NATIONAL SPACE WEATHER PROGRAM

2012 SPACE WEATHER ENTERPRISE FORUM

SUMMARY REPORT

Note: Speaker and audience remarks are paraphrased and not to be used as quotations.

2012 SPACE WEATHER ENTERPRISE FORUM SUMMARY

This document provides a synopsis of the 2012 Space Weather Enterprise Forum (SWEF)—an event sponsored by the National Space Weather Program (NSWP) Council and hosted by Mr. Samuel P. Williamson, Federal Coordinator for Meteorology and Chair of the NSWP Council, on June 5, 2012, at the National Press Club in Washington, DC. This year's theme was *Solar Maximum 2013 – How Space Weather Will Affect You!*

Motivation

The next peak of solar activity expected in 2013 has already begun, and the effects of these powerful space weather events are negatively impacting the technical infrastructure that underpins our economy and society. The Nation faces many uncertainties from increasing reliance on space weather-affected technologies for communications, navigation, security, electrical power generation and distribution, and other activities. We also face increasing exposure to space weather-driven human health risks as trans-polar flights and space activities, including space tourism and space commercialization, increase.

Key Takeaways and Forum Outcomes

All available presentations from the 2012 SWEF and supporting material can be found at: http://www.nswp.gov/swef/swef_2012.html. The key takeaways and outcomes are summarized as follows:

- The NSWP SWEF website provided a wealth of information for forum participants and served as an excellent source of information about the space weather enterprise.
- The SWEF is helping to meet the NSWP goal to improve education and public outreach.
  - Eleven media outlets covered the SWEF, including Space News, The Washington Post, The Baltimore Sun, The Associated Press, Kyodo News (Japan), and Agence France Presse.
  - NASA and NOAA Public Affairs provided live Twitter updates during the forum.
- The diversity and number of the attendees are indicative of the strong partnerships and alliances the space weather community has built over the past few years.
  - An excellent cross-section of stakeholders interested and engaged in space weather activities were in attendance, including policymakers, analysts, and users in the areas of space, energy, aviation, communications, and national security.
  - The approximately 210 attendees included representatives from the Federal government and the military (39%), industry (29%), the research and academic communities (13%), international stakeholder agencies (6%), the media (8%), and supporting staff.

Note: Speaker and audience remarks are paraphrased and not to be used as quotations.

- The NSWP announced the launching of the new National Space Weather Portal to provide one-stop shopping for a wide-range of information on space weather science, research, and services provided by the NSWP member agencies.
  - The pages of the portal were developed by the NSWP and are hosted by NOAA's Space Weather Prediction Center at http://www.spaceweather.gov/portal.
- The space weather community is anxiously waiting for the release of the National Research Council decadal survey on solar and space physics.
  - This report, due out in July 2012, will have a great influence on the course of science, research, and development in pursuit of improved space weather capabilities.
- The NSWP member agencies highlighted their roles in and contributions to the Unified National Space Weather Capability (UNSWC).
  - The UNSWC is a product of the partnerships established through the NSWP and is intended to improve the quality and effectiveness of the community's collective investments to provide the best possible service to the Nation.
- The Federal government is taking the threat of a potentially devastating space weather event very seriously and is working to develop mitigation strategies and options.
  - The OSTP Working Group for Ground Induced Currents has been established and includes NSWP member agencies and the electrical power industry.
  - FEMA has published a federal response plan to address space weather disasters.
  - The National Defense University conducted the Secure Grid 2011 exercise to examine vulnerability and response options for impacts to the national power grid from geomagnetic storms.
  - In a June 11, 2012, *Electric Utility Week* article, experts stated that they view with alarm the inadequate preparedness of our Nation's power system for large solar storms.
- SWEF continues to provide an excellent venue for congressional interaction with regard to space weather services and supporting research.
  - Congressman Trent Franks expressed strong support for the community's national efforts to improve space weather support and services to help prepare the Nation to mitigate the impact of potentially catastrophic space weather events.
  - Several congressional staffers participated in the forum this year.
- Although much emphasis has been placed on extreme space-weather-related disaster scenarios, SWEF highlighted the need to pay attention to the more common, modest space weather events that can cause significant systems interruptions and degradation.
  - Routine minor impacts to GPS, the power grid, and satellite operations could total billions of dollars per year across industry and government, according to speakers at the SWEF.
- From a social science perspective, the message formulation and context is a key element of the risk communication process. The message should:

- Be based on what people know about previous disasters like previous blackouts and power outages.
- Include specific and familiar terms, like watch and warning, and include human impacts and effects.
- Be personalized with possible action to take.
- Be delivered in a redundant and diversified manner, to include the use of social media.

Program

Sponsorship: The NSWP Council is part of the U.S. Federal meteorological coordinating infrastructure under the Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM). The Council brings together the nine Federal agencies involved in providing space weather products and services, space weather research, users of space weather information, and other offices that set policy or provide funding for the Federal portion of the space weather enterprise. The purpose is to facilitate coordination, collaboration, and leveraging of activities, results, and capabilities across the Federal agencies. The nine agencies participating in the NSWP are the National Oceanic and Atmospheric Administration (NOAA), National Aeronautics and Space Administration (NASA), Department of Defense (DOD), National Science Foundation (NSF), United States Geological Survey (USGS), Federal Aviation Administration (FAA), Federal Emergency Management Agency (FEMA), Department of State (DOS), and Department of Energy (DOE).

Objectives: The SWEF brought together the space weather community to share information and ideas among policymakers, senior government leaders, researchers, service-provider agencies, private-sector service providers, space weather information users, the media, and congressional legislators and staff to pursue the following objectives:

- Share information across the enterprise and raise awareness for new users, decision makers, and policymakers.
- Identify effective approaches to build resilience across society, particularly in critical infrastructure protection and support.
- Identify effective approaches to raise awareness in the broader society.
- Improve communications within and external to the enterprise.
- Collect information to support the development of new NSWP Science and Implementation Plans.

Format: A panel format was used, which included brief presentations by the expert panelists followed by ample time for lively exchange across a diverse group of attendees. The Opening Plenary Speaker was Dr. Cora Marrett, Deputy Director of the NSF; Dr. Tamara Dickinson from the Office of Science and Technology Policy (OSTP) provided her perspective as Luncheon Speaker; and Congressman Trent Franks provided inspiring Closing remarks. The four panel sessions are summarized as follows:

Note: Speaker and audience remarks are paraphrased and not to be used as quotations.

What is Space Weather and Why it Matters: As we enter into a period of increased activity as part of the 11-year solar cycle, space weather events will become more frequent and intense. This session described the nature of space weather and how it affects our daily lives. The panelists highlighted recent spectacular solar events and their impact on Earth and our vulnerable critical technical infrastructure.

Critical Infrastructure Protection, Mitigation, and Response: We depend on critical systems and activities affected by space weather, such as the electric power grid, communications, positioning and navigation, and national security. These effects must be understood, mitigation actions developed, and acceptable levels of risk assessed to build and support an informed and resilient society. This session covered the main areas in which space weather can have a significant impact on modern technological society.

The Unified National Space Weather Capability: Over the past year, the Federal agencies engaged in the NSWP have been working to establish closer coordination in providing space weather science, research, and services to the Nation. The Unified National Space Weather Capability (UNSWC)—the focus of this session—is seeking to achieve maximum efficiency and effectiveness in the provision of space weather services, research, and technology to the partners' customers and stakeholders.

Responding to New and Emerging Extreme Events: This session examined the challenges and opportunities associated with raising the awareness and understanding of space weather impacts on daily life, national security, the global economy, infrastructure, and business continuity. It highlighted the current means of providing space weather information to the public and examined the nature of the public response to extreme environmental events.

The Way Forward

To continue to improve the space weather enterprise and provide better services to the Nation, the National Space Weather Program member agencies will pursue the following actions:

- Complete the Memorandum of Understanding to formally establish the UNSWC.
- Promote and continue to expand the capabilities of the National Space Weather Portal to improve access to space weather services and supporting research.
- Develop new NSWP Science Roadmap and Implementation Plans, using input from the NSWP Council member agencies, SWEF, and the National Research Council (NRC) Decadal Survey on Solar and Space Science.
- Expand efforts for education and public outreach to ensure that key stakeholders and the general public understand the nature of space weather and properly respond to space weather events that may impact their lives.
- Prepare articles for the media outlets and science journals to raise awareness of space weather and its potential impacts.

Note: Speaker and audience remarks are paraphrased and not to be used as quotations.

Session 1: Welcome and Opening Remarks

Mr. Samuel P. Williamson, Federal Coordinator for Meteorology

Mr. Samuel P. Williamson is the Federal Coordinator for Meteorological Services and Supporting Research. Previously, Mr. Williamson served as the principal planner for the tri-agency Next Generation Weather Radar Program. He began his career as a Weather Officer in the United States Air Force Air Weather Service and has served the National Oceanic and Atmospheric Administration in numerous positions for over 30 years. He was a visiting Executive Fellow at the Harvard University John F. Kennedy School of Government as well as a Senior Staff Associate for the National Science Foundation. As a Senior Science Advisor to the Committee on Science of the United States House of Representatives, he helped shape the legislative agenda for science, space, and technology policy. Mr. Williamson is a retired senior military officer of the District of Columbia Air National Guard.

The key points from Mr. Samuel P. Williamson's remarks were:

- Mr. Williamson opened the forum by welcoming participants to the 6th Annual Space Weather Enterprise Forum. He reviewed the forum objectives and reminded those participating of the importance of the approaching solar maximum, which is expected in 2013.
- Our society has become critically dependent upon systems that can be adversely affected by severe space weather, such as solar storms. Radiation has threatened astronauts during space missions, and polar airline flights have been diverted to lower latitudes due to communication problems, resulting in considerable expenses. However, the space weather community believes the worse is yet to come.
- Research is being conducted by NSF and NASA, and capabilities have been developed by NOAA and DOD. These items will be addressed later in the program.
- Over the past year, the NSWP agencies have worked to establish closer coordination in providing space weather science, research, and services to the Nation. The Unified National Space Weather Capability (UNSWC) seeks to achieve maximum efficiency and effectiveness in the provisions of space weather services, research, and technology.
- Mr. Williamson concluded by reviewing the forum's agenda, summarized the upcoming sessions, and highlighting the role of the Closing Plenary Speaker, the Honorable Trent Franks (R-AZ). He then introduced the Opening Plenary Speaker, Dr. Cora Marrett.

