

2009 Community Review of the NCEP Space Weather Prediction Center

**Carried out by the
University Corporation for Atmospheric Research**

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Executive Summary

A review of the National Oceanic and Atmospheric Administration (NOAA) Space Weather Prediction Center (SWPC) was conducted in June 2009 as part of a comprehensive review of the National Centers for Environmental Prediction (NCEP). The SWPC review panel was asked to examine the Center's mission to determine its relevance, appropriateness and alignment with NCEP's strategic plan, in addition to assessing the quality, relevance and impact of its operational products and services, and the productivity and quality of its scientific activities.

Since joining the National Weather Service (NWS) in 2005, SWPC has achieved many accomplishments amid a reorganization and the recruitment of a new Director. For example, SWPC created several new partnerships with other federal agencies, commercial service providers, and international organizations to benefit its customers. They identified a plan to modernize the Space Weather Forecast Office (SWFO) and create the Space Weather Prediction Testbed (SWPT). Additionally, the Director has successfully made the case to NOAA on the need for an appropriate budget to carry out the mission, and it is expected that the Center will see a budget increase in the coming years.

At the site visit, the review panel identified three overarching issues that threaded throughout the discussions and interviews: (1) the new mission, (2) the internal organizational change, and (3) preparing for the next Solar Maximum. Findings and recommendations, which target these three areas, were organized according to NCEP's strategic plan themes: Customers and Partners, Products and Services, Information Systems, Science and Technology, People and Organization, and Business Processes. Most of the recommendations are related to each other and should not be evaluated in isolation, but rather implemented collectively.

Key findings and recommendations include:

Customers and Partners

Finding: Faced with the lack of a stable and sufficient budget, SWPC has leveraged resources and capabilities with other federal partners. For example, inadequate funding has resulted in the lack of an operational follow-on to the L1 solar wind monitor capability furnished by the National Aeronautics and Space Administration (NASA) Advanced Composition Explorer (ACE) scientific spacecraft. By means of SWPC's coordination with other agency partners, through the Office of the Federal Coordinator for Meteorology (OFCM) and the Office of Science and Technology Policy (OSTP), a potential option for a follow-on L1 solar wind monitor has been identified and is being studied.

Recommendation: NOAA should continue leading efforts within OFCM and OSTP in coordinating an inter-agency partnership for the continuity of solar wind measurements from L1.

Products and Services

Finding: The *Enlil* model, scheduled for transition into operations, represents a landmark change from empirical to physics-based forecast models, and promises to extend the lead time

for geomagnetic storm warning from the current 2-50 minutes provided by ACE out to 1-4 days. However, the transition process is not trivial and will require careful planning and implementation.

Recommendation: The SWPC should develop a formal project management plan to transition the *Enlil* model into operations. The *Enlil* transition will be the inaugural activity of the new Space Weather Prediction Testbed. It is imperative that the transition from research to operations (R2O) is implemented effectively, since it will set a precedent for future transitions.

Information Systems

Finding: The SWFO is running on DEC and HP computers that are 25 or more years old for which parts can no longer be purchased and which are difficult to repair. Recently, additional funding has been identified for SWPC to begin planning the migration from these legacy information systems to modern equipment.

Recommendation: NCEP should ensure the continuation of sufficient funding and SWPC should implement its plan: (1) to complete the migration from legacy hardware/software information systems to modern equipment; and (2) to maintain and upgrade the equipment, as necessary, after the migration is completed.

Science and Technology

Finding: The SWPC mandate is to provide a suite of space weather prediction products for its customers and stakeholders in a timely and seamless manner over time scales ranging from a few minutes to decades. SWPC can only provide competitively new and improved products by establishing a solid and long-term innovation process with the research community.

Recommendation: NOAA should develop a space weather research program internally that is aligned with the SWPC mission. This could be implemented through a partnership between the Office of Oceanic and Atmospheric Research (OAR) and SWPC with a well-defined role for the Cooperative Institute for Research in Environmental Sciences (CIRES) and a more vigorous effort to entrain university research more broadly. Additionally, a well-trained development staff to ensure successful R2O transition is required. The SWPC should undertake the first steps toward establishing a viable research and development program as follows:

- Organize a workshop to develop a long-range plan for numerical space weather prediction.
- Establish an advisory committee to oversee development and implementation of the long-range plan.

People and Organizational Culture

Finding: The SWPC employee skills and job functions may not be aligned for optimum efficiency and goal achievement.

Recommendation: Upon completion of a thorough review of staff roles and responsibilities, the SWPC management team should review the current personnel qualifications and assignments to assess any possible gaps. This process may reveal individual shortfalls that may be filled by providing additional training, direction or detailed guidance to employees tasked with new or different responsibilities as a result of the reorganization.

This recommendation is an example of one that impacts the others. If the team does not have the proper training or tools, they will not be able to address and correct deficiencies in the organization.

Business Processes

Finding: The current capability of SWPC to transition promising space weather analysis and forecasting technology into operations is not sufficient. There are opportunities that are being missed due to a less-than-optimal business model.

Recommendation: Develop comprehensive, robust business models for the SWPT and the R2O function. There are a number of successful organizational arrangements (e.g., the Applied Meteorology Unit at Cape Kennedy, FL) and processes that can be adapted or emulated during development of the business models. A well-trained development staff is required to ensure a successful R2O transition.

