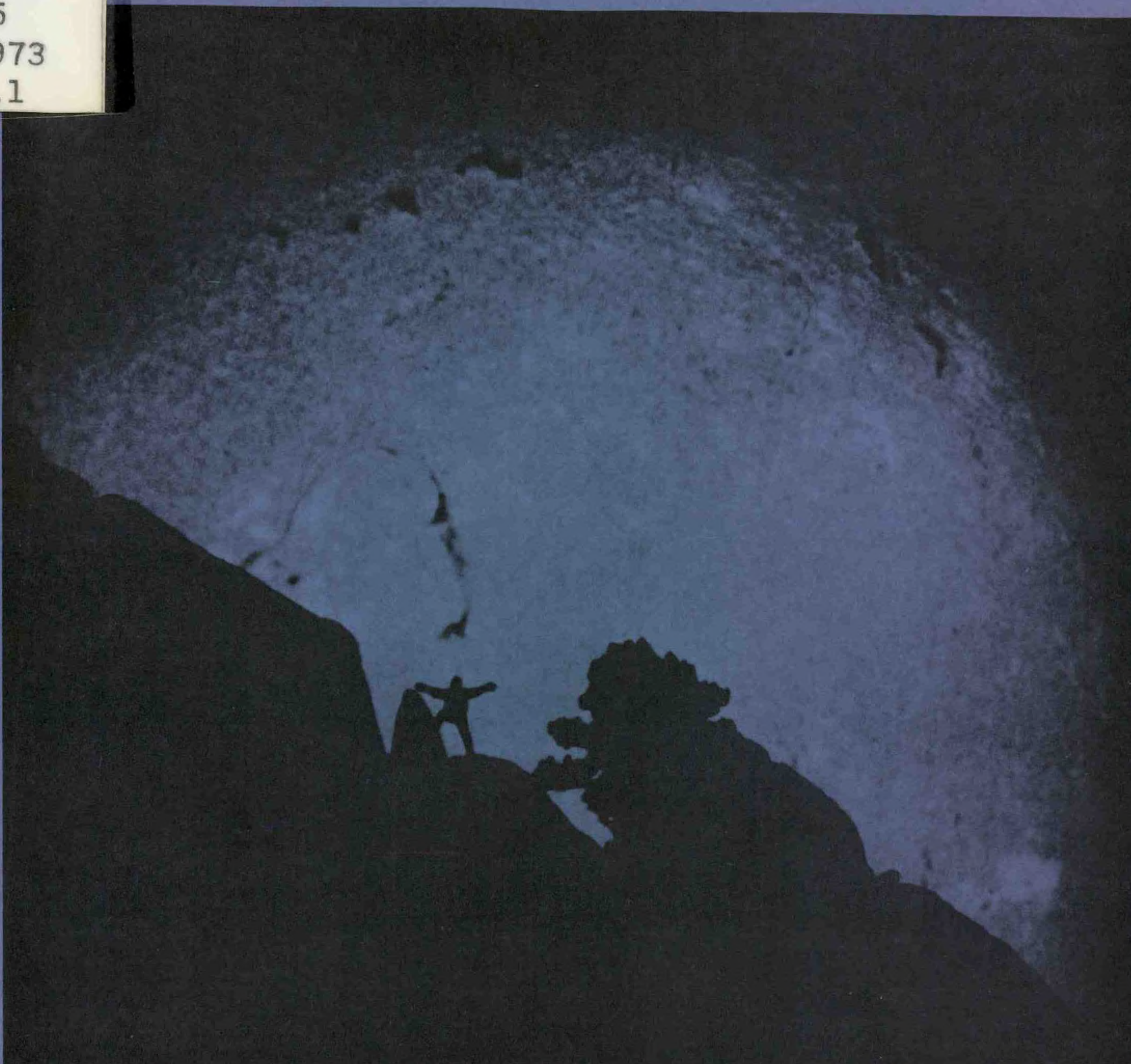

SPACE ENVIRONMENT LABORATORY

SEL CONDUCTS RESEARCH IN THE FIELD OF SOLAR-TERRESTIAL PHYSICS, DEVELOPS TECHNIQUES NECESSARY FOR FORECASTING OF SOLAR DISTURBANCES AND THEIR SUBSEQUENT EFFECTS ON THE EARTH ENVIRONMENT, AND PROVIDES REAL-TIME ENVIRONMENT MONITORING, AND FORECAST SERVICES ON A CONTINUING BASIS.

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Environmental Research Laboratories

SPACE ENVIRONMENT LABORATORY

Donald J. Williams, Director
A. Glenn Jean, Deputy Director

Boulder, Colorado
June 1973

TABLE OF CONTENTS

SPACE ENVIRONMENT LABORATORY

Donald J. Williams, Director
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INTRODUCTION

For three decades the Department of Commerce has conducted research and provided services in the field of solar-terrestrial relationships. This continuing effort has stemmed from an early recognition that the entire solar-terrestrial environment (sun-earth system) must be considered in order to understand, predict and improve man's daily interaction with his immediate earth environment. This work was first pursued within the Department by the Interservice Radio Propagation Laboratory and the Central Radio Propagation Laboratory in the National Bureau of Standards (1941), followed by the Space Disturbances Laboratory of ESSA (1965) and at present by the Space Environment Laboratory (SEL) of NOAA (1971).

Since the advent of satellite technology in 1957, great strides have been made in furthering our understanding of the solar-terrestrial environment. From the space research program conducted by the United States, Europe, and the Soviet Union, have come the discovery and mapping of the earth's radiation belts, the discovery and mapping of the earth's magnetic field configuration in space, the discovery and investigation of the nature of the interplanetary medium including the solar wind and the interplanetary magnetic field, investigations of the nature of the interaction between planetary environments (Earth, Moon, Venus, and Mars) and the interplanetary medium, and initial investigations of the planetary environments themselves (Earth, Moon, Venus, and Mars).

Not only does SEL participate in and contribute to these studies but also continues the Department of Commerce function of applying our knowledge of the solar-terrestrial environment to man's environmental needs on earth. Some of these needs can be met by (a) continued research in solar-terrestrial physics; (b) development of accurate predictive techniques to forecast impending solar disturbances and their subsequent effects on the earth environment; and (c) maintaining a real-time data base containing current information on the state of the solar-terrestrial environment. Recognition of the importance of such solar-terrestrial activity and support for its continuance has consistently been expressed at national and international space physics planning sessions for the past several years (e.g., see Woods Hole Summer Studies 1968; 1970).

Some of the environmental needs to which the SEL effort in solar-terrestrial relationships directly apply are listed below. The critical nature of these needs has developed over the past decades at a pace determined by the steadily increasing complexity and technological sophistication of society. Environmental disturbances which would occur unnoticed in society fifty years ago could easily prove to be disastrous today. These services are expected to increase in importance in coming years.

(a) *Electrical Power Distribution Systems Requirements*. Electrical power systems in the northern latitudes of the United States experience inconveniences and interruptions during geomagnetic storms. A group of electrical power companies is conducting research on the causes and effects of these disruptions. With advance warnings of magnetic storms capable of producing these disturbances in power distribution systems, the power operators and dispatchers are in a position to maintain high reliability of electric service. In the past, geomagnetic storms have been responsible for power blackouts in large cities as well as extensive interruptions in long distance telephone communications. There is a continual growing possibility that large geomagnetic storms, if not forecast, can increase the incidence of serious power interruptions especially during periods of "brown-outs", now a routine condition in the northeast U.S.

(b) *Communication Requirements*. Military and civilian programs require forecasts and real-time information concerning high latitude communication capabilities. A Memorandum of Agreement is in effect between the Department of the Air Force, Headquarters, the Air Weather Service and the Department of Commerce, NOAA, for cooperative space environmental support activities between the Environmental Research Laboratories (ERL), the Air Force Global Weather Central (AFGWC), Offutt Air Force Base, Nebraska and the Aerospace Environmental Support Center (AESC), Ent Air Force Base, Colorado. Cooperative activities under this agreement include: joint AWS and NOAA staffing of the Space Environment Services Center at Boulder and of the SEL

High Latitude Monitoring Station at Anchorage, Alaska, sharing of data and data transmission facilities, planning of joint observing programs, etc. Regular monitoring and forecasts of energetic particle events are supplied to the Concorde supersonic transport program. Extensive communication forecast and monitoring services are provided in Alaska by SEL to such users as FAA, FCC, FBI, State of Alaska Communications System, Bureau of Indian Affairs, oil industries and fisheries.

(c) *Research Requirements*. National and international space research programs require real-time and forecast support in order to optimize and, in some cases, implement a particular research mission. For example, the SKYLAB program of NASA requires SEL real-time and forecast support to determine the most promising regions of the sun to study at any particular time. Rocket programs requiring specific environmental conditions for launch also regularly utilize the SEL capability.

(d) *Radiation Hazards*. APOLLO missions require both up-to-the-minute information concerning the solar-terrestrial environment and forecasts of impending activity. As man remains in space for longer periods of time (up to 60 days in the forthcoming SKYLAB mission) these services become more critical. Future SST operation will require the prediction and measurement of radiation capable of penetrating to altitudes used by these aircraft.

MISSION

SEL conducts research in the field of solar-terrestrial physics, develops techniques necessary for forecasting of solar disturbances and their subsequent effects on the earth environment, and provides real-time environment monitoring and forecast services on a continuing basis.

Theoretical and experimental research studies are conducted in order to understand the fundamental physical process responsible for and causing, (1) the observed energy release in the form of electromagnetic and particle radiation at the solar surface during solar disturbances; (2) the propagation of this energy through the interplanetary medium to the near-earth environment; (3) the transfer of this energy from the near-earth interplanetary medium into the earth's magnetic field, the magnetosphere; and (4) the behavior and subsequent effects of this energy within the magnetosphere, the ionosphere and upper atmospheric regions. These studies are conducted utilizing data from NOAA and other agency-supported satellite experiments, rocket launches and ground-station operations.

