensure the equipotential behavior of the spacecraft as well as an excellent Faraday shield for electric field radiation shielding. Long booms place the magnetometers and search coil sensors away from the main spacecraft body to reduce interference to a minimum.

The POLAR spacecraft is similar in design to WIND except for the addition of a despun platform and a real time data rate capability that is an order of magnitude greater (56 KB s^{-1}), as required to support the imaging investigations. POLAR will be placed in a 90 deg inclination, elliptical orbit with a 9 R_E apogee and a 1.8 R_E perigee, as shown in Figure 5. Initially and during the prime mission, the orbit apogee will be located over the north polar regions but with a small (10 deg or less) southward tilt towards the Earth–Sun line. This is required by the visible, ultraviolet and X-ray imaging experiments carried onboard (Torr *et al.*; Frank *et al.*; Imhof *et al.*, this issue) whose prime objectives are to acquire images and carry out a quantitative assessment of the energy deposited in the auroral region. Over the life of the POLAR mission, orbital mechanics will cause the orbital line of apsides to precess slowly to higher latitudes, swing over the north pole and continue southward. However, the perigee altitude is sufficiently high such that the maximum precession rate is less than 10 deg yr^{-1}. Like WIND, POLAR carries a propulsion system with 500 m s^{-1} delta-V maximum capability. This system will be used to perform attitude re-orientation maneuvers every six months and to raise the initial injection perigee from a few hundred kilometers to the 1.8 R_E desired by the Science Team to sample the auroral particle acceleration region. The attitude maneuvers are required because the POLAR spin axis will be placed normal to the orbit plane to allow the imagers to view the high latitude regions almost continuously, and to enable the particle instruments to map the complete charged particles distribution function, including the loss cone (Roederer, 1970). As the Sun angle changes during the year, the amount of power generated by the solar array will vary. To maintain adequate power margins and to satisfy the thermal requirement that the despun platform not be exposed to the sun for extended periods of time, the POLAR spacecraft spin axis orientation will be 'flipped' 180 deg every six months using the onboard propulsion system.

3. The Science Instruments

The complement of instruments and investigations associated with the GGS Program and summarized in Tables I–V are representative of the state-of-the-art in the field of experimental and theoretical space and magnetospheric physics research. These investigations were competitively selected by NASA in 1980 in response to an Announcement of Opportunity for the then planned Origin of Plasmas in the Earth's Neighborhood (OPEN) program which would have involved four space-

