JSC SRAG Operations for 2024 Lunar, Gateway, and Mars Missions

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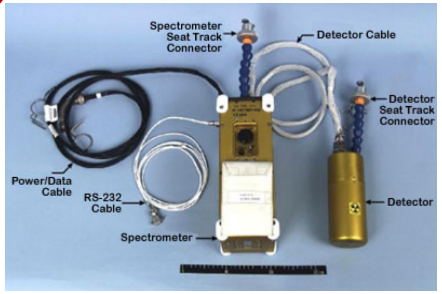
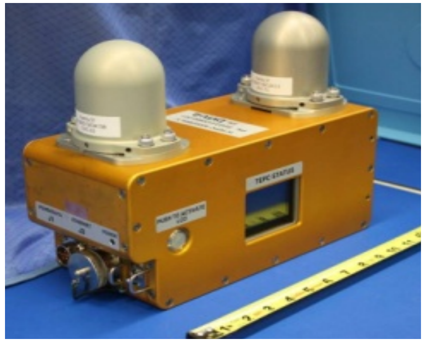
Outline

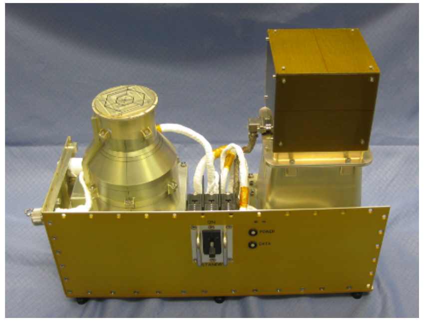
- SRAG Operations and Instrumentation on ISS
  - SRAG's purpose is to protect astronauts from radiation exposure
- Exploration Missions and Operations
- MPCV Radiation System Sensors
- Artemis-1 Mission Profile
  - Introduction of STARGOAT visualization tool
- Artemis-2 Mission Profile
  - Predictions
  - Sample over full launch window

ISS Instrumentation

- CPDS – Charged Particle Directional Spectrometer
- **REM – Radiation Environment Monitor**
    - Active dosimeter with USB interface
- TEPC – Tissue Equivalent Proportional Counter
    - Located in ISS Service Module
- IV-TEPC – new TEPC detector
    - Moves about ISS every 4-6 weeks
- ISS-RAD – Radiation Assessment Detector



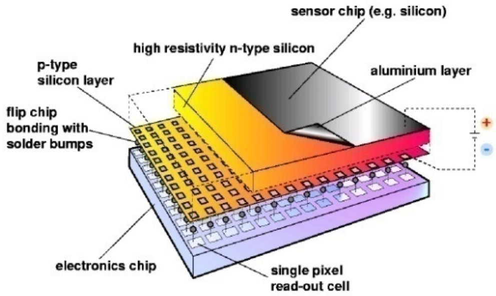


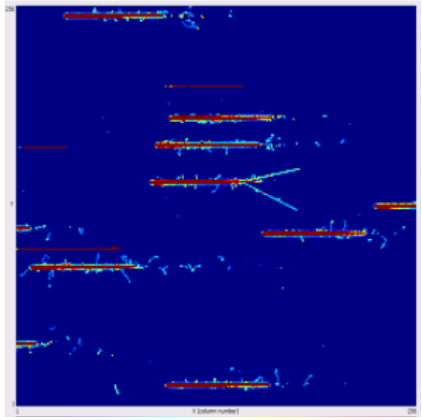


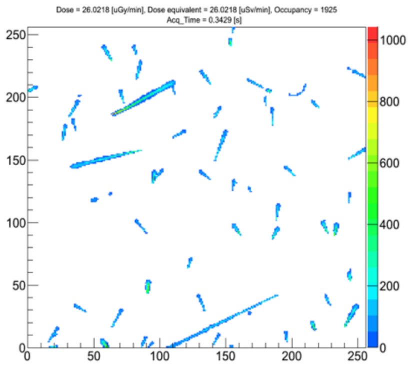
Radiation Environment Monitor (REM)

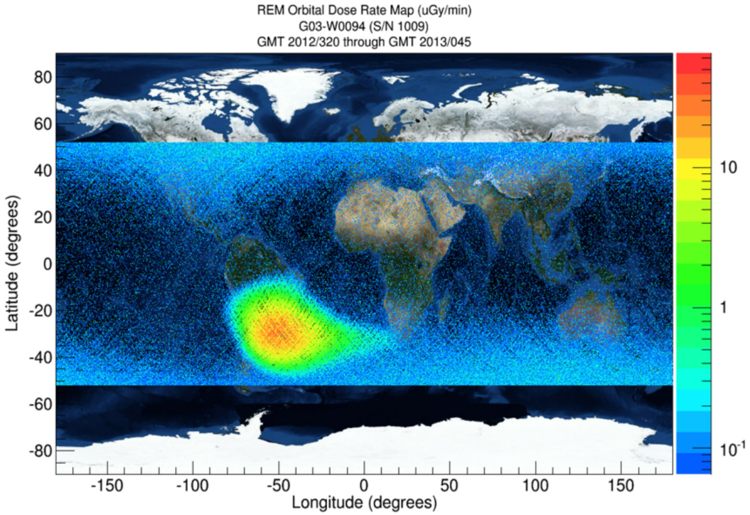
<u>The Timepix Detector</u>

- Developed as a High Energy Physics application of medical imaging technology
- Hybrid Pixel Detector with independent counting and readout circuitry in each pixel footprint
- 256 x 256 pixel grid with total area of 2 cm^2