The knowledge gathered from these studies is applied to the development of prediction techniques which are required for accurate temporal and spatial forecasting of solar disturbances and their subsequent effects throughout the near-earth interplanetary medium, the magnetosphere, the ionosphere, and upper atmosphere. These techniques when proven, together with the extensive real-time data service maintained by the laboratory, are applied directly to the routine forecasting of solar events and provide early warning and real-time information concerning the state of the solar-terrestrial and, particularly, the near-earth environment. The laboratory is the national and international focal point for current information concerning the solar-terrestrial environment and supplies this information as a continuing service to a wide variety of users.

The laboratory also provides ERL with expertise and advice concerning satellite instrumentation and interface techniques within NOAA and other agency satellite programs in the area of solar-terrestrial physics.

ORGANIZATION

The overall manpower allocation of SEL is roughly as follows:

40%	Research
35%	Services
25%	Support

This division is implemented through six Program Areas which comprise the Laboratory. These Program Areas are listed and briefly described in the following pages.

Program Area	*Leader*
Interplanetary & Magnetospheric Physics	D. Evans
Ionospheric Physics	A. G. Jean (acting)
Numerical Analysis & Computer Techniques	R. Slutz
Instrument Development	R. Grubb
Real-time Data Service	C. Hornback
Space Environment Services Center	R. Doeker

PROGRAM

In pursuing the SEL mission of understanding the solar-terrestrial environment and its impact on man and his interaction with his own immediate environment, SEL through its Program Areas has defined the following long-term goals for its research and service program:

1. The development of a physical solar-terrestrial environment model (STEM) beginning at the solar surface and extending into the upper atmosphere and lower ionospheric regions. This model will be developed and employed by researchers in order to understand the physical processes responsible for shaping the solar-terrestrial environment and governing its dynamics. STEM will also serve a key role in NOAA's solar-terrestrial environment monitoring and forecast services program.

2. The development of reliable and accurate forecasting techniques to enable our service personnel to describe the state of the solar-terrestrial environment in both the short and long range forecasts.

3. The development and operation of a flexible and effective real-time data service in order to provide accurate, up-to-date information concerning the state of the solar-terrestrial environment.

To implement the SEL research and service program, data are available from:

1. A variety of SEL experiments onboard a number of separate ongoing satellite and rocket programs. Some of these programs are OGO, IMP, S^3, ITOS/NOAA, SMS/GOES, and ATS.

2. A network of SEL operated solar observatories yielding visible, Hα, and radio noise observations of the sun.

3. An SEL spectroheliograph yielding observations on a variety of solar atmospheric lines along with a measurement of solar magnetic field strength and polarity in active regions.

4. A network of ionospheric stations near Boulder, Colorado and Anchorage, Alaska yielding observations on ionospheric absorption effects, ionospheric propagation effects at high and mid-latitudes, ionospheric structural irregularities and traveling disturbances and optical emissions from ionospheric heating experiments.

5. A number of large area antennas from which intensity observations are obtained from cosmic radio sources and interplanetary and ionospheric irregularities.

SEL is also taking an active role in the field of space environment modification. Present knowledge of certain portions of the solar-terrestrial environment is now sufficient to begin active experimentation with that environment in order to partially control processes which interact with and influence the upper atmosphere and the surface magnetic field. An example of this is SEL's proposed program of cold plasma injection at geostationary altitudes (6.6 earth radii) in order to trigger naturally occurring magnetospheric plasma instabilities. The result of such a stimulation would be the scattering of the ambient energetic trapped particle population down the field line into the ionosphere. The resulting ionospheric disturbance should be easily detected by ground instrumentation and possibly result in a visible aurora.

Such active environmental experimental programs not only will lead to a greatly enhanced understanding of man's overall environment but can also lead to a better use and protection of this environment in the future.

SEL PROGRAM AREAS

The SEL research and service program considers the solar-terrestrial environment (the sun-earth system) as a set of several strongly interacting subsystems (see fig. 1). The basic driving force for the entire system is the sun which in turn is coupled to the near-earth environment by the interplanetary medium. Energy transferred into the interplanetary medium in the vicinity of the sun will thus couple to and interact with the near-earth environment, which encompasses the region from the outermost boundary of the geomagnetic field at distances of 10 earth radii or more to the upper atmosphere at an altitude of approximately 50 km.

The interaction of the various components of this system (sun, corona, interplanetary medium, magnetosphere, plasma sheet, trapping regions, ionosphere, and upper atmosphere) produce significant environmental effects ranging from the earth's surface (induction effects due to geomagnetic storms cause large and undesirable transient effects through ground

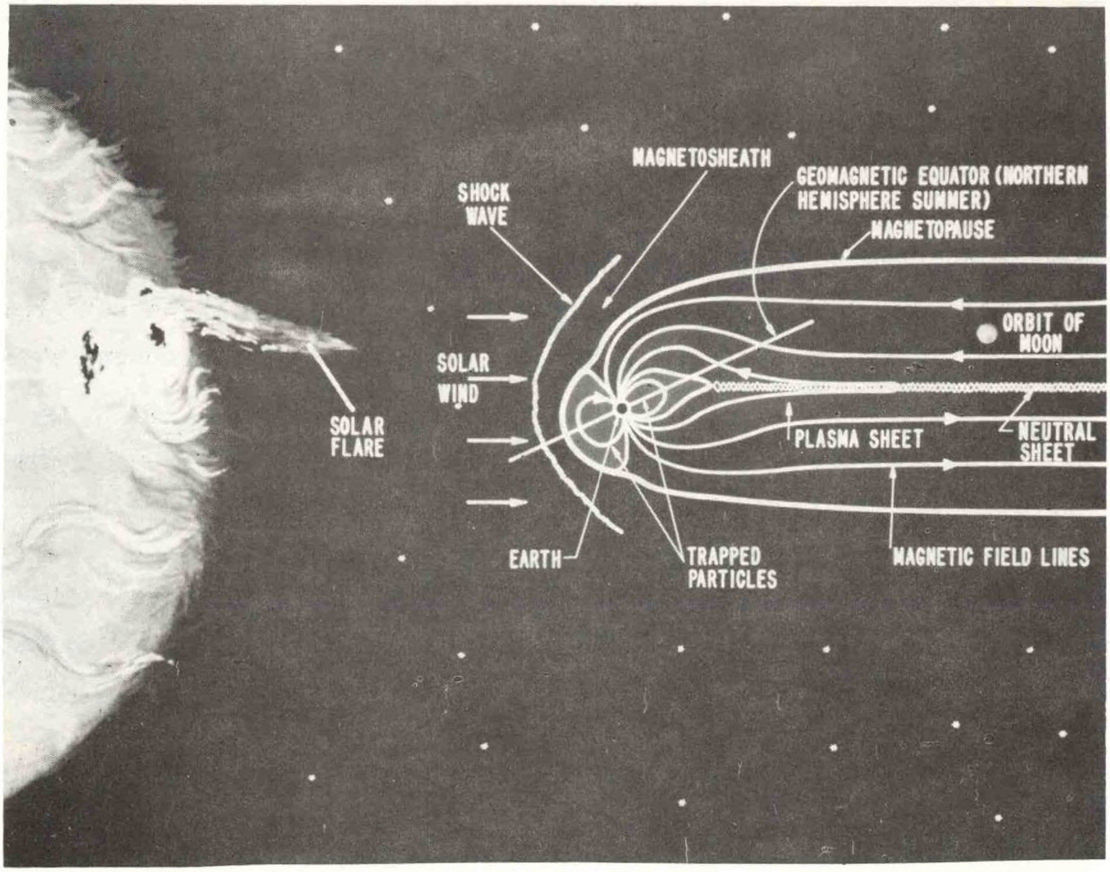


Figure 1. Diagrammatic view of the solar-terrestrial environment showing results of the interaction between the earth's near-dipole like field and the solar wind. Not shown on this scale are the ionosphere and its interaction with the magnetosphere, the earth's resulting field configuration contained within the magnetopause.

power distribution systems), through the atmosphere (increased ionization and radiation from high-energy solar protons; large scale atmospheric variations correlated to transient energy inputs in the upper atmosphere), and on into the ionospheric regions controlling radio propagation (spatial and temporal variations in ionospheric parameters due to solar flare short and long term wavelength emissions, particles precipitated out of the radiation belts, and low energy solar protons).

Keeping this unified concept of the solar-terrestrial environment in mind, we now briefly describe the responsibilities of the various program areas comprising SEL.

Interplanetary and Magnetospheric Physics
D. Evans, Program Leader

The research effort in this program area is directed to the understanding of all aspects of the transfer of energy and particles from the sun to the near earth environment and ultimately into the earth's atmosphere. Within this effort may be included general studies of the interplanetary medium and the flow of particles through this medium, the transfer of energy and momentum from the interplanetary plasma into the magnetosphere, and, finally, the dynamics of the magnetosphere-ionosphere-atmosphere system itself.

