Agency Space Weather Requirements and Collaborations to Advance Space Weather Forecasting Needs (E. Semones, NASA JSC)

NASA Space Exploration and Space Weather Workshop - October 17, 2019

Eddie Semones - NASA Johnson Space Center

CNN - Apollo 11 Documentary

ISS Lessons Learned - Space Weather

- Space Weather Forecasts are provided daily by NOAA SWPC for ISS and disseminated to international partners

- Lots of internal and international collaboration experience on ISS for crew radiation protection during SEPs, especially in Cycle 23

  - Many comparisons of in-flight measurements and environment models: GCR, trapped radiation, and SEPs

- Because of geomagnetic shielding/substantial vehicle shielding solar energetic particles do not pose immediate and continuous threat during the ISS orbits

- International collaboration experience on ISS for crew radiation protection

  - But no significant collaboration on space weather forecasting between operational radiation groups of space agencies to date - but we have learned how to collaborate

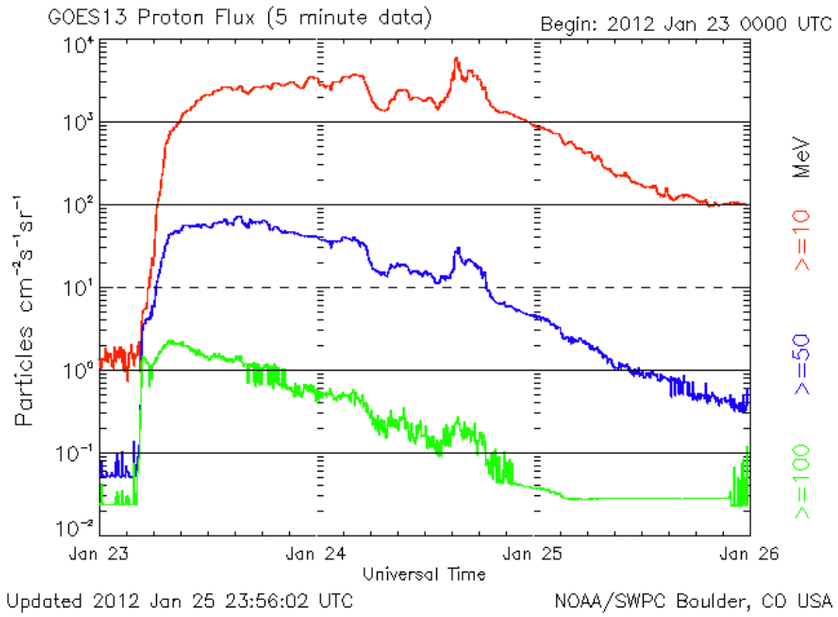
Successes - ISS SEP Operations

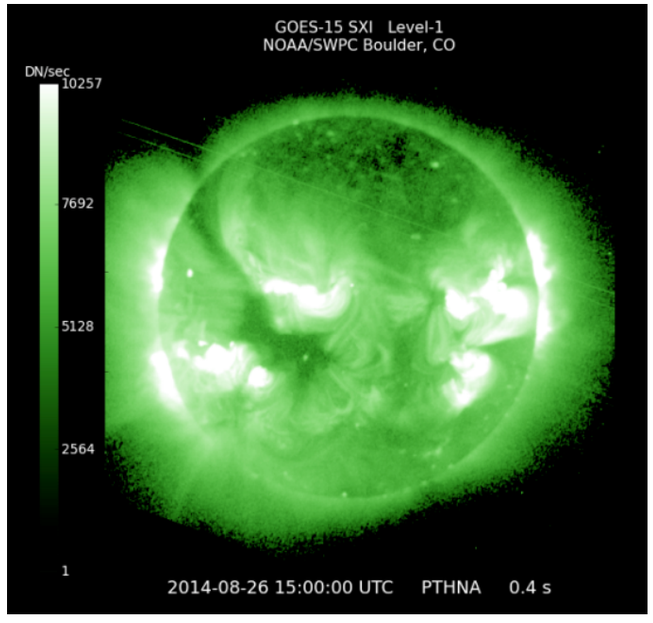
- Radiation flight controller monitors console during space weather contingency operations such as Solar Energetic Particle (SEP) events
  - Alert/Warning messages to management and flight control team
  - Ensure ISS radiation monitoring system availability

- If SEP dose projection is determined to be negligible, then no action will be taken

- If energetic particle event has increased above threshold or radiation detector alarm activation is confirmed, inform crew to remain in higher shielded areas during intervals of high risk orbital alignments.

