FY 1984

SPACE ENVIRONMENT LABORATORY

Annual Report

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

COVER PHOTO

The existing GOES satellites are equipped with monitors which observe the solar X-ray emission from the total Sun. These observations are some of the most useful to the civilian and military solar-terrestrial community. It is now technically feasible to observe solar X-rays with spatial information which would greatly enhance the value of observations. This is illustrated by the X-ray image of the Sun (cover) and the interpretative sketch (fold-out frontispiece).

The image is from the American Science and Engineering Corporation telescope onboard the National Aeronautics and Space Administration Skylab taken in the 3 to 54 Angstrom passband of that instrument spacecraft on 28 May 1973 at 0336 U.T. The accompanying line drawing illustrates the wide range of phenomena which is visible in this kind of data.

The Sun is dark in X-rays, except for heated tubes of magnetic field. This heating is particularly strong in the closed flux tubes (both ends attached to the surface of the Sun) in the centers of activity (the bright, active regions). On images such as this, intense brightenings occur during solar flares; these show the first stages of high temperature flare energy release. (There are no flares in this photo.)

Some active regions which may be judged as benign may be in fact revealed (only in such images) to be interconnected to other active regions which are capable of producing hazardous proton flares. Thus, minor activity in one region may trigger significant disturbances in the other.

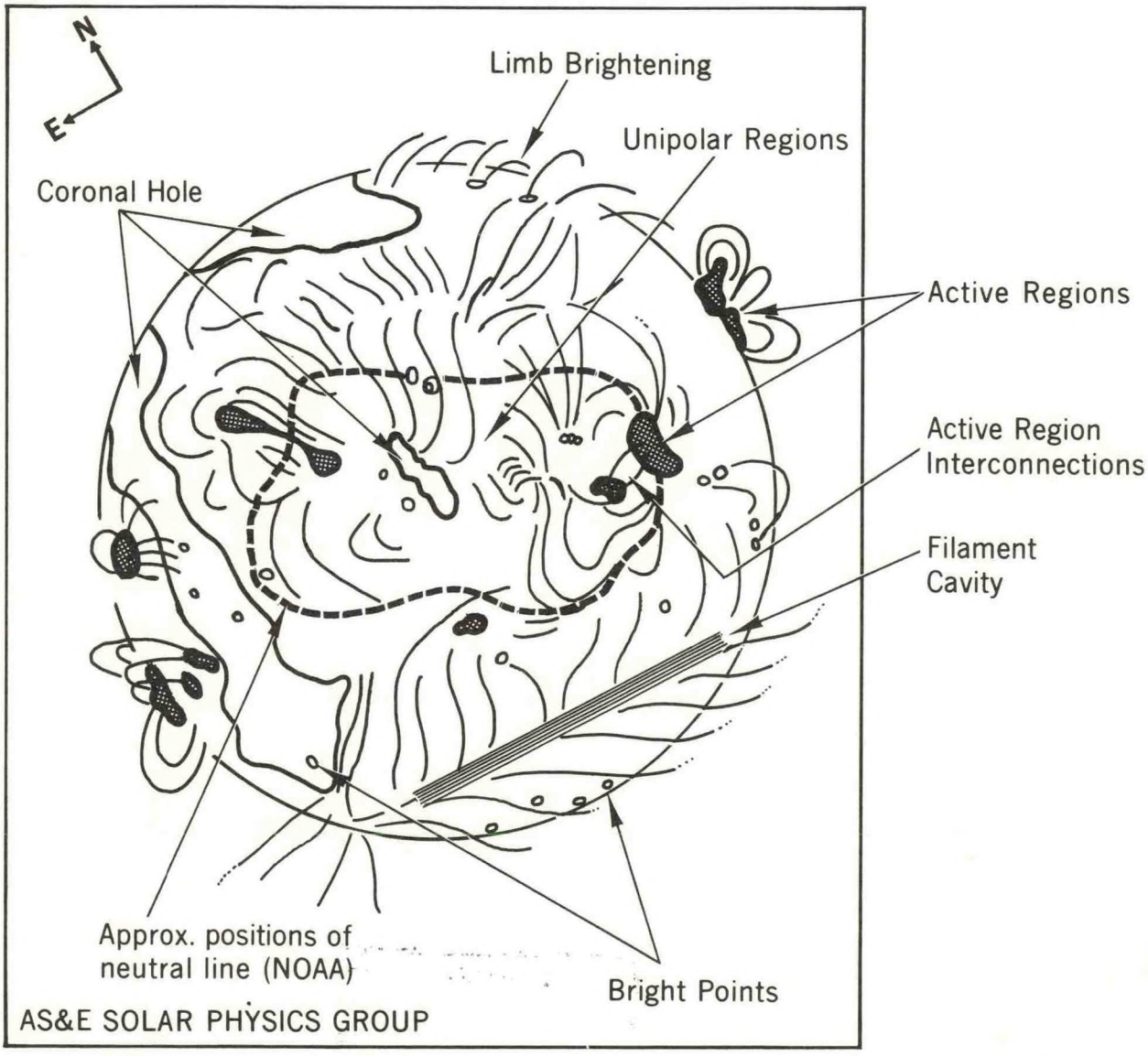
The dark areas are called X-ray coronal holes. These regions have open magnetic flux tubes which are sources of the high-speed, solar wind streams that often cause major geomagnetic storms.

Filament cavities are sites (cradles) of long prominence clouds above the solar surface. These are often the launching points for coronal mass ejections. When such huge explosions of hydrogen gas and ionized plasma occur, the dark cavities suddenly brighten and glow in X-ray light.

The Space Environment Laboratory plans to use images such as this in future years to provide monitoring of solar disturbances from GOES-NEXT space platforms.

Cover:
Soft X-ray images of the Solar Corona at 0336 GMT on May 28, 1973 obtained in Filter #3 (3 - 32 Å and 43 - 54 Å).

Below:
Schematic diagram of the sun at the same time with appropriate designation of coronal features.



SPACE ENVIRONMENT LABORATORY

ANNUAL REPORT - FY 1984

October 1, 1983 to September 30, 1984

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DEPARTMENT OF COMMERCE

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NATIONAL OCEANIC AND
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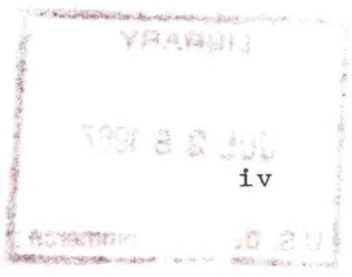

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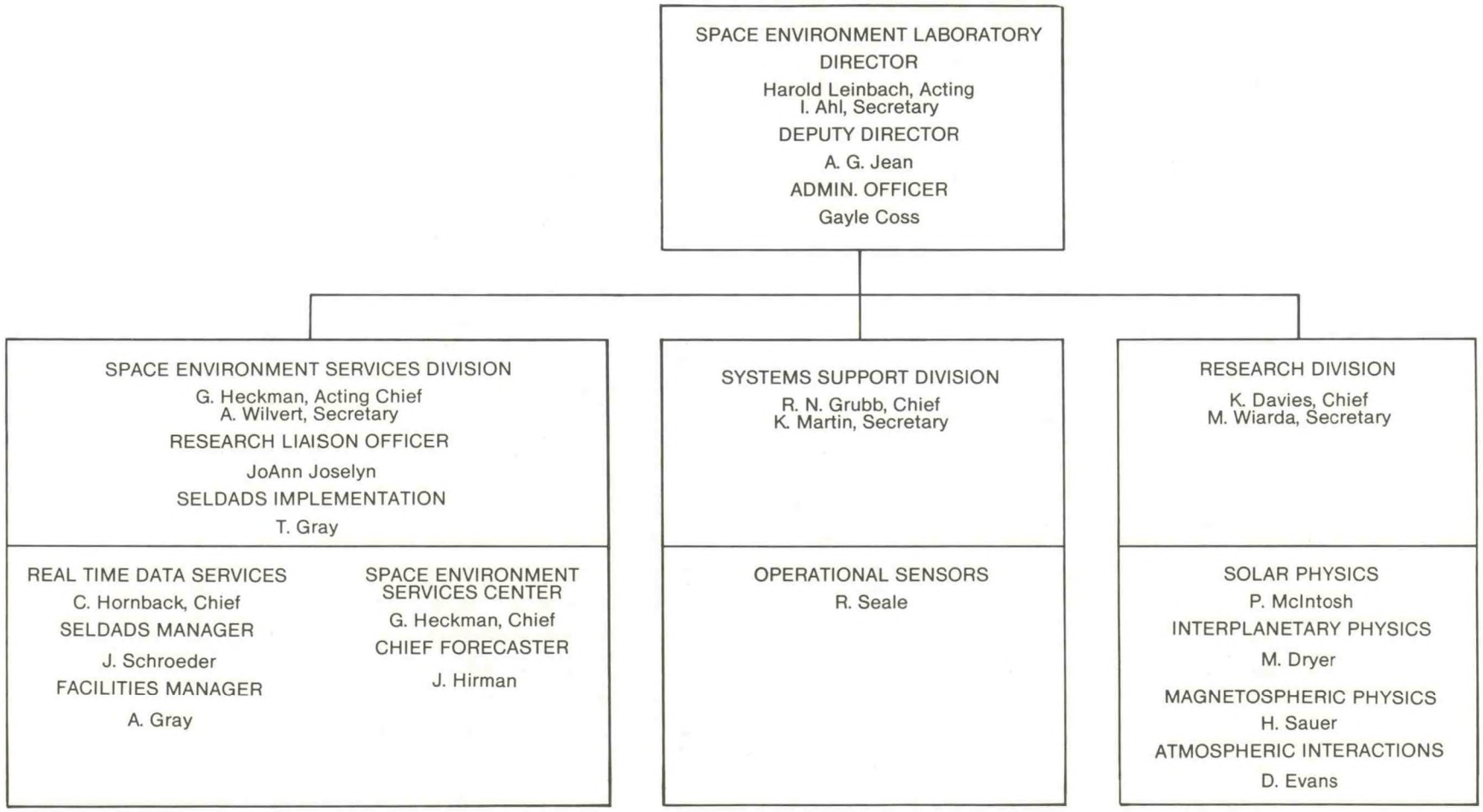
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D. Evans

INTRODUCTION

The Space Environment Laboratory conducts research and provides services in the solar-terrestrial field. This field concerns the relationship between solar activity and geophysical effects which can adversely affect activities including: communications, transportation, energy dissemination, and national defense.

