Millennium Hotel – Boulder, Colorado
April 8 – 11, 2014

Key components of our global infrastructure and economy are at risk from space weather. Modern society depends on reliable access to advanced technologies such as GPS, satellite communications, and a stable energy distribution network. No other natural occurring phenomenon has the potential to be so far reaching in its impact to mankind. Consequently, space weather mitigation strategies are being addressed by many nations. Meeting the space weather needs is beyond the capability of any single agency or country, and we recognize that society is best served by the ability of all nations and all sectors - public, private, and academic to work together as partners to meet our common goals to plan, prepare and respond to space weather storms.

The 2014 Space Weather Workshop will bring together the diverse elements of the space weather community. Representatives from research centers, the commercial space weather services sector, international organizations, and several federal government agencies will participate in a variety of sessions relevant to space weather. Topics include:

- The economic effects of geomagnetic storms on electric utilities, commercial aviation services and satellite navigation systems such as GPS.
- The international coordination of space weather activities from space weather service organizations around the globe.
- Advances in space weather modeling, and the emerging needs of the operational and forecasting community.
- The development and implementation of spacecraft and instruments of value for both research and operations.
- Recent research regarding solar cycles past and present and long term trends in space weather.

In addition to the plenary sessions there will be poster sessions and a roundtable discussion about growing the space weather enterprise. The roundtable consists of a panel represented by distinguished members of the public and private sectors. The Wednesday evening banquet will be held at the University of Colorado, Folsom Field Stadium Club and feature Fran Bagenal, Professor of Astrophysical and Planetary Sciences, Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, presenting "A Romp Through the Outer Solar System."

Space Weather Workshop 2014 is co-sponsored by the NOAA Space Weather Prediction Center, the NSF Division of Atmospheric and Geospace Sciences, and the NASA Heliophysics Division.

http://www.spaceweather.gov/sww

2014 Space Weather Workshop Abstracts
Millennium Hotel Ballroom

Tuesday, April 8

8:30 **Conference Welcome**
William Murtagh, NOAA/SWPC

8:40 **Space Weather Morning Forecast**
SWPC Space Weather Forecasting Office

8:50 **State of the Space Weather Prediction Center**
Brent Gordon, NOAA/SWPC

9:10 **Solar Cycle – It's Here, Finally**
Doug Biesecker, NOAA/SWPC

Solar cycle 24 threatened to fizzle out early, but late 2013 and early 2014 have brought renewed promise. There was an initial peak in February, 2012 but we now know that solar max will occur no earlier than September, 2013. This is consistent with the forecast that was made 5 years ago, or so I hope to show. In 2009, the Solar Cycle 24 Prediction Panel predicted that solar maximum would reach a peak of 90 in May, 2013. However, it is clear that anything the prediction got correct relied as much on luck as on forecasting skill. What is clear is that the northern and southern hemispheres of the Sun are significantly out of phase. That the Southern hemisphere peaked at a higher sunspot number and later than the Northern hemisphere is the reason solar maximum is occurring now, and not in early 2012. We will also show how activity in this cycle stacks up against previous cycles and speculate on how the rest of the cycle will play out.

9:30 – 10:30 **Geomagnetic Disturbances and the Electric Power Grid**
Chair: William Murtagh, NOAA/SWPC

9:30 **The Major Solar Eruptive Event in July 2012: Defining Extreme Space Weather Scenarios**
Daniel Baker, University of Colorado, Boulder

A key goal for the space weather community is to define extreme conditions that might plausibly afflict human technology. On 23 July 2012 solar active region 1520 (~133°W heliographic longitude) gave rise to a powerful coronal mass ejection (CME) with an initial speed that was determined to be >3000 km/s. The eruption was directed away from Earth toward 144°W longitude. STEREO-A sensors detected the CME arrival only about 18 hours later and made in situ measurements of the solar wind and interplanetary magnetic field. We have posed the question of what would have happened if this huge interplanetary event had been Earthward directed. Using a well-proven geomagnetic storm forecast model, we find that the 23-24 July event would certainly have produced a geomagnetic storm that was comparable to the largest events of the 20th Century (Dst ~ -500nT). Using plausible assumptions about seasonal and time-of-day orientation of the Earth's magnetic dipole, the most extreme modeled value of storm-time disturbance would have been DST=-1182nT. This is probably considerably larger than the famous Carrington storm of 1859. This finding has far reaching implications because it demonstrates that extreme space weather conditions such as those during March of 1989 or September of 1859 can happen even during a modest solar activity such as the one presently underway. We argue that this extreme event should immediately be employed by the space weather community to model severe space weather effects on technological systems such as the electric power grid.

9:50 **North American Electric Reliability Corporation (NERC) Geomagnetic Storm (GMD) Standards**
Frank Koza, PJM Interconnection

NERC is in the process of preparing mandatory standards that will require electric industry entities to (1) have operating procedures to deal with severe GMD events and (2) to perform periodic assessments of the transmission system to be able to withstand Benchmark GMD event(s) without causing a wide area blackout, voltage collapse, or uncontrolled cascading outages. A summary of the proposed standards will be presented.

10:10 **Establishing the Geomagnetic Disturbance Benchmark Event for Evaluation of the Space Weather Hazard on Power Grids**
Antti Pulkkinen, NASA

The awareness about potential major impact geomagnetically induced currents (GIC) can have on the North American high-voltage power transmission system has prompted Federal Energy Regulatory Commission (FERC) to launch a geomagnetic disturbances (GMD) standards drafting process. The goals of the GMD standards are to quantify and mitigate the GMD hazard on the North American grid. North American Electric Reliability Corporation's (NERC) is coordinating the standards drafting process that is now entering Phase II involving quantification of the impact GIC can have on individual parts of the North American grid. As a part of the Phase II GMD standards drafting process, substantial effort has been made for generating benchmark GMD scenarios. These scenarios that quantify extreme geoelectric field magnitudes and temporal waveforms of the field fluctuations are the foundation for subsequent engineering and impacts analyses. The engineering analyses will include the transmission system voltage stability and transformer heating assessments. The work on the GMD scenarios has been a major collaboration between a number of international entities involved in GMD research and transmission system operations. We will discuss in this paper the key elements of the benchmark GMD generation process and show the latest results from our work on the topic.