1. Introduction

1.1 Purpose: Summary and Context of Charge

The University Corporation for Atmospheric Research (UCAR) was requested in November 2008 by the National Centers for Environmental Prediction (NCEP) to conduct a thorough and thoughtful review of the nine Centers that comprise NCEP, as well as the NCEP Office of the Director. NCEP is organized under the National Weather Service (NWS) of the National Oceanic and Atmospheric Administration (NOAA). The nine Centers include:

- Aviation Weather Center (AWC; Kansas City, MO)
- Climate Prediction Center (CPC; Camp Springs, MD)
- Environmental Modeling Center (EMC; Camp Springs, MD)
- Hydrometeorological Prediction Center (HPC; Camp Springs, MD)
- NCEP Central Operations (NCO; Camp Springs, MD)
- Ocean Prediction Center (OPC; Camp Springs, MD)
- Space Weather Prediction Center (SWPC; Boulder, CO)
- Storm Prediction Center (SPC; Norman, OK)
- Tropical Prediction Center (TPC; Miami, FL)

This report focuses on the Space Weather Prediction Center (SWPC).

The 2009 review of NCEP was undertaken because the centers of NCEP are viewed collectively as a critical national resource that delivers national and global weather, water, climate and space weather guidance, forecasts, warnings and analyses to its partners and external user communities. These products and services respond to user needs to protect life and property, enhance the Nation's economy and support the Nation's growing need for environmental information. As the centerpiece of the National Weather Service's science-based forecast enterprise, NCEP serves as the focal point for weather, climate and space weather modeling, analysis and dissemination of forecast products and services. As such, it is essential that NCEP be held to a set of high standards that define the quality, quantity, timeliness, impact and improvement over time of its products and services. An independent, external evaluation of the effectiveness with which NCEP is accomplishing its mission and realizing its vision was deemed necessary.

It has been over a decade since most centers have been assessed, as external reviews of each center occurred independently most recently during the period 1996 – 2001. In particular, the complementary roles and interactions among the centers were not comprehensively reviewed. The goal of the current review is to evaluate the entire range of NCEP activities, including the way in which the various centers interact with each other, and in some cases rely upon each other, and with other NOAA, federal, academic and non-governmental entities.

This is a particularly appropriate time to conduct such a review insofar as many national and international challenges have arisen that require NCEP to operate at the highest possible level of scientific and technological excellence. Examples of challenges that the Nation must meet for which NCEP's products and services are essential include the following:

- The growing threat of hazardous weather reached a new and staggeringly high level of severity in the 2005 hurricane season during which 28 named storms threatened the U.S. Atlantic and Gulf of Mexico coastlines, including Hurricane Katrina that caused massive damage and loss of life in New Orleans and along the Gulf coast.
- The 2007 International Panel on Climate Change released its fourth assessment report, stating unequivocally that the Earth's climate is changing at an unprecedented rate as a result, in part, of human activities. This recognition, along with the growing predictive understanding of the influence of El Niño and the Southern Oscillation, and a host of other climate factors and conditions, on climate-sensitive sectors of the U.S. population and economy, has led NOAA to begin planning for a suite of National Climate Services.
- Adverse weather continues to strongly affect the aviation industry, and the NWS' pledge of support to satisfy the weather requirements of the Federal Aviation Administration's Next Generation Air Transportation System (NextGen) will place increased demands on NCEP services.
- Solar activity, in the form of flares and coronal mass ejections, has a profound influence on the Earth's atmosphere (causing beautiful aurora displays) and can project fluxes of high energy particles that can disrupt communications, navigation, satellites, electric power grids, and human space flight. Solar activity has an approximately 11-year cycle and has been at a minimum for the past few years, and is expected to rise to its next maximum in 2013. Given the increasing dependence of the U.S. and world economies on aviation, telecommunications, and the Global Positioning System (GPS), the coming Solar Maximum has the potential to be highly disruptive.

Because the threat to life and property from weather, climate and space weather anomalies has never been higher and continues to rise, the products and services of NCEP must be of the highest quality, timeliness and impact.

In order to provide a review that could be most useful to NCEP, the UCAR review was organized into five panels, each of which was asked to review two NCEP centers both individually and as a complementary pair. The five panels were asked to review:

- AWC and SPC
- CPC and HPC
- EMC and NCO
- OPC and TPC
- SWPC

In each case, the pair of centers was chosen specifically because the two centers in each pair are expected to work more closely together, having affinities of mission and/or stakeholder communities.

Each panel was asked to review the centers' vision and mission to determine its relevance, appropriateness and alignment with NCEP's strategic plan. The review also assessed the productivity and quality of the scientific activities, and the quality, relevance and impact of operational products and services. Special emphasis was placed on the ability to gauge and meet customer demand and emerging requirements, the effectiveness of activities intended to support

technology transfer based on research conducted either within or outside NOAA, and the effectiveness of collaboration with the academic research community or the private sector. The review evaluated the balance between operations and research and development and assessed the plans for evolving the suite of products and services. Finally, as indicated above, the interactions of each center with its “sister” center (except SWPC) and the outside communities were evaluated. The full charge to the review panels is provided in Appendix A.

1.2 Procedure

The review panel conducted its site visit at SWPC on June 9-10, 2009. To prepare for the visit, a set of questions was provided in advance to the Director, Dr. Tom Bogdan. In return, a comprehensive binder of material was provided to the review team. This included responses to the panel’s questions; SWPC overview documents; and information on customers, products, services, transition of research to operations, performance measures, budgets, strategic plan, etc. Surveys were also distributed to the center’s product subscription list (customers), representatives from academia, and the Air Force Weather Agency.

At the site visit, the Director presented highlights of the center, including successes and challenges. The majority of the visit consisted of interviews with the staff from the Office of the Director, Administrative and Technical Support Branch, Space Weather Services Branch, Development and Transition Section, Research and Customer Requirements Section, Space Weather Forecast Office, and the NWS Employees Organization. Members of the Cooperative Institute for Research in Environmental Sciences (CIRES) staff were also interviewed. In all, 14 people were interviewed individually and 8 groups were interviewed. These discussions allowed the panel to get a real perspective on the center’s strengths and areas that need improvement. This review would have not been possible without the openness and cooperation of the SWPC staff who are all very passionate about the organization. The visit concluded with a briefing of initial findings and recommendations to the SWPC management team and NCEP Director, Dr. Louis Uccellini.

