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# SRAG Gaps/Needs for Artemis

# Artemis Responsibilities

- SRAG is tasked with mitigating crew exposure to space radiation
- During Artemis, vehicle mostly travels in free space, exposing crew to the full impact of enhancements due to SPEs (EVA) / ESPEs (IVA/EVA)
- SRAG has worked to improve our capability to monitor and react to changes in the space environment through the following
  - Understanding health effects
  - Vehicle design
  - Active crew and area monitoring
  - **Space weather forecasting**
- **Gaps in our current technology have been identified – focus on understanding of SPEs and implications for other areas**

# Where are We?

- What are SRAG's current operational needs/gaps for Artemis?
- Are there near-term gaps that would impact the ability to meet requirements for human safety?
- How are high-priority gaps communicated and handled?

# Radiation Protection: Crew Health

| Starport ID | Gap Title | Gap Type | Categorization |
|---|---|---|---|
| 725 | Probabilistic Risk Models of Crew Health | Knowledge Gap | Near Term Architecture Enabling |
| 1020 | Biomedical Countermeasures to Mitigate Health Effects from Exposure to Space Radiation | Knowledge Gap | Mid Term Architecture Enabling |
| | Space Radiation Biomarker Technologies for In-flight Monitoring and Health Management | Knowledge Gap | Mid Term Architecture Enabling |

Gaps address the needs for

- Reliable risk modeling
- Countermeasures for effects of radiation exposure
- Understanding early indications of pathological changes

# Radiation Protection: Vehicle Design

| Starport ID | Gap Title | Gap Type | Categorization |
|---|---|---|---|
| 364 | Radiation shielding - Solar Particle Event (SPE) | Engineering Gap | Near Term Architecture Enabling |
| 1173 | Radiation Shielding: Galactic Cosmic Radiation – Passive Technologies | Development Gap | Mid Term Architecture Enabling |
| 1179 | Radiation Shielding: Combined Galactic Cosmic Radiation (GCR) with protection from Solar Particle Events (SPEs) – Active Technologies | Technology Gap | Mid Term Architecture Enabling |

Gaps address the need for improved shielding capabilities for the varied space environment conditions

# Radiation Protection: Monitoring

| Starport ID | Gap Title | Gap Type | Categorization |
|---|---|---|---|
| 733 | Advanced space radiation environment characterization systems: charged and neutral particle spectroscopy | Technology Gap | Near Term Architecture Enabling |
| 735 | On board dosimetry systems ' charged particle alert and warning | Engineering Gap | Near Term Architecture Enabling |

Gaps address the need for improved monitoring of the space environment

# Radiation Protection: Space Weather Forecasting

| Starport ID | Gap Title | Gap Type | Categorization |
|---|---|---|---|
| **362** | **Solar Particle Events: Radiation models and forecasting** | **Development Gap** | **Near Term Architecture Enabling** |
| **883** | **Earth-independent Space Weather Forecast and Crew Alert Systems** | **Development Gap** | **Mid Term Architecture Enabling** |
| 915 | GCR Radiation models and forecasting - Prediction of solar cycle modulation | Knowledge Gap | Mid Term Architecture Enabling |

Gaps address the need for improved

- Understanding of long-term behavior of the space environment
- Prediction and quantification of short-term changes to the space environment