The focal point for the nation's present solar-terrestrial services is in the Space Environment Laboratory at Boulder, where, with the cooperation of the Air Weather Service, the monitoring and forecasting services are carried out to meet a wide variety of civilian, military, commercial, and federal agency requirements. The scope of the laboratory activities includes: the real-time collection of solar-terrestrial data; the issuance of forecasts, alerts, and warnings of adverse solar-terrestrial conditions; the archiving and processing of solar-terrestrial data from all over the world; and the development of an understanding of the behavior of the solar-terrestrial environment to yield significant service improvements.

SEL is composed of three Divisions: the Research Division, the Systems Support Division, and the Space Environment Services Division. This report describes the cooperative work of the three divisions in providing real-time space environment services and the necessary supporting research and development activities.

Highlights of the year include the installation of the new Space Environment Laboratory Data Acquisition and Display System (SELDADS II), which will replace the obsolescent SELDADS I, and the inauguration of the satellite data relay system, which distributes solar-terrestrial data to users via satellite data relay.

For the second year, Congress restored funds for SEL; however, the issue of the cut contained in the President's budget will arise again for FY 1986.

SPACE ENVIRONMENT SERVICES

Introduction

The Space Environment Services Center (SESC) in Boulder is operated jointly by the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Air Force Air Weather Service (USAWS) and exists to provide predictions, alerts and real-time information describing solar geophysical disturbances to users throughout the United States. In addition, it is designated as the World Warning Agency (WWA) for the International Ursigram and World Days Service (IUWDS), which is operated under the International Council of Scientific Unions (ICSU). SESC collects data from its own sensors, from cooperating agencies and institutions, and from other countries, both through IUWDS and through bilateral exchange agreements. The data collected include solar images and parametric measurements of the Sun, the interplanetary medium, and the Earth's magnetosphere and ionosphere.

Solar activity forecasts, geomagnetic forecasts, and warnings of events in progress as measured by real-time observations, are valuable to a great variety of users. For example, the NASA Space Shuttle program uses this information in orbital planning and planning for astronaut safety. Ionospheric communications, including low-frequency navigation systems (Omega), are perturbed during strong flares, proton events, and geomagnetic storms; the space environment forecasts and warnings aid users in coping with the ionospheric disturbances. The orbits of navigational satellites may be modified by increased density of the heated upper atmosphere during magnetic storms. The Navy issues corrected satellite ephemerides based on the forecast or observed level of magnetic activity. The same magnetic activity can induce strong voltage and current transients in electric power distribution lines, leading to possible system outages. In long pipelines, the induced currents may upset cathodic corrosion protection systems. In both situations, customers utilize geomagnetic forecasts and warnings to minimize adverse effects on systems. Many geophysical prospecting companies using airborne magnetometers will avoid flights during the magnetically disturbed conditions that would affect measurements.

Some of the affected systems and operations which are served by the Space Environment Services Center are:

Military and civilian radio communications and telecommunications

Military and civilian navigation systems

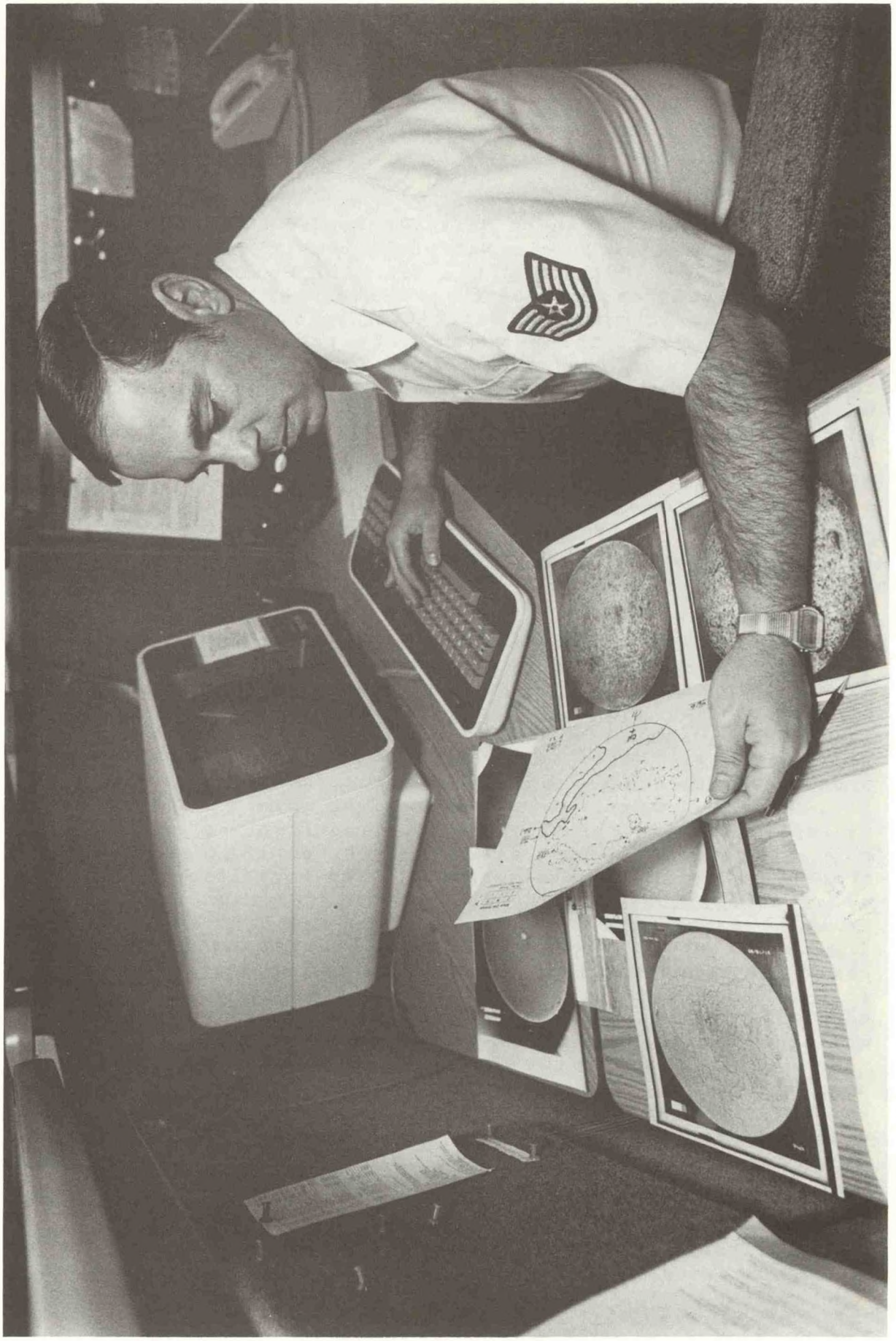

Figure 1. Forecast Center.

Military radars and surveillance systems

Electric power transmission grids

Pipeline flow meters and corrosion protection systems

Telephone long-line operations

Launch and orbit variations caused by satellite drag

Spacecraft charging anomalies

Geophysical exploration and mapping

Personnel and systems subject to solar cosmic radiation hazards

Biological systems influenced by magnetic activity

Scientific research campaigns

Questions posed by the general public

Current Progress

SPACE ENVIRONMENT SERVICES

Forecasts, used by about one-third of the SESC customers, consist primarily of predictions made daily of the expected occurrence of solar and geomagnetic activity and other standard measures of solar variation. Most of the forecasts are for the following 3 days, although forecasts for 27 days and several years in advance are made of some specific indices. SESC maintained a full schedule of alerts issued all 365 days of FY 1984.

Alerts of solar activity and geomagnetic disturbances are issued in 6 major categories when disturbances exceed any of several increasing thresholds. Computers are used as a first level of detection of disturbances but alerts are reviewed by trained, experienced personnel before they are issued. In FY 1984, the automated alert system detected 865 events, but subsequent review showed that 29% would have been wrong. The actual alerts issued by the SESC after human correction contained an error rate of 0.5%.

Indices, summaries, and data allow users to diagnose problems in operating systems or plan the execution of scientific experiments that must be carried out under specific environment conditions. The indices and summaries issued by the SESC in FY 1984 were based on standard 3- hour and 24-hour intervals.

