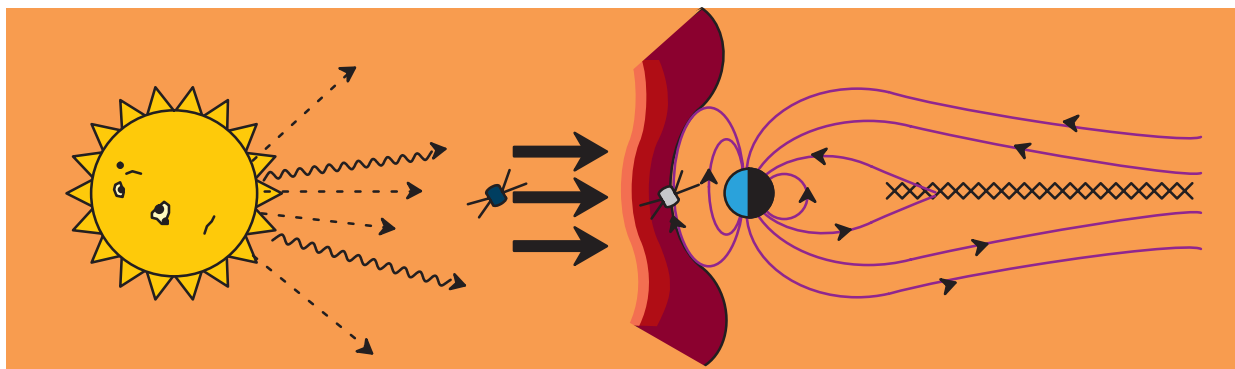


# Space Environment Laboratory in Review 1993



**U.S. Department of Commerce**  
**National Oceanic and Atmospheric Administration**  
**Environmental Research Laboratories**

January 1994





*As the Sun sets behind the Flatirons in Boulder, Colo., our telescope captures an enthusiastic SEL worker in silhouette.*

*COVER: Image of the solar atmosphere in soft x-rays. Bright structures are more dense and (or) hotter than elsewhere; they outline magnetic fields. The image is from the Yohkoh satellite of the Japanese space agency, ISAS. The x-ray telescope was prepared by the Lockheed Palo Alto Research Laboratory, the National Astronomical Observatory of Japan, and the University of Tokyo with the support of NASA and ISAS.*



Space  
Environment  
Laboratory

## *A Message from the Director*

Demand for space environment services continues to grow as Space Environment Laboratory (SEL) concludes its 28th year. The Laboratory's talented and dedicated staff have much to be proud of as we deliver high-quality, uninterrupted services to our customers. Increasingly sophisticated research and development enable us to continually improve our services.

In the spirit of Total Quality Management, SEL has made a directed effort to refine its internal processes, improve its services, and interact with customers. In the last year we have initiated some new services; they are described briefly on page 12.

Recently, there has been much discussion about "reinventing government," or streamlining each agency's activities to provide better service to its customers more efficiently. We look forward to being a part of the efforts in the Department of Commerce and NOAA to implement the ideas in the National Performance Review. We have begun by reorganizing the Lab into a two-division structure, described on page 6, which has resulted in high morale and more efficient operations.

SEL is an improving, achieving organization. We provide services vital to the Nation's economic welfare. Although this report presents only highlights of Space Environment Laboratory's activities and accomplishments (including a list of publications), they suffice to show that the Lab has accomplished much despite somewhat constricted funding.

Your comments about SEL or this report will be warmly welcomed.

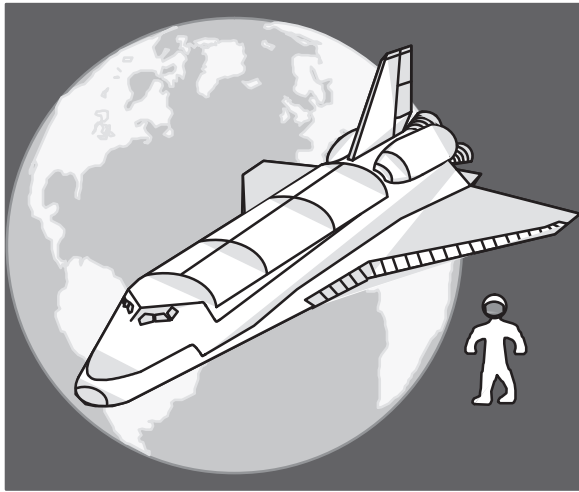
### **Dr. Ernest Hildner, Director**

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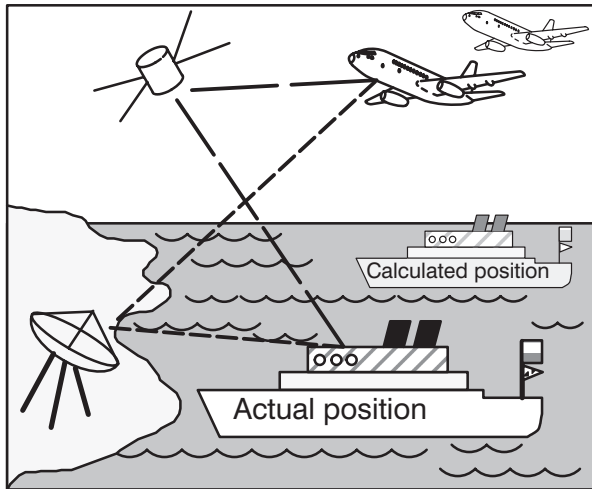
# Welcome to Space Environment Laboratory

## *Who we are and what we do*

### *Effects of disturbances in the solar-terrestrial environment*



*Astronauts can be exposed to serious radiation hazard during major solar activity.*



