ARTEMIS

Artemis II-III Forward Work

SRAG Activities

WRMISS

September 7 , 2023

Eddie Semones on
behalf of SRAG-JSC

Artemis To Do List *from last year*

Radiation Operations, Hardware, and Space Weather

- Establish/Update human radiation exposure standards
  - Career/Acute-SPE/Nuclear Tech shielding updated
  - GCR shielding under review
- Review/ Pursue all relevant precursor data of space radiation environment
  - ISS lessons learned (trapped/GCR/neutron environments)- REMs/CAD/RAD/HERA/ANS
  - Chang'E Lander, CRaTER, CLPS
- Develop comprehensive set of vehicle design, radiation monitoring, forecast support requirements

Updates ←

  - NASA-NOAA MOU updated
  - SRAG-SWPC-M2M Summit
- Develop equipment/mitigations deemed Government Furnished Equipment (GFE)
  - HERA delivered for initial Artemis mission and being tested long term on ISS
  - Complete ARES design and Build for Gateway HALO Module Certify and Deliver ARES to HALO ←
  - Complete ARES design and Build for HLS SpaceX Starship. Certify and Deliver ARES to HLS ←
- Establish firm relationships with vehicle vendors for design requirement verification and ALARA activities
  - Orion shelter concept is completed and Gateway HALO underway with NG – Determine final Gateway Shelter location ←
  - New Collaboration with SpaceX - Determine final HLS Shelter location ←
- Conduct training and certification of console operators
- Complete initial ISEP Scoreboard initial versions Update Scoreboards with Art 1 feedback ←
- Complete ARRT – (Acute Radiation Risks Tool for Exploration Missions)
- Create comprehensive Concept of Operations and Flight Rule development utilizing all assets available
- Complete a full mission support campaign of the uncrewed: Artemis 1 mission - ~~Now Sep-Oct 2022~~ Nov 16, 2022 – Dec 11, 2022 ←
  - Matroshka AstroRad Radiation Experiment (MARE) Hardware Delivery
- Conduct FCT simulations of contingency events – SPEs with crew actions
- Perform mission exposure assessments to inform crew selection ←
  - Artemis Cadre announced in late 2020 but now all crew being considered – expect Artemis II crew announcement ~~in ~2022 ??? –~~ Announced April 2023 ←

Big Picture

Artemis 2: (Late 2024- early 2025) – ~10 day mission

- HERA delivered - 2 strings
- CAD work (3 US + 1 CSA crew to wear CAD)
- ▪ensure battery/displays within certification
- Bluetooth connection on Orion for real-time data
- HERA Display updates for FCT and SRAG console

- Flight Rule Development
  - When to enter (dose rate threshold) and exit shelter (@peak + X hours)
    Launch Commit Criteria – (LCC) - will be driven by hardware limits (SLS)
    Space Weather Conditions – GOES: >50 MeV p+

- Sheltering Procedure Development – Orion

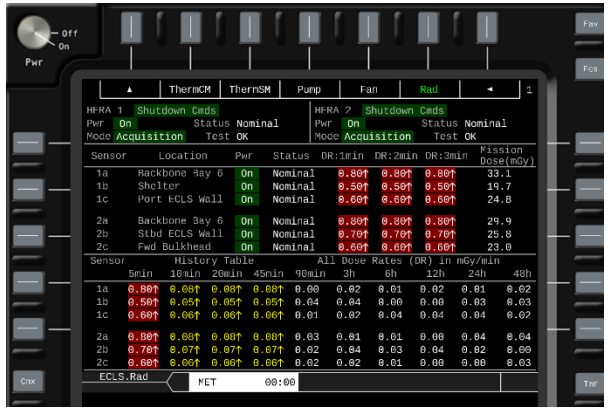
Artemis 3: (Surface mission ~2026) – 25 day – 34 day

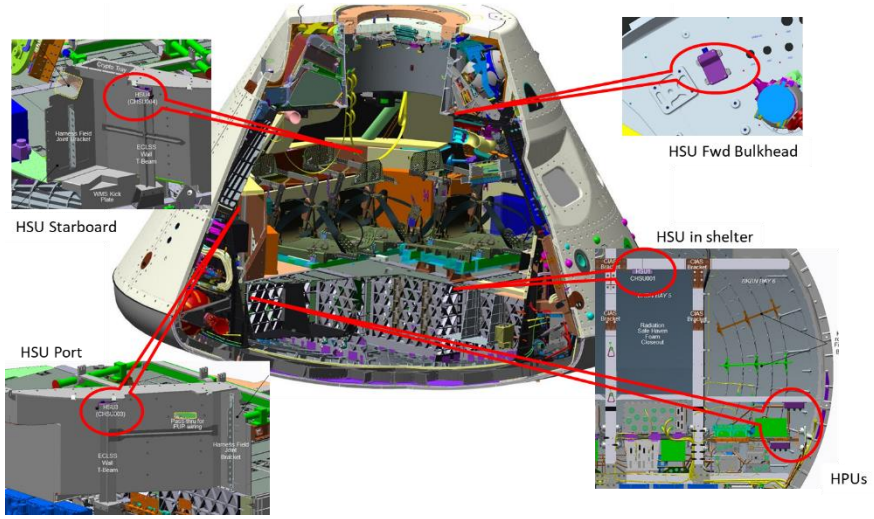
- Complete shelter analysis - determine shelter location/ ARES instrument location/allocation – HLS Starship
- Complete certification/Integration of ARES
- Complete additional flight rules for Starship and EVA Operations
  - When to enter (dose rate threshold) and exit shelter (@peak + X hours)

Artemis-II is coming soon….

Extending work from Artemis I to prepare for crewed missions

- Radiation crew displays and C&W integration
- Shielding evaluations for contingency scenarios
- Training and Integration for mission support
- SPE Forecast Model development to increase response capability for Solar Events





NASA astronauts Reid Wiseman, Victor Glover and Christina Koch, along with Canadian Space Agency astronaut Jeremy Hansen

ARTEMIS II

First Crewed Test Flight to the Moon Since Apollo

1 LAUNCH
Astronauts lift off from pad 39B at Kennedy Space Center.

2 JETTISON SOLID ROCKET BOOSTERS, FAIRINGS, AND LAUNCH ABORT SYSTEM

3 CORE STAGE MAIN ENGINE CUT OFF
With separation.

4 PERIGEE RAISE MANEUVER

5 APOGEE RAISE BURN TO HIGH EARTH ORBIT
Begin 23.5 hour checkout of spacecraft.

6 ORION SEPARATION FROM INTERIM CRYOGENIC PROPULSION STAGE (ICPS) FOLLOWED BY PROX OPS DEMO
Plus manual handling qualities assessment for up to 2 hours.

7 ORION UPPER STAGE SEPARATION (USS) BURN
Begins high Earth orbit checkout. Life support, exercise, and habitation equipment evaluations.

8 PERIGEE RAISE BURN

9 TRANS-LUNAR INJECTION (TLI) BY ORION'S MAIN ENGINE
Lunar free return trajectory initiated with European service module.

10 OUTBOUND TRANSIT TO MOON
Outbound Trajectory Correction (OTC) burns as necessary for Lunar free return trajectory; travel time approximately 4 days.

11 LUNAR FLYBY
6,479 miles / 10,427 km (mean) lunar farside altitude.

12 TRANS-EARTH RETURN
Return Trajectory Correction (RTC) burns as necessary to aim for Earth's atmosphere; travel time approximately 4 days.

