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PROGRESS OF SPACE RESEARCH 1978-1979

Report submitted by the Committee on Space Research (COSPAR) of the International Council of Scientific Unions (ICSU)

Note by the Secretariat

This report is submitted by the Committee on Space Research (COSPAR) of the International Council of Scientific Unions (ICSU) in accordance with the request of the Scientific and Technical Sub-Committee for the submission of annual reports by COSPAR on scientific and technological developments in the exploration and practical uses of outer space, first made by the Sub-Committee at its twelth session in 1975 (A/AC.105/150, para. 73) and reconfirmed at its subsequent session.

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FOREWORD

COSPAR is submitting this report, "Progress of Space Research - 1978-1979" on the request of the United Nations Committee for the Peaceful Uses of Outer Space, and more specifically, that Committee's Scientific and Technical Sub-Committee. The purpose of the report is to summarize the highlights of space research activities which have been carried out between approximately mid-1978 and mid-1979. The report is based on data and information submitted by several of COSPAR's leading scientists. I wish to acknowledge here the effort they have put into preparing this report in their specific areas; these contributors are:

Prof. J.R. Arnold, La Jolla, U.S.A. (Chapter V);
Dr. E.C. Barrett, Bristol, U.K. (Chapter I);
Dr. A. Bewersdorff, Köln, F.R.G. (Chapter VII);
Prof. H.-J. Bolle, Innsbruck, Austria (Chapter I);
Dr. A.D. Danilov, Moscow, USSR (Chapter II);
Mr. E.A. Godby, Ottawa, Canada (Chapter I);
Prof. T.H. Jukes, Berkeley, U.S.A. (Chapter IV);
Prof. K. Labitzke, Berlin, F.R.G. (Chapter I);
Dr. J. Lemaire, Brussels, Belgium (Chapter III);
Dr. A. Nishida, Tokyo, Japan (Chapter III);
Dr. D.E. Page, ESA, The Netherlands (Chapter III);
Prof. L.E. Peterson, La Jolla, U.S.A. (Chapter VI);
Mr. S. Ruttenberg, Boulder, U.S.A. (Chapter I);
Dr. M.J. Rycroft, Cambridge, U.K. (Chapter III);
Prof. S.M. Siegel, Honolulu, U.S.A. (Chapter IV);
Prof. Yu.A. Surkov, Moscow, USSR (Chapter V).

Our sincere thanks also go to Dr. G. Kockarts, of Brussels, Belgium, who was so kind as to devote the necessary time to editing the contributions to this report and arranging for the typing of the body of the report at his institute.

In submitting this report, I wish to point out that COSPAR has changed its structure in June 1979, but that we will be continuing our annual reports to the Scientific and Technical Sub-Committee and, indeed, we hope that the new structure of our Committee will permit these reports, and all work put out by our Committee, to be more up to date and informative in the future.

August 1979.

Professor J.F. Denisse,
President of COSPAR.

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CHAPTER I. Remote sensing from space

1. New Technology

In this period significant advances were made in the operation of new satellites for Earth resource and environmental monitoring, in the development of reception facilities for both satellite observational data and in situ data relayed by satellites to central collection points, and in the planning of satellite systems for the future.

Prominent amongst new satellites were Nimbus-G (launched on 24 October 1978) and Tiros N (launched on 13 October 1978); the latter is being followed by its first operational counterpart, NOAA-A, in the Spring of 1979. Nimbus-G carries 8 scientific experiments, summarized in Table 1.

Of these, interest is focussed especially on ERB, SMMR and CZCS, which represent the newest concepts in environmental monitoring from satellite altitudes. SMMR and CZCS may be expected to provide the most significant new results, and, through their demonstration of new observational capabilities with regard to the hydrosphere and the state of coastal waters, to herald important new possibilities in environmental management and protection. Tiros-N also embodies major technological advances in the sensing instruments it carries, especially in its multichannel Advanced Very High Resolution Radiometer (AVHRR) and its Microwave Sounding Unit (MSU). These systems will provide more information on the state of the atmosphere primarily for operational meteorology and associated sciences, extending the well-established services of the previous polar-orbiting weather satellite families (ESSA and NOAA). Of particular significance to space missions, high altitude commercial aircraft activity, long-range communications, and electrical power distribution undertakings is the Tiros-N Space Environment Monitor (SEM), which will support more accurate alerts of high energy solar radiation levels above the atmosphere.

TABLE 1 : Instrument Summary

Instrument	Type of Device	Parameter Determonation	Discipline
LIMS-Limb Infrared Monitor of the Stratosphere	Limb Scanning Infrared Radiometer	H_2O, HNO_3, NO_2, O_3, Temperature Vertical Profiles	Pollution Meteorology
SAMS - Stratospheric and Mesospheric Sounder	Limb Scanning Pressure Modulated Infrared Radiometer	CH_4, CO, H_2O, NO, N_2O, Temperature - Vertical Profiles	Pollution Meteorology
SAM 11 - Stratospheric Aerosol Measurement	Solar Extinction Photometer, Limb Viewing	Aerosols - Vertical Profiles	Pollution, Meteorology
SBUV/TOMS - Solar and Back-scattered Ultraviolet/Total Ozone Mapping System	Sun and Earth Viewing Monochromators, Nadir Viewing and Nadir Scanning	Solar UV Irradiance, Ozone Profiles, Global Maps of Total Ozone	Pollution, Meteorology
ERB - Earth Radiation Budget	Sun and Earth Viewing Spectroradiometer, Nadir Viewing and Nadir Scanning	Solar irradiance, Flux and Radiance of Earth Reflected Short-wave and Emitted Long-wave Radiation	Meteorology
SMMR - Scanning Multi-Channel Microwave Radiometer	Earth Viewing, Microwave Radiometer, Nadir Scanning	Sea Ice, Sea Surface Temperatures and Winds, Cloud Liquid Water Content, Precipitation, Water Vapor, Soil Moisture, Snow Cover	Oceanography, Meteorology
CZCS - Coastal Zone Color Scanner	Earth Viewing Radiometer Nadir Scanning	Chlorophyll, Sediment Distribution, Gelbstoffe Concentration (Salinity), Coastal Water Temperature, Currents	Oceanography, Meteorology
THIR - Temperature Humidity Infrared Radiometer	Earth Viewing Infrared Radiometer, Nadir Scanning	Correlative Imagery for Other Experiments, Sea Surface Temperature Patterns	Supports All Discipline Investigations

A less innovative, but in its way extremely significant, development in satellite observation systems of the Earth has been the movement of a U.S. GOES (Global Operational Environmental Satellite) satellite from a "stand-by" parking position over the Americas to a new location at 60°E, over the Indian Ocean (IO) in order to make good the deficiency in the geostationary weather satellite coverage which would have resulted from the delay in the preparation of the planned Soviet satellite to cover that region of the world for FGGE (the First GARP Global Experiment). Under a special contingency arrangement, control of the moved satellite (renamed GOES-IO) has been transferred from NASA to ESA, which receives data from the satellite at a tracking station at Villafranca, near Madrid, Spain. So, the globe is now encircled by 5 geostationary satellites which are providing highly-repetitive image cover of virtually and effectively the entire circumglobal zone between about 55°N & S of the Equator.

Less happily, we must report the early demise of Seasat-A 106 days after its launch on 26 June, 1978: contact with the satellite was lost on 9 Oct. 1978 after an unexplained short-circuit drained all power from its batteries.

