ISEP: A Joint SRAG/CCMC Collaboration to Improve Mitigation of Space Weather Effects on Crew Health in the Exo-LEO Era

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Background

The Space Radiation Analysis Group (SRAG) at Johnson Space Center (JSC) is tasked with monitoring changes to space weather and mitigating any resultant impacts to crew health and safety. As human spaceflight goals extend from Low-Earth Orbit (LEO) missions like the International Space Station (ISS) to the moon, Mars and beyond, SRAG will need to update their current approach for crew monitoring of and protection from radiation exposure due to energetic Solar Particle Events (ESPEs).

Challenges faced in planning exo-LEO missions include the lack of protection from the Earth's geomagnetic field employed by the ISS in addition to limited communication capability between the crew and the ground. In the event of an ESPE, the current ISS trajectory ensures that the vehicle is only traveling through fields of higher radiation exposure for a brief period of time; the Earth's geomagnetic field prevents the penetration of the high-energy particles of concern throughout the majority of the orbit. Exo-LEO missions, on the other hand, require that the vehicle travel through free space, exposing vehicle and crew to the full impact of the ESPE.

NASA has combined multiple approaches to resolve this radiation exposure issue. New vehicles are designed to take advantage of advances in particle transport modeling capabilities and shielding technology, allowing redistribution of mass throughout the vehicle to areas of thinner shielding when the energetic particle flux has increased to levels of concern. Although vehicle shielding is an important aspect of radiation exposure protection, there is a continued requirement to monitor and predict the space weather environment. To this end, SRAG maintains a console position in Mission Control with 24/7 mission support capability. In the event of increased solar activity, SRAG collaborates with the Flight Control Team (FCT) to determine if crew action (i.e., shelter) is required. During any increase in solar activity, the FCT needs three pieces of information to effectively decide the crew response in light of other required mission tasks: if an event (ESPE) will occur, how 'intense' an observed event will be, and how long will an observed event will last. An ideal alert system limits false alarms, therefore causing the crew to take action unnecessarily, without ignoring events that pose a hazard to the crew.

SRAG's current operational concept for ISS missions focuses on short-term forecasts, best described as 'now-casting'. Console operators are in daily communication with the Space Weather Prediction Center (SWPC) for situational awareness purposes. When conditions exist that may lead to increased solar activity, operators receive notifications from SWPC. In the case of a well-connected ESPE, the console operator may only have on the order of minutes to several hours to notify the FCT of the event and provide a recommendation for crew action. As NASA shifts to exo-LEO missions, the increased time in free space as well as the reduced ability to communicate with the crew will force a transition in crew protection strategy that emphasizes improvments to both the accuracy and the lead time in forecasting capabilities.

Methods

The Integrated Solar Energetic Proton Event Alert/Warning System (ISEP) represents a collaboration between SRAG and the Community Coordinated Modeling Center (CCMC) at Goddard Space Flight Center to bring state-of-the-art space weather models from research and development at universities and small businesses to operational use at NASA (R2O). The first stage of this project involved selection of a subset models that provided ESPE forecasts of interest and that were far enough along in their development to necessitate minimal additional work prior to delivery to CCMC for hosting. Following this selection, SRAG and CCMC have collaborated both to bring the modeling effort to completion and to develop 'Scoreboards' to act as a user interface for the models hosted on the CCMC computing systems.

The ISEP team is currently focusing on models projecting SPE probability, proton peak flux and flux time series to augment SRAG's current space weather monitoring approach. The MAG4 model in work at the University of Alabama at Huntsville is currently being integrated into the Probability Forecast Scoreboard. The HESPERIA collaboration from the European Union has been asked to provide updates to the Relativistic Electron Alert System for Exploration (REleASE) and the University of Malaga SEP (UMASEP-500) models for representation in the Proton Peak Flux Scoreboard. A small business venture with Predictive Sciences Inc, in collaboration with the University of New Hampshire, will develop the joint CORona-HELiosphere (CORHEL) / Energetic Particle Radiation Environment Module (EPREM) model for integration into a Flux Time Series Scoreboard. The SEP event model SEPMOD, from the University of California at Berkeley, will also be hosted by the Flux Time Series Scoreboard. In addition to these external collaborations, individual CCMC model developers are also providing work to be hosted by the ISEP project.

After delivery of the source code by the model developers to SRAG/CCMC, the two groups will review the content and results, both for the ability to host the code on the CCMC hardware and for the ability of the model to output results useful to the console operator. SRAG and CCMC are evaluating results based on improvements to both forecasting capability and accuracy of model results. Model developers have been asked to provide one month of model results for the purpose of this comparison. The multiple models represented by the Scoreboard approach allow for an ensemble approach to give the console operator fuller insight into the space weather environment and possible changes to activity; it is incumbent on the operator to then understand the model bases well enough to make an informed decision on recommendations for any crew action.

Results

ISEP will deliver three individual Scoreboards representing the three classifications of models: Probability Forecast, Peak Proton Flux, and Flux Time Series. At present, the Probability Scoreboard (Figure 1) and Peak Proton Flux Scoreboards have been drafted. CCMC has defined and provided a standardized JSON output format to the model developers to streamline the process of adding the current model outputs of interest. This preset output will also simplify the integration of any new model work performed in later years of this project.