Opening Plenary Speaker

Dr. Cora Marrett, Deputy Director, National Science Foundation

Dr. Cora B. Marrett is the Deputy Director of the National Science Foundation (NSF). Before this appointment, she held the position of Assistant Director for Education and Human Resources (EHR) at NSF. In EHR, she led NSF's mission to achieve excellence in U.S. science, technology, engineering and mathematics (STEM) education at all levels. Dr. Marrett holds a Bachelor of Arts from Virginia Union University, a Master of Arts and a doctorate from the University of Wisconsin-Madison, all in sociology. She received an honorary doctorate from Wake Forest University in 1996 and was elected a fellow of the American Academy of Arts and Sciences in 1998 and the American Association for the Advancement of Science in 1996. In May 2011, Virginia Union University awarded Marrett an honorary degree as a distinguished alumna.

The following are key points from Dr. Marrett's remarks:

- Dr. Marrett's talk cited some of the priorities and challenges associated with space weather from the NSF perspective. She noted that NSF has played a pioneering role in the NSWP by contributing to the fundamental understanding of the space weather system.
- She emphasized that space weather is a manifestation of a highly coupled system. She brought up an interesting point that pictures of the auroras and solar storms have become very important to the general public. The public is drawn to space weather pictures, but unfortunately much of the space weather science behind the pictures remains unseen.
- NSF's contribution includes improving understanding of the unseen science of the space weather coupled system through actively partnering with other agencies and stakeholders to facilitate the transition of this knowledge to address societal needs. She thanked the audience for their partnerships with NSF.
- Although space weather impacts and concerns are vast and far reaching, Dr. Marrett wanted to drawn attention to the two impacts that are especially important to this forum: (1) the effect on the electrical grid, and (2) degradation of Global Positioning System (GPS) signals. GPS signal degradation impacts a large number of systems, anything from shipboard navigational systems to more widespread services such as automated teller machines (ATMs) and Facebook services. Space weather is unlike other natural phenomena because of its potential for global consequences. As society becomes more technologically advanced, the kinds of space weather disruptions that are possible will have potentially greater consequences.
- Dr. Marrett noted that the President's Science Advisor, Dr. John Holdren, joined with Dr. John Beddington, the Chief Science Advisor to the British Prime Minister, to call attention to the potential consequences of space weather. Again illustrating not just a high level commitment but also the necessity of bringing these effects to the public's attention. Their joint announcement emphasized the importance of coordinating and developing space weather mitigation strategies.

Note: Speaker and audience remarks are paraphrased and not to be used as quotations.

- She noted that use-inspired research is fundamental to NSF's investments in space weather research.
- Interagency and international partnerships are important, as is taking advantage of cross-cutting programs; even established partnerships can take advantage of new kinds of collaborations. She cited an example of multidisciplinary collaboration in the development of NSF's cube satellite, a partnership between the University of Michigan and SRI International, which has already completed two launches. The data already transmitted from this effort will expand our knowledge of space weather.
- As NSF moves forward, it will continue to provide frontier research to increase understanding of space weather. The research results will include more realistic models based on better observations, enhanced observation platforms, and education of the next generation of space weather scientists.
- Dr. Marrett concluded by stressing that NSF's commitment to support frontier, use-inspired research; strengthen the ties with the operational community; and maintain a leadership role in the NSWP.

{Note, no question/answer session followed.}

Session 2: Space Weather and Why it Matters

As we enter into a period of increased activity as part of the 11-year solar cycle, space weather events will become more frequent and intense. This session described the nature of space weather and how it affects people's daily lives. The panelists highlighted recent spectacular solar events and their impact on Earth and on vulnerable critical technical infrastructure.

Moderator: Dr. Michael Morgan, Director of the Division of Atmospheric and Geospace Sciences, National Science Foundation

Dr. Michael Morgan, the Session 1 moderator, is the Division Director of Atmospheric and Geospace Sciences at the National Science Foundation (NSF). He is also currently a Full Professor within the University of Wisconsin - Madison's Department of Atmospheric and Oceanic Sciences, where he specializes in understanding the characteristics and sensitivity of short-range numerical weather prediction (NWP) forecasts and forecast errors over the continental United States. He has served on numerous committees in academia and the University Corporation for Atmospheric Research (UCAR). His prior appointment as an American Meteorological Society/UCAR Congressional Fellow resulted in spending time on Capitol Hill, where he focused on energy and environmental issues specifically related to the U.S. Senate's Environment and Public Works Committee.

The following are key points from Dr. Morgan's presentation:

- We are nearing the peak of the 11-year solar activity cycle in 2013. Because of where we are in the cycle, there is a potential for intense solar activities.
- In the past, people believed space was benign and did not know that the space environment could adversely impact (directly and indirectly) our technological infrastructure, which is susceptible to solar activity.
- There have been number of recent solar events. Society depends on critical technologies that are susceptible to the affects of space weather. This susceptibility is a collateral consequence of solar activity. For example, pumps that supply potable water could fail because of power disruptions caused by geomagnetic activity. A society's inability to deliver potable water becomes a collateral consequence. The banking industry could become less efficient because solar activity could adversely impact ATMs. Healthcare delivery could suffer a collateral consequence if a downed power grid results in refrigerators failing to keep drugs at the proper temperature.
- The Carrington Event, a massive solar activity event, occurred on August 28 to September 4, 1859. The likelihood/probability of another Carrington Event within the next year is estimated to be 12%. However, because we now depend on technologies that are far more susceptible to solar activities, a present-day Carrington event will have far more severe consequences than the first Carrington Event. Full recovery from a Carrington Event today could take at least 3-4 years.
- We need to be able to predict the space weather equivalent to Hurricane Katrina.
- Society should ask, "How can we protect our critical infrastructure from a catastrophic event?"
- Major space environment hazards must be considered when developing a satellite. For example, a satellite solar array's power generation efficiency could decrease due to solar radiation damage. A single solar event could adversely affect a satellite's microelectronics.

Panelists:

Dr. Louis Lanzerotti, Distinguished Research Professor of Physics, Center for Solar-Terrestrial Research, New Jersey Institute of Technology

Dr. Louis J. Lanzerotti, distinguished research professor of physics at the New Jersey Institute of Technology (NJIT), has spent four and a half decades contributing to space weather research, including studies of space plasmas and geophysics and engineering problems related to the impact of atmospheric and space processes on both terrestrial technologies and those in space. Much of his research has involved close collaborations with telecommunications service providers on commercial satellites and long-haul (principally transoceanic) cables. His research has also involved geomagnetism, solid earth geophysics, and some oceanography. This research has been applied to design and operation of systems associated with spacecraft and cable operations. Prior to joining NJIT in 2003, Dr. Lanzerotti worked for more than three decades at Bell Laboratories-Lucent Technologies in Murray Hill, NJ.

Note: Speaker and audience remarks are paraphrased and not to be used as quotations.

The following are key points from Dr. Lanzerotti's presentation:

- Dr. Lanzerotti's presentation examined the historical record, which demonstrates that as the complexity and interconnectivity of technical systems has increased, they have become more susceptible to space weather effects. Examples of these adverse effects throughout history include:
  - Interference on aircraft radio communications.
  - Impairment or failure of surface communications systems including railroad communications, telegraph, land and ocean telephone cables
  - Disruption of electric power distribution
  - Degraded satellite operations
  - Interference with Global navigational satellite systems
- The Earth is a complex environment. Space has complex and rapidly changing plasma environments that interact with the atmosphere and can adversely impact man-made infrastructure.
- Space is not empty. It contains cosmic rays, solar x-rays, solar radio waves, solar particles, magnetic fields, radiation belts, magnetospheric plasmas, ionospheric electrical currents, etc.
- We have not taken heed from lessons learned from the historical record of solar activity and its impacts on infrastructure. For example, existing power distribution systems have become more susceptible to space weather activity than power distribution systems built in the early 20th century.

Dr. C. J. (Karel) Schrijver, Senior Fellow, Advanced Technology Center, Solar and Space Science, Lockheed Martin Space Systems Company, Palo Alto, CA

Dr. Schrijver is a Senior Fellow at the Advanced Technology Center (ATC), Solar and Space Science at the Lockheed Martin Space Systems Company. In that capacity, he conducts basic research into understanding and predicting space weather and the behavior of the Sun, including its impacts on Earth and climate. He has worked on the quiescent, long-term evolution of the solar magnetic field as well as on explosive, eruptive phenomena. Dr. Schrijver is also the principal physicist at Lockheed Martin's Solar and Astrophysics Laboratory (SAL) within ATC. As such, he works closely with ATC engineers in their effort to build both the science instruments and spacecraft for the Interface Region Imaging Spectrograph (IRIS), a NASA Small Explorer Mission scheduled for launch in late 2013.

The following are key points from Dr. Schrijver's presentation:

- The Solar Dynamics Observatory (SDO) provides over two terabytes of data each day. The SDO instruments provide broad spectrum, high resolution coverage of the sun. This information is archived and available to users upon request.
- Archived SDO data allow us to study what drives space weather. For example, it has been effective in studying coupled disturbances, in which a solar activity in one area causes another disturbance at great distances across the solar disk.

Note: Speaker and audience remarks are paraphrased and not to be used as quotations.