13 CREW MODULE SEPARATION FROM SERVICE MODULE

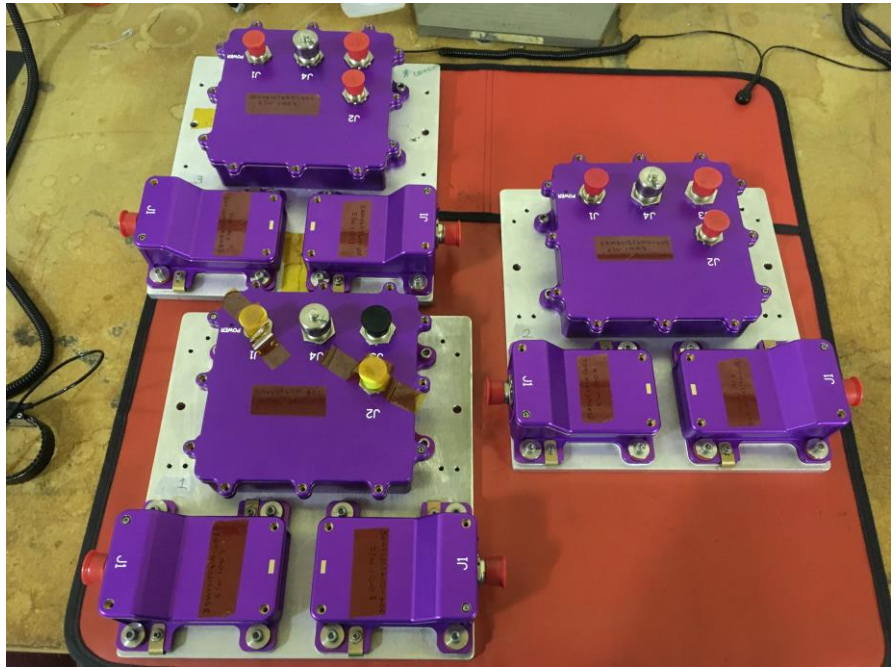
14 ENTRY INTERFACE (EI)
Enter Earth's atmosphere.

15 SPLASHDOWN
Ship recovers astronauts and capsule.

PROXIMITY OPERATIONS DEMONSTRATION SEQUENCE	
1	10
2	11
3	12
4	13
5	14
6	15
7	16
8	17
9	

Going Forward - HERA Is Our Art-2 and beyond Orion Instrument

- HERA is a fully autonomous radiation monitoring instrument for NASA exploration programs, specifically the Orion spacecraft
- Each HERA consists of an HPU (HERA processing unit) and two HSU's (HERA Sensor Unit), each containing a timepix for a total of 3
- Qualified for shock/vibe/thermal environments
- Data processing provide dosimetry, science data, crew display and caution and warning data



Three HERA Flight Strings for Artemis 2 during calibration at BNL Tandem

Remaining Issue

- HERA internal battery end-of-life
  - No impact to real-time functioning of hardware. If battery should die, impact is only to the first date/time stamp in stored data files.

HERA Certified Flight Systems (6 total , 2 used each flight)

Part Number	Serial Number	Assembly Name (System Reference)	Mission Effectivity
SEH46122436-302	1005	HERA Processor Unit (EM1 Flight)	Artemis-I
SEH46122426-302	1008	HERA Sensor Unit (EM1 Flight)	Artemis-I
SEH46122426-302	1009	HERA Sensor Unit (EM1 Flight)	Artemis-I
she46122600-304	1005	HERA Processor Unit (System 1)	Artemis-II
SEH46122610-304	1009	HERA Sensor Unit (System 1)	Artemis-II
SEH46122610-304	1010	HERA Sensor Unit (System 1)	Artemis-II
SEH46122600-304	1006	HERA Processor Unit (System 2)	Artemis-II
SEH46122610-304	1011	HERA Sensor Unit (System 2)	Artemis-II
SEH46122610-304	1012	HERA Sensor Unit (System 2)	Artemis-II
SEH46122600-305	1007	HERA Processor Unit (System 4)	Artemis-III
SEH46122610-304	1013	HERA Sensor Unit (System 4)	Artemis-III
SEH46122610-304	1020	HERA Sensor Unit (System 4)	Artemis-III
SEH46122600-305	1008	HERA Processor Unit (System 5)	Artemis-III
SEH46122610-304	1015	HERA Sensor Unit (System 5)	Artemis-III
SEH46122610-304	1016	HERA Sensor Unit (System 5)	Artemis-III
SEH46122600-305	1009	HERA Processor Unit (System 6)	Artemis-IV
SEH46122610-304	1017	HERA Sensor Unit (System 6)	Artemis-IV
SEH46122610-304	1018	HERA Sensor Unit (System 6)	Artemis-IV
SEH46122600-305	1010	HERA Processor Unit (System 7)	Artemis-IV
SEH46122610-304	1014	HERA Sensor Unit (System 7)	Artemis-IV
SEH46122610-304	1019	HERA Sensor Unit (System 7)	Artemis-IV

A-II, A-III, -IV HERA units used for two flights before being returned for potential refurb.

From HERA Sustaining Engineering Plan (SEP), June 2023 - RDWK-10234.

Other Work

Artemis II	Artemis III	Artemis IV	Artemis V	Artemis VI
CAD Bluetooth Certification	---	---	---	---
RAM Delivery (6 units)	No RAMs	No RAMs	No RAMs	No RAMs
CAD Delivery (nominal 4 units)	CAD Delivery (nominal 4 units)	CAD Delivery (nominal 4 units)	CAD Delivery (nominal 4 units)	CAD Delivery (nominal 4 units)

All Assumes L-30 delivery for RAM/CAD**

Issues to be Addressed in FY 24

- CAD internal battery end-of-life
- CAD LCD Failures
  - LCD issue does not affect functioning of hardware, only visual readout. Connection to PDU via BlueTooth allows for direct viewing of minute-by-minute dose rates daily by SRAG console

- Artemis II
  - Completed software integration for real-time data transfer to crew Surface Pro 5 laptops via Bluetooth
  - Future work:
    - Negotiate pre-launch delivery and optimize CAD display refresh rate, data cadence and data transfer frequency to mission duration including the pre-launch period
    - Negotiate CAD battery or unit replacement in the event of launch delays
    - Establish data downlink protocols for monitoring in-flight dose
- Artemis III
  - Integrate CAD Service software with new computer infrastructure
  - Perform CAD parameter optimization for mission duration as will be done for Artemis II
  - Plan dosimetry handoffs between CAD and EVA suit dosimeter and the new format of the dosimetry report

Artemis II: CAD Work

- **Issue Title: Crew Active Dosimeter Bluetooth DFTO**
- **Issue Overview:** The CAD device connects to laptop via bluetooth during nominal ISS operations. Expect same nominal ops for Artemis missions. No issue but have received some push back regarding the need to perform in mission rather than on the ground. Reply was made to program that with HERA we tested operation on the ground and still ran into issues with lost data packets during A-1. Was not a HERA issue but upstream of HERA, i.e. the vehicle PDU. For this reason, we recommend performing the DFTO during A-2.
- Important to note here that if the LCD fails (see Issue 2 on pages 5 and 6) that connection via Bluetooth still allows ground teams to track crew exposure on a daily basis, even if crew cannot observe exposures directly on the LCD.

Artemis II: Shelter

- **Issue Title: Radiation Storm Shelter DFTO**
- **Issue Overview:** Part of Artemis Ops during adverse Space Weather is a reconfiguration of moveable mass within the vehicle into a shelter the crew can ingress/egress. There is not a direct issue but rather pushback from VIO regarding the needed to perform this check during A-2 mission. VIO concern was disruption of vehicle CG if crew did not put mass back where it is nominally stowed. Our understanding is that FOD did not think this was an issue. We have tested the reconfiguration on the ground. Program bookkeeping 90 minutes for activity. Radiation stance is that this should be performed on A-2 if possible, to rule out any issues the crew may encounter. Procedure for the activity remains to be written.

Evaluation of Crew Shelter Onset Criterion in Orion

The purpose of this analysis was to evaluate the effectiveness of selected shelter onset criterions and termination criterions to manage Orion free space shelter activities to manage mission ESEP (>100 MeV p+) exposures.