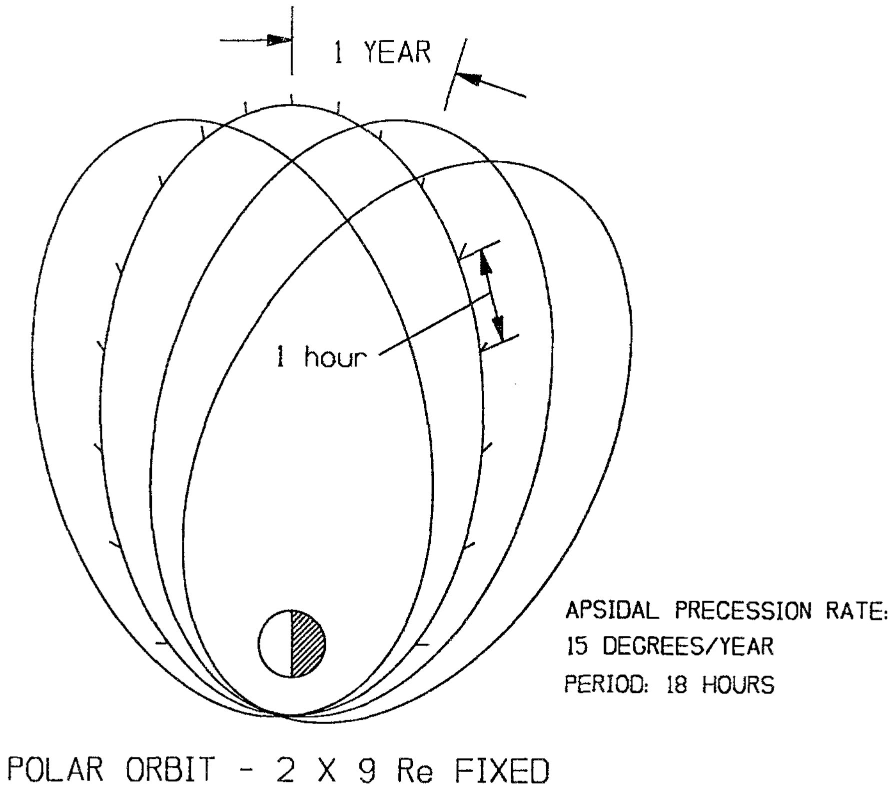

Fig. 5. The POLAR spacecraft orbit. This orbit was selected as a compromise among conflicting requirements by imaging and charged particle investigations.

craft strategically placed in the four key geospace regions discussed earlier. The evolution of the OPEN program into an international collaboration caused the reorganization of several selected science teams and also led to the decision to replace some of the spacecraft and instruments with contributions from international partners like the Institute of Space and Astronautical Science in Japan who provided the GEOTAIL spacecraft. In addition, budget and schedule limitations led NASA to delete the EQUATOR spacecraft and its investigations originally proposed for the OPEN program, and the decision to utilize data from existing, orbitinq spacecraft and ground-based measurements in its place.

Other significant changes for the science experiments involved the POLAR despun platform. Initially it was conceived as a two-axis despun system to allow imaging as well as the positioning of narrow field of view particle detectors along the ambient magnetic field line thus making possible the mapping of the cor-

TABLE I
WIND

Investigation	Principal investigator	Institution
Radio and plasma waves	J. Bougeret	Paris Observatory
Solar wind experiment	K. Ogilvie	Goddard Space Flight Center
Magnetic fields investigation	R. Lepping	Goddard Space Flight Center
Energetic particle acceleration, composition, and transport	T. von Rosenvinge	Goddard Space Flight Center
Solar wind ion composition study, the 'mass sensor', and suprathermal ion composition study	G. Gloeckler	University of Maryland
Three-dimensional plasma analyzer	R. Lin	University of California at Berkeley
Transient gamma-ray spectrometer	B. Teegarden	Goddard Space Flight Center
Gamma-ray spectrometer	E. Mazets/T. Cline	Ioffe Institute, Russia/Goddard Space Flight Center

TABLE II
POLAR

Investigation	Principal investigator	Institution
Magnetic fields experiment	C. Russell	University of California at Los Angeles
Electric fields investigation	F. Mozer	University of California at Berkeley
Plasma waves investigation	D. Gurnett	University of Iowa
Hot plasma analyzer	J. Scudder	University of Iowa
Thermal ion dynamics experiment	T. Moore	Marshall Space Flight Center
Toroidal imaging mass-angle spectrograph	E. Shelley	Lockheed Palo Alto Research Laboratory
Charge and mass ion composition experiment	T. Fritz	Boston University
Comprehensive energetic-particle pitch-angle distribution	B. Blake	Aerospace Corporation
Ultraviolet imager	M. Torr	University of Washington
Visible imaging system	L. Frank	University of Iowa
Polar ionospheric X-ray imaging experiment	W. Imhof	Lockheed Palo Alto Research Laboratory

responding charged particle loss cone. However, power, mass and other design considerations led to the simplified single-axis despun platform currently implemented in this spacecraft.

TABLE III
GEOTAIL

Investigation	Principal investigator	Institution
Electric fields detector	K. Tsuruda	Institute of Space and Astronautical Science
Magnetic Fields Measurement/ Geotail Inboard Magnetometer	S. Kokubun/M. Acuña/ D. Fairfield	Nagoya University Solar Terrestrial Environmental Laboratory/Goddard Space Flight Center
High-energy particles	T. Doke	Waseda University
Low-energy particles	T. Mukai	Institute of Space and Astronautical Science
Plasma waves investigation/ Multi-channel analyzer	H. Matusumoto/ R. Anderson	Kyoto University/ University of Iowa
Energetic particle and ion composition	D. Williams	The Johns Hopkins University Applied Physics Laboratory
Comprehensive plasma investigation	L. Frank	University of Iowa