10:30 **Break**

10:50 – 11:50 **Geomagnetic Disturbances and the Electric Power Grid, Continued**
Chair: William Murtagh, NOAA/SWPC

10:50 **Defense Threat Reduction Agency (DTRA) Magnetohydrodynamic (MHD)-E3 Phase IVB: Measured Harmonic Response of Power Grid Transformers Subjected to Severe E3/GIC Currents**
Amber Walker, Scientific Applications & Research Associates (SARA)

This presentation provides an overview of the harmonic responses measured during the DTRA Phase IVB power grid transformer test conducted at the Idaho National Laboratory (INL) September 2012. These tests are the conclusion of the fourth phase in a series designed to explore the primary and secondary threats associated with the E3 (late-time) part of a high altitude nuclear scenario.

11:10 **Progress and Challenges in Specifying Geomagnetic Activity for the Electrical Power Grid**
Chris Balch, NOAA/SWPC

It has been long known that Geomagnetic Disturbances lead to geomagnetically induced currents (GIC) in Electrical Power Systems and these in turn can lead to difficulties in the operation of the grid. More recently, efforts to model the physical processes involved has led to a growing appreciation for the need of to know the Geoelectric Field. The calculation of the Geoelectric field consists of two key components: the external driving current systems in the ionosphere and magnetosphere which are created by space weather, and the earth conductivity which controls the response of natural currents below the Earth's surface and significantly affects the resultant Geoelectric field that is applied to the power grid. In many cases, the Earth conductivity can be very complex and is not always well known.

In this talk I will explain a technique to derive a normalized Geoelectric field which incorporates the contribution of the space weather drivers and can be used as input to evolving conductivity models as a way to estimate the Geoelectric field in a specific location.

11:30 FEMA and Space Weather
L.A. Lewis, FEMA

If a space weather event will likely… Directly or indirectly cause or exacerbate a major disaster or emergency Interfere with or seriously degrade FEMA's response & recovery capability Create political, public, or media pressure/expectation for FEMA action Principal responsibility is capability to provide timely space situational awareness across the emergency interagency with our partnership with NOAA Space Weather Prediction Center and international partners as required. Have an ability to answer the "so what" questions for our state and local partners and be able to discuss or explain the potential for high impacts as a result of a space weather event. A portion of the FEMA response to this type of event is detailed in the planned Power Outage Incident Annex (POIA) to the Federal Interagency Operations Plan for both Response and Recovery. The POIA will detail how the Federal government delivers core capabilities to respond to and recover from the impacts of a significant power outage incident. The requirement exists to develop the POIA to provide the level of fidelity necessary to adequately detail the Federal actions of the Response and Recovery mission areas during a significant disruption to the national bulk power system. The POIA will address appropriate Federal authorities and coordination mechanisms to among the Federal interagency, SLTT, and private sector entities. The end result will be a POIA that supports all other incident annexes of the FIOPs and outlines the appropriate response and recovery procedures across a wide spectrum of incidents.

11:50 – 12:00 Aviation and Space Weather
Chair: Robert Rutledge, NOAA/SWPC

11:50 Space Weather Ballooning
Tony Phillips, Spaceweather.com

Supported in part by spaceweather.com, high school students in California have developed a "Rapid Response Space Weather Payload" for suborbital research helium balloons. The payload, which is relatively inexpensive and easy to assemble, can be quickly deployed by a small launch crew to measure the effect of solar and geomagnetic storms on Earth's atmosphere. Sensors include a GPS altimeter, a radiation counter, a cryogenic thermometer and, soon, an ozonesonde. Five test flights to the stratosphere since Oct. 2013 have validated our approach, which is now ready for sharing with the space weather community.

12:00 Lunch

1:00 - 2:30 Poster Session – Operational Space Weather Services and Analysis Tools and Magnetosphere Research and Applications

2:30 - 5:20 Aviation and Space Weather
Chair: Robert Rutledge, NOAA/SWPC

2:30 An Epidemiologic View of Low Dose Ionizing Radiation and Cancer: Putting Risk into Perspective
Alice Sigurdson, National Cancer Institute

Elevated risk of cancer and other radiation-related health outcomes from exposure to cosmic radiation are concerns of airline workers and the general public, who are exposed to 1-3 µSv per hour depending on the flight. But the magnitude of the risk is difficult to estimate and problematic to communicate. One of the primary difficulties involves characterizing the dose-response at low doses, although studies in humans suggest risk is linear with dose below 150 mSv. Studies of low dose radiation in

children, who are more sensitive to radiation effects, are suggestive of linearity below about 50 mSv. To directly study cancer risk below about 10 mSv in adults would require impracticably large sample sizes, bearing in mind that average natural background and medical radiation exposure to the US public is about 6 mSv per year (3 mSv for each based on estimates from 2006). One approach has been to model excess risk at low doses using several assumptions about gender, age at exposure, risk transfer from one population group to another, type of radiation, and dose rate. Another has been to use intermediate markers of potential cancer risk, such as chromosome translocations. Despite the limitations of epidemiologic studies to quantify radiation-related health outcomes in flight crew, some perspective in a general sense can be gained by comparing risks from other types of radiation exposure. Estimates of effective dose from computed tomography (CT) scans vary from about 2-8 mSv per examination compared to approximately 0.2-6 mSv annually to air crew flying between 600 to 1000 hours per year. In a recent study of cancer risk after CT in persons under age 18, on average, one excess leukemia and one excess brain tumor would be expected in the 10 years following 10,000 head CT scans. Airline pilot and flight attendant cohorts have been followed for cancer and other health risks in the US and Europe. While some air crew studies have suggested increased risks for breast cancer, melanoma and non-melanoma skin cancer, more recent studies suggest that lifestyle factors may explain the observed associations. While the exact health risks at low doses may never be known with certainty, when possible, prudent steps should be undertaken to reduce unnecessary exposure to workers and the public.