- SDO data are being used to drive Virtual Solar Observatories which have become essential for studying the sun's structure and dynamics. These "observatories in a computer." can use SDO data to drive depictions of the Sun's magnetic field and other analyses that provide three-dimensional visualizations of solar dynamics.
- We tend to focus on extreme events/rare events. This focus on extreme events is evident in media coverage as well as in a number of scientific studies. However, solar activity of a non-extreme nature is pervasive. The U.S. Department of Energy (DOE) and the North American Electric Reliability Council (NERC) publish reports on "power grid disturbances." Based on 1,216 reports from 1992 through 2010, there was a significant increase in grid disturbances in periods following severe solar and geospace activity. The correlation of grid disturbances with major solar flaring reveals a weakness in the U.S. power grid not recognized to date. The economic impact of space weather on the U.S. economy likely exceeds $3 billion per year. By comparison, the oft-cited Hydro-Quebec blackout in March, 1989, had an estimated impact of just $2 billion.
- It is possible to infer the prehistoric record of solar activity and its impact through chemical tracers in ice cores.
- To determine the probability of very rare extreme events, we need to combine studies of our Sun with data about many other Sun-like stars. NASA's Kepler spacecraft, designed to detect Earth-like planets orbiting distant stars, can also provide insight into the "solar" activity of those stars. Combining information from the Kepler spacecraft with information about our own Sun facilitates probability computations.
- Conclusions: Even though extreme solar events are unlikely to be much more extreme than what the Earth has already experienced, the susceptibility of our technological infrastructure is larger than typically realized, "with costs of billions each year in the electric power grid alone." An appropriate response to the societal impacts of space weather requires (1) a dedicated organization for interdisciplinary studies to assess the coupling of solar activity with effects on the U.S. economy and safety, (2) strategies for prevention and mitigation of adverse impacts due to solar activity, and (3) an observing system ranging from the Sun to geospace for science/research and forecasting.

Mr. Charles Gay, Deputy Associate Administrator of the Science Mission Directorate, NASA Headquarters

Mr. Charles J. Gay has served the National Aeronautics and Space Administration (NASA) in senior management positions for over seven years. He is currently the Deputy Associate Administrator for the Science Mission Directorate. He was previously Deputy Director of the Office of System Safety and Mission Assurance at Goddard Space Flight Center. He also served as Deputy Director of the Heliophysics Division at NASA Headquarters, where he was responsible for programmatic development and implementation of NASA's solar physics and geospace science program. In 2005, he served as the Deputy Director of the newly formed Earth Sun System Division, where he was responsible for the development and operations of over 50 spacecraft, spanning multiple NASA Centers, agencies, industry teams, and international partners.

Note: Speaker and audience remarks are paraphrased and not to be used as quotations.

The following are key points from Mr. Gay's presentation:

- Heliophysics is the study of the Sun and its interaction with the Earth and the solar system.
- Modern society is increasingly dependent on technologies that are susceptible to the effects of space weather.
- The magnetosphere protects us from most of the harmful effects of space weather.
- The ionosphere acts as a relay station for high frequency (HF) radio communications, thus enabling global communications. Space weather can adversely impact the ionosphere and disrupt HF communications.
- Disturbed ionospheric conditions can result in disruptions to GPS and other navigation systems which, in turn can impact an ever-increasing number and variety of systems and services such as banking transactions, precision agriculture, construction, and surface and air transportation.
- The space environment can also degrade satellite solar panel efficiency, shortening the life of these critical components and disrupting spacecraft computer systems and operations.
- The Heliophysics System Observatory (HSO) utilizes the entire NASA fleet of solar, heliospheric, and geospace spacecraft as a distributed observatory to investigate the larger-scale and/or coupled processes at work throughout the complex system that makes up the space environment. NASA collects and archives data from these missions and develops algorithms to analyze and interpret these data. The HSO facilitates a better understanding of space weather's physical structure and a better understanding of how to model the impacts of space weather.
- NOAA satellites and some HSO spacecraft provide a real-time capability to monitor space weather conditions and make space weather predictions.
- There are a number of upcoming satellite launches that will support the Heliophysics Program. These satellites (and their launch dates) include, but are not limited to, the Astra satellite (August 2012), the IRIS satellite (June 2013), the Magnetospheric Multiscale Satellite (March 2015), and the Solar Orbiter and Solar Probe satellites (January 2017 and July 2018, respectively)
- Focused research programs are guiding the design and operation of productive scientific missions.
- NASA is pursuing a deeper understanding of the fundamental physical processes that underlie the awesome phenomena of space. The payoff will be understanding how technical systems, human society, and the habitability of planets are affected by solar variability.

Colonel Daniel Edwards, Chief, Integration, Plans, and Requirements Division, Directorate of Weather, Headquarters, United States Air Force

Colonel Daniel C. Edwards is Chief, Integration, Plans and Requirements Division, Directorate of Operations, Deputy Chief of Staff, Operations, Plans and Requirements, Pentagon, Washington, D.C. The Division plans weather and space environmental

support for the Air Force Weather (AFW) functional area, and oversees integration of technology and weather into command and control, mission planning, and other systems.

Colonel Edwards entered the Air Force in 1989 as a distinguished graduate of the Air Force Reserve Officer Training Corps at the University of Nebraska-Lincoln. He has been a wing weather officer, reconnaissance weather officer, flight commander, a Wing Executive Officer, Field Operating Agency Branch Chief, Field Operating Agency Division Chief, and Squadron commander. Colonel Edwards is from North Platte, Nebraska.

The key points from Colonel Edwards's presentation were:

- Space weather is a global phenomenon that impacts DOD and civil systems alike.
- Space weather has impact across the DOD in terms of space situational awareness, satellite operations/health, GPS-guided systems, and communications/radar.
- DOD-related space weather impacts include satellite communications (SATCOM) interference, radar interference, HF Radio blackout, geolocation errors, and satellite orbit decay.
- There is a need for NSWP partners to expand and leverage each other's ground-based and space-based solar activity data collection capabilities.
- There is a need to better understand the threat of solar activity and to mitigate its effects. This requires: (1) solving the tough forecasting problems, (2) moving from nowcasts to physics-based forecasts, and (3) designing systems to mitigate/plan around space weather impacts.
- The AFW Space Weather Operations Center (SWOC) at Offutt Air Force Base is DOD's space weather provider. This center is DOD's only 24/7 space weather forecast center. It is supported by five solar observatories. The center has a close operational partnership with the National Centers for Environmental Prediction (NCEP)/Space Weather Prediction Center (SWPC).
- Partnerships with operational and research communities are vital to meeting national space weather needs. Accordingly, DOD leverages organic interagency and international sources of data to support military operations and resource protection.
- The SWOC issues products tailored to specific missions, customers, and operational needs to DOD users worldwide (e.g., the SWOC issues alerts, warnings, forecasts, and mission-tailored products). These products include (but are not limited to) Radar Auroral Clutter, Hi-flyer Radiation Dosage, Single and Dual Frequency GPS Errors, and Forecast and Observed Scintillation for UHF SATCOM Situational Awareness.

Session 2 Questions:

- Dr. Morgan (NSF): Regarding the paucity of observations, are there plans to design ground and space networks to adapt sampling to improve prediction?

Note: Speaker and audience remarks are paraphrased and not to be used as quotations.

- Answer from Mr. Gay: The current Heliophysics System Observatory (HSO) and future missions are facilitating and will improve the availability of observations and our capability to predict solar activity.
- Answer from Dr. Schrijver: It's a complex system and we need to get as much data as we can; but we need to figure out what information we need. We need to complement the real observations with virtual observations. For example, combine observations by in situ instruments with "observations" from models.

- Mr. Chris Beck (Senior Advisor for Science and Technology, U.S. House of Representatives Committee on Homeland Security): Dr. Schrijver mentioned a $3 billion impact. Is that impact related to the "electric power sector" only or does that dollar figure include other sectors? How did he arrive at this number (the $3 billion impact)?
  - Answer from Dr. Schrijver: To clarify, the dollar figure presented is a potential dollar impact and includes the electric power sector only. He and his colleagues determined this number by surveying electric power companies and looking for "substantial disturbances noticed by customers." Further mining of this survey information will take more effort and more time. Industry experts don't want to disclose the information for any number of reasons. For example, a company could view disclosing information as compromising their competitive advantage or exposing vulnerabilities. Disclosing information might also open the company to litigation. So a way is needed to elicit information from the electric power sector without compromising the sector's health/competitiveness.

- Ms. Janice Marconi (Marconi Works International): Solar activity going on now could impact the upper latitudes. Would the impact of that activity be moderate or severe?
  - Answer from Dr. Lanzerotti: If you have energetic particles you could get HF blackouts whether the energy associated with these particles is considered high or low.

- Mr. Nelson Jacobsen (Help Earth Foundation): Can we get the data? If we can get the data, we can get those data out to the public. The (National Reconnaissance Office) is turning two satellites over to NASA. What is the impact of this gift?
  - Answer from Mr. Gay: It will not directly and immediately affect NASA's current space weather endeavors.
  - Answer from Dr. Schrijver: Anyone is welcome to tap into the space weather data archive.

- Mr. Richard Garber (Canadian Department of National Defense): What are the international dynamics of space weather and collaboration?

- Answer from Dr. Schrijver: The dynamics of space weather and collaboration are, by definition, international because you want to make the best use of limited resources.
- Answer from Dr. Lanzerotti: There is close collaboration and data/information sharing between Canada and the United States.
- Answer from Col Edwards: We rely on other countries and our allies to share data, warnings, and advisories.
- Answer from Mr. Gay: We have great collaboration with allies, especially for in situ observations.

- Dr. Steve Tracton (Capital Weather Gang): Why wasn't the Deep Space Climate Observatory (DSCOVR) satellite on the graphic depicting the HSO? What is the status of DSCOVR? When will it be launched?
  - Answer from Mr. Gay: It was not mentioned on the HSO slide because DSCOVR is not a NASA mission. It is a NOAA/DOD effort and is slated to replace the ACE satellite. (No answer on the status of DSCOVR was given by the panelists).

- Mr. Max Cacas (SIGNAL Magazine): How bad is the Solar Max going to be?
  - Answer from Dr. Lanzerotti: I will pass on giving a specific forecast. However, keep in mind that even small solar activity can cause major disruptions. A CME related to the intensity and timing of an event cannot be predicted very well.
  - Answer from Dr. Schrijver: Predictability of intensity and timing is an incredibly difficult endeavor. To do this, we would have to be able to look under the surface of the Sun. We don't have the ability to do this. As Dr. Lanzerotti remarked, even in low sunspot activity, disruptions to susceptible infrastructure can occur.