*Electronic navigation can be in error due to the shifting of radio waves*

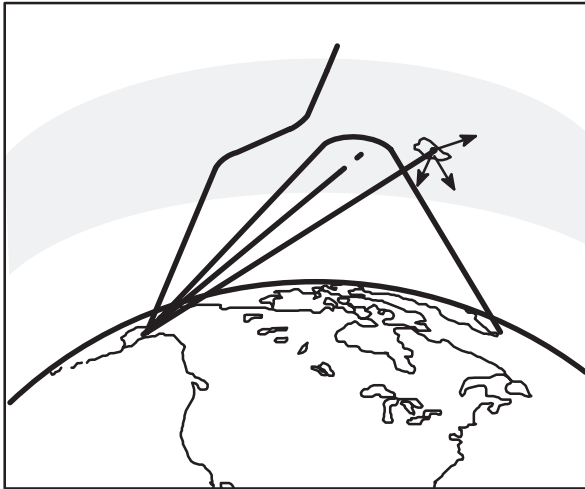
On the trip back after an explosion in their spacecraft on the way to the moon, the crew of Apollo 13 had to navigate their “lifeboat” through the dangerous radiation belts around Earth. The Space Environment Laboratory (SEL) was the “lighthouse,” providing critical guidance to this wayward vessel.

Not every user of Space Environment Services has human life in the balance, but many users find our services vital to their operations. Our customers are affected in diverse ways by variations of the space environment:

- **Electric power companies**—failures of power distribution grids
- **Satellite operators**—sharp increases in satellite drag and unwanted torques; radiation damage to electronics
- **Positioning**—radio-navigation errors
- **Manned space flight**—radiation hazards to astronauts
- **Space exploration and research**—seeking or attempting to avoid anomalous conditions for experiments
- **Pipeline companies**—corrosion avoidance
- **Radio communication**—frequency selection
- **Air Force and other national security**—adverse effects on surveillance satellites

The “weather,” or variations, in the space environment is what concerns our users. This weather begins on the Sun and disrupts the space between the Sun and Earth, touching the atmosphere above Earth and sometimes reaching to the ground on which we stand.

*Effects of disturbances in the solar-terrestrial environment*



*Radio waves that bounce off the atmosphere go astray.*



*Power grids overload during large geomagnetic storms.*

## *Mission*

**To serve the Nation's need to reduce adverse effects of solar-terrestrial disturbances on human activities, Space Environment Laboratory will**

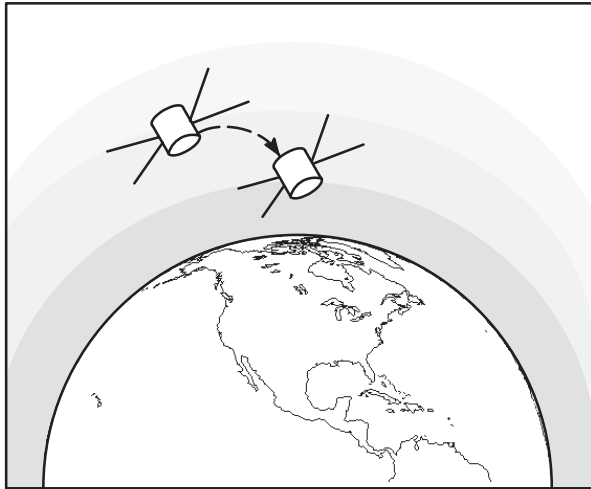
- acquire, interpret, and disseminate monitoring information.
- prepare and disseminate forecasts and alerts of conditions in the space environment.
- conduct research and development in solar-terrestrial physics and in techniques to improve monitoring and forecasting.
- prepare high-quality data for national archives.
- use its expertise to advise and educate those affected by variations in the space environment.

SEL, in Boulder, Colorado, is one of the 11 Environmental Research Laboratories of the National Oceanic and Atmospheric Administration (NOAA).

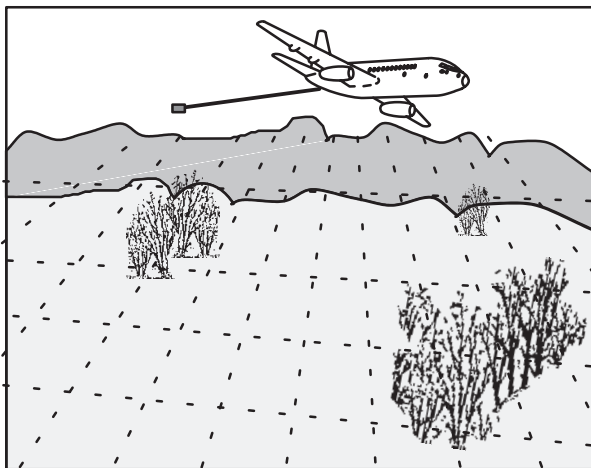
The major source of funding of the Space Environment Lab is direct Congressional appropriation. However, funds also come from other agencies, from other NOAA programs.

SEL conducts research in solar-terrestrial physics, develops techniques for forecasting solar and geophysical disturbances, provides real-time monitoring and forecasting of solar and geophysical events, and prepares data to be archived by NOAA's National Geophysical Data Center. SEL's research scientists, working toward a better understanding of the Sun-Earth connection, study the Sun's electromagnetic, particle, and magnetic-field emissions and the processes by which they affect Earth's space environment.

## *Effects of disturbances in the solar-terrestrial environment*



*Satellites are "aged" and tend to fall to Earth prematurely. Their electronics also can be damaged.*



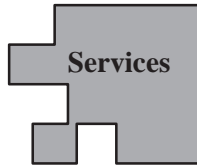
*Measurements from magnetic and electrical surveys often are incorrect during geomagnetic storms.*

SEL's Space Environment Services Center (SESC) is the national and world warning center for disturbances in the space environment that can affect people and equipment. We work closely with the U.S. Air Force's Space Forecast Center in Colorado Springs, which provides services to U. S. military customers. SESC is jointly operated by NOAA civilians and uniformed NOAA Corps and U.S. Air Force personnel. Cooperative ventures abound in SEL as graduate students, post-doctoral students, visiting scientists, Cooperative Institute fellows from the University of Colorado, and contractors all contribute to the vibrant atmosphere of the Lab.