# Solar Particle Events (SPE): Radiation Models and Forecasting

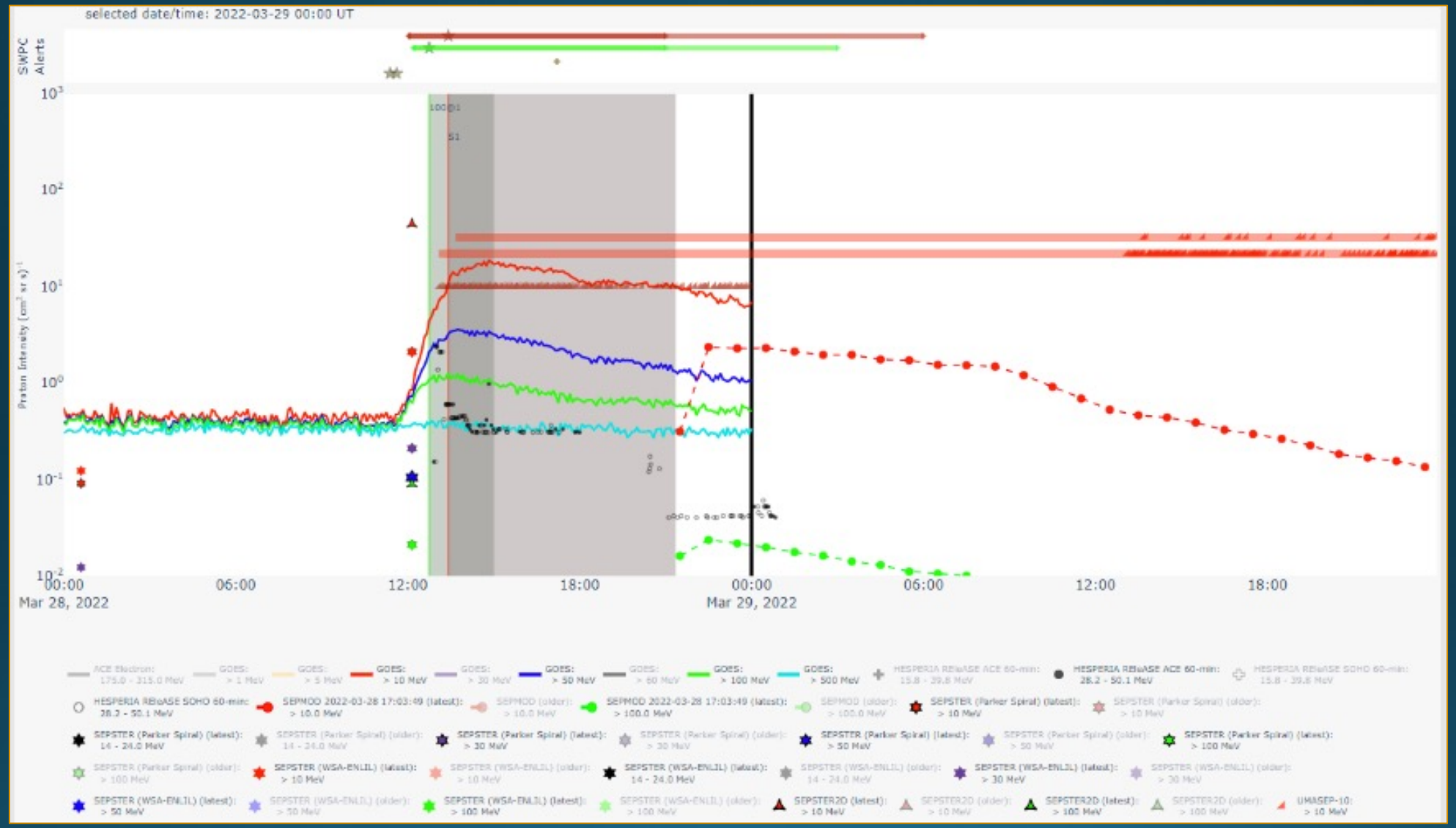
- Type
  - Near-Term Architecture Enabling
- Description
  - State-of-the-art radiation forecasting allows for relatively reliable prediction of incoming solar particle emission events, but provides poor predictions of duration, intensity, and the intensity-time profile of the entire event.
  - Increased warning times and accuracy of real-time operational forecasting is needed to inform mission operations of radiation hazards following development of the SPE event as well as the prediction of all clear periods.
  - Develop an integrated suite of solar event and flare forecasting models utilizing current sun-Earth observation assets (e.g., GOES, SOHO) with an operational interface to support cis-lunar and lunar surface operations.
  - Evaluate model performance or forecast compared with solar observations post event to validate.
  - Advance models and develop crew interface to utilize on-board space environment observation data (e.g., HERMES on Gateway) to meet Mars mission objectives.