3:00 **Aircrew Dosimetry: Monitoring and Operational Services in France**
Nicole Vilmer, Observatoire de Paris

3:20 **WASAVIES: Warning System for Aviation Exposure to Solar Energetic Particles**
Yuki Kubo, National Institute of Information and Communications Technology (NICT)

Solar flares and coronal mass ejections often produce solar energetic particles (SEPs) in the heliosphere. A fraction of SEPs is sometimes energetic enough to reach the terrestrial atmosphere and the flux is sometimes large enough to cause a ground level enhancement (GLE) as measured by ground-based neutron monitors as well as a significant radiation dose of aircrews at the top of the troposphere. Although the total dose of aircrews is dominated by galactic cosmic rays, the dose rate is higher during the several hours of GLE. As a short-term space weather forecast, it is therefore important to predict the time variation of the dose rate at flight altitude as soon as possible when GLEs occur. In order to inform the situation of such a space radiation hazard to aircrews, a physics-based forward model has been developed, which is called WASAVIES (WArning System for AVIation Exposure to Solar energetic particles). This model is based on the numerical simulation of SEP transport in the heliosphere and of the air shower produced by nuclear reactions between SEPs and terrestrial atmosphere. WASAVIES gives the fastest and simplest way to predict the time profile of dose rate during GLE. We introduce present status of WASAVIES project in this presentation.

3:40 **Progress Towards Maps of Ionizing Radiation at Altitude (MIRA): The new Civil Aeromedical Research Institute (CARI)-7 and Enhanced Solar Radiation Alert (ESRA)**
Kyle Copeland, FAA

The FAA has separate models for estimating aircrew exposures to galactic cosmic radiation and solar cosmic radiation. Improving the model for galactic cosmic radiation, call the CARI program, has been the main impetus of research in recent years. Nuclear shower data generated using MCNPX for the next generation CARI program (CARI-7) will be used to improve the FAA Solar Radiation Alert System. When these improvements are in place, a new program called MIRA (Maps of Ionizing Radiation at Altitude) is envisioned which combines the outputs of the two models to generate now-cast world maps based on GOES satellite, kp index, and ground level neutron monitor data.

4:00 **Break**

4:20 **A New Space Weather Index for Aviation**
Matthias Meier, German Aerospace Center (DLR)

Solar Particle Events (SPE) can temporarily produce significant contributions to the radiation exposures at aviation altitudes. This effect has been a matter of concern for many years. After the Halloween storms several airlines began to implement mitigation measures such as rerouting and lowering flight altitudes triggered by alerts on the NOAA S-scale for solar radiation storms. These alerts are based on the integral proton flux above 10 MeV measured aboard the corresponding GOES-satellite which is operated outside the Earth's atmosphere in a geosynchronous orbit. This integral proton flux has, however, been proved to be an insufficient parameter for the application to the radiation field at aviation altitudes without an accompanying analysis of the shape of the energy spectrum due to the neglect of the shielding effect of the upper atmosphere. Consequently, false alarms could not be avoided. Since mitigating measures can be quite cost-intensive, there has been a demand for appropriate space weather information among responsible airline managers for about a decade. Against this background, we propose the introduction of a new Space Weather index D, which is based on dose rates caused by solar protons at aviation altitudes during solar radiation storms, as a relevant parameter for the assessment of their contribution to the corresponding radiation exposure.

4:40 **Health Standards for Long Duration and Exploration Spaceflight: Ethics Principles, Responsibilities, and Decision Framework**
Ron Turner, Analytic Services Inc (ANSER)

NASA is in the process of planning for exploration class missions of long duration and beyond low Earth orbit (LEO). Current health standards may be hard to meet in many of these missions. A committee of the National Research Council, Institute of Medicine (IOM) conducted a study to examine policy and ethical issues relevant to crew health standards for these missions. The committee considered the application of existing health standards and the potential development of a new set of standards for missions beyond LEO. These standards would address potential hazardous exposures and working conditions that are uncertain, unknown or that go beyond current NASA risk limits. NASA is looking in particular for a framework of ethical and policy principles that can help guide decision-making associated with implementing health standards for exploration class space missions when existing standards cannot be fully met, or the level of knowledge of a given condition is sufficiently limited that an adequate standard cannot be developed, for the mission. This presentation will discuss the findings and recommendations of the committee.

5:00 **Increasing Biological Hazards from Solar Energetic Particles and Galactic Cosmic Rays**
Nathan Schwadron, University of New Hampshire

The Earth-Moon-Mars Radiation Environment Module has successfully exploited space weather data to project radiation hazards through the inner heliosphere at Earth, the Moon, Mars and out to ~5 AU. The Lunar Reconnaissance Observatory (LRO) Cosmic Ray Telescope for the Effects of Radiation (CRaTER) has made direct measurements of radiation at the Moon enabling in-depth studies of radiation interactions with tissue-equivalent plastic. The CRaTER project has led to innovation of new techniques for measuring and quantifying the full spectrum of radiation interactions with the Dose-Spectra from Energetic particles and Neutrons (DoSEN) instrument. Modeling in work with the NSF Sun-2-Ice project and the NASA Corona-Solar Wind Energetic Particle Acceleration (C-SWEPA) Projects is providing understanding of the link between coronal mass ejections and prompt SEPs. The Sun and solar wind are currently exhibiting extremely low densities and magnetic field strengths, representing states that have never been observed during the space age. The highly abnormal solar activity has caused the longest solar minimum between cycles 23 and 24 observed in over 80 years and continues into the unusually small solar maximum of cycle 24. As a result of the remarkably weak solar activity, we have also observed the highest fluxes of galactic cosmic rays seen in the space age, and relatively small solar energetic particle events. We examine the implications of these highly

unusual solar conditions for space exploration and show that radiation remains a significant and worsening factor.