- ISS higher shielded locations used to protect crew
  - Service module aft of treadmill (panel 339), Node 2 crew quarters, and U.S. Lab





- This response evolves over numerous hours with international coordination. Beyond low earth orbit missions will require this process to be much faster. SEPs can reach peak flux levels in < 5 hours.

Forecasts-ISS

A bad week …. ??

Space Weather Forecast (September 04, 2017 - September 10, 2017)

Solar Activity: Solar activity is expected to be at low levels with a chance for M-class flares from 04-11 Sep due to potential significant flare activity from Active Regions (ARs) 2673, 2674, and the return of old Region 2672.

Geomagnetic Activity: Geomagnetic field activity is expected to be at unsettled to active levels on 04 and 07-09 Sep.

Particle Activity: No proton events are expected at geosynchronous orbit.

This Week….

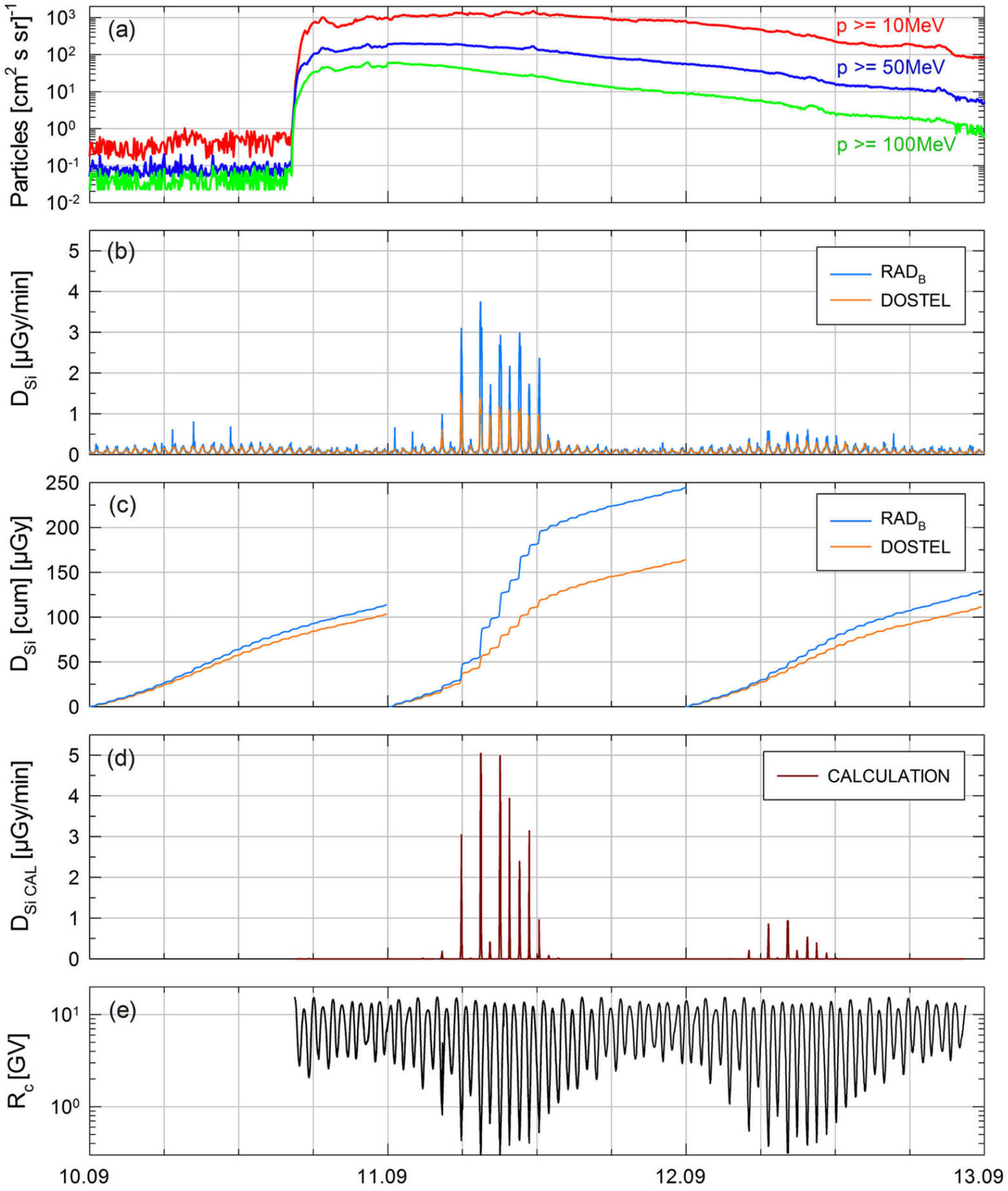
Space Weather Forecast (October 14, 2019 - October 20, 2019)

Solar Activity: Solar activity is expected to continue at very low levels.