As noted in the Methods, each Scoreboard will host results from multiple models to encourage an ensemble approach for analysis of model output results. The Scoreboard shown in Figure 1 is populated by artificial data; however, the concepts represented here will be carried throughout the project. The left side of the Scoreboard summarizes the probability of the event of interest; in this case, SPEs (defined as >10MeV proton flux >10pfu) and ESPEs (defined as >100MeV proton flux >1pfu). The summary also includes an 'All-Clear' Forecast of interest to the FCT during short-term planning operations. The right side of the Scoreboard details the probability forecast over a span of time selected by the viewer. The operator can select the projections of interest based on model capability. In case further analysis is desired, the console operator will also have the capability to download the output text.

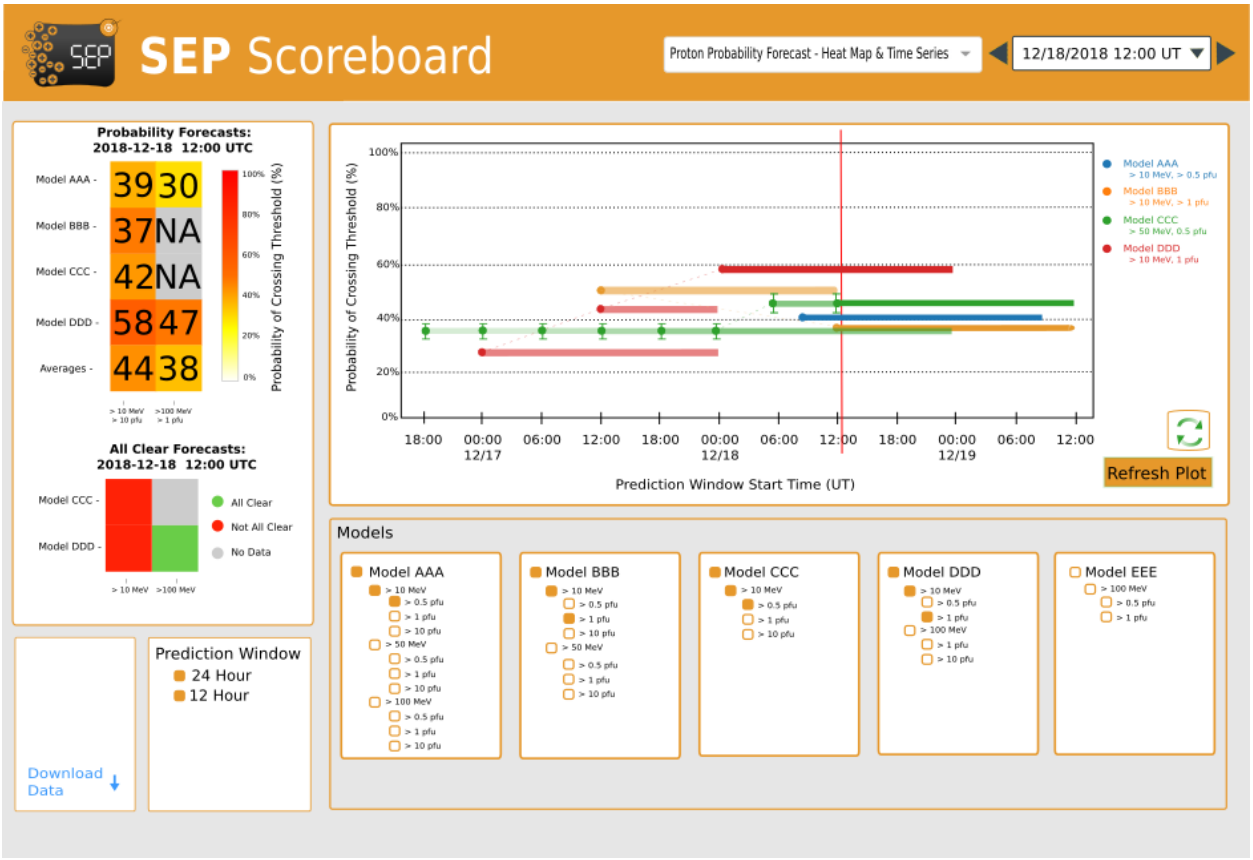

Figure 1: Preliminary mockup of Probability Forecast Scoreboard. This scoreboard will compares event probability models, including an 'All-Clear' Forecast for operational use.

Discussion

As the current models mature, the developers will work with CCMC to host the resulting code and test the results using historical and real-time satellite data streams for functionality prior to approval for internal operational use. These models will have a user interface in the form of a model Scoreboard that will allow the SRAG console operator to view and compare the results from several different models simultaneously; this ensemble approach also requires the console operator to

understand the background and associated caveats of each model in order to formulate the best crew response to changes in the space weather environment.

As ISEP progresses, SRAG and CCMC will explore development and use of new space weather models that can enhance the console operators' ability to understand the impact of changes to the space environment. SRAG and CCMC are also Investigating the use of new space weather modeling approaches. Current interests include the use of machine learning and updated data analysis techniques to further improve event forecasting capabilities. The ISEP team is thus incorporating an R2O approach to improve space radiation exposure mitigation capabilities in the exo-LEO mission era.