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As you read further in this report, you may find this list of often-used acronyms helpful:

ESDIM	NOAA's program of data and information management
GOES	NOAA's geosynchronous weather satellite
ISAS	Japanese Space Agency
NOAA	National Oceanic and Atmospheric Administration
SEL	Space Environment Laboratory
SELDADS	SEL's central computing system
SELRAS	SEL's long-term database, under development
SEM	Space Environment Monitor, instrument on board a NOAA satellite
SESC	Space Environment Services Center
SXI	Solar X-ray Imager; it will fly on a GOES satellite in 1997
TIROS	NOAA's polar-orbiting weather satellite
USAF	U.S. Air Force
WIND	NASA spacecraft that would orbit around the Lagrange L <sub>1</sub> point between Sun and Earth



## *Services at SEL*

SEL's Services Division provides data, value-added products, alerts, and warnings to extramural customers. It is the larger of the Lab's two divisions; its three branches serve both internal and external

users. The Space Environment Services Branch operates the Space Environment Services Center, the nation's civilian real-time, 24-hour-per-day space-weather service. The Systems Management Branch manages and maintains the computer systems for SEL. The Systems Development Branch translates user software and hardware requirements into high-quality, reliable computer systems.

Let's step inside the Services Division and see the some of the activities that routinely occupy the staff:



*The Forecast Center is the heart of the services offered at SEL.*

◆ Forecasts and Warnings. A forecaster and solar technician ("soltech"), working as a team, are in the process of dealing with reports of a major solar flare. The soltech is beginning to notify priority-one customers, primarily by fax, of the start of the flare. At the same time, she is monitoring incoming data and the health of the SESC communications system. The forecaster is examining the real-time observatory reports and the GOES x-ray monitor to determine the possible terrestrial effects of the flare.

The soltech's priority-one alerting is interrupted by a "hot-line" call from the Air Force: their data line to SEL's computer system is out and they need backup. The soltech notifies the on-call personnel about the problem and then goes back to alerting customers.

Meanwhile, the forecaster uses a newly developed and recently

installed prediction model. This model uses recent data from a dozen or more observing sites around the world, of which SESC is the hub. The model has determined that a solar proton event is likely from the flare and calls NASA's Space Radiation Analysis Group to advise them of the prediction so that they can inform the Space Shuttle's Flight Surgeon about the imminent radiation hazard to orbiting astronauts' health.

◆ Data Acquisition. Although it's now after normal work hours, the on-call staff begins to diagnose the Air Force data line problem: the software programs that handle the data line could not process noisy data from GOES. The source of the noise problem is eventually traced back to the Satellite Ground Station. An unusual amount of snow has accumulated on the antenna and removing the snow corrects the noise problem. Further checks verify that all sys-

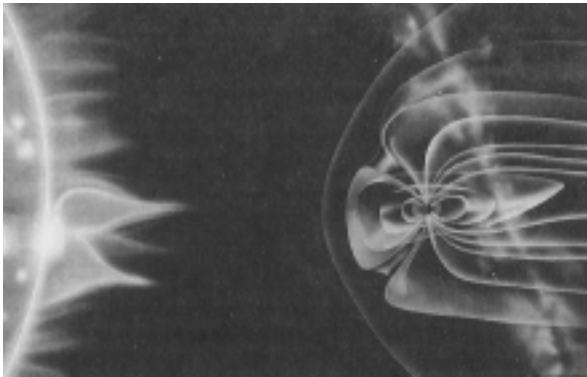
tems are again working as they should.

It's time to go home and get some rest. Tomorrow the on-call staff will discuss options for preventing snow from building up on the antenna and will begin working with development personnel to determine why this problem caused the preprocessor software to fail.

◆ Software Development. A system developer has finished testing an updated prediction model to be used by SESC forecasters and has installed it on our computer system, SELDADS. To validate the model, real-time GOES x-ray data from a major solar flare are needed. The software correctly detects the start of the flare and alerts the SESC staff. The model predicts a significant proton event. Is it credible? The forecaster believes that the model output is correct...will the event happen as predicted?



## *Research at SEL*



*The Sun-Earth Environment holds its secrets in an invisible matrix.*

The Research and Development Division is concerned with understanding the space environment, from the surface of the Sun to the top of Earth's neutral atmosphere, and applying our knowledge to improve forecasting of solar and geomagnetic disturbances and their subsequent effects on the near-Earth environment

To accomplish these goals the Division focuses on specialized areas. The Solar and Interplanetary Branch addresses the following questions:

- Where and when will disturbances leave the Sun?
- How strong will they be after they have travelled to Earth?
- Will a particular disturbance generate a geomagnetic storm severe enough to cause radio-navigation and communications problems?

The Geospace Branch examines near-Earth processes involving the magnetosphere:

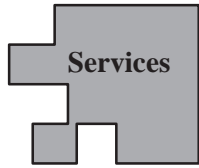
- What happens when a disturbance strikes Earth's magnetic field?
- Will electric distribution grids be blacked out?

The Space Influences on the Terrestrial Environment Branch examines the effect of space influences on Earth's upper atmosphere.

- What are the chemistry and dynamics of the upper atmosphere in response to space environment events?
- Will satellites encounter increased drag as the atmosphere expands?

Researchers within the Division perform three meshing functions: conduct basic research, develop applications for transition into the Space Environment Services Center, and serve as experts in response to questions from customers.

Another vital activity of SEL's researchers is their ongoing exchange of ideas with other scientists around the world. Collaborating on papers, speaking at scientific conferences, and working on new instruments with technical experts in universities and other government agencies are important aspects of the Research Division's mission.



## *Services Looks at Improvements in Geomagnetic Forecasting*

Our Space Environment Services Center provides daily forecasts of geomagnetic activity to agencies, businesses, and programs affected by rapid changes in Earth's magnetic field. Geomagnetic activity can have adverse effects on a wide range of systems including electrical power distribution grids, spacecraft systems, geophysical survey instruments, ionospheric communications systems, and long-line communication circuits. Effects on biological systems have not been proven but are an intriguing possibility.