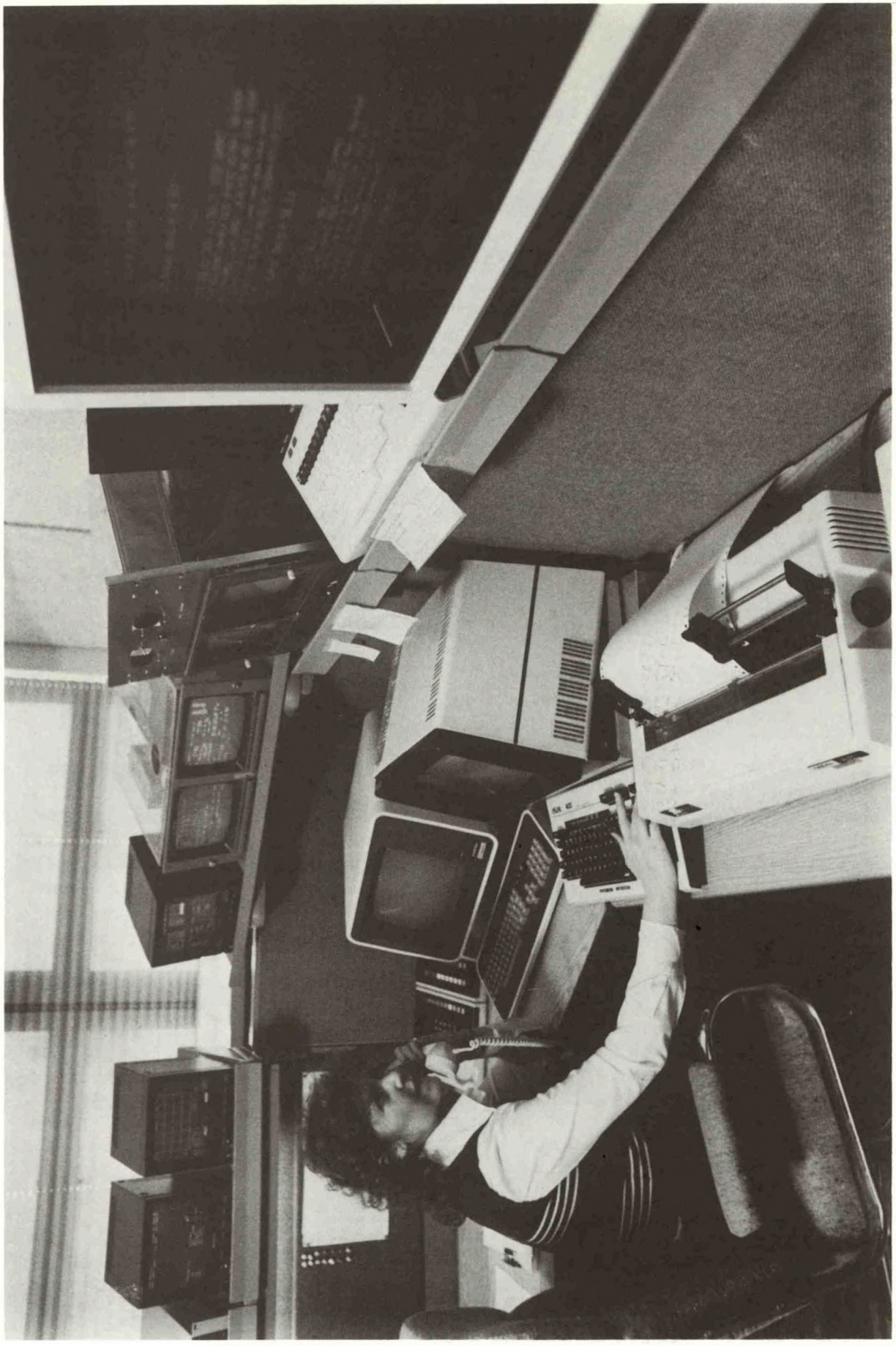

Figure 2. SESC Console.

FORECAST OPERATIONS

The primary role of the SESC is the monitoring, analysis and interpretation of space environment data flowing in real time into the service center. Here the human factor becomes critical in the extraction of useful information from several hundred raw data streams. The data are monitored continuously for quality, edited, combined and analyzed to form a synthesized picture of the space environment. From this process, indices and forecasts are derived to serve the SESC customers.

The SESC operations were carried out in FY 1984 by a staff of NOAA and USAF forecasters and solar-technicians providing services 24 hours per day, 7 days per week. The forecast center, located in Boulder, moved into new facilities in FY 1984. The new facility, Figure 2, is designed to provide the duty staff with ergonomically correct, easy to use data displays, computer terminals and communication equipment.

REAL-TIME DATA AND SOURCES

SESC collects data from its own sensors, from cooperating agencies and institutions, and from other countries through international exchange agreements. The result is a pool of complementary data that allow a real-time assessment of conditions in the solar-terrestrial environment from the Sun through interplanetary space and down into the Earth's environment, including the ionosphere and magnetosphere. The types of data available to SESC in FY 1984 are discussed below.

Solar Optical Observations

Solar observations with optical telescopes provide information on the state of the solar atmosphere (quiet or disturbed) such as the presence of active regions and the global distribution of solar magnetic fields. The observations are used to identify regions of high potential for solar flares, filaments with high probability of eruption, and coronal holes (sources of high-speed solar wind).

The major sources of solar optical data are the Air Weather Service global network of observatories; the Australian Dept. of Science observatories in Australia; and the U.S. National Solar Observatories at Kitt Peak and Sacramento Peak.

Solar Radio Observations

Solar radio telescope observations provide an indication of the energetic solar disturbances, acceleration of

energetic electrons, and the passage of shock waves through the solar atmosphere. Sources of data include the Air Weather Service global network, the Canadian solar radio measurements from Algonquin, and measurements made at Boulder, Colo.

Geomagnetic Field Observations

Geomagnetic observations provide quantitative information on the geographic extent and severity of the geomagnetic variations that occur as a result of solar wind and/or magnetospheric disturbances.

Satellite observations of the geomagnetic field at geosynchronous orbit, and ground-based data from an 18-station network (through the cooperative efforts of the Dept. of the Interior, National Science Foundation, and Universities of Alaska and New York State) are transmitted in real time to the SESC to monitor the effects of solar wind disturbances on the Earth's magnetosphere.

Solar X-ray Observations

Solar X-rays produce interruptions to ionospheric communications simultaneously with the sighting of the optical solar flare. Continuous observations of solar X-ray emissions from the whole Sun are provided by the space environment monitors on the geostationary operational environmental satellites (GOES). Data are collected at Boulder by radio link directly from the satellites.

Energetic Particle Emissions

Solar emissions of high-energy protons, electrons, and alpha particles may cause radiation damage to satellite systems and are potential health hazards to astronauts in space and to passengers in aircraft flying at high latitude. The same particles also cause outages on high frequency (HF) radio circuits in polar areas and are correlated with errors in very low frequency (VLF) navigation systems. The presence of upper atmosphere heating, a consequence of the magnetospheric particle precipitation and Joule heating by ionospheric currents, can be inferred by the magnitude of the total energy deposition measured by sensors on polar-orbiting satellites.

Particle observations are made on the polar-orbiting TIROS (Television and Infrared Observation Satellite), polar-orbiting, and the geosynchronous GOES.

Solar Wind Observations

Solar wind perturbations presage the occurrence of geomagnetic storms at the Earth. Preliminary solar wind

data from interplanetary spacecraft are received in real-time by the SESC. These data include solar wind density and velocity and the interplanetary magnetic field direction and amplitude. The primary source of these data, the NASA International Sun-Earth Explorer (ISEE-3), was dispatched from its location between the Earth and the Sun in FY 1984 and sent on a comet encounter mission under the name International Cometary Explorer (ICE). This has resulted in a decrease in its usefulness to space environment operations.

Other Geophysical Data

Other geophysical data (including cosmic ray, ionospheric, and geomagnetic) are collected in Alaska at a station jointly operated by the Air Weather Service and NOAA, from the NOAA observatory at Table Mountain near Boulder, and from various sources in an international exchange program.

COMMUNICATIONS FOR DATA COLLECTION

The Space Environment Service operates communication links to collect data from NOAA satellites, observatories and monitoring stations. NOAA also provides data collection from the Real-Time Geophysical Observing Network which supplies geomagnetic data, using the Data Collection System on the GOES satellites as a collection point from the widely scattered observatories. Data from RGON and NOAA/TIROS Space Environmental Monitor and Energetic Particle instrument systems are relayed from the National Environmental Satellite Data and Information Service (NESDIS) at Suitland, Maryland, to Boulder. SESC receives required data from the USAF from the Air Weather Net at Carswell AFB. SESC provides a dedicated voice line to connect the SESC at Boulder, the Holloman AFB Solar Observatory, Sacramento Peak Observatory, Kitt Peak Solar Observatory, Offutt AFB, and the NORAD Missile Warning Center. NOAA and the USAF cooperate to maintain data communications from Greenland and Alaska via the High Latitude Monitoring System into Boulder.

The USAF provides communication lines to collect data from its own observatories and monitoring stations to a central point for relay to the Space Environment Services Center.

Data collection was a troublesome area during FY 1984. The old system depends on several networks that are still using old, out-of-date equipment that are no longer serviced by the vendors who supplied it. Replacement of the networks with ties to new systems was delayed during the year by problems in procurement in other agencies that sponsor the networks.

