The National Space Weather Program

Strategic Plan

June 2010

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NATIONAL SPACE WEATHER PROGRAM

STRATEGIC PLAN

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Foreword

On behalf of the National Space Weather Program Council, I am pleased to release the new *National Space Weather Program Strategic Plan*. Under the auspices of the Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM), the Committee for Space Weather (CSW) prepared this plan for the Council's consideration and approval. The initial strategic plan, published in 1995, established the National Space Weather Program (NSWP) and set in motion a series of activities that have, over the intervening years, fostered substantial progress in the national space weather enterprise. Two editions of the NSWP Implementation Plan in 1997 and 2000 played significant roles in charting the course of development of our national space weather capabilities.

In 2005, the Federal and Interdepartmental Committees for Meteorological Services and Supporting Research directed the OFCM to conduct a comprehensive review of the NSWP. To perform this independent review and assessment, a committee of six individuals with expertise encompassing the science and applications aspects of space weather was convened. The recommendations from this independent assessment, the input from numerous space weather conferences, and the legacy of 15 years of progress in the national space weather enterprise provided a solid foundation upon which to build this new NSWP Strategic Plan. The Plan will promote the space weather advances our Nation will need as our technology-enabled society races forward in this new century and, at the same time, enhance our society's awareness of the potential impacts of space weather.

I want to take this opportunity to express my sincere appreciation to the members of the National Space Weather Program Council and the Committee for Space Weather for their dedicated efforts in support of this critical national program.

Samuel P. Williamson
Federal Coordinator for Meteorology
and
Chairman, National Space Weather Program Council

Executive Summary

The National Space Weather Program (NSWP) is a Federal interagency initiative established in 1995 to improve our capability to make timely and reliable predictions of significant disturbances in space weather and to provide this information in ways that are tailored to the specific needs of those who are potentially affected by them. It has also fostered an increased awareness of space weather within the stakeholder community as well as the general public. The NSWP organizations have established research and development facilities, promoted new observing capabilities, worked to transition successful research results into improved products and services, initiated forums to discuss and publicize the importance of space weather to society, helped prepare government and civil authorities to mitigate the impact of space weather, and helped build the training and education pipeline for new space weather professionals.

The term “space weather” refers to the variable conditions on the Sun, throughout space, and in the Earth’s magnetic field and upper atmosphere that can influence the performance of space-borne and ground-based technological systems and endanger human life or health. Adverse conditions in the space environment can disrupt satellite operations, communications, navigation, and electric power distribution grids, leading to a variety of socioeconomic losses and impacts on our security. As our society becomes more technologically advanced, our vulnerability to space weather significantly increases.

The NSWP is guided by the vision of a future society better prepared for the effects of space weather and supported by an effective and efficient space weather enterprise. The Strategic Plan describes this vision, the mission of the NSWP, and the goals the program will pursue to achieve this vision.

Vision: A nation that capitalizes on advances in science and forecasting to better cope with the adverse impacts of space weather on human activity and on advanced technologies that underlie our global economy and national security.

Mission: The NSWP serves as the focal point for the Federal Government’s national space weather enterprise and partnerships. By providing an active, synergistic, interagency forum for collaboration, the NSWP facilitates mutually beneficial interactions among the Nation’s research and operational communities. The NSWP develops effective and efficient strategies and options to meet the various space weather challenges facing the Nation and works to advance basic scientific research and exploration, enhance reliable space environmental services, increase public awareness, and support national policy formulation.

Goals:

I. Discover and understand the physical conditions and processes that produce space weather and its effects.
II. Develop and sustain necessary observational capabilities.
III. Provide tailored and accurate space weather information where and when it’s needed.
IV. Raise national awareness of the impacts of space weather.
V. Foster communications among government, commercial, and academic organizations.

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Introduction

"Space weather" refers to the variable conditions on the Sun, throughout space, and in the Earth's magnetic field and upper atmosphere that can influence the performance of space-borne and ground-based technological systems and endanger human life or health.

Adverse conditions in the space environment can cause disruption of satellite operations, communications, navigation, and electric power distribution grids, leading to severe socioeconomic losses as well as impacts on our security. Given the growing importance of space to security and economic well-being, it is critical that the Nation continue to explore ways to mitigate the deleterious effects of severe space weather.

The National Space Weather Program (NSWP) was established in 1995 to provide coordination and oversight in support of space environmental forecasting, research, data acquisition, model development, technology transition, operations, education, and public outreach.

As we approach the next peak of solar activity, our Nation faces many uncertainties resulting from our increased reliance on space weather-affected technologies for communications, navigation, security, and other activities, many of which underpin our national infrastructure and economy. We also face increased exposure to potential space weather-driven human health risks as trans-polar flights and commercial space activities increase and humans spend longer periods of time in space.

The NSWP has played and will continue to play a vital role in guiding our national effort by the Federal Government, the private sector, and academia to foster substantial improvements in our national space weather enterprise. This plan builds on the first strategic plan that was developed in 1995. It will guide the future efforts of the national space weather enterprise in pursuing vital capabilities and in developing world-leading space environmental products and services for the Nation.

Space Weather Impacts on Society

Our knowledge of the space environment is advancing toward a better understanding of the Sun, its radiant energy, the continuous solar wind, and the occasional expulsion of turbulent and high energy plasmas from the Sun's outer layers. While the Earth's magnetic field provides a partial shield against hazardous space radiation and "solar storms," solar wind dynamics drive the near-Earth environment. The complex interactions of solar radiation and the Earth's environment cause a wide variety of effects on spacecraft and ground systems critical to our everyday lives.

Although we have already learned much about the Sun-Earth relationship, our present ability to make accurate space weather forecasts is relatively immature, as was the case with atmospheric weather forecasts several decades ago.

Space weather effects on human activity are less intuitive than the very familiar rain, snow, and wind of terrestrial weather. However, space weather phenomena do reveal themselves on a daily basis. Member organizations of the National Space Weather Program are working continuously to understand space weather and to help the Nation mitigate its negative impacts.

Space weather can impact, among other things, satellite operations, orbits, and communications; the distribution of electric power; the Global Positioning System (GPS) and other navigation systems; communications of almost every kind; commercial and military aviation; the safety of humans in space; the accuracy of surveying; the extraction of oil and natural gas from far beneath the Earth's surface; and national security and military activities around the world. The potential impacts of an extreme event are highlighted in the National Research Council report, *Severe Space Weather Events—Understanding Societal and Economic Impacts: A Workshop Report*. Additional details on the impacts of space weather are presented in Appendix A and in a Space Weather Primer on the Space Weather Prediction Center website at

http://www.swpc.noaa.gov/primer/primer.html

A more comprehensive review is presented in the monograph *The Sun, The Earth, and Near-Earth Space: A Guide to the Sun-Earth System (2009)* by John A. Eddy, ISBN 978-0-16-083809-9, published by the U.S. Government Printing Office, Washington, DC.

Our Nation's reliance on technological systems continues to grow rapidly, and many of these systems are susceptible to failure or unreliable performance because of extreme space weather conditions. As our ability to provide timely and reliable space weather forecasts improves, we will be able to better mitigate or avoid these vulnerabilities. Although today's ability to forecast space weather is not yet commensurate with traditional weather forecasts, the technical skills, the technological and scientific advancements in remote sensing and computational sciences, and the satellite data are now emerging to significantly improve our understanding of space weather and to significantly upgrade the quality and timeliness of space weather forecasts, products, and services.