2. Overview of the Space Weather Prediction Center

2.1 Mission and Description

The Space Weather Prediction Center (SWPC) mission statement, created in 2008 along with its first strategic plan, is:

*To provide space weather products and services
that meet the evolving needs of the Nation.*

The vision is:

A Nation prepared to mitigate the effects of space weather through the understanding and use of actionable alerts, forecasts, and data products.

The SWPC is the Nation's official source of space weather alerts, watches, and warnings. SWPC operates 24x7 and employs an Information Technology (IT) system that is designated a Federal Information Processing Standards (FIPS)-199 system by the National Institute of Standards and Technology. This IT system is also only one of four Department of Homeland Security designated "National Critical Systems" within the National Weather Service (NWS).

Based on the Department of Commerce Boulder Campus in Colorado, SWPC employs approximately 50 FTE civil servants and provides partial on-site support to an additional 20 affiliates associated with the joint NOAA-University of Colorado Cooperative Institute for Research in Environmental Science (CIRES).

The SWPC coordinates its activities, products, and services with its Department of Defense (DOD) counterpart, the Air Force Weather Agency (AFWA). With annual expenditures in excess of \$8M per year, SWPC delivers its services, and over 13,000 routine and event-driven products per year, over the internet, using an email service with over 8300 subscribers, an ftp data server that distributes nearly half a terabyte of data per month, and an external space weather data server (E-SWDS).

The SWPC is the flagship Regional Warning Center of International Space Environment Service (ISES) that promotes cooperation and information exchanged among 12 Regional Warning Centers around the globe. The SWPC serves a large customer base, covering a broad spectrum from the private sector to other governmental agencies. Industries and activities impacted by space weather include aviation, satellite operations, electric power grids, radio communications, navigation, and manned space flight.

2.2 History

The SWPC traces its origin to the Interservice Radio Propagation Laboratory of the National Bureau of Standards (NBS) that was formed in the early 1940's to deliver high-frequency (HF) radio blackout forecasts for the Allied Forces. Renamed the Central Radio Propagation Laboratory and transferred from Washington to Boulder in 1954, this agency at one time employed several hundred civil servants and was composed of numerous divisions that carried out space environment monitoring, modeling, forecasting, and basic solar-terrestrial research. However, in the late 1950's and early 1960's both the DOD and newly-established National Aeronautics and Space Administration (NASA) slowly diverted government resources away from the solar-terrestrial activities of the NBS. By the 1970's, the component destined to become SWPC was in NOAA and had been reduced in size to less than a hundred civil servants.

The Space Environment Laboratory (SEL) and then later the Space Environment Center (SEC) both attempted to maintain and advocate a complete end-to-end space weather program within NOAA despite declining resources. By January 2005, when SEC was moved from the Office of

Oceanic and Atmospheric Research (OAR) to the National Weather Service (NWS), the SEC budget was less than \$7M per year, a small fraction of the combined \$1B space science research budgets of the other federal agencies.

To deal with the dwindling budget and increased external demands in the last several years, a new strategy was required. The concept was to focus on the unique and economically important aspect of NOAA's space weather program: operational space weather alerts, watches and warnings. NOAA began implementing this strategy when SEC was formally transferred from the research line office of NOAA (OAR) into the operations line office (NWS). In 2007, SEC was renamed the Space Weather Prediction Center (SWPC) to better reflect its new operational mission. In June 2008, the Center completed its first strategic plan.

2.3 Linkages to other NCEP Centers

The SWPC engages the Aviation Weather Center (AWC) in developing joint products and services for commercial aviation. Both organizations fully support NOAA's promise to support the Next Generation Air Transportation System (NextGen) by populating a 4D (space) weather cube with current specifications and future predictions of the aviation environment including GPS positioning errors.

The Climate Prediction Center (CPC) and SWPC communicate on the status of solar variability and its impacts on climate. Discussions are underway to identify better and more appropriate sources of solar data for CPC operational models.

NCEP Central Operations (NCO) maintains a very close working relationship with the SWPC IT team in matters related to security, and certification and accreditation of the SWPC computer system. NCO will be a partner in helping SWPC port many of its applications and processes to the Advanced Weather Interactive Processing System-II (AWIPS-II) platform.

The Environmental Modeling Center (EMC) will work closely with SWPC once the *Enlil* model (see section 6.3 for a description) is ready to be transitioned into operations.

The SWPC maintains close communications with NCEP HQ so they are fully aware of the intra-NOAA activities and initiatives.

3. Developments Since Last Review

The last review of the Space Environment Center (SEC) was conducted in 2000. However, SEC was located in the research arm of NOAA and had quite a different mission and breadth of activities than SWPC does today. So, the review panel did not feel it was fair to compare developments since the last review. Rather, a discussion of the change of mission is provided.

In January 2005, when SEC was formally transferred from the research line office of NOAA (OAR) to the operations line office (NWS), basic research was no longer a component of the

Center's mission. NOAA concluded they could not support an end-to-end space weather program given a dwindling budget and increased external demands. Rather, it chose to strengthen partnerships with National Science Foundation (NSF), NASA, and DOD to carry out the necessary basic research in space science that is essential to develop the next generation of operations products and services. By disposing of the programmatic requirement to carry out space weather basic research, NOAA is able to reallocate resources to focus on the transition from research to operations (R2O) of prospective community-developed models, and deliver improved forecasts and warnings for customers and stakeholders. The Center now focuses on the unique and economically important aspect of NOAA's space weather program: operational space weather alerts, watches and warnings. In 2007, SEC became SWPC, to better reflect its new operational mission. In June 2008, the Center completed its first strategic plan.

This change in mission had several implications including management, organizational, and communication challenges which resulted in less than optimal productivity. Some challenges remain. SWPC is still redirecting its efforts and changing its corporate culture to become fully aligned with the reduced scope of its purview and its focus on customer products and services.

