CHAPTER 7

PROGRAM MANAGEMENT

The National Space Weather Program (NSWP) has been implemented by scientists, engineers, and technicians in government, academia, and industry. The program builds on existing capabilities and establishes an aggressive, coordinated process to set national priorities, focus agency efforts, and leverage resources to gain the biggest return. Organization and planning of the program requires a structure guaranteeing effective feedback and communication between the various communities involved. Appendix D contains points of contact and sources of information to facilitate this interaction.

7.1 Management Structure

The management structure for NSWP, organized within the OFCM includes the National Space Weather Program Council (NSWPC) and the Committee for Space Weather (CSW).

7.1.1 National Space Weather Program Council (NSWPC)

NSWPC is a multi-agency group designed to provide oversight and direction to the integrated process of setting national priorities, focusing agency efforts, and leveraging existing resources. It was established with the approval of the Federal Committee for Meteorological Services and Supporting Research (FCMSSR) in December 1994. NSWPC establishes policy, coordinates interagency efforts, and approves interagency agreements developed within the scope of the program. It also defines and coordinates the implementation of the NSWP. The NSWPC ensures that common needs are met and the interests of each agency are addressed. Member agencies retain responsibility for planning, programming, and budgeting their own resources to meet agency obligations to the NSWP.

NSWPC consists of designated representatives from Federal agencies involved in space weather activities. The representatives are the official spokespersons for their agencies on matters such as program scope, requirements, and resource commitments. Agencies

involved are NSF, NASA, and the Departments of Commerce, Defense, Transportation, Energy, and the Interior.

7.1.2 Committee for Space Weather (CSW)

The CSW is aligned under the NSWPC and functions as a steering group responsible for tracking NSWP progress, identifying problems that threaten to delay or interrupt the program, and recommending corrective actions to the Program Council. Like the Program Council, the CSW is a multi-agency organization and is also composed of representatives from NSF, NASA, and the Departments of Commerce, Defense, Transportation, Energy, and the Interior.

7.2 Relationship Between NASA's Living With a Star Program and the NSWP

Living with a Star (LWS) is an exciting new NASA initiative that will provide major contributions to the National Space Weather Program (see Appendix B). LWS will accelerate the deployment of the present Solar Terrestrial Probe series and establish a new set of space weather research satellites (the Space Weather Research Network). LWS will also provide significant funding enhancements for space weather data analysis, theory and modeling. LWS provides key observational assets for testing space weather models, conducting basic space weather research and prototyping new operational platforms and instrumentation.

To ensure maximum benefit to the NSWP, LWS activities will be coordinated with other NSWP activities through NASA membership on the Committee for Space Weather (CSW) and by CSW members' participation in LWS planning. Furthermore, to ensure needed coordination of the basic research components of the NSWP, NASA and NSF intend to establish a collaborative research, data analysis, and modeling effort in space weather by combining efforts in the annual NSF/DOD NSWP research competition with the NASA LWS research announcements.

7.3 National Security Space Architect (NSSA)

The National Security Space Architect (NSSA), under the Office of the Assistant Secretary of Defense, is currently completing a two-year study of the Department of Defense's requirements for space weather services for the next 15 to 25 years. On December 4, 1997, the Space Weather Architecture Study Terms of Reference directed the NSSA to lead an integrated Space Weather Architecture Study with the DOD, NASA, NOAA, and other government agencies. Accordingly, the NSSA formed a Space Weather Architecture Development Team (ADT) composed of representatives from major stakeholders and conducted an architecture study to develop architecture alternatives.

The Space Weather Architecture Study was conducted in two phases. Phase I determined that an architecture study was warranted and gathered the information necessary to conduct it. Phase II developed and analyzed architecture alternatives and generated Space Weather architecture findings and recommendations.

After the study was completed, the National Security Space-Senior Steering Group (SSG) endorsed an Architecture Guidance Memorandum that identified the Assistant Secretary of Defense for Command, Control, Communications, and Intelligence (C3I), in coordination with NOAA, as the overall agency responsible for overseeing a Space Weather Transition Team, composed of key space weather stakeholders. A Space Weather Transition Team was organized to develop a plan to provide guidance on implementing the approved recommendations. The recommendations are summarized in Appendix C.