NSWP strategic plan initiatives can result in social, economic, and national security benefits that affect, among others, the following national and international activities:

- Economic development
- Communications
- Aviation
- Transportation and freight shipping by air, land, and sea
- National energy policy and activities
- Homeland security/emergency management
- National defense
- Scientific research

Benefits for these and other economic and societal activities can be realized if designers of technological systems can (1) anticipate space environmental conditions to which the hardware will be subjected; (2) depend on accurate and timely predictions of space weather; (3) take advantage of post-event analyses to determine the source of system anomalies and failures; and (4) build historical databases and develop subsequent engineering strategies for future planning. Accurate and timely space weather forecasts enable operators and users of vulnerable systems to take mitigating actions, thereby minimizing the adverse effects of space weather. Thanks to the work of government, industry, and academia, space weather capabilities are in place. However, our observing and forecasting ability is still relatively limited.

Strategic Plan for the Next Decade

To build upon the progress made since its inception 15 years ago, the NSWP will pursue expanded ***goals*** to execute its ***mission*** in order to achieve a ***vision*** of the future national space weather enterprise.

This plan covers a period of roughly 10 years and will be reviewed and updated as necessary. The NSWP's Committee for Space Weather will develop an implementation plan based on this strategic plan that will contain detailed timelines to address program goals and activities. Progress will be closely monitored using appropriate metrics, documented in the implementation plan, which will track milestones toward the completion of stated program goals.

Vision:

A nation that capitalizes on advances in science and forecasting to better cope with the adverse impacts of space weather on human activity and on advanced technologies that underlie our global economy and national security.

Mission:

The NSWP serves as the focal point for the Federal Government's national space weather enterprise and partnerships. By providing an active, synergistic, interagency forum for collaboration, the NSWP facilitates mutually beneficial interactions among the Nation's research and operational communities. The NSWP develops effective and efficient strategies and options to meet the various space weather challenges facing the Nation and works to advance basic scientific research and exploration, enhance reliable space environmental services, increase public awareness, and support national policy formulation.

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V. Foster communications among government, commercial, and academic organizations.

Program Goals and Objectives

Several objectives support each of the five program goals to help focus agency efforts to achieve the mission and attain the vision.

Goal I:
Discover and understand the physical conditions and processes that produce space weather and its effects.

Forecasting space weather depends on understanding the fundamental processes that give rise to hazardous events. Continued support for research is essential to achieve the level of understanding required for accurate predictions. Particularly important is the study of processes that link the Sun-Earth system and that control the flow of energy within the coupled system. Development of new instrumentation and observing capabilities are also important for discovery, understanding and as input to space weather models. Metrics need to be established so that improvements in forecasting capabilities can be monitored and assessed. Eventually, a chain of coupled models will be available that will reliably and accurately simulate and predict space weather events in the Sun-Earth system. Technology development is critically important for the success of the program and, in light of recent budget decisions, opportunity exists for great advancements. In order to achieve this goal, the NSWP seeks to:

- Set priorities for research to meet operational and science needs.

- Conduct basic research to advance understanding of solar processes and how the Sun's activity connects to and drives changes on the Earth and its near-space environs.

- Conduct applied research that addresses urgent needs to provide operational space weather services.

- Identify and assess existing gaps between the elements that need to be coupled together to create space weather models.

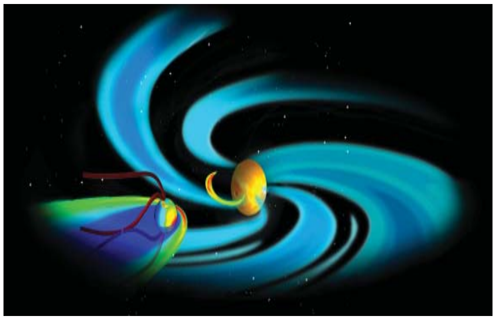


Figure 1: Space Environmental Modeling Regime (Source: Community Coordinated Modeling Center, NASA Goddard Space Flight Center)

- Develop and test models of the coupled Sun-Earth system that are accessible to the scientific user community, leading to useful physics-based models.

- Quantify the variability and climatology of space weather parameters for use in research, engineering, and operational applications.

- Develop robust technology transition and data processing capabilities, including product test beds for scientific and technological advances and advanced data assimilation techniques to benefit operations and provide for improved products and services.

Goal II:
Develop and sustain necessary observational capabilities.

Figure 2: The Advanced Technology Solar Telescope (ATST). (NSF National Solar Observatory project. Rendering by Tom Kekona, K. C. Environmental, Inc.)

Model development, verification, and maintenance require quality observations taken from space and on the ground. The reliability and accuracy of space weather models strongly depend on the quality of the data ingested. Continued improvement and development of space weather observing capabilities could result in better coverage, timeliness, and accuracy. Development of advanced technologies will improve the quality and affordability of new observing systems and optimize the path from research to operational use. The program should continually review the status of current and future space weather observing capabilities and plans to ensure consistency and efficiency in the implementation and use of these resources. To achieve this goal, the NSWP seeks to:

- Review completed space weather observing plans and consolidate them into a single coherent strategy to ensure efficient use of resources to meet observational requirements.
- Develop the necessary observational capabilities.
- Sustain useful space weather observing capabilities and explore improved coverage, timeliness, and quality of the data sources that are both vital and urgent.
- Ensure that historical space weather datasets are preserved within a national data center and made readily available to all, including the scientific research and engineering communities.

Goal III:
Provide tailored and accurate space weather information where and when it's needed.

Over the next 10 years, the NSWP will ensure processes are implemented to provide space weather data, analyses, and predictions with the accuracy, timeliness, and granularity required by the end user. To achieve this goal, the NSWP seeks to:

- Conduct periodic surveys of space weather data and product requirements needed by various user communities to help agencies determine resource priorities.

Figure 3: Space Weather Prediction Center, Boulder, Colorado

- Improve and expand the space weather operational processing center capabilities, to include:

    - Communications and data processing.
    - Product generation and tailoring.
    - Product distribution and integration into user applications.

- Facilitate the transition of needed space weather information and prediction capabilities to the Nation's space weather service providers.

Goal IV:
Raise national awareness of the impacts of space weather.

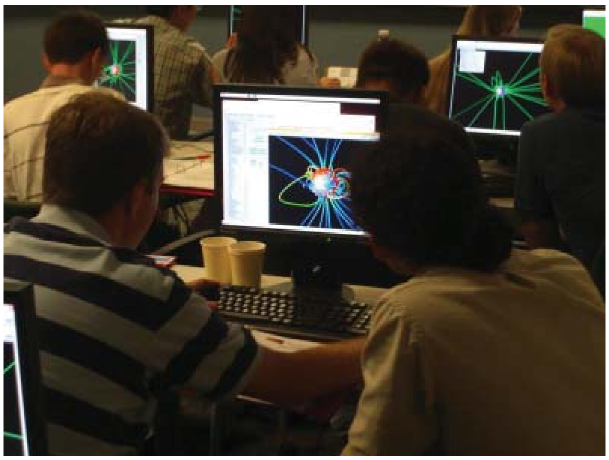


Figure 4: Students Study Space Weather Phenomena (Source: Center for Integrated Space Weather Modeling)

The space weather enterprise requires proactive education and outreach efforts in an effort to ensure effective knowledge transfer at all levels. The national educational pipeline, from elementary through graduate school, needs to be surveyed and improved in an effort to ensure that no shortages of critical science, technology, engineering, and mathematics skills exist or will occur in the future. A well-informed general public that understands space weather concepts and the importance of space weather in addressing critical national needs is equally important. This can be achieved by the efficient use of far-reaching existing and emerging communications technologies.

Effective transfer of space weather knowledge will require a better understanding of the impacts of space weather on technology and on commercial and military customers, to include the associated economic and political impacts on the Nation's civil and military assets. The future will see increasing use of simulations and mitigation exercises to ensure operators of systems and the general public are better prepared for space weather events. In order to achieve this goal, the NSWP seeks to:

- Encourage and improve educational programs in space weather for grades K-12 and for undergraduate and graduate academic institutions.

- Develop and maintain interactive and engaging web sites and explore the use of other emerging communications technologies, including Internet-based social networking and mobile phone applications.