SEL's forecasts are plagued by uncertainty due to a paucity of observations and incomplete understanding of the physical behavior of the disturbances as they depart from the Sun, propagate through space, and interact with Earth's magnetic field.

A new format to provide users with a *probability forecast* of geomagnetic activity was developed and implemented in the last 2 years. This type of prediction allows a forecaster to communicate the level of uncertainty in the forecast.

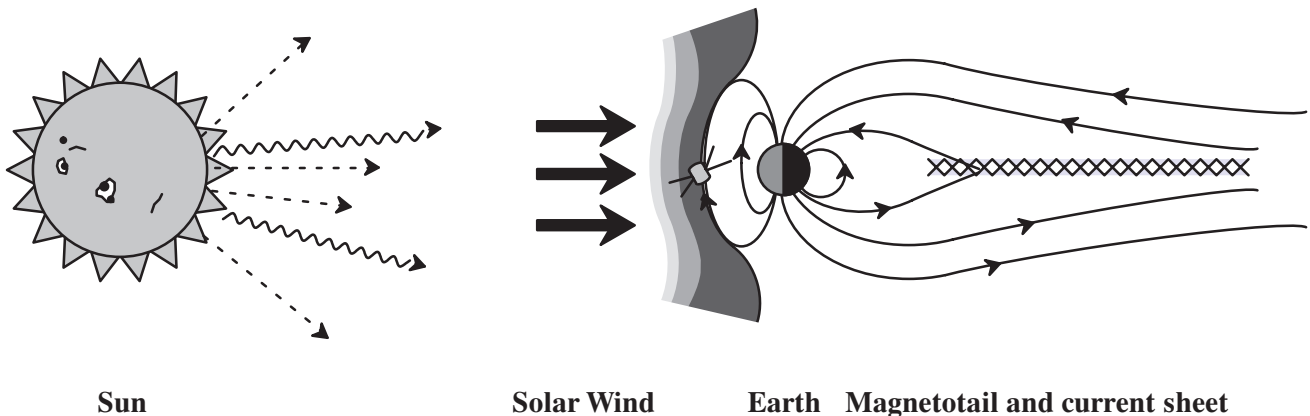
The new forecasts are based on expected time of arrival and duration of geomagnetic activity in response to solar events. Probability forecasts allow users to make optimal operating decisions. SESC is developing a solar events database that will be used to improve forecasting guidance algorithms.

Although we hope to improve forecast quality, our efforts have been limited by at least three factors:

- The origins of solar wind disturbances that cause effects on Earth are poorly understood.
- Solar wind structures evolve considerably during their travel from Sun to Earth, thereby reducing the value of solar diagnostics.
- The pre-event state of the magnetosphere creates unknown influences on the amplitude and character of geomagnetic disturbances.

SEL's research efforts to improve our understanding of these factors will be described next.

*Now...we can make a 3-day guess*







## *R&D Looks at Improvements in Geomagnetic Forecasting*

Forecasting services currently rely on solar observations to predict impending geomagnetic activity. Because the solar wind takes anywhere from 2 to 4 days to travel from the Sun to Earth, predictions based on what we observe at the Sun are not highly reliable. What we have lacked is an observing platform in the solar wind ahead of Earth that could radio a warning that an imminent disturbance is on its way. This has limited our services: we have not had a short lead-time forecast. However, that situation is about to change.

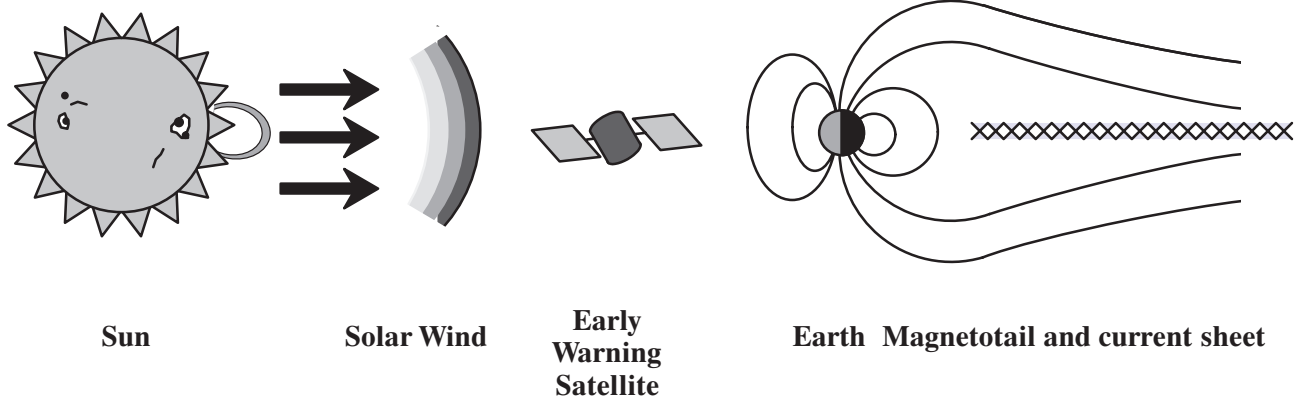
Now, SEL and the U.S. Air Force are jointly planning to obtain real-time solar-wind data from the NASA WIND spacecraft, scheduled for launch in April 1994. Eventually, WIND will settle into an

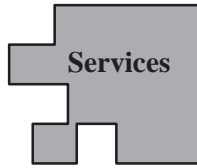
orbit in space around the forward Lagrange point, defined as the point between the Sun and the Earth where the gravitational forces balance. This point is considerably closer to the Sun than are any of our Earth-orbiting satellites; it is approximately one and a half million kilometers Sunward of Earth. Solar wind data observed at this position will finally give us a reliable 1-hour warning of impending major geomagnetic activity.