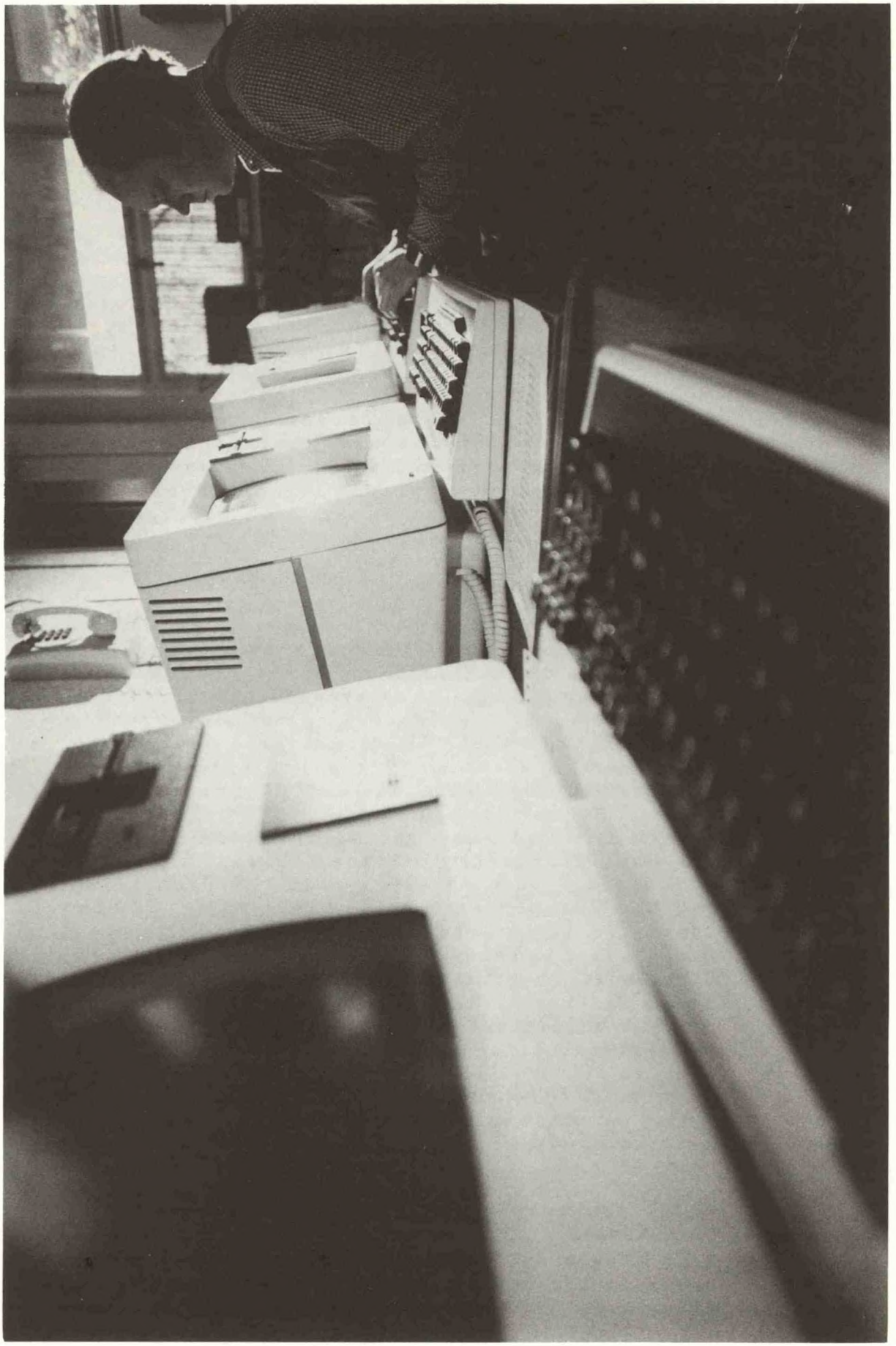

Figure 3. Photo of SELDADS.

DATA DISPLAY SYSTEMS

The primary data system in the service operation is the Space Environment Laboratory Data Acquisition and Display System (SELDADS) for collecting, processing, integrating, storing and displaying solar-geophysical data from observing systems of the DOC, DOD, DOE, DOI, and the National Science Foundation, as well as international data exchange programs. Real-time data entering SELDADS are converted to engineering units, quality controlled, tested for significant solar-geophysical events and stored for later access and archiving. Processing of the data occur continuously, 24 hours per day, 7 days per week. The primary users of the data base are the SESC forecasters. Displays and interactive analyses of the data are used by SESC to provide its forecasts, alerts and summary data. Data are also provided to meet the operational requirements of the Department of Defense and other national users. Summary data are transferred from SELDADS after one month for inclusion in the National Geophysical Data Center for archives. SELDADS was operational over 99% of the time in FY 1984. During the year, the move to a new forecast center meant that all the current data display equipment had to be removed from the old forecast console and re-installed in new display furniture in the new center.

DISTRIBUTION OF SERVICE PRODUCTS

Service products are distributed to users in a number of ways commensurate with customer needs: Radio broadcasts on the shortwave time service WWV contain hourly announcements of space environment indices and predictions; users can call a tape-recorded message in Boulder at their own expense to obtain the same information; alerts of disturbances are distributed by telephone to users who need such information in real time; teletype messages that contain more information than can be included in verbal messages are sent on a collect basis to users who do not have access to other networks.

In its role as the World Warning Agency for the IUWDS, the SESC distributes its products to regional warning centers on each of the major continents.

A major new development in FY 1984 was the initiation of a satellite broadcast service for distribution of the space environment services. The broadcast includes a standard package of forecasts, alerts, and indices that serve the widest practical user community. A standardized data format is accessible by users with microcomputers, large-scale computer systems, or standard printer systems. For example,

the user may display a real-time plot of solar X-ray flux. Information can be used by commercial companies to provide further specialized services to segments of the user community.

TECHNICAL IMPROVEMENTS IN SERVICES

Geomagnetic forecasts and alerts are required by approximately two-thirds of SESC's customers. An improved format for geomagnetic forecasts was developed during FY 1984. Forecasts for 1-, 2-, and 3-day periods indicate the likelihood that the activity level will fall in each of six categories of disturbance, from very quiet to very stormy. A "climatological" data base of magnetic records is being established to provide numerical guidance for the forecaster and to give a basis of comparison for forecast verification.

A study was begun to establish the operational needs and priorities for images and magnetograms of the Sun. It is clear that in the future images will be transmitted from remote observatories in digital format, avoiding the cumbersome photographic processes needed to record the images and transmit facsimile pictures. The use of digital images will open the way for quantitative analysis and comparison of images. For example, these new techniques will facilitate the creation of synoptic solar maps, which even now in their hand-drawn format are a primary input to forecasting of solar activity. The requirements for a new image system, called SELSIS (Space Environment Laboratory Solar Image System) were formulated, and procurement of some of the components was initiated.

The measurement of magnetic shear in active regions of the Sun is being investigated as a way of improving flare forecasts. Shearing of the fields leads to storage of energy, which then may be converted into various forms of particle and electromagnetic radiation in a catastrophic process, identified as a solar flare. Advance knowledge of the total energy available would assist forecasters in estimating the maximum size flare that might occur. The rate of energy build-up may indicate when an unstable level may be reached and a flare will begin.

INTERNATIONAL DATA EXCHANGE

SESC acquires space environment data through international data exchange agreements. Such access is assisted by an international warning and a prompt solar and geophysical data exchange program designated the International Ursigram and World Days Service (IUWDS). Through participation

in the IUWDS, a permanent service of the International Council of Scientific Unions (ICSU), the United States obtains data that would not otherwise be available. IUWDS data exchange is accomplished through Regional Warning Centers which collect the necessary data from observing facilities in their portion of the world, exchange the data with other centers one or more times per day, and then redistribute the foreign data to users within their portion of the world. The SESC has been designated the World Warning Agency for IUWDS.

Future Plans

SERVICES

The basic Services carried out in FY 1984 will be continued in FY 1985, including real-time monitoring, data collection, and processing; the issuance of forecasts, alerts, and indices from the forecast center of the SESC, on a 24-hour per day, 7-day per week basis; and the distribution of service products.

Several improvements in services are planned for FY 1985:

The new geomagnetic forecast format will come on line as part of the Phase I software for SELDADS II.

A new product, to be published in the weekly "Preliminary Report and Forecast of Solar Geophysical Data," will provide a continuous plot of conditions in the space environment at synchronous satellite orbit. The new data displays will assist satellite operators in rapid diagnosis of problems with their spacecraft; problems have increased because of the satellites' electronic components, which are sensitive to disruption in the space environment.

Renovation of the forecast facility will be completed with the installation of new graphics displays that are part of the SELDADS II system. The new equipment will provide displays that tell the current status of disturbances in the solar terrestrial environment, and the operational status of the SELDADS computers and of the communication links into and out of the service center. The forecast personnel will spend much of their non-forecast duty time in establishing requirements for the content, format, and protocol for each of the display systems being constructed as part of the new SELDADS.

The primary new activity will be the implementation of SELDADS II, which is described in the last section.

Other activities will be the design of a processor that will be used to collect real-time data from the NASA International Cometary Explorer (ICE). The processor will allow the solar wind data from the ICE to continue to be available in real time at least some of the time, even though the ICE is in a less desirable orbit for forecast services than was the ISEE.

TECHNICAL IMPROVEMENTS IN SERVICES

The project to improve the geomagnetic forecast format will move into forecast operations as the first phase of SELDADS II comes on line. The development work on the use of shear as a flare forecaster will continue in cooperation with the Air Force observatories. This work will also be integrated into the more advanced capabilities to be developed on the image analysis system including the capability to automate some of the current manual analysis of the synoptic-type solar image data.

Present knowledge indicates that solar flares, and solar mass ejections associated with solar filaments and the steady emission from coronal holes, are capable of producing geomagnetic storms. A study will be made of why these occur for only about one-half of the observed solar events judged to be capable of producing geomagnetic activity.

RESEARCH AND DEVELOPMENT

Introduction

Research and development in support of the National Space Environment Service are carried out in the Space Environment Laboratory by the Research Division and the Systems Support Division.

The Research Division carries out research in the field of solar-terrestrial relations with the objective of improvement of our understanding of the effects of solar activity on human activity.

The Systems Support Division provides general support to the Space Environment Services Division and to the Research Division in planning, development, and provision of Instrument and Data systems.

Current Progress

OPERATIONAL SATELLITE INSTRUMENTATION

Data from operational Space Environment Monitors (SEM) which are carried on the NOAA/TIROS and GOES spacecraft are essential to the operation of the National Space Environment Service. The provision of instruments of existing design to replacement spacecraft and the development of new or improved instruments for existing or new spacecraft designs is therefore a very important supporting activity.

Instruments are normally produced by contractors (or sub-contractors) to the National Aeronautics and Space Administration, which acts in turn as a contractor to NOAA for the provision of the entire operational satellite. SEL sets the requirements for the SEM's and assists with the technical supervision of the instrument contractor. SEL has also been asked by NASA to perform recalibration and repair as necessary on off-the-shelf instruments awaiting flight, and also recently to requalify one existing GOES High Energy Proton and Alpha Detector (HEPAD) instrument, and assemble a second from spare parts for the GOES-G and -H program. This detector provides operational informa-tion on radiation hazards caused by very high energy solar particles during very large solar flare events.

During the year, SEL delivered the first HEPAD to the GOES contractor. The second instrument is expected to be delivered in October.

The existing TIROS SEM instruments awaiting flight were supported as necessary. Two Medium Energy Proton and Electron Detector (MEPED) units were repaired and requalified.

The GOES-NEXT program was supported by finalizing the SEM requirements and revising the resulting specifications. The spacecraft Request for Proposals has been issued and responses will be under review at the close of FY 1984.

The framework of a new software system for the off-line processing of GOES and TIROS data was completed during 1984. The new system was rendered necessary by changes in the satellite telemetry system. Off-line processing, i.e., separate from real-time processing which provides data to the SESC, provides a magnetic tape data base for use within SEL. This is used for data quality control and research and development on new service applications of the data. The tapes are also archived with NESDIS World Data Center-A for use by other scientific organizations. The new system will provide explicit routine quality control and is also being designed so that as much as possible of the system can ultimately operate within SELDADS II rather than the ERL computer system.