TABLE IV
Ground-based

Investigation	Principal investigator	Institution
Canadian auroral network for the origin of plasmas in Earth's neighborhood program unified study	G. Rostoker	University of Alberta
Satellite experiments simultaneous with Antarctic measurements	J. Dudeney	British Antarctic Survey
Sondrestrom radar	J. Kelly	Stanford Research Institute
Dual auroral radar network	R. Greenwald	The Johns Hopkins University Applied Physics Laboratory

The evolution of the technology of imaging charged particle detectors during the long period between investigation selection and the start of the implementation phase introduced new elements in the development of the GGS instruments. To recover the science capability lost with the single axis despun platform design and to bring the instrumentation to 'world class science' levels, major design updates and science enhancements were allowed by the GGS Project Office in almost all GGS experiments immediately following the selection of the prime contractor in 1988. Not only additional new technology detectors were incorporated in the instruments, but advanced data processing techniques were added to their data processing units

TABLE V
Theory and Modelling

Investigation	Principal investigator	Institution
Mission-oriented theory	M. Ashour-Abdalla	University of California at Los Angeles
Theory, modeling, and simulation support	D. Papadopoulos	University of Maryland
Theory, simulation, and modeling	M. Hudson	Dartmouth College
Modeling of the atmosphere-magnetosphere-ionosphere system	M. Rees	University of Alaska

made possible by technological developments and devices which were non-existent or high risk at the time of investigation selection. Similar 'enhancements' were implemented in the ground based and theoretical investigations as well.

The GGS instruments cover a very large dynamic range of measurement capability in the areas of electromagnetic fields, plasma and energetic particles, global auroral imaging and cosmic and gamma-ray bursts. The applicable spectral coverage and dynamic ranges are summarized in Figure 6. The requirement to acquire simultaneous data from several spacecraft as a requisite for scientific success led to a strategy of overlap coverage in particle instruments and partial and full redundancy in imaging and electric and magnetic field detectors to prevent catastrophic single point failure modes. In addition, several technological factors drove the conceptual design of the instruments. First and foremost was the ready availability for spaceflight use of microprocessors and memory devices. In contrast, while ISEE3 contained a single microprocessor based instrument with a total of 512 bytes of storage, the averaqe GGS instrument incorporates at least two microprocessors and several tens of kilobytes of memory. Thus the concepts of 'microprocessor control' and 'flight software' took a whole new dimension, allowing an unprecedented versatility in the achievement of desired performance characteristics and in the operational philosophy for the GGS science instruments. Second and distinct from previous spacecraft, WIND, POLAR, and GEOTAIL are operated in the 'store and dump mode'. This implies that there exist long periods of time (e.g., 24 hr for WIND) when the spacecraft are not in contact with the ground controllers and the instruments must be designed to 'safe' themselves if any anomaly occurs. This requirement for autonomous response to faults was not present in previous missions of this type.

The following papers describe the instruments in detail as well as their outstanding performance characteristics which are expected to yield data of unprecedented scope and quality essential to accomplish the GGS science objectives. The global GGS data sets and the specialized ISTP contributions, interpreted in the frame-