At present we are developing the algorithms necessary to predict the level and time of onset of geomagnetic activity, based on the measured solar wind at WIND's proposed orbit position. The only major limitation of these real-time data is that we will get only 2 hours of real-time data per day.

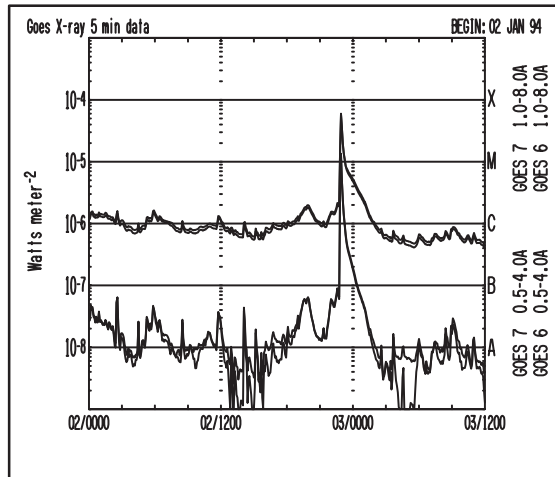
To overcome that limitation and increase our coverage to 24 hours per day, we are working with NASA to place a real-time solar-wind package on the ACE research spacecraft, currently being designed and scheduled for launch in 1997. The NOAA package will consist of a computer for on-board processing of the solar wind data, an antenna, and a transmitter. NOAA will be responsible for finding a way to receive the signal from ACE at various ground stations around the world and sending it to our Space Environment Services Center in real time. The U.S. Air Force will probably be our partner in this.

*Soon...we hope to provide a highly accurate 1-hour alert*





## Services Data Management Services



*Data Plot used by Forecasters to report on and forecast the space weather.*

### SELDADS

Data Management is critical to our customer services. The work we do is based on data, and the backbone of our data system is called SELDADS (Space Environment Laboratory Data Acquisition and Display System). It serves the nation as the real-time repository for solar-terrestrial data from ground-based observatories and satellite sensors. Aside from the collection of data, the system is responsible for the integration and distribution of solar-geophysical data, for processing the data into indices, for supporting duty-forecaster data analyses, assisting the forecaster in developing forecast products, and driving the forecaster's six display screens.

The current system has been in operation since 1986. An improved data acquisition subsystem, employing networked personal computers, was completed during the past year. This has increased system reliability and maintainability. Three new customer-support subsystems have been implemented, making more of SESC's products available to a wider range of customers at lower cost to the government.

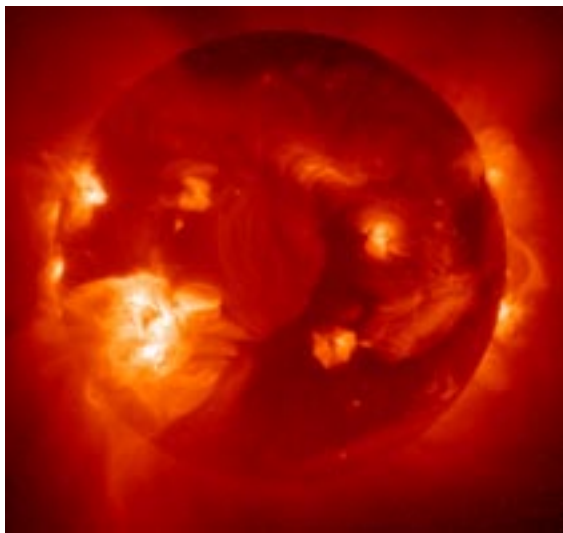
### SELDADS III

Increasing amounts of incoming data and demands for data dissemination have now saturated SELDADS II. To handle higher rates of data, new data sources, images, new analysis and forecasting techniques, and an increasing customer base, *a new hardware and software system is needed*. Planning has begun on SELDADS III. This major hardware and software procurement, with some custom software development, will enable

- data acquisition and processing.
- data management and storage.
- user (forecaster and public) interfaces for data access and manipulation.
- data monitoring and display.
- data analysis and product generation.
- product distribution and customer support.
- data transfer to archives.



## *Data Management Development*



*An x-ray image of the Sun, from the Yohkoh satellite launched in 1992, gives new insights about changing solar magnetic fields.*

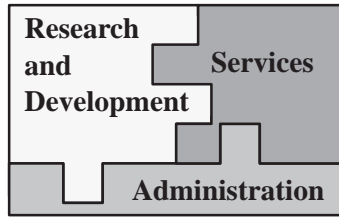
### **Managing Megabytes of Data**

To provide better warning and advisory services, we need to better understand the space environment and the terrestrial consequences of disturbances in space. The lifeblood of such research is the continued acquisition of observational data. The sensors on NOAA/TIROS and GOES satellites return more than 1 gigabyte of data each year. Some 20 years of data have been accumulated, and still greater flows of data are expected in the future.

For 20 years, SEL has ensured the integrity and validity of NOAA's space environment observations and has provided for the analysis and interpretation of data in a timely manner. Now, SEL must plan for the even larger data flows of the future. With support from NOAA's ESDIM (Environmental Services Data Information Management program), SEL has re-processed historical data from the instruments on GOES and NOAA/TIROS and transferred them from aging magnetic tape media to modern magnetic tape cassettes. The next step is to design and implement the SEL Retrieval and Analysis System (SELRAS). This will be a modern distributed computer system with a carefully crafted "user-friendly" interface. SELRAS will allow both the timely analysis and display of contemporary science data as they are gathered; the historic observations that have been preserved with ESDIM funding will undergo careful analysis. SELRAS can then serve both operational forecasters and researchers.

### **Image Processing**

SEL's future holds both the continuing acquisition of data from existing monitoring instruments and the growing use of digital images (pictures) of the Sun and, perhaps, Earth's upper atmosphere. Compared with time-series data, images typically comprise far larger data flows and much more intensive computer processing. Anticipating the difficulties of dealing with imagery, SEL is working with a Small Business Innovative Research firm to develop computer techniques to rapidly process images. We want to automate the extraction of the critical information from those images and store each basic image, and its associated information, in the most efficient manner possible.