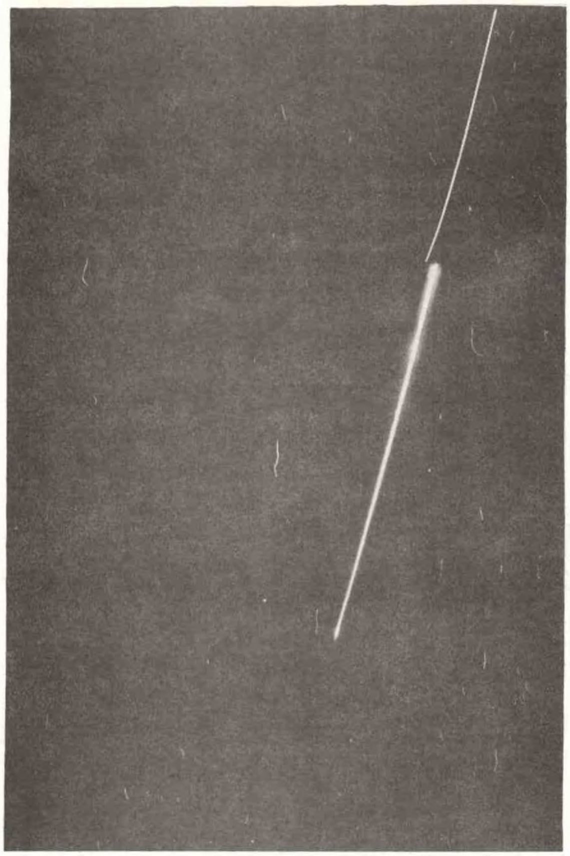
From these studies, physical models of interplanetary and magnetospheric processes are developed and used to follow, and perhaps to predict, the evolution of such dynamic processes.

At the present time this effort includes the analysis of data already obtained from a variety of scientific satellites and sounding rocket instruments, the design and construction of new instrumentation to extend this data base, and finally a theoretical program directed toward a true understanding of the available data.

High quality data concerning the magnetic and particle environment in the relevant regions of space as obtained from the Pioneer, IMP, and ITOS series of scientific satellites together with the OGO-6, S^3, and solar probe HELIOS are available for analysis. In the future data from instruments aboard the ATS-F, TIROS-N, GOES/SMS, and the international Mother/ Daughter IME satellites are anticipated.

Supplementing the use of satellites in a continuing program of sounding rocket launches (see fig. 2a, 2b) intended to study in detail the ionosphere or low altitude region of the magnetosphere. Finally, a ground based study of plasma irregularities in the interplanetary medium has begun and is expected to yield much new information. This last experimental program uses large area antenna arrays to study the scintillations of stellar radio sources that are introduced when the radio wave passes through plasma irregularities within the solar system.

Figure 2a. The launch of Proton II from Andoya, Norway. The lower streak is the spent Nike stage.



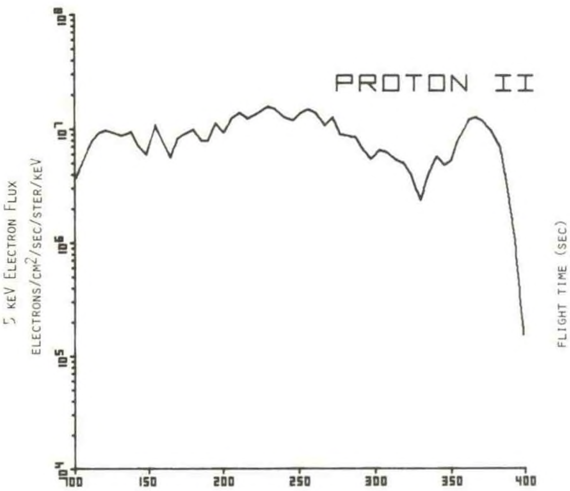


Figure 2b. A plot of 5 keV electron flux observed during the flight of Proton II. This is a remarkably widespread and structureless auroral electron bombardment. The decrease in flux after 390 seconds is due to the absorption of these electrons during re-entry of the payload in the atmosphere.

Looking toward the more distant future, a deep involvement with the NASA shuttle program is anticipated. The thrust of this particular effort is toward active modification of magnetospheric parameters as opposed to the present program of passive observations. Such active controlled experiments are necessary unambiguous tests of theoretical models.

Examples of recent studies are:

a. The great solar event of August 1972 provided a unique opportunity to test the theories concerning the propagation of solar plasma and shock waves in the interplanetary medium. Numerous spacecraft, ranging in position from .7 AU to 2 AU recorded the effects of this solar outburst. In addition to the satellite observations, the brightness of comets, located at even greater heliocentric distances, were studied to detect the time of arrival of the shock wave at those positions. Finally the radio emissions from Jupiter at 5.25 AU were studied for variations that might occur because of the outward propagating shock. There was excellent comparison between this variety of observational data and theoretical models.

b. A dynamic magnetospheric model yielding time variations and the topology of the magnetosphere given a single parameter input.

c. The equilibrium structure of radiation belt electrons has been evaluated by balancing pitch-angle scattering loss with inward radial diffusion from an average outer zone source. Excellent agreement was found between the theoretically predicted equilibrium flux versus L profiles and quiet time observations over a wide range of electron energies.

d. Strong pitch angle diffusion concepts and their application to solar protons in the magnetosphere.

e. The initiation of the ion-cyclotron instability in the plasmapause-ring current interaction region.

f. Equatorial distribution of geomagnetically trapped alpha particles.

Ionospheric Physics

A. G. Jean, Acting Program Leader

The major thrust in this program area is to gain an understanding of the input boundary conditions to the ionosphere and an understanding of the resulting dynamic behavior of the ionosphere and its interactions with the upper neutral atmosphere. Investigations of ionospheric spatial and temporal irregularities, the interaction of the ionosphere with the magnetosphere and the response of the ionosphere to natural and artificial transient energy inputs are some of the topics researched.

Examples of recent studies are:

a. Development of a theoretical model of the equatorial F-region. This model accounts for the anomalous distribution of electron density near the equator. Figure 3a shows the foF2 (related to electron density) along the vertical axis for ±40° magnetic latitude versus time. The top figure neglects and the bottom, figure 3b, includes electric field effects. Actual data, plotted in figure 4, show agreement with the model results when electric fields are included.

b. Energy balance in the thermosphere. The energy balance in the lower thermosphere (80-150 km) is being studied theoretically. The major sources and sinks of energy are being evaluated, along with their variability with season, latitude, etc. Figure 5 shows typical heating rate profiles for most of the major heating sources in this region.

c. Model of F-region storm. A model has been established which describes the increases and decreases of electron densities during a storm. The model is based on a point heat source located on the auroral oval at noon from which a disturbance emanates. The earth's rotation causes the source to move faster than the disturbance thus setting up a "wake" which sweeps across the earth. A "storm front" is established along the envelope at which disturbances are focussed. Ahead of the front, a wind is set up which lifts the plasma to levels of low electron loss thus giving rise to the positive phase. At and behind the front a change of chemical composition occurs which causes enhanced electron loss and thus produces the negative phase.

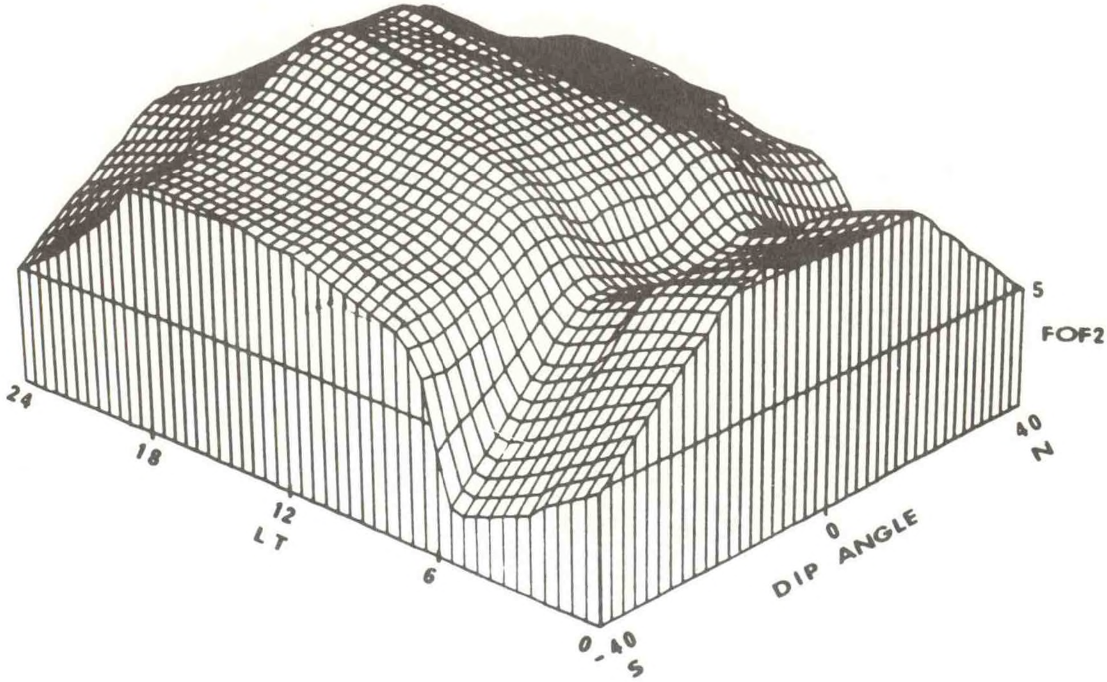


Figure 3a. Ionospheric model without electric field.