While SWPC experienced a major shift in the last few years, they continued to achieve many goals. Highlights of the Center's accomplishments over the last three years include:

- Space Weather for Aviation Services Providers webpage was created
- Real-time US Total Electron Content (TEC), which provides nowcasts of the total electron content over the continental U.S., was transitioned into operations
- Completion of post-launch testing and evaluation of the Solar X-ray Imager (SXI) on board GOES 13
- New D-Region Absorption Product (D-RAP) was transitioned into operations
- External Space Weather Data Server (E-SWDS) was placed in operations
- Hosted the first Space Weather Enterprise Forum in Washington D.C.
- Reorganized and renamed the SWPC to align with new operational focus
- First summit between SWPC and Commercial Space Weather Interest Group was held
- Regional Geomagnetic Field Disturbance (Weimer) model was transitioned into operations
- NOAA Polar Orbiting Environmental Satellite (POES)-18 Space Environment Monitor data were validated and transitioned into operations

4. Summary of Stakeholder Surveys

To gain better knowledge of the stakeholder perspective, the panel developed surveys that were distributed to about 14,000 of SWPC's customers, including people on its customer product subscription list and representatives of the academic community. The panel also provided a list of questions to AFWA.

Over 700 customers provided responses. The panel analyzed the responses from the various categories: electric power industry; oil or gas pipeline; GPS, navigation, surveying, and drilling;

ham radio operators; commercial space weather information providers; radar; aviation; aurora viewing; research; spacecraft and space operations; media; DOD operations; and others. The survey revealed that, by far, the majority of SWPC's customers are satisfied with its products and customer services. Many comments and suggestions were provided, including the need for a more user-friendly, updated webpage and more online educational resources.

The panel received 40 responses from the academic survey, which revealed that SWPC is their main source of space weather information and all products are of value to the respondents. They use SWPC products in both their teaching and research activities. The vast majority is satisfied with SWPC products, availability, services, and communications. A small but significant number of respondents expressed dissatisfaction with the pace at which products are improved or replaced. Many thoughtful comments and suggestions were provided, including recurring requests to better link archival data to SWPC products, and to establish stronger collaborations with the academic community.

The AFWA survey response was generally positive on the working relationship between the two organizations. The biggest issue was data sharing – AFWA wants more data and additional data types, especially as new space weather prediction models are transitioned into its inventory.

The panel conducted a preliminary analysis of the survey results, with the expectation that SWPC will conduct further analysis.

5. General Observations and Overarching Issues

Since joining NWS, SWPC should be commended for many accomplishments amid a reorganization and recruitment of a new Director. The SWPC leadership has created several new “partnerships for progress” with other federal agencies, commercial service providers, and international organizations to benefit its customers. They have identified a plan to modernize the Space Weather Forecast Office (SWFO) and create the Space Weather Prediction Testbed (SWPT). Additionally, the Director has successfully made the case to NOAA on the need for an appropriate budget to carry out the mission, and it is expected the Center will see a budget increase in the coming years.

Based upon discussion at the site visit, the review panel found three overarching issues that threaded throughout many of the discussions and interviews: the mission change, the internal organizational change, and preparing for the next Solar Maximum.

5.1 SWPC Mission

The new SWPC mission originated from a strong desire by senior NOAA leadership to refocus the space weather program on operational products and services, and thereby reduce the breadth of space weather activities and program purview. This decision was driven by budget pressures, which in turn led to program stagnation. The SWPC is still redirecting efforts towards an operational focus and aligning with a reduced scope of its purview to focus on customer products

and services. The change in the mission created some challenges that are reflected in the findings and recommendations.

The panel fully supports SWPC's mission as an operational center. It makes best use of the resources available and allows SWPC to focus on improving its current space weather products and services to meet the rapidly changing requirements of its customers. The move from OAR to NWS more accurately reflects SWPC's function. This also means that SWPC needs to leverage the significant advances in domestic and international space science research funded by agencies such as NASA, NSF, Office of Naval Research (ONR), Air Force Office of Scientific Research (AFOSR), Department of Energy (DOE), and the European Space Agency. However, the panel cautions that an overemphasis on operational products with an underemphasis (or no emphasis) on involvement with the science will ultimately lead to intellectual stagnation.

The refocused mission and reduced breadth of activities also means that SWPC is no longer in a position to perform satellite-related functions. Activities related to satellite data acquisition, processing, validation, and verification are not aligned with the NWS mission, but are better aligned with the National Environmental Satellite, Data, and Information Service (NESDIS) mission. The NESDIS already carries out these functions for terrestrial weather activities across the NWS. The panel supports the transfer of the satellite data activities from SWPC to NESDIS, which allows SWPC to focus on space weather prediction.

5.2 Internal Organizational Change

The move from OAR to NWS and the operational mission required a reorganization of SWPC, resulting in a new management structure and new staff responsibilities. The reorganization was in place in October 2007 and became official in February 2008. While the reorganization was necessary, it came at a price. Coordination, effective communication, and maintaining good morale have all been challenges.

The review panel acknowledges that the organizational transition has been difficult and is not complete. The growth of SWPC's budget is a positive result of the Director's external efforts. However, there is a need for the Director to pay increased attention to internal matters.

As an example, interaction with CIRES is an area that needs major improvement. The transition in the SWPC mission to an operational focus has caused uncertainty and concerns, particularly among CIRES scientists. There is much misinformation; for example, several CIRES staff members said, "we are not allowed to do research anymore." Through the interviews with both SWPC and CIRES staff, it became clear to the panel that SWPC needs to clarify its expectations and requirements for the activities of the CIRES researchers. This is particularly important as the parties prepare for the upcoming contractual competition.