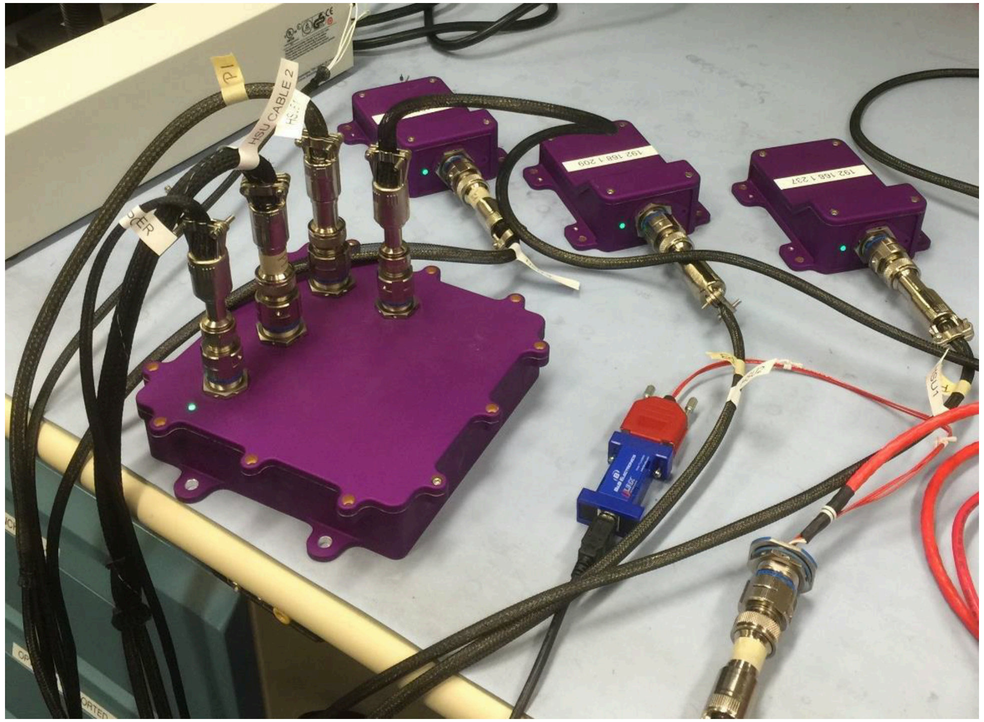




Pixel Detector Image from Medipix collaboration website: http://medipix.web.cern.ch/medipix/img/medipix2/web_flipchip.gif

MPCV Radiation System

- Hybrid Electronic Radiation Assessor (HERA)
  - Active instrument provides telemetered data stream
  - System consists of two redundant strings
    - Each string - 1 Power Unit and 2 Sensor Units

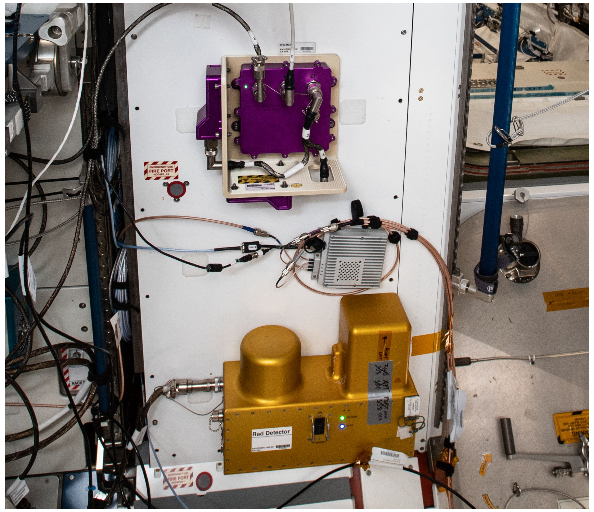


- Radiation Area Monitors (RAMs)
  - Passive detectors from Shuttle and ISS heritage

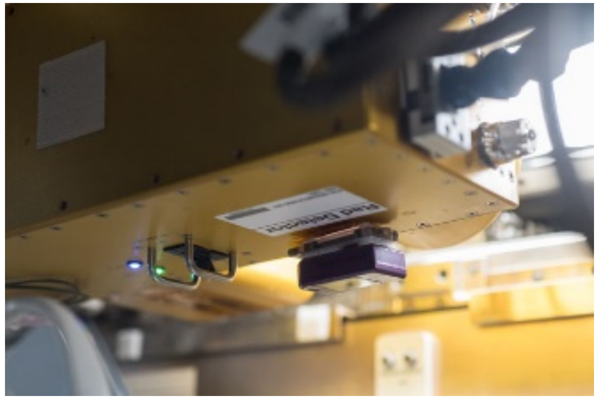
- Crew Active Dosimeter (CAD)
  - Active dosimeter provides individual dosimetric measurement
  - Data retrieved after the mission

Testing MPCV Radiation System

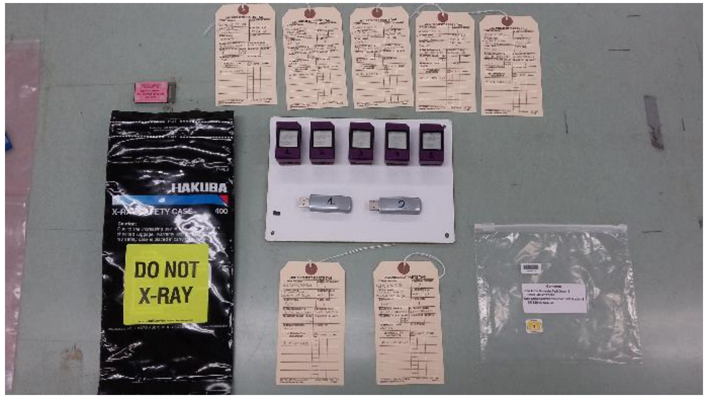
- ISS Hybrid Electronic Radiation Assessor (HERA)
  - Arrived at ISS in early 2019
  - 30 day test completed
  - 1 HPU and 2 HSUs



- CADs DTO – CPAD + RAM stack
  - 5 flew on ISS – 3 worn by crew
  - Bluetooth data transfer to SSCs