In the realm of satellite data reception and handling, very significant memoranda have been signed by NASA and ESA concerning the acquisition by European ground stations, and preprocessing and distribution of the resulting data, from Landsat satellites and several ESA - coordinated investigations involving data received in Europe from Nimbus-G and Seasat satellites. These provide for Landsat data to be made available to interested users by Earthnet, a European ground station network set up by ESA, whilst Seasat data are to be used by the Seasat Users Research Group of Europe (SURGE) under the auspices of the European Association of Remote Sensing Laboratories (EARSeL). Nimbus-G data will be utilized by a further group of European investigations sponsored by the Commission of the European Communities (the EEC). Data Collection Platform (DCP) networks have undergone significant extensions in conjunction with several satellites, for example Meteosat and Tiros-N. In the latter case, the Argos Service operated by CNES, Toulouse, France, in cooperation with NOAA, was switched on on 16 October 1978, with some 30 user platforms being identified during the first orbits.

Progress in the design and development of further satellite systems for the future has continued apace, for example with the French SPOT system, and the Landsat-D programme. A very significant advance in Landsat-D will be its additional 7-channel resolution and a higher spatial resolution (30 m) than its 4-channel Multispectral Scanner (MSS), which will be the same system as that flown on Landsats 1, 2 & 3 (minus the thermal channel, which, on Landsat 3, failed on 11 July 1978). Significant progress is also being made in identification of suitable experiment proposals for the Spacelab Metric Camera, from a total of 91 proposals received from 24 different countries.

2. Meteorology and climate of the troposphere

2.1. Performance of the global observing system for the first GARP global experiment, 1979

Since 1966, WG VI and its successor, WG 6 (change in numeration only) has been studying the observational requirements for a global meteorological experiment that had been suggested by the ICSU/IUGG Committee on Atmospheric Sciences, and then which became a central focus of the Global Atmospheric Research Programme (GARP). For GARP, a special joint agreement was made between ICSU and the World Meteorological Organization, and a Joint Organizing Committee (JOC) was established to provide the scientific studies and recommendations for a global experiment. Global observations were necessary so that the atmosphere could be observed in sufficient detail to be specified as an initial condition for comprehensive numerical models of the global circulation. These models, according to the original concept of GARP and the global experiment, would then be used to test the hypothesis that the large-scale components of the global circulation were determinate (i.e., predictable) to periods of one to several weeks. The test of this predictability hypothesis would be the comparison of numerically derived predictions of the evolution of the atmosphere from a given initial state, with the evolution actually taking place in the real atmosphere, as documented by the Global Observing System.

JOC turned to COSPAR and requested that technical studies be made on the feasibility of using satellites and satellite-related techniques to complement the conventional ground-based operational meteorological observing system to provide global coverage of required spacing, time sampling and accuracy. COSPAR assigned this task to WG VI/6.

It is not the purpose here to review all the iterations that took place in the JOC COSPAR dialogues, but to report that the Global Observing System, as envisaged by WG VI, at its Special Meeting, London, October 1968, and modified in several subsequent special meetings of WG 6, and as finally implemented by the various nations, did come into being late in 1978. It is functioning this year (1979) in support of the Global Weather Experiment, also called the First GARP Global Experiment (FGGE). The direct satellite contributions to FGGE 1979 include :

- polar-orbiting operational satellites (USA, USSR) that carry infrared and microwave sounders. Radiances observations from these instruments are used to derive vertical profiles of temperature and humidity, sea surface temperature, and information on snow and ice cover. Cloud information is also obtained.

- research satellites (USA, USSR) on which experimental sounders are also used. The data from the research satellites is valuable to FGGE but is considered supplemental to those data from the operations polar orbiting satellites.

- equatorial orbiting satellites (ESA, Japan, USA) in geostationary orbits. There are five of these satellites which provide complete and to some extent overlapping coverage in the low latitudes. The satellites provide cloud images every thirty minutes or so, from which cloud tracers are selected. Sequences of the images allows wind fields to be derived from the movements of the selected clouds. The ESA satellite also carries a sensor in the water-vapor band which allows determination of water-vapor in the middle troposphere and some wind information can also be derived from these observations in areas where clouds do not obstruct the field of view. There was to have been a USSR satellite in this group, but technological delays prevented it from being implemented in time for FGGE. A spare USA satellite was brought into position to cover the Indian Ocean region, also in support of the Monsoon Experiment (MONEX); the operational responsibility for the observations and wind derivations was accomplished through the cooperation of ESA.

Other special observing systems using satellites are :

constant-level balloons supplied by the USA in the tropics, floating at a level of 140 mb. These balloons transmit randomly their call letters and on-board sensor data (pressure, temperature), which is received by the USA operational polar orbiting satellite (TIROS-N) and processed initially on-board by a special data tracking and relay package supplied by France; France takes responsibility for all the initial data processing for the various kinds of mobile stations that transmit information via the TIROS-N satellite.

- Small ocean buoys in the Southern Hemisphere. These are also located through the French data system on the TIROS-N satellite. In-situ pressure and temperature at the ocean surface levels are relayed. Some special experimental buoys have strings of thermistors that measure temperature in the upper hundred meters or so of the ocean. The development of the FGGE buoys was carried out by Canada, and a number of countries participated in the implementation of the system, through purchase of buoys, or assistance in deployment, or both.

- observations from commercial aircraft. A few commercial aircraft carried automatic data systems (wind from interial navigation systems, and air temperature) which were relayed to ground collection centers by satellites.

Non-satellite special observing systems included temporary upper-air stations in data sparse land and island regions, special aircraft with wind-finding dropsondes and special ships with upper-air stations; both of these sub-systems were intended to supply vitally needed wind data in the tropical band, ± 10° about the equator.

The operation of the satellite-based system for FGGE was largely successful. The few shortcomings, discussed below, did not jeapardize the goals of acquisition of a suitable global data set for the First Intensive Observational Period. There were to have been two USA operational polar-orbiting satellites, to provide temperature and humidity observations 4 times per day and many opportunities for the data system to track and relay data from the balloons and buoys. The first satellite, TIROS-N, showed some anomalous behavior in its first week and the follow-on second satellite was delayed while the problems were diagnosed and remedies devised. The second launch was scheduled for sometime in May, which will fulfill requirements for part of the Second Intensive Observing Period.

The tropical constant-level balloons performed well, with preliminary analysis indicating that the data are good. In one way, however, they performed too well. As a result of safety requirements (for aircraft flying in the tropics), the balloon systems contained a cut-down device such that if the balloon descended a set amount from its nominal flight altitude of 140 mb, the cut down would activate. The lower bound was set by aircraft safety requirements, and, of course, was a very conservative setting. There happened to be, during the First Intensive Observational Period, much tropical convection, reaching to high levels, and many of the balloons evidently entered such convective areas, accumulated some water or ice that forced them to descend to levels where the cut-down activated, and thus were lost. The result was that there were fewer balloons in the air at any one time than had been hoped, but a sufficient number survived to provide adequate wind information at the 140-mb level.

The gap in the coverage of the contemplated system of geostationary satellites was mentioned above. This was remedied by close cooperation between the USA agencies involved (NOAA and NASA) and the European Space Agency (ESA).

One system contemplated for FGGE was not implemented in the final plan. The WG 6 meeting at Rome (November 1970) produced a suggestion that large super-pressure constant-level balloons be used as carriers of ultra-lightweight wind-finding dropsondes. The carrier balloons would circle the tropics at stratospheric levels, in the quite constant zonal circulation there, and drop sondes on command from a ground station, relayed through a satellite. The sonde data would also be relayed through the satellite to sound collection stations. The system required some careful engineering development to keep the system simple but reliable, and reliance would also have had to have been placed on the dependability of the zonal stratospheric circulation (which undergoes the well-known quasi-biennial oscillation). It turned out, after many tests, that some engineering problems were difficult to overcome in good enough time for the decision, and, since the quasi-biennial oscillation cannot be predicted with any useful skill, it was decided to replace the proposed carrier balloon system by a combination of special ships and drop-sonde aircraft, supplemented by constant-level balloons in the uppermost level of the troposphere. The carrier balloon development, however, provided much useful knowledge for the further development of the wind-finding dropsondes used from ships and aircraft, in which the sondes are tracked by use of the world-wide system of low-frequency constant-phase radio transmitters (the Omega system).