*Customer Service Throughout SEL*



*SEL User Notes, a quarterly bulletin for users, has created a sense of community and better communication with our customers.*

**Customer Focus Group**

Customer service at SEL has taken on new importance with the creation of a special group to look at customer issues full time. The small Customer Focus Group teams up with management as well as with many individuals in the Lab to support specific projects.

**SEL User Notes**

We have started a quarterly bulletin which is mailed to all users (an example of *SEL User Notes* is shown to the left). It includes information about SEL, solar data, and activities of interest to users. Many of our users have responded to our request in the bulletin to tell us more about themselves, thus providing us the two-way communication we desire with our customers.

We have revised our customer database to merge all our previously disparate lists of SEL customers and have improved accuracy by surveying our customers for corrections and updates.

**In-depth Customer Survey**

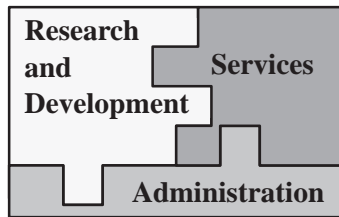
We are particularly proud to have won a Small Business Innovation Research grant to evaluate how well our products serve our customers. This project will involve direct conversations with customers, an exhaustive correlation of users with data usage, and eventually, recommendations for revised product definition and distribution.

**Educational Materials**

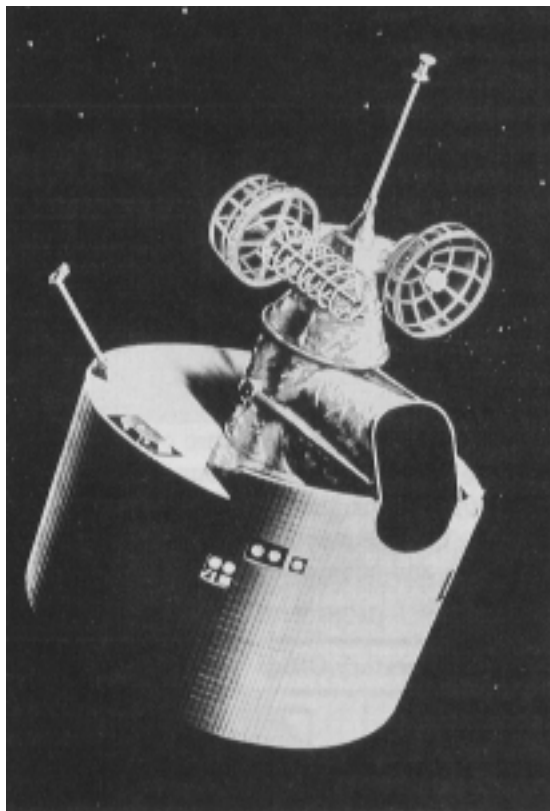
The education of our users and of the public at large has been an important effort in SEL. We have prepared written materials for public distribution, and have supported teachers in several areas, including an internship for two high-school physics teachers who wrote a space environment curriculum guide for grades 5–12.

**Users Conference**

Finally, we look forward to advancing our educational efforts and our two-way communication with customers. We plan to convene a Users Conference in Spring 1994. A previous Users Conference, in 1990, was a big hit with customers who learned about SEL and the space environment, were able to meet and learn from our staff, and made their needs for data and services clear to us.



## *Support for Research and Services*



*Sensors record the raw material and computers shape the products of a data-centered organization.*

### **Computing Resources**

SEL's employees rely on our computing resources and our computer network to accomplish the remarkably diverse tasks within our Lab. SESC forecasters and solar technicians rely on SELDADS to collect, process, analyze, display, and distribute space environment data 24-hours a day. Our research staff uses our vast archive of data to better understand the effects of near-Earth events on our environment; staffers use high-performance workstations to explore modeling and prediction

techniques. Most employees use document preparation software to write research publications, user products, or documentation. Management and administrative personnel use computers to manage budgets, personnel activities, and a customer database. Computers bind the many facets of our work.

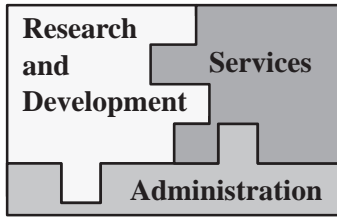
### **Observing Systems**

Our services are built upon data, and the satellite-based observations are particularly important to SEL. SEL plans, contracts, and supervises the design and construction of the polar-orbiting NOAA satellite's SEM (Space Environment Monitor) instruments. The engineering model for the next series of spacecraft has been delivered for spacecraft integration testing, and the first flight instrument will be delivered early in FY94.

Earth-based observations are also vitally important. Cooperative arrangements with the National Solar Observatory, and with the USAF's worldwide Solar Electro-Optical Network provide valuable, unique solar images. Similarly, SEL receives data from a network of about 100 ground-based magnetometers, through the USAF/USGS Intermagnet program; most of the data are relayed through NOAA's GOES satellites.

### **Future observations**

The next GOES is a new-generation spacecraft. The first GOES to use 3-axis rather than spin stabilization, this satellite will provide us with the capability to operate instruments that are continuously pointed toward the Sun. This will require a new design of the whole-Sun solar x-ray flux sensor for the data stream which has been the kingpin of our solar flare monitoring since 1974. With funding from the USAF, and in collaboration with NASA, we are now developing a Solar X-ray Imager (SXI) for GOES. Similar x-ray telescopes flown previously on Skylab, and currently on the Japanese Yohkoh spacecraft, have demonstrated immense potential for improving both the monitoring and forecasting of solar activity. Images of x-ray emission reveal the solar coronal structures high above the Sun's visible surface. The SXI is expected to fly on GOES-L late in this decade.