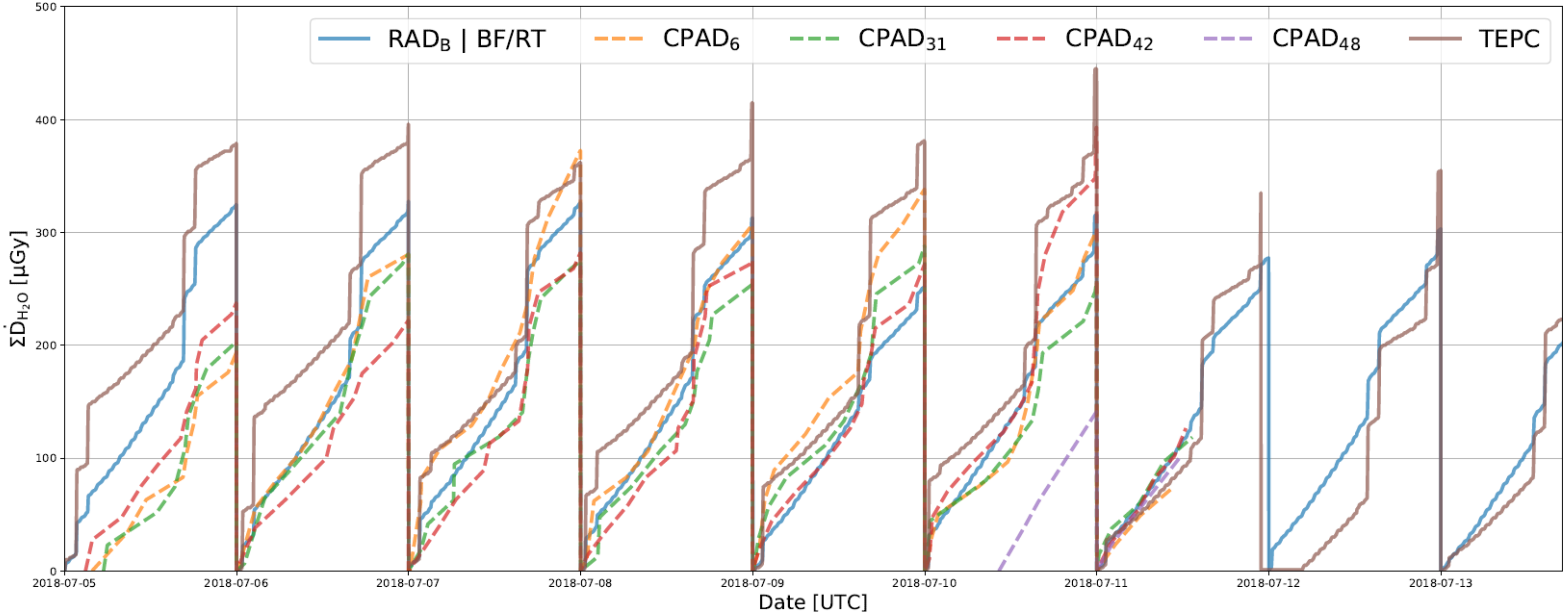


CAD Deployed on ISS RAD

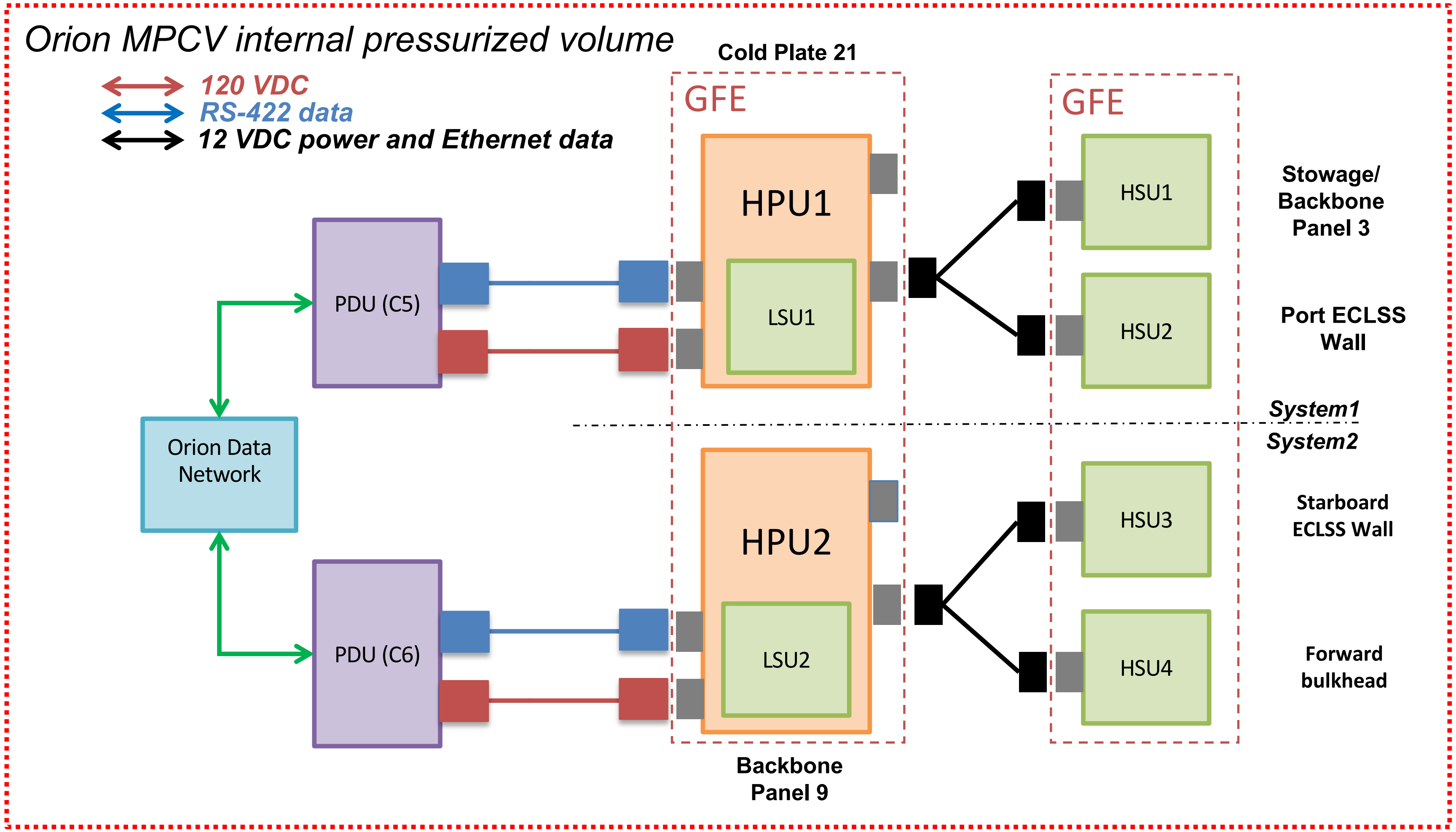


CAD Measurements on ISS (July 2018)