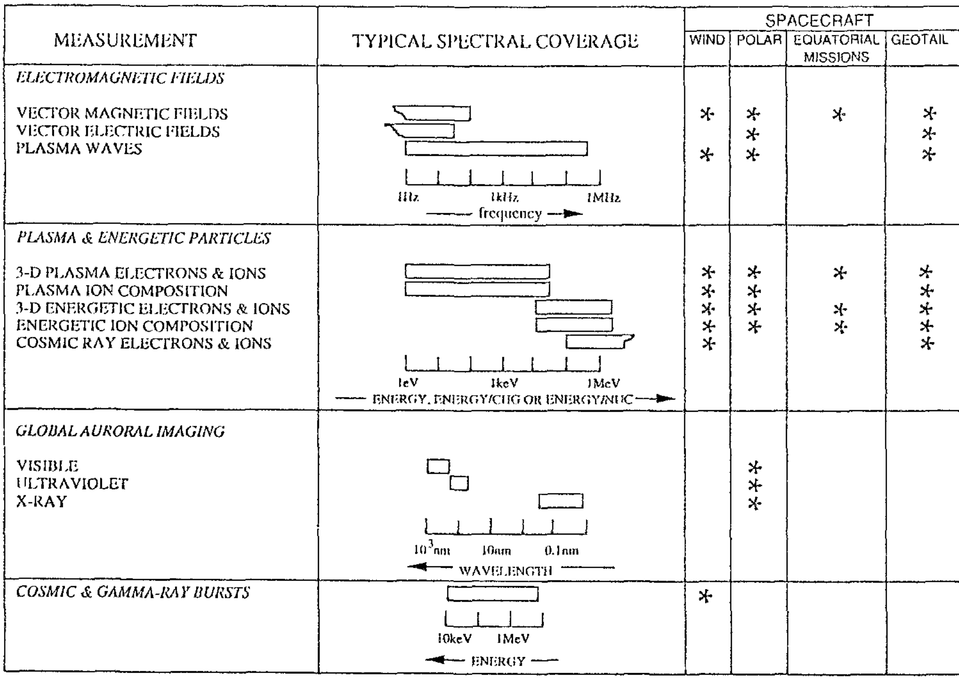

Fig. 6. The measurements, spectral coverage and dynamic range of the GGS flight instruments. Significant overlap redundancy exists among similar classes of experiments.

work provided by the models and theoretical investigations, are expected to lead to the detailed understanding of the global geospace system behavior as well as that of many incomplete and poorly known phenomena such as magnetic field line merging and reconnection, the triggering mechanisms for magnetospheric substorms and the production of the aurora that results from energization and flow of charged particles throughout the magnetosphere (Dyer, 1972; McCormac, 1976). Significant contributions will also be made to the study of the bow shock and solar wind flow past the Earth, and how all of the above phenomena are controlled by the interplanetary medium and ultimately by the Sun (Kamide and Slavin, 1986; Hargreaves, 1992).

The heritage of the GGS instruments and science team is extensive, beginning with the earliest spaceflight instruments developed for upper atmosphere, ionosphere and magnetosphere research. Each instrument represents the latest contribution of small, dedicated research groups associated with universities, industry and government laboratories. In contrast to the large orbiting laboratory class spacecraft, the majority of the GGS instruments are built 'in-house' and with the direct participation of the investigators and team members involved. This implementation mode, prevalent during the early years of the space program evolved significantly with the advent of very large, observatory class spacecraft, with the attending increase in complexity in terms of documentation and management requirements.

The long duration of the implementation phase of the GGS instruments (14+ years) introduced many new elements which affected significantly the cost and risk associated with each investigation. However, the instruments described in this issue illustrate the extraordinary efforts carried out by the GGS investigators in overcoming these very difficult challenges. The outstanding contributions of the large number of engineers, scientists, mathematicians, data analysts, instrument managers, software specialists and innumerable other personnel that make a complex program like GGS a success, are evidenced throughout the papers in this issue.

4. The Central Data Handling Facility and Science Planing and Operations Facility

As mentioned in the introduction and in parallel with the integration and test of the spacecraft and flight instruments, imaginative science planning and instrument operations tools, data analysis and visualization concepts are being developed to complement the measurements and promote the efficient interpretation and analysis of the data. These concepts involve ideas and products derived from a strong interaction among modellers, theoreticians, experimentalists and data processing specialists. These are described in detail in this issue in the papers by Ashour-Abdalla *et al.*, Papadopoulos *et al.*, Hudson *et al.*, Mish *et al.*, where new concepts and data products such as 'mission oriented theory', 'theory projects', 'key parameters', 'science planning tools', and others are described.