- Conduct independent assessments of impacts of space weather on customers, including the economic and political impacts on the Nation's assets.

- Develop models to quantitatively assess the economic impacts on technical systems, particularly the North American electric power distribution network.

- Develop and conduct regular mitigation exercises and social science analyses to study public behaviors and responses to space weather services.

Goal V:
Foster communications among government, commercial, and academic organizations.

NSWP agencies will work closely to set funding priorities across the member agencies in order to attain the greatest benefit at the least cost to the government. All space weather activities can be improved and made more effective by expanding interagency dialogue and by enforcing process integrity and progress monitoring to ensure the highest quality program activities and products. The program will engage commercial and academic organizations interested in all aspects of space weather and establish a cooperative environment to encourage the development of new capabilities. This will include the improvement and expansion of technical exchange and user conferences, such as the annual Space Weather Workshop, the Space Weather Enterprise Forum, the American Meteorological Society Space Weather Symposia, the Institute of Navigation's general and technical meetings, and the American Geophysical Union Convention. To achieve this goal, the NSWP seeks to:

Figure 5: Diversity of Partners (Source: Adapted from NWS presentation at the 2009 Space Weather Enterprise Forum)

- Provide input into national and international space weather policy and standards development.

- Build on disaster reduction efforts currently underway and expand engagement with government, civil, and public stakeholders.

- Encourage partnering opportunities with a diversity of organizations and agencies involved in or affected by space weather, both nationally and internationally.

- Strengthen communications and coordination to ensure government, commercial, and academic organizations work together to facilitate cooperation and improve the efficiency and effectiveness of the space weather enterprise. An effective communications strategy will be developed and sustained to improve the ability to convey information about space weather impacts to decision makers and to the public.

The National Space Weather Program Management Plan

The National Space Weather Program (NSWP) is a Federal interagency initiative established in 1995 to improve our capability to make timely and reliable predictions of significant disturbances in space weather and to provide this information in ways that are tailored to the specific needs of those who are potentially affected by them. The NSWP was conceived and structured as a partnership among government agencies, fostering a close working relationship with industry and academia to build on existing governmental and civil capabilities and to establish a collaborative process among these separate entities to recommend national priorities, coordinate agency efforts, and leverage national resources. It has also simultaneously encouraged and included contributions from the user community, operational forecasters, researchers, modelers, and experts in instruments, communications, and data processing and analysis – across the government, in research universities, and from industry.

Currently, eight Federal agencies and entities participate in the program. The Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM) within the National Oceanic and Atmospheric Administration (NOAA) administers the NSWP and its governing committees. The *National Space Weather Program Council (NSWPC)*, which implements and manages the interagency program, is made up of senior representatives from each of the Federal agencies involved in space weather endeavors. They serve as the principal spokespersons on matters such as program scope, requirements, and resource commitments, which then shape individual agency policy and plans to focus on interagency efforts and resources. The NSWPC provides oversight to ensure common needs are met and the interests of each agency are addressed.

The operative arm of the NSWP is the *Committee for Space Weather (CSW*), made up of representatives from each of the agencies involved in the program. The CSW serves as the principal means for advancing the goals of the NSWP. An OFCM-appointed executive secretary, who serves both the NSWPC and the CSW, is the focal point for NSWP activities.

The OFCM also creates other committees, working groups, and joint action groups as needed for specific activities mandated by the NSWPC or CSW. For example, the *Committee for Space Environmental Sensor Mitigation Options (CSESMO)* was established by the NSWP in 2008 to assess and recommend options to provide continuity of space environmental sensing capabilities in low-Earth orbit and regarding the solar wind. The two reports produced by the CSESMO represent a significant milestone in interagency cooperation in developing an overarching space weather sensing architecture. In addition to the CSESMO, the NSWP has established other ad hoc groups when necessary.

The NSWP can be viewed as a hierarchy of activities starting with "Foundational Elements" which support "Service Providers", and ultimately providing benefits to a wide variety of "Customers." Basic and applied research support the four foundational elements of the NSWP as indicated in the figure below. The development of *scientific understanding* is essential to generate new assessment and forecasting capabilities. The ability to forecast space weather accurately is a measure of our scientific understanding. *Observations* in near real time provide the vital input for forecasting models, and they provide situational awareness. Archival data also provide a measure of truth for models, and they can also be used to correct them. Space environmental models and applications then provide useful tools for both operational forecasting and ongoing research and development. *Education and outreach* is critical to the ultimate success of the NSWP. It is necessary to educate researchers about forecaster and customer needs, and then forecasters about customer needs and the possibilities of emerging research, and, finally, customers and decision makers about space weather hazards and their mitigation.

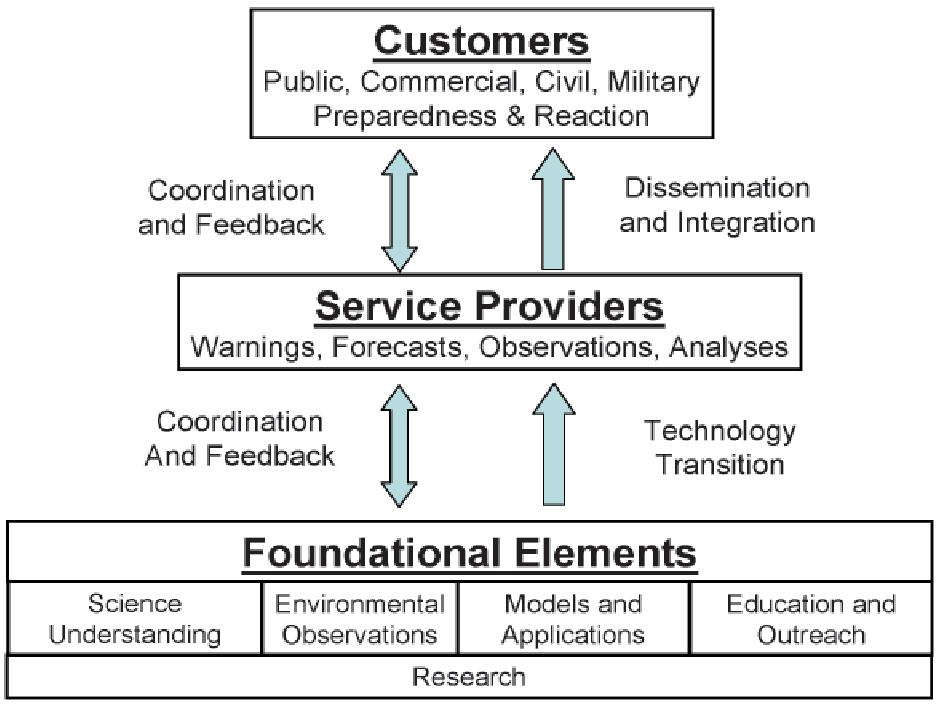


Figure 6: National Space Weather Program Elements

All elements of the NSWP provide support for optimal customer service through the interaction among customers, space weather forecasters, and space weather research and development activities. Communications between these elements, including feedback from forecasters and users, ensure efficient flow of information and products from the research and development community to customers and end users. An effective technology transition process is essential to bringing to bear the fruits of research and development on space weather forecasting.

Program Accomplishments and Assessment

Since 1995, major progress has been made in reaching the goals set out in the original NSWP Strategic Plan. The NSWP has also prompted a fundamental shift in awareness of space weather within the space science research community as well as in the general public. Some specific accomplishments are cited below.