In summary, the plans envisaged by WG VI for a global observing system, at their special meeting in 1968, actually materialized into a satisfactorily functioning system about one decade later, in support of the largest-scale meteorological experiment ever implemented.

2.2. Earth's Radiation Budget

Some twenty experts met at Alpbach, Austria, just prior to COSPAR XXI, Innsbruck, to review plans for satellite systems to observe the Earth's radiation budget, which is one of the most important elements in the earth-atmosphere-ocean-space-sun climate system.

A report, "Towards an Internationally Coordinated Earth Radiation Budget Satellite Observing System: Scientific Uses and Systems Considerations", has been issued by WG 6. The title essentially describes the contents, in which required accuracies are derived from knowledge of the elements that contribute to the Earth's radiation budget; technical considerations are given for instrument and satellite configurations to make it possible to combine observations from several satellites to obtain a coherent data field for analysis, and details are given of the USA planned three-satellite system for launch circa 1983, and plans being discussed in ESA for a European satellite to test observing principles and to provide complementary data to that to be obtained from the USA experiment.

The report recognizes that a long-term effort will be needed, longer than lifetimes of operational or research satellites, to provide data for analysis on the relations of the Earth's radiation budget to climatic variability. The technical, inter-comparison, calibration and data validation procedures recommended in this report will be a guide towards implementation of a long-term observing system.

2.3. Impact of satellite sounding data on weather forecasting

During the symposium on Remote Sounding of the Atmosphere from Space, held at COSPAR XXI in Innsbruck, 1978, the assessment of the impact that satellite sounders have on numerical weather prediction has been discussed. Satellite temperature sounder data are now used world-wide in numerical weather prediction, and are almost meeting the full requirements as defined by modelers. Their impact on the forecast has different weight in different parts of the world. It fills a wide gap especially in the southern hemisphere. In areas where the density of radiosonde stations is high, the impact of the satellite data is more difficult to assess because the numerical analysis and forecasting models are still strongly biased to the radiosonde data and their sampling mode. At this point research by different groups continues in order to optimize sounder performances by careful selection of spectral intervals and implementation of new sounding techniques especially in the microwave part of the spectrum. New models are being developed and designed more directly for satellite data.

New ideas have been developed to use meteorological data for meso-scale investigation of the atmosphere circulation, the hydrological cycle and the air-sea interaction. These were reported in other sessions which turned out to be one of the highlights of the symposium. Because of the high horizontal frequency of the measurements and with the help of interactive data processing systems it becomes possible to study the wind fields and temperature structure at a scale of several hundred by several square km.

Important new aspects which were only touched on in the symposium were the possibilities which are now opened to assess and to monitor climate parameters such as the radiation budget in which cloudiness and aerosol concentration play an important rôle. It became clear that these investigations will take on additional importance after the FGGE, from about 1983 on.

3. Earth survey

3.1. Ground receiving stations (Landsat)

Landsat 2 & 3 are still operated during the year and transmitting data on a regular basis. Landsat-D is scheduled for launch in the last quarter of calendar year 1980.

Argentina has selected a contractor for construction of their Landsat receiving station to be located near Mar Chiquita. It is expected that Landsat data will be received by the end of 1979.

Australia signed contracts for the provision of a data reception at Alice Springs and for an MSS data processing facility. Australia expects to be receiving Landsat data by December 1979 and processing it by March 1980.

Brazil reports a 20% increase in the productive Landsat data products for 1978 over the previous year. At present, INPE is producing 18,000 images and 180 CCT's per year. Data sales are made to 120 users, approximately one/fourth of which are from 20 other countries.

The Fucino station which is now part of the European Space Agency Earthnet, has acquired and archived on high density digital tape, 67,500 Landsat scenes.

The Kiruna (Sweden) station, also part of Earthnet, began acquiring Landsat data on June 1, 1978 and has acquired 4,000 Landsat scenes.

India has concluded contracts with several firms for the supply of hardware for its Landsat station to be located approximately 55 km South of Hyderabad. It is expected that the Indian Landsat Station will be in operation in the latter half of 1979.

Japan completed the antenna and building for their Landsat ground station in September 1978. A new organization called the Earth Observation Centre (EOC) has been established under the National Space Development Agency (NASDA) of Japan. The full Landsat receiving and processing facility should be ready for operation early in 1979.

The USA is planning in 1979 to use domestic communications satellites to relay data from the Landsat Ground Stations to the Goddard

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Space Flight Center and from Goddard to the EROS Data Center.

Zaire is still attempting to acquire funding for their Landsat station and is continuing to participate in Africa-wide efforts under the auspices of the Economic Commission for Africa, to establish a regional remote sensing program.

Canada is continuing to receive data from Landsat 2 & 3, and Tiros-N from its stations at Prince Albert and Shoe Cove. Data from 38 passes of Seasat were recorded at Shoe Cove during the satellite's brief life from July of October 1978.

The Regional Remote Sensing Centre at Ouagadougou is now well established. Six French-speaking students have completed a training course in Ouagadougou and are now taking a 4-month course in Remote Sensing at Laval University, Quebec. A new course at Ouagadougou for approximately 12 French-speaking students started in the spring of 1979. In July, a course for English-speaking students will be started.

As a typical example, Landsat images of intense dust storms in the USA, Iran and Pakistan were analyzed. The flow of the dust in these storms is in individual, nearly horizontal streaks, from "point" (small area, of the order of 0.01 km^2) sources. It was concluded from these studies that the predominant mechanism of these dust storms is saltation. Aerodynamic entrainment of sand particles (for which high wind velocity is required) only triggers the saltation. As soon as saltation starts, the aerodynamic entrainment is choked off through a friction increase and accompanying reduction of effective wind velocity at the surface. Saltating sources keep up their erosive action even when the wind becomes weaker, moving slowly (with the average velocity of the saltating particles, of the order of 20 cm/sec) but creating in their passage ribbons or sheets of unstable, flowing sand.

From these studies and an analysis of the depositional landforms in the Western Desert in Egypt, a better understanding has been gained in the deflation, transport and deposition by sand storms, and practical inferences can be drawn about the character and choice of location of counter measures to induce soil stability.

So far as other satellites are concerned, steady progress has been made in the development and evaluation of many environmental programmes in which an integration is sought between conventional and satellite data. About 1000 participants attended the Large Area Crop Inventory Experiment (LACIE) Symposium, in Houston, Texas, in October 1978. Very good wheat predictions were reported for Soviet harvests, but less acceptable predictions for U.S. spring wheat. On the basis of the very extensive experience gained from LACIE, the U.S. Department of Agriculture is proceeding to develop its own "World-wide Multi-crop Information System", whilst a NASA team is continuing more fundamental studies on multispectral signatures of corn, wheat and soybeans in anticipation of higher-resolution data from the Thematic Mapper of Landsat-D, which is expected to support more uniform crop prediction results.

The use of meteorological satellites and Landsat for the identification of potential locust breeding grounds in north-west Africa is being developed further prior to the planned establishment of a dedicated Unit in Algiers to be founded within the next 12 months: staff for the Unit are in training at present, arranged by the Desert Locust Control Commission (DLCC) in conjunction with the Remote Sensing Unit of FAO.

Plans are in an advanced stage of preparation for the foundation of a more comprehensive regional Remote Sensing Centre to extend the functions of the existing Training Centre at Ougadougou in Upper Volta. It is anticipated that this Unit will make intensive, multidisciplinary uses of data from meteorological and Earth resource satellites in conjunction with conventional observations. This is a cooperative project involving Upper Volta, Canada, France and the USA under the auspices of the Economic Commission for Africa. International cooperation of this kind for the establishment of regional remote sensing centres seems ideally suited to the needs of many groups of countries, especially in less developed regions, where the necessity for conventional data to be supplemented by observations from satellites is most urgent.