The NSSA study represents a detailed examination of space weather requirements over the next two and a half decades. Although organized by the DOD, the involvement of NOAA, NASA, NSF, FAA, and other non-DOD agencies ensured that the recommendations reflect the needs and roles of the commercial space weather customers, as well as researchers in government, academia, and industry. Because of its critical role in coordinating interagency efforts in space weather, the Committee for Space Weather will provide oversight to ensure continued pursuit of the NSSA recommended activities. The NSSA recommendations consist of a set of actions and activities that must be accomplished to achieve the desired architecture. The CSW will monitor these activities and update them as necessary. Because of the emphasis on defense requirements, some of the activities may differ slightly from priorities set earlier by the NSWP. Members of the CSW will coordinate to resolve these differences. Adjustments to the NSSA recommendations will be made only with full concurrence of the DOD membership on the CSW. The NSSA recommendations represent an aggressive and ambitious program to achieve improvements in space weather capabilities as quickly and as cost effectively as possible. This detailed study will provide an effective means for planning and organizing activities and for tracking progress in space weather.

7.4 Coordination with the Research Community

Active involvement from all space weather stakeholders has been a high priority since the inception of the program. Formal and informal mechanisms have been used to maintain effective coordination among space weather researchers, instrument developers, data providers, operational forecasters, and customers. On the research side, space weather information is exchanged at semiannual meetings of the American Geophysical Union and annual workshops convened by the CEDAR, GEM, and SHINE communities. Over the past three years, all of these venues have featured special sessions on Space Weather.

To facilitate communication among researchers, the operational community, and space weather customers, the Space Environment Center has established Space Weather Week, the first of which occurred in April 1999. The first part of this week is focused on the

transition of research to operations, meetings which were initially held separately in January of 1997 and 1998. Space Weather Users Meetings had previously been held every three years, but have now been combined with the research to operations meetings to form the second half of Space Weather Week. Together, these meetings provide an excellent forum to bring researchers together with both the operations and user communities.

Aggressive research programs supporting space weather goals continue to be supported by NSF, NASA, NOAA, and the DOD. Many areas of research in space and plasma physics directly support program objectives by advancing knowledge in fundamental scientific areas. However, early in the program it was recognized that rapid progress could be made only by implementing a more targeted research program. Toward this end, NSF, AFOSR, and Office of Naval Research (ONR) contributed to funding competitively-selected research proposals in key areas. These competitions were held in 1996, 1997, 1999, and 2000. The program announcements included a description of the areas of scientific emphasis to fill gaps in our existing knowledge and predictive capabilities. The proposals were selected by panels who evaluated them on the merit of the research and their potential to contribute to space weather goals. As indicated in the description of research in Chapter 3, these awards included many innovative approaches to space weather model development and predictive capabilities, as well as more basic research aimed at improving our understanding of space weather phenomena.

In the future, the Committee on Solar Terrestrial Research (CSTR) of the National Academies will periodically review past progress and make recommendations to the CSW on areas of emphasis for future space weather proposal competitions. On the basis of those recommendations, as well as the comments and insights of the research community, CSW will formulate the updated space weather announcement of opportunity.

7.5 Coordination with the User Community

Equally important for effective progress in space weather goals is to establish a good interface with space weather customers. Interaction between space weather customers and operational forecasters has previously taken place at the Space Environment Center in Boulder during the Space Weather User Conferences held every three years. In 1998, meeting attendees favored meeting annually, at least during the solar maximum period, and also endorsed merging the meeting with the Space Weather Research to Operations workshops previously held in January in Boulder. The two meetings were held consecutively for the first time in April 1999 in an event referred to as Space Weather Week. This successful format for encouraging feedback between the scientific community and space weather customers will continue on a yearly basis for the next several years.

In addition to the Users Conference, two other more specialized workshops were conducted. The first was a workshop on Geomagnetically Induced Currents held at the

Electric Power Research Institute (EPRI) headquarters in Washington, D. C., during October 1996. The second was a workshop on Space Weather Effects on Navigation and Communication Systems which was held at COMSAT headquarters in Bethesda, MD, in 1997.

Identifying the requirements of the satellite industry has been difficult due to the highly competitive nature of the industry, the complexities associated with insurance coverage, and the legal aspects of satellite communications. To initiate discussions with satellite industry representatives, NSF made an award to Sterling Software whose representatives, armed with nondisclosure agreements, interviewed top industry executives. The DOD has also initiated efforts with each of its services to improve and expand the documentation of space weather impacts on military operations.

7.6 Non-Federal Involvement

NSWP is a cooperative effort within several agencies of the Federal government. However, achieving the goals of the program requires the participation of a variety of entities outside the Federal government, including universities, research institutes, laboratories, and businesses. Indeed, the role of the Federal government, through OFCM's CSW and cooperating agencies, is largely one of management and coordination. Several areas provide opportunities for participation by non-Federal entities.

Requirements. Requirements for space weather support should be forwarded to the appropriate agency responsible for providing support. DOD agencies should request support from the Air Force Weather Agency. Other government and private agencies should request support directly from the Space Environment Center (SEC). Support requirements that exceed the current state of the art should be stated as early as possible. See Appendix D for addresses.