- *NSWP initiated an interagency collaboration to establish the Community Coordinated Modeling Center (CCMC) in 1998 to support development of advanced space weather models for research and operations.*

- *NSWP has supported the annual Space Weather Workshop and Space Weather Enterprise Forum bringing together researchers, governmental policymakers, users, and private sector vendors.*

- *NSF, NASA, and DoD agencies have carried out dedicated programs supporting basic research aimed at promoting the NSWP goal of providing improved space weather products and services.*

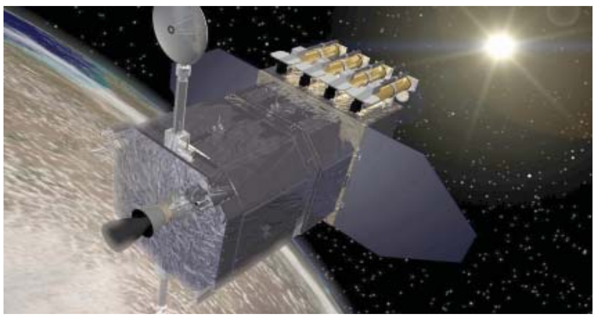


Figure 7: The first Living with a Star mission, Solar Dynamics Observatory, launched in 2010. (Source: NASA Goddard Space Flight Center)

- *NASA in 2001 embarked on the very expansive Living with a Star (LWS) program, which is providing essential space missions, data analysis, and modeling development relevant to space weather research.*

- *The international extension of LWS coordinates worldwide activities to advance understanding of the connected Sun-Earth System.*

- *The DoD has supported three Multidisciplinary University Research Initiatives (MURI) that address important space weather modeling problems.*

- *NSF established the Center for Integrated Space Weather Modeling (CISM), a multi-institution collaboration dedicated to creating physics-based space environmental models.*

- *The Air Force Space Weather Center of Excellence (CoE) was established to develop technologies for specifying, forecasting, and mitigating the effects of the space environment on DoD systems.*

- *NASA developed a Space Weather Laboratory at Goddard Space Flight Center to provide a focus for space-based, ground-based, theoretical, and modeling studies of space weather driving factors.*

Figure 8: Since 2003, the American Geophysical Union has published online, "Space Weather: The International Journal of Research and Applications." (Source: AGU)

- *In 2006, the American Meteorological Society convened a policy workshop to develop recommendations regarding space weather impacts to increase the safety, reliability, and efficiency of aviation operations.*

- *NASA along with other NSWP organizations supported International Heliophysical Year (2008-2009) programs that have raised space weather awareness within the United Nations scientific activities.*

- *NSWP, in 2008, conducted an impact study on the potential loss of solar wind monitoring capability and degraded space environmental sensing capability planned for the National Polar-orbiting Operational Environmental Satellite System (NPOESS).*

- *The NSWP provided an interagency-approved recommendation for the continuity of solar wind measurements and an in-depth assessment of mitigation options regarding the loss of planned NPOESS space environmental sensing capability.*

- *NASA has included real-time radio beacons on a variety of spacecraft and continues to support long duration missions to provide timely space environmental data for use in the operational space weather centers.*

- *USGS has undertaken significant upgrades of its magnetic observatory network, including establishing a new observatory in the Aleutian Islands, improving data transmission links so that they support real-time data transportation and dissemination, and increasing data-sampling rates from 1-minute to 1-second.*

- *NASA developed a cutting-edge space weather app for the iPhone and iPod Touch called "3D Sun," a space weather monitoring system for the public. More than 70,000 people in 81 countries downloaded it within six months of its deployment in December 2009.*

- *DOC/NOAA has continued its program of geostationary space weather measurements with the launches of the GOES O and P satellites in 2009 and 2010, respectively. The GOES R program is in development and will carry significant improvements on all of its space weather sensors.*

In 2005, the OFCM convened a high-level panel to assess the status of the NSWP and make recommendations. The panel included six researchers with meteorological, space physics, space weather, engineering, and policy backgrounds. The extensive review was conducted over the course of nearly a year and involved site visits to space weather operations centers and interviews with other space weather stakeholders. The panel concluded that the NSWP resulted in a number of noteworthy achievements, most of which likely would not have been attained without the program's existence. Furthermore, the existence of the NSWP has brought about a monumental shift in awareness of space weather within both the space science community and the general public. The panel concluded that "the continuation of the NSWP is strongly warranted because of the enormous potential to enhance the Nation's space weather mission over the next 10 years through improved operational capabilities, which will capitalize on the transition of innovative research."

The report from the assessment panel contains detailed findings and recommendations that cover research, models, transition to operations, operations, and program management. The program goals and objectives described in the previous section were formulated to address the panel's key recommendations:

1. Establish centralized program management and national funding prioritization.
   - Establish a focal point for the program within the Executive Office of the President's Office of Science and Technology Policy (OSTP) and the Office of Management and Budget (OMB).

2. Ensure continuity of critical data sources needed for space weather forecasts and operations.
   - Develop and execute a strategy to preserve the continuity of solar wind and other key space weather measurements.
   - Maintain critical ground-based assets such as USGS magnetic observatories.

3. Strengthen the science-to-user chain.
   - Maintain and strengthen both targeted and strategic space weather research.
   - Enhance emphasis and resources for transition of models to operational users.
   - Increase the role of the private sector in supplying products and services.

4. Emphasize public and user awareness of space weather for critical national needs.
   - Quantify the national benefits that arise from the NSWP.
   - Enhance academic education programs for new space weather professionals.

Input from the Space Weather Community

The NSWP has established a number of formal and informal mechanisms to ensure community involvement in the program and coordination among participating stakeholders.

The annual Space Weather Workshop (SWW) and Space Weather Enterprise Forum (SWEF) have been extremely successful venues for bringing Federal, industry, academic, and international stakeholders from the space weather operational, research, and user communities together to advance the state of national and international space weather support and services. They also have been very successful in addressing the needs of the public and addressing the societal and economic effects of space weather. Input from the SWW and SWEF have been incorporated in this strategic plan and will drive recommendations in the implementation plan.

The American Geophysical Union established the International Journal of Space Weather to provide a forum for the international space weather community to report new results, share experiences, and educate the general public. Participating Federal agencies have sponsored several high-profile workshops to discuss policy issues and space weather impacts on various technologies, including aviation, electric power, satellite operations, navigation, and communications. Also, a number of studies have been conducted on impact assessments, technical risks, and economic loss stemming from space weather events.

Recently, the American Meteorological Society adopted a Policy Statement on Space Weather and created a committee within its Scientific and Technological Activities Commission, in recognition of the increasing influence space weather has on our society. The Society promotes improved modeling and stronger ties between research and operations, continuity of observations, and coordinated government, industry, and academia research on impacts and cost-benefit analyses.

Finally, the World Meteorological Organization has initiated dialogue on space weather data and products to better coordinate international efforts in this area.

Summary

As we approach the next peak of solar activity, our Nation faces many uncertainties resulting from increased reliance on space weather-affected technologies for communications, navigation, security, flight safety in the atmosphere and space, and other activities, many of which underpin our national infrastructure and economy. We also face increased exposure to potential space weather-driven human health risks as transpolar flights and human spaceflight activities increase.

The NSWP will continue to play a vital role in guiding our national effort among the Federal agencies, the private sector, and academia to foster substantial improvements in our national space weather enterprise. This strategic plan will lead to advances to help us understand the natural processes that produce space weather and its effects. It will encourage support to develop capacity to provide accurate space weather information, tailored to need, where and when it is needed. The plan will guide efforts that will enhance awareness of the Nation's space weather enterprise and space weather's effects and challenges. It will foster the education and development of a new generation of space weather engineers and scientists. Finally, it will help encourage Federal agency information exchange and will support national and international space weather policy and standards development.

APPENDIX A

Space Weather Impacts on Society

The following sections provide additional details on the space weather impacts on advanced technologies and other activities that are so critical to the normal conduct of our daily lives.

A. ***Satellite Systems***. Space weather affects satellite missions in a variety of ways, depending on the orbit and satellite function. Our society depends on satellites for weather information, communications, navigation, exploration, search and rescue, research, national defense, space travel, and routine business transactions, involving automated teller machines and charge card purchases. The impact of satellite system failures is more far reaching than ever before, and the trend will almost certainly continue.