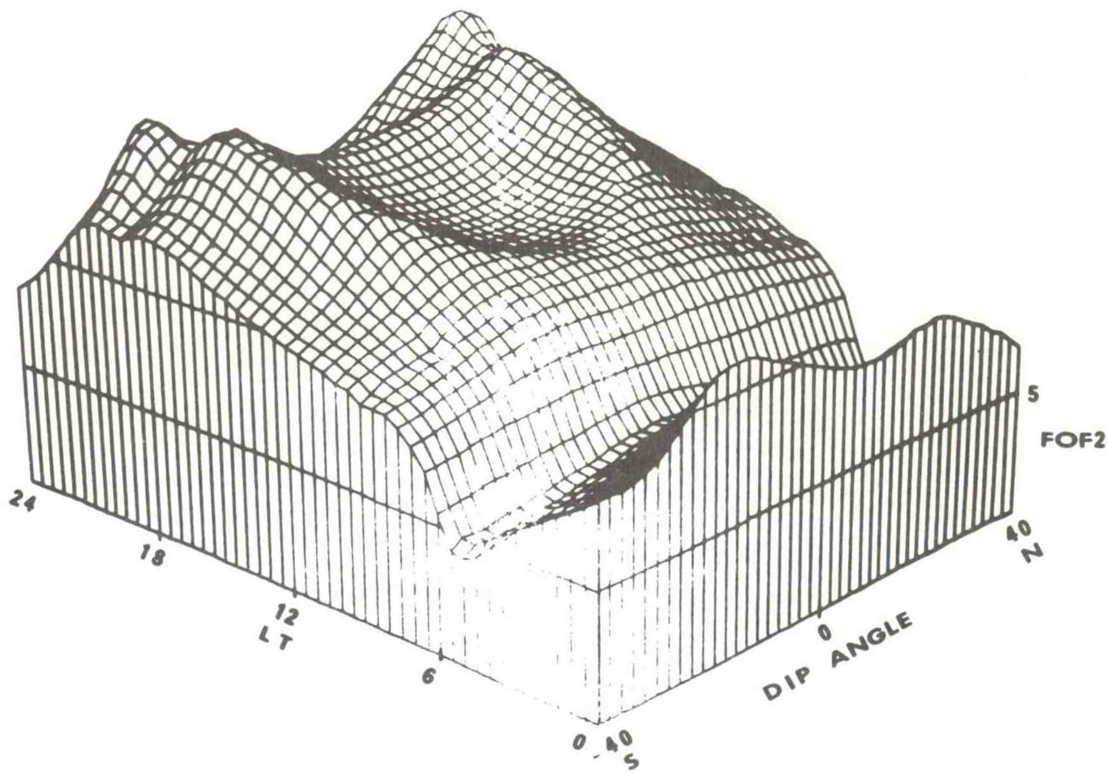


Figure 3b. Ionospheric model with electric field.

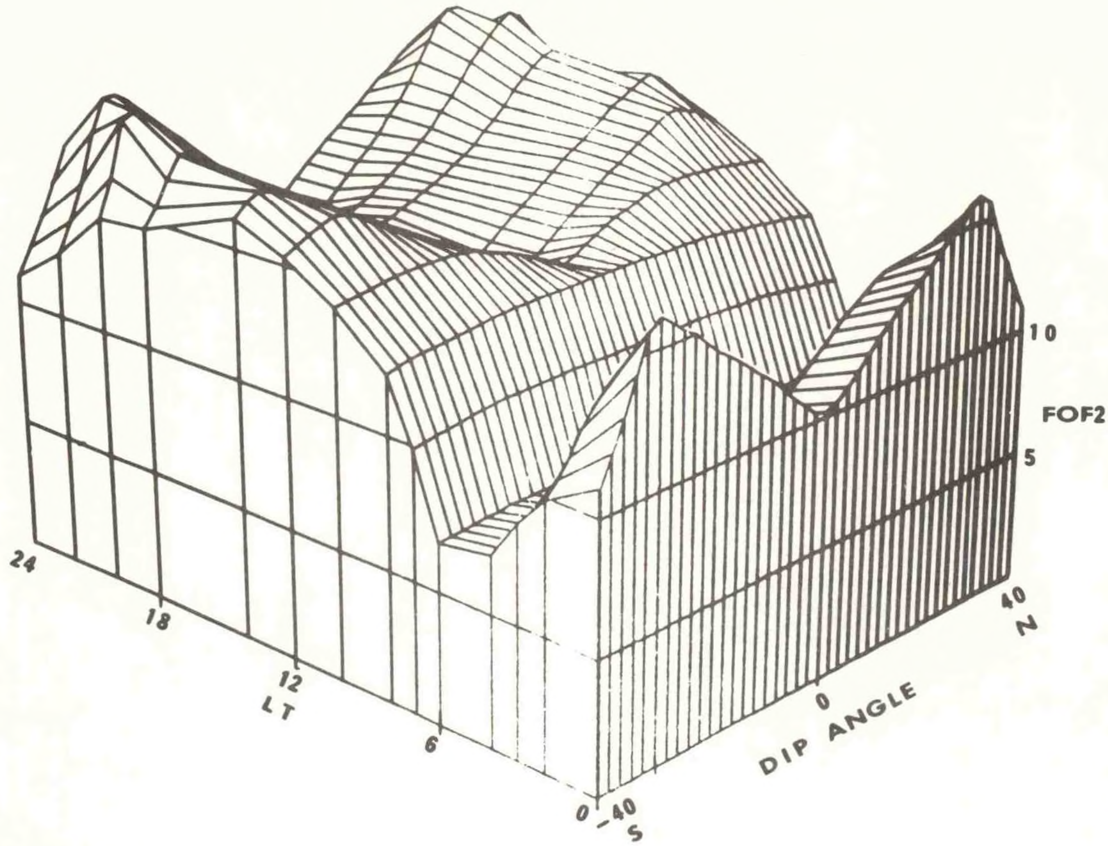


Figure 4. Ionospheric data showing agreement with ionospheric model with electric field (fig. 3b).

d. Ionospheric scintillation model. To predict ionospheric scintillation effects, that perturb satellite communications systems, a model developed at Stanford Research Institute is undergoing modifications and further development. Scintillation indexes have been computed from this model for conditions expected for the geostationary satellite ATS-F.

e. Solar flux model. Several sources were used to develop a "standard" solar flux model for moderate solar conditions in the 1 to 3000 Å range.

The development of improved theoretical models of upper atmosphere processes, and needed improvements in the empirical description of the upper atmosphere, each require more refined and informative methods of measurements. The program area specializes in developing and applying advanced methods of measurement, data analyses, and interpretation, usually based upon digital data acquisition and data processing techniques.

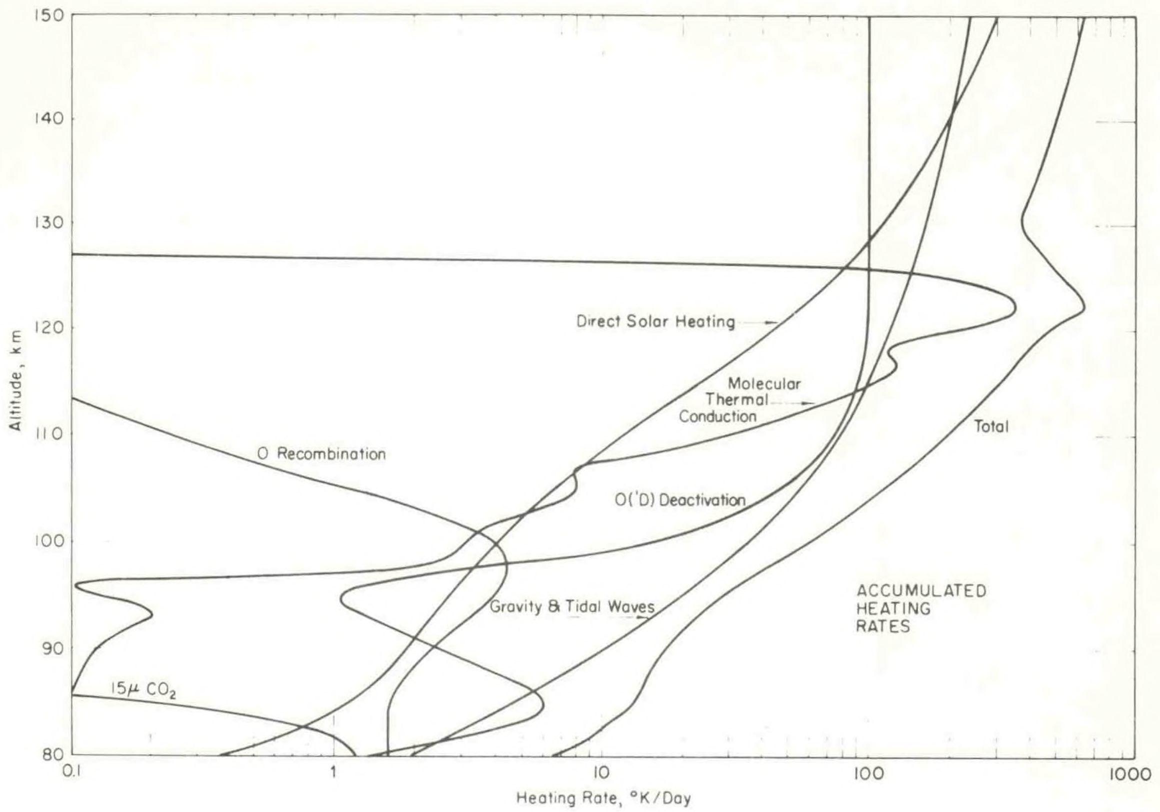


Figure 5. Heating rate profile due to various major energy sources in the lower thermosphere.

Examples of experimental activities include:

a. The SEL is the principal investigative agency for the radio beacon experiment on the ATS-F satellite to be launched in 1974, and particle and magnetic data will become available from the GOES satellite after launch in 1973.

b. Measurement of mean and random motions of winds near the 100 km level by the ground-based "Kinesonde" as verified by concurrent meteor-wind measurements.

c. Development of an automatic, real-time, method of obtaining continuous electron density profiles of the ionosphere by the ground-based "Dynasonde".

d. Development of a new method of radio echolocation, including accurate distance measurement, which is applicable in studies of the interactions between the ionosphere and troposphere, and the magnetosphere and ionosphere. In a study recently concluded, the method has also been applied to observations of induced heating effects in the ionosphere.