Cumulative dose measured by each CAD compared with RAD and TEPC ops instruments



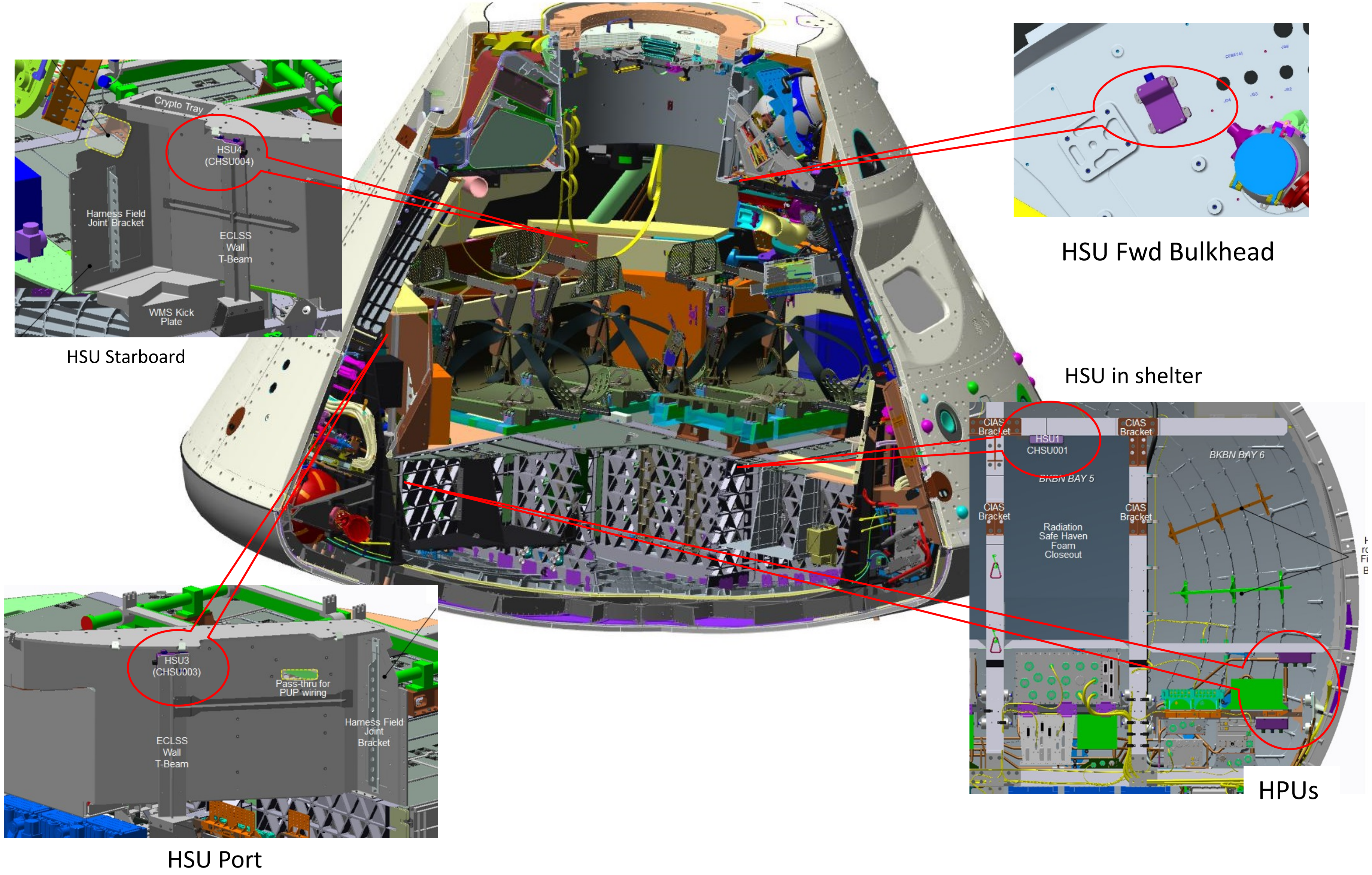
Orion HERA Architecture & Interfaces



Note: Cables and Harnesses are manufactured and delivered by LM

EM-1: System 1
EM-2: System 1 + System 2

HERA Vehicle Locations

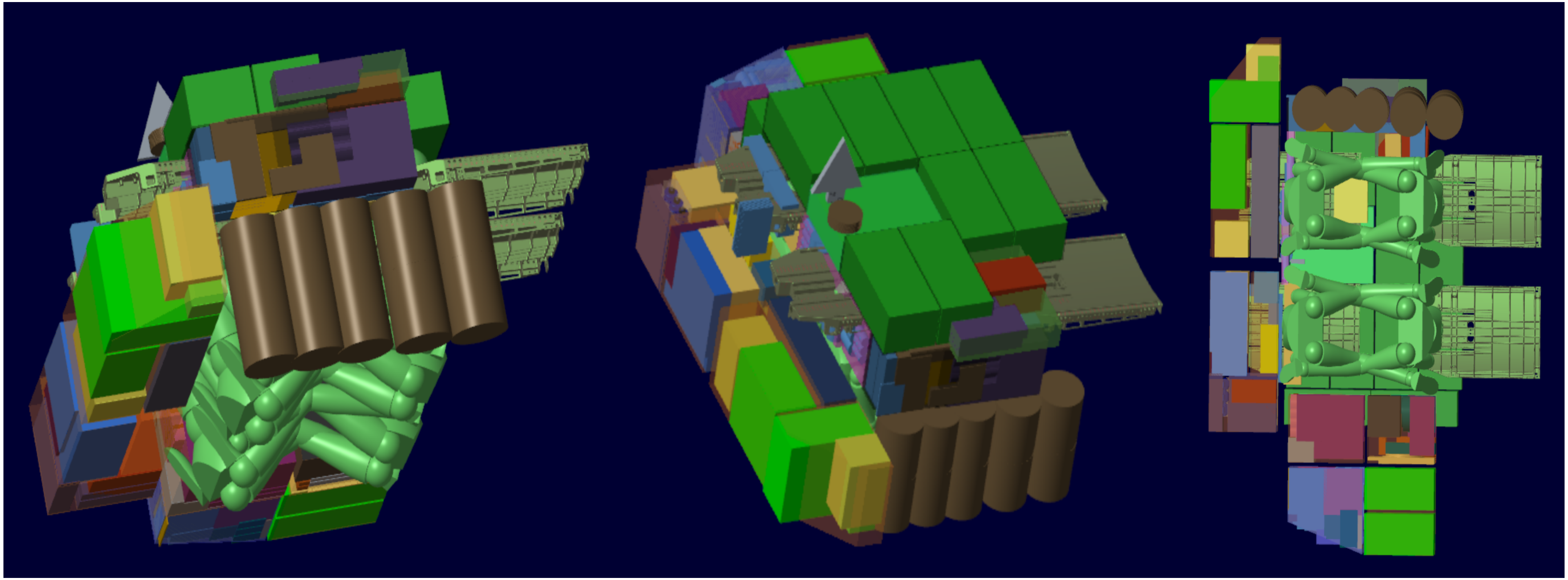


MPCV Radiation Mitigation Planning

- HERA system is connected to the Caution and Warning System
  - Audible alarm sounds when HERA threshold is exceeded
  - If ground communication is available Radiation Console determines if sheltering is needed, otherwise crew will shelter upon HERA alarm
  - Acute radiation impact assessment modeled based on HERA measurements

- Stowage configuration optimized based on Human in the Loop (HITL) test
  - HITL test consisted of many simulated 4 person crews in the medium fidelity mockup at NASA/JSC