SELSIS - SPACE ENVIRONMENT LABORATORY SOLAR IMAGING SYSTEM

During the year a working group was formed to study the future direction of the handling of image data in the SESC. All solar image data are currently used in photographic form, and are obtained from remote observatories by wire photo systems. These systems are old and in need of replacement. The working group recommended that, rather than replace the existing systems, we move to digital image transmission, storage, and display, which is now becoming practical at reasonable cost. The recommendation was accepted and implementation is underway.

The cooperating observatories that provide the images are moving to make all data available in digital form. The benefits expected are improved image quality and, most importantly, the ability to combine image data from more than one source and to carry out quantitative image processing. The system will bring images from Kitt Peak National Observatory, Holloman AFB, and our local H-alpha telescope into the SESC storage system and also permit the exchange of images with NASA Johnson Space Center during Shuttle Spacelab missions that require this support.

The system will be implemented in coordination with existing plans to acquire a scientific graphics workstation; a second identical workstation will be the basis for the SESC image display and processing system. All the necessary hardware is now on order.

SOLAR PHYSICS

Activity was directed toward research to improve medium- and long-range solar predictions (in the range of weeks to 10 years) and toward basic understanding of the structure and evolution of the solar corona, as a prelude to predicting the propagation of solar disturbances toward the Earth and other bodies in the solar system. Statistical studies of geomagnetic and sunspot activity resulted in advances in predicting the levels of solar-terrestrial activity as much as a decade ahead.

Solar Mapping

The goal of this activity is to replace the daily maps of the Sun, drawn by hand, with maps and charts plotted from digital files stored on computer disks, as illustrated in the H-alpha synoptic chart shown in Figure 4. The digital data will serve to make SESC products more uniform and objective, and provide a data base for computer manipulation. An immediate improvement is realized in the accuracy of over-lying images from different observing systems, taken at different times. Software developed this year permits computer production of the daily disk solar map, complete with annotation of SESC serial numbers for solar active regions. Provision is made to allow plotting of a map from data obtained one or more days earlier so that an operational map can be constructed in times when weather or equipment problems prevent receipt of solar image data.

Implementation of these mapping procedures will eliminate duplication of effort in producing the daily maps for real-time use and the production of synoptic charts used in long-range forecasting and in support of solar-terrestrial research. The conversion to a digital data base will permit coupling of solar maps with digital solar image processing as it is developed. Development of computer displays from the digital data files can proceed with current data rather than delaying this development until advent of the digital imaging. This work will facilitate application of research involving large-scale solar magnetic fields and the solar corona.

Work continued, under contract to NASA, to provide real-time communication of daily maps of solar magnetic fields from Stanford University to SESC. The Stanford maps are plotted at the same scale and format as the maps generated from other solar images available to SESC.

A computer program was developed for using these data to compute the distribution of large-scale, solar magnetic fields at the height above the solar surface where these fields are expected to couple directly to the inter-planetary magnetic fields. This quantitative model of the solar

coronal environment will be a basis for predicting the propagation of solar disturbances from the Sun.

The data base of H-alpha synoptic charts (global maps of the Sun for each complete 27-day solar rotation) was maintained and prepared for archival publication in Solar-Geophysical Data. These edited charts have been used to construct time series of limited latitude zones of the Sun for monitoring long-term, large-scale evolutions. The formation of strong centers of sunspots and solar flares and the occurrence of large, stable coronal holes have been tentatively associated with patterns of convergence and divergence, respectively, in the evolving large-scale patterns of magnetic fields. The maintenance of the data base on large-scale solar activity is a necessary prelude to the development of practical methods for making 27-day, solar-terrestrial predictions.

Large-Scale Solar Activity

A collaborative study of solar maps combining large-scale magnetic-field patterns with filaments and coronal holes has resulted in a detailed description of the process of reversing the polarity of the poles of the Sun. The polar reversal occurs a year or two after the peak in the 11-year cycle. Study of this process may offer clues to the physics of the solar cycle and a basis for long-term solar predictions. This study found that the process was discontinuous, and occurred in organized meridional flows rather than through a diffusive process.

Long-range predictions of sources of strong X-ray flares have been resumed in support of NASA research programs directed toward solar and magnetospheric physics. The prediction technique uses time series of H-alpha synoptic charts to derive maps of velocities over the entire solar surface. Anomalies in the large-scale flows, such as excessive shear and convergence, precede the occurrence of major sunspots.

A new model for the formation and structuring of sunspot groups has been developed from study of the relationships between sunspots and the large-scale magnetic fields.

Long-Term Solar-Terrestrial Activities

A study of recurrent geomagnetic activity led to a new index for separating the recurrent component from the eruptive component in geomagnetic activity. This study is being extended to use the index to make predictions of sunspot cycles several years earlier than previously possible.

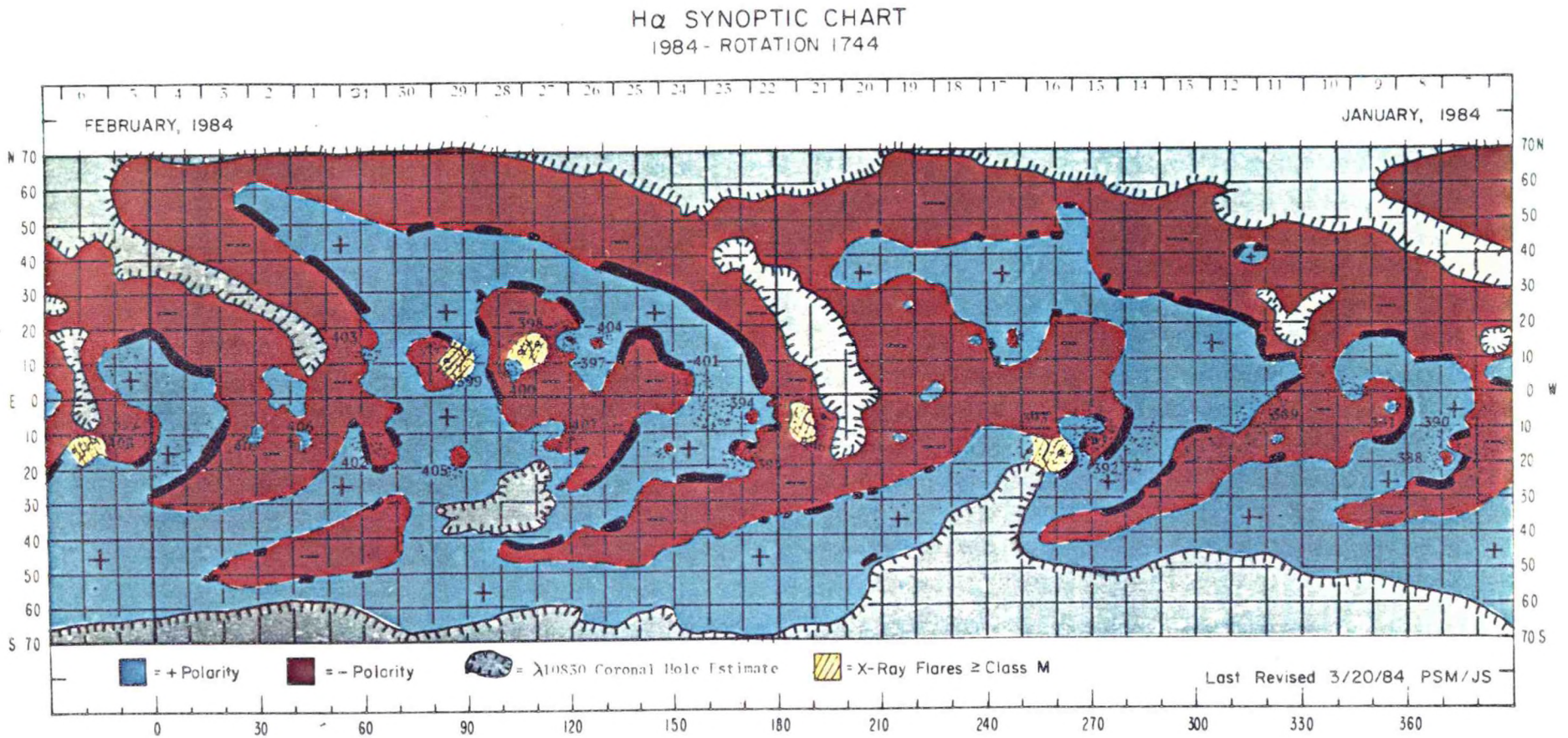

Figure 4. Charts of the Sun, showing large-scale aspects of solar activity, assist solar forecasters and provide data base for studies of the causes of solar disturbances. This global map of the Sun is color coded to emphasize polarity of solar magnetic fields, coronal holes, and the sources of strong X-ray bursts. The ribbons of black represent solar filaments, fence-like structures that form above the boundaries between opposite magnetic polarities. Large sunspots are dots, usually within the yellow areas. Small dots signify areas of enhanced magnetic fields. The grey coronal holes are mapped from the infrared HeI line at (lambda) 10830. All other details are mapped from photographs taken in the hydrogen line at (lambda) 6563. This chart is a prototype of those that will be produced routinely with new computer graphics programs being developed in SEL.

Solar Flare Evaluation

Provisional mathematical models have been established for the early rise and decay of the X-ray flux from solar flares, as a step in the development of an automated means for early detection of X-ray flares and prediction of their peak intensity and rate of decay. If successful, the models will improve predictions of communication disruptions caused by solar X-ray bursts.

Solar Active Regions

A catalog is being compiled of outstanding active regions in terms of their X-ray flare production to link solar active region formation to the large-scale solar evolution. These data were used to update the correlation between sunspot class and flare activity reported at the Solar-Terrestrial Predictions Workshop sponsored by Observatoire de Paris.