Example Criteria :

Shelter was initiated when 1 criterion was exceeded. Cases included:

GOES >100 MeV > 50 pfu (*GOES pfu primary cases studied at first*)

Highest HERA > 50 μGy/min

Highest HERA > 35 μGy/min/min

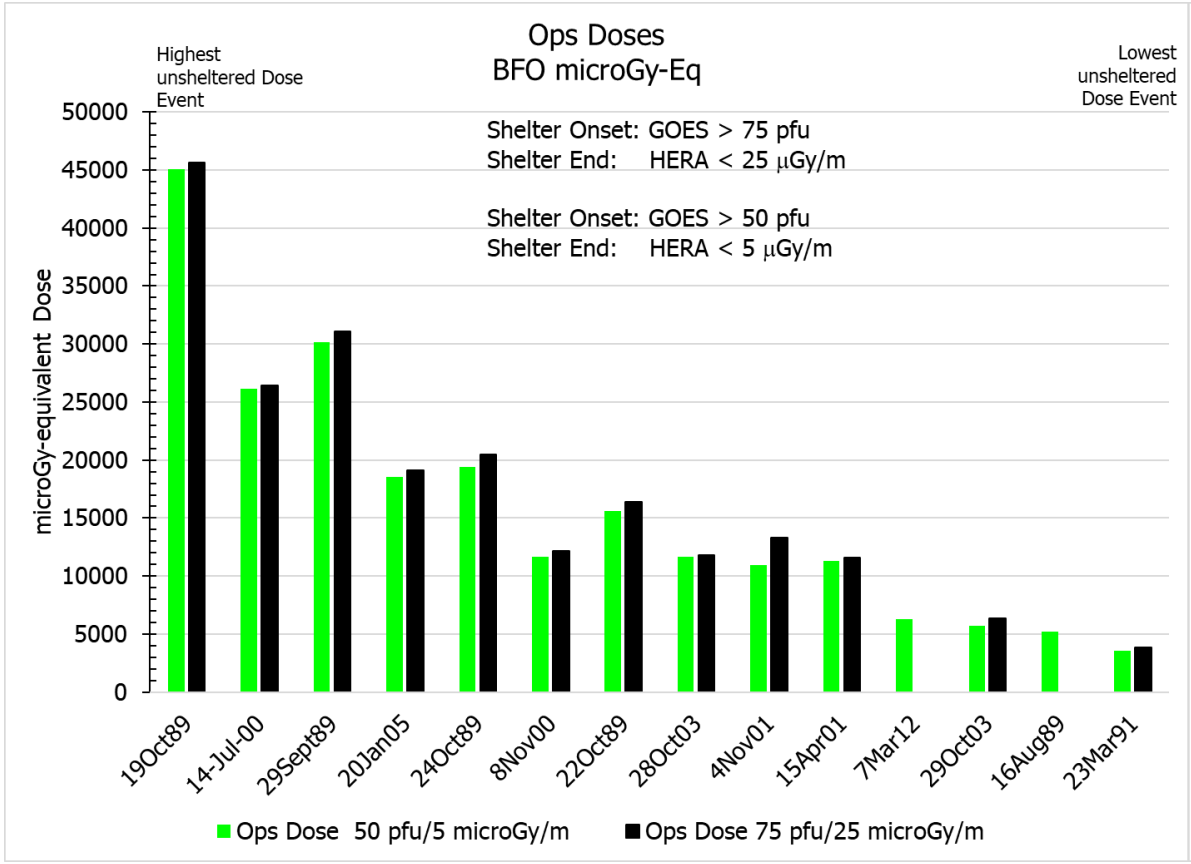
Highest HERA > 75 μGy/min

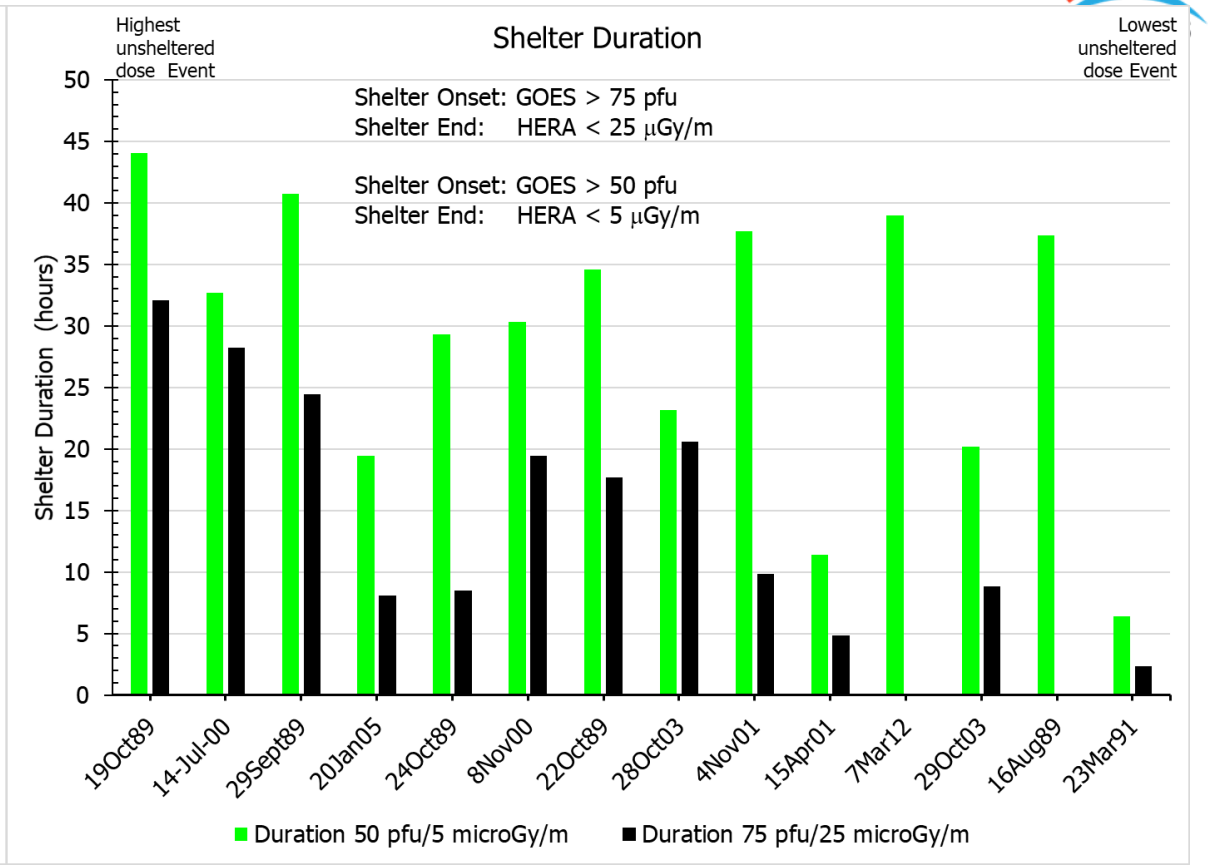
Shelter was initiated 'instantaneously' at the initiation time and maintained.

Shelter was terminated at 5 μGy/min by highest HERA dose rate

Original draft criterion was 2.5 μGy/min. This was changed to 5 μGy/min during the course of the analysis because the shelter times were excessive

Evaluation of 50 pfu Flux as a Shelter Onset Criterion





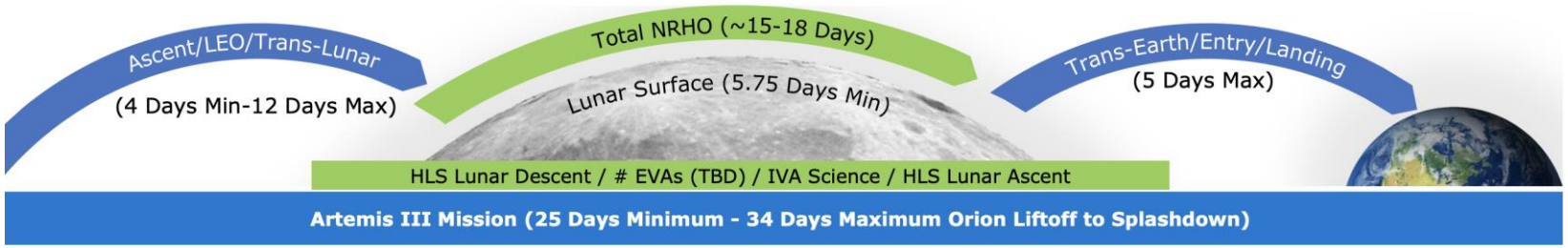
Comparing two different sets of criteria.

Increasing the initiate shelter threshold from 50 pfu to 75 pfu (GOES) and increasing the terminate shelter dose rate from 5 μGy/min to 25 μGy/min

Significant reductions in shelter timw without a large change in BFO dose.

- Some events no longer require shelter.
- However, the largest events still have very large shelter durations in excess of 20 hours

Artemis 3



Paradigm Shift – Orion – 6 monitoring points integrated/hard-mounted/pre-installed.