The successful achievement of the science objectives of GGS depends critically on the ultimate ability to acquire, process and analyze vast amounts of data from very sophisticated and complex instruments which may interact strongly with the carrier spacecraft. This difficult problem has been recognized for many years and addressed in a variety of ways with increasing success. One of the elements that has proven to be of high value is the prompt generation of medium time resolution, summary data sets which can be used as general indexes to the more general, high time resolution data. Typical examples of these data sets are the Dynamics Explorer 'data pool tapes', Voyager 'summary tapes', AMPTE's 'summary data tapes', etc. These data products allow the rapid assessment and selection of intervals of high scientific interest for further detailed study. This approach is driven by the fact that the typical ratio of data volume analyzed in detail to the total data volume generated is usually small. For the design of the GGS system, this ratio was estimated at a ten percent average over the total investigation complement. This fraction has been organized in terms of 'Key Parameters' selected for each investigation from recommendations of the Science Working Group and Principal Investigators. These data have a typical time resolution of 1 to 3 min and reflect fundamental geophysical parameters and time series associated with each investigation. A summary of the GGS Key Parameters for each GGS investigation is given elsewhere in this issue in the paper by Mish *et al.* It is extremely important to note that these Key

Parameters are uncalibrated, utilize 'predict' orbit and attitude data rather than actual, processed values and hence cannot be used for formal scientific work. Their fundamental utility lies in the fact that they are processed immediately following data reception at NASA' s Goddard Space Flight Center and made available for scientific assessment within 48 hours of acquisition. Thus, a prompt analysis of the Key Parameters can be used to respond to changing geophysical conditions or solar events, reconfigure the operating modes of the science instruments and evaluate potential high interest periods for further study. A secondary, engineering function of the Key Parameters is to provide a quick assessment of the performance of the instruments and to observe their operating modes for consistency with the primary science goals of the mission.

The organization that has the responsibility of processing the data acquired by the GSFC Data Capture Facility (DCF) into Key Parameters and other data products for distribution to the GGS Investigators, is the Stanley Shawhan Central Data Handling Facility, named after the late, first Director of NASA' s Space Physics Division. A block diagram of this facility and its functional interfaces is shown in Figure 7. It operates fundamentally as a 'black box' where raw data are processed routinely under central direction and configuration control into key parameters and level zero data products that are distributed to the ISTP/GGS investigators for processing at their Remote Data Analysis Facilities (RDAF's). Detailed descriptions of the functional blocks and data products are given in the paper by Mish *et al.* (this issue).

The responsibility for coordinating the science operations of the GGS instruments is handled by the Science Planning and Operations Facility (SPOF) under the direction of the GGS Project Scientists and the Science Working Group. This facility receives, analyzes and coordinates the commands requested to be sent to the instruments by the investigators with the purpose of identifying and resolving science conflicts. Engineering evaluation, instrument health monitoring and conflict resolution are carried out at the Project Operations and Control Center (POCC). The proposed instrument configuration and operational modes are formatted into short and long range 'Science Operation Plans' which are evaluated for consistency with the GGS science objectives to insure conflict-free operation of the instruments. After this process is completed, the results are passed to the Project Operations Control Center where the final 'command loads' are assembled for transmission to the spacecraft at the appropriate times and subsequent execution. To perform the functions of science coordination, conflict resolution and key parameter quality monitoring the SPOF has its disposal a number of specially developed tools in the form of geophysical data bases and models, orbit visualization and analysis software, and interactive key parameter display software. The tools, data products and software utilized by the SPOF have been designed to follow the general guidelines recommended by the Inter-Agency Consultative Group (IACG), mentioned earlier in this paper, to promote standardization and common format throughout ISTP