Geomagnetic Activity: Geomagnetic field activity is expected to reach unsettled levels on 14-15 Oct due to possible weak CH HSS effects.

Particle Activity: No proton events are expected at geosynchronous orbit.

NASA-DLR comparisons of Sept 10, 2017 SEP



Flight Note sent during Sept 10, 2017 SEP

GMT254

Space Weather Event Status:
An Energetic Solar Particle Event (ESPE), defined as >100 MeV protons greater than 1 particle flux unit (pfu), occurred at 10Sep/16:25 GMT associated with an X8.2 flare from Active Region (AR) 2673 at 10Sep/15:59GMT. The result of an ESPE can increase radiation dose rate exposure for ISS and crew at certain high latitude passes.

As defined in Flight Rule B14-7 (Radiation Environment Conditions Definition) this places us in a radiation environment **Contingency** condition.

Current Proton flux values at 11Sep/02:30GMT
>10MeV at 1094pfu
>100MeV at 54pfu

ISS High Risk Orbital Alignment during Event:
The next upcoming high dose rate passes will not occur until **11Sep (GMT254)** – 1hr 46min from now**:**

In GMT254 (GMT)	**Out GMT254** (GMT)	**Duration** (minutes)
04:19	04:24	5
05:50	06:00	10
06:37	06:43	6
07:23	07:35	12
08:10	08:18	8
08:57	09:09	12
09:44	09:53	9
10:31	10:43	12
11:18	11:28	10
12:06	12:15	9
12:54	13:00	6
13:42	13:46	4

Per Flight Rule B14-103, Section B1, SRAG recommends crew avoid low shielded areas for the duration of each high risk orbital alignment. Low shielded areas per B14-103 are Service Module Crew Sleep Compartments, Service Module Transfer Compartment, Pressurized Mating Adapters, Air Locks, and the window in the US Lab (WORF).

Note: The ISS Rad Detector is enabled as the prime ISS C&W instrument (COL1A2). In the event that dose rate values should reach >50μGy/min it will annunciate the ISS C&W High Dose Rate Alarm. These values are not expected in the next 12hrs.

Microelectronics - Impact & Actions:
Per FCOH 7.10.4 (Severe Radiation Environment Notification for Microelectronics), FD shall verify MSFC and IPs are aware of this situation and notify those Flight Controllers

Beyond Low-Earth Orbit Differences: Gateway-Lunar Surface

- Each SEP event will impact Gateway and each Lunar Surface mission
  - Will need more detailed forecasting to discern which ones may be serious with advance warning
  - NASA will continue to utilize SPWC for core forecasting for Gateway, but additional operational tools will be utilized for fast response to mission control
- Three questions the Console Operator always fields during periods when large active regions are present on sun:
  - Will there be an event (SEP)?
  - How intense will it be?
  - How long will it last?

Need reliable All-Cleat for SEP to support Gateway-Lunar Surface mission planning

Need reliable forecasts of SEP event peak flux and temporal evolution to support Gateway-Lunar Surface operations

- To help answer these questions SRAG-CCMC have collaborated on a joint project to assemble suite of models in scoreboard framework that includes (we hope) significant EU/ESA component

METRIC/SI (ENGLISH)

NASA TECHNICAL STANDARD

National Aeronautics and Space Administration

NASA-STD-3001,
VOLUME 2, REVISION B

Approved: 2019-09-09
Superseding NASA-STD-3001,
Volume 2, Revision A

NASA SPACEFLIGHT HUMAN-SYSTEM STANDARD

VOLUME 2: HUMAN FACTORS, HABITABILITY, AND ENVIRONMENTAL HEALTH

6.8.1.5 Space Weather Monitoring

[V2 6099] The program **shall** set requirements specifying appropriate capabilities to be provided for real-time monitoring of space weather for characterization of the radiation environment and operational response by ground personnel and the crew.