Research Opportunities. In addition to the NSWP targeted research opportunities mentioned in Section 7.3, other research opportunities are expected to be available through the Federal agencies that support the program. Although these opportunities will not be explicitly tied to the NSWP, they will support the broad goals of the program and, in many cases, its specific objectives. From DOD, opportunities will be available through the Air Force Office of Scientific Research, the Office of Naval Research, and for developmental research, the Defense Modeling and Simulation Office (DMSO) through the Air and Space Natural Environment Modeling and Simulation Executive Agent. DOC, through NOAA's Office of Oceanic and Atmospheric Research, will offer opportunities as will NASA's Office of Space Sciences. On a more limited basis, DOE will offer some opportunities through its Solar Terrestrial Research Program within the Office of Basic Energy Science.

Rapid Prototyping. A Rapid Prototyping Center (RPC) is already in place at the SEC and another RPC focusing on military requirements is in development through the Air Force's Space and Missile Systems Center (SMC), Air Force Space Command, and the Air Force

Weather Agency. The Community Coordinated Modeling Center (CCMC) is an additional link in the chain as a feeder process to the RPCs, bringing research models into the operational sphere. Procedures to nominate appropriate models to these centers have been established and more information is available from the centers themselves. See Appendix D for instructions on contacting these organizations.

Producing Tailored Products. Not all space weather support requirements will be met by products issued by the SEC. Some civilian operators will require very detailed forecasts for specific weather elements at specific places and times. The opportunity exists to access SEC products, tailor them to customers' specific requirements, and disseminate them to operators as a business opportunity. Although this type of effort receives cooperation as appropriate from Federal agencies, it should not expect to receive Federal support.

7.7 Agency Roles and Responsibilities in the National Space Weather Program

DOC (represented by NOAA), DOD, DOT (represented by the Federal Aviation Administration), NASA, DOI, DOE, and NSF recognize common interests in space weather observing and forecasting. Aware of the need for prudent employment of available resources and the avoidance of duplication in providing these services and support for agency mission responsibilities, the cooperating agencies have sought to satisfy the need for a common service program under the NSWP. This section provides information on how the participating agencies contribute to the program today and in the future. The general information on each agency provided in the following subsections is further detailed in Table 7-1, which indicates which space weather domains (from Table 2-2) the agencies address, and in which areas they intend to focus their efforts.

NOAA and the Air Force have separate, distinct, statutory roles in providing space weather observations, forecast and warning services, and data archival to the civil sector, DOD, and other Federal agencies. NOAA, through the SEC, provides centralized space weather support to non-DOD government users (e.g., NASA) and to the general public. The United States Air Force (USAF), through the 55th Space Weather Squadron (55 SWXS), provides unique and sometimes classified support to all DOD users. To avoid duplication, the two agencies share responsibilities to produce certain space weather databases, warnings, and forecast products. Both agencies also support space weather research.

The 55 SWXS and the SEC provide cooperative support and backup for each other in accordance with existing agreements. USAF assigns personnel to Operating Location A, 55 SWXS, collocated with the SEC, to assist in the operations of SEC and to participate in activities of mutual interest and benefit to the USAF and NOAA.

NASA and NSF play key roles in advancing operational space weather support through research. Both agencies deploy systems that collect data to support research focused on

Table 7-1. Agency Participation Matrix

	Physical Understanding	Model Development	Observing Systems	Technology Transfer
Solar coronal mass ejections	1,2,3,6	1,2,5,6	1,2,3,5	1,2
Solar activity/flares	1,2,6	2,5,6	1,2,5	2,7
Solar and galactic energetic particles	1,2,3,6	2,5,6	1,2,3,5	1,2
Solar UV/EUV/soft x-rays	1,2,6	5,6	1,2,5	1,2,7
Solar radio noise	1,6	5,6	1,2,5	1,2
Solar wind	1,2,3,6	1,2,5,6	1,2,3,5	1,2
Magnetospheric particles and fields	1,2,3,4,5,6	1,2,3,4,5,6	1,2,3,5	1,2,3
Geomagnetic disturbances	1,2,3,4,5,6	1,2,3,4,5,6	2,3,4,5	1,2,3
Radiation belts	1,2,3,5,6	1,2,3,5,6	1,2,3,5	2,3
Aurora	1,2,3,4,5,6	1,2,4,5,6	1,2,3,5	1,2
Ionospheric properties	1,2,3,4,5,6	1,2,4,5,6	2,3,5	2,7
Ionospheric electric field	1,2,4,5,6	1,2,4,5,6	1,2,3,5	2,7
Ionospheric disturbances	1,2,3,4,5,6	1,2,4,5,6	2,3,4,5	2,7
Ionospheric scintillations	1,2,5,6	1,2,5,6	2,5	2,7
Neutral atmosphere (thermosphere and mesosphere)	1,2,5,6	1,2,5,6	2,5	1,2

Organization codes: 1=DOC, 2=DOD, 3=DOE, 4=DOI, 5=NASA, 6=NSF, 7=DOT

improving our understanding of space weather processes. They also manage much of that research.