Energetic particles that originate from the Sun, from interplanetary space, and from the Earth's magnetosphere continually impact the surfaces of spacecraft. Highly energetic ions penetrate electronic components, causing bit-flips in a chain of electronic signals that can result in spurious commands within the spacecraft or erroneous data from an instrument. These spurious commands have caused major satellite system failures that might have been avoided if ground controllers had had advance notice of impending particle hazards. Less energetic particles contribute to a variety of spacecraft surface charging problems, especially during periods of high geomagnetic activity. In addition, energetic electrons responsible for deep dielectric charging can degrade the useful lifetime of internal components.

Highly variable solar ultraviolet radiation continuously modifies terrestrial atmospheric density and temperature, affecting spacecraft orbits and lifetimes. Increased far ultraviolet radiation heats and expands the atmosphere, causing significant perturbations in low-altitude satellite trajectories. At times, these effects have been severe enough to cause premature re-entry of orbiting assets. It is important that satellite controllers be warned of these changes and that accurate models are in place to realistically account for the resulting atmospheric effects. The main problems due to drag effects are related to attitude control, orbit decay, and tracking of space debris. The existing and future spacecraft are also vulnerable to changes in atmospheric drag; re-entry calculations for such vehicles are highly sensitive to atmospheric density, and errors can threaten the safety of the vehicles and their crews.

> Japan launched Nozomi (1998)--its representative in an international fleet of Mars probes. A strong burst of solar energy (April 2002) knocked out the communications and electrical systems, ultimately altering its trajectory. The ¥11 billion ($88 million) satellite will remain in a highly elliptical orbit around Mars but will not complete its mission.

The solar proton flux associated with intense solar activity can be strong enough to affect the sensitive guidance systems on launch vehicles and could cause damage to payloads. Because of the sensitivity and critical timing of most launch activities, space weather is a consideration in pre-launch scheduling and preparations. The enormous cost of launches and payloads demands that an accurate assessment be made at the time of launch.

B. ***Power Systems***. Modern electric power grids are extremely complex, extensive, and interrelated. The long power lines that link users throughout the Nation are susceptible to electric currents induced by the dramatic changes in high-altitude ionospheric currents that occur during geomagnetic storms. Surges in power lines from induced currents can cause massive network failures and permanent damage to transformers and to multimillion-dollar equipment in power-generation plants. The resulting social and economic impacts and the threat to well-being and safety during widespread power outages can far outweigh the costs of prevention and mitigation through modifications in electric power grids and other steps.

Present electric power distribution systems have acquired a much increased susceptibility to geomagnetically induced currents due to widespread grid interconnections, complex electronic controls and technologies, and large inter-area power transfers. The phenomenon occurs globally and simultaneously, and industry operations allow for little redundancy or operating margin to absorb the effects. Mitigation of such effects is quite possible, provided that advance notice is given of an impending storm and specific strategies to minimize disruption and damage exist within the power industry. An equally important economic issue from the industrial standpoint is that of preventing or minimizing costly false alarms.

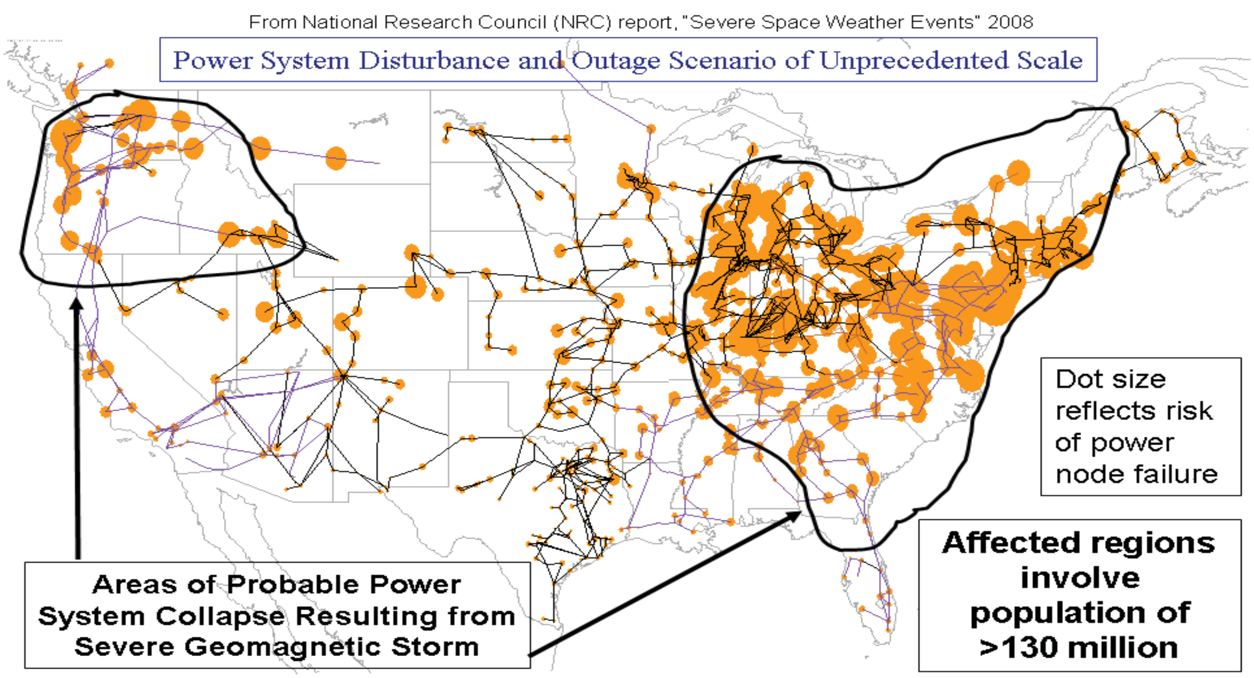


Figure 9: Simulation of ground induced current flows and possible power system collapse for the U.S. electric power grid due to an extreme geomagnetic super-storm disturbance scenario. (Source: Kappenman, J., W.Radasky, Too Important to Fail, *Space Weather, 3*, 2005.)

Future so-called ‘smart’ grids may have greater susceptibilities to space weather impacts both because of the greater separation between wind and solar power generation sites and metropolitan centers and because of the sophisticated electronic command and control and power systems they will support.

C. ***Navigation***. Most modern navigation systems depend upon satellites such as the Global Positioning System (GPS). A GPS receiver uses radio signals from several orbiting satellites to determine the range from each satellite and from these it determines its own precise geographic location. The radio signals must pass through the ionosphere and significant errors in positioning can result when the signals are refracted and slowed by ionospheric conditions or intentional interference techniques. Use of advanced receiver technology, such as dual-frequency receivers, can eliminate some of the uncertainty. Ionospheric delay corrections for a region can be determined from a network of precisely positioned dual-frequency receivers, and then transmitted in near-real-time to users of single frequency GPS receivers in the region. This is the principle behind the U.S. Wide Area Augmentation System (WAAS) that is being developed by the Federal Aviation Administration (FAA) and the Department of Transportation (DOT) for use in precision flight approaches. However, rapidly varying structures in the ionosphere associated with sharp density gradients can have time scales faster than the WAAS message repetition rate of six minutes. This can lead to loss of availability for many hours, during extreme geomagnetic storm events—a problem that defines one of the greatest challenges for the WAAS program.

D. ***Communications.*** Communications at all frequencies are affected by space weather. High frequency (HF) radio communications are more routinely affected because this frequency band depends on reflection by the ionosphere to carry signals great distances. Ionospheric irregularities contribute to signal fading; highly disturbed conditions, usually near the aurora and across the polar cap, can absorb the signal completely and make HF radio propagation impossible. Accurate forecasts of these effects can give operators more time to find an alternative means of communication. Telecommunications companies increasingly depend on higher frequency radio waves that penetrate the ionosphere and are relayed via satellite to other locations. Signal properties can be altered by ionospheric conditions so that they can no longer be received at the Earth’s surface. This may cause degradation of signals, but, more importantly, can prohibit critical communications, such as those used in search and rescue efforts, military operations, and other critical computer-linked networks.