## Organization and Staff

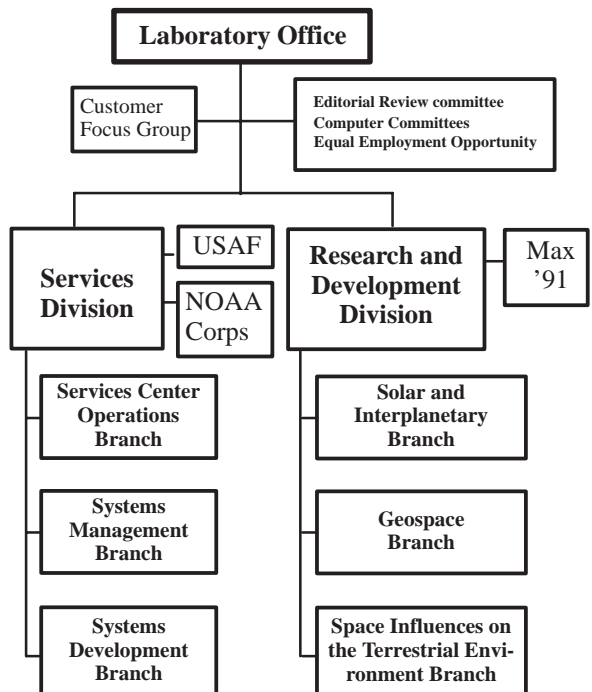
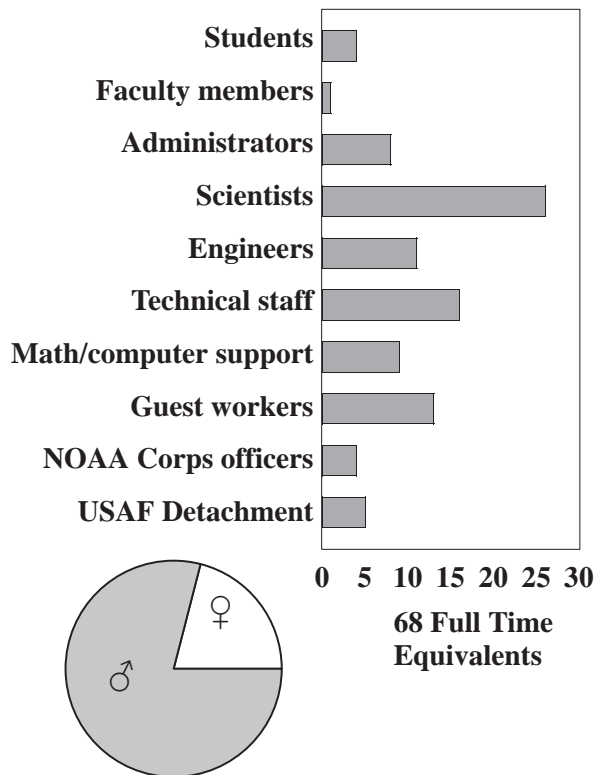
### Laboratory Organization

Most of the SEL staff work in one of two functional areas: service operations or research. Each area cooperates and contributes to the goals of the other. The Laboratory Director and his immediate staff provide leadership and administrative support to these efforts.

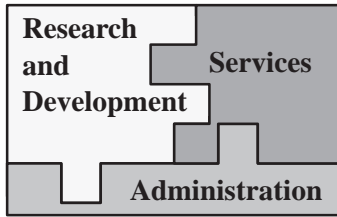
SEL's strength is its people—motivated, dedicated, willing to work long hours during crises, and always adapting to the rapid changes in technology and customer demands. SEL puts great emphasis on education and training for its staff.

This organizational structure has units small enough for close teamwork but large enough to accomplish programmatic goals. Computer and support staff in each division work with scientific and technical staff to accomplish the stated objectives.

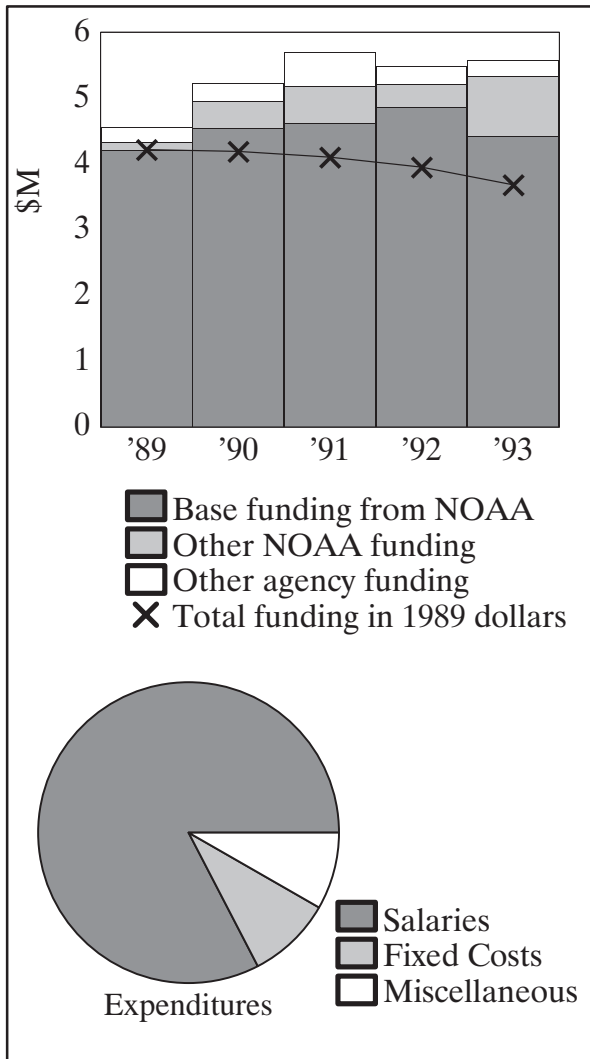
Important elements in the structure of SEL are the Lab's associations with other groups: the U.S. Air Force, NOAA Corps, the Cooperative Institute for Research in Environmental Sciences at University of Colorado, and other-agency sponsors.