DOI and DOE participate by collecting data that, while supporting their missions, contribute to the operational space weather database. They also support limited research related to those data.

DOT, through the Federal Aviation Administration, participates as a regulator of the commercial space industry and as an implementor and operator of advanced Global Positioning System (GPS)-based systems for air navigation. Space weather's adverse effects on manned space flight, high altitude aircraft operations, and the availability and accuracy of GPS-based navigation make understanding and mitigating these impacts an imperative for the FAA.

7.7.1 Department of Commerce (DOC)

DOC's NOAA is responsible for monitoring and forecasting the near-Earth space environment for nonmilitary applications. NOAA's programs support governmental, commercial, educational, and scientific communities. Activities focus on satellite instrumentation, data assimilation, environmental forecasting, and research and numerical modeling. NOAA and DOD cooperate on programs of mutual interest.

Currently, NOAA operates space environment instruments on Geostationary Operational Environmental Satellites (GOES), and polar-orbiting satellites to monitor solar emissions and in situ plasma fluxes. In the future, NOAA will operate the joint DOC-DOD National Polar-Orbiting Operational Environmental Satellite System (NPOESS). In addition, NOAA has proposed a solar wind monitoring program that would support the NSWP.

NOAA's SEC and National Geophysical Data Center (NGDC) receive, process, analyze, and assimilate space weather data collected by worldwide networks of satellite and ground-based instruments. SEC is responsible for real-time and operational data. NGDC is responsible for the national and World Data Center archives. Future data activities will focus on greater spatial coverage of relevant parameters from national and international partners.

Nowcasts and forecasts are routinely prepared and distributed by SEC. Numerical analyses and model simulations are conducted by SEC and NGDC. In support of the NSWP, SEC has been working to test, evaluate and incorporate superior algorithms to forecast the space environment.

Research and modeling activities at SEC and NGDC include analysis of in situ measurements and development of numerical models conducted by government scientists and international visitors. In support of the NSWP, NOAA through its Rapid Prototyping

Center tests and evaluates physical models developed by academia, government, and industry under routine, near-real-time conditions.

7.7.2 Department of Defense (DOD)

7.7.2.1 Support for Observing, Forecasting, Modeling, and Research

DOD will continue to support observing, forecasting, modeling, and research efforts supporting operational assets in the near-Earth space. Through the Defense Modeling and Simulation Office (DMSO), DOD supports development of authoritative representation of the near-Earth space environment for use in joint service modeling and simulation programs. Through 55 SWXS, DOD will continue to monitor data from various ground sites and space-based observation platforms to provide warning, observing, and forecasting support for both military and civilian assets in conjunction with SEC.

In support of the NSWP, the Air Force Research Laboratory (AFRL) and various contracting agencies develop modeling techniques for use at 55 SWXS. AFRL will continue to be the focal point for space weather models for DOD and models from outside agencies will be validated and transitioned via the Rapid Prototyping Center with the help of AFRL.

DOD will support research to improve the understanding of space weather phenomena, particularly in the near-Earth regions. The department recognizes that knowledge of solar and interplanetary phenomena is critical to forecasting in the magnetosphere and ionosphere, and it continues to advocate research in those areas as well. Efforts to develop sensors and spacecraft to measure the space environment will be leveraged with other agencies to build and deploy effective platforms. Data from these systems will then be assimilated into the operational models and archived for climatological studies.

7.7.2.2 National Security Space Architect

The Office of the National Security Space Architect (NSSA) will track progress made toward the space weather architecture and recommendations resulting from their architecture study conducted between December 1997 and September 1999. As periodic reviews of the NSWP occur, the NSSA, Program Council, and CSW will coordinate actions and may enlist NSSA's assistance for a detailed review to match breakthroughs in technology or changes in requirements. The NSSA will be represented in this process via the DOD members on the NSWPC and CSW and will have full rights to identify issues or request an update to the architecture.

7.7.2.3 Restructuring DOD Space Weather Support

To improve space weather support to the DOD and National Programs, the Air Force is restructuring its space weather operations. This action directs an end-to-end restructuring of organizational and operational responsibilities for the space weather mission support area within the DOD. It will integrate terrestrial and space weather services within the Air Force, leverage Air Force Weather capabilities to improve the space weather mission area, and retain strong leadership by Air Force Space Command (AFSPC) for program acquisition and modernization.