Numerical Analysis and Computer Techniques
T. B. Gray, Program Leader

This program group provides support to all of SEL who have need for computer program preparation, computer techniques development or computer assisted analysis of data. Areas of recent and continuing interest are listed below.

a. Development of computer programs to process, analyze and display data obtained from a number of satellite and rocket experiments.

b. Provide active programming support and assistance in numerical analysis techniques development to the ionospheric modeling group of SEL who are engaged in developing a computer-based numerical model of the earth's ionosphere.

c. Develop and implement a real-time computer system to monitor, archive and display data on the near earth space environment as observed by a number of geostationary satellites, including GOES, SMS, ATS-F.

d. Provide support to the Computer Laboratory in the form of system programming and documentation for certain areas of specialization such as plotting routines for both the batch and time-share computer systems, spectral analysis routines and special tape handling routines.

e. Provide general programming and numerical analysis support to the laboratory scientific staff and limited consulting support to outside agencies in this area.

f. Maintain programs for the Space Environment Data Base systems and for the National Earthquake Information Center Data Base system. Both of these systems were developed and implemented on the time-sharing computer by members of the group.

g. Maintain a library of solar geophysical data tapes, including satellite data and data collected by the Real Time Data Systems group of this laboratory.

Instrument Development
R. Grubb, Program Leader

The Instrument Development Group serves SEL programs in both the research and service areas. Activities range from major programs providing sensor and data acquisition systems through the provision of advice and physical facilities to all other SEL staff carrying out electronic work. The group also carries out projects for other ERL Laboratories and outside agencies when effort is available and the program complements SEL objectives.

Examples of current activities are:

a. Operational Space Environment Monitors. A Space Environment Monitoring (SEM) subsystem is being implemented on the SMS/GOES spacecraft series to provide data on energetic particles, solar X-rays, and the earth's magnetic field in geostationary orbit. The first of these satellites is to be launched late in CY 1973. The Instrument Development Group sets performance specifications and, in collaboration with the NASA program office, provides liaison and guidance for the NASA contractors responsible for the SEM portion of the spacecraft. A telemetry receiving system figure 6 and on line data processing and display system for the SEM data is in an advanced stage of planning and installation using the joint resources of the Instrument Development, Real Time Data Services, and the Numerical Analysis and Computer Program areas.

A comprehensive particle monitoring subsystem has been specified for the TIROS N and follow on operational satellites. In this case, it is expected that the flight instrumentation will be provided to the spacecraft contractor directly by the Instrument Development Group using a combination of in-house development and outside laboratory and industrial contractors.

b. Sounding Rocket Program. SEL scientists, supported by the Instrument Development Group, have conducted numerous sounding rocket launches or contributed instruments to cooperative payloads. The most recent program, in cooperation with the Norwegian Government, provided sensors for

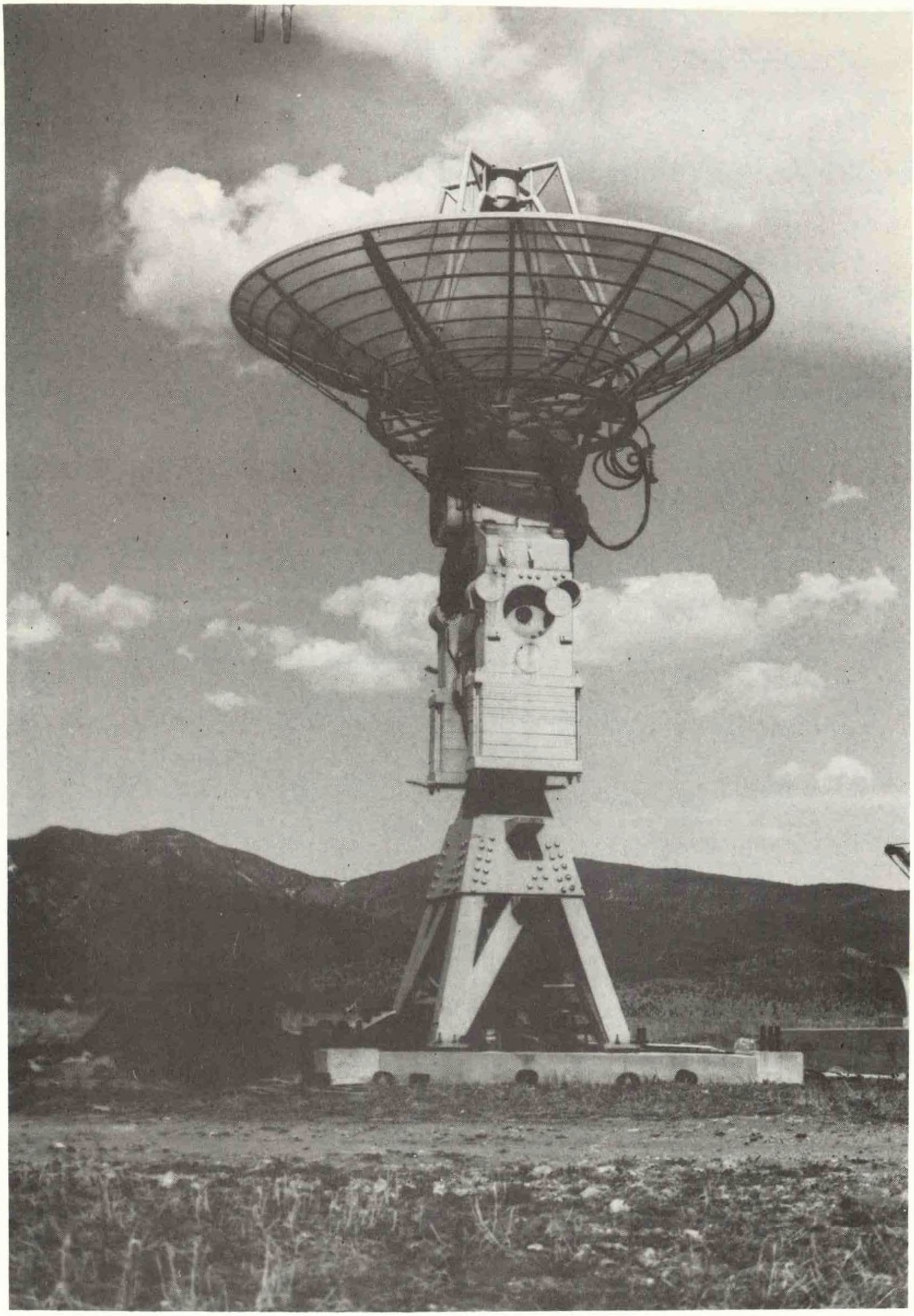


Figure 6. SMS/GOES Telemetry receiving antenna at Boulder.

4 auroral research flights. In 1973/74, a complete Javelin rocket payload will be integrated with sensors from SEL and other laboratories. The payload is expected to fly in the earth winter of 1975.

c. Satellite Experiments. The Instrument Development Group provides a wide range of support to the SEL scientific staff on satellite experiment programs extending from conceptual design through support at integration and launch operations as the particular program requires. This support includes system and circuit design, design analysis, packaging design, fabrication, checkout and calibration of assembled units, project management, and contract monitoring. Two experiment programs are active during 1973, the ATS-F Low Energy Proton Experiment figure 7 (Principal Investigator, T. Fritz) and the International Magnetospheric Explorer (Mother/Daughter) solid state detector experiment (Principal Investigator, D. J. Williams).

Support for the ATS-F experiment consists of the evaluation and checkout of the assembled experiments (one flight and one flight spare), since this project was transferred from GSFC to SEL immediately after fabrication was completed. Delivery of the first unit is expected in late May, 1973, for a launch approximately one year later.

The International Magnetospheric Explorer Experiment will proceed through the conceptual design phase and will see some initial new circuit development in 1973. The group's responsibilities thus far have included production of major portions of the proposal technical and management sections and NASA project liaison during initial program definition. The experiment opportunity is provided under the joint NASA-ESRO program to launch three satellites, the first two of which are scheduled for a January 1977 launch.

Work is underway to develop several new on-board techniques for data processing including multidimensional pulse height analysis. In addition, it is intended that several integrated circuit modules will be developed within this program to improve the performance achievable over that of discrete component modules for certain critical pulse analog and pluse height discriminator portions of the experiment. Time-of-flight measurement techniques are being investigated as a possible means of improving heavy ion specied identification.