Although the Center's reorganization has been challenging, the panel recognized the hard work and dedication of the staff, from the Director through the Branch and Section Chiefs and into the work centers. It was very evident from the visit that this organization has passionate and enthusiastic individuals who care very much for the organization and its mission.

5.3 Preparedness for Solar Maximum

Throughout the review, an issue that repeatedly emerged was the preparation needed for the upcoming Solar Maximum, now projected for 2013. Given our Nation's increasing reliance on space-based assets to perform multiple missions for commerce, resource protection, and military operations, it is imperative that SWPC be postured to provide the best possible space weather impact products.

The upcoming Solar Maximum will stress SWPC operations and impose a timeline for addressing issues. If SWPC is not optimally functioning then stakeholders and customers will be adversely affected.

The SWPC has identified a few critical areas that it needs to address to prepare for Solar Max:

- 1) Modernization of the Space Weather Forecast Office,
- 2) Modernization, certification, and accreditation of the SWPC IT system, and
- 3) Development of the Space Weather Prediction Testbed

The SWPC has developed a plan for addressing these areas and the panel believes it should be supported by NOAA. The success of SWPC also depends on identifying and attracting the best possible talent for its workforce. While the approach to Solar Maximum is gradual at the present time, there may still be Earth-impacting events that can occur as solar activity "ramps up," and it is imperative to provide as much realistic training to new forecasters as soon as possible.

6. Findings and Recommendations

Most of the recommendations are related to each other and should not be evaluated in isolation, but rather implemented collectively.

6.1 Mission and Vision

See previous section on general observations and overarching issues.

6.2 Customers and Partners

The growth of the number of SWPC's customers and partners over the last few decades, and particularly the growing vulnerability of our increasingly technological society over the last solar cycle, is evidence of the growing use and importance of space weather information and services. Ensuring the highest quality products in response to evolving customer needs requires SWPC to maintain customer interactions, provide mechanisms to gather requirements, and provide advice and education on the impacts of space weather. While SWPC has reached out to numerous customer segments to gain an understanding of their impacts and requirements, the lack of sufficient resources in recent years has led to gaps in the customer feedback process and

education. To help bridge gaps, SWPC has tried to leverage the broader space weather community's capabilities and resources to meet customer requirements by developing and promoting partnerships.

Finding CP1: Faced with the lack of a stable and sufficient budget, SWPC has leveraged resources and capabilities with other federal partners. For example, inadequate funding has resulted in the lack of an operational follow-on to the L1 solar wind monitor capability furnished by the NASA Advanced Composition Explorer (ACE) scientific spacecraft. By means of SWPC's coordination with other agency partners, through the Office of the Federal Coordinator for Meteorology (OFCM) and the Office of Science and Technology Policy (OSTP), a potential option for a follow-on L1 solar wind monitor has been identified and is being studied.

Recommendation CP1: NOAA should continue leading efforts within OFCM and OSTP in coordinating an inter-agency partnership for the continuity of solar wind measurements from L1.

Finding CP2: The SWPC is proactive in reaching out to existing customers and recruiting prospective customers. By organizing workshops, attending trade meetings, and making "house calls," SWPC determines its evolving customer needs and tries to identify new areas of interest. SWPC has compiled customer needs and requirements based on what they know is possible in the realm of forecast models. However, this process is mostly *ad hoc*, and conducted by a small number of staff members. The majority of SWPC interactions with customers are through phone conversations and email. There is no formal process for receiving customer input. They have established a High Activity Response Team to be activated during busy periods of severe space weather, involving more SWPC staff members to deal with stakeholder, customer, and media inquiries.

Recommendation CP2: A formal plan is needed to identify current and new potential customers, and a process should be developed for customer requirements collection, validation, and feedback to ensure the value, usability, and relevance of SWPC products and services.

Finding CP3: Raising awareness of space weather within NOAA and with external stakeholders is a critical component of SWPC's plan to demonstrate the value and importance of its mission. Education and outreach activities for the public have been descope during the last few years, in order to focus limited resources on products and services. Nevertheless, SWPC did retain the outreach component that involves marketing its products and services to stakeholders. This targeted activity resulted in the successful prospect of an increased budget for the upcoming years. The SWPC has also been responsive to educating customers on the benefits of SWPC services, yet this activity is mostly informal and sporadic. Ongoing education of stakeholders and customers is necessary to require appropriate levels of support for the long term and to improve the relevance and impact of SWPC products and services.

Recommendation CP3: A formal education and outreach plan for stakeholders and customers is needed to increase understanding of the value and importance of space weather based on SWPC products and services. However, in the current budget climate, the public component of the SWPC education and outreach portfolio should remain dormant.

6.3 Products and Services

The SWPC produces a diverse range of products and services. These cover space weather conditions on the Sun, in interplanetary space, and at the Earth. The products are largely data driven and are used to provide space situational awareness information useful to a wide range of customers. The information is presented in both text and graphical form using the NOAA space weather scales for Geomagnetic Storms, Solar Radiation Storm, and Radio Blackouts as well as other indices and parameters. Alerts are generated when particular measurements exceed set thresholds and are distributed via email to a growing list of subscribers. Forecasts for short, medium and long time scales are produced at daily, weekly, and monthly intervals. These forecasts are empirical in nature and are largely based on climatology and observational correlations. The SWPC also provides access to a multitude of real-time space weather measurements that are used directly by end users or are used by other groups to produce value-added products for end users.

The survey results reveal that users generally have a high level of satisfaction with SWPC products. This does not mean that the services are always meeting customer needs but rather reflects the level of understanding of a knowledgeable clientele. They appreciate the efforts of the SWPC staff, while recognizing that deficiencies in data and lack of knowledge about space weather phenomena (particularly the buildup to solar eruptions) limit the present ability to forecast space weather. The need for new products and services is determined through outreach to customers, but user requirements must be convolved with what is possible to determine where the maximum benefit can be achieved for the effort expended.