  - About half of the test subjects were astronauts
  - None of the test subjects had ever seen the procedure and most were unfamiliar with the mockup layout
  - Average time to reconfigure the cabin was about 30 minutes

Orion Stowage Re-configuration



Stowage Re-configuration Model Results

- SRAG used two stowage configurations for analysis going to CDR
  - High fidelity stowage model is now incorporated
  - Optimized for Pre-launch stowage (506 lb)
  - Optimized for Return stowage (362 lb)

Whole Body Effective Dose* Radiation Analysis Results for a simulated 1972 King Spectrum SPE Using MPCV 702 CAD Model post CDR

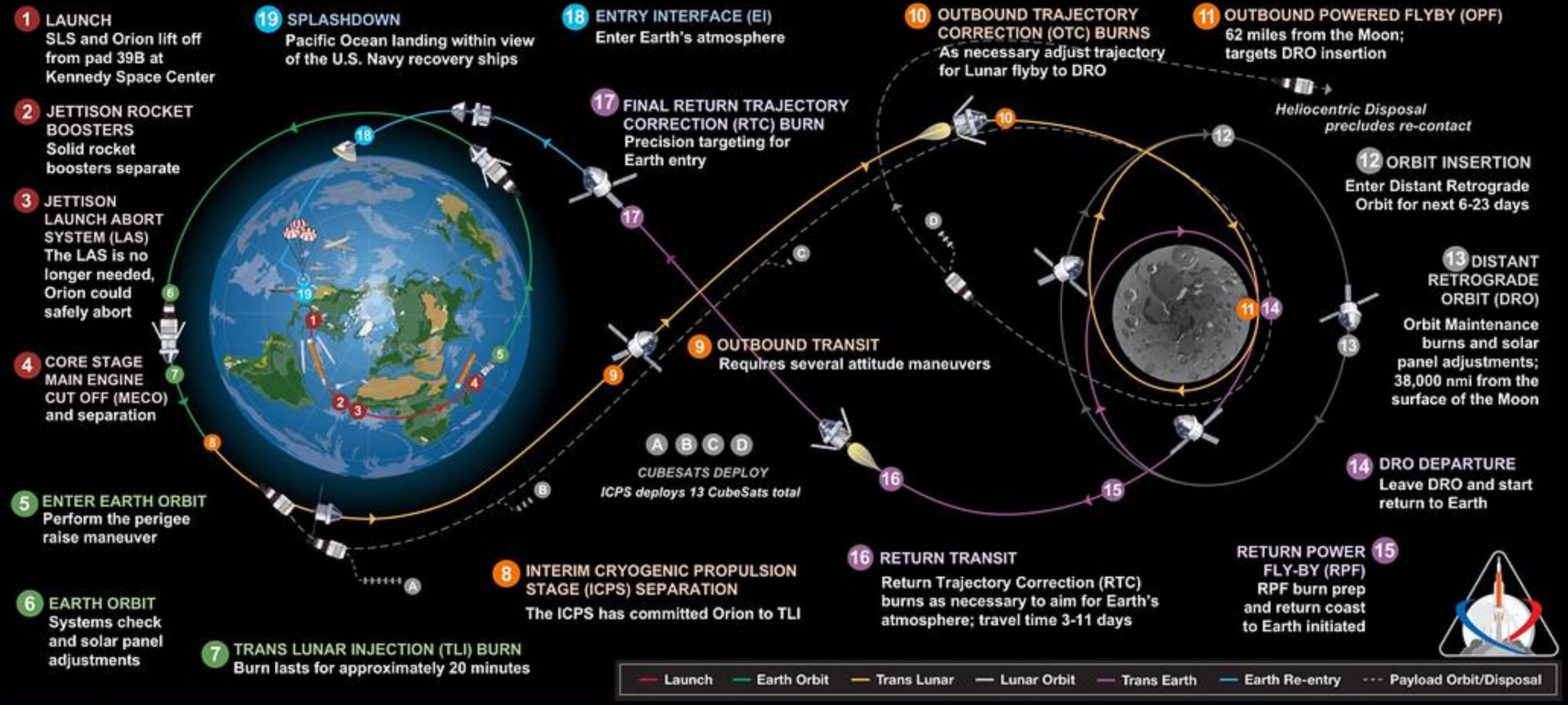
	Crew 1	**Crew 2**	**Crew 3**	**Crew 4**
Crew in Seats	**210** mSv	**208** mSv	**252** mSv	**226** mSv
Optimized Pre-launch Stowage	**67** mSv	**69** mSv	**72** mSv	**60** mSv
Optimized Return Stowage	**85** mSv	**80** mSv	**84** mSv	**77** mSv