3.2. Oceanography

Interesting new applications of satellite observation systems are being researched currently using data from Seasat-A, the first dedicated mission concerned with detailed features of the marine environment. Seasat's synthetic aperture radar completed some 300 data-gathering passes, and provided many images of sea ice, waves and coastal conditions. The spacecraft's scatterometer provided sea surface wind speed data, and its scanning multi-frequency microwave radiometer gave sea surface temperature and wind speed data, for 99 days apiece. Seasat's altimeter and visual and infrared radiometer returned data for 70 and 52 days, respectively. The objectives of the Seasat program, a proof-of-concept mission were 3-fold, and are expected to be met in large measure :

(i) To demonstrate techniques to monitor the Earth's oceanographic phenomena and features from space on a global scale;

(ii) To provide oceanographic data in a timely fashion to scientists who study marine phenomena, and to those users who regard the oceans as a resource, namely ocean shippers, fishermen, marine geologists, etc., and

(iii) To determine the key features of an operational (full-time) ocean monitoring system.

Great benefits may be expected to accrue from the anticipated successful attainment of these goals.

4. Meteorology and climate of the middle atmosphere

The meteorology of the stratosphere and mesosphere (10-80km) is becoming increasingly important for a number of reasons. Such meteorological information is required for studies of the world climate, for long-range weather prediction studies, and for the Stratospheric Monitoring Program; the latter is expected to determine whether the stratospheric ozone layer is being depleted due to anthropogenic influences.

Stratospheric-mesospheric meteorological information, in the past, has been sketchy, and provided primarily by the meteorological rocketsonde. More recently, meteorological satellite information has been utilized, but with some caution. Within the past year, however, several complex satellites have been launched, with instruments which have the capability of providing more stratospheric meteorological and constituent information than any observational system heretofore utilized. Of prime interest is the recently launched operational Tiros-N satellite. This satellite contains the High Resolution Sounder (HIRS), the Stratospheric Sounding Unit (SSU), and the Micro-Wave Sounding Unit (MSU). A large mass of meteorological data derived from observations taken by these instruments are now being evaluated. Preliminary results are very encouraging and indicate that the satellite data may be utilized fully to aid in the programs indicated above. In combination with rocket soundings and conventional methods, satellite soundings have laid the basis for a more profound understanding of the dynamics and climatology of the middle atmosphere and the complex processes which occur during warming events in the winter. Advanced instrumentation is under development to extend the sounding capability to the distribution of a number of important constituents in the stratosphere and mesosphere which are connected to pollution and climate problems.

CHAPTER II. The Earth's Upper Atmosphere

1. Low Latitude Studies

Two rocket flights were conducted from Thumba (India) in December 1978 as a part of Soviet-Indian colloboration program for the study of ionospheric parameters in the E and F_1 layers in the equatorial electrojet region. The measurements were made during nighttime and sunrise conditions. The comparison with similar experiments made in 1975 shows that the diurnal variations of the ion composition and electron concentrations are different for periods of low and high solar activity.

Two payloads of HF quadrupole probe and VLF quadrupole probe were flown successfully in Centaure rockets from Thumba (India) in January and March 1978. Data on electron densities and electron temperature combined with data on electric fields and conductivities give a unique view of the altitude structure of the electron density and the electron temperature in the 90-130 km range for a counter electrojet day and for a normal day.

Intensive studies of electron density irregularities in the nighttime equatorial ionosphere have been made during October 1976, March 1977, and March 1978, by using VHF/UHF scintillation, airglow, VHF backscatter and satellite in situ measurements. During the development phase, irregularities with scale lengths ranging from one meter to several kilometers are excited within distinct patches at single or multiple spatial locations. The east-west dimension of individual patches varies between 100-1000 km and they extend in altitude range from a minimum of 10 km to values as large as 1000 km.

Plasma density measurements from a polar orbiting Defense Meteorological Satellite Program (DMSP) satellite at 840 km have shown the existence of significant plasma depletions near the magnetic equator in the post-sunrise hours. The phenomenon is observed regularly during magnetically quiet periods near the equinoxes. The magnitude of the depletion depends upon longitude and the time elapsed since sunrise in the lower F-region.

The electron density profiles obtained over Ahmedabad (India) during the low solar activity period of 1974-75 have been used to investigate the effects of magnetic activity on D-region ionization at low latitudes for the first time. It has been shown that the electron densities in the altitude range of 75 to 90 km are poorly correlated with magnetic activity indices like A_p or K_p. Eight moderately strong magnetic storms were observed during the period of observation. A superposed epoch analysis of these events shows that the electron density does not change significantly during either the onset or the recovery phase of the storms. This confirms that at low latitudes the energetic particle flux is insignificantly low both during geomagnetically quiet as well as moderately disturbed periods. This also suggests that the concentration of minor constituents relevant to the ion chemistry of the D-region are not affected significantly during these events.

A Centaure II rocket with payloads for measuring electron density, ion density, keV-protons and airglow photometers has been launched under an Indo-Bulgarian collaboration program in October 1978 from Thumba (India). The electron density and ion density profiles derived from these experiments reveal an exponential buildup from 90 km to the peak of the E region around 106 km, and electron density increases from a value of 2×10^2 cm^{-3} at 92 km to 1.5×10^3 cm^{-3} at 106 km i.e. a change of an order of magnitude over a height range of 14 km. This large change cannot be explained on the basis of simple photochemical considerations.

2. High Latitude Studies

Electron density profiles, taken during the "Polar High Atmosphere" program in the first quarter in 1977 over Andenes (Norway) showed a peculiar structure around 230 km altitude. Since the complex payloads made it possible to measure all relevant plasma parameters simultaneously, a detailed study of this effect was performed. The occurrence of an electron density minimum is related to a similar behavior of the total electron flux, the energy flux and the electron temperature, combined with typical variations in the electric field and the supra-thermal electron flux.

A substantial number of latitude encounters between AEROS-B and ISIS II have been studied in order to understand better the morphology and dynamics of the cleft region. The AEROS satellite, being in a sun-synchronous orbit along the 1500/0300 local time meridian, passes through the dayside cleft on every orbit, often at a highly oblique angle covering several hours of magnetic local time within the cleft. Such oblique incidence passes can be used for an analysis of local time variations along the cleft under varying levels of magnetic activity. The ISIS plasma, particle and magnetic field measurements identify the location of the cleft and field-aligned currents. The combined data sets were used to study the cleft morphology in terms of its ionospheric effects in the context of plasma convection along and through the cleft. Rapid poleward convection across the narrow cleft throat produced ionospheric signatures that are contrasted with those outside of the throat where convection is primarily tangential to the cleft. These effects depend upon variations of magnetic activity and interplanetary magnetic field direction.

About 40 rocket flights made from Heiss Island Rocket Station (USSR) were analyzed to get variations of the turbopause height from mass-spectrometer measurements. It was found out that this level in polar atmosphere varies from about 90 km up to 120 km and shows strong dependence on neutral temperature. The highest temperature corresponds to the lowest turbopause. It gives some new clues to the understanding of the origin of the turbulence in the mesosphere.

3. Sun-Atmosphere Relationships

Six Soviet and three American rockets were launched in June 1978 as a part of the first stage of the JASPIC Project. The aim of the project is to solve the well-know problem of the role of corpuscular sources in mid-latitude E-region ionization. The measurements made by both Soviet and American techniques agree and confirm the role of keV-electrons in the nighttime mid-latitude E-region ionization.