Finding PS1: The SWPC products have not changed very much over the last 3-5 years. There have been insufficient resources to develop new products. However, new customer needs continue to emerge, such as forecasts of Total Electron Content (TEC) and scintillation, and services for trans-polar aviation, The SWPC has made initial efforts to transition models and tools to address such needs.

Recommendation PS1: The SWPC should continue with its efforts to address transitioning empirical techniques/models/tools into operational services.

Finding PS2: The *Enlil* model, scheduled for transition into operations, represents a landmark change from empirical to physics-based forecast models, and promises to extend the lead time for geomagnetic storm warning from the current 2-50 minutes provided by ACE out to 1-4 days. However, the transition process is not trivial and will require careful planning and implementation.

Recommendation PS2: The SWPC should develop a formal project management plan to transition the *Enlil* model into operations. The *Enlil* transition will be the inaugural activity of the new SWPT. It is imperative that the R2O transition is implemented effectively, since it will set a precedent for future transitions.

6.4 Information Systems

Modern information systems are an essential component of achieving SWPC's mission. The Center relies on its IT infrastructure to acquire the observations of the environment; to process them into useful information; to drive computer-based models; and to disseminate forecasts, warnings, and products to customers. The SWPC is also required to meet security requirements as a National Critical System (NCS). However, vital information systems could not be upgraded or, in some cases, even maintained in recent years, which resulted in a series of IT Certification and Accreditation violations and the potential loss of SWPC's Authority To Operate. On the positive side, the SWPC IT staff should be commended for the remarkable feat of providing real-time display and delivery of SWPC products and services, given the budget constraints during the past years.

Finding IS1: The SWFO is running on DEC and HP computers that are 25 or more years old for which parts can no longer be purchased and which are difficult to repair. Recently, additional funding has been identified for SWPC to begin planning the migration from these legacy information systems to modern equipment.

Recommendation IS1: NCEP should ensure the continuation of sufficient funding and SWPC should implement its plan: (1) to complete the migration from legacy hardware/software information systems to modern equipment; and (2) to maintain and upgrade the equipment, as necessary, after the migration is completed.

Finding IS2: Since SWPC is relying on legacy information systems, no viable backup exists for product/service generation and distribution, and critical satellite data streams.

Recommendation IS2: A catastrophe mitigation and Continuity of Operations (COOP) plan for SWPC should be developed. For example, NCEP could investigate the possibility of using the AFWA as a backup to ensure that products are available to customers.

Finding IS3: Presently, SWPC products are disconnected from those of the other NCEP and NWS centers. A cornerstone of the NWS modernization and restructuring is Version 2 of the Advanced Weather Interactive Processing System (AWIPS), which is a technologically advanced information processing, display, and telecommunications system. Presently AWIPS integrates meteorological and hydrological data that enable the forecaster to prepare and issue more accurate and timely forecasts and warnings.

Recommendation IS3: As part of the modernization of the SWFO, NWS should investigate incorporating space weather information into AWIPS-II.

Finding IS4: The IT security requirements necessary for a FIPS199 designation (National Critical System) are severe and pose hardships on the co-located CIRES staff.

Recommendation IS4: SWPC management, working with NCEP Central Operations, should develop an IT Security Plan that will accommodate the requirements of all components of the Center.

6.5 Science and Technology

The SWPC's science activities include providing real-time data, alerts, warnings, analyses, and once per day forecasts of the next three days. The Center aims to improve upon current forecast capabilities by increasing its lead-time and accuracy, and by expanding the spatial coverage and distribution of the forecast domain through numerical modeling and data assimilation. While basic scientific research is not a component of its mission, SWPC does leverage the research of other federal agencies (e.g., NASA, NSF, DOD); collaborates with partners, customers, and commercial service providers; and establishes new collaborations to transition models from research to operations. However, the move to a purely operational mission has resulted in research and development gaps not being adequately handled by the broader space weather community. (N.B.: These gaps are beyond the scope of this review.)

Finding ST1: The SWPC portfolio of science activities has evolved significantly since the last Center review. The conduct of basic solar-terrestrial research is no longer part of the SWPC core mission. Many CIRES activities, on the other hand, are focused on this basic research and its role in support of the evolved SWPC mission is unclear.

Finding ST2: In response to its new mission, SWPC leadership and staff have developed a comprehensive and actionable operational plan.

Recommendation ST1: Given the need for partnerships between SWPC and the research community, SWPC should establish a scientific partnership with CIRES that is consistent with SWPC's mission, and stronger and formal partnerships with the broader space weather research community for the successful implementation of its plan.

Finding ST3: The SWPC mandate is to provide a suite of space weather prediction products for its customers and stakeholders in a timely and seamless manner over time scales ranging from a few minutes to decades. SWPC can only provide competitively new and improved products by establishing a solid and long-term innovation process with the research community.

Recommendation ST2: NOAA should develop a space weather research program internally that is aligned with the SWPC mission. This could be implemented through a partnership between the OAR and SWPC, with a well-defined role for CIRES and a more vigorous effort to entrain university research more broadly. Additionally, a well-trained development staff to ensure successful R2O transition is required. The SWPC should undertake the first steps toward establishing a viable research and development program as follows:

- organize a workshop to develop a long-range plan for numerical space weather prediction, and
- establish an advisory committee to oversee development and implementation of the long-range plan.

6.6 People and Organizational Culture

The SWPC is the primary provider of space weather data, information, and services to the private, academic, and governmental sectors. Therefore, the Center depends on a highly skilled workforce that excels in service, teamwork, and innovation. The panel found SWPC staff to be knowledgeable, enthusiastic, and passionate about the organization and mission.