*The Lab employs a wide variety of technical people.*



## Funding and Collaborative Programs



*Our financial profile for the past 5 years, showing where our funds come from and where they go.*

## Other-Agency Funding and Cooperation

In addition to the major funding from Congressional appropriation, SEL's funds also come from other agencies, from other NOAA programs, and from special requests for one-time situations.

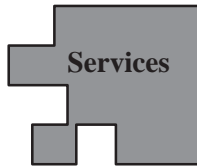
SEL's collaborations with other agencies far exceed its "work for hire." Most of the work we do with other agencies is based on cooperative agreements or memoranda of understanding reflecting "in-kind" sharing, where real dollars don't exchange hands. Nonetheless, each year SEL performs work funded by other agencies on projects that complement our current activities and mission. Some of our current other-agency projects are as follows:

- collection and analysis of GOES-6 and GOES-7 magnetic field and energetic particle data (for NASA).
- development of a data base necessary to determine whether or not dramatic increases in electron fluxes at low latitudes are associated with rapid decreases in the low-latitude ionospheric ring current (for NASA).
- preparation of an algorithm to predict time of arrival and dynamic pressure of solar-flare-initiated interplanetary shocks when they hit Earth (for U. S. Air Force Phillips Laboratory).
- joint operation of the High Latitude Monitoring Station at Elmendorf Air Force Base in Anchorage, Alaska (for USAF, U.S. Geological Survey, and the University of Alaska).
- development of the TIROS satellites' Space Environment Monitors (for NASA, which manages the procurement for NOAA).

Other NOAA programs in which SEL is currently involved are the ESDIM Project (described on page 9) and Climate and Global Change, where we are researching solar influences on Earth's environment.

In these times of sweeping cuts in Federal funding, we at SEL know we must work more efficiently than ever before. We are determined, however, to maintain and improve our high level of solar-terrestrial research and services; our customers deserve no less.

## SEL Staff and Associates



Abeyta, Jim	5827
Balch, Chris	5693
Barrett, Bill	6872
Brown, Rita	5828
Bushnell, Bob	3966
Carran, Kurt	3188
Combs, Larry	5299
Cruickshank, Cheryl	3930
DeFoor, Tom	7575
Doggett, Kent	3317
Finelli, Dave	7409
Gallucci, Mike	7448
Heckman, Gary, Chief	5687
Hill-Raben, Viola	5691
Hines, Bob	3593
Hirman, Joe	5688
Ito, Dave	3994
Jones, Sallie	7720
Keifert, Carroll	3900
Kunches, Joe	5275
Levine, Patricia	7224
Lewis, Dave	3170
Lloyd, Cheryl, Sec'y.	3204
Luteran, Ed	3593
Masten, Bob	5716
Miller, Warren	3749
Nelson, Gayle	3990
Raben, Vern	5711
Real, Dan	3409
Recely, Frank	3204
Retallack, Bill	3845
Sargent, Howard	3697
Sayler, Steve	3959
Schroeder, Dean	3780
Seegrist, Larry	5045
Speich, Dave	3316
Stephenson, Judy	3997
Sutton, Doug	5153
Taylor, John	5712
Will, Janet	5689

Wilson, Chris	7224
Winkelman, Jim	3283

### NOAA CORPS

Bernard, LT Brent	6498
Coles, ENS George	3867
Millett, LCDR Neal	6498
Steward, LTJG Graham	6498

### U.S. AIR FORCE

Bascome, TSgt. Jim	3593
Cohen, MSgt. Norm	3834
Gehred, Capt. Paul	5697
Perry, Maj. Dale	5999
Schmeiser, TSgt. Mike	5694

### GUEST WORKERS

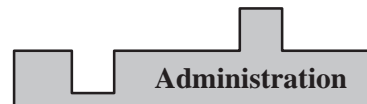
Gray, Al	3593
Coop. Ins. Res. Env. Sci.	



Bergstedt, Pam, Sec'y.	3113
Bornmann, Patricia	3532
Detman, Tom	5394
Donnelly, Dick	5100
Dryer, Murray	3978
Evans, Dave	3269
Garcia, Howard	3916
Golding, Brian	3681
Greer, Sue	5418
Joselyn, Jo Ann	5147
Matheson, Lorne	3164
McIntosh, Patrick	3795
Puga, Larry	5763
Sahm, Susan	5884
Sauer, Herb	3681
Singer, Howard	6959
Smith, Zdenka	3473
Trolinger, Joanna	3980
Zonfrelli, Joe	7394
Zwickl, Ron, Chief	3029

### GUEST WORKERS

Bouwer, Dave	3899
Contractor	
Burkhart, Grant	3616
University of Colorado	
Codrescu, Mihail	6763
Coop. Ins. Res. Env. Sci.	
Davies, Ken	5401
NOAA	
Dusenbery, Paul	3824
University of Colorado	
Fuller-Rowell, Tim	5764
Coop. Ins. Res. Env. Sci.	
Gonzalez, Alicia	3274
Inst. de Pesquisas Espacias	
Gonzalez, Walter	3274
Inst. de Pesquisas Espacias	
National Research Council	
Huynh, Minh	3608
Contractor	
Kiplinger, Alan	5892
NASA, University of Colorado	
McAllister, Alan	3186
National Research Council	
Pizzo, Victor	6608
San Juan Institute	
Shaw, David	5713
University of Colorado	
Smith, Dean	3186
Berkeley Research Inst.	
Speiser, Ted	3824
University of Colorado	
Yeh, Tyan	5401
National Central Univ., Taiwan	



Ahl, Irene, Sec'y.	3311
Conlon, Kathy, Admin.	3313
Grubb, Dick	3284
Hildner, Ernie, Director	3311
Homan, Cheryl	3444
McGarvey, Judy	3314
Poppe, Barbara	3992