[Rationale: Radiation protection for humans in space differs from that on Earth because of the distinct types of radiation, the small population of workers, and the remote location of astronauts during spaceflight. Radiation sources in space have distinct physical and biological damage properties compared to terrestrial radiation, and the spectrum and energy of concern for humans differ from that for electronics. Space weather can directly impact a broad portion of the space radiation environment on short- and long-time scales. Space weather conditions are to be known at all times during missions to allow for appropriate radiation protection planning.]

National Aeronautics and
Space Administration

GP 10016
INITIAL RELEASE (DRAFT)
RELEASE DATE: MONTH XX, XXXX

GATEWAY PROGRAM SUBSYSTEM SPECIFICATION FOR CREW HEALTH AND PERFORMANCE (CHP)

Date: Month XX, XXXX
Revision: Draft

Approved for Public Release
This document has been approved for public release per DAA STI # 63831 and TN #70531

Gateway program subsystem specification for crew health and performance (CHP)

L2-CHP-0204 Space Weather Awareness

The Gateway CHP Subsystem shall provide infrastructure to support space weather situational awareness. [***HSR 6089***]

A space weather situational awareness framework is required to be implemented to ensure crew radiation protection (NASA Standard 3001 Vol 2 requirement [V2 6099]). This framework involves infrastructure in orbit around the sun, at Sun-Earth L1, L5, GEO and other potential locations and data transfer between these assets, Mission Services and the vehicle/crew

L2-CHP-0921 Earth-Independent Space Weather Monitoring

The Gateway CHP shall validate autonomous space weather monitoring and early warning capabilities for progressively Earth-independent operations with tools and technologies including but not limited to Gateway space weather measurement assets.

Collaboration with SMD Heliophysics on Gateway space weather science monitoring platform for operational forecasting utilization. Learn to quantify accuracy of SPE forecasting beyond LEO. Low false alarm. Predict 24 hours in advance.• All-clear (storm onset) forecasting many hours in advance, with low false alarm rate and high accuracy. This allows astronauts to confidently schedule trips outside of the their lunar-surface-based habitat/shelter.• SPE storm intensity forecasting• SPE energetic particle spectrum and bioeffectiveness forecasting• Based on experience with space weather forecasting, plan future space assets and integration of current ground- and space-based assets for observing the Sun and solar wind, likely to need to solar observations at various solar longitudes away from Sun-Earth line. • For continuously improving forecasting, need a framework model that allows integration and upgrade with the latest models as new correlations are discovered.

L2-CHP-0920 SPE Radiation Protection

The Gateway CHP shall validate SPE radiation protection capabilities.

Advanced radiation sensors will be incorporated into the habitat to measure the astronauts' exposure to radiation in real time so that they can take shelter during solar particle events (SPE), to assess the effectiveness of radiation shielding, and to validate radiation transport models for the habitat structure. This CTO will focus on validating the construction of the shelter and use of wearables (vest, head gear) during construction in zero and partial gravity as needed to meet the NASA Standards.

National Aeronautics and
Space Administration

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

HLS-RQMT-001
Revision A
RELEASE DATE: October 2, 2019

HUMAN LANDING SYSTEM (HLS) REQUIREMENTS DOCUMENT

HLS-HMTA-0088 Radiation protection, limitations and monitoring

The system should protect, limit and monitor crew exposure to radiation.

Rationale: Crew occupational exposure to ionizing radiation is managed through system design, in-flight monitoring and procedures, mission architecture and planning, and the application of appropriate countermeasures. Space Permissible Exposure Limits (PELs) are specified in NASA-STD-3001, Volume 1, and include age- and gender-dependent career cancer risks limits and dose limits for short–term and career non-cancer effects. As defined in NASA-STD-3001, Volume 1, exposures are maintained as low as reasonably achievable (ALARA) to ensure astronauts do not approach radiation limits and that such limits are not considered as tolerance values. In practice, the application of the ALARA principle dictates that actions be taken during design and operational phases to manage and limit exposures to ionizing radiation.

HLS-HMTA-0089 Crew Radiation Exposure Limits

The program shall design systems using the ALARA principle to limit crew radiation exposure.

Rationale: The ALARA principle is a legal requirement intended to ensure astronaut safety. An important function of ALARA is to ensure that astronauts do not approach radiation limits and that such limits are not considered tolerance values. ALARA is an iterative process of integrating radiation protection into the design process, ensuring optimization of the design to afford the most protection possible, within other constraints of the vehicle systems. The protection from radiation exposure is ALARA when the expenditure of further resources would be unwarranted by the reduction in exposure that would be achieved.