Under this restructuring, the Air Force Weather Agency (AFWA) will provide space environmental information to all DOD and National Program users. As part of this restructuring, the 55th Space Weather Squadron (55 SWXS) was realigned under AFWA on 1 October 1999. In this way, HQ USAF/XOW through AFWA, and the Air Force major commands through their operational- and tactical-level units, share responsibility for providing and applying space weather information for military operations.

The Air Force is in the process of establishing an improved space weather center capability within the AFWA infrastructure at Offutt AFB, Nebraska. As this capability becomes operational, the responsibility for providing space weather support will transfer from the 55 SWXS at Schriever AFB, Colorado, to the new AFWA Space Weather Operations Center. This transition will occur over the period from the summer of 2000 through the first quarter of Fiscal Year 2003.

This restructuring improves the Air Force's space weather support organization in order to enhance the mission effectiveness of DOD and National Program operations and planning. The basic plan has been developed to create the most effective organizational structure and technical capability to provide mission-tailored space weather products. Fused with terrestrial weather information, these products will yield an integrated, "mud to sun" analysis and forecast of the environment through which DOD and National Program missions are conducted.

This effort is intended to improve space weather mission support in several ways. These include:

- Realignment of space weather information providers to better meet strategic-, operational- and tactical-level mission needs
- Improved timeliness, accuracy, and relevance of space weather information to better focus on national defense needs
- Improved integration of space weather providers into their customers' operations and planning, which will foster better application of force enhancement information
- More rapid integration of emerging space weather technologies to meet operational requirements
- Improved training to provide more fully qualified space weather providers and users

- Improved structure for the collection and validation of space weather requirements

A major benefit of this plan is to spread space weather expertise throughout Air Force Weather forces, raising awareness of the effects of space weather on DOD and National Program operations and enhancing mission accomplishment. In summary, this restructuring effort addresses those areas of space weather services which can be improved to meet current and future national defense requirements.

7.7.3 National Science Foundation (NSF)

NSF supports and will continue to support basic research in solar-terrestrial sciences, including the Sun, solar wind, magnetosphere, ionosphere, and thermosphere. NSF supports theoretical and observational research with the goals of increasing fundamental understanding of space environment processes and improving space weather predictive capability. The research includes the development and operation of ground-based space environment monitoring instrumentation; the development of ionospheric, thermospheric, and magnetospheric specification models; and the analysis of post-event databases. The worldwide array of NSF-sponsored instruments, observatories, and facilities will continue to provide vital ground-based measurements in coordination with space missions sponsored by other agencies.

Research areas of emphasis are (1) solar region evolution and eruptive events, (2) interplanetary transport, (3) magnetospheric physics and dynamics, (4) ionospheric physics and dynamics, and (5) upper atmosphere physics and dynamics. Knowledge of the processes that are fundamental to each of these areas will be enhanced by a multi-disciplinary approach to investigating the basic mechanisms through which these areas interact.

7.7.4 National Aeronautics and Space Administration (NASA)

NASA will continue its traditional role of research in the physics of the solar-terrestrial system. This research program is carried out under the theme "Sun-Earth Connection" and now "Living with a Star," both of which seek to explore and understand as one system the dynamics of the Sun and its interactions with Earth and other planetary bodies and with the interstellar medium. Key questions addressed relevant to space weather include the following: What causes solar variability? How does the Sun and its variability affect Earth and other planetary space environments? The Sun-Earth Connection uses the solar system as a laboratory to understand basic plasma physical processes such as the acceleration of particles to high energies and generation of intense radiation belts or plasma enhancements, processes that can affect electronic and biological systems exposed to the space environment.

The ongoing and future space science flight programs of NASA and its partners are making, and will continue to make, critical contributions to space weather research. The International Solar Terrestrial Physics (ISTP) Program is providing new experimental and theoretical advances in solar-terrestrial physics. The ISTP missions (Geotail, WIND, POLAR, SOHO), the complementary missions (Yohkoh, Fast Auroral Snapshot (FAST), IMP-8, SAMPEX, ACE, TRACE, IMAGE), and TIMED will significantly advance the state of knowledge in solar-terrestrial physics. ACE provides the first 24-hour-per-day broadcast of real-time solar wind data used for space weather forecasting by the DOD and NOAA. NASA is a partner with USAF in the development of the Solar Mass Ejection Imager (SMEI). Future missions under consideration include a solar stereo mission that could provide images of coronal mass ejections directed toward the Earth and arrays of microsatellites to provide multi-point measurements in the magnetosphere.

NASA missions are designed under several guiding principles:

- To improve and advance empirical understanding of events and conditions in space
- To develop and use new technology
- To establish proof of concept and the value of new observational methods in space (e.g., energetic neutral particle imaging of the magnetosphere)
- To develop a database that determines the empirical nature of space weather conditions
- To observe, interpret, and understand the causes of and to predict the variable particle and electromagnetic radiations that emanate from the Sun and affect the space environment of Earth and other planets.