HLS and Gateway – soft-stowed, crew installed, single (**1 only** *perhaps*) monitoring point for much larger habitable volume

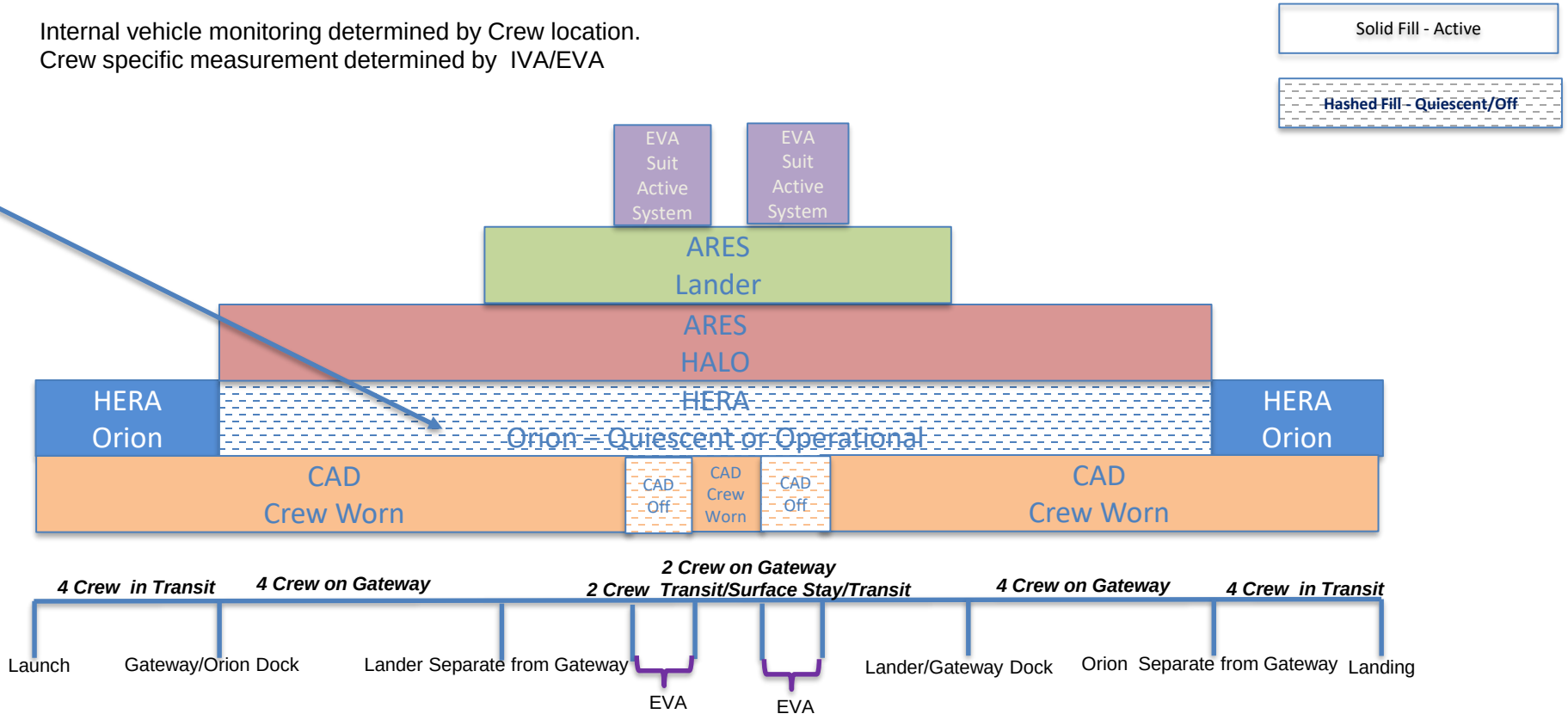
Missions infrequent (hard to get operational rhythm – less measurement collaboration

Before Artemis 3, SpaceX will carry out an uncrewed Starship lunar landing, and also must demonstrate cryogenic fluid transfer in Earth orbit. **No indication** yet on whether any radiation detection instrumentation will be flown on this demonstration.

Artemis Instrument Usage by Crewed Vehicle

Learning recently that HERA will be on entire mission!!!

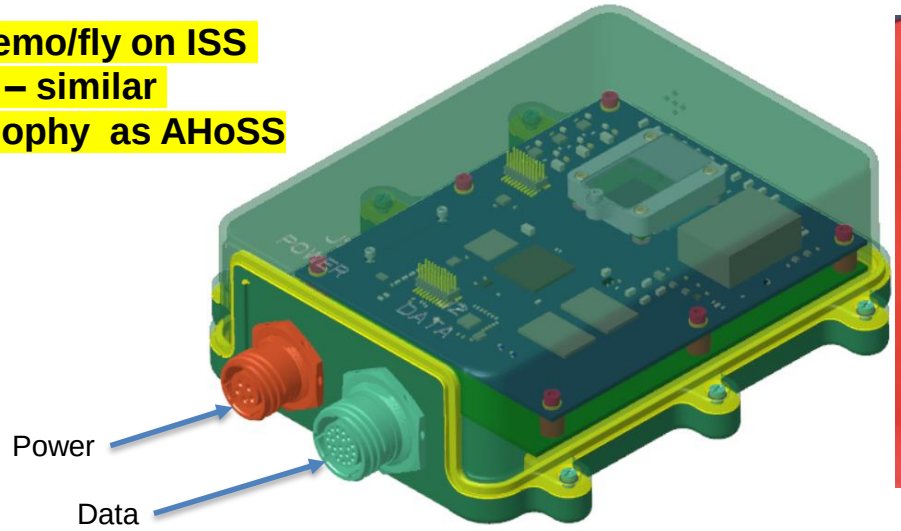
Internal vehicle monitoring determined by Crew location.
Crew specific measurement determined by IVA/EVA



Active Radiation Environment Sensor (ARES) Overview – HLS/Gateway Starship Detector

- Description of Sensor: Uses an active radiation sensing chip that incorporates currently-developed technology used in ISS, Orion, and CLPS mission radiation monitoring hardware. Its small profile, low mass, and low power consumption makes this an attractive solution for radiation sensing and detailed radiation field sampling capability on any vehicle.
- Core board capabilities are listed in the Technical Specification table →
- Housing and interface:
  - Velcro mounting with separate power and data interfaces
  - Qualified vehicle-independent design. Certification completed at final assembly

Will demo/fly on ISS ASAP – similar philosophy as AHoSS



(Notional Design - For Reference Only)

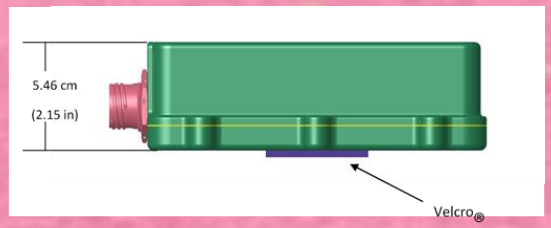
Technical Parameters	
Instrument Type:	Silicon Radiation Sensor
Data Product:	LET Spectrum, dose rate, cumulative dose
Expected Flight Unit Mass:	1.6 kg (including housing)
Operating Temperature Range:	-24 to +61 °C
Non-operating (Survival) Temp Range:	-35 to +72 °C
Communication Interface:	RJ45 CAT 5E/6A MIL-DTL-38999 Connector / 1000BaseT Std Gigabit Ethernet
Data Transmission Rate:	Adjustable (2 msg./min – 2 msg./hr) - Science/Status: 1.5 kB/min – 1.5 kB/hr - Data Downlink: 510 kB/min (as req.)
Commanding:	Only Time Command required for nom. op. - Contingency commands: <30 B/Cmd - All current commands: <50 Bytes
Power Consumption:	3.6 Watts
Input Voltage:	28 VDC
Electrical Interface:	MIL-DTL-38999 Series III Connector
Housing:	Anodized Al-6061
Physical Volume:	7.36” x 5.70” x 2.15” (NTE 100 $in.^3$)
Mass:	NTE 2.01 kg (4.4 lbm)
Launch, Acoustic, & Shock Load Limits:	Legacy designs surviving loads: - 6.8 grms Vibe (soft-stowed) - TBD shock (Velcro attachment, base design)
Radiation Sensitivity (SEU):	TBD