HLS-HMTA-0090 Ionizing Radiation Alerting

The system shall include a method to alert all crewmembers when radiation levels are expected to exceed acceptable levels.

Rationale: The data from charged particle monitoring are the fundamental environmental information required for radiation transport calculations and crew exposure evaluation. Given an accurately measured energy spectra incident on the vehicle during an SPE, detailed crew exposure can be evaluated. This limits the uncertainty of a single absorbed dose measurement in determining crew exposure from an SPE. The crew, at all times, is to be alerted to excessive fluence of particles. Should communications from MCC be interrupted or lost, the crew requires onboard warnings when the radiation environment crosses dangerous thresholds so that appropriate countermeasure actions can be taken. Varying user-defined thresholds may be set according to the radiation environmental conditions that may be encountered, depending on mission phase. The intent is for the vehicle data management system to provide the alerting functionality. Crew needs to be given sufficient time to prepare for a high radiation event.

Forecast Requirements

Integrated Space Weather Project Requirements

★ Required Functionality

↯ Target Functionality

Probability Forecast

Cadence	All Clear Forecast		M + X Flares	X Flares	CME	Fast CME	>50 MeV	>100 MeV
6 hr	24 hr	48hr						
★	★	↯	★	★	★	★	↯	★

Event Onset Forecast

Event Onset	Peak 10 MeV	Peak 30 MeV	Peak 50 MeV	Peak 100 MeV	Onset Profile	GLE	Connectivity
★	★	★	↯	★	★	★	★

Intensity Profile Forecast

Time Profile	Duration	Time to Peaks	Time and Peak 10 MeV	Time and Peak 50 MeV	Time and Peak 100 MeV	ESP	Dose
★	★	★	★	↯	★	↯	★

[SW 2001] The system shall provide a 'All-Clear Forecast' for M and X-class flares, SPEs and ESPEs with a confidence level of at least 90%, a cadence not to exceed 6 hours and a minimum forecast period of 24 hours.

Rationale: Knowledge that an event will not occur over a short duration (e.g., the next 24-72 hours) is useful for mission planning, including contingency EVA tasks.

SEP Model Landscape – initial collaborations

Continuous/ Probabilistic

Continuous Probabilistic:
SWPC
UK Met Office
MAG4 (Falconer)
FORSPEF (NOA)
SPRINTS

Continuous Profile:
PREDICCS (UNH)

Non Near Real-Time/ Complex

STAT: MAS+EPREM (PSI and UNH)
EPREM+ENLIL (UNH + Odstricil)
iPATH (Li)

SEPMOD (Luhmann)
SPARX (Dalla, Marsh)
SWMF FLAMPA (UMich)
Zhang Model (FIT)

Solar Event Triggered

Flare:
AFRL PPS
COMESEP SEPForecast (BIRA)
FORSPEF (NOA)
SPARX (Dalla, Marsh)

Flare and CME:
COMESEP SEPForecast
FORSPEF (NOA)
SOLPENCO (Arans)

Flare and proton intensity:
UMASEP (Núñez)

CME:
SEPSTER (Richardson)
St. Cyr (Mauna Loa CME)

Electron intensity:
HESPERIA REleASE

Flare, Radio, H-alpha:
SWPC PPM

Flare, Radio:
Laurenza Model

Radio:
AER SEP Model (Winter)

Collaboration Obstacles

- Funding entities allowing funded project deliverables to be utilized by partner agencies. There may be contractual/home institute issues that prevent this.
  - Can models developed for EU-ESA be augmented/updated/tailored by projects (with NASA supplied funding) for example post delivery or project completion?
- Many EU/ESA/UK funded projects look promising to contribute to the forecasting needs for manned space operations:
  - COMESEP
  - SPARX
  - HESPERIA (UMASEP/RELeASE)
  - FLARECAST
  - ASPECS
- NASA-SRAG operations are very interested in models developed within these projects but need help with high level agreements.

Recommendations

- Communicate new forecast needs and requirements to forecasting centers (SWPC) and researchers to establish core forecasts beyond LEO

- Create international SEP forecasting collaborations between space agencies

  - Not only at modeler/scientific project level, but at space agency operations/implementation level: SRAG/CCMC

- Lay the groundwork for Gateway-Lunar Surface by developing forecast tools now that can be tested during ISS operations, before longer Gateway missions take place

- Build the foundation for human Mars missions by collaborating on space weather architectures that could be flown on manned vehicles to provide input data for forecast models at locations away from Sun-Earth