Much of the Sun-Earth Connection research grants program also contributes to developing basic principles and methods by which space weather may be understood and predicted. More information on "Sun-Earth Connection" and "Living with a Star" is provided in Appendix B.

7.7.5 Department of the Interior (DOI)

DOI participates in the NSWP through its United States Geological Survey (USGS), which operates a series of geomagnetic observatories and participates in worldwide collection and real-time exchange of geomagnetic data. It provides these data to USAF and NOAA operational centers for determination of geomagnetic indices to support warning and forecasting and to NGDC for archiving to support research. DOI also conducts research in geomagnetic and electrical fields, particularly in how they relate to the structure of Earth’s core and mantle.

In the future, DOI plans to expand its network of geomagnetic observatories. In the near term, expansion will provide data from land areas from which data have not been available in the past. In the longer term, USGS plans to organize an effort to collect geomagnetic data over the broad ocean areas. Research conducted or supported by DOI will continue to be focused in areas where it is concentrated today, but will evolve to

exploit the increase in the number of geomagnetic observations available and the changing distribution of spatial coverage.

7.7.6 Department of Energy (DOE)

DOE will continue its ongoing program to supply energetic particle and plasma sensors at geosynchronous and Global Positioning System (GPS) orbits and to support the analysis and distribution of those data in a timely manner. In addition, DOE should be considered as a candidate agency to provide similar environmental sensors for other future magnetospheric monitoring tasks within the NSWP.

DOE's Los Alamos National Laboratory has supplied plasma monitors for many NASA solar wind missions. Through Los Alamos, DOE is providing real-time solar wind data from the ACE spacecraft, as well as the expertise necessary to support ACE. DOE should also be considered as a candidate agency to provide sensors for future NSWP solar wind spacecraft to follow ACE.

Los Alamos carries out an extensive program of space physics research that is sponsored by both DOE and NASA and that includes data analysis and interpretation as well as space plasma theory and modeling. DOE will continue to support this activity as a contribution to the research and modeling components of NSWP activity.

7.7.7 Department of Transportation (DOT)

Within DOT, the Federal Aviation Administration (FAA) is responsible for regulating and promoting the U.S. commercial space transportation industry. It licenses the private sector launching of space payloads on expendable launch vehicles and commercial space launch facilities. In addition, it also sets insurance requirements for the protection of persons and property and ensures that space transportation activities comply with U.S. domestic and foreign policy. Low-cost, reliable access to space is the foundation on which many other commercial and strategic applications of space technology are based. The benefits and spin-offs from these technologies, in turn, touch almost every aspect of the ability of the United States to remain at the forefront of world technological advancement and economic prosperity.

An important DOT space application is to successfully field a Global Positioning System (GPS)-based capability to support en route, terminal, and precision approach operations for airports and helipads/heliports in the U.S. and offshore areas such as Canada and Mexico. Towards this end, the FAA is developing the Wide Area Augmentation System (WAAS), a geographically expansive augmentation to the basic GPS service designed to improve the accuracy, integrity, and availability of the basic GPS signals. The WAAS will improve basic GPS accuracy to approximately 7 meters vertically and horizontally, improve system availability through the use of geostationary communication satellites carrying transponders, and provide important

integrity information about the entire GPS constellation. DOT is working with the International Civil Aviation Organization to foster acceptance of a single Global Navigation Satellite System integrating this capability with other satellite-based augmentations worldwide.

7.8 International Space Weather Efforts

7.8.1 International Space Weather Environment Service

The International Space Environment Service (ISES)--formerly the International URSIgram and World Days Service (IUWDS)-- is the organization through which the United States participates in international, real-time exchange of data and forecasts for the space environment. ISES consists of regional warning centers in major areas of the world. The warning centers serve their own regions by collecting data and exchanging it for data from other warning centers. Each warning center provides daily forecast advice to the World Warning Agency, operated by NOAA as a part of the SEC in Boulder. Each day, the Boulder center issues a consensus set of forecasts and summaries of activity back to the regional warning centers. Data collected in near real-time include geomagnetic and ionospheric observations as well as other solar-terrestrial data. The ISES data exchange program is currently evolving as various centers convert their data services to use of the Internet and the ISES plans that various regional centers can assume responsibility for some part of the effort of providing forecasts and alerts. ISES is also evolving as a vehicle for arranging tracking of satellites such as ACE. DOC will work with the regional warning centers to arrange for additional collection of data needed for the NSWP and for cooperation in implementing improved space weather services.

ISES organizes a series of international workshops to evaluate requirements and methods of improving solar-terrestrial predictions. These are held at approximately 5-year intervals and cover methods of observing and forecasting activity from the Sun through the interplanetary space and into the neutral atmosphere, ionosphere, and magnetosphere. The last workshop was held in Japan in 1996. The next one is expected in 2000 or 2001.