# Solar Particle Events (SPE): Radiation Models and Forecasting

- Impact
  - Without advanced SPE forecasting capability, the hazard will continue to impose operational constraints for astronauts outside of LEO and especially for lunar surface/sortie operations.
  - Crew are at increased risk of exposure with the potential for acute health effects if shelter is not reached in a timely fashion, while false-positive predictions will decrease mission efficiency if crew are unnecessarily seeking shelter.
- Elements
  - All beyond-LEO human missions

# Solar Particle Events (SPE): Radiation Models and Forecasting

- Funded Projects
  - Develop probabilistic, peak flux, and time profile scoreboards (AES) *TRL5*
  - Assess and integrate new models into scoreboards (AES) *TRL5*
  - Machine Learning/Artificial Intelligent solar event modeling (ESI/STMD) *TRL3*
- Gap Closure Activities
  - Advance multiple models /methods to predict all-clear periods, probability of occurrence, early warning, peak intensity, and time profile of solar particle events.
  - Advance multiple full disk and active region models to predict flare occurrence.
  - Develop user interface to view ensemble of predictive results in terms of a scoreboard and assess operational ease of use.
  - Advance scoreboard models and develop crew interface to utilize on-board space environment observation data.




Intensity Scoreboard showing model outputs for 28 Mar 2022 ESPE. Featured models include the empirical models UMASEP, REleASE and SEPMOD as well as the physics-based model SEPMOD.

# Earth-Independent Space Weather Forecast and Crew Alert Systems

- Type
  - Mid Term Architecture Enabling
- Description
  - Develop on-board, integrated space weather observation system (x-ray, chronograph, fields and particles, magnetograph) and assess Mars-centric observational (orbital, deep-space) asset needs supporting Earth-independent solar particle event monitoring to enable human Mars missions off the Earth-Sun axis.
  - Develop real-time, operational, autonomous forecasting software fed by solar observational inputs capable of monitoring/predicting SPE radiation hazards without access to Earth-based communications.
  - Ensure available data necessary along the Mars-Sun line for inputs into models and reliability of current state of the art procedures providing actionable information once event is detected.
  - Reduce mass, power, volume of detector/technology systems.
  - Test systems on crewed platforms to close gap for Mars transit and surface operations.

# Earth-Independent Space Weather Forecast and Crew Alert Systems

- Impact
  - Delayed response time and delayed accuracy in seeking shelter from SPE events.
  - Crew will be at increased risk of in-mission health/performance decrements and long-term health consequences if there are long delays in seeking shelter, while a high false-positive rate of SPE forecasted events will negatively impact mission efficiency and objectives.
- Elements
  - Transit Habitat, Mars Descent System, Mars Ascent Vehicle, Mars xEVA, Mars Pressurized Rover, Mars Long Duration Surface Habitat