Pitch-angle distribution measurements of energetic electrons ($53 < E_e < 400$ keV) from Explorer 45 have been used to study the variation of energetic electron precipitation into the subauroral and mid-latitudinal ionosphere (L = 2...5). The variations of the trapped electron fluxes as a function of time and L-value show an increase of amplitude with increasing energy for the slot region. After the injection the 400 keV-electron fluxes need more than 12 days to come back to the quiet time level. The variation of the pitch-angle diffusion coefficient during the geomagnetic storm and the recovery phase shows a characteristic behavior. During quiet, undisturbed periods the diffusion coefficients are much higher in the slot region than outside. During the main phase this excess vanishes and there is no pronounced slot region. During the recovery phase the diffusion coefficients slowly approach their quiet time values, reacting sensitively to any new, even smaller disturbance. This behavior clearly appears for electrons with $E_e \geqslant 180$ keV and vanishes towards lower energies.

An analysis of relationships between the auroral electrojet with the mesospheric temperatures at altitudes of 51 to 90 km has been carried out for a representative high latitude location at Fort Churchill (Canada). The study reveals the existence of mesospheric temperature variations in phase with auroral electrojet intensity variations, the maximum correlations occurring with a time lag of the order of 9 to 12 hours.

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CHAPTER III. Plasmas in the Solar System

1. The Solar Wind and its Interaction

In 1978 - 1979, exciting new results have been obtained from the analysis of data from satellites and deep space probes launched in previous years (such as IMP 7 and 8, Helios 1 and 2, and Pioneer 10 and 11, Mariner 10), and from the first look at new data obtained on recently launched missions like Voyager 1 and 2, ISEE 1, 2 and 3, Pioneer-Venus, Venera 11 and 12, Prognoz 7 and Geos 1 and 2.

Concerning the microscopic properties of the solar wind, further attention has been paid to the electron distribution function and to the role of its two parts, the core and the halo. These two components have been studied using Mariner 10 data, and it has been suggested that Coulomb collisions are important for the core of the distribution, while the halo may be considered collisionless and isothermal. The occurrence of this halo tends also to be correlated with the interplanetary sector structure. It has also been shown with Helios data that intense ion-acoustic (electrostatic) waves are observed in regions with highly non-Maxwellian distributions, characteristic of double proton streams (two peaks in the proton velocity distribution).

Data on the radial dependence of the solar wind are now available for the near ecliptic heliocentric distance from 0.3 AU (Helios 1 and 2) to about 12 AU (Pioneer 10 and 11). The radial component of the magnetic field decreases as $R^{-2.10\pm0.03}$ and the tangential component as $R^{-1.29\pm0.06}$ (or $R^{-1.23\pm0.05}$ for low solar wind speeds). The main differences with Parker's model are associated with compressional interaction regions at the leading edges of high velocity streams. Non-locally generated Alfvén waves being swept out from the sun undamped have been observed in the heliocentric range 1- 3.3 AU, and the wave amplitude is found to decrease as $R^{-1.5\pm0.08}$. At very low frequencies the magnetic turbulence has also a compressional part with an amplitude decreasing with distance as R^{-1}. The fact that the radial dependence of the amplitude of the radial component fluctuations is $R^{-1.3}$ while the magnitude of the radial component decreases as R^{-2}, has been interpreted as evidence for amplification of the absolute radial magnetic flux in the solar wind. The different radial behavior of the field components and fluctuations has been interpreted as evidence for a hierarchy of vortex cells, the corresponding vorticity manifesting itself as Alfvén waves amplified as the cells undergo radial expansions as the solar wind expands away from the Sun.

Comparisons of near Earth satellite data with Pioneer 10 solar wind observations have shown that the same major features in the speed-time profile persist to distances as great as 12 AU while speed variations become, however, smaller at large radial distance. A standard deviation for the solar wind velocity of 5% at 30 AU is predicted. Voyager 1 and 2 plasma data confirm previous findings of Pioneer 10 and 11 up to 4 AU.

Important results, that have affected our understanding of the solar wind interaction with magnetospheres, were obtained from Geos 1, 2 and ISEE 1, 2 and 3. The discovery of large concentrations of oxygen ions during geomagnetic storms in the Earth's magnetosphere has given much larger importance to the Earth's ionosphere, as a source of magnetospheric plasma, than previously commonly accepted. Oxygen of terrestrial origin has also been found in the magnetosheath and in the plasma mantle, with high energies, indicating that it has undergone some accelerating process somewhere. ISEE 1-2 data demonstrate that the bow shock speed is of the order of 10 km/sec, although higher velocities are occasionally observed. The magnetopause also moves with a similar speed, but its motion is more wave-like. More and more evidence has been added using ISEE data in favour of a 'patchy' reconnection, at the magnetopause, between the Earth's magnetic field and the interplanetary magnetic field, although a detailed study of the mechanism is not yet available.

Evidence for intrusions of solar wind plasma elements into the magnetosphere has been found from ISEE 1 and 2 observations. From theoretical arguments it has been suggested that impulsive penetration of small scale plasma irregularities is strongly controlled by the orientation of their magnetization with respect to the geomagnetic field. The Plasma Boundary Layer in front of the magnetosphere has been found to extend over all geomagnetic latitudes and has been considered as the stopper region of the intruding solar wind filaments.

The solar wind interaction with other planetary objects has also received much attention as planetary missions have been flown (Venus) or are planned (cometary fly by). At the moment, however, discussion is still dominated by the data collected on previous probes. The importance of induced currents in Venus or Mercury has been studied. Magnetic induction in the ionosphere of Venus may perhaps solve disagreements on the magnitude of the intrinsic Venus magnetic moment. On Mercury, the induced currents are very important in preventing direct contact of the solar wind with the surface of the planet when the solar wind dynamical pressure increases well above the average.

2. Magnetospheric physics

The identification of the sources of ions for the ring current and plasma sheet has been an outstanding question in recent years. The ISEE-1 spacecraft is finding a significant ionospheric component for the plasma sheet far out in the magnetotail. While protons are the dominant constituent, minor ions indicate an ionospheric source by an inference technique. By comparing the ion distribution functions between protons, oxygen and helium ions, it is concluded that the low energy portion of protons in the plasma sheet originates in the ionosphere and the higher energy portion in the solar wind. Solar cycle, annual, and diurnal variations of the electron density in the plasmasphere have been studied. The presence of D^+, He^{2+} and O^{2+} in the thermal plasma ($\sim$ 1eV/e) of the plasmasphere is another important new result. The ion mass spectrometer aboard Prognoz-7 has detected oxygen ions streaming with the solar wind in the plasma mantle.

Electric and magnetic field measurements of ISEE during magnetopause crossings have shown the existence of electric field components tangential to the actual magnetopause in the rest frame of the magnetopause. These tangential electric field components were oriented with respect to the magnetopause sheet currents such that there was an electrical power dissipation of between 30 and 110 watts/km^2. This observed local level of power dissipation would correspond to a total power of 10^{12} watts if it existed over the entire front of the magnetopause, in agreement with requirements of reconnection theories.

The general dawn-to-dusk electric field in the front magnetosphere has also been measured by GEOS 1 and 2, but there is often a transition to anti-sunward flow near the flank of the magnetopause. The local time of this transition as seen by GEOS is typically 0900.

Highly erratic "turbulent" electric fields have been observed by ISEE, GEOS and S3-3 at $L > 4$ in the night side magnetosphere under disturbed conditions. The turbulence is observed when crossing auroral belt shells at both middle and equatorial latitudes. The amplitudes frequently exceed expected convection field intensities by an order of magnitude. Very strong electric fields are also observed in the evening sector by GEOS and S3-3 and have been interpreted to indicate a substantial potential drop along field lines in the upper region of the ionosphere.