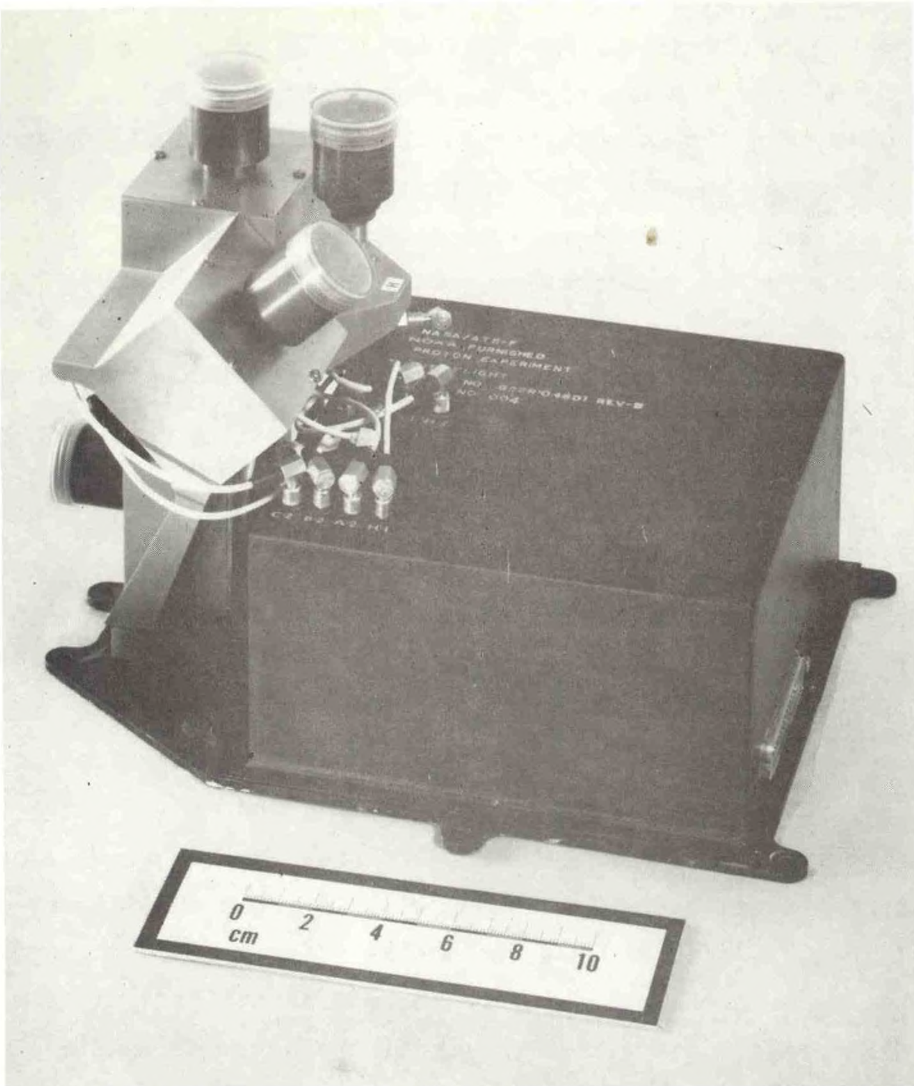


Figure 7. Proton counter for ATS-F satellite.

d. ATS-F Radio Beacon Experiment (Principal Investigator, K. Davies). The group provides basic specifications and liaison with the NASA project and contractors constructing the satellite transmitter. A comprehensive receiver for the beacon transmissions is in the advanced stages of construction and checkout under the ground sector of the program funded by the ATS-F project. The receiver and data acquisition system figure 8 utilize a minicomputer both for receiver control and calibration as well as for data acquisition.

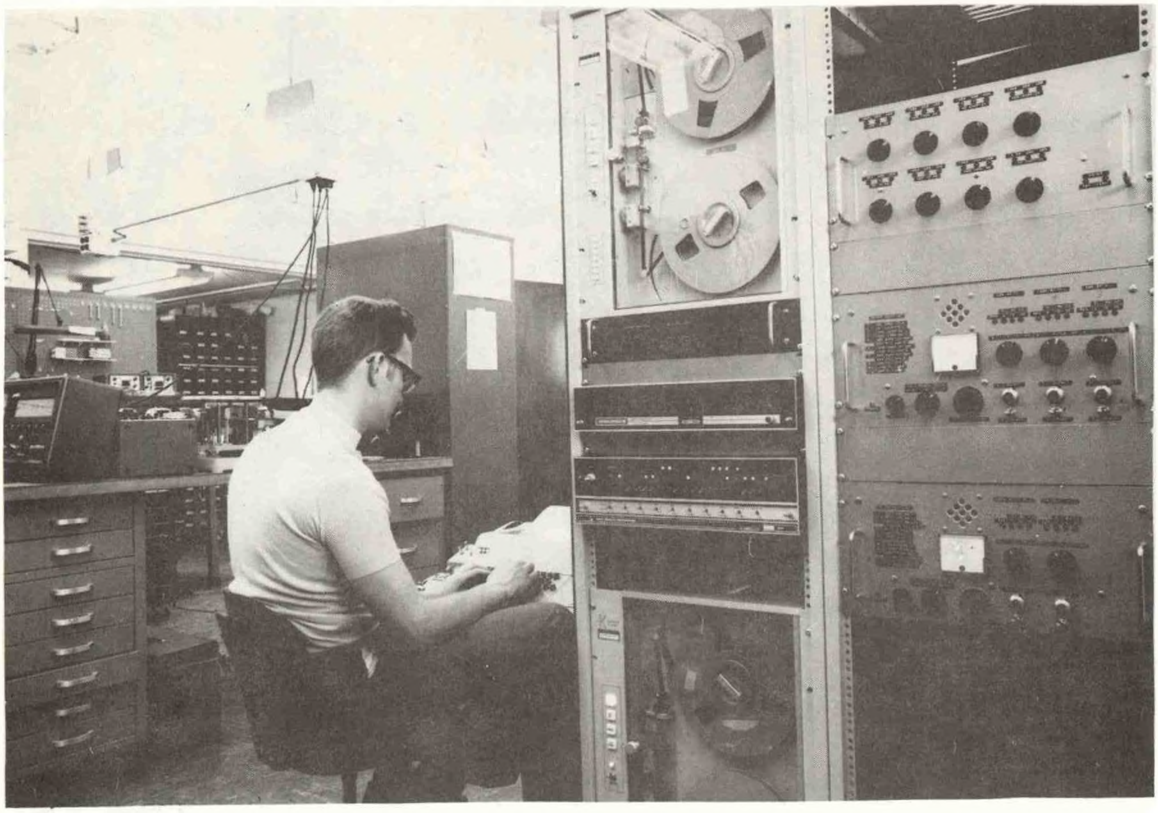


Figure 8. Operator programming the data acquisition system for the ATS-F beacon receiver. The three units in the right hand rack are the IF and phase detector sections of the receiver. To the left are two incremental tape recorders, a Nova mini-computer, and two interface units. The computer adjusts the data acquisition in accordance with varying signal characteristics, automatically calibrates the equipment etc.

e. Electromagentic Properties of Rocks and Soil. In a program funded by the Department of the Defense, the group has developed systems for measuring the *in situ* electromagnetic properties of rocks and soil at MHz frequencies. The work is concluding with a field program designed to gather a catalog of data on typical materials. A by-product of the instrumentation effort was the development of a programmable calculator controlled network analyzer system permitting the automatic acquisition and reduction of swept frequency transfer impedance characteristics.

Real Time Data Services

C. Hornback, Program Leader

One of the main functions of NOAA is monitoring of the environment; in this instance the solar-terrestrial environment. The RTDS is responsible for the SEL real-time data acquisition and processing system. This system includes the High Latitude Monitoring Station at Anchorage, Alaska, the Table Mt. Observatory near Boulder, and the data display systems in the Space Environment Services Center. Sources of data at Anchorage are various ground-based radio experiments which provide information on the state of the arctic ionosphere and the geomagnetic field.

At Boulder, data available in real-time include:

a. Solar proton and magnetic data (through the courtesy of Dr. G. Paulikas, Aerospace Corporation, and Dr. P. Coleman, UCLA, respectively) from the ATS-1 satellite in synchronous orbit over the Pacific Ocean.

b. Solar radio and ionospheric radio experiments at Table Mountain.

c. Solar proton, solar X-ray and magnetic data will be available from the GOES satellite (launch date late 1973) in mid-1972. These data will be received directly at Table Mountain near Boulder and processed in real-time for use by the SESC.

At Anchorage and Boulder, data are processed in real-time by small computers and forwarded to Boulder for use by forecasters in the Space Environment Services Center. The data are also stored in the ERL time-share computer where the information is available to users via teletype.

Space Environment Services Center
R. Doeker, Program Leader

The Space Environment Services Center (SESC) the national and international center for space environment information provides real-time data, analyses and forecasts, to national and international users. The SESC maintains a real-time solar geophysical data base in a time-share computer which is available to users via telephone and TTY. The contents of this data base and instructions on how to obtain the data are described in an informal report available from SEL titled "SESAME Data Base User's Manual".

Included in this data base are:

a. Solar data, collected from a global network of solar radio and solar optical telescopes, figure 9.

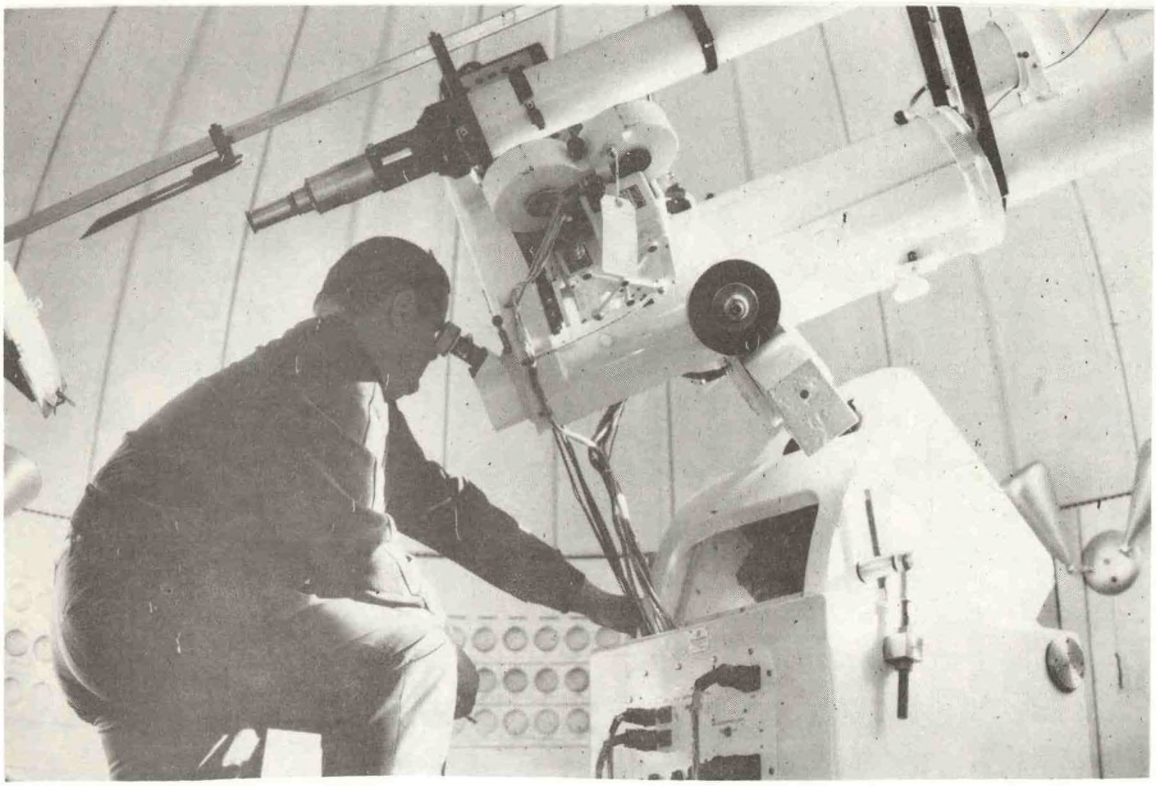


Figure 9. View inside the Space Environment Laboratory's Solar Observatory, Boulder, showing Hα white-light telescope, TV monitor, and 35 mm camera.