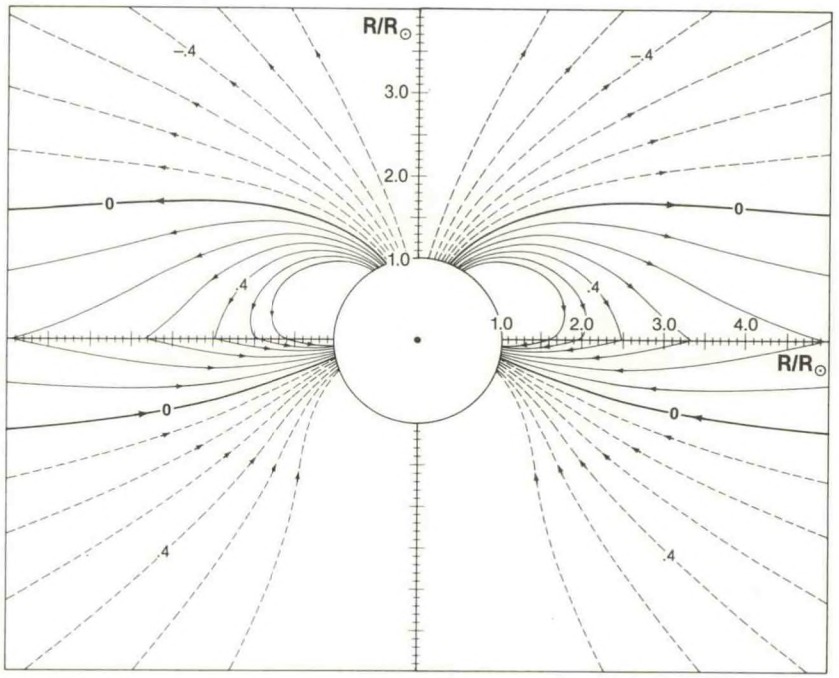

Figure 5. Represents the magnetic structure with quadruple of the solar corona between 1 and 5 solar radii (R_o). We increase the size of the southern polar coronal hole and decrease the size of the northern coronal hole.

Coronal Modeling

Work continued on theoretical and empirical models of the solar corona. A study of the structure and electrical currents of the corona was completed. For the first time, it has been shown that interaction between global azimuthal current around the Sun with the underlying magnetic potential leads to redistribution of density in solar corona. During solar minimum, the density in the equatorial plane is two to three times larger than in polar direction (pole-equator asymmetry). Inclusion of a quadruple field introduces north-south asymmetry in addition to pole-equator asymmetry. The influence of a quadruple magnetic field on the solar corona is illustrated in Figures 5 and 6. Modeling of solar filaments is underway to aid in predicting instabilities over neutral lines that precede solar flares and coronal transients. Algorithms have been produced for computing source surface magnetic field distributions from photospheric magnetic fields, and calculating the connection points between the Earth and the solar surface.

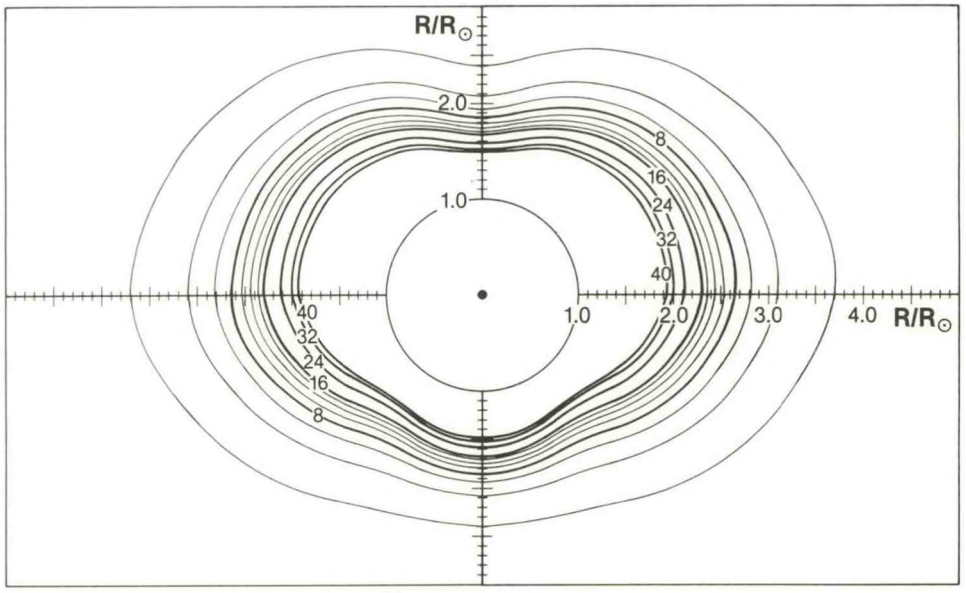

Figure 6. Shows the corresponding isodensity contours which are affected by the presence of teh quadruple: The South-North asymmetry in density distribution results in different accelerations of solar wind from the two poles.

INTERPLANETARY PHYSICS

Approximately two-thirds of the SESC customers would benefit from improved forecasts of the occurrence of magnetic storms. The results of studies directed toward this objective are discussed below.

It is known that solar flares accompanied by Type II radio noise bursts are apt to produce shock waves in the solar wind, which travel through the interplanetary medium and produce a geomagnetic storm.

A comparison was made of the predicted times of arrival of shock waves at the Earth and the observed geomagnetic storm sudden commencement for 59 solar flare events. The predictions used the Air Force Geophysical Laboratory algorithms for shock-wave propagation based on the shock velocity at the Sun deduced from Type II bursts. The median prediction was 1.35 hours late with a standard deviation of 6.9 hours. A "Users' Guide", with instructions on reporting of these Type II shock velocities, has been distributed to all USAF solar radio observing sites.

Propagation of Solar Wind Disturbances

A time-dependent, magnetohydrodynamic (MHD) numerical model for the propagation of shock waves through the interplanetary medium was tested using data for a series of solar events in August 1979. Figure 7 shows the distribution of disturbance speed with distance from the Sun, in the ecliptic plane, for solar disturbances on 16 August 1979 and 18 August 1979. Qualitative agreement, but with changes in phase and amplitude differences, was achieved with an approximation to a fully 3-dimensional (3-D) model. Work has started on a fully 3-D, time-dependent model starting with the special case of flare-generated shock waves. Both the approximate and fully 3-D models are initialized at 18 solar radii. Closer to the Sun, 2-D and the approximate 3-D model predictions of the structure of coronal disturbances have been compared with many types of coronal observations in white-light, radio, X-ray, and UV wavelengths. This work opens up the possibility, from an operational viewpoint, that real-time observations of coronal structures can be used as input for a fully 3-D model. Fundamental studies, using higher moment equations, were completed to demonstrate the need for incorporating thermal conduction and multifluid aspects into these interplanetary global circulation model programs.

Geomagnetic Activity Forecasts and Warnings

The approximate 3-D model was used with observed solar hydrogen alpha and magnetograph data (to provide "best esti-

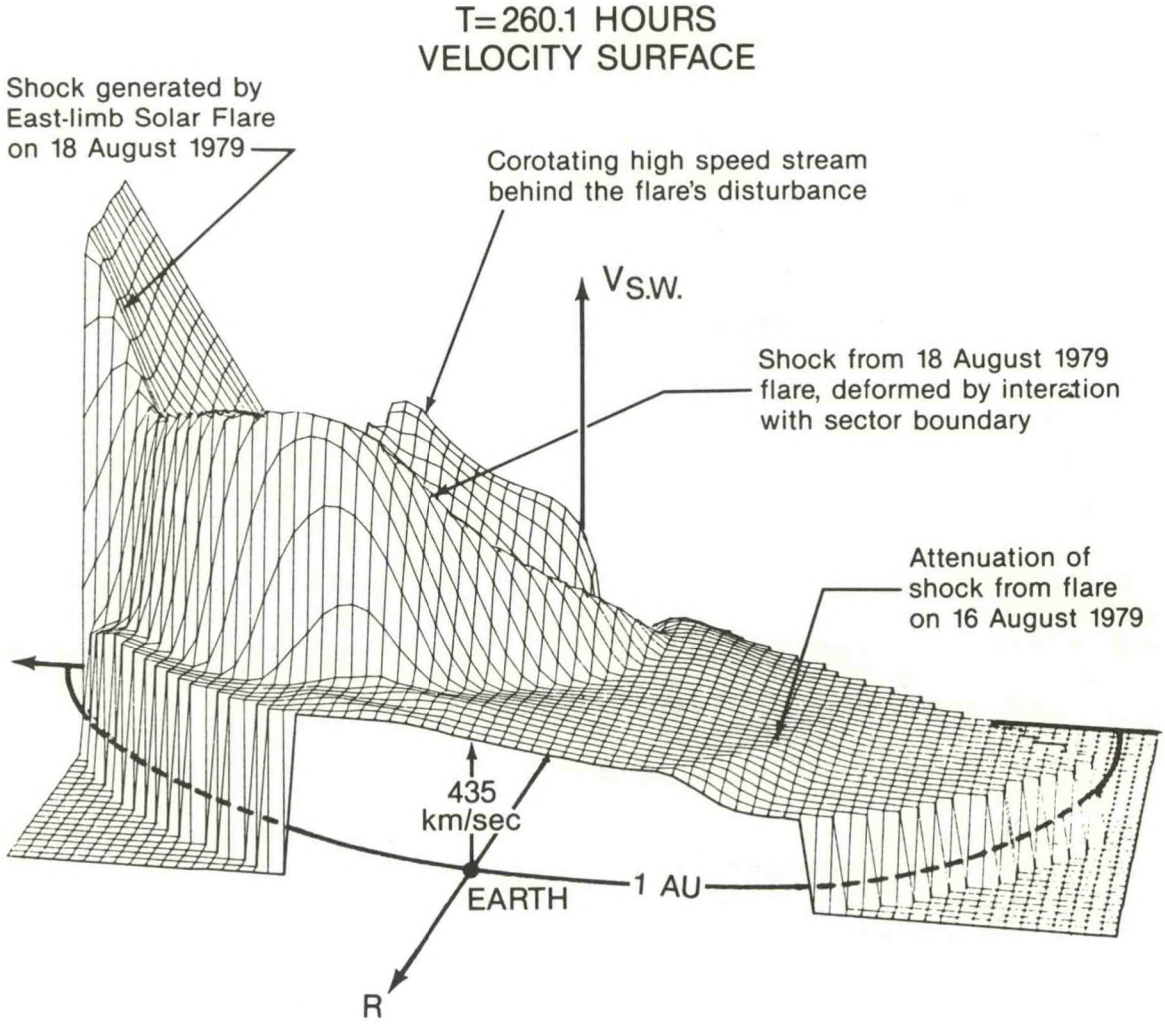

Figure 7. The velocity surface shown is an example of the output of the two-dimensional model. This numerical model computes the evolution of solar disturbances as they propagate through the interplanetary medium and shows how solar events, even when not directed towards Earth, if sufficiently energetic, can affect the Earth's environment. The Sun is located at the origin of the coordinate system.

mate" of solar output) to give time series of the Poynting energy parameter, and cross-tail electric field at Earth's location for a 2-week period in August 1979. This output could conceivably provide a forecaster with predictions to answer four questions: Will a disturbance occur? When will it occur? How large will it be? How long will it last?