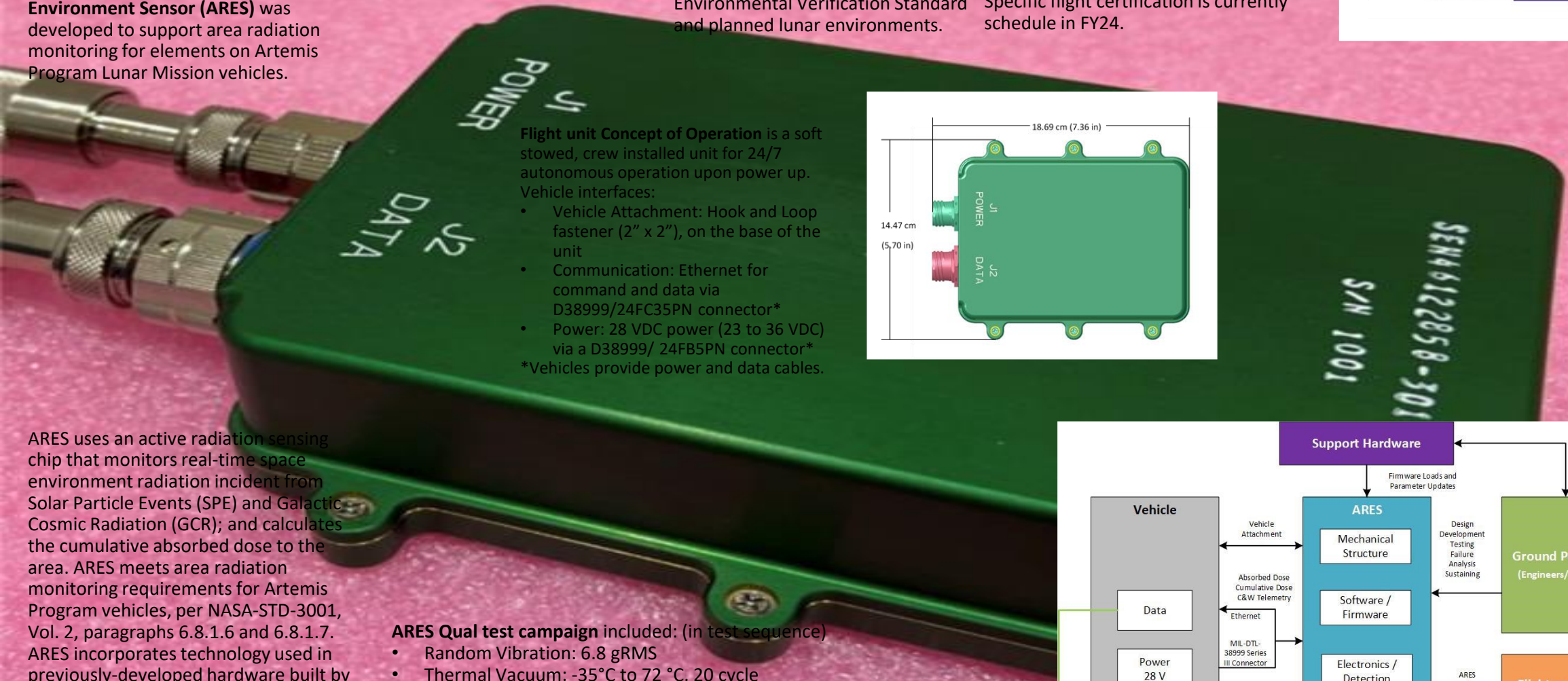
ARES

The NASA **Active Radiation Environment Sensor (ARES)** was developed to support area radiation monitoring for elements on Artemis Program Lunar Mission vehicles.

ARES qualification program tested at levels above the Max Predicted Environments (MPE). The campaign is a tailored subset of Goddard Space Flight, GSFC-STD-7000A, General Environmental Verification Standard and planned lunar environments.

ARES flight assemblies have started for Artemis deliveries. Multiple units are in fabrication with calibration activities planned late FY23. Program Specific flight certification is currently schedule in FY24.





Flight unit Concept of Operation is a soft stowed, crew installed unit for 24/7 autonomous operation upon power up.
Vehicle interfaces:

- Vehicle Attachment: Hook and Loop fastener (2” x 2”), on the base of the unit
- Communication: Ethernet for command and data via D38999/24FC35PN connector*
- Power: 28 VDC power (23 to 36 VDC) via a D38999/ 24FB5PN connector*

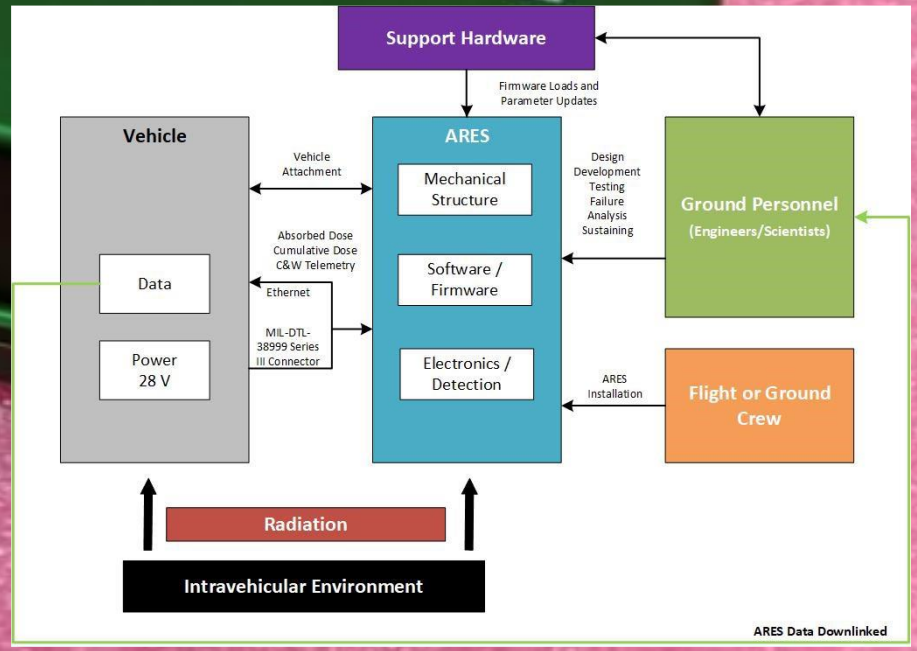
*Vehicles provide power and data cables.

ARES uses an active radiation sensing chip that monitors real-time space environment radiation incident from Solar Particle Events (SPE) and Galactic Cosmic Radiation (GCR); and calculates the cumulative absorbed dose to the area. ARES meets area radiation monitoring requirements for Artemis Program vehicles, per NASA-STD-3001, Vol. 2, paragraphs 6.8.1.6 and 6.8.1.7. ARES incorporates technology used in previously-developed hardware built by SD/RadWorks in an improved radiation tolerant design.

ARES charge particle measurement data meets the absorbed dose, the charged particle flux), LET distribution requirements. ARES also provides high dose alarm indication for prescribed threshold exceedance.

ARES Qual test campaign included: (in test sequence)