5:20 End of Session

Wednesday, April 9

8:30-8:40 **Space Weather Morning Forecast**
SWPC Space Weather Forecasting Office

8:40-10:10 **Commercial Space Weather Interest Group (CSWIG)/**
American Commercial Space Weather Association (ACSWA) Roundtable Session:
Growing the Space Weather Enterprise

Keynote Speaker:
Dr. Conrad C. Lautenbacher, Jr., Chief Executive Officer, GeoOptics, Inc.

Growing the Space Weather Enterprise: Roles and Contributions

Features Speakers**:**

Mr. William Murtagh, Program Coordinator, NOAA Space Weather Prediction Center (SWPC)

The View from SWPC: Utilizing the Diversity of the Commercial Space Weather Industry

Dr. Tamara L. Dickinson, Principal Assistant Director for Environment and Energy, Assistant Director for Disaster Resilience and Space Science, Office of Science and Technology Policy (OSTP), Executive Office of the President

The View from OSTP: Building and Coordinating the National Space Weather Strategy

Moderator and Organizer**:** Dr. Devrie Intriligator, Director, Space Plasma Laboratory, Carmel Research Center, Inc.

10:10 **Break**

10:30 - 12:10 **Agency Activities**
Chair: Brent Gordon, NOAA/SWPC

10:30 **Space Weather Research at the National Science Foundation**
Richard Behnke, National Science Foundation

10:50 **NASA Heliophysics Division**
David Chenette, NASA

11:10 **United States Air Force Weather Agency**
Colonel David Bacot, USAF

11:30 **National Weather Service**
William Lapenta, NOAA/NWS/NCEP

11:50 **National Environmental Satellite, Data, and Information Service (NESDIS)**
Patricia Mulligan, NOAA/NESDIS

12:10 **Lunch**

1:00 - 3:00 Poster Session - Solar and Interplanetary Research and Applications

3:00–3:20 Special Presentation

3:00 Solar Terrestrial Relations Observatory (STEREO) as a "Planetary Hazards" Mission
Madhulika Guhathakurta, NASA

NASA's twin STEREO probes, launched in 2006, have advanced the art and science of space weather forecasting more than any other spacecraft or solar observatory. By surrounding the sun, they provide previously-impossible early warnings of threats approaching Earth from the solar far side. They have also revealed the 3D shape and inner structure of CMEs—massive solar storms that can trigger geomagnetic storms when they collide with Earth. This sharply improves the ability of forecasters to anticipate the timing and severity of such events. Moreover, the unique capability of STEREO to track CMEs in three dimensions allows forecasters to make predictions for other planets, giving rise to the possibility of interplanetary space weather forecasting too. STEREO is perhaps the only NASA mission for which "planetary hazards" refers to more than one world. The STEREO probes also hold great and, in some cases latent, promise for the study of comets and potentially hazardous asteroids.

3:20 - 5:00 Space Weather Impacts: An Insurance Industry Perspective
Chair: Jason Reeves, Zelle Hofmann

The insurance panel session will review the impact of space weather on insurance and reinsurance. Insurance provides business and society an efficient method of transferring and sharing risk. Insurers invest in modelling, risk management, wording and pricing mechanisms that measure traditional and emerging risks. There is an obvious overlap between the concerns of insurers and the governmental entities who are addressing the challenges of space weather.

Jason Reeves is an English solicitor and a Texas attorney based in Zelle Hofmann's London office. He will provide some key background on insurance and reinsurance. Reto Schneider is Head of Swiss Re's Emerging Risk Management team in Zurich and has a special focus on space weather. Emma Rio is a Vice President and is a Senior Underwriter for Swiss Re's Property Treaty (reinsurance) team in London. Space weather is a specialist project she has embraced in addition to her responsibilities as an underwriter. David Wade is a leading underwriter at Atrium, a Lloyd's syndicate in London. He underwrites satellites and is routinely involved in assessing the risks of space weather on his portfolio. Each of the panel members speaks regularly on space weather in an insurance context.

The panelists will provide a 360 degree (re)insurance view of space weather: the emerging risk perspective; the underwriting perspective; and the claims perspective. Any complete discussion of space weather must involve an industry that is dedicated to understanding risk.

5:00 End of Session

Thursday, April 10

8:30 - 8:40 **Space Weather Morning Forecast**
SWPC Space Weather Forecasting Office

8:40 - 10:40 **International Coordination of Space Weather Activities**
Chair: Terry Onsager, NOAA/SWPC

8:40 **A COSPAR/International Living With a Star (ILWS) Roadmap Towards Advanced Space Weather Science to Protect Society's Technological Infrastructure**
Karel Schrijver, Lockheed Martin

As mankind’s technological capabilities grow, society constructs a rapidly deepening insight into the workings of the universe at large, being guided by exploring space near to our home. But at the same time our societal dependence on technology increases and with that comes a growing appreciation of the challenges presented by the phenomena that occur in that space around our home planet. The complexity of the coupled Sun-Earth system, the sparseness by which it can be covered by remote-sensing and in-situ instrumentation, and the costs of the required observational and computational infrastructure warrant a well-planned and well-coordinated approach with cost-efficient solutions. COSPAR and the International Living With a Star program tasked an international team with the development of a roadmap with the goal of demonstrably improving our observational capabilities, scientific understanding, and the ability to forecast. With the team at a midpoint in its overall exercise, this presentation summarizes its charge, maps out its progress, and invites input from the space weather user community. The team's website (with its membership) is at http://www.lmsal.com/~schryver/COSPARrm.