b. Data from satellites including the Pioneers, VELA, ATS-1, ITOS, providing solar X-ray, solar proton, solar wind, magnetic field, etc. Data from the GOES satellites which will be available in 1974 on a real-time basis include, solar X-ray, solar proton and magnetic field.

c. Miscellaneous data from other ground observatories including: geomagnetic, ionospheric, cosmic ray and neutron data, etc.

d. Three day forecasts of the level of solar activity, including percentage probability of large flares; of geomagnetic conditions; and of average solar radio flux.

Data not included in the data base but available via telephone or teletype upon request include:

1. Brief resumes of data in the data base shown above.
2. Alerts and warnings concerning major solar geophysical events.
3. Weekly data summaries including solar photographs.

This real-time data service is provided through the cooperative efforts of several agencies including the Department of Commerce, the Department of Defense and NASA. In particular, the close cooperation of the Air Weather Service and NOAA/SEL has resulted in a Memorandum of Agreement on data collection and forecasting activities. The latter has resulted in a Joint Geophysical Analysis Center at Boulder which is staffed by personnel of the AWS and SEL.

Typical services rendered during the past year by SESC have been:

a. On-the-spot support to NASA by SESC personnel through actual manning of the space radiation console at Johnson Space Center during the flights of Apollo 16 and Apollo 17.

b. Almost continuous participation in the developing ATM SKYLAB program (see fig. 10). Space environmental support to meet the unique needs of the ATM Principal Investigators required the full time services of six SESC forecasters, the addition of new observatories and the development of a wirephoto communication system.

c. Support to a wide variety of national and international rocket programs.

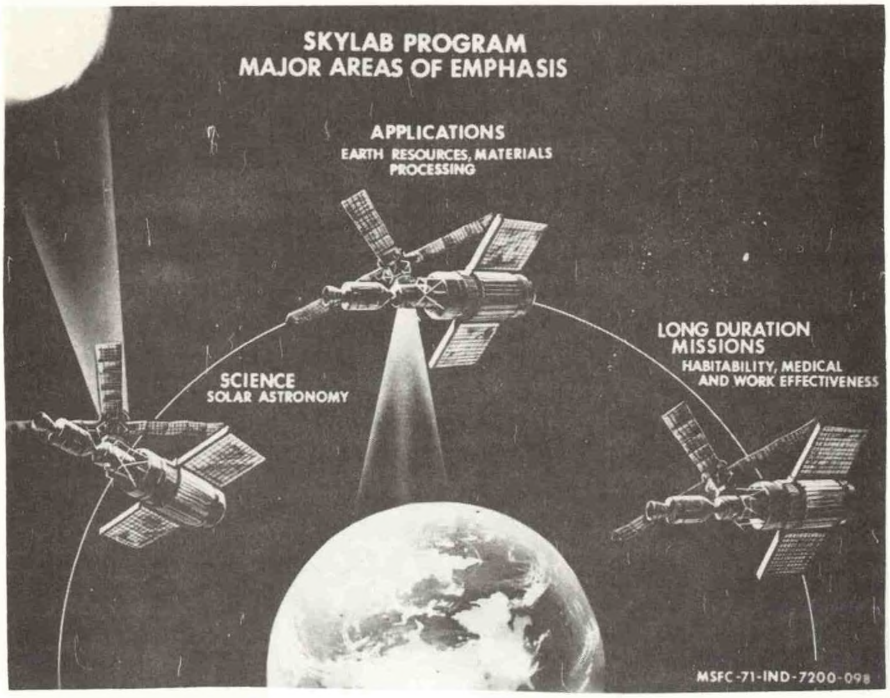


Figure 10. SKYLAB (NASA photo).

d. Support to the Air Weather Service, international SST program, to various communications services, and to electric power distribution systems (fig. 11).

e. The publication of an extensive report (TM ERL SEL-22) on the August 1972 flares and geophysical effects. Figure 12 an excerpt from this report, shows a 12 day plot of key data for this unusual storm of August 1972.

Major improvements in SESC services are expected to result from increasing cooperation between the AWS/USAF and SEL/NOAA in the operation of the Joint Geophysical Analysis Center at Boulder. This joint center will enable both agencies to significantly increase services and to accelerate development of forecasting capabilities. It is anticipated, for example, that each forecaster will participate directly in applied research and developmental efforts to solve specific operational problems.

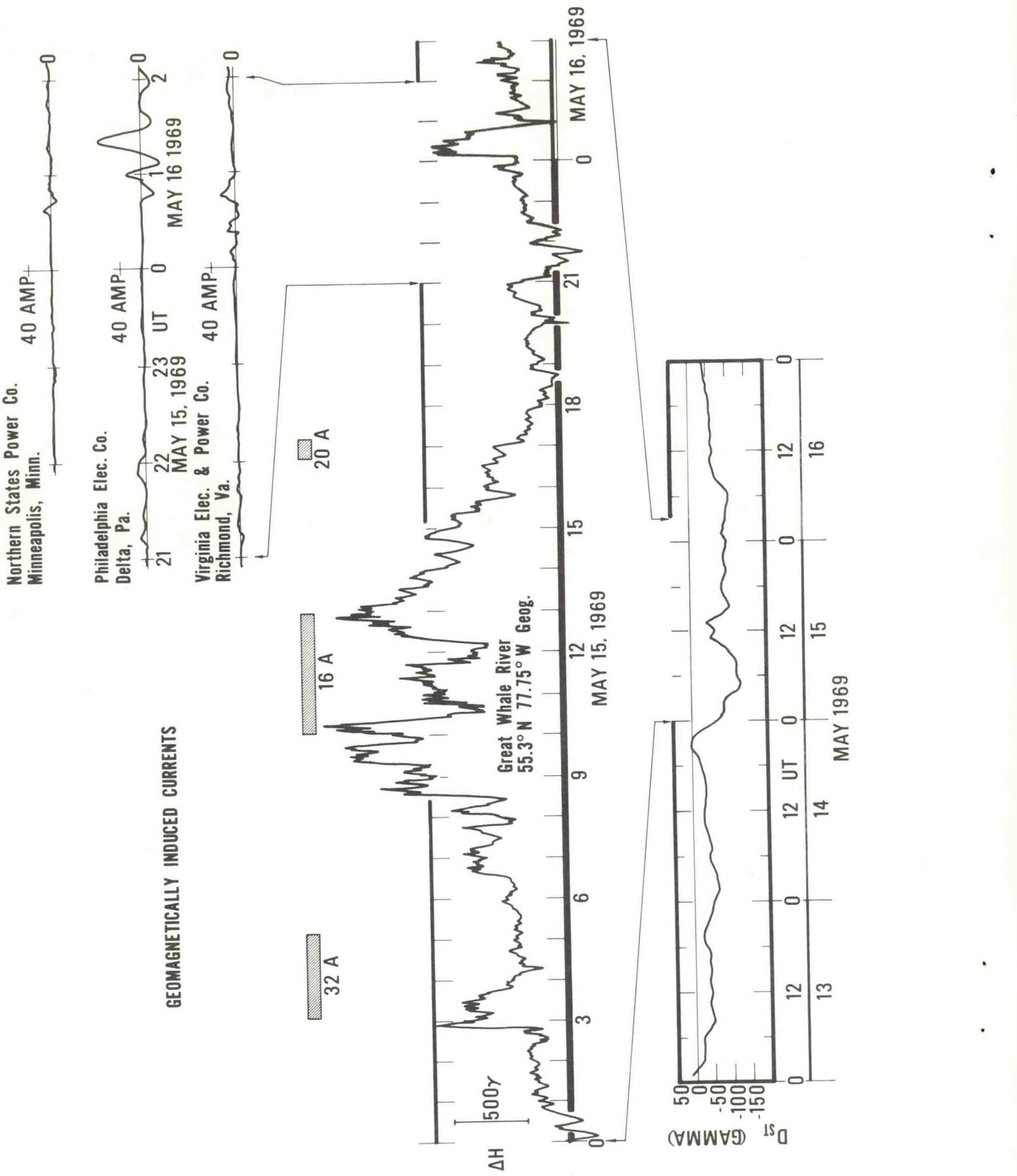

GEOMAGNETICALLY INDUCED CURRENTS
Northern States Power Co.
Minneapolis, Minn.
40 AMP
Philadelphia Elec. Co.
Delta, Pa.
21
22
23
UT
0
1
2
MAY 15, 1969
MAY 16 1969
Virginia Elec. & Power Co.
Richmond, Va.
20 A
16 A
32 A
Great Whale River
55.3°N 77.75°W Geog.
ΔH
500γ
3
6
9
12
15
18
21
0
MAY 15, 1969
MAY 16, 1969
D_{ST} (GAMMA)
50
0
-50
-100
-150
12
UT
13
14
15
16
MAY 1969

Figure 11.