As a way of improving the relevance of the workshops, ISES is considering a proposal to conduct coordinated international campaigns to test improved prediction techniques, with the involvement of scientists who have developed the techniques and the end users (forecasters and customers). If the proposal is accepted, SEC's Space Weather Operations is planning to be involved as a central forecast center in the prediction campaigns in several ways. This includes the coordination of campaigns, the provision of collecting data and the actual execution of the campaigns from the perspective of forecasting, research, and development. These campaigns will provide a window for international participation, with U.S. participation through the NSWP.

7.8.2 ESA Space Weather Program

The European Space Agency (ESA) organized a Workshop on Space Weather during 11-13 November 1998 at ESTEC, Noordwijk, The Netherlands. One of the goals was to determine the current state of the field in different countries. The second goal was to put together a global picture concerning all scientific, technological, economic and environmental issues concerning space weather with the emphasis being placed on defining potential user requirements for European Space Weather Services. Future space weather workshops are being planned.

ESA also solicited a report on the state of the art in space weather modeling and on a proposed ESA strategy. This report was prepared by the Finnish Meteorological Institute and published in October of 1998. It evaluates the present space weather requirements and capabilities worldwide, with particular emphasis on European plans and capabilities.

Following this report, ESA issued a tender to develop a space weather program tailored to the needs of the agency, with a deadline of September 13, 1999. This announcement of opportunity specifically requests analyses of needs, cost benefits, and detailed mission scenarios of a European Space Weather Program. In particular, the objectives of the solicitation are the following:

- Investigate the benefits of a space weather program
- To provide secretarial management of a European space weather working team
- To establish a detailed rationale for a space weather program
- To establish detailed program contents, including a space segment, and a definition and prototyping of services to be provided
- To define the structures which need to be implemented by ESA and member states
- To produce a draft program proposal, project implementation plan, cost estimate, and risk analysis
- To develop a web-based data base

The ESA announcement of opportunity mentions explicitly collaborations and coordination with international space weather programs and efforts such as the National Space Weather Program. Therefore, opportunities for coordination exist in the short and intermediate term with the consortium selected to conduct the ESA program study. It is to be expected that the ESA study will benefit from experiences obtained in the US both in the analysis of relevance, and in the prioritization of US efforts. Furthermore, US and European efforts can and should be coordinated to avoid duplication of efforts and for resource sharing. Because of the expected long time duration of the expected ESA program, this opportunity for collaboration extends into the far future.

7.8.3 Space Weather Programs in Other Countries

The *Swedish Institute of Space Physics* (IRF) studies how solar magnetic activity can be modeled and predicted with intelligent hybrid systems (IHSs) using SOHO data. They use neural networks to study and predict satellite anomalies from the space weather state, radio communication conditions (indicated for example by the foF2), and geomagnetically induced currents and their effect on electric power systems and gas pipeline systems. Global magnetic field variations have been predicted by using geomagnetic activity indices.

In September 1996, IRF planned to build and launch a very small student satellite to be named Munin after one of the god Odin's ravens. The scientific objective of Munin is to collect data on auroral activity in both the Northern and Southern Hemispheres, such that a global picture of the current state of activity can be made available on-line. The data acquired by Munin will then serve as an input to the prediction of space weather. Student projects involving the processing and reduction of the data are envisioned. This satellite project will be used for technology development and in Space Engineering Education run by the Department of Space Physics of Umeå University. The data collected will be published on the Worldwide Web, free for all to use.

The role of the *Australian Space Forecast Center* (ASFC) is to monitor and forecast the solar-terrestrial environment, the region of space encompassing the Sun, the solar wind, the Earth's geomagnetic field and ionosphere. To fulfill this role, the ASFC receives data from a network of solar, geomagnetic and ionospheric observatories within the Australian region. It also exchanges data with similar organizations in other countries to provide a continuous flow of solar-terrestrial information.

In France, a forecast center is a regional center of the ISES (International Space Environment Service), dependent on the ICSU (International Council of Scientific Unions). It is located at the Paris-Meudon Observatory, in the Solar Department (DASOP), and the scientific service is known as COMPAS. It forms part of the *Laboratory of Solar and Heliospheric Physics* (CNRS). The user area covered officially by the Paris-Meudon Center is Western Europe (23% of the users are in France, 47% in the remainder of Western Europe). Further, 18% of the users are from Eastern Europe and 12% from the rest of the world. More than half of the users are scientific organizations (example: EISCAT), the others being related to telecommunications, monitoring of ionizing radiation, and especially to space activities. The Meudon Center cooperates with space agencies (mainly CNES and ESA, but it also provides forecasts to the Indian and the Canadian Space Agencies) for various applications. These applications include validation of scientific data, conditions in the terrestrial environment during satellite launches, causes of anomalies on board satellites, and dangerous re-entries of certain satellites of great mass (Skylab) or carrying nuclear generators (Cosmos 1402 and Cosmos 1900). However the most significant need at the European level remains the supply of data and forecasts for calculation of Earth observation satellite

orbits—the series represented by SPOT (CNES), ERS (ESA) and Topex-Poséidon (CNES - NASA).