The existence of $\sim$kilovolt electric potential drops (V) along auroral magnetic field lines has been well documented. An important empirical relationship has been found between the value of V and the observed energy flux (ε) carried by the precipitating auroral electrons, such that ε/V is a constant. The plasmasheet electron density can be deduced from the experimental value of this constant.

The first near-Earth release of chemicals at orbital velocities occurred over Alaska and Scandinavia. Photoionized barium immediately striated along magnetic field lines. The striated clouds were accelerated and spread to lengths of 1000's of km. They convected anti-sunward toward the midnight auroral region. Dramatic energization of the barium ions began as the ions reached an altitude of about 4000 km, with indications that the energy gain was in excess of 500 eV.

Plasma wave experiments on GEOS have detected structured ULF emissions above the proton gyrofrequency. These waves consist of a series of harmonically related emissions whose fundamental frequency is often equal to the local proton gyrofrequency. They propagate almost perpendicular to the magnetic field and have a peculiar relationship to the proton distribution function. GEOS has also detected an electrostatic wave below the electron gyrofrequency which is amplitude modulated at a VLF frequency. Such signals are accompanied by VLF electromagnetic waves at an identical frequency and are associated with an increase in the cold helium ion concentration. A survey of plasma waves in the magnetosphere has been started; active experiments continue to be conducted with controlled wave and particle emissions.

High-time resolution imaging of the aurora has been conducted on board Kyokko and EUV pictures are being taken from an altitude of about 4000 km every 128 seconds.

An important result of interest for the entire solar system is more and more evident from ISEE 1-2-3, Pioneer 10-11, Mariner 10 and Helios 1-2 data. Magnetospheres like that of the Earth and also of Jupiter are always emitting high energy protons and electrons. Jovian electrons have been observed close to the sun inside Mercury's orbit, at 10 AU, and up to 16° out of the ecliptic plane; 'terrestrial' protons and electrons have been observed at least up to geocentric distances of 200 R_E. Sources for these particles may be the standing bow shock waves and/or the magnetosphere with its changing activity.

Much work is still going on related to the Jovian magnetosphere observations made by the Pioneers. It has become clear that large changes in the solar wind dynamical pressure caused the large compression (from 100 R_j to 50 R_j) of the Jovian magnetosphere observed by Pioneer 10. It also appears that the fast planetary rotation is reflected in the flapping of the equatorial current sheet, and therefore in the motion of the magnetopause. New results are expected to come from the Voyagers' traversals of Jupiter's magnetosphere in March and July 1979.

CHAPTER IV. Life Sciences and Space Research

1. Biological test material

US-USSR Space agencies have agreed upon a program involving US participation in the Cosmos 79 flight. Fourteen experiments are projected using a variety of biological test materials from plants to quail eggs. One in-flight study will seek to repeat and extend the wild carrots cell and embryo experiments described at the Innsbruck Symposium on gravitational physiology. In addition to reexamination of "normal" carrot cell ontogeny under weightlessness, experiments will be extended to carrot tumor cells. Other aspects of this program will address rat metabolism, especially with reference to the still incomplete picture of the impact of weightlessness on the dynamics of skeleto-muscular support systems. An additional experiment,also of general significance for mammals, includes study of the mating behavior of rats under weightlessness. Ontogenetic experiments will include the embryonic development of the quail from the fertilized egg.

Still further US-USSR cooperation in space research was revealed in plans for a 1981 joint mission concerned with primates.

2. Planetary biology

The US Space Science Board is completing a study report on a strategy for research in planetary biology for the next decade. This report is expected to be published late in 1979. The Board's Committee on Planetary Biology and Chemical Evolution is concerned with the study of life, its chemical precursors, origin, evolution and present state, as well as its effect on the Earth and other planetary bodies in the solar system and beyond. Although recent interest in this field was focussed on the Viking Project, emphasis have now shifted to reflect more fundamental issues which include the rôle played by carbon in early solar system evolutionary processes and the mechanisms by which life could commence on Earth and elsewhere.

3. Detrimental activities in space

In response to a request from the *ad hoc* Panel on "Potentially Environmentally Detrimental Activities in Space" (PEDAS), Working Group 5 submitted a position statement to Prof. K. Rawer. This statement may be summarized as follows : Purely mechanical hazards of an in-space character are not within the province of this group; however vaporization of space detritus upon re-entry could introduce exotic elements into the atmosphere. Metals such as beryllium and cadmium would be a particular concern. Likewise, leakage of radioisotopes and/or the deliberate injection of specialized probe (e.g. barium) material may be viewed similarly. Chemically unstable species such as propellants would presumably exist only for brief periods of time in the atmosphere prior to transformation into innocuous substances. At current tonnages of materials introduced into space, it is not likely that any of the foregoing could be considered as an atmospheric hazard. Three biohazards which allegedly arise from space activities are discussed. These include : contamination of the planets by terrestrial microorganisms; contamination of Earth by extraterrestrial microorganisms in returned samples; contamination of Earth by mutated terrestrial microorganisms exposed to space-craft or space environments. With respect to the planet heretofore considered the best prospect for life in the solar system, Mars, the best technical assessment weighs very strongly against any possible danger from contamination of the terrestrial biosphere from space-related or extraterrestrial sources.

CHAPTER V. Planetary Science

The exploration of the planetary system by spacecraft continued in a very active phase during the period covered by this report.

1. Venus

Both the USSR and the USA carried out successful missions to Venus in 1978. These missions added a wealth of new information to our knowledge of our sister planet.

Two spacecraft, Venera 11 and 12, both consisting of both landers and flyby's, were launched to Venus in 1978. The main goals of these missions were as follows :

- study of the chemical composition of the atmosphere, emphasizing minor constituents;
- study of the nature of clouds;
- study of the thermal balance of the atmosphere;
- study of the atmospheric structure as a function of height (temperature, pressure, overloads during entry);
- study of the electromagnetic activity in the atmosphere;
- study of the upper atmosphere emissions and plasma phenomena;
- study of the gamma bursts.

The landers' payloads comprised mass-spectrometer and gas-chromatograph, spectrophotometer, back-scattering, nepholometer, X-ray fluorescent analyzer, electromagnetic low-frequency analyzer. The flyby's payloads included plasma analyzer UV-spectrometer and gamma-ray telescope.

Each lander was linked by radio to the flyby spacecraft which passed the planet at a distance of about 37,000 km. All scientific instruments operated properly and provided important scientific information. The gamma-ray telescope continues to operate after the Venus encounter, and the data stored are being correlated with the respective events registered by the Prognoz-7 Earth satellite.

The Pioneer Venus spacecraft reached Venus in December 1978. By means of an orbiting spacecraft and a series of atmospheric entry probes, it carried out a wide-ranging series of investigations on the atmosphere of the planet, the interaction with the inter-planetary medium, and by means of radar, on the solid surface. The composition of the atmosphere presents many interesting features. At the time of this report, it is widely believed, but not absolutely certain, that argon-36 is far more abundant there than on the Earth, while argon-40, as expected by most scientists, is of similar abundance in the two atmospheres. Other rare gas abundances also may suggest that, unlike the Earth and Mars, Venus has some remnant primordial gases. The total abundance of nitrogen is again similar to the Earth's. The lower atmosphere contains a significant amount of water vapour.

The solid surface of the planet shows some interesting topographic features including a great equatorial rift valley.

2. <u>Mars</u>

The observations of Mars by the Viking lander and orbiter spacecraft have continued through a complete Martian year. The condensation and vaporisation of water and carbon dioxide have been observed locally and on a global scale. Wind transport of dust has also been observed on both scales. Geological interpretation of returned images continues to yield new results.

3. <u>Jupiter and Outer Planets</u>

The Voyager 1 and 2 spacecraft continued their outward journeys during this period. At the time of writing, Voyager 1 has completed successful encounter with Jupiter and its satellites. Results will be described in our next report. The programs for both spacecraft continue.