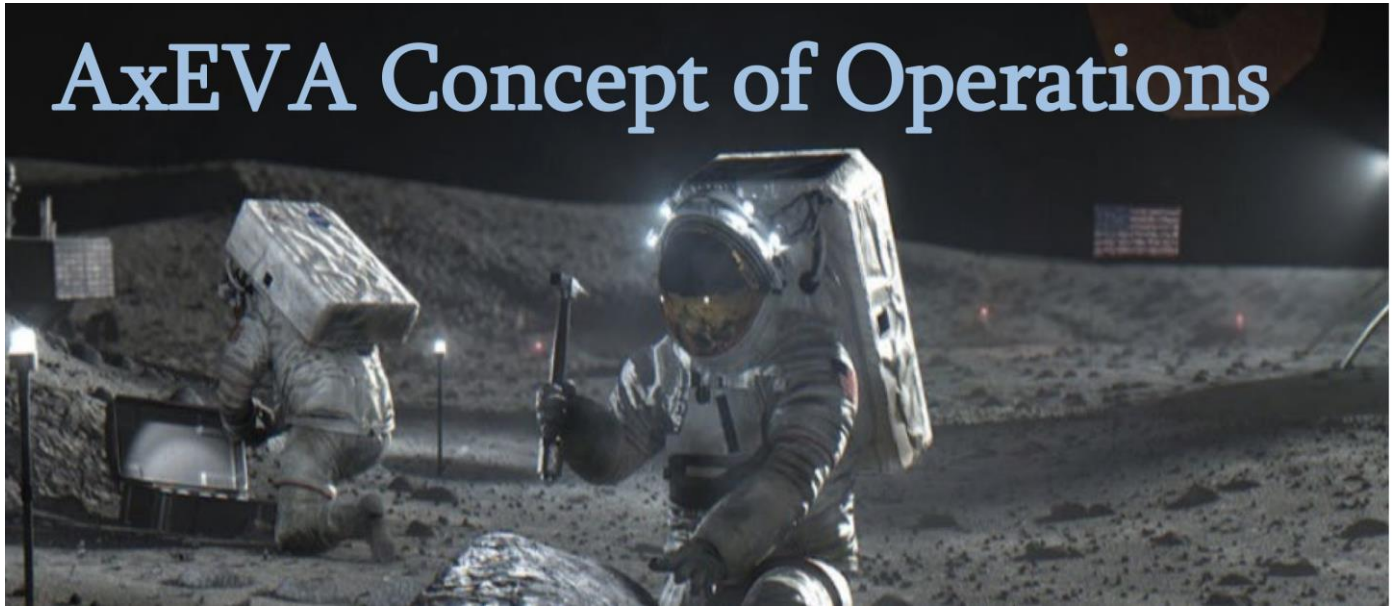
- Random Vibration: 6.8 gRMS
- Thermal Vacuum: -35°C to 72 °C, 20 cycle
- Burn In: 200hrs
- EMI/EMC: testing tailored for GP11461
- Power Quality including: Tailored International Space Power System Interoperability Standards (ISPSIS)
- Electrical bonding and grounding: NASA-STD-4003, class H and class S
- Science Validation



Evaluation of Crew Shelter Onset Criterion in Orion, HLS, and surface EVA

(Steve Johnson and SRAG Console/Space Weather Team)

Need to evaluate the effectiveness of elected shelter onset criterions and termination criterions to manage space shelter activities across multiple platforms simultaneously to manage mission ESEP (>100 MeV p+) exposures.



EVA Radiation Response Philosophy

ISSUE: EVA crew on lunar surface can receive excessive exposure during solar energetic particle events.

OBJECTIVES: Provide guidance for protective action to prevent exceeding mission exposure limits.

- Ensure protective action is taken to protect against the largest events.
- Provide guidance to enable EVAs during periods of enhanced proton fluxes without resulting in excessive exposures

CONSTRAINTS: Solar proton events are not equal. They vary in duration, intensity, energy and evolution in time.

The character of event is only discernible as it evolves. Nowcasting with help from models.

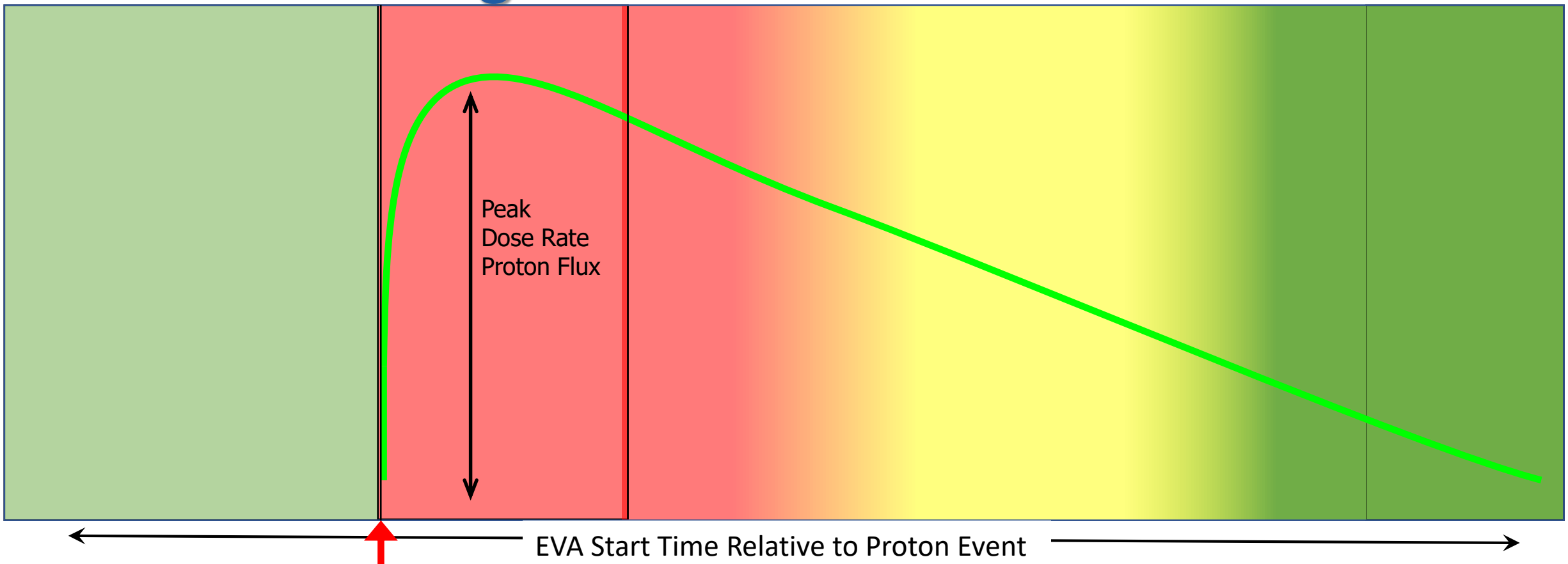
The highest dose rates are at event peaks of the highest energies present. Typically - 3 to 12 hrs.

EVA Radiation Response Philosophy

Monitoring:

- Real-time monitoring and alerting onboard xEVAS
  - Data required to be passed as telemetry to ground.
  - Only external environment measurement is the Suit monitor.
- HLS-based (ARES) - Telemetry to ground.
- Orion based (HERA) - Telemetry to ground.
- SRAG – ground advises EVA crew
  - Monitors measurements from all spacecraft.
  - Monitors Space weather assets
  - Provides recommendations/advisories via Flight Surgeon

Energetic Solar Particle Event



No Event Before Egress:

Go

If Onset During EVA:

Terminate

Prior to and During Event Peak:

No Go

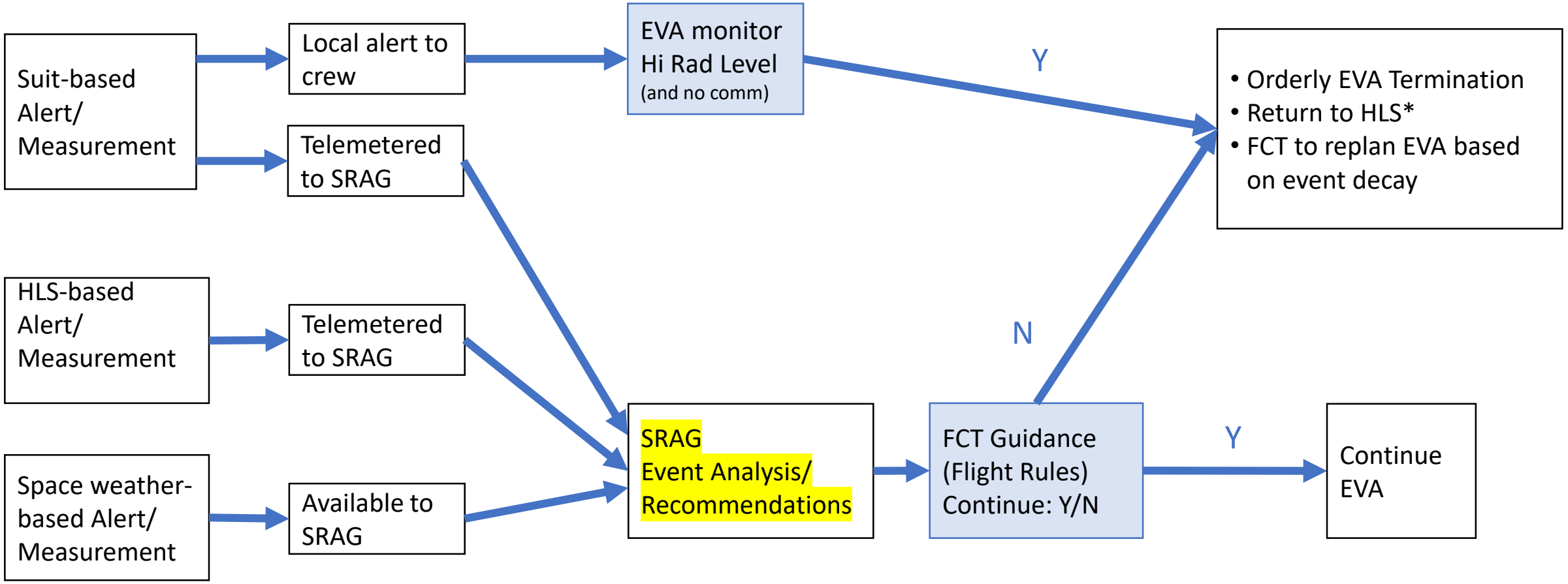
After Event Peak:
Steady Decline
Proceed based on caution
Dose rate limit or reduced Duration.