Session 3: Critical Infrastructure Protection, Impact Mitigation, and Response

We depend on critical systems and activities affected by space weather, such as the electric power grid, communications, positioning and navigation, and national security. These effects must be understood, mitigation actions developed, and acceptable levels of risk assessed to build and support an informed and resilient society. This session covered the main areas in which space weather can have a significant impact on our modern technological society.

Moderator: Ms. Heather King, Executive Officer, PPD-8 Program Executive Office, Federal Emergency Management Agency (FEMA)

Ms. King presently serves as the Executive Officer for the Program Executive Office housed within FEMA, where she is responsible for shepherding Presidential Policy Directive 8 / National Preparedness. Prior to this new role, she oversaw the development of Comprehensive Preparedness Guidance (CPG) for state, local, tribal, and territorial jurisdictions. Prior to joining National Planning Coordination and Assistance (NPCA), she

served in several capacities within the U.S. Department of Homeland Security (DHS) and FEMA, including the response and recovery lead for FEMA's then newly created Private Sector Division and program specialist for FEMA's Community Preparedness Division, where she provided subject matter expertise in program guidance, implementation, and evaluation of the Citizen Corps Program. Ms. King holds a Bachelor of Science Degree in communications from Virginia Commonwealth University and is currently completing her Masters degree in Public and International Affairs at Virginia Tech.

Ms. King introduced the panel and highlighted ways that space weather can have significant impacts on our modern society.

Panelists:

Mr. Micah J. Loudermilk, Energy & Environmental Security Policy, Institute for National Strategic Studies, National Defense University

Mr. Micah J. Loudermilk is the Senior Research Associate for the Energy & Environmental Security Policy Program at National Defense University (NDU). His program work focuses primarily on the critical nexus between energy and national security, as well as the significant defense-related energy problems that confront the US military in the 21st century. Since joining NDU in 2010, Mr. Loudermilk has led numerous projects and conducted detailed analysis on the potential for major energy changes across the Department of Defense. Additionally, Mr. Loudermilk has researched and written extensively on cyber security and strategy, national security policy, small-scale nuclear reactors, the future of nuclear power in the US, and European energy politics. Prior to joining NDU, Mr. Loudermilk worked with the Center for Strategic and International Studies. He is under contract to NDU through Booz Allen Hamilton.

The following are key points from Mr. Loudermilk's remarks:

- Mr. Loudermilk provided an overview of the Secure Grid 2011 Exercise, hosted at NDU in October 2011. This was the third in an ongoing series of exercises that NDU has conducted in conjunction with U.S. Northern Command and DHS on U.S. power grid vulnerabilities, specifically risks posed by geomagnetic storms. The most recent exercise focused on the potentially catastrophic effects a major geomagnetic storm would have on the nation's electrical infrastructure. His presentation discussed the exercise scenario, objectives, and key discussion points.
- Key discussion point from the exercise include: 1) capacity of industry to respond and make key decisions, 2) roles of industry, government authorities, and first responders, 3) communication between grid stakeholders, 4) ability to maintain public order during a potential national crisis, 5) group coordination and fragmented lines of authority, 6) backup generation capabilities, transformer replacement, and restoration of power, 7) cascading and secondary effects and grid complexity, and 8) severe uncertainty over the true effects of a large geomagnetic disturbance (GMD).

- Key exercise recommendations include: 1) immediate replacement of the ACE spacecraft, 2) hardening of grid or at least of limited, critical pieces, 3) improvements needed in forecasting accuracy of GMD events, 4) better education of actors and responders is necessary, 5) need to establish appropriate response plans and lines of authority in advance, 6) better coordination among industry and government, 7) adoption of transformer sharing plans, portable generation equipment, etc., and 8) comprehensive study of cascading failures.
- Additional highlights include: 1) disaster-prone states are better prepared for natural disasters, 2) what kind/type of backup generators do actors/responders have (learned that they can't restore power until certain critical parts of the grid are fixed first), 3) it is very hard to predict grid behavior, 4) major outages occur in short amount of time, 5) what is our actual capacity to protect and defend the national electrical grid, 6) are there options beside shutting down the grid, 7) what do we do to improve overlapping lines of authority for state and local utilities (how do we manage key players), and 8) communication is difficult, especially with non-government players.

Mr. Scott Pugh, Interagency Programs Office, Science & Technology Directorate, Department of Homeland Security

Mr. Scott Pugh has worked in the DHS S&T Directorate since 2007 and has been a key contributor to multiple energy infrastructure security initiatives. He is currently a member of the White House Office of Science and Technology Policy (OSTP) Geomagnetic Induced Current Interagency Working Group and the Federal Smart Grid Task Force. In the civilian sector, he worked at Rocky Mountain Institute with CEO Amory Lovins to implement the advanced energy initiatives described in the DOD-funded study "Winning the Oil Endgame" and served as a member of the Defense Science Board Energy Strategy Task Force that produced the 2008 report "More Fight – Less Fuel." Mr. Pugh is a retired Navy Captain who served as a nuclear submarine commanding officer and as Naval Academy Director of Mathematics and Science.

The following key points are from Mr. Pugh's remarks:

- DHS S&T has proactively worked with government and industry to improve national readiness to respond to severe space weather events through initiatives such as funding the 2011 JASON study "Impacts of Severe Space Weather on the Electric Grid"; partnering with USNORTHCOM to plan, fund and conduct a 2011 interagency and industry severe space weather wargame at NDU; and funding the development and recent rapid deployment demonstration of a prototype 345KV recovery transformer from an ABB manufacturing facility in St. Louis, Missouri, to a Centerpoint Energy substation near Houston, Texas, in less than one week.
- Extreme space weather is not a new phenomenon, but the combination of space weather with modern infrastructure is a new problem.
- 345KV+ transmission growth has significantly increased from 1921 to 2010. Today we not only have a national grid but a Northern American Grid that partners with and connects to the grids in Canada and Mexico.

Note: Speaker and audience remarks are paraphrased and not to be used as quotations.

- Even though coronal mass ejections (CME) don't typically hit Earth, DHS is tied into the NASA model that warns if a CME is approaching. However, the model only provides 18-30 hour warnings.
- On the other hand, NASA's Advance Composition Explorer (ACE) warns if CMEs will be strong or weak but can only provide a 20-45 minute warning (really not a lot of time to do things).
- Once a CME reaches Earth, it affects the earth's magnetic field. Geomagnetic induced current (GIC) conditions produce direct current (DC) that can damage AC transformers. The US has about 2000 extremely high voltage transformers.
- Today people are starting to think about what will happen, and numerous agencies have published studies that reflect this interest (National Academy of Sciences, JASON, NERC).
- Mr. Pugh concluded by noting that, as we move forward, research is being conducted to lessen transformer vulnerabilities by developing smaller, more mobile versions.

Dr. Michael Gregg, Professor of Oceanography, University of Washington

Dr. Michael Gregg is a Professor of Oceanography at the University of Washington. He has been a member of JASON for 30 years. JASON is a group of academic scientists, mathematicians, and engineers that provides technical advice to the U.S. government, principally by means of intensive summer studies that begin with briefings from government and academic experts.

The following are key points from Dr. Gregg's remarks:

- JASON is a group of academic scientific, mathematicians, and engineers who advise the Federal government on technical issues. At the request of DHS, during its 2011 Summer Study JASON examined the vulnerability of the North American electric grid to severe space weather and reported findings and recommendations in its report, *Impacts of Severe Space Weather on the Electric Grid* (JSR-11-320, Nov. 2011, MITRE Corp., McLean, VA).
- The study concluded that the response of the electric grid to strong CMEs is not understood well enough to make accurate damage estimates. For example, a major CME could leave large areas and millions of people without power for many months.
- The threat of severe damage, however, is real and calls for protective measures now. Finland and Quebec, both at greater risk than the United States, have demonstrated the effectiveness of mitigation. For example, following the experience of Hydro Quebec, for perhaps $100 million the 1,000 most vulnerable U.S. transformers could be protected with neutral-current-blocking-capacitors protected by shunts. Dr. Gregg also noted that, during severe events, protecting the equipment is more important than keeping the power flowing. Customers understand this priority if they are told about it ahead of time.
- Dr. Gregg mentioned that a full study of grid behavior hasn't been done, but people are working it. They were told that NERC is developing a national grid

- Observations vital for space weather warnings are presently supplied by SOHO, ACE, and STEREO satellites. Developed for research rather than operational warnings, ACE is well past its design life, making essential its interim replacement in 2014 with the refurbished DSCOVR satellite. Longer term, more is needed, such as replacing DSCOVR with a constellation of low-cost vehicles in quasi-satellite orbits.
- The proposed constellation could increase direct warning times to several hours, from an hour or less now, and greatly improve observations of CME structures as they pass earth. In addition, operational satellites are needed to maintain the three-dimensional views now provided by the STEREO research satellites.
- Dr. Gregg also noted that, during the study, JASON found several gaps between agencies in the space weather enterprise. There are various interagency administrative issues with no real agency lead. These gaps include inadequate coupling between Air Force and NOAA space weather organizations, inadequate transitions of predictive models from NASA to NOAA, and NERC not having access to DOE work on electric grid modeling

Mr. Anthony Russo, Director, National Coordination Office for Space-Based Positioning, Navigation, and Timing

Mr. Anthony Russo has served as the Director of the National Coordination Office for Space-Based Positioning, Navigation, and Timing since January 19, 2010. He is a Senior Executive Service (SES) official from the Research and Innovative Technology Administration (RITA), U.S. Department of Transportation. Mr. Russo previously served as Deputy Director of the National Coordination Office, on assignment from the Department of Defense. His expertise is in policy development, requirements definition, planning, and budgeting for space-based systems, including the Global Positioning System (GPS). He retired from military service as an Air Force Colonel. Mr. Russo is the former commander of the 527th Space Aggressor Squadron, which identified potential threats and vulnerabilities to GPS service and built effective countermeasures.