In Japan, the *Space Environment Information Service* of the Hiraiso Solar Terrestrial Research Center provides space weather services. These services include updates on solar and geomagnetic activity, providing near real-time data from the ACE spacecraft, and daily plots of high-energy particle fluxes measured by the Space Environment Monitor (SEM) on GMS-4, the Japanese geosynchronous meteorological satellite. These data, as well as ground-based geomagnetic field data, are available via web access. Similar web access is provided to ionospheric sounding data in Japan. The Hiraiso center also maintains the Space Environment Real-time Data Intercommunication Network (SERDIN). SERDIN is a core facility required for space weather forecasts and is designed to perform acquisition, analysis, and distribution of space environment data in an automated manner. A wide variety of solar and geophysical data are collected via either local area network at Hiraiso Center or the wide area network (domestic and overseas) links in near real-time.

In Canada, NRCan (Natural Resources Canada) provided forecast services while support for basic research on the space environment is obtained through NSERC (Natural Sciences and Engineering Research Council). The Canadian Space Agency (CSA) provides major funding of facilities for use by Canadian scientists. Because of Canada's high latitude location, its technological systems are considerably more vulnerable to adverse space weather. A long-term space plan has thus been proposed through the CSA to integrate the extensive remote sensing facilities into an enhanced, ground-based, Canadian super-array. A new national facility for data assimilation and modeling has also been proposed.

7.8.4 Coordination of International Space Weather Activities

The Scientific Committee for Solar-Terrestrial Physics (SCOSTEP), during its 9th Quadrennial Symposium at Uppsala in August 1997 helped organize a special evening session to consider international space weather issues. NSF participants gave a presentation on the US National Space Weather Program at that meeting. Similar reports were presented by representatives of a number of other countries which have space assets and desire to understand and forecast disturbances in near-Earth space that affect their operations. After the meeting, the group of several hundred participants voted to ask SCOSTEP to lead an oversight effort to provide a coordinated international space weather program. This will be done as part of S-RAMP, which stands for "STEP-Results, Applications, and Modeling Phase", a new program adopted by SCOSTEP for the period 1998-2002. S-RAMP is to be the follow-on program to STEP (Solar Terrestrial Energy Program). At the Uppsala meeting, a Space Weather Working Group of S-RAMP was set-up and the first meeting of this Space Weather Working Group was convened at the COSPAR General Assembly in Nagoya, Japan, in July 1998 to discuss future activities. A new International Space Weather Clearinghouse web site was

established at the University of Michigan to provide a forum for this group's activities (URL: http://aoss.engin.umich.edu/intl_space_weather/sramp/).

The American Geophysical Union's fifth Western Pacific Geophysics Meeting was held in Taipei, Taiwan, in July 1998 after the COSPAR Meeting. Scientists representing the US, Japan, Taiwan, Korea, Canada, and Australia provided talks on their countries' national space weather programs. The S-RAMP Steering Committee met in Taipei and identified the especially active solar period of April-May 1998 as a "Special Study Interval". The Committee encourages scientists involved in all aspects of solar physics, interplanetary and magnetospheric physics, upper atmosphere and middle atmosphere physics, and space weather topics to concentrate on phenomena recorded by the extensive array of satellites and ground-based facilities operating at that time.

The Committee also approved the idea of organizing the First S-RAMP Space Weather Campaign for September of 1999. The objective of this campaign was to study the effects of space weather disturbances on the coupled magnetosphere-ionosphere-thermosphere system on a global scale, including the impacts on technological systems such as electric power grids, satellites, and ground- or space-based communication and navigation systems. In order to better understand the physical processes, as well as to provide a quantitative assessment of the effects on technological systems, the campaign also included observations from other global arrays of radio, optical and magnetic instruments. An effort was made to have efficient communications of activity alerts, information about observations, and electronic transfer of data and images worldwide. Special effort was and will continue to be made to see that scientists in developing countries have good access to data in a timely manner. The Space Physics and Aeronomy Research Collaboratory (SPARC) at the University of Michigan supported this campaign by providing real-time access to a wide range of space and ground-based data and model outputs. The results obtained during this campaign are expected to be discussed at the First S-RAMP Conference in Sapporo, Japan, in October 2000.