- HSIR requires two things for this analysis
  - Analysis show less than 150 mSv for each crew member
  - ALARA principle is adhered to

*Effective Dose as defined in National Council on Radiation Protection and Measurements (NCRP) Report No. 132

Artemis 1

The first uncrewed, integrated flight test of NASA's Orion spacecraft and Space Launch System rocket, launching from a modernized Kennedy spaceport



Total distance traveled: 1.3 million miles – Mission duration: 26-42 days – Re-entry speed: 24,500 mph (Mach 32) – 13 CubeSats deployed

Artemis-1 Mission Analysis

- Trajectory: 42 day Trajectory
- Shield Point: Crew 1 Chest Location in Orion Seat 1 of EM-2 Vehicle
- Trapped: AP8/AE8
- GCR: Badhwar-O'Neill 2014, 2009
  - Expected to be similar to Oct 2020 which is EM1 schedule launch date
- Radiation Transport: HZETRN2015

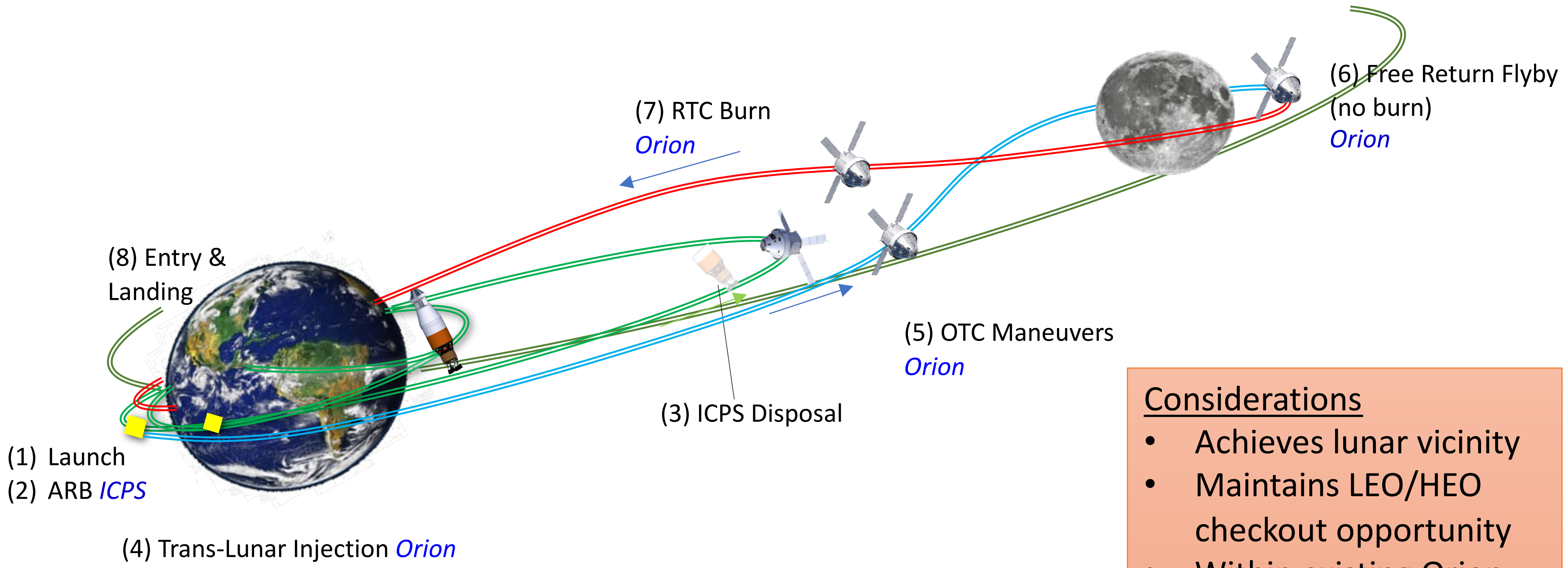
New Tool to View

- New video tool for viewing analysis results
- SRAG Trajectory And Radiation belt Godot Animation Tool (STARGOAT)
- "Godot" is pronounced "Go-Dough". It’s French. It’s a video game engine used to make STARGOAT
- Displays spacecraft, trajectory in space, trapped radiation cloud, planetary bodies, dose rate, cumulative mission dose, and altitude


WRMISS.txt
Sub Menu
APR 10 2020
03:39:32 [UTC]
DOSE RATE = 7.20E-2 MICRO-GY/MIN
CUMULATIVE DOSE = 0.00E+2 MICRO-GY
ALTITUDE = 1.69E+2 KM
ENERGY RANGE
≥10 ≥50 ≥100
CAMERA
REC
TRAJECTORY PLAYER
REC

Artemis-2 Mission Overview: Free Return Hybrid Triple

Notional



1-2) LEO parking orbit, 1-2 orbit checkout, and ICPS Apogee Raise Burn (ARB) demonstration

3) Orion separates after ARB, achieves safe separation distance, ICPS performs disposal burn

4) Orion flight test system characterization occurs in HEO (16-24 hrs), TLI performed by Orion