The following are key points from Mr. Russo's remarks:

- Mr. Russo presentation covered the history and organization of GPS, as well as U.S. policy on GPS. The Federal lead for GPS issues is housed in the National Coordination Office, which is hosted by NOAA. The speaker noted that NOAA is the only agency that has been a continuing member.
- The US has a very robust GPS constellation, which includes 31 space vehicles currently in operations but requires only 24 to operate. These satellites are well built, located in a high orbit to avoid collisions, and were designed to live 7 years, but some are already 21 years old. The bottom line is that these very good, very reliable systems have continuously exceeded performance commitments.

Note: Speaker and audience remarks are paraphrased and not to be used as quotations.

- Most people are aware that GPS technology is prevalent in our society and is an essential part of critical infrastructures. However, one new development is that GPS technology is being used in the agriculture sector, where it has provided an economic benefit of $14 million to $30 million per year. Technologies have been applied to crop rotation and seed, fertilization, and water dispersion. In addition, future GPS-guided aircraft will have saving efficiencies projected to be in the tens of billions of dollars.
- Space weather, especially charged particles, can impact GPS applications since propagation delays increase range errors. The worst case is that users are unaware that their systems have range error degradation and continue their operations as if the data are accurate. Space weather also brings increased signal noise and rapid signal phase changes, which not only degrade performance but could also result in loss of track.
- In closing, Mr. Russo noted that new services and better performances are coming on line, such as progress from one GPS civil signal to four civil signals.

Session 3 Questions:

- Jeffrey Love (USGS Geomagnetism Program): Is it possible to better advertise future exercises and scenarios so the word gets out to the rest of the community?
  - Answer: A short 'yes' response was echoed by the moderator and all panelists.

- Steve Tracton (Washington Post, Capital Weather Gang): Can you comment on the vulnerability of U.S. nuclear power plants to space weather effects?
  - Answer from Micah Loudermilk (NDU): The Secure Grid 2011 Exercise didn't explicitly look at this issue. There are a wide range of very severe cascading and secondary effects that can result from a widespread grid blackout but that were beyond the scope of the exercise. The assumption is that backup generators will be in place, but should they not be, the plants would be extremely vulnerable.
  - Answer from Scott Pugh (DHS): FEMA is looking into this issue, but the solution depends on the supply of diesel generators when there is no grid.
- Follow-on question: Is there something in place now?
  - Scott Pugh answered yes.
  - Heather King (FEMA) added that NOAA is working with state and local planners on what considerations need to be made in this area as well.

- John Grunsfeld (NASA HQ): One of the panelist stated that GPS jamming is occurring, please elaborate.
  - Answer from Anthony Russo (National Coordination Office for Space-Based Positioning, Navigation, and Timing): Yes, proliferated global GPS jamming is occurring, in particular for aircraft navigation.

- Janice Macaroni (Marconi Works International): What surprised you most at the table top exercises besides line of communication?

Note: Speaker and audience remarks are paraphrased and not to be used as quotations.

- Answer from Micah Loudermilk (NDU): That other areas of the operating zone may NOT have power—as opposed to traditional disaster response. Additionally, that everything is dependent on clear lines of authority and communication - which are currently not in place—to include the question of what available mobile assets exist nearby that can get access/permission to move to the affected area quickly, etc.
- Answer from Scott Pugh (DHS): Space weather is a different animal and introduces a new challenge. There is now a waiting period before first responders can mobilize. FEMA cannot preposition resources for this, as it can for hurricanes. FEMA officials will need to know where to go, and that information might not immediately be available when the electrical grid is down.

Luncheon Speaker

Dr. Tamara Dickinson: Dr. Tamara Dickinson is a Senior Policy Analyst at the Office of Science and Technology Policy and works on issues related to disasters (natural and man-made), critical infrastructure, NASA Space Science Programs, and space weather. She is on a detail from the U.S. Geological Survey (USGS) where she served as the program coordinator for the National Geological and Geophysical Data Preservation Program and Geology Lab Program. Prior to joining the USGS, Dr. Dickinson held several positions at the National Research Council, including Associate Director and Acting Director for the Space Studies Board, and at the National Science Foundation, serving as the Program Director for the Petrology and Geochemistry Program. She also served as the Discipline Scientist for the Planetary Materials and Geochemistry Program at NASA headquarters. Dr. Dickinson has held a research position at the Smithsonian Institution Natural History Museum. Her research focused on the origin and evolution of lunar materials and meteorites.

Dr. Tamara Dickinson's Key Points

- OSTP was established by Congress in 1976 with a broad mandate to advise the President and others within the Executive Office of the President (EOP), develop and implement sound science and technology policies and budgets, and collaborate with the private sector, state and local governments, science and higher education communities, and other nations in this regard.
- OSTP is under the Executive Office of the President and contains four divisions—(1) science, (2) technology, (3) energy and environment, and (4) national security and international affairs.
- OSTP has about 100 staff; its work is organized by the National Science and Technology Council (NSTC), whose primary objective is the establishment of clear and national safeguards for Federal science and technology investments to make sure all mission goals are met.
- The NSTC's five primary committees are the (1) Committee on Environment and Natural Resources and Sustainability, (2) Committee on Homeland and National

- A subcommittee of the Committee on Environment and Natural Resources and Sustainability is the Subcommittee on Disaster Reduction.
- In 2005, the Subcommittee on Disaster Reduction produced a ten year strategy that included addressing six grand challenges—(1) provide hazard information, (2) seek to understand natural processes, (3) develop hazard mitigation, (4) reduce vulnerability, (5) assess disaster resilience, and (6) promote risk-wise behavior.
- The Subcommittee on Disaster Reduction deals with specific topics of concern, one of which being space weather.
- In 2010, the Subcommittee on Disaster Reduction decided to produce an implementation plan for space weather.
- The Space Weather Implementation Plan's near-term actions include enhancing capabilities of operational centers, identifying critical measurements and planning investments, enhancing awareness across all sectors, fostering exchange of ideas and information, and increasing operational data sources.
- Vulnerability to a solar storm event has increased greatly since the last solar maximum, sparking space weather awareness in the professional societies, including the American Meteorological Society (AMS) and American Geophysical Union (AGU).
- The Administration is now briefed regularly on space weather events, is helping provide space weather workshops through the Space Weather Prediction Center (SWPC) and other organizations, and is facilitating collaboration and services with the United Kingdom.
- Recent progress in space weather include the Deep Space Climate Observatory (DSCOVR), the National Earth Observation Strategy and Assessment, and mitigation issues.
- The Advanced Composition Explorer (ACE), which was launched in 1997, needs to be replaced. Instruments from this spacecraft provide real-time solar wind data.
- The DSCOVR mission is a three-agency program and will help replace ACE. NASA's Goddard Space Flight Center will be refurbishing DSCOVR. The Air Force will be providing the launch with DOD funding, and NOAA will be funding the DSCOVR refurbishment, satellite operations, product processing, archiving, and forecast product development. Launch is expected in June 2014.
- The National Earth Observation Strategy was developed at Congress's request and has three components: (1) provide federal assessment of earth observations by societal benefit areas, (2) identify critical data streams, and (3) prioritize observing systems on which those data streams depend. Space weather is treated as a separate societal benefit area.
- With respect to mitigation activities, OSTP established the Geomagnetic Interagency Working Group in 2012. In 2011 the White House tasked FEMA with providing the Federal interagency response plan to space weather, and in 2012 the President asked the OSTP and the National Security Staff to move forward aggressively with space weather mitigation efforts.

Questions: None

Note: Speaker and audience remarks are paraphrased and not to be used as quotations.

Session 4: The Unified National Space Weather Capability

Over the past year, the Federal agencies engaged in the National Space Weather Program have been working to establish closer coordination in providing space weather science, research, and services to our Nation. The *Unified National Space Weather Capability*—the focus of this session—is seeking to achieve maximum efficiency and effectiveness in the provision of space weather services, research, and technology to our customers and stakeholders.

Moderator: Dr. David Applegate, Associate Director for Natural Hazards, U.S. Geological Survey (USGS) and Cochairman, Subcommittee on Disaster Reduction (SDR), Committee on Environment and Natural Resources (CENR), National Science and Technology Council (NSTC)

David Applegate was the Session 4 moderator. He is Associate Director for Natural Hazards at USGS. In that role, he leads USGS hazards planning and response activities and oversees the Coastal & Marine Geology, Earthquake Hazards, Global Seismographic Network, Geomagnetism, Landslide Hazards, and Volcano Hazards Programs. He co-chairs the National Science and Technology Council's interagency Subcommittee on Disaster Reduction and co-leads the Department of the Interior's Strategic Sciences Group. Prior to joining USGS in 2004, he worked on science policy at the American Geological Institute for 8 years and before that served with the U.S. Senate Committee on Energy and Natural Resources as the American Geophysical Union's Congressional Science Fellow and as a professional staff member.

The following are key points from Dr. Applegate's presentation:

- The focus of this session is on the current effort to strengthen coordination on space science, research, and application.
- The NSWP Council played a pivotal role in developing the Space Weather focus section in the SDR Grand Challenges series document.
- As a member of the NSWP, the USGS "brings the ground truth" to space weather observation by providing data from its 14 geomagnetic observatories and the capability to apply geomagnetic information for space weather analysis.
- The USGS has a long-term archive of geomagnetic data. Dr. Applegate mentioned that USGS was honoring Mr. Jack Townsend who has been and continues to be instrumental in contributing to the integrity of the USGS long-term archive over his 69-year career.

Panelists:

Dr. Kathryn Sullivan, Assistant Secretary of Commerce for Environmental Observation and Prediction, National Oceanic and Atmospheric Administration

Dr. Sullivan is the Assistant Secretary of Commerce for Environmental Observation and Prediction and Deputy Administrator for the National Oceanic and Atmospheric

Note: Speaker and audience remarks are paraphrased and not to be used as quotations.