The customer survey results reflect a high degree of satisfaction with operational products and customer service from SWPC. This result is remarkable given the tremendous adjustments made during the Center's reorganization over the last three years. Budget shortfalls, and the recognition that the organization was spread too thin, led SWPC to reorganize and develop an exclusive focus on an operational mission. The SWPC leadership recognizes, and the panel concurs, that this organizational shift has been difficult but will increase the Center's utility to the nation. Now that the transition is complete, SWPC needs to examine current employee skill sets against those required for the current organization's operational focus.

Finding POC1: Due to budget constraints, the time frame for the reorganization may not have allowed for a thorough evaluation of the documentation associated with the Center's functions. For example, while position descriptions are available, they are not current and require updates.

Recommendation POC1: Clearly define the roles and responsibilities in the current SWPC organization. This should be done by reviewing employee job descriptions currently being utilized at the Center, assessing their clarity, and evaluating specifics of the objectives, definitions, duties, responsibilities contained in the descriptions. This will be critical for updating the current organization and R2O. As a follow-on, incorporate these updated descriptions into a user-friendly business manual that reflects the current directives and reporting structure of the organization. The manual should also include appropriate skill sets for all positions within the organization, and be aligned with objectives, directives and the overall mission.

Finding POC2: Internal communication within SWPC may not be optimal. Employees seem to be unclear on certain directives and ideas.

Recommendation POC2: Evaluate the accessibility and continuity of current formal and informal internal communication modes and methods. Communications should reach all employees in a timely fashion with a well-understood prioritization. A standard procedure for employees to routinely 'check into' communications should be established in order to ensure relevant notifications, directives and information are received and understood by staff.

Finding POC3: The SWPC employee skills and job functions may not be aligned for optimum efficiency and goal achievement.

Recommendation POC3: Upon completion of a thorough review of staff roles and responsibilities, the SWPC management team should review the current personnel qualifications and assignments to assess any possible gaps. This process may reveal individual shortfalls that may be filled by providing additional training, direction or detailed guidance to employees tasked with new or different responsibilities as a result of the reorganization.

This recommendation is an example of one that impacts the others. If the team does not have the proper training or tools, they will not be able to address and correct deficiencies in the organization.

Finding POC4: As we near Solar Maximum, the number of forecasters may not be sufficient to provide consistently accurate products and services to the user community.

Recommendation POC4: Evaluate the manpower needs for forecaster capability as it relates to increasing future demand for services as Solar Maximum approaches.

Finding POC5: The current NOAA Human Resources (HR) hiring process is impeding SWPC's ability to staff positions adequately.

Recommendation POC5: Create a small team to evaluate and formulate a structured plan to mitigate the current NOAA HR hiring process, which is impeding SWPC's ability to achieve its mission objectives. It is possible that this team could work closely with other NCEP or NWS teams that are addressing the same issues.

Finding POC6: The current SWPC management structure is not optimal. For example, the administrative staff is outside the Office of the Director, with the unintended consequences of reducing effective communication and efficiency with the entire staff.

Recommendation POC6: SWPC should reconsider the organizational chart to create more efficient communication and best utilize the staff's capabilities.

6.7 Business Processes

The SWPC integrates business processes that encourage innovation, manage change, promote efficiency, and holds individuals accountable. The Center leadership and staff have a good understanding of their business processes and the importance of aligning their processes with those of NCEP, NWS, and NOAA. This was evidenced in the staff interviews and a review of the FY09-13 Strategic and Implementation Plan. SWPC staff members are encouraged to continue pursuing the goals and objectives laid out in the plan, especially when it comes to identifying and incorporating "best practices" into the organization.

With the recent mission change from research and operations to an exclusive operations focus, the SWPC leadership and staff have recognized the importance of developing a robust capability to identify promising technology being developed in the research community and transition it efficiently and rapidly into operations. This recognition is evident in the SWPC documentation that the team reviewed, and in the strategic plan.

The SWPC can take actions to develop and use best practices, but to optimize operations, the Center must be "on the radar" of its parent organizations in the Washington, D.C. area.

Finding BPI: Awareness of space weather and its impacts and importance has not been consistently recognized and advocated at NOAA/NWS headquarters. Anecdotal evidence is

strong that temporary appointments of SWPC personnel to positions in the Washington, D.C. area have been beneficial to raise space weather awareness within the headquarters staff.

Recommendation BP1: Establish a permanent space weather liaison in the Washington, D.C. area. SWPC and NCEP leadership should determine the appropriate location and level for the position to reside.

Finding BP2: The current capability of SWPC to transition promising space weather analysis and forecasting technology into operations is not sufficient. There are opportunities that are being missed due to a less-than-optimal business model.

Recommendation BP2: Develop comprehensive, robust business models for the SWPT and the R2O function. There are a number of successful organizational arrangements (e.g., the Applied Meteorology Unit at Cape Kennedy, FL) and processes that can be adapted or emulated during development of the business models. A well-trained development staff is required to ensure a successful R2O transition.

Finding BP3: The SWPC transition to an operations mission focus has caused turmoil among the SWPC leadership, staff and CIRES scientists. There is a need to rectify this unrest in order to optimize the CIRES capability present at the SWPC facility. While the long-term view (~3 years) to place the CIRES scientists under NOAA/OAR purview appears to be the correct approach, the short-term problem persists and is further complicated by the upcoming re-competition for the CIRES contract in 2010.

Recommendation BP3: The SWPC should define its expectations and requirements for the function currently being performed by CIRES researchers in preparation for the upcoming contractual competition. Possible options include a Memorandum of Understanding/Agreement that spells out the working relationship between the two staffs, which can be developed either as part of the request for proposals or negotiated upon contract award. This would be most helpful to both sides.