This figure illustrates the effect of geomagnetically induced currents in large power transformers during geomagnetically disturbed time periods. The bottom graph of the figure shows a four-day period in May 1969. Plotted in this portion of the figure is D_{ST} (a measure of worldwide geomagnetic activity) versus time. It can be seen that a period of enhanced activity on a worldwide basis began just prior to the 15th of May and lasted on through the 16th of May. The middle plot in the figure shows the response of a ground-based magnetometer at the Great Whale River station for the time period 0000 hours UT, May 15, through 0003 hours UT, May 16, corresponding to an expanded version of the region indicated in the bottom plot. It can be seen that very large and rapid magnetic variations occurred at Great Whale River during this disturbed period. The top three graphs show recording of current induced into the coils of large power transformers at the power company stations indicated during the time period 2100 hours, May 15, through 0002 hours, May 16, corresponding to the indicated portion of the middle plot. The Philadelphia Electric Power Company, located in Delta, Pennsylvania, is close to the geomagnetic meridian at Great Whale River. It can be seen that very large (up to 80 amps) currents were observed to be induced into the power transformers coinciding with the block of activity shown in the middle graph. The shaded rectangles in the middle graphs show the time periods when additional large induced currents were observed in the power stations and the numbers indicate the maximum values obtained. It can be seen that closely associated with geomagnetic activity large induced currents are observed in power station transformers. In addition to these effects, which produce problems in the lifetime of these transformer systems, safety relays also are randomally tripped by the transient geomagnetic variations. This latter effect has been responsible for the blackout of urban areas in the past during geomagnetic disturbances.

Figure 12.

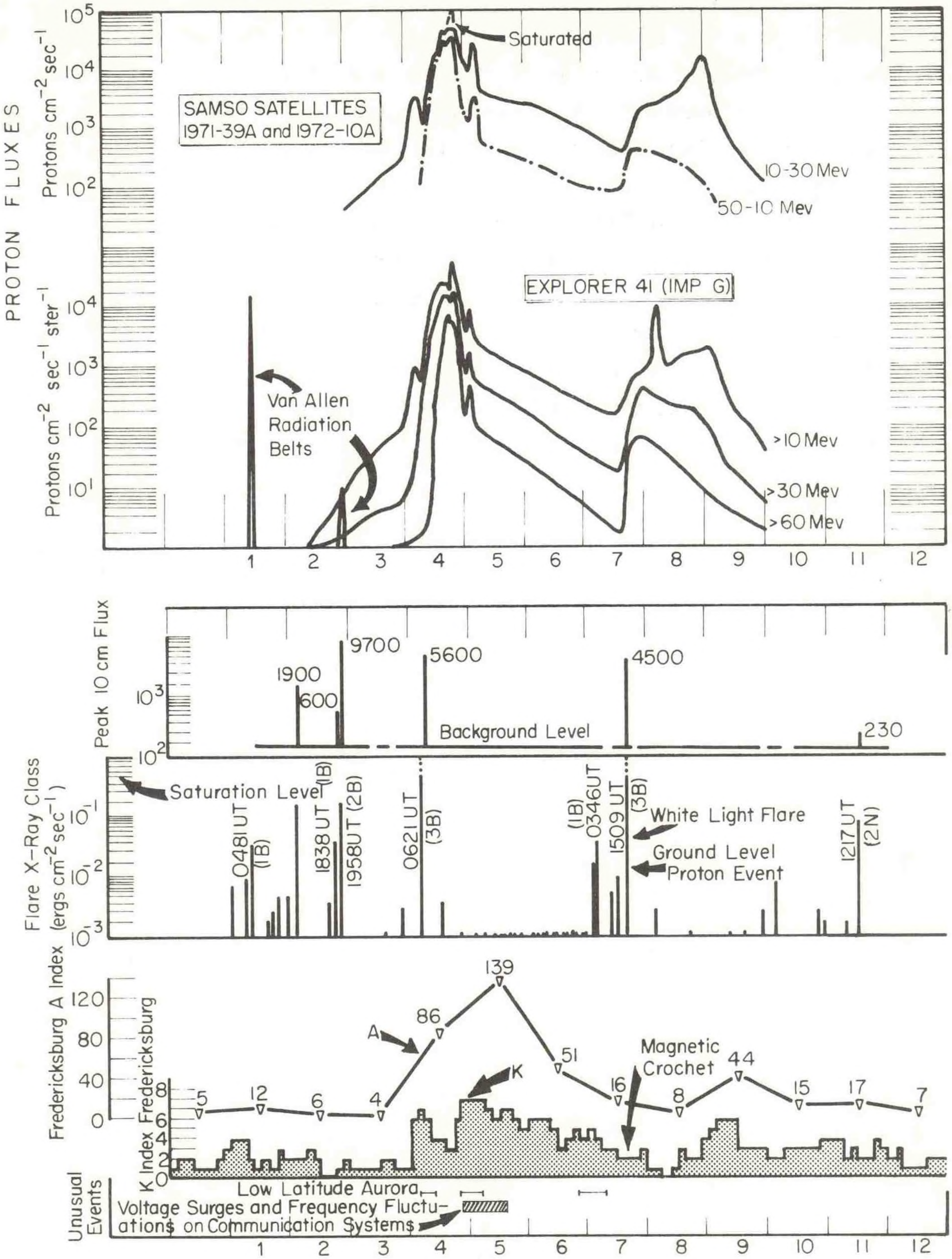
The proton flux profiles illustrated in the upper portion of the chart on the opposite page were observed by (1) two geostationary satellites of the Space and Missile Systems Organization (SAMSO) and (2) the Solar Proton Monitoring Experiment on board Explorer 41. A number of well defined peaks and troughs are evident, reflecting the separate flare-associated surges in particle counting rate. Note the good agreement between these two independent experiments. The spikes in the Explorer 41 curves near 01/0800 and 02/2300 UT represent detector response to the earth's radiation belts.

Beneath the satellite data a histogram of flares and the average peak flux of their associated 10 cm radio bursts are presented (one flux unit on the chart is equivalent to 10^{-22} watts m^{-2} Hz^{-1}). The reader should bear in mind that only activity originating within region 331 is summarized here. Although other spot groups on the sun's disk were producing flares at the time, none had the characteristics of a geophysically significant event. Twice the 1 to 8Å ionization chamber on the SOLRAD satellite saturated. As a consequence only a lower limit to the peak flux is available for determining the X-ray class of the 04/0621 and 07/1509Z flares.

The remark "white light flare" on the 7th implies segments of the photosphere — an atmospheric layer visible in ordinary sunlight — brightened in the vicinity of the spot group. Normally the flare phenomenon must be observed thru a narrow bandpass filter — one that isolates nearly a single wavelength in the solar spectrum. Reported ionospheric effects served to confirm the event's unusually intense emission in the visible, UV, EUV and X-ray regimes of the electromagnetic spectrum.

Fredericksburg, Virginia geomagnetic indices for early August are shown along the bottom of figure 12. The K value is a measure of the maximum magnetometer deflection (from the quiet-day curve) occurring during each of the eight, 3-hr periods into which a day is divided. Any particular index may take on an integral value between 0 and 9 inclusive. The range in gammas corresponding to one of these numbers is a function of the observatory's magnetic latitude, and increases in a quasi-logrithmic fashion from 0 to 9. On the other hand the A index represents a daily weighted mean of eight K values. This number may or may not reflect the true intensity of the storm since it is dependent upon the time of day the geomagnetic disturbance begins.

Particle data presented are through the courtesy of the Space and Missile Systems Organization, Defense Support Program; the Aerospace Corporation; Dr. C. O. Bostrom, Applied Physics Lab, GSFC; and Dr. D. J. Williams, NOAA.


PROTON FLUXES
Protons cm^{-2} sec^{-1}
SAMSO SATELLITES
1971-39A and 1972-10A
Saturated
10-30 Mev
50-10 Mev
EXPLORER 41 (IMP G)
Protons cm^{-2} sec^{-1} ster^{-1}
Van Allen Radiation Belts
>10 Mev
>30 Mev
>60 Mev
Peak 10 cm Flux
1900
600
9700
5600
4500
230
Background Level
Flare X-Ray Class (ergs cm^{-2} sec^{-1})
Saturation Level
0481 UT (1B)
1838 UT (1B)
1958 UT (2B)
0621 UT (3B)
0346 UT (1B)
1509 UT (3B)
White Light Flare
Ground Level Proton Event
1217 UT (2N)
Fredericksburg A Index
K Index Fredericksburg
A
K
Magnetic Crochet
Unusual Events
Low Latitude Aurora
Voltage Surges and Frequency Fluctuations on Communication Systems

Examples of the benefits of operational research within the past year include the enhanced capabilities for predicting geomagnetic storm activity, based both on direct observations of interplanetary magnetic field sector boundaries by space probes, and the inference of sector boundary crossings from observations of the nature of the geomagnetic field at high and polar cap latitudes.

In another effort, synoptic maps of the large scale magnetic fields on the sun are being constructed, based on the chromospheric structures photographed in Hydrogen alpha light by the NOAA/AWS solar patrol observatories. These maps, which can be updated in real-time, provide significant information on the evolution of solar activity, and definite clues about the possibility of major solar flares and the propagation of solar disturbances to the earth.