Administration (NOAA). She was the inaugural director of the Battelle Center for Mathematics and Science Education Policy in the John Glenn School of Public Affairs at Ohio State University. Prior to joining Ohio State, Dr. Sullivan served a decade as President and CEO of the Center of Science and Industry (COSI) in Columbus, Ohio, one of the nation's leading science museums. Dr. Sullivan joined COSI after three years' service as Chief Scientist at NOAA, where she oversaw research and technology programs agency-wide. Dr. Sullivan holds the distinction of being the first American woman to walk in space.

The following are key points from Dr. Sullivan's presentation:

- One goal of a Weather Ready Nation is that a society is prepared for and able to respond to space-weather-related events. This is facilitated by critical observations, partnerships, connections and interdependencies, and customer growth.
- With an increase in solar activity, NOAA is working with its partners since no one organization can meet all the needs of the nation. So NOAA must partner. The Executive Branch is coordinating the roles each agency can play to protect the public. As partners, we realize that we all have critical dependencies.
- Critical elements of the NOAA National Weather Service (NWS) effort in this partnership include observing, monitoring, and predicting solar activity and educating the public.
- NOAA works constantly with partners to educate the public and develop online training tools for the NWS Weather Forecast Offices and the public.
- Participating in the World Meteorological Organization (WMO) Space Weather Portal ensures that the right people have the information they need to make an informed decision.
- NOAA has committed to improving operations and continuing and expanding coverage of critical observations. GOES-R will have an X-ray sensor, expanded dynamic range, and flare location. The Space Environment In-Situ Suite on GOES-R will detect energetic particles. The Solar Ultraviolet Imager is also on GOES-R. The GOES-R launch is estimated to occur in 2014. DSCOVR will provide critical warnings at Lagrange Point 1 (L1). NOAA is collaborating with NASA and DOD for the projected Summer 2014 launch.
- With respect to new models and products, the Wang-Sheeley-Arge and Enlil model have transitioned into NOAA operations.
- The Space Weather Prediction Testbeds (sponsored by NASA, NOAA, and academia) is developing the Ovation Auroral Forecast Model, which will predict location and characteristics of the aurora with a 40-minute lead time.
- NOAA/NWS will upgrade its operational product suite with critical new data sets. This update will lead to actionable products for NOAA customers.
- U.S. partners work with the WMO, the International Civil Aviation Organization, and UN Committee on the Peaceful Uses of Outer Space.
- The number of subscription customers to products from the NOAA Space Weather Prediction Center (SWPC) is growing rapidly each year.

Note: Speaker and audience remarks are paraphrased and not to be used as quotations.

- The Sunjammer (a Solar Sail Technology Demonstration Mission) can provide information that could add hours to the geomagnetic storm warning lead time.
- We must work together productively and fluidly to realize these advances.

Dr. Fred Lewis, Director of Weather, Headquarters, United States Air Force

Dr. Fred Lewis is Director of Weather, Deputy Chief of Staff for Operations, Plans and Requirements, Headquarters U.S. Air Force, Washington, D.C. As the Director of Weather, Dr. Lewis develops doctrine, policy, requirements, and standards to organize, train, and equip the weather career field to support the Air Force, Army, designated unified/subunified commands, and the Intelligence Community. He directs the 1,150-person Air Force Weather Agency located at Offutt Air Force Base, Nebraska, and provides functional oversight of the more than 4,300-person Air Force Weather (AFW) total force. In December 1985, he became the first AFW officer selected for Space Shuttle duty, but he never flew a Shuttle mission due to the Challenger disaster. He served on the U.S. Transportation Command Staff, including two years spent as Director of the Joint Transportation Corporate Information Management Center.

The following are key points from Dr. Lewis's presentation:

- Space Weather is a total team sport (comprised of international, industry, academia, and government partners).
- Our common challenges and opportunities include:
  - Expanding and leveraging each other's ground-based and space-based data collection capabilities.
  - Solving the tough forecasting problems (e.g., generating physics-based model improvements and moving from nowcasts to physics-based forecasts).
- The DOD has more than 40+ years in providing support to warfighters.
- DOD partners include NASA, NOAA, the University of Utah, and the Naval Research Laboratory.
- DOD has the only 24/7 space weather forecast center.
- Products from the DOD center include text messages, three-dimensional graphics of a particular area of interest, and data in Global Information System/Google Earth format.
- The Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC) has provided good information. COSMIC 2 is still being developed.
- The Space Weather Analysis and Forecast System (SWAFS) is a single integrated baseline of more than three space weather models and applications. SWAFS is used for operational analysis, forecasts, and space weather impacts.
- The Uniform National Space Weather Capability (with national partners working together) will continue to team for identification of the solar max and beyond. We are going to (1) modernize and leverage ground- and space-based sensing capabilities, (2) support national space weather forecasting needs (physics-based forecasting), (3) mutually leverage organic interagency and international sources of data to support operations and resource protection, (4) exploit the nation's space weather expertise for space situation awareness into the future, (5) share

Dr. Barbara Giles, Director, Heliophysics Division, Headquarters, National Aeronautics and Space Administration

Director of the Heliophysics Division, Dr. Giles joined Marshall Space Flight Center, where she was part of a team that built suborbital and spaceflight heliophysics instrumentation. Her research interests focused on the Earth's magnetosphere with emphasis on the ionosphere's contribution to magnetospheric dynamics. In 2004, Dr. Giles came to NASA Headquarters as the Program Scientist for the Radiation Belt Storm Probes Mission and led the science procurement for that mission. She was the Program Scientist for the Solar Terrestrial Probes Program (STP) and managed the procurement for the next Explorer Program missions. In her current role as the Heliophysics Strategic Planning Lead at NASA headquarters, she charted the Heliophysics Division's course for the future by planning new missions to study the Sun, its effects on Earth's space environment, and its influences out to the far reaches of the heliosphere.

The following are key points from Dr. Giles's presentation:

- Although there is now more attention on the solar activity, we're still learning about the severity of the impacts.
- At NASA Headquarters, the job is to understand the Sun and its interactions with Earth and the solar system. The three goals of the Heliophysics Division are to (1) open the frontier to space environment prediction, (2) understand the nature of our home in space, and (3) safeguard the journey of exploration.
- NASA meets its goals by developing theories and conducting experiments, which lead to models (demonstrating our understanding of what's going on). Then NASA puts what has been learned from this research into operations. Feedback from operational users then drives new science and research needs, and the cycle continues.
- NASA will conduct a Senior Review to determine which current HSO missions NASA can continue to support
- Future missions of the NASA Heliophysics Program include the IRIS mission, the Radiation Belt Storm Probes, the Solar Orbiter Collaboration: Living with a Star (LWS). These NASA missions and the Space Environment Testbeds are the way to understand more about the Sun.
- The National Research Council Solar and Space Science Decadal Survey, which is anticipated to be complete by July 2012, will be a key document for NASA and NSWP science and technology planning.

Dr. Richard Behnke, Head, Geospace Section, National Science Foundation (NSF)

Dr. Behnke's research interests center on studies of the dynamics of the Earth's ionosphere using incoherent scatter radar techniques. Dr. Behnke joined the NSF in 1982. Presently, he heads the Geospace Section in the Division of Atmospheric and Geospace Sciences where he leads a Section that emphasizes forward-looking and transformative basic research in aeronomy, magnetospheric physics and solar physics. Dr. Behnke is a co-chair of the Committee for Space Weather of the NSWP.

The following are key points from Dr. Behnke's presentation:

- The NSF has played a pioneering role in the formation of the NSWP and works actively with the other NSWP partners (NSF, NASA, DOD, Department of Commerce [DOC], USGS, DOE, and Department of Transportation [DOT]).
- The NSF made significant contributions to the fundamental understanding of the space weather system.
- To demonstrate the complexity of space weather phenomena, Dr. Behnke showed an extended magnetic field-aligned plasma structure that formed just prior to the onset of a geomagnetic substorm, indicating the presence of wave-induced particle precipitation. Scientists are just now beginning to understand the presence and importance of plasma structures as an integral part/driver of wind-induced particle precipitation.
- The community is beginning to model the magnetic field in CME. As the model simulation shows, a CME is a massive burst of solar wind and magnetic fields rising above the solar corona.
- The Nation needs more people educated in space science (e.g., people seeking graduate and postdoctoral appointments). The NSF is involved in a faculty development program—an effort to facilitate tenure track for postdoctoral individuals. The NSF is also sponsoring graduate fellowships. The NSF has the Advanced Modular Incoherent Scatter Radar summer school in Alaska. The Center for Integrated Space Weather Modeling in Boulder, Colorado, has a summer school that concentrates solely on space weather.
- New projects in which the NSF is involved include the Radio Aurora Explorer, the Colorado Student Space Weather Experiment, and the CubeSat for Ions, Neutrals, Electrons, and Magnetic Fields.
- The NSF is supporting development of the Advanced Technology Solar Telescope. Telescope construction is to begin in the Spring/Summer of 2012.
- There will be a joint NSF/NASA Space Weather Modeling Competition this fiscal year. Total funds of $4 billion will be spent for this competition.

Dr. Arthur Charo, Senior Program Officer, Space Studies Board, National Research Council

Dr. Charo is the senior staff officer at the NRC supporting the work of the Space Studies Board's Committee on Solar and Space Physics and Committee on Earth Science and Applications from Space. Since joining the NRC in 1995, he has directed studies that

have resulted in over 30 reports, notably the first "NRC decadal survey for solar and space physics" (2002) and "Earth science and applications from space" (2007). Prior to joining the NRC, he pursued his interests in national security and arms control at Harvard University's Center for Science and International Affairs, where he was a fellow from 1985 to 1988. From 1988 to 1995, he worked as a senior analyst and study director in the International Security and Space Program in the Congressional Office of Technology Assessment (OTA).