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4. The Moon

It should be noted that scientific study of lunar samples and data, returned by U.S. and Soviet missions to the Moon, is giving results of increasing scope and significance. The chronology on the Moon forms a basis for comparison with the incompletely understood record of events seen on the surfaces of other planets and satellites.

CHAPTER VI. Space Techniques as Applied to Astrophysical Problems

1. Optical, Ultraviolet and Infrared Astronomy

The International Ultraviolet Explorer, IUE, a joint US/ESA venture, was placed in successful orbit in January 1978 and continues to operate well. The spacecraft contains a 45 cm Cassegrain telescope with spectrometers capable of 0.05 Å resolution in the 2200-3300 Å range. The spacecraft has now measured dozens of stars of many spectral types to determine physical characteristics of the stellar atmospheres and make comparisons with our Sun; has observed distant and faint galaxies with bright emission lines or UV continuum, such as the Seyfert galaxy NGC4151 and the QUASAR 3C273; and has observed absorption lines due to interstellar gas and dust from many directions. The latter will help determine the amount of material, and its atomic, molecular and ionic composition from many different directions in the galaxy. An extensive guest investigator program allows scientists from many institutions and nations to participate in the IUE.

The Space Telescope of the USA is now through a definition phase, and under construction for Shuttle launch. This instrument, which will be the definitive tool of optical astronomers in the decade following launch in 1984, contains a 2.4 meter diffraction limited telescope and a series of five instruments at the focal plane. These operate generally in the visible to UV range (0.12 to 1.1. micron), but may be refurbished with newer instruments of wider wavelength coverage, and/or better sensitivity or resolution. The telescope, and its instrument complement, will be able to "see" to a resolution of ∿ 0.1 arc/sec, and to a limiting magnitude of 29 for a point source, a factor of 10 and 30 better than that obtainable with the best ground based telescopes. This will permit attacking the most important and fundamental problems in cosmology, i.e. red-shift-distance relations, Hubble diagrams, galactic evolution, compact galaxies such as QSO's and Seyferts, etc. We will be able to "see" back in time factors of 3-5 further than hitherto possible.

At present five instruments have been approved for the telescope :

1) a wide-field/planetary camera (WF/PC);
2) a faint-object spectrograph (FOS);
3) a high resolution spectrograph (HRS);
4) a faint-object camera (FOC);
5) a precision high speed photometer (HSP)

The FOC is contributed by a European consortium, the rest are primarily U.S. instruments. Plans are being formulated for a science institute (SCI) constituted independently of NASA to operate the instruments.

The Infra-red Astronomy Satellite (IRAS), a joint US/Netherlands project, is now in the advanced stages of construction for a launch in 1981. This survey instrument will detect objects radiating in the 10-1000 μm range with sensitivities a factor of 10^6 better than previously obtained. Among other objectives, this will provide a catalog of perhaps 10^5 infra-red sources and their positions for further investigations.

Several new astronomical instruments are now in the planning stage in conjunction with the U.S. or European Spacelab programs. These include :

1) An Extreme UV Explorer (EUV) to search for sources and emission in spectral regions (100-10 Å) ordinarily thought to be obscured by galactic absorption. Results from a similar instrument on the Apollo-Soyuz flight have already indicated unexpected results from this spectral region, such as emission from Hz43.
2) A cosmic background explorer (COBE) to search for isotropics and spectral effects from the "3°K" radiation, thought to be left over from the "primordial fireball" associated with the initial explosion of the Universe ("Big-Bang theory").
3) A cooled infrared telescope (SIRTIF) to be flown on Spacelab.
4) Several UV or optical telescopes for specific investigations on Spacelab.

2. High Energy Astrophysics

The first of the series of the High Energy Astronomical Observatories (HEAO-1) was launched 12 August 1977 and re-entered the atmosphere on Einstein's 100th birthday 14 March 1979. This spacecraft, which contained a variety of instruments in the 0.1 keV to 10 MeV photon energy range, has provided many new discoveries :

1) discovery of a new class of soft X-ray emitting systems the Rs Can Ven cataclysmic binaries;
2) the most definitive measurement of the spectrum and isotropy of cosmic background X-rays in the 3-60 keV range. The spectrum over this range can be fit to a temperature of kT = 45 keV;
3) identification of over 100 sources with their optical or radio counterparts;
4) measurements of the X-ray emission of many new extragalactic sources, such as perhaps 5 QSO's, 5 BL lac sources, 30 Seyfert galaxies, as well as numerous other galaxies, and clusters of galaxies;
5) extension of the spectrum into the keV range of many galactic binary sources and extra-galactic sources. Many of these have their dominant emission in the hard X-ray region;
6) discovery of more γ-ray burst sources, and definite determinations of spectrum and time variation;
7) new results on limits to galactic center and plane emissions in the 0.5-10 MeV range. These are particularly important in view of recent cosmic-ray models developed to explain the origin of high energy ($\sim$ 100 MeV) gamma-rays as seen from COS-B.

The HEAO-2, launched November 1978, contains a grazing-incidence X-ray telescope with 30 cm diameter and 5 m focal length, with a complement of four local plane instruments. The device is working well in orbit, and has a proven sensitivity of 2 x 10^{-3} u.f.u. (UHURU flux units) in the 0.15 - 2.5 keV range. The upper limits of energy is determined by grazing-incidence optics. This is about 500 times better than the UHURU (1970) and 100 times better than HEAO-1 (1979). Already the telescope has measured the distribution of soft X-rays in the Crab Nebula, obtained important results on the 1N N -1N S curve for distant sources, determined the details of complex X-ray line emissions from hot ($\sim 5 \times 10^{6\circ}$K regions), etc. The HEAO-2 also has an extensive guest investigator program.

The HEAO-C, to be launched in November 1979, contains two cosmic-ray experiments to measure charge and isotopic compositions near geomagnetic cut-off (one of these is European) and a spectrometer to search for γ-ray lines to sensitivities $\sim 10^{-4}$ph/cm^2-sec.

The COS-B is continuing to operate well, and by the end of 1979 will have measured over 10^5 cosmic γ-rays in the 30-300 MeV range. It has now detected about 35 sources, mostly confined to the galactic plane. Four of these are radio pulsars and all show a similar double-pulsed structure, when normalized to the same time scale. The general diffuse emission from the galaxy shows correlation with cosmic-ray and gas content, but not dust distribution.

During the past year significant progress has been made in the study of the cosmic gamma-ray burst phenomenon. These short (1-30 sec) intense (to 10^{-4} ergs/cm^2) bursts of unknown origin, which were first discovered by the U.S. Vela satellite network in 1973, have a spectrum which peaks at $\sim$ 200 keV, but may well extend into the MeV range. The establishment of an interplanetary "timing" network, consisting of detectors on many spacecraft, was completed in 1978, with the HEAO, Helios, and the France/USSR collaborative experiments (the Signe III network) on Prognoz 7, and Venera 11 and 12. Already this network has established that the sources are not confined to the galactic plane, and have indicated several different classes of time morphology.

Important new space experiments in high energy astronomy under construction or planning include the European Space Agency (ESA) EXOSAT - an X-ray explorer; the joint French/USSR Gamma-1; a follower to the COS B; NASA's Gamma-Ray Observatory (GRO). This has as its objectives a factor of 10 sensitivity over the HEAO-1, HEAO-C and COS B in the 100 keV to 1000 MeV range, and is particularly designed for high resolution work. Also, a much larger grazing-incidence X-ray telescope, the 1.2 m AXTAF is being defined to follow the discoveries on the HEAO-2. Many smaller experiments on balloons, and on the Shuttle/Spacelab will continue. These are usually designed for specific observations.