9:00 **WMO's Role in the Development of Space Weather Service Delivery Requirements for International Aviation**
Ian Lisk, UK Met Office

9:20 **WMO and Coordination Group for Meteorological Satellites (CGMS) Involvement in Space Weather**
Jerome Lafeuille, WMO Space Programme

Over the past four years, the World Meteorological Organization (WMO) has initiated an effort aiming to support the coordination and improvement of operational space weather monitoring and forecasting services, in close partnership with the International Space Environment Service (ISES). Activities currently include a review of observation needs and capabilities, data exchange, product delivery, and services to users. In a first step, specific attention is paid to two user areas: services to aviation as part of the WMO relationship with ICAO, and preparedness to severe space weather events in the broader context of Disaster Risk Reduction. In parallel, WMO is working with the Coordination Group for Meteorological Satellites (CGMS) with a view to engage CGMS satellite operators in the planning, implementation, and technical coordination of operational space-based observation capabilities for space weather. It is anticipated that the longstanding experience of international coordination of meteorological and climate activities in the framework of WMO and CGMS will help the space weather community to evolve to a fully operational, mature stage for the benefit of the global community.

9:40 **Space Weather Initiatives at the UN Committee on the Peaceful Uses of Outer Space**
Mangala Sharma, U.S. Department of State

The UN Committee on the Peaceful Uses of Outer Space (COPUOS) supports several initiatives related to space weather. Among them are the space weather agenda item initiated in 2013, the International Space Weather Initiative (that followed on from the International Heliophysical Year),

and space weather guidelines to enhance the long-term sustainability of outer space activities. This presentation provides a broad overview of these activities, focusing the role of COPUOS in promoting international cooperation in space weather research, services, capacity building, and societal resilience against space weather hazards.

10:00 **New International Space Environment Service (ISES) Website and Forecaster Discussion Tools**
Sunhak Hong, Korean Space Weather Center

To improve outreach to worldwide users of space weather information and to enhance communication among ISES members, the ISES website has been renewed. It has been open to the public since August, 2013 (www.spaceweather.org) with a new design and new content. The most notable change is that discussion pages have been added, which enable information sharing among ISES members. In this menu, the "Latest Forecasts" page provides a forecast portal of space weather by adopting new technology which directly brings each RWC's forecast to the ISES site. The "Space Weather Discussions" page provides a Social Network Service (SNS) based upon a bulletin board to discuss specific topics for space weather among ISES members. The "Enlil Discussions" page gives results from the Enlil model and analyses of the results by USA(SWPC), Australia(IPS), Korea(KSWC) and other partners. It is expected that this new ISES website will be helpful to share information and to inform the public of space weather.

10:20 **Advanced Forecast For Ensuring Communications Through Space (AFFECTS)- A Multi-Institution Research Project to Mitigate Space Weather Hazards**
Jens Berdermann, German Aerospace Center (DLR)

In the EU FP7 project AFFECTS (Advanced Forecast For Ensuring Communication Through Space, http://www.affects-fp7.eu/), European and US scientists have developed an prototype space weather warning system to safeguard the operation of telecommunication and navigation systems on Earth to the threat of solar storms. The AFFECTS consortium is a prime example for an international research collaboration, where institutions and enterprises in Germany, Belgium, Norway, Ukraine and the United States share data and expertise in order to treat the different aspects of hazardous space weather events. In the presentation we show scientific results as well as the state of the art space weather products developed within AFFECTS.

10:40 **Break**

11:00 - 12:00 **International Coordination of Space Weather Activities, Continued**
Chair: Terry Onsager, NOAA/SWPC

11:00 **Activities Related to Space-Weather Impact on Critical Infrastructures at the EC's Joint Research Centre**
Elisabeth Krausmann, European Commission

The JRC collaborates actively with international partners in assessing the risk of space-weather impact on critical infrastructures. In particular, it aims at understanding the vulnerability of the European power grid to severe space weather as a starting point for ripple effects caused by interdependencies with other types of critical infrastructures. In addition, the JRC carries out research on assessing the effects of ionospheric scintillation on GPS signal propagation. This presentation will give an overview of the findings of the space-weather and power grids workshop co-organised in October 2013 by the JRC, the Swedish Civil Contingencies Agency, and NOAA's Space Weather Prediction Centre, with the contribution of the UK Civil Contingencies Secretariat. The workshop aimed at launching a dialogue on the topic to encourage authorities, regulators and operators in Europe and North America to learn from each other. The event was attended by 50 representatives from European and North American power-grid operators, regulators, emergency-response organisers, space-weather experts,

academia, the European Space Agency and the European Commission. It addressed space-weather phenomena and the dynamics of their impact on the grid, experiences with prediction and now-casting in the USA and in Europe, risk assessment and preparedness, as well as policy implications arising from increased awareness of the space-weather hazard. The presentation will also give an update of the JRC's work on the impact of ionospheric scintillation on navigation signal propagation. Work is in progress to analyse ionospheric scintillation observations on multiple GNSS constellations (GPS, GLONASS, Galileo) and multiple frequencies (L1,L2,L5,E1,E5,G1,G2).

11:20 European Space Agency (ESA) Space Situational Awareness (SSA) Space Weather Services – Federated Service Concept

Juha-Pekka Luntama, European Space Agency

The ESA Space Situational Awareness (SSA) Programme was started in 2009 to support the European independent utilisation of and access to space for research or services, through providing timely and quality data, information, services and knowledge regarding the environment, potential threats and the sustainable exploitation of outer space. The SSA objectives will be carried out in successive programmatic steps with a view to achieve a full operational capability over a framework of ten years. ESA will be responsible for the technical definition and the developments of the European SSA system up to the operational stage.