> In May 1998, communications were lost with a geostationary satellite. This affected 90 percent of the pager and cell networks in the U.S., and also television, cable sources and numerous private networks (such as credit card transfers). Recovery involved moving spacecraft and using backup capabilities as available. At the time, the space environment had been disturbed for two weeks. Similar disruptions of the ionosphere have been associated with failures of spaceborne equipment in the past.

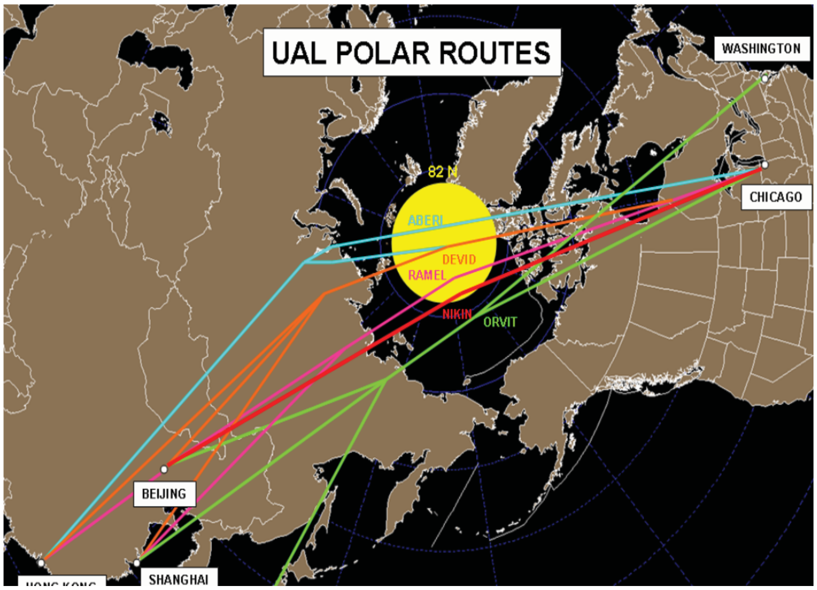


Figure 10: In 2009, United Airlines operated 1411 of the total 8527 polar flights, utilizing the four existing polar routes over Russia. (Source: United Airlines, Mike Stills)

E. ***Aviation***. Space weather impacts on aviation have long been recognized as a problem in military missions, especially high-altitude reconnaissance missions and flights over polar regions. Recent years have seen an immense growth in civil aviation. With commercial airliners flying higher and longer, the aviation industry has started to pay attention to space weather conditions that might affect equipment, crews, and passengers. The rapidly increasing number of flights between North America and the Far East that follow routes across the northern polar cap are cause for particular concern. Changes in the ionosphere caused by space weather can disrupt high frequency radio communications and disrupt or reduce the accuracy of satellite navigation systems. In addition, intense solar flares produce increased levels of high-energy particle radiation that add to the enhanced exposure to galactic cosmic rays already present at higher altitudes and latitudes. In common with the response to severe terrestrial weather, flights have been delayed or rerouted because of concerns over space weather, which can incur significant expenses for the airlines as well as potential health hazards for passengers and crews.

F. Human Space Exploration.
Energetic particles present a health hazard to astronauts on space missions as well as threats to satellite systems. The atmosphere protects us from these particles since it ultimately absorbs all but the most energetic cosmic ray particles. During space missions, astronauts performing extravehicular activities are relatively unprotected. The fluxes of energetic particles can increase to dangerous levels (by factors of hundreds) following an intense solar flare or during a large geomagnetic storm. Timely warnings are essential to give astronauts sufficient time to return to their spacecraft prior to the storm's arrival. Even during intravehicular activities, crew members are exposed to radiation

> In 2001, during the inaugural launch of an Athena rocket with four payloads from Kodiak, Alaska, an intense solar flare with a strong proton storm caused numerous problems. The launch was ultimately delayed 72 hours. Nearby communications and HF radio were hampered for this entire time. The payload might have been damaged and the guidance system knocked out if the launch had proceeded as scheduled. A $3 million booster and four-satellite payload were saved.

levels well above any terrestrial occupation. Periods of increased solar activity only heighten the exposure. Adequate prediction of such events allows crew members to move to locations within their spacecraft that are more adequately shielded.

The same applies even more so to potential human excursions on wholly unprotected surfaces such as that of the Moon. Without appropriate countermeasures, an increase in cancer risk is most severe for flights that leave the protection of the Earth's magnetosphere. This is particularly the case for longer duration human flights such as those to near-Earth objects or Mars, because of the long-term accumulated dose from penetrating galactic cosmic rays.

G. ***Surveying.*** Magnetic disturbances associated with geomagnetic storms directly affect operations that use the Earth's magnetic field for guidance, such as magnetic surveys, directional drilling, or the use of magnetic compasses. Aeromagnetic surveys are an efficient but costly method of geophysical prospecting for minerals. These surveys can be seriously compromised if sudden disruptions of the Earth's magnetic field occur during the flights and are not sufficiently accounted for. Situational awareness and knowledge of space weather conditions is thus a requisite in cost-effective geophysical surveying.

Figure 11: GPS precision surveying. (Source: http://www.gps.gov)

Directional, often horizontal, drilling is a technique employed by the oil and gas industry to extract the maximum amount from oil field reserves by drilling outward in many directions from a vertical rig. Magnetic field guidance is a cost-effective navigation technique for this but is prone to large inaccuracies during magnetic storms. Directional drilling requires a directional accuracy of 0.1 degree over a typical horizontal traverse of 5 to 10 km. The orientation of the Earth's field at a North Sea location may change up to 0.2 degree daily. During a magnetic storm, deviations are often on the order of several degrees. Accurate position information translates into helpful geological information to guide drilling exploration in the deep ocean. Over vast areas of the ocean, precise positioning enables accurate altimeter measurements for ocean surveying ships to pinpoint desired drilling locations, which results in major reductions in time-on-station operational costs and enhanced success in the discovery of oil reserves.

H. ***Mitigation Strategies***. Design engineers make use of information on space climate to specify the extent and types of protective measures that need to be designed into a system and to develop operating plans to minimize deleterious space weather effects. They also make use of space environment information, after the fact, to determine the sources of equipment failures and to develop corrective actions.

Table 1. Response Options to Mitigate Space Weather Impacts

Satellites	• Turn off sensitive spacecraft subsystems. • Avoid satellite maneuvers during adverse space weather conditions. • Increase monitoring of satellite operations for anomalies. • Adjust calculations of low-Earth orbits to account for increased drag. • Reschedule launch activities to prevent damage or loss.
Electric power	• Prepare to reduce system load. • Disconnect system components. • Plan and schedule power station maintenance efficiently.
Navigation	• Prepare for use of backup systems. • Safely plan and schedule precision-sensitive maneuvers.
Communications	• Seek alternate frequencies. • Alter ray paths or relay to undisturbed regions to avoid scintillation effects. • Prepare for use of alternate means of communication.
Aviation	• Reroute polar flights with minimal impact. • Prepare for Wide Area Augmentation System degradation.
Humans in space	• Increase specific protection against radiation exposure. • Plan and schedule extravehicular activities and launches efficiently. • Delay or postpone space tourism launches or activities to reduce radiation exposure.
Surveying	• Plan and schedule high-resolution geological surveying and exploration efficiently. • Plan and schedule high-resolution magnetic surveying efficiently.