Toward Event End:

Go

Scenario/ConOps: EVA Rad Event

*HLS Shelter is A/L



If EVA suit High Radiation Level alarm and no comm, EVA would return to lander/shelter

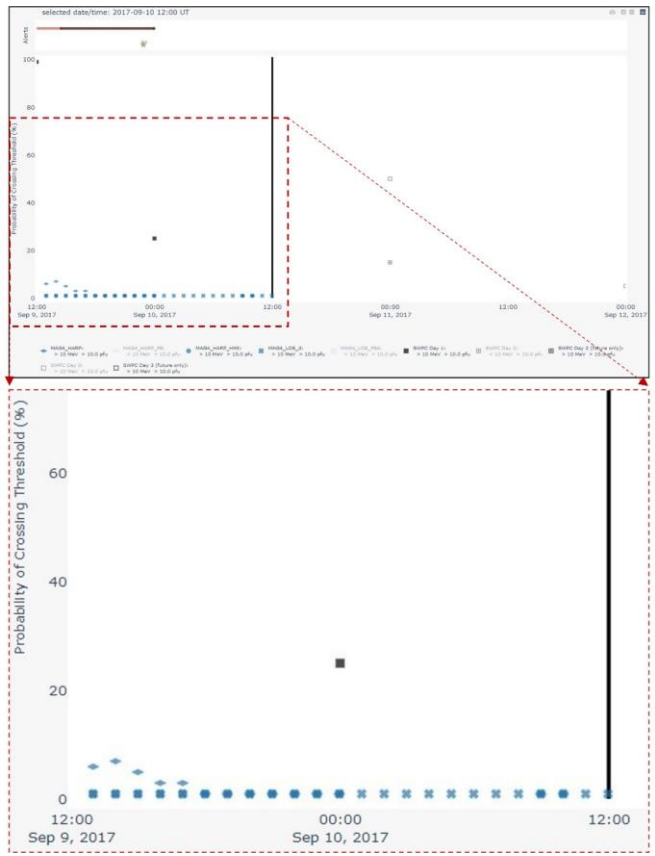
A Brief Overview Of Integrated Solar Energetic Proton Event Alert/Warning System (ISEP)

- Project began in 2018 - joint collaboration between JSC/SRAG and GSFC/CCMC
  - GSFC/M2M supports SRAG and CCMC in real-time use of Scoreboards
  - Identified SPE models for transition to real-time operational use
  - Developed Scoreboard design
- Emphasized link between researchers and end users
  - Researchers: update models / outputs as needed
  - End Users: understanding of requirements / training on model strengths
- Three Scoreboards are now in daily use for Radiation console support

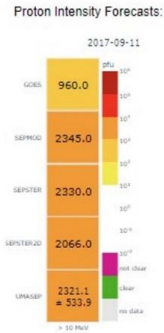
https://ccmc.gsfc.nasa.gov/ISEP/

https://ccmc.gsfc.nasa.gov/scoreboards/sep/

SPE Model Scoreboards

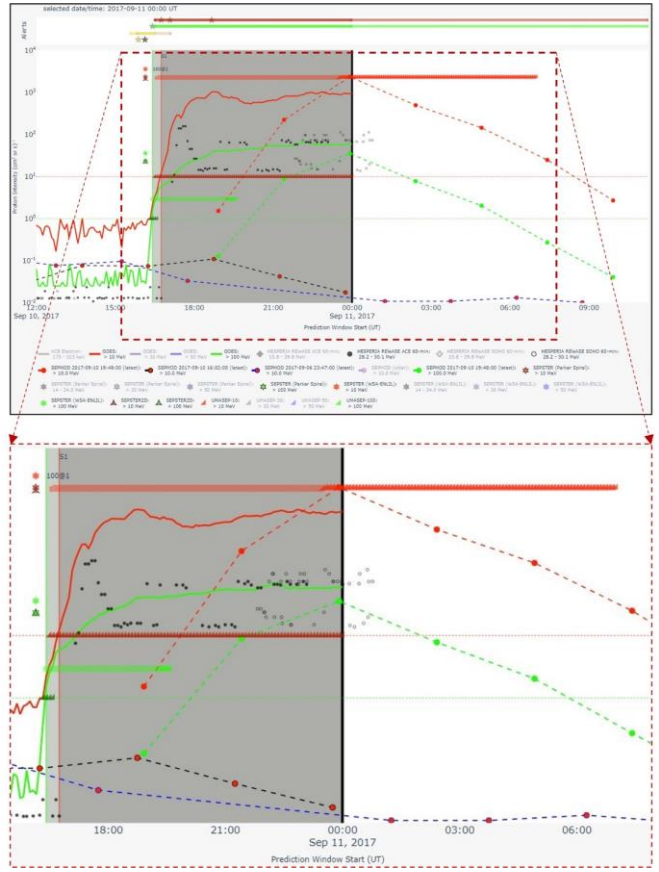


a)



b)

c)

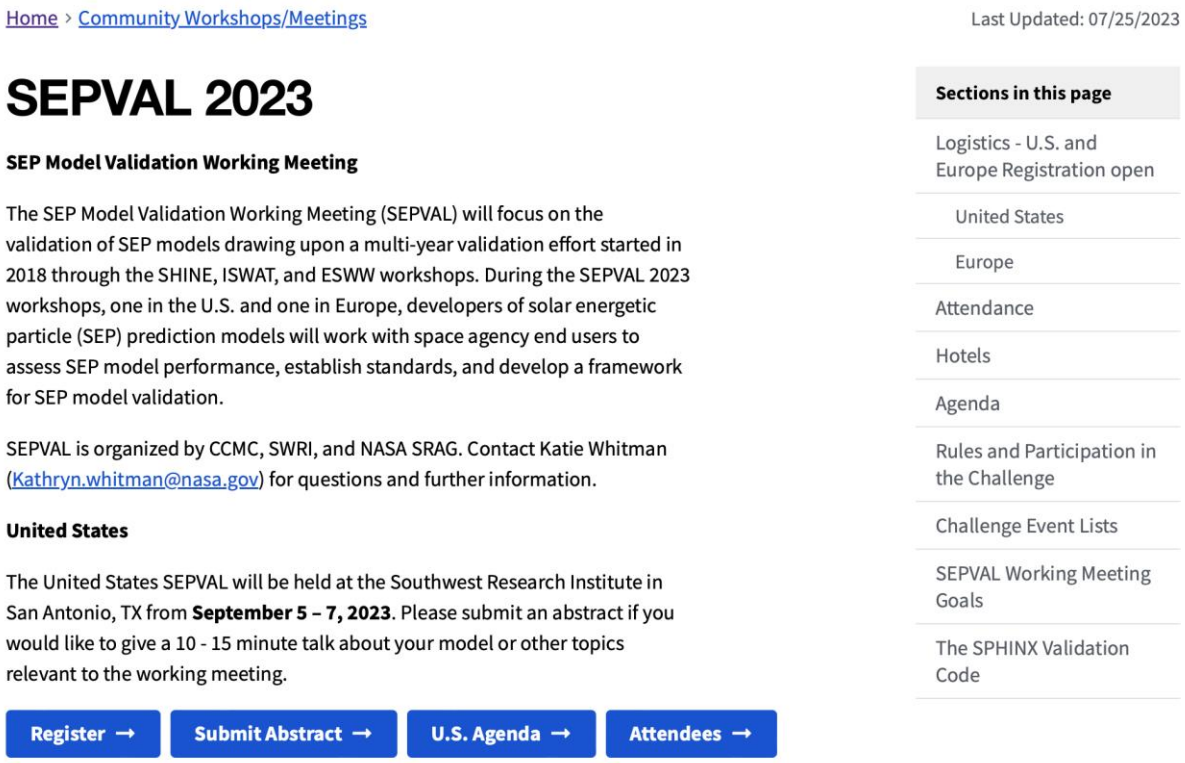


Left to Right: Probability Scoreboard, Peak Proton Flux Heat Map (Intensity Scoreboard) and Flux Time Series (Intensity Scoreboard) compiling historical projections for Sept 2017 event

How will ISEP Enhance Beyond-LEO Mission Support?