Space Weather Segment is one of the three thematic domains of the ESA SSA system. The objective of the Space Weather Segment is to develop a system to monitor, predict and disseminate Space Weather information and alerts to end users. The SSA programme actively addresses space weather service users in domains including spacecraft designers and operators, human space flight mission operators, launch operators, transionospheric radio link service users and operators, space surveillance and tracking services and many non-space systems operators affected by Space Weather including e.g. power system operators. The ESA SSA system also includes general data services geared towards expert users and the scientific community.

The first space weather precursor services were initiated during the SSA Period 1, which ran from 2009 to 2012. These services have been available to the end users since 2012 through the SSA SWE portal (http://swe.ssa.esa.int). The portal and some of the SWE applications are centrally operated at the SWE Data Centre (located at the ESA Redu site) and supported by the SSA SWE Coordination Centre (SSCC) and helpdesk, located at the Space Pole in Brussels.

This initial, federated network of services is being further developed as part of SSA Period 2 in 2013 - 2016. SSA Period 2 will continue to expand the range of data and applications available through the SWE system. More partners coupled with targeted developments of individual applications will further expand the range of products available. The SSA SWE system will also take further steps towards packaging existing applications into the list of 37 (+2) services identified as SSA SWE user priorities, and coordinating their provision through a distributed network of Expert Service Centres (ESCs). ESCs are the key components of the federated SSA SWE system. Complementary development activities will be ongoing in parallel in ESA R&D programmes, in national initiatives and in the EU research programmes to produce new technologies and space weather assets in Europe, many of which may contribute to the foreseen further expansion of the SSA SWE service network.

This presentation will introduce the federated service concept that was selected as the approach in the development of the ESA SSA Space Weather Segment. In this concept the space weather services to the end users are offered by the European centres of expertise through the ESA SSA system. The presentation will show the current status of the system and highlight the next steps in the system development identifying some of the key system drivers. Finally, the presentation will show the most important long term technology objectives in the space weather area of the ESA SSA Programme.

11:40 **UK Government Progress to Build Resilience to Severe Space Weather**
Mark Gibbs, UK Met Office

The presentation will give an overview of;

- Recap of the UK Government approach
- Progress made to date
- Development of the UK's space weather forecasting capability
- Next steps

12:00 **Lunch**

1:00 - 2:30 **Poster Session – Ionosphere/Thermosphere Research and Applications**

3:00 - 5:00 **Space Weather Modeling**
Chair: Howard Singer, NOAA/SWPC

3:00 **Whole-Atmosphere/Ionosphere Modeling at NOAA: Recent Progress and Plans**
Rashid Akmaev, NOAA/SWPC

An update of the status and future developments of the Whole Atmosphere Model (WAM) and the Integrated Dynamics in Earth's Atmosphere (IDEA) project will be presented. These include WAM validation with the global CHAMP zonal wind data and ground-based nighttime FPI observations in the equatorial thermosphere. First medium-range "weather forecast" in the whole atmosphere and ionosphere during the January 2009 sudden stratospheric warming will also be presented. The IDEA model consisting of WAM interactively coupled with the Global Ionosphere-Plasmasphere (GIP) model was initialized from operational weather data at 00Z on January 13, ten days prior to the peak of the SSW (January 23). The IDEA model successfully predicts both the timing and amplitude of the peak warming in the polar cap about 2 days before the operational NCEP weather forecast. The forecast of the major tidal waves SW2 and TW3 shows an increase in amplitudes and phase changes in the dynamo region during and after the peak. The forecast of the ionospheric response is analyzed for changes in daytime plasma drifts and total electron content (TEC) in the equatorial American sector. These changes compare well with available observations, including a clear shift and increase of daytime maxima to earlier hours.

3:20 **Forecasting Solar Flares: Status and Recent Developments**
KD Leka, Northwest Research Associates

Reliable forecasting of large solar flares has long been identified on NOAA and other agencies' wish lists. Many research groups have been involved in trying to improve flare forecasting algorithms, and at NorthWest Research Associates we have been involved in both research and in spearheading coordinated comparison campaigns to help identify which approaches are promising, and which are not. In this talk, I will give a brief overview of the status of research, including our recent results from a NOAA/Small Business Innovative Research Phase-I project aimed at improving the published forecasts from NOAA/Space Weather Prediction Center. In summary, while SWPC forecasts can match essentially what the "state of the art" can do in particular scenarios, the NWRA Discriminant Analysis Flare Forecasting System ("DAFFS"), performs significantly better at predicting larger flares, especially for the longer forecast outlooks. Funding for this work is acknowledged from NOAA/SBIR contract WC-133R-13-CN-0079. Leka, Barnes and Wagner acknowledge additional support from NASA NNH09CE72C, NNH12CG10C, and Braun through NSF grant AGS-1127327.

3:40 **The Space Weather Modeling Framework (SWMF)-Geospace Capabilities for Transition to Operations**
Tamas I. Gombosi, University of Michigan

Based on the results of two CCMC reports (one on dB/dt and the other on Regional K), SWPC recommended the University of Michigan's Space Weather Modeling Framework (SWMF) to transition to operations. This talk will describe SWMF and its validation for geospace modeling.

4:00 **Rapid, Low-Cost Prediction of Geomagnetic Perturbations from Real-Time Solar Wind Measurements**
Daniel Weimer, Virginia Tech

Rapid, low-cost predictions of ground magnetic field perturbations are available from an empirical model. This model was derived from global measurements of the magnetic field at 149 stations in the Northern Hemisphere that were collected over an eight-year period. Variations in the ionospheric conductivity, under the influence of both the season and solar radiation, are implicitly included. Using real-time measurements of the solar wind and interplanetary magnetic field (IMF), forecasts of geomagnetic activity can be obtained with an approximately 1 hour lead time, depending on the velocity of the solar wind. Global-scale maps of all three vector components of the magnetic field can be obtained nearly instantaneously using only a small, desktop computer. Comparison tests conducted by the NASA CCMC have shown that the empirical model performs better than others, including numerical MHD models run on supercomputers. That is, when evaluating the closest match to the actual level of the perturbations in the geomagnetic field, this model is at the top in the majority of the metrics that were tested. At higher frequencies the model does not do so well with predictions of the more rapid variations, that are due to random processes. Therefore the model performance is lower on metrics that only examine the variability, or rate of change of the magnetic field, on short time scales while ignoring the absolute values in the comparison with measurements. As the high-frequency variations tend to occur in proportion to the low-frequency levels that are well predicted, there could be methods to correct for this one deficiency. Nevertheless, the model does well on predictions of "regional-Kp" at mid-latitudes. At present the empirical model does not include substorms, that contribute to the more pronounced variations at high latitudes, where the performance is lower on the metrics that test variability. A substorm prediction could be a future addition, using maps of their magnetic effects that have already been derived.