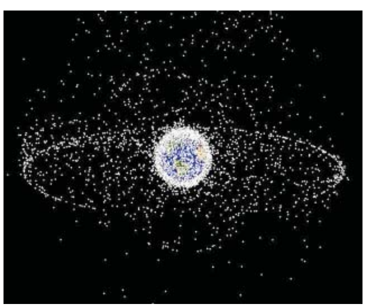


Figure 12. Orbit Debris Simulation (Source: NASA Johnson Space Center)

I. ***Space Weather in a Broader Context*.** Space weather research, observations, and technology development have broader application to other disciplines important to modern civilization. For example, the knowledge gained in studying solar processes can be applied to research on solar variability on long-time scales and its association with climate change. The Sun is the dominant forcing factor responsible for the Earth's climate, and variations in total solar irradiance may be causally linked to changes in regional environmental conditions. Although the NSWP concentrates on explosive space weather variations (i.e. solar flares and coronal mass ejections) that can have an immediate effect on terrestrial systems and space travelers, the understanding of solar dynamo processes resulting from space weather research can also contribute to studies of more long-term variations in solar radiation.

Similarly, mitigating hazards to spacecraft resulting from orbital debris is becoming increasingly more challenging as the number of space objects continues to grow exponentially. The ability to avoid collision with debris requires accurate tracking of objects under the influence of constantly changing atmospheric densities. Space weather research allows for more accurate specification and forecasting of atmospheric density and better predictions of orbits.

While the approach of Near-Earth Objects (NEO) cannot be avoided, space weather observational assets include space-based and ground-based instruments capable of detecting and tracking objects that may potentially impact the Earth. To meet space weather objectives, these observational capabilities undergo continuous improvement in sensitivity and coverage, thereby increasing the probability of early detection of approaching objects and the accuracy of subsequent tracking of those objects. An example is the Large Angle and Spectrometric Coronagraph (LASCO) instrument on the Solar and Heliospheric Observatory (SOHO) that, in the process of continuously observing the Sun, has also observed many previously undiscovered comets. These data can be used for orbit determination and potential threat identification.

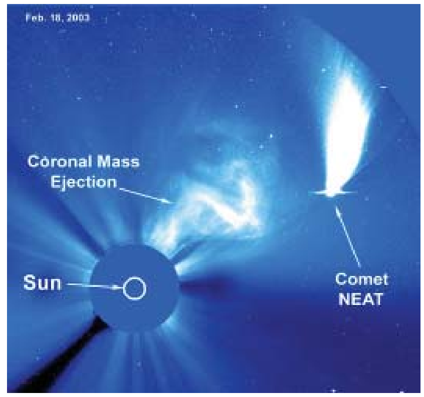


Figure 13. Comet NEAT passed through SOHO's C3 coronagraph field of view. (Source: NASA Goddard Space Flight Center)

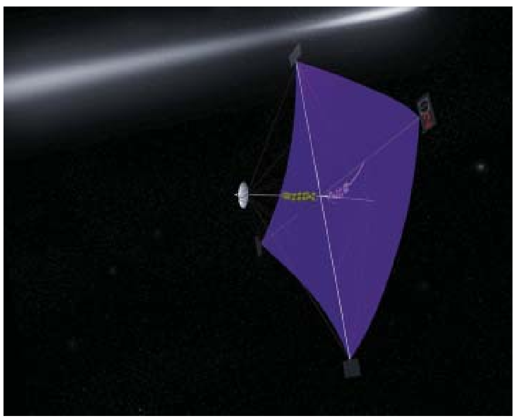


Figure 14. Artist's concept of a solar sail-powered spacecraft. (Source: NRC Decadal Survey, courtesy of NASA Marshall Space Flight Center.)

Another important technology area is plasma science, which aims to study the behavior of ionized gases. Because the entire space weather system is dominated by magnetized plasma, space weather research will advance understanding of basic plasma processes—knowledge that can be applied to the development of new technologies. These include industrial and medical devices, lighting and laser equipment, fusion and energy production, and many others.

New propulsion and power technologies are needed to enable further planetary and heliospheric missions. An important part of any space mission is the ability to loft a spacecraft into space and propel it to its intended orbit or destination. Solar sails have long been envisioned as a simple, inexpensive means of propulsion that could provide access to and maintenance of unstable orbits that would otherwise require large, expensive propulsion systems. The potential of solar sails is being explored for a number of missions and has, in fact, been tested in space. The National Research Council 2003 Decadal Survey on Solar and Space Physics strongly recommended continued research and development of this technology.

APPENDIX B
Member Agencies Roles and Missions

Department of Commerce (DOC). Within DOC, NOAA has the mission of describing and predicting the space environment. NOAA's Space Weather Prediction Center (SWPC) has a dedicated operational forecast center that serves as the national and world warning center for disturbances that can affect people and equipment working in the space environment. NOAA maintains unique space weather expertise to assist in the design of new systems and to reduce effects on existing systems. The agency also collects, provides, and archives space environment data from its polar-orbiting and geostationary satellites, from other agencies, and through international data exchange. Research and development is directed toward understanding processes and interactions as energy leaves the Sun, propagates through the interplanetary medium, and arrives at the Earth's atmosphere.

Department of Defense (DoD). The Air Force provides operational space weather support to warfighters, coalition partners, civilian partner agencies, and classified national-level users. This support includes remotely sensed data from ground- and space-based platforms /systems, operational space weather model output, and mission-tailored products. Examples of tailored support includes a variety of alerts and warnings for significant space weather phenomena that will impact DoD operations, the hourly analysis of the Earth's geomagnetic field, and specification and forecasts of the ionosphere directly supporting high frequency (HF) radio and satellite communications. The Air Force Research Laboratory and the Naval Research Laboratory work with each other, a variety of other governmental agencies, and academia to develop operational space weather models, ground- and space-based sensors, and system impact applications.

Department of the Interior (DOI). The Department of the Interior's U.S. Geological Survey's Geomagnetism Program provides high-quality, ground-based magnetometer data continuously from 13 observatories distributed across the United States and its territories. The program collects, transports, and can disseminate these data in near real time, and it also has significant data processing and data management capacities. Working through the INTERMAGNET organization, and with other national geomagnetism programs, the USGS Geomagnetism Program assists in the coordinated, global-scale monitoring of the Earth's magnetic field. The Geomagnetism Program also supports research on magnetic field activity, magnetic storms, and magnetic climatology, and it is currently developing a real-time storm-time disturbance (Dst) service.

Department of Energy (DOE). The core space weather program within DOE and its national laboratories supports research, applications, and operations in the satellite-based detection of nuclear explosions. The program develops and supplies the Air Force and other agencies with instruments that are flown on the Global Positioning System and other geosynchronous platforms to measure local plasma and particle distributions and remote ionospheric electron content, all in near real time. Related efforts also provide the databases, assimilative models, and scientific support to the broader community, including research on possible impacts on electricity delivery and reliability.

Department of Transportation (DOT). The Federal Aviation Administration (FAA) has the responsibility to provide the operational requirements for space weather services in support of aviation and for coordination of these requirements with the International Civil Aviation Organization. The increasing number of polar flights by commercial airliners and the emerging commercial space transportation sector have elevated the importance of space weather products and integration of the data into the National Airspace System (NAS). As a result, the FAA is formulating space weather requirements for the NAS by 2013, and plans to integrate space weather data and products into the Next Generation Air Transportation System by 2016.

Department of State (DOS). The Office of Space and Advanced Technology (OES/SAT) ensures that U.S. space policies and multilateral science activities support U.S. foreign policy objectives and enhance U.S. space and technological competitiveness. OES/SAT has primary responsibility for U.S. representation to the United Nations (UN) Committee on the Peaceful Uses of Outer Space (UNCOPOUS), where a wide range of space policy issues are discussed. The office also leads interagency coordination on all civil space-related international agreements implementing important NASA, NOAA, and USGS cooperation with other space agency partners, and plays a key role in the implementation of National Space Policy focused on dual-use space applications such as space-based positioning, navigation, and timing, satellite-based remote sensing and Earth observation, and space weather monitoring.