- Scoreboard function was thoroughly tested during Artemis-I mission (Nov-Dec 2022)
- Operators given opportunity for detailed feedback, which will be incorporated for Artemis-II
- New Flare Scoreboard in development
- Dose projection methodology in work
- Model validation workflow in development to improve operators' understanding of model strengths

SRAG Space Weather Team @SwRI in San Antonio, TX



Home › Community Workshops/Meetings

Last Updated: 07/25/2023

SEPVAL 2023

SEP Model Validation Working Meeting

The SEP Model Validation Working Meeting (SEPVAL) will focus on the validation of SEP models drawing upon a multi-year validation effort started in 2018 through the SHINE, ISWAT, and ESWW workshops. During the SEPVAL 2023 workshops, one in the U.S. and one in Europe, developers of solar energetic particle (SEP) prediction models will work with space agency end users to assess SEP model performance, establish standards, and develop a framework for SEP model validation.

SEPVAL is organized by CCMC, SWRI, and NASA SRAG. Contact Katie Whitman (Kathryn.whitman@nasa.gov) for questions and further information.

United States

The United States SEPVAL will be held at the Southwest Research Institute in San Antonio, TX from **September 5 – 7, 2023**. Please submit an abstract if you would like to give a 10 - 15 minute talk about your model or other topics relevant to the working meeting.

Register → | Submit Abstract → | U.S. Agenda → | Attendees →

Sections in this page

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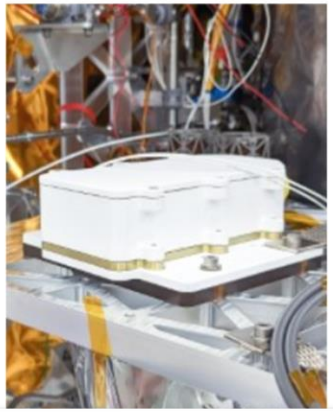
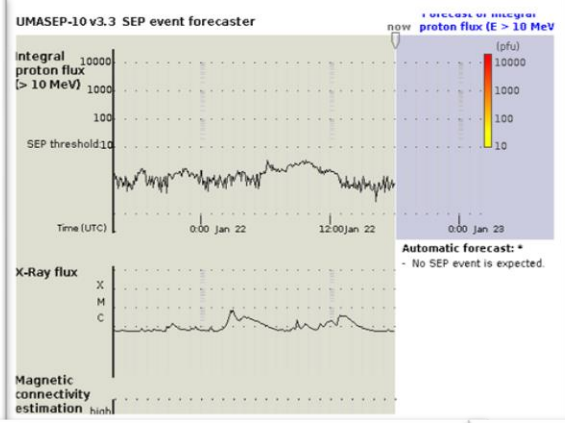
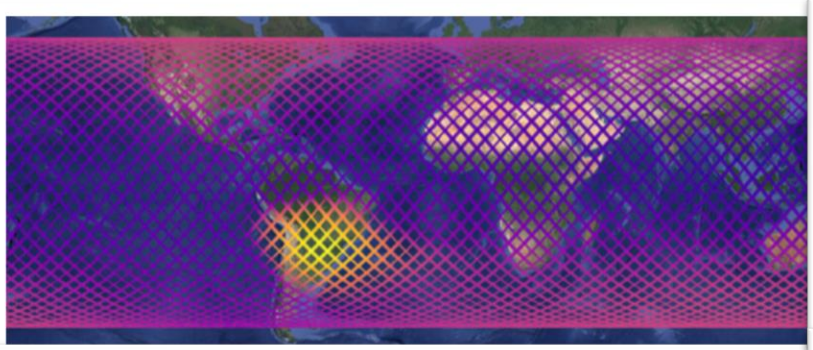
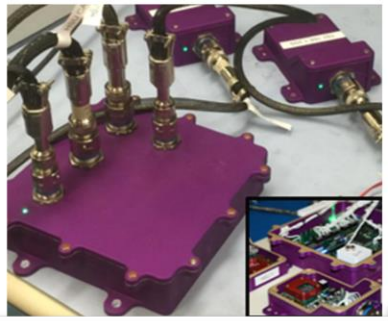
- Attendance
- Hotels
- Agenda
- Rules and Participation in the Challenge
- Challenge Event Lists
- SEPVAL Working Meeting Goals
- The SPHINX Validation Code

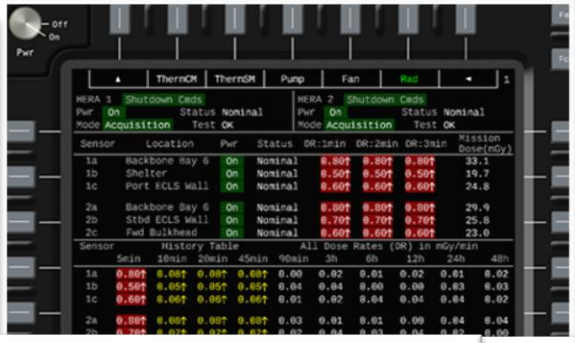
https://ccmc.gsfc.nasa.gov/community-workshops/ccmc-sepval-2023/#agenda

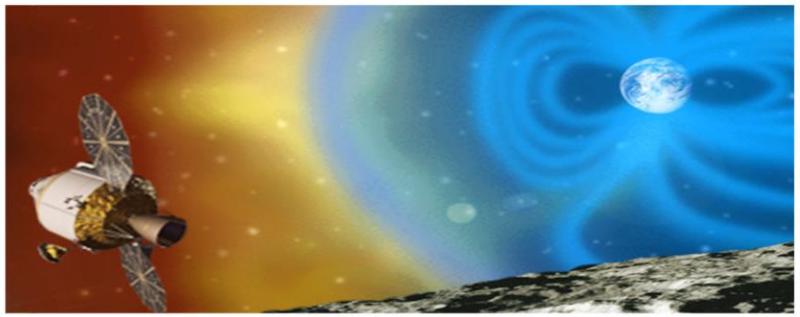


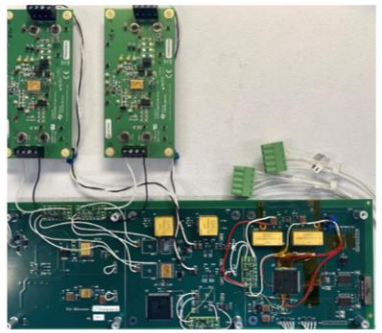


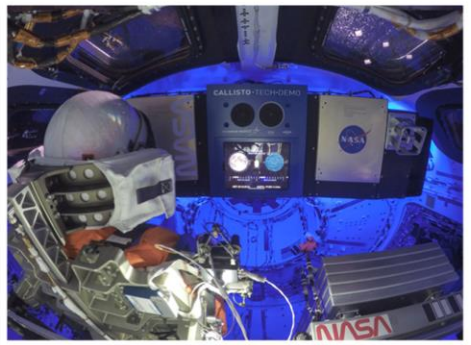


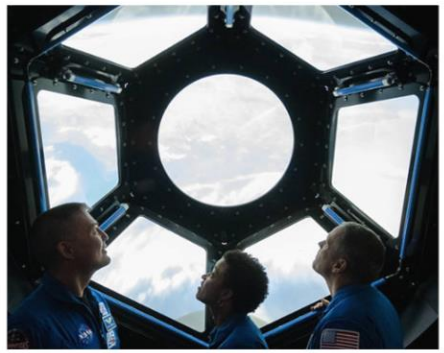












RadWorks enables our Operations – Thank You – Any ??????