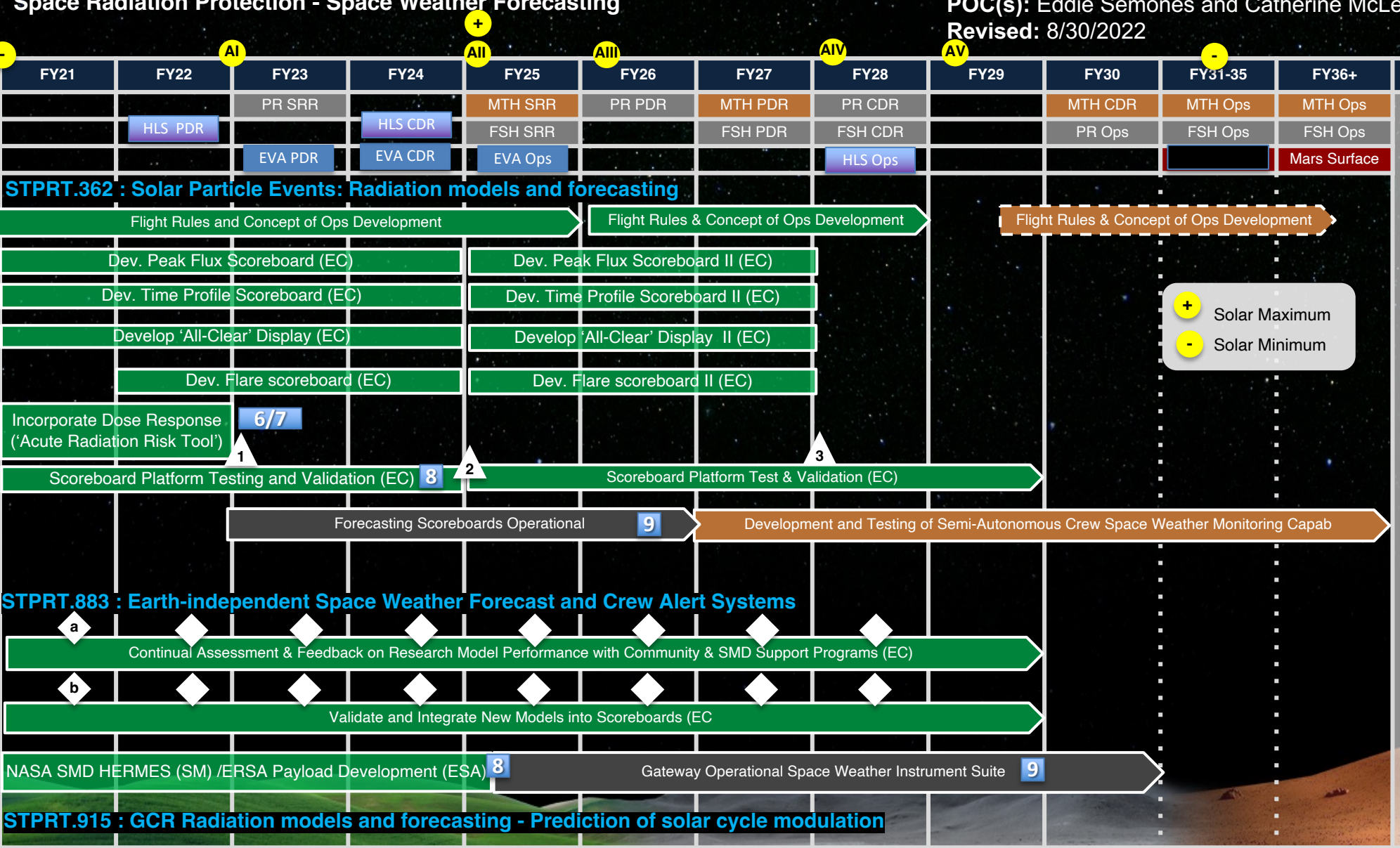
# Earth-Independent Space Weather Forecast and Crew Alert Systems

- Funded Projects
  - Collaborative effort between SMD/HEOMD/STMD
  - Pathfinder measurements: initial phase of sensor technology testing and data analyses using HERMES heliophysics radiation measurement experiment. (SMD F; Integration onto Gateway F); TRL=8
- Gap Closure Activities
  - Advanced sensor development, miniaturization, & spaceflight validation of components (U); TRL= 6
  - Integrated instrument suite payload for crew missions & operational testing (U); TRL=4
  - Software/model development for Earth-independent warning and actionable procedures (U); TRL=4

# ECLSS-CHP SCLT ROADMAP – REVISION 2022.0 NASA INTERNAL ONLY

## Space Radiation Protection - Space Weather Forecasting

**POC(s):** Eddie Semones and Catherine McLeod
**Revised:** 8/30/2022




### Additional Information

#### Deliverables

1. [RAD.DEL.1] Scoreboards delivered for testing on Artemis I. [TRL 6/7] Q4FY22
2. [RAD.DEL.2] Scoreboards delivered for usage on Artemis II & II.I [TRL 8] Q4FY24
3. [NEW] Scoreboards delivered for usage on Artemis IV & V. Q4FY27

#### Decision Points

a) [RAD.DEC.1] Assessment of Space Weather Research and Scoreboard progress – Annual Review

b) [RAD.DEC.2] Assess Model Performance and integrated scoreboard platform – Annual Review

Ground
LEO
Lunar orbit
Lunar surface
Mars transit
Mars surface
Deliverables
Decision point
Funded
Unfunded
Artemis missions
6 TRL / 6 HRL

Funding Codes: EC, SMD

See acronyms list at front of document. All mission information is notional and for the purpose of SCLT work only.

# Mission Impacts

- Gaps have been identified in SRAGs current capability to effectively support Artemis mission
- Address all aspects of radiation mitigation needs, 2 address SPE impacts
  - SPE forecasting and modeling (near-term)
  - Earth-independent forecast and alert systems (mid-term)
- Artemis missions in free space require advances in space weather modeling technologies
- Closure of these gaps represents development and incorporation of technologies for crew protection during enhancements to the space environment