The following are key points from Dr. Charo's Presentation:

- The NRC Decadal Survey in Solar and Space Physics should be available by mid-July 2012.
- Why undertake a Decadal Survey? The fundamental answer is that the survey facilitates planning, coordination, advocacy, and outreach.
- The first "Decadal Survey in Solar and Space Physics" report was issued in 2002.
- The current survey will (1) provide an overview of the science, (2) identify the most compelling science challenges that have arisen from recent advances and accomplishments, and (3) identify the highest priority scientific targets for the 2013-2022 interval.
- The survey has a Steering Committee (19 members) with representatives from across the space weather community.
- The last survey presented challenges. The most prominent challenge was developing a near real-time predictive capability for understanding and quantifying the impact on human activities of dynamical processes at the Sun, in the interplanetary medium, and in the Earth's magnetosphere and ionosphere.
- Due to the National Polar-orbiting Operational Environmental Satellite System program restructuring, there is less capability with respect to space weather.
- Fundamental needs for advancing our understanding of space weather include real-time upstream measurements of solar wind parameters, solar energetic particle intensities, and real-time detection of a CME.
- The Solar and Heliospheric Observatory, the Solar Terrestrial Relations Observatory, and the SDO are examples of NASA research missions that are being used for operations.
- There have been a number of space-weather-related documents that informed the current decadal survey (agency planning documents, the *National Space Weather Program Strategic Plan* (2010), and previous NRC studies).
- Funding continues to be a challenge. For example, NOAA did not receive the requested funding for the GPS Radio Occultation/COSMIC-2 mission.
- The way to do more with less money is to engage in data buys, new architectures, small satellites, and hosted payloads and to elevate the problems (e.g., to the Executive Office of the President).
- Dr. Charo noted that findings of the 2007 Earth Science Decadal survey could easily be applied to the Solar and Space Science Decadal Survey. That survey found that "there is a lack of clear agency responsibility for sustained research programs and the transitioning of proof-of-concept measurement into sustained

Session 4 Questions

- Dr. Louis Uccellini (NOAA/NCEP): Transitioning research to operations (R2O) continues to be the real "Valley of Death." The Space weather community can learn from the NASA/NOAA/DOD Joint Center for Satellite Data Assimilation by setting priorities for the most critical data. As a result, NCEP is now using the microwave data from the recently launched Suomi NPOESS Preparatory Program in operations.

- Mr. Titus Ledbetter (Space News): DSCOVR is planned to be launched on an unproven vehicle. Is there any concern about its reliability?
  - Answer from Dr. Kathy Sullivan: NOAA consults with its NASA partners. She was confident that sound decisions will be made.

- Mr. Titus Ledbetter (Space News): Does DOD recognize the importance of the DSCOVR mission?
  - Answer from Dr. Lewis: Yes.

- Mr. Peter Martinson (21st Century Science and Technology Magazine): Russia and China were not mentioned as partners. Is there any attempt to engage Russia and China? Do you know what their activities are and what they've been doing?
  - Answer from Dr. Uccellini: Through the auspices of the WMO, Russia and China are at the table in terms of observations and modeling.

- Dr. Steve Tracton (Capital Weather Gang): Given all the recent news about the NWS budget shortfalls, what is the potential impact on the space weather program?
  - Answer from Dr. Uccellini: The budget for space weather prediction is going up. We received extra funding for improved IT security as well as R2O projects. With the current budget, some of the activities might be delayed but not canceled.

- Dr. David Applegate (USGS): What is the awareness in the DOD about space weather?
  - Answer from Dr. Lewis: It's good because the impacts of space weather are real and can be seen.

- Mr. Nelson Jacobsen (Help Earth Foundation): With respect to commercial space flight, are there talks about risks and spreading the cost of (1) developing the equipment and (2) monitoring?
  - Answer from Dr. Uccellini: The community is setting requirements for data and provision of services. This is a high priority for the space weather community.

Note: Speaker and audience remarks are paraphrased and not to be used as quotations.

Session 5: Responding to New and Emerging Extreme Events

This session examined the challenges and opportunities in raising awareness and understanding of space weather impacts on daily life, security, the global economy, infrastructure, and business continuity. It highlighted the current means of providing space weather information to the public and examined the nature of public response to extreme environmental events.

Moderator: Dr. Robert E. O'Connor, Program Director, Decision, Risk and Management Sciences, Division of Social and Economic Sciences, Directorate of Social, Behavioral and Economic Sciences, National Science Foundation

Since 2001 Dr. Robert O'Connor has been directing the Decision, Risk and Management Sciences Program at the National Science Foundation (NSF). Dr. O'Connor represents the NSF on the National Climate Assessment and Development Advisory Committee. He also serves on the Subcommittee on Disaster Reduction of the National Science and Technology Council of the Executive Office of the President. Prior to coming to the NSF, Dr. O'Connor was a Professor of Political Science at the Pennsylvania State University where he also was part of the senior management team for the Center for Integrated Regional Assessment. The U.S. Department of Energy, U.S. Environmental Protection Agency, the National Oceanographic and Atmospheric Administration, and the National Science Foundation funded Dr. O'Connor's research into public perceptions of cumulative, uncertain long-term risks such as climate change.

Dr. O'Connor opened the session by noting that the NSF also funds basic sciences from anthropology, sociology, behavioral, and risk management. He praised the SWEF community's physical science involvement and progress and how this group uses the knowledge to make society more resilient to natural disasters.

Panelists:

Dr. Genene Fisher, Senior Advisor for Space Weather, National Weather Service, National Oceanic and Atmospheric Administration

Dr. Genene Fisher, Senior Advisor for Space Weather at the NOAA National Weather Service (NWS) is responsible for leading space weather policy and programmatic activities within NWS Headquarters. She currently serves as co-chair for the NSWP Committee on Space Weather. Prior to joining NOAA, Dr. Fisher spent ten years as a Senior Policy Fellow at the American Meteorological Society's Policy Program, where she focused on space weather policy issues and societal impacts. She worked closely with industry, including the GPS and aviation communities, on how to integrate space weather information into operations. She successfully expanded space weather activities within the AMS organization, resulting in the formation of the Space Weather STAC Committee and the annual Space Weather Conference.

The following are key points from Dr. Fisher's remarks:

Note: Speaker and audience remarks are paraphrased and not to be used as quotations.

- Dr. Fisher focused her talk on NWS activities that will help prepare the nation to respond to space weather events. Her presentation covered customers and service trends, improving operational services for a Weather Ready Nation, interagency activities, international collaborations, and education and outreach.
- The Space Weather Prediction Center (SWPC) subscription service has increased, jumping to 27,000 subscribers, with 50 million hits on the SWPC website just during March 2012.
- NOAA is committed to space weather by upgrading its operational product suite, providing critical new data sets, improving modeling capabilities, and enhancing its prediction testbeds operations.
- NWS contributes to Federal-level space weather activities by working with OSTP, DHS, FEMA, and international partners to put mitigation strategies in place that will better safeguard critical infrastructure from the impacts of severe space weather to include participation in table top exercises such as Secure Grid 2011.
- NWS has been very active in space weather education and outreach by activating the National Space Weather Portal and the WMO Space Weather Product Portal, developing space weather training module for NWS Weather Forecast Offices (WFO), engaging SWPC in social media outlets, overhauling the SWPC web page, and working the UCAR to develop a COMET space weather module.
- Dr. Fisher concluded by providing the audience with an overview of the new Unified National Space Weather Portal (http://www.swpc.noaa.gov/portal/) and encouraged participants to check it out.

Dr. Phil Evans, Government Services Director, United Kingdom Meteorological Office.

Dr. Evans has worked for the United Kingdom (UK) Meteorological (Met) Office since 1988. He initially worked in research and development on ground based remote sensing systems. Since then, he has held a number of roles including responsibility for Strategy and Planning, Business Development, Commercial and International relations and most recently as the Met Office's Chief Advisor to Government. Dr. Evans was responsible for all of the services the Met Office provides within the public sector from predictions of climate change advice on the spreading of airborne animal diseases to the 'free at the point of use' services provided to emergency responders and the general public.

The following are key points from Dr. Evan's remarks:

- Dr. Evans began will stating how his section, the Government Services Directorate, fits into the UK Met Office. He went on to note that the UK is probably not as vulnerable to space weather impacts as the US and as a consequence there has been limited awareness of the risks of space weather. However that has changed in the past two years and interest from the UK Government is growing strongly, but there is still limited public awareness. In the UK government, critical risk is managed in the national risk register, of which space weather was just added this year.

Note: Speaker and audience remarks are paraphrased and not to be used as quotations.

- By following President Obama's and Prime Minister Cameron's direction, the UK has progressed in terms of understanding the risks and how it intends to mitigate those risks. This resulted in US/UK workshops to research goals and roadmaps and infrastructure requirements. A third workshop on policy issues is scheduled for Jun 2012.
- The UK Meteorological Office and NOAA SWPC established an agreement to help develop a UK operational capability, increase operational resilience, improve usability of services, collaborate on coupling lower atmosphere/thermosphere/ionosphere/heliosphere, and share data and development of new forecast capabilities.
- The UK Met Office has made a decision to integrate and grow their relationship with the NOAA SWPC by training its forecasters on SWPC operations and establish 24/7 UK space weather operations that includes a daily SPWC forecaster telecon. The next step is to develop collaborations with UK academic partners.
- Dr. Evans then drew parallels between space weather and other environmental hazards, in particular, the 2010 Icelandic volcanic eruption.
- He concluded by providing lesson learned on better public and media communications to include: 1) focus on the impact of the hazard and not the hazard itself, 2) defend the credibility of the science, especially when the media or public doubts it, 3) know that the events may be interesting to us, but not to the public unless you explain the impacts to them, and 4) know that the public will validate information by looking at different sources.

Dr. Geoff Crowley, President/Chief Scientist, Atmospheric & Space Technology Research Associates (ASTRA) and Executive Committee, American Commercial Space Weather Association (ACSWA)

Dr. Geoff Crowley is the CEO and Chief Scientist for ASTRA LLC. Prior to founding ASTRA, Dr. Crowley worked in four large organizations—the National Center for Atmospheric Research, Air Force Research Laboratory, Applied Physics Laboratory, and Southwest Research Institute—where he performed fundamental research on various areas of space physics and space weather. He has published over 100 scientific articles on his research. He is best known for his work on the thermospheric neutral gas at high latitudes, including his discovery of the cellular structures that occur there, and his modeling, for the first time, of high density features in the cusp region. Dr. Crowley was a cofounder of ACSWA and currently serves on its Executive Committee.