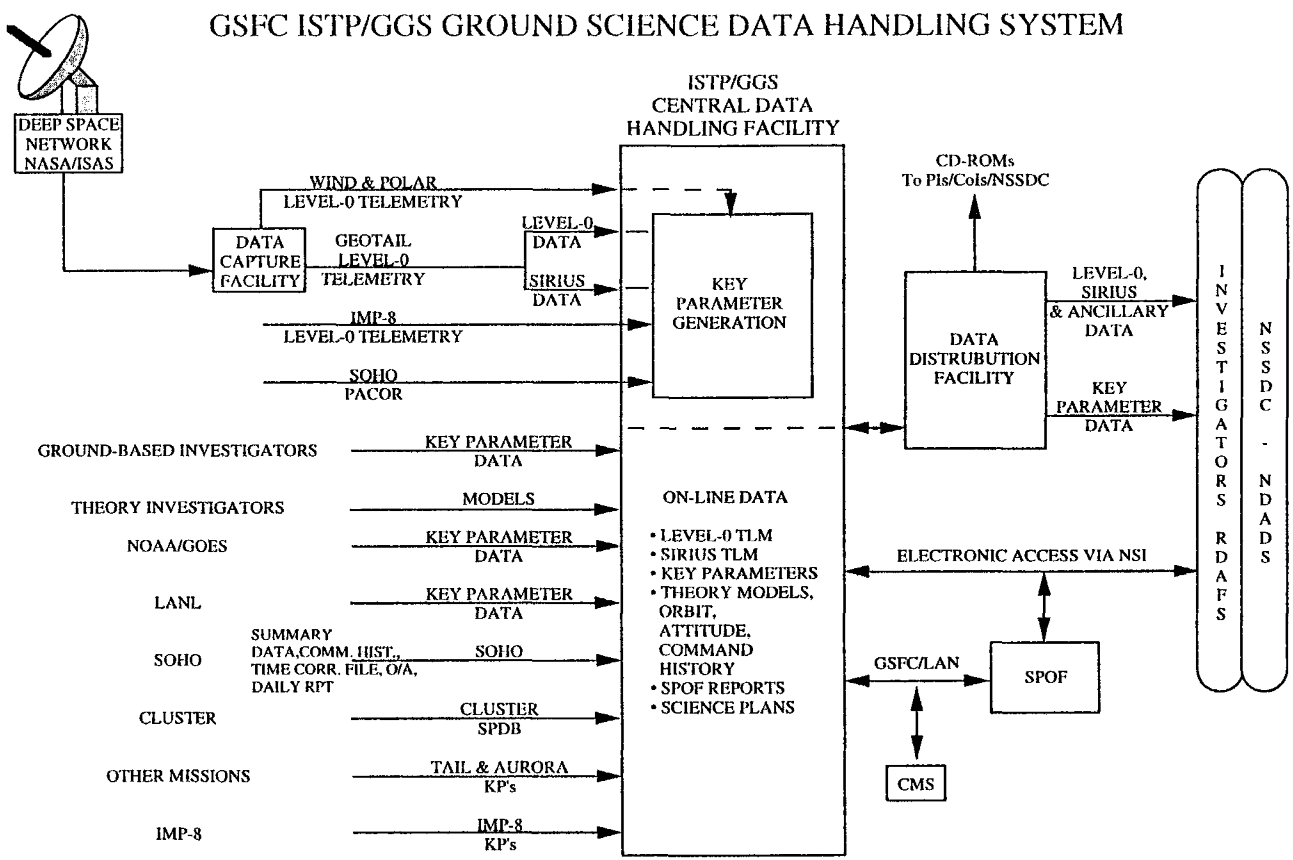

Fig. 7. Overview of the ISTP/GGS ground data system showing the serial flow of data from the spacecraft, receipt by the Deep Space Network on to the Data Capture Facility, the Central Data Handling Facility, the Data Distribution Facility and finally to the individual PI Teams for processing at the Remote Data Analysis Facilities and the NSSDC. Also shown is the Science Planning and Operations Facility, an off-line facility where the science planning is coordinated.

missions. Further descriptions of these systems and facilities are also given in the Whipple and Mish *et al.* papers (this issue).

Acknowledgements

On behalf of the GGS investigators, we would like to express our appreciation to NASA, ESA, and ISAS which have made the GGS, STSP and GEOTAIL programs possible, to the GGS Project Manager J. Hrastar for his unrelenting efforts to make the project a success, to W. Worrall and the staff of the CDHF and SPOF organizations for their outstanding efforts on the ground data system, and to the countless other personnel that have contributed over the last 14 years to this program. The outstanding coordination efforts of the National Space Science Data Center and the IACG through its Working Groups in the areas of science campaigns, the promotion of common methods, formats, data products and standards, electronic data communication, etc., is hereby recognized and appreciated.

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