Appendix A

National Centers for Environmental Prediction Review Charge to the Review Panels

Charge:

The University Corporation for Atmospheric Research (UCAR) will carry out a review of the National Centers for Environmental Prediction (NCEP) in 2009 through a series of panels that will assess the individual Centers, their interaction with each other and with other NOAA, federal, academic and non-governmental entities to determine how effectively NCEP is accomplishing its mission and realizing its vision. In particular, for each Center and NCEP as a whole, the Review will assess:

- Statements of mission, vision and five-year plans.
- Productivity and quality of scientific activities and/or operational products and services with an emphasis on the progress since the most recent review.
- Relevance and impact of the research and/or products. Ability to meet customer demand and emerging requirements.
- Effectiveness of activities or specific plans for transition of research to operations (R2O), including research conducted outside NCEP within NOAA, within the federal research enterprise, and in academia or the private sector.
- Effectiveness of activities or specific plans for support of research by and/or joint efforts with program elements within NOAA that provide support for or conduct research as their primary mission and also with outside entities (academia; research laboratories) via the provision of operational products, services and in-house support (operations to research - O2R).
- Balance between operational responsibilities and research and development initiatives.
- Programmatic plans for new scientific activities and operational products and services, including plans for continuations and terminations.

In addition, the Review will address any specific other issues or questions raised in the course of the review.

Procedure:

1. The Review will be organized under the leadership of an Executive Committee composed of two co-chairpersons, representatives of the operational environmental prediction and NCEP user communities, and each of the chairpersons of the individual Center Review Panels. Each Center Review Panel will have 5-6 members with diverse representation from academia, federal labs and users. The Executive Committee will develop a slate of panel members in consultation with the Director of NCEP. The Executive Committee will recommend a panel review slate to the President of UCAR, who will appoint the Review Panels.
2. The following documentation will be requested from each Center and NCEP:
 - Vision and mission statement (strategic plan, if extant)
 - Organization chart and list of present staff and visitors (staff turnover since last review)
 - Summary narrative of recent highlights and accomplishments
 - Summary narrative of R2O and O2R activities
 - Summary narrative of collaborative work
 - List of publications and/or reports since last review (with sample of reprints)
 - List of products and services, along with selected samples
 - Summary of budget, sources of support and expenditures
 - The NCEP and/or individual Center responses to the reviews conducted between 1996 and 2001.
3. Each Center will be asked to submit documentation, at least one month before the on-site visit, to UCAR for distribution to Review Panel members before the on-site visit.
4. An on-site review (typically 1.5-2 days) will be conducted at each Center. The date for each review will be fixed in consultation with the Center Director and the Director of NCEP.
5. Each Review Panel will provide a preliminary briefing to the Director of NCEP at the conclusion of each on-site review.
6. Each Review Panel will write a report of its findings. A draft of the review report for each Center will be shared with the Center Director to correct any factual errors.
7. The Executive Committee will write a final report, directed to the President of UCAR, that summarizes the findings of the reviews of the individual Center as well as NCEP as a whole, and will make recommendations for improvements.

UCAR will provide administrative help for the preparation of the individual Center Review Panel reports and the final report of the NCEP Review.

Appendix B

SWPC Review Panel Membership

Genevieve Fisher, Panel Chair
American Meteorological Society

David Boteler
Natural Resources Canada

Maura Hagan
National Center for Atmospheric Research

John Lanicci
Embry-Riddle Aeronautical University

Chris St. Cyr
NASA Goddard Space Flight Center

Michael Stills
United Airlines

NCEP Review Executive Committee Members

Frederick Carr (Co-chair)
University of Oklahoma

James Kinter (Co-chair)
Center for Ocean-Land-Atmosphere Studies

Gilbert Brunet
Environment Canada

Kelvin Droegemeier
University of Oklahoma

Gene Fisher, Panel Chair
American Meteorological Society

Ronald McPherson
American Meteorological Society (Emeritus)

Leonard Pietrafesa
North Carolina State University

Eric Wood
Princeton University

APPENDIX C

Acronyms and Terms

ACE	Advanced Composition Explorer
AFOSR	Air Force Office of Scientific Research
AFWA	Air Force Weather Agency
AWIPS	Advanced Weather Interactive Processing System
AWC	Aviation Weather Center
BP	Business Processes
CIRES	Cooperative Institute for Research in Environmental Sciences
CP	Customers and Partners
CPC	Climate Prediction Center
D-RAP	D-Region Absorption Product
DEC	Digital Equipment Corporation
DOD	Department of Defense
DOE	Department of Energy
Enlil	Time-dependent 3D MHD Model of the Heliosphere
EMC	Environmental Modeling Center
E-SWDS	External Space Weather Data Server
FIPS199	Federal Information Processing Standards publication
FTE	Full Time Employees
FTP	File Transfer Protocol
GOES	Geostationary Operational Environmental Satellite
GPS	Global Positioning System
HF	High Frequency
HP	Hewlett Packard
HR	Human Resources
ISES	International Space Environment Service
IS	Information Systems
IT	Information Technology
LWS	Living with a Star
MHD	Magnetohydrodynamics
NASA	National Aeronautics and Space Administration
NBS	National Bureau of Standards
NCEP	National Centers for Environmental Prediction
NCO	NCEP Central Operations
NCS	National Critical System
NESDIS	National Environmental Satellite, Data, and Information Service
NextGen	Next Generation Air Transportation System
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
NWS	National Weather Service
OAR	Office of Oceanic and Atmospheric Research
OFCM	Office of the Federal Coordinator for Meteorology
ONR	Office of Naval Research
OSTP	Office of Science and Technology Policy

POC	People and Organizational Culture
POES	Polar Orbiting Environmental Satellite
PS	Products and Services
R2O	Research to Operations
SEL	Space Environment Laboratory
SEC	Space Environment Center
ST	Science and Technology
SWFO	Space Weather Forecast Office
SWPC	Space Weather Prediction Center
SWPT	Space Weather Prediction Testbed
SXI	Solar X-ray Imager
TEC	Total Electron Content
UCAR	University Corporation for Atmospheric Research