The following are key points from Dr. Crowley's remarks:

- The majority of the space weather that users care about happens in the ionosphere, since electromagnetic signal degradation deprives communications, navigation, and surveillance system users.
- Dr. Crowley described some of the scientific and engineering capabilities of the ACSWA members, which include world-class capabilities that could help improve the national infrastructure and response to extreme events.

Note: Speaker and audience remarks are paraphrased and not to be used as quotations.

- Dr. Crowley reviewed the history of space weather to include how its growth has enabled a community of commercial space weather providers. The commercial providers offer various space weather services that extend from the Sun to Earth's atmosphere, including ionospheric and thermospheric effects that are of interest to operational systems. These commercial providers recently formed the ACSWA (website: www.acswa.us). It was founded in 2010 and has nine commercial organizations as members. They are providers of quality space weather data and services and develop operational space weather best practices. ACSWA represents the interests of commercial space weather providers, commercial space weather international arenas, and supports advisory services to government agencies.

Dr. Brenda Phillips, Professor, Center for the Study of Disasters and Extreme Events, Fire and Emergency Management Program (FEMP) Graduate Student Coordinator, Department of Political Science, Oklahoma State University

Brenda Phillips is a Professor at Oklahoma State University. She is the lead editor of *Social Vulnerability to Disasters* (CRC Press) and the lead researcher for *Effective Emergency Management: Making Improvements for Communities and People with Disabilities*, (National Council on Disability). Her textbooks include *Introduction to Emergency Management* and *Disaster Recovery*, and her published research can be found in a wide variety of scientific journals. Dr. Phillips teaches courses on high risk populations, community relations, disaster recovery and mitigation, research methods, and international relief in the Fire and Emergency Management Program at Oklahoma State University.

The following are key points from Dr. Phillip's remarks:

- Emergency managers are translators of information, which is a complicated process. Disaster response is not constantly on people's minds, even if they reside in a disaster prone area. There are just too many everyday distracters.
- Dr. Phillips described the process of how people receive a warning by first processing it and then responding to it. Although the process is complicated, once they receive a warning, they need to be able to understand it, find out if it is credible, confirm it with other sources, personalize it, decide if taking action is feasible, and then finally, actually take action.
- Barriers people encounter before taking action in response to a warning include the following:
  - Are they socially or geographically isolated (off the grid)?
  - Are they a new mother or elderly and have limited social networks?
  - Is there a language barrier (warnings aren't given in Chinese or Spanish) or are do they have a cognitive disability?
  - Is the warning credible (whom do I know that can confirm it, like a neighbor)?
  - Does the warning apply to my situation (is it really going to affect my house)?
  - If they do take action, what will it cost them in the short term or long term (can we afford it)?

Note: Speaker and audience remarks are paraphrased and not to be used as quotations.

- Does the message say how to take action (are they responding to the geomagnetic storm or to the blackout)?
- It is important to personalize the message with user-friendly material and familiar terms. Personalize with possible actions to take (this is important!). Get the message or warning out in multiple ways (include social media). Consider using well known local celebrities to send the message. The public will respond to a Heisman Award winner from their area, their local TV Weather Broadcaster, or their local emergency manager. However, be sure the senders are competent, objective, consistent, honest, and trustworthy, but most importantly, they must be familiar to the public.

Session 5 Question:

- Dr. Robert E. O'Connor (National Science Foundation): When you get a space weather warning, what is the public expected to do?
  - Answer: The warnings are not designed for the general public to take action, since the most severe impact will be to the infrastructure operators (the audience concurred and offered similar responses).
  - Follow-on question: What does a power company actually do? (unknown questioner)
  - Answer: It is ultimately up to infrastructure operators or companies to decide whether they will shut down the grid in order to prevent widespread damage. (speaker unknown)

Session 6: Summary and Wrap-Up

Forum Wrap-up / Take Away

Dr. Paul Try, Senior Vice President and Program Manager, Science and Technology Corporation

Dr. Paul D. Try is Senior Vice President and Program Manager at Science and Technology Corporation (STC), and recent past Director of the International Global Energy and Water Cycle Experiment (GEWEX) Project Office (IGPO) of the World Climate Research Programme (WCRP). He received his Ph.D. in atmospheric sciences from the University of Washington with specialization in radiative transfer/remote sensing. Dr. Try has over 35 years as a professional in environmental sciences. He has extensive expertise in high level multi-agency research management as well as in atmospheric physics, modeling and simulation, remote sensors (satellite and radar), atmospheric propagation, and support to military satellite and precision guided munitions employment. Dr. Try retired from the US Air Force as a colonel. He is a fellow of the American Meteorological Society (AMS) and a past president of the AMS (1996-97), and he has recently served on four committees of the National Academy of Sciences.

The following are key points from Dr. Paul Try's remarks:

- As society becomes more technology-dependent, it will become more vulnerable to space weather impacts.
- From what the SWEF participants heard today, it may be that the accumulation of smaller space weather events has a greater impact than the extreme events, which could aggregate to as much as $30 billion a year in economic impacts. The public and the space weather community may not be aware of this.
- Greater outreach and education is still needed. As the participants heard today, the space weather threat is still not well recognized by the general public. The space weather community needs to articulate this message better, including explaining clearly the impacts of the smaller disturbances and how they affect the average citizen.
- An audience comment made during the forum raised these kinds of concerns. What happens if a GPS signal is degraded and a train operator does not know about the degradation, and therefore does not know the train position system isn't functioning properly but carries on as if it were?
- Supported by today's discussions and the JASON study presentation, a critical need still exists for risk management and mitigation efforts on the electrical grid. Space weather effects on the electric power grid must be determined on a system-wide basis. Currently, there is high uncertainty in vulnerability and the magnitude of the effects. Speakers believed mitigation options could be affordable.
- Dr. Try also mentioned an earlier comment that NOAA may address the need for solar wind monitoring at L1 through a commercial data buy He considered this to be worrisome. Who is going to be producing the data to buy, and will that provider be reliable when needed?
- He stated that interagency coordination is always difficult to accomplish. Support and interest from OSTP or the Office of Management and Budget help the process.
- He noted that Dr. Lewis' earlier comment that there needs to be even more emphasis on partnerships since all the partner agencies are facing budget cutbacks. Public-private partnerships also need improvement.
- Partnerships are critical, which is why the efforts of the Unified National Space Weather capability, along with those of OFCM and the NSWP council, are so valuable. Dr. Try emphasized that the NSWP members and partners must continue to work hard to sustain and improve interagency coordination.

Session 6 Question:

- Question: Perverse incentives within the utility industry make a decision to shut down transformers, given a warning, very difficult. How can these decisions be better made or assisted?
  - Answer: The key is to communicate the level of uncertainty in the warning and assign a percentage to the risk so that industry decision makers can make a reasoned decision more easily.

Note: Speaker and audience remarks are paraphrased and not to be used as quotations.

Closing Plenary Speaker

The Honorable Trent Franks, United States Representative (R-Arizona)

Congressman Trent Franks is a conservative Reagan Republican, and he has spent most of his life working on children's issues. He is a former member of the Arizona House of Representatives. While in the U.S. House of Representatives, he served as Vice-Chairman of the House Commerce Committee and Chairman of the House Sub-Committee on Child Protection and Family Preservation. He has served on the Budget Committee, the Small Business Committee, and now serves on the Armed services Committee and the Judiciary Committee, and is now Chairman of the Constitution Subcommittee. He is a member of the Republican Study Committee, the House Working Group on Judicial Accountability, House Working Group on Waste, Fraud and Abuse, the Congressional Hispanic Conference, the Liberty Caucus, the DUI Caucus, the Human Rights Caucus, the India Caucus, the Refugee Caucus, and the Education Freedom Caucus.

The following are key points from Congressman Franks' remarks:

- Mr. Franks commented that he has come to believe that an electromagnetic pulse (EMP) is potentially the most significant of our short-term national security threats, and he considers the work of the audience to be significant because, unlike others, this audience understands the profound danger of either a CME from the sun or a weaponized EMP.
- He commented that he was struck by the DOD testimony that this could be the one threat that could defeat the US military since the military relies on the civilian electrical grid for 99.9% of its electricity. On the other hand, there is no way for the military to control the civilian electrical supply so that it will stay constant and functioning.
- He told the forum participants that they are the ones that monitor, measure, and provide space weather warnings, which makes them a sort of unsung hero on the invisible front lines of America's security. He commented that his office is committed to doing what it can to make the work of the space weather community known, as well as to help people understand how significant it is.
- He stated that it is important to harden the electrical grid so that there are responsive hardware-based solutions, because statistics show that warnings will be wrong 2 out of 3 times. Infrastructure operators and private companies will have to choose to either shut the grid down, which may lead to some deaths, or not shut it down and risk damaging the electric grid, which potentially could lead to even more deaths.
- He commented that we need a national standard and need to regulate as necessary, so that our grid is hardened and we present a less inviting target to terrorists. The Sun doesn't care. It will do what it is going to do, but we need to be prepared, and that is what this community is all about.
- In concluding, Mr. Franks said he hopes that, if someday this event were to occur, it will have such a small impact that only a few of us will recognize the disaster

Comment from Dr. Steve Tracton (*The Washington Post*, Capital Weather Gang):
Speaking from his personal opinion and not that of the *Washington Post*, Dr. Tracton said that he was unhappy that the speaker was using this forum to promote a political agenda at a scientific meeting since the effects of an EMP are radically different from those of a geomagnetic storm.
Congressman Franks replied that he had mentioned in his speech that the two are separated and clearly different. Furthermore, he is called to protect our national security and the American people, and he apologizes to no one for that.

Closing Remarks

Mr. Samuel P. Williamson, Federal Coordinator for Meteorology

Mr. Williamson closed the forum by reviewing the forum objectives and letting the audience know that the presentations and conference summary would be posted on the forum web site. He then concluded by thanking the speakers and participants.

Note: Speaker and audience remarks are paraphrased and not to be used as quotations.