3. Solar Research

NASA's Solar Maximum Mission (SMM) is now in preparation for a launch in October 1979. This spacecraft contains a set of complementary instruments to cover most solar emissions in wavelengths from 10 MeV gamma-rays to the near UV, with wavelength, spatial and time resolutions appropriate to specific objectives on the active Sun. In addition, a coronagraph will measure "moving phenomena", i.e. plasma ejection from the solar surface into the far coronal regions. This program is part of the international Solar Maximum Year (SMY) extending from August 1979 for 14 months. In addition to providing new information on correlated solar active phenomena, the program is specifically designed to make a significant attack on the problems of solar flares.

The next significant space mission is the joint NASA/ESA Solar Polar (formerly out-of-ecliptic) Mission. This two-spacecraft mission is designed specifically for high ecliptic latitudes, and the two spacecraft will view the solar heliosphere in the range from 4-1 AU, with latitudes as high as 90°. The instruments are a complement designed to study the local solar wind, solar and galactic cosmic-rays, electric and magnetic fields, radio emissions near the plasma frequency, and direct solar electromagnetic emissions, such as X-rays and UV. This will allow construction of the 3-dimensional heliosphere, and its connection to the solar surface.

The NASA Solar Optical Telescope (SOT) is now under advanced definition for an early flight on the Space Shuttle. This is an $\sim$ 70 cm diffraction-limited system, of which the objective is to obtain solar images in various wavelengths with resolutions of 0.1 arc/sec. This resolution is comparable to the scale height of the solar atmosphere.

CHAPTER VII. Materials sciences

1. Recent studies

From June 1978 through June 1979, ground based studies have reaffirmed and continued to provide understanding and insight that the virtual absence of gravity, available for prolonged periods during free space flight, can have a significant impact on a number of phenomena involving fluids. In some few cases, these studies have already involved space flight experiments, while in many more cases they are in preparation for future space flight experiments. In at least one case, the previous space experiment provided improvements in crystal perfection which upon further consideration has led to improvements in terrestrial crystal growth through the application of heat pipes to decrease thermal discontinuities.

Over last year, 5 new experiments were flown successfully aboard an American SPAR rocket and 10 in the F.R.G. TEXUS rocket. Other experiments were done on the Soviet SALYUT. A few typical results may be quoted here :

Preliminary conclusions from observations of dendrite remelting and macrosegregation indicated a marked reduction in nucleation events and an increased dendrite arm spacing on the low gravity case as compared to the terrestrial reference experiments.

In studies of the columnar-to-equiaxed microstructured transition in small samples of NH_4Cl-H_2O, the thermal effects were the most striking, with the result that the columnar to equiaxial transition was rendered impossible despite the presence of sufficient nuclei.

Remelting of composite material gave new insight into the various transport mechanisms acting in dispersed systems that can lead to regrouping and separation of components during liquid phase processing.

In the US and in the member states of ESA, about 150 projects involving more than 200 scientists primarily in academic institutions are presently in progress. The majority of them are now oriented more towards basic research and aim at demonstrating the influence of gravity on individual mechanisms that are met in materials sciences, such as

- transport of energy and matter in one- or multi-component systems
- alignment and spatial distribution in dispersions
- formation of defects in crystals
- critical phenomena

The ultimate aim of these studies and experiments, of course, will be to develop new means of control over process variables at levels not achievable on Earth.

2. Low Gravity Projects

Six means for performing low gravity research are available or being planned for the future, as follows :

1. Drop tube (approximately two seconds of weightlessness).

2. Aircraft, up to 40 seconds of weightlessness in a Keplerian parabolic trajectory.

3. SPAR and TEXUS rockets (five minutes of weightlessness in coasting flight after power cut-off; samples recovered after parachute descent); five more flights planned through 1980.

4. Materials Experiment Assembly (MEA) (up to five days in orbit in the Space Shuttle). MEA is an autonomous package which will support five experiments with a minimum of integration effort.

5. Spacelab Materials Processing Experiments (five or more days of weightlessness on the Space Shuttle); hands-on experiments operated by mission or payload specialists in a laboratory environment.

6. Materials Experiments Carrier (MEC) will be an automatic, free-flying satellite to support a large number of experiments for three or more months; will use the 25kW power module for support.

For the more comfortable opportunities 5 and 6, a number of facilities are under development, each of which is designed to serve a large number of individual experiments. Among them may be quoted : Fluid Experiments System, Solidification Experiments Systems, Process Chamber, Fluid Physics Module.

In summary, it is seen that the Microgravity Program, having completed its exploratory period, is entering a disciplined scientific phase involving careful relevant ground-based experimentation and equipment development. Promising areas and experiments have been selected and are awaiting the Shuttle-Spacelab era.

ACRONYMS

AEROS	Aeronomy Satellite
AVHRR	Advanced Very High Resolution Radiometer
CNES	Centre National d'Etudes Spatiales (France)
COBE	Cosmic Background Explorer
COS-B	Celestial Observation Satellite
COSPAR	Committee on Space Research
CZCS	Coastal Zone Color Scanner
DCP	Data Collection Platform
DLCC	Desert Locust Control Commission
DMSP	Defence Meteorological Satellite Programme
EARSeL	European Association of Remote Sensing Laboratories
EEC	European Economic Communities
EOC	Earth Observation Centre
ERB	Earth Radiation Budget
EROS	Earth Resources Observation Systems Data Center (USA)
ESA	European Space Agency
ESSA	Environmental Survey Satellite
EUV	Extreme Ultraviolet
FAO	UN Food and Agriculture Organization
FGGE	First GARP Global Experiment
FOC	Faint-Object Camera
FOS	Faint-Object Spectrograph
GARP	Global Atmospheric Research Programme
GEOS	Geostationnary Earth Orbiting Satellite
GOES	Global Operational Environmental Satellite
HEAO	High Energy Astronomical Observatory
HF	High Frequency
HIRS	High Resolution Sounder
HRS	High Resolution Spectrograph
HSP	High Speed Photometer
ICSU	International Council of Scientific Unions
INPE	Instituto de Pesquisas Espaciais (Brazil)
IO	Indian Ocean
IRAS	Infra-Red Astronomy Satellite

ISEE	International Sun-Earth Explorer
ISIS	International Satellite for Ionospheric Studies
IUE	International Ultraviolet Explorer
IUGG	International Union of Geodesy and Geophysics
JOC	Joint Organizing Committee
LACIE	Large Area Crop Inventory Experiment
LIMS	Limb Infrared Monitor of the Stratosphere
MEA	Materials Experiment Assembly
MEC	Materials Experiment Carrier
MONEX	Monsoon Experiment
MSS	Multispectral Scanner
MSU	Microwave Souding Unit
NASA	National Aeronautics and Space Administration (USA)
NASDA	National Space Development Agency (Japan)
NOAA	National Oceanic and Atmospheric Administration (USA)
PEDAS	Potentially Environmentally Detrimental Activities in Space
QSO	Quasi-Stellar Object
S3-3	(SSS) Small Scientific Satellite
SAM11	Stratospheric and Aerosol Measurements
SAMS	Stratospheric And Mesospheric Sounder
SBUV/TOMS	Solar and Back-scattered Ultraviolet/Total Ozone Mapping System
SCI	Science Institute
SEM	Space Environment Monitor
SMM	Solar Maximum Mission
SMMR	Scanning Multichannel Microwave Radiometer
SMY	Solar Maximum Year
SOT	Solar Optical Telescope
SPOT	Système Probatoire d'Observation de la Terre
SSU	Stratospheric Sounding Unit
SURGE	Seasat Users Research Group of Europe
THIR	Temperature Humidity Infrared Radiometer
UHF	Ultra-High Frequency
ULF	Ultra-Low Frequency
UV	Ultraviolet

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VHF	Very High Frequency
VLF	Very Low Frequency
WF/PC	Wide-Field/Planetary Camera