National Aeronautics and Space Administration (NASA). The Heliophysics Division of NASA's Science Mission Directorate is tasked to fulfill the science strategy laid out by the National Research Council's Decadal Survey. It advances our understanding of events and conditions in space; develops and uses new technologies; develops and maintains data that determine the nature of space weather conditions and provide insight into physical understanding; and generally observes and interprets the variable heliophysics system. The NASA Space Operations Mission Directorate (SOMD) is responsible for all human space operations in Low-Earth Orbit and beyond. SOMD provides the agency with all oversight for safe and effective operation of human exploration, including launch services, space transportation, and space communications in support of both human and robotic exploration. The NASA Office of the Chief Engineer is responsible for developing agency standards for environmental impacts on spacecraft systems and subsystems and addresses space weather issues across NASA.

National Science Foundation (NSF). NSF is responsible for maintaining the health of basic research in all areas of the atmospheric sciences. The Foundation supports theoretical, observational, and numerical modeling research with the goals of increasing fundamental understanding of space environment processes and improving space weather predictive capability. 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 atmospheric physics and dynamics. Knowledge of the processes that are fundamental to each of these areas is enhanced by a multi-disciplinary approach to investigating the basic mechanisms through which these areas interact.

APPENDIX C

Bibliography

Eddy, John A. *The Sun, The Earth, and Near-Earth Space: A Guide to the Sun-Earth System*, National Aeronautics and Space Administration (NASA), U.S. Government Printing Office, 2009, Washington D.C.

Grand Challenges for Disaster Reduction: Space Weather Implementation Plan, National Science and Technology Council Subcommittee on Disaster Reduction (SDR), 2010. Available at: http://www.sdr.gov/

Heliophysics: The Solar and Space Physics of a New Era, Report to the NASA Advisory Council Heliophysics Subcommittee, NASA Heliophysics Roadmap Team, 2009.

Impacts of NPOESS Nunn-McCurdy Certification and Potential Loss of ACE Spacecraft Solar Wind Data on National Space Environmental Monitoring Capabilities, Office of the Federal Coordinator for Meteorological Services and Supporting Research, 2008. (For Official Use Only)

Integrating Space Weather Observations and Forecasts into Aviation Operations, American Meteorological Society & SolarMetrics Policy Workshop Report, 2007. Available at: http://www.ametsoc.org/atmospolicy/documents/space%20weather%20&%20aviation%20report.pdf

The National Space Weather Program: The Implementation Plan 2nd Edition, FCM-P31-2000, Office of the Federal Coordinator for Meteorological Services and Supporting Research, 2000. Available at: http://www.ofcm.noaa.gov/nswp-ip/tableofcontents.htm.

The National Space Weather Program: The Strategic Plan, FCM-P30-1995, Office of the Federal Coordinator for Meteorological Services and Supporting Research, 1995. Available at: http://www.ofcm.gov/nswp-sp/text/a-cover.htm

A Policy Statement of the American Meteorological Society (Adopted by AMS Council on 5 May 2008). Available at http://www.ametsoc.org/policy/2008spaceweather_amsstatement.html

Report of the Assessment Committee for the National Space Weather Program, FCM-R24-2006, Office of the Federal Coordinator for Meteorological Services and Supporting Research, 2006. Available at http://www.ofcm.gov/r24/fcm-r24.htm.

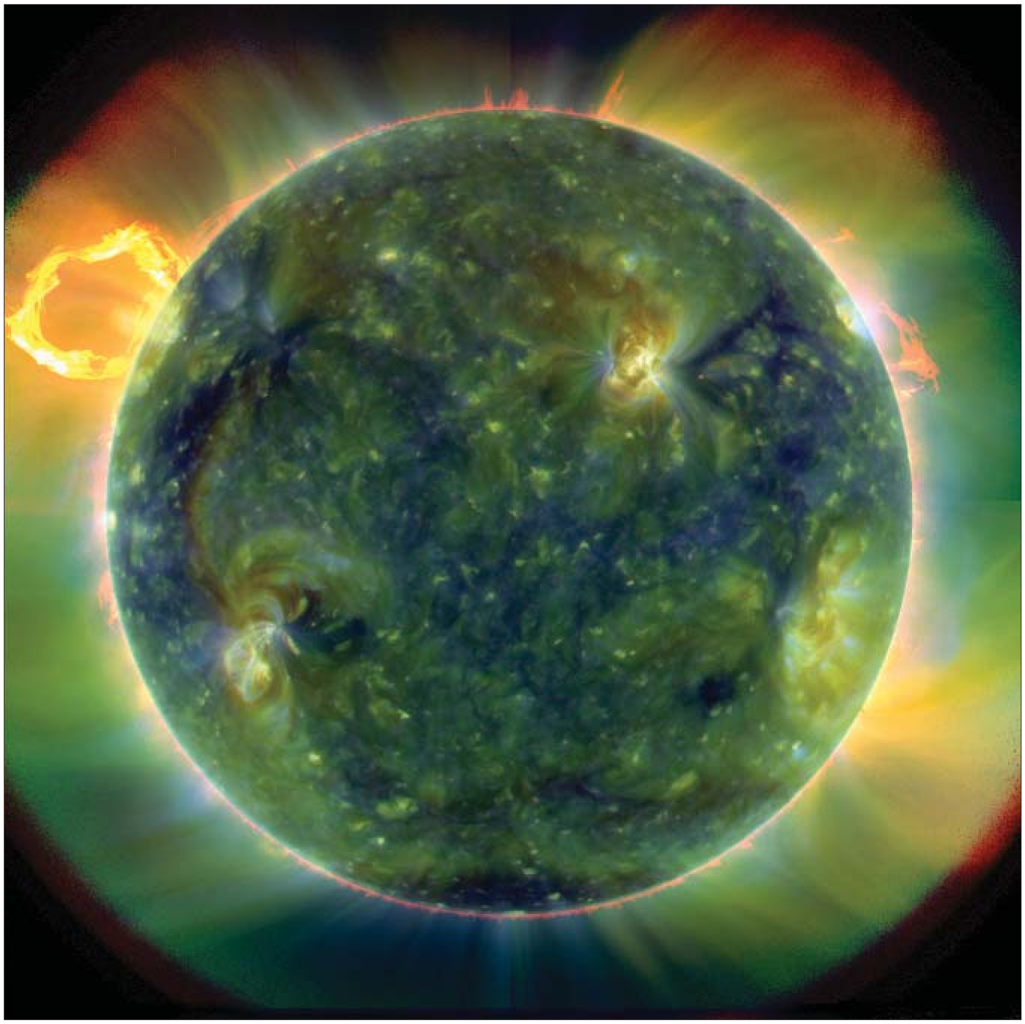
Severe Space Weather Events – Understanding Societal and Economic Impacts Workshop Report, Committee on the Societal and Economic Impacts of Severe Space Weather Events, National Research Council, The National Academies Press, Washington D.C., 2008.

Space Weather Primer, NOAA (National Oceanic and Atmospheric Administration) Space Weather Prediction Center, 2006. Available at: http://www.swpc.noaa.gov/primer/primer.html

Summary Report on NPOESS Space Environmental Sensor Mitigation Options and Recommendations, Office of the Federal Coordinator for Meteorological Services and Supporting Research, 2009. (For Official Use Only)

Summary Report on Solar Wind Monitoring Continuity Options and Recommendations, Office of the Federal Coordinator for Meteorological Services and Supporting Research, 2009. (For Official Use Only)

The Sun to the Earth – and Beyond: A Decadal Research Strategy in Solar and Space Physics, Solar and Space Physics Survey Committee, Committee on Solar and Space Physics, Space Studies Board, Division on Engineering and Physical Sciences, National Research Council, The National Academies Press, Washington, D.C., 2003.



First Light, Solar Dynamics Observatory. Credit: NASA

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