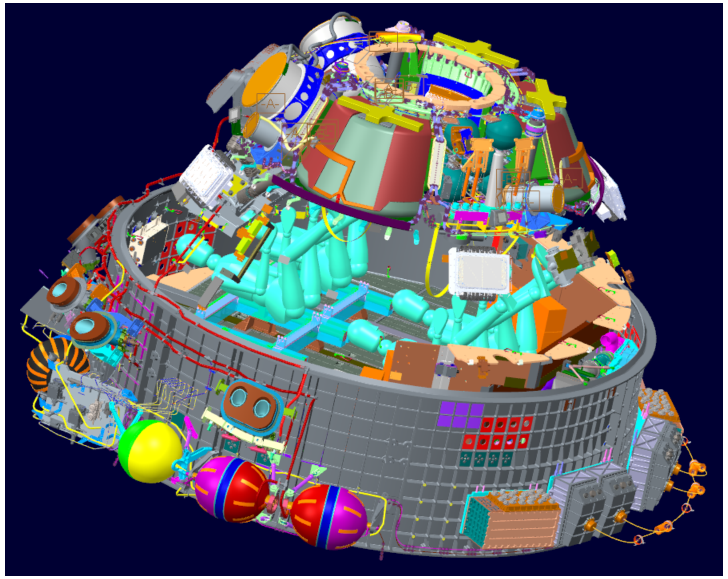
6) Free return flyby, no Orion critical burns required

8) Nominal mission return and cis-lunar entry velocity targeting San Diego vicinity

Considerations

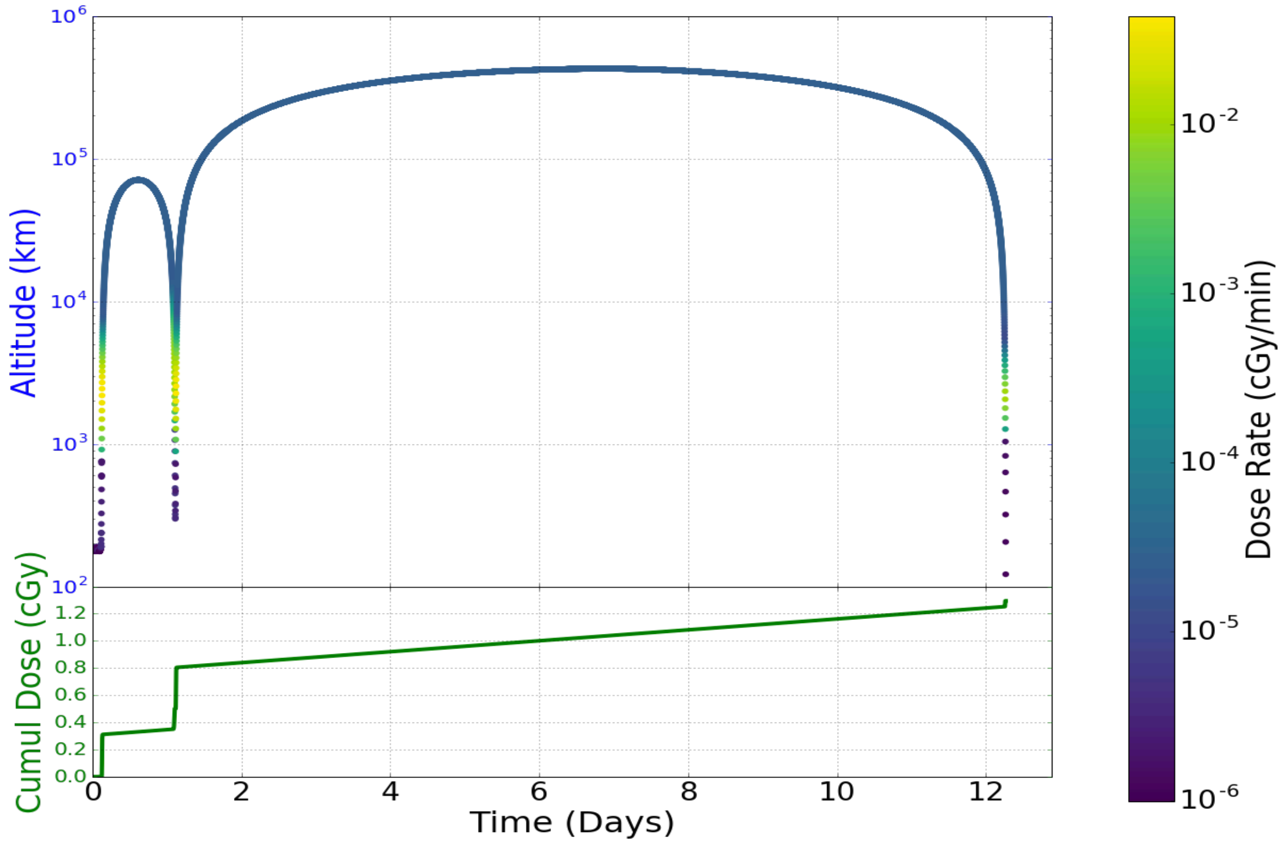
- Achieves lunar vicinity
- Maintains LEO/HEO checkout opportunity
- Within existing Orion capabilities
- Likely within ICPS capability

Artemis-2 Mission Analysis



- Trajectory: Hybrid Triple
- Shield Point: Crew 1 Chest Location in Orion Seat 1 of EM-2 Vehicle
- Trapped: AP8/AE8
- GCR: Badhwar-O'Neill 2014, August 2010
  - Expected to be similar to Fall 2021 which is EM2 schedule launch date
- Radiation Transport: HZETRN2015