4:20 **Community Coordinated Modeling Center: Prototyping and Accelerating Implementation of Advanced Space Weather Models and Forecasting Systems**
Masha Kuznetsova, NASA

The Community Coordinated Modeling Center (CCMC, http://ccmc.gsfc.nasa.gov) hosts a broad range of state-of-the-art space weather models developed by the international space science community. The CCMC collection is frequently upgraded and expanded by new deliverables from NASA and NSF funded space weather modeling projects. Over the years the CCMC acquired the unique experience in preparing complex models and model chains for operational environment. The presentation will focus on geospace models at the CCMC and tools and systems for prototyping, assessment, and demonstrating operational potential of geospace models. We will review on-going CCMC-SWPC collaborative activities in support of transition of geospace models to operations and discuss opportunities for further expansion of CCMC-SWPC partnership.

4:40 **Transitioning Research Models into Operations**
George Millward, SWPC/NOAA

It is commonly stated adage that a "valley of death" separates the research modeling of the academic community and the models that form the backbone of operational weather forecasting. And yet crossing this valley is a necessity if we are to exploit the latest research and provide better forecasts. This process, transitioning, often involves twists and turns and can, maybe unexpectedly, trigger

advances in aspects of the underlying research itself. I will describe my experiences transitioning space weather models into operations at the National Weather Service, referencing the transition of the WSA-Enlil Heliospheric model and also the upcoming work on a Geospace, Magnetospheric forecast model.

5:00 **End of Session**

Friday, April 11

8:30 - 8:40 **Space Weather Morning Forecast**
SWPC Space Weather Forecasting Office

8:40 - 10:20 **Space Based Observations and Advances**
Chair: Rodney Viereck, NOAA/SWPC

8:40 **National Geophysical Data Center (NGDC)**
Eric Kihn, NOAA/NGDC

The Solar Terrestrial Physics division of the NOAA National Geophysical Data Center (NGDC) in Boulder, Colorado, is focused on the dissemination of high quality space climate and space weather data sets and services. This includes key NOAA space data sets such as GOES, POES, DMSP, and also ground array data collected through the World Data Center. This talk will present some of the capabilities and resources of the NOAA fleet, cover plans for access and dissemination methods for the data, and discuss the development of higher order products at NGDC in response to community needs.

9:00 **Solar Energetic Particle Measurements Intercalibration Workshop: Today's Topics and Long-Term Goals**
Juan Rodriguez, NOAA/NGDC

Following the Friday morning session of the Space Weather Workshop, NOAA will host an informal workshop on the comparison and intercalibration of solar energetic particle (SEP) measurements. The purpose of this workshop is to discuss the intercalibration of SEP measurements and to foster new cooperative intercalibration efforts. SEPs consist of ions (protons, helium nuclei, and heavier ions), electrons, and energetic neutral atoms emitted by the Sun in association with solar flares and coronal mass ejections. Of long-standing scientific interest since the discovery of ground level enhancements by Scott Forbush in 1942, SEPs have been monitored continuously since the 1970s as an important aspect of space weather. Their effects include the radiation hazard posed to robotic and human space flight and to aircraft passengers and crew at high latitudes, as well as the absorption of radio waves in the polar cap by the secondary ionization caused by their precipitation into the upper atmosphere. The level of agreement among various SEP measurements has received much attention for scientific reasons and for the societal need to have consistent space weather observations. While in some cases agreement between different instruments has been good, there is currently no general consensus on a standard for comparisons. With international organizations such as the Coordination Group for Meteorological Satellites (CGMS) turning their attention to space weather observations, the time is opportune for a workshop on the intercalibration of SEP measurements. Topics for discussion during the workshop include: (1) operational and scientific needs for relative and absolute accuracy in SEP measurements, (2) performance comparisons (past, ongoing, and planned), (3) differences observed in on-orbit comparisons and their possible causes, (4) calibrations (beam measurements and simulations) performed prior to launch, (5) methods for estimating energy spectra from measurements with broad spectral responses and cross-species contamination, and (6) candidate(s) for "standard" measurement(s) to which to relate other measurements. A key outcome of this workshop will be a recommendation of a path forward for establishing a set of guidelines for intercalibration efforts, a necessary step in achieving a consistent international scale for solar radiation storm alerts. This path forward could include the selection of a SEP event for an initial broad community 'deep dive' intercalibration effort.

9:20 **Solar Proton Events of Solar Cycle 24**
Richard Mewaldt, Caltech

We report on a 360° longitudinal survey of solar proton events during 2010-2014 using data from the STEREO, GOES, and other near-Earth spacecraft. During the first 5 years of Solar Cycle 24, twenty-eight solar proton events were identified at Earth with peak >10 MeV proton intensities of >10 protons/cm2-sr-s, which is NOAA's criterion for "solar proton events affecting the Earth's environment". In addition, 27 events also met the NOAA criterion at one or both STEREO spacecraft but not at Earth, and 6 other events met the criterion at all three locations. Compared to the first 5 years of cycles 21-23 the number of solar proton events is comparable, but the total fluence of >10 MeV protons is several times lower than in cycles 23 and 22. (These comparisons will be updated using data from the first 5.25 years of cycle 24). We discuss factors that may have affected the intensity of solar protons during cycle 23. The largest event in this survey was the July 23, 2012 event observed by STEREO-A, which was the most intense, observed at 1 AU in more than 20 years. The energy spectrum and other characteristics of the July 23 event will be compared to characteristics of other large SEP events from this and previous cycles.