MAGNETOSPHERIC PHYSICS

Research in the Magnetospheric Physics Area is directed toward understanding of the dynamical processes by which material and energy are transported from the solar wind into the magnetospheric system, stored, and eventually dissipated in the Earth's ionosphere. Both applications and supporting research are pursued, directed toward enhancement of the quality and utility of the Laboratory's space environment products and services.

Polar Cap Data

The first two volumes of a series of atlases of energetic particle observations by instruments aboard the NOAA/TIROS series of low-altitude, polar-orbiting satellites have been published. These data cover the period from January 1979 through May 1983, and will be continued in subsequent volumes to the present. These data permit the operational or research user to identify solar cosmic ray and other event periods of interest, establish an event chronology of importance to synoptic studies, and intercompare equivalent data from other satellites.

Omega VLF Study

A study was undertaken in support of the Omega Navigation System to investigate long delayed (days) recoveries of the system signals following disturbances caused by Polar Cap Absorption (PCA) events. System responses during and following five large PCA events were compared with the associated particle fluxes measured on the SMS/GOES and NOAA/TIROS series of satellites. A close correlation was found between the recovery of the VLF signals and the flux of energetic protons in the range of 4-8 Mev. A simple algorithm was defined which allows the prediction of the VLF phase recovery based on the real-time observations of the proton flux. Operational tests of this algorithm have been implemented.

Data Support

A report is being prepared that will provide summary information concerning the instruments constituting the Space Environment Monitors aboard the appropriate GOES satellites, and form a basis for the use of the data both in-house and by external groups.

External Cooperative Support

Laboratory scientists provided consultation and energetic particle data from the GOES and TIROS satellites to the Defense Nuclear Agency (DNA) for use in its Long Wave

Program, which studies the propagation of Extremely Low Frequency (ELF) and Very Low Frequency (VLF) waves at high latitudes.

Satellite data and analyses were also provided to the scientific community as a cooperative activity in the Middle Atmosphere Program (MAP), an international cooperative program under the aegis of the Scientific Committee on Solar-Terrestrial Research directed toward the study of the structure and dynamics of the high-altitude, middle atmosphere through coordinated high-altitude research rockets, and by ground-based and satellite observations.

Laboratory scientists participated in NASA/Air Force working group meetings on Spacecraft-Environment Interaction in order to evaluate the environmental causes of spacecraft anomalies and failure, and to asses the operational monitoring of the near-Earth environment needed to provide useful warnings and forecasts of satellite disruptive periods. Also, there was participation in a NASA working group meeting on Spacecraft-Environment Interaction held at the U.S. Air Force Academy in October, 1984.

Magnetospheric Acceleration Processes

Approximate analytic procedures have been developed to represent and characterize the magnetospheric tail acceleration process by which magnetospheric particles are energized by the cross-tail electric field. These energetic particles are precipitated into the auroral zones, and also provide a significant source of charged particles to the Earth's ring current system, which is responsible for a major portion of geomagnetic disturbance. The level of geomagnetic disturbance is presently the single, most important parameter in determining disturbance to communications, power transmission, and satellite systems. An extension of the original theoretical development of this important mechanism by SEL scientists has received broad acceptance by the scientific community.

Magnetospheric Boundary Phenomena

Theoretical work and model calculations continue on the dynamical processes occurring at magnetospheric boundaries. Comparison is made between model calculations and satellite observations in the context of trying to define the reconnection process by which interplanetary field lines, convected outward from the Sun by the solar wind, interacts with the geomagnetic field at the magnetopause. Understanding boundary properties is crucial to understanding the processes by which solar wind energy is coupled to the magnetospheric system.

ATMOSPHERE-IONOSPHERE-MAGNETOSPHERE INTERACTIONS

The objectives of the research in the atmosphere-ionosphere-magnetosphere interactions area are to understand the transfer of energy (both in the form of electrical and mechanical energy) from the Earth's magnetosphere into the upper atmosphere and to understand and characterize the various consequences that may arise in the Earth's ionosphere and upper atmosphere because of this energy input.

The observations from instruments on board the NOAA/TIROS series of spacecraft continued to be processed and used both in research, and in a growing number of operationally oriented programs. Normally, about 96% of all data gathered by these satellites is recovered and archived within ten days of receipt. Difficulties with noisy data from the total energy detector on NOAA-7 were experienced at the end of FY 1983 and the NOAA-8 spacecraft suffered a failure in June 1984. However, the NOAA-6 spacecraft was re-activated and data are being received from that satellite. NOAA-9, scheduled for launch in late 1984, will not contain a space environment monitor, which will reduce these observations to a single spacecraft for the first time since June 1979.

Work continued on the development of the estimate of the power dissipated in the auroral atmosphere by precipitating particles, based on single passes of these satellites over the Earth's polar regions. Estimates of the total amount of power being deposited into the atmosphere may characterize the degree of geophysical activity and its consequences in a more quantitative manner than is possible with conventional magnetic indices. In the course of this study a set of statistical "maps" showing the global pattern of energy input to the atmosphere for various levels of total power input was also developed.

The statistical patterns of energy input show an isolated island of energy input located at very high latitude at about 2 p.m., which is particularly apparent at low levels of activity. Other researchers have pointed out that this particular location is also the site of a local maximum in other geophysical phenomena, notably the intensity of currents flowing between the ionosphere and a dynamo located in the magnetosphere. A study using the NOAA/TIROS data was conducted to determine the nature of the particle energy influx at this location. The energy input is exclusively in the form of electron precipitation having thin, auroral, arc-like geometries. Independent observations demonstrated the disturbance introduced into the ionosphere by this precipitation. Moreover, correlations of these TIROS data measurements with those on board high-altitude, scientific satellites suggest that the fundamental cause of this precipitation is a dynamo process driven in the outer magneto-

sphere by a direct solar wind interaction. The comparatively simple geometry of this process may allow a theoretical analysis to be done which, in turn, will shed light upon the more complex nighttime magnetospheric-ionospheric-atmospheric processes.

Numerous scientific collaborations utilizing the NOAA/TIROS data were conducted during the last year. Generally, these involved the use of the data in conjunction with ground-based and satellite measurements of individual geophysical events. In addition, the statistical maps of the energy input, created from the large data base of observations that now exists, are being used by a research group at University College, London, as an input to a model of upper atmospheric dynamics. The use of these data for such a purpose could be of great benefit to the objective of deducing the density and temperature of the upper atmosphere from the satellite observations of total energy deposition.

There were several instances of the use of the NOAA/TIROS data in support of operational programs. The historic observations were used to determine the particle environment through which large, polar-orbiting satellites (such as the Shuttle) will be required to pass. These particles, impinging upon the satellite, can produce malfunctions which, experience has shown, grow more frequent as spacecraft become larger and more complex. To this end, an analysis was done on the frequency and nature of the unusually large energy flux events that are encountered by these satellites from time to time. This analysis was forwarded to the Jet Propulsion Laboratory for evaluation.

In the same vein, these data were supplied to NOAA's National Environmental Satellite, Data, and Information Service (NESDIS), and sometimes directly to a user, to assist in their interpretation of satellite system malfunctions that often tend to occur repeatedly within a limited period of time. One such instance centered around September 1983, and SEL was called upon to supply data from that period.

Future Plans

OPERATIONAL SATELLITE INSTRUMENTATION

The Laboratory will participate in the review of contractors' proposals for GOES-NEXT. The ongoing operational satellite space environment monitoring sensor program will continue to be supported by the delivery of the HEPAD for GOES-I and by any other technical support required.

The off-line processing system will be completed and automatic, routine, quality control implemented whenever possible. The system will be at least partially implemented on SELDADS II.

SELSIS - SPACE ENVIRONMENT LABORATORY SOLAR IMAGING SYSTEM

Programming for the digital communications and image storage and display will commence in early FY 1985. It is planned to have the system in limited operation by March 1985.

SOLAR PHYSICS

- Increase the opportunities for achieving, and the plans for using, a spaceborne monitor for coronal transients, solar flares, and coronal structures that influence the propagation of disturbances and material from the Sun.

- Complete operating manual for computerized, routine, solar mapping and train SESC staff so as to assure a reliable data base for both short-term and long-term solar-terrestrial predictions.

- Edit preliminary H-alpha synoptic charts for publication and for use in development of long-range solar forecasting.

- Study large-scale patterns of solar magnetic fields and their relation to the formation of centers of strong solar activity. Convert results to procedures for use in SESC 27-day (and longer) solar-terrestrial forecasts.

- Develop real-time computation of source-surface magnetic field configuration above the solar surface for use in operational evaluation of solar events. Refine communication and display of Stanford solar magnetic maps.

- Extend coronal modeling to more complex conditions at solar maximum. Add theory of fine structure in magnetic flux tube under the influence of external fields. Continue modeling of solar filaments. Attempt to tie results to efforts to model the interplanetary environment.

- Refine and continue to disseminate forecasts for the time of sunspot minimum and amplitude of Sunspot Cycle 22. Continue studies of other methods for solar cycle predictions in comparison with methods developed by laboratory scientists.

- Develop a computer technique for early recognition of an X-ray solar flare, prediction of the time of peak

intensity, the magnitude of peak intensity, and the rate of decay.

- Make comprehensive study of coronal hole images at all observed wavelengths and determine utility for predictions of geomagnetic activity.

- Investigate source of the semi-diurnal X-ray detector variations between widely separated geosynchronous satellites.

- Investigate epochal nature of solar activity (4-7 months "pulses") and its relationship to the evolution of large-scale solar magnetic fields. This will include study of the phenomenon of active/inactive solar longitudes. Examine whether these studies suggest practical steps toward long-term, solar-terrestrial predictions.

- Implement a verification system for one selected SESC forecast product. This would be a cooperative project with the SESC. It will address those basic philosophies and principles that would be used in the future for bench marks of forecast algorithms and for decisions on directions of research efforts.

INTERPLANETARY PHYSICS

Forecast Verification:

The predictive capabilities of the approximate 3-D MHD model will be tested against additional real-events to better understand the effects of different input parameters on the accuracy of the predictions.

Propagation of Solar Wind Disturbances:

The approximate 3-D model will be incorporated into the new scientific work station computer. Additional graphical displays will be added, together with a complete 360 degrees ecliptic plane projection of propagating disturbances. In collaboration with several contractors, a graphical capability will be developed for the 3-D model as well as an extended heliolongitudinal and heliolatitudinal capability. The model will be expanded to handle various kinds of solar disturbances such as eruptive prominences, and coronal hole streams, as well as solar flares. The solution to a two-component (electrons and protons), five-moment solar wind will be pursued together with a related study on the effect of an interplanetary electrostatic field in regions of high density, and magnetic field gradients, and electric charge separation.

MAGNETOSPHERIC PHYSICS

- Extend the Energetic Particle Atlas series to include current data.
- Continue support to external users including Long Wave Navigation Program, Spacecraft-Environment Interaction working groups, and similar activities.
- Investigate the potential of GOES magnetometer data for prediction of geomagnetic disturbance.
- Begin a study of numerical simulation techniques in magnetospheric plasma processes. Analytical work in this field has emphasized the MHD approach. It has become increasingly evident that approximations, such as charge neutrality, inherent in the MHD equations limit their application to magnetospheric processes. Plasma numerical simulations, while complex, approach the problem at a microphysics level, where such approximations can be avoided.
- Continue theoretical and model boundary work on reconnection and plasma sheet boundary phenomena.

ATMOSPHERE-IONOSPHERE-MAGNETOSPHERE INTERACTIONS

- A senior researcher from the Atmosphere-Ionosphere-Magnetosphere Interactions group will spend FY 1985 as a visiting scientist at the Stanford Space Telecommunications and Radio Laboratory and at the Lockheed Research Laboratories, Palo Alto. These research groups are very active in the field of space research, and both are vitally concerned with the impact of the near-Earth environment upon both communications and space systems. The research work performed during this period will greatly increase SEL's understanding and expertise in this important field.
- Routine processing of TIROS/NOAA data will continue, and arrangements have been made to ensure that requests for data, particularly from operational sources, will be filled.

SELDADS II

The Space Environment Laboratory Data Acquisition and Display System (SELDADS) provides computer-assisted access to solar-geophysical data from a variety of satellites and ground-based observatories around the world in near real-time. The SELDADS II system now in development will replace the aging SELDADS I system and provide for improved access, analysis, and display of these data with increased reliability.

Current Progress

A new Data General MV10000 was installed in July in the newly prepared site near the SELDADS I, which will remain in operation until the Phase I application software of the new system is complete. Acceptance testing began in August. Software supplied will include a customized data base (software) system and a comprehensive graphics (software) system. A series of WICAT 150 computers will serve as preprocessors to operate separately on each incoming and outgoing data stream to prepare the data for introduction into the main processor, which will concentrate on data base management and analysis software. Status displays required for basic forecast center operation will be driven both by preprocessors and by the main system to provide redundancy and continuity in the new system. The preprocessors will be identical so that one that fails while handling high priority data can be replaced by another handling lower priority tasks.

A Project Management Panel to manage the development of software for the new system has been appointed and personnel for the development effort have been identified within the Laboratory. The conceptual design for the application software has been completed and the products to be generated in the first phase of the implementation have been identified.

Future Plans

The implementation will proceed in three phases. Phase I will provide a capability equal to the present SELDADS I system, and after some period of parallel operation of SELDADS I and the Phase I system, SELDADS I will be turned off. Phase II software will implement analysis capabilities that are presently known, but have not been implemented because of the saturation of SELDADS I. Phase III software will begin the implementation of new forecast techniques such as models. Phase I software will take most of the effort in FY 1985; a beginning of Phase II will occur later in the year. Phase I is expected to be completed early in 1986 and major effort will then shift to Phases II and III.

SPACE ENVIRONMENT LABORTORY PERSONNEL - FY 1984

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Ahl, Irene V.	Secretary
Jean, A. Glenn	Deputy Director

ADMINISTRATIVE SUPPORT, Gayle Coss, Administrative Officer

Aldridge, Carol	Secretary (Typing)
Conners, Linda N. ***	Budget Assistant
Erbert, Karen E.	Budget Assistant
Reidy, Anne M.***	Secretary (Typing)

SERVICES DIVISION, G. Heckman, Acting Division Chief

Chief Forecaster, Joseph W. Hirman

Research Liaison Officer, JoAnn J. Joselyn

SELDADS II Implementation Project,	Thomas G. Gray, Project Leader
Algiene, Thomas	Electronics Technician
Starr, Irma J.	Computer Assistant

Real-Time Data Services, Charles R. Hornback, Chief

SELDADS Manager, Jacob D. Schroeder

Facilities Manager, Alvin M. Gray

Abeyta, James R.	Computer Programmer
Barrett, William	Electronics Engineer
Hale, Harold D.	Electronics Technician
Hines, Robert G.	Electronics Engineer
Jones, Paul H.***	Electronics Technician
LeGrand, Frechet***	Mathematician
Seegrist, Larry E.	Electronics Technician
Wasmundt, Donald F.	Electronics Engineer

Space Environment Services Center, Gary R. Heckman, Chief

Abbott, Ann E.	Data Center Clerk
Balch, Christopher	Physical Science Technician
Brown, John T.***	Physical Scientist
Carran, Kurt L.	Communications Manager
Chilson, I. Gayle	Physical Science Technician
Cowley, Franklin C.	Mathematician
Cruickshank, Cheryl M.	Computer Programmer Analyst
Dunbar, Paula K.	PhysicalScience Technician
Flowers, William E.	Space Scientist
Goehringer, Bette C.	Communications Relay Operator
Hill, Viola J.	Mathematician
Jahn, Fredrick, Jr.**	Physical Science Technician
Kiefert, Carroll	Physical Science Technician
Kildahl, Karl	Space Scientist
Kunches, Joseph M.*	Physical Scientist
Pena, Diana**	Data Clerk
Pourier, Alonna K.*	Data Clerk
Recely, Frank J. , Jr.	Space Scientist
Smith, Jesse B., Jr.	Space Scientist
Spear, Kerry A.*	Physical Science Aid
Speich, David M.	Space Scientist
Sutorick, Joseph A.***	Space Scientist
Tomlinson, Kathy*	Data Clerk
Wilvert, Audrey J.	Secretary (Typing)

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Jacobwith, Thomas	Clerk Typist
Jones, Beulah F.***	Clerk Typist
Speiser, Theodore W.*	Physicist
Wiarda, Marianne W.	Secretary (Typing)

Atmospheric Interactions, David S. Evans, Project Leader

Richmond, Arthur E. ***	Physicist

Magnetospheric Physics, Herbert H. Sauer, Project Leader

Rufenach, Clifford	Physicist

Interplanetary Physics, Murray Dryer, Project Leader

Quintana, Annabelle D.**	Mathematics, Student Trainee
Puga, Lawrence***	Physical Science, Student Trainee
Smith, Zdenka A.	Physicist

Solar Physics, Patrick McIntosh, Project Leader, Acting

Garcia, Howard	Physical Scientist
Sargent, Howard H., III	Space Scientist
Scott, Joel	
Wagner, William	

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Arellano, M. ***	Student Engineering Trainee
Barrett, William P.	Electronics Engineer
Detman, Thomas	Physicist
Dayhoff, Raymond E.	Electronic Technician
Dillon,MatthewJ.**	StudentEngineering Trainee
Falcon, Janet E.	Mathematician
Jones, John E.	Electronics Engineer
Lewis, Dave	Physicist
Maish, Michael***	Electronics Engineer
Martin, Kathleen, S.	Secretary (Typing)
Matheson, Lorne	Physicist
Orswell, Prentice L.***	Electronics Engineer
Retallack, Wiliam M.	Computer Programmer
Seale, Richard	Electronics Engineer
Stephenson, Judith J.	Mathematician
Taylor, John H.	Electronics Engineer
Walden, David C.***	Computer Programmer
Walter, Steven J.***	Physicist
Winkleman, Jim	Mathematician

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LT. Walter Latimer
LT. James W. O'Clock

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TSgt. Larry Combs
Msgt. Phillip Powell
Major Bruce Springer
Msgt. Harry Sorg

USAF (At Anchorage, Alaska)

Capt. Thomas Clark
S. Sgt. James Kizer

GUEST WORKERS

Coy, Steven	Student Trainee
Gao, Meiqing	Research Assistant
Gillis, Ed	Student Trainee
Martin, Richard	Post Doctoral
Yeh, Tyan	Guest Worker
Sami Cuperman	University of Tel Aviv, Israel
Dusenbery, Paul	Post Doc and University of Colorado
Sang Moo Han	Tennessee Technological University
Kartalev, Mario	Center of Mechanics, Bulgaria
Kling, Ron	University of Colorado
Neff, James	University of Colorado
Osherovich, Vladimer	Post Doc
Spjeldvik, Walther	CIRES

THIS LIST INCLUDES ALL SEL FU11-TIME AND PART-TIME EMPLOYEES ONBOARD DURING FY 1984, INCLUDING:

* Intermittent Employees
** COOP Students
*** Personnel no longer employed at SEL

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