9:40 **The Van Allen Probes and New Results Relevant to Space Weather**
Harlan Spence, University of New Hampshire

The NASA Van Allen Probes mission includes charged particle instruments designed to provide unambiguous separation of ions and electrons and clean energy and angular responses even in the presence of extreme penetrating background radiation environments of Earth's radiation belts. In this presentation, we highlight results from mission instruments relevant to space weather. We focus primarily on one instrument package, known as the Radiation Belt Storm Probes (RBSP) - Energetic Particle, Composition, and Thermal Plasma (ECT) suite. The coordinated RBSP-ECT particle measurements, analyzed in combination with

10:00 **Responsive Environmental Assessment Commercial Hosting (REACH) Demonstration**
Dan Kimmich, USAF/ SMC/XR

The REACH demonstration leverages a fleeting opportunity on Iridium NEXT using its commercial communication architecture to provide unprecedented coverage and refresh rate. REACH, a hosted-hosted payload, uses residual space within the Automatic Dependent Surveillance - Broadcast (ADS-B) to fly micro-dosimeters. The project is a cost effective means to satisfy a majority of the JROC Gap for LEO energetic charged particle characterization. Defending on-orbit space systems from natural and hostile acts is critical to the US and its allies to ensure persistent access to key warfighting capabilities. REACH provides a unique, fleeting opportunity to deliver a low cost, significant capability to enable global access, persistence, and awareness. The first launch of REACH pods will occur on a Dnepr rocket in February 2015, illustrating the ability to field space systems in only 25 months from PDR to launch.

10:20 **Break**

10:40 - 12:00 **Space Based Observations and Advances, Continued**
Chair: Doug Biesecker, NOAA/SWPC

10:40 **Forecasting Daily EUV Solar Irradiance for Atmospheric Models**
Rachel Hock, USAF AFRL

11:00 **IMPACT: Integrated Modeling of Perturbations in Atmospheres for Conjunction Tracking**
David Thompson, Los Alamos National Laboratory

The IMPACT project (Integrated Modeling of Perturbations in Atmospheres for Conjunction Tracking) is developing an integrated system to address the space debris and collision avoidance problem. We are combining physics-based density modeling of the upper atmosphere, satellite drag forecasting for quiet and disturbed geomagnetic conditions, orbit propagation, and conjunction

analysis with rigorous non-Gaussian uncertainty quantification. The IMPACT framework is an open research framework enabling the exchange and testing of a variety of models. We will present capabilities and results including a demo of the user interface and visualizations.

11:20 Space Weather Observations from the GOLD Mission
Richard Eastes, University of Central Florida

The Global-scale Observations of the Limb and Disk (GOLD) mission of opportunity will provide unprecedented imaging of the Earth's space environment and its response to forcing from the Sun and the lower atmosphere. The mission, which NASA selected in April 2013, will fly a far ultraviolet imaging spectrograph that is scheduled for a 2017 launch into a geostationary (GEO) orbit on a commercial communications satellite. From this vantage point most of a hemisphere will be imaged. Fundamental space weather parameters that will be derived from the images include composition (O/N2) and temperature (simultaneously) of the thermosphere as well as nighttime ionospheric densities. These images allow changes in time to be distinguished from changes in location because the same locations will be imaged at a thirty-minute cadence, and they will provide context for other measurements from low Earth orbit or the ground. The resulting information is essential for understanding of the Sun's effects on Earth and to advancing our physical understanding of coupling between the space environment and the Earth's atmosphere. GOLD's capability to provide real time data and knowledge gained from the observations will advance space weather specification and forecasting capabilities.

11:40 COSMIC-2: A Platform for Advanced Ionospheric Observations
Paul Straus, Aerospace Corp.

The equatorial component of the COSMIC-2 program will consist of 6 satellites to be flown in a 24 degree inclination/520 km altitude orbit. In addition to the primary GNSS radio occultation (RO) payload, to be provided by JPL, the USAF plans to fly a pair of space weather sensors: a multi-frequency radio beacon and the Ion Velocity Meter (IVM) in-situ plasma sensor package. These three instruments will provide data to address key issues related to the specification and forecast of ionospheric densities and the instabilities/irregularities associated with ionospheric scintillation. The TriG GNSS receiver will provide a substantial increase in the number of daily ionospheric observations relative to COSMIC-1, both in the RO limb-viewing and overhead geometries. These data are expected to provide significantly improved data refresh and coverage for assimilative ionospheric models enabling more accurate ionospheric specifications in the important equatorial region. In addition, TriG will make routine measurements of ionospheric scintillation at L-band frequencies, as pioneered by the CORISS instrument on C/NOFS. The radio beacon, together with a network of ground receivers, will enable direct measurement of scintillation effects on trans-ionospheric signal propagation across the UHF to S-band frequency spectrum. The IVM sensor will measure the in-situ density and plasma depletions associated with scintillation-producing irregularities. Together, the beacon, TriG, and IVM will provide an unprecedented ability to map equatorial ionospheric instabilities and their effects. The IVM sensor will also provide observations of plasma drifts from which electric fields, the most important physical driver for equatorial ionospheric structure, can be inferred. This will enable advancements in ionospheric models to further improve specifications and forecasts. In addition to discussing ionospheric science and operational support aspects of the COSMIC-2 mission, this presentation also discusses high level COSMIC-2 programmatic status and plans, particular with respect to the mission sensors

12:00 Workshop Closing
Brent Gordon, NOAA/SWPC

12:10 End of Conference