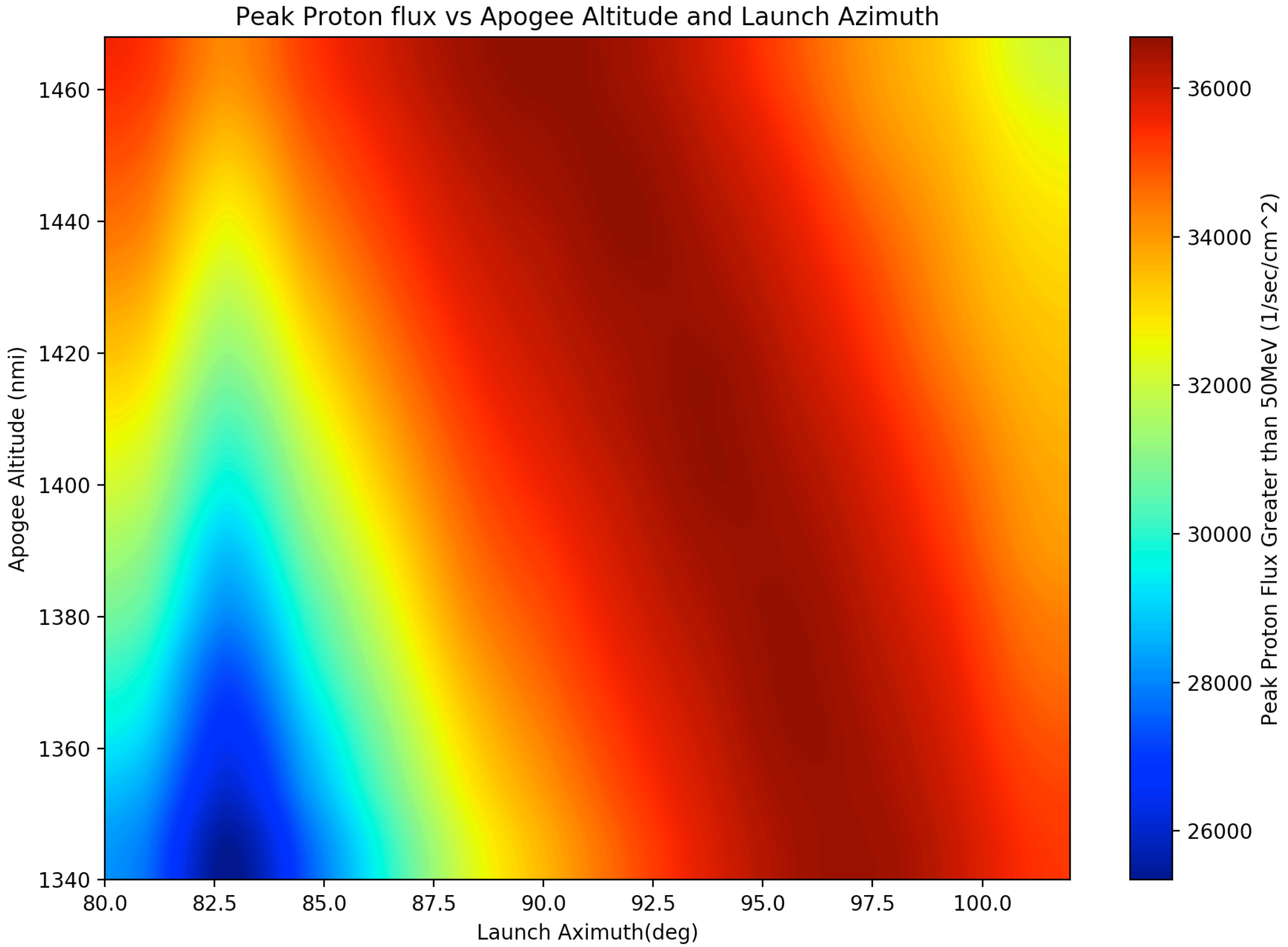
Artemis-2 Hybrid Triple Trajectory



- 3 passes though trapped radiation belts contribute ~2/3 of modeled dose
- 12 days of GCR contributes ~1/3 of modeled dose

Artemis-2 Launch Window Variations

- If Artemis-2 does not launch at the scheduled time there is a window of time that the launch can occur in
- Within this window the angle of launch varies
- Results in passes through the radiation belts at various points
- Analysis done to determine external environment >50 MeV integral particle flux
- 168 trajectories analyzed (Provided my Lockheed-Martin Space)
- Varies launch azimuthal angle and maximum LEO apogee



Peak Proton flux vs Apogee Altitude and Launch Azimuth
Apogee Altitude (nmi)
1460
1440
1420
1400
1380
1360
1340
80.0
82.5
85.0
87.5
90.0
92.5
95.0
97.5
100.0
Launch Aximuth(deg)
36000
34000
32000
30000
28000
26000
Peak Proton Flux Greater than 50MeV (1/sec/cm^2)

Summary

- Radiation System Flight Hardware for Artemis-2 is nearing completion
- Tests of all hardware have been performed on ISS.
- SRAG has a new tool for visualizing dose and dose-rate along any given trajectory
- Analysis of launch window for Artemis-2 shows less than factor of 2 flux for >50MeV protons indicating that radiation concerns will be minimal across the full launch window
- Further analyses will be performed for each instrument location in Artemis-1 and Artemis-2 to generate pre-flight predictions, which will be compared to measurements post-flight

Acknowledgments

Kevin Beard[1,3], Hatem Nounu[1,2], Phil Quinn[1,3], Ramona Gaza[1,3], Chirag Patel[4], Hesham Hussein[4], Razvan Gaza[4], Jeff Snively[5], and Andy Scott[5]

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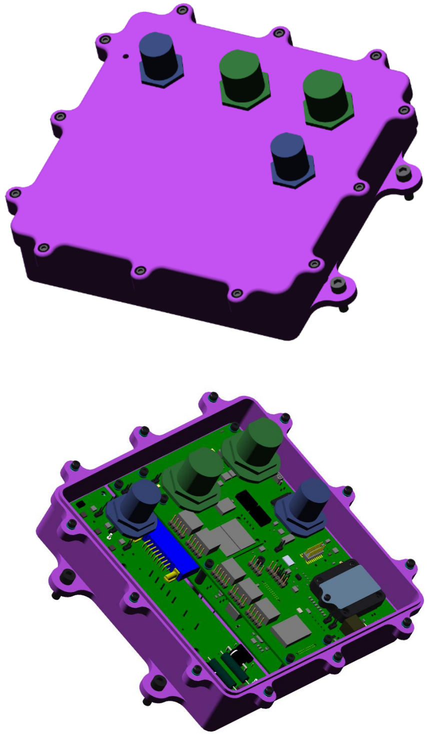
We Are Going
2024

Radiation System will be ready

HERA Power and Sensor Units

- HERA on EM-2+ consists of 2 Power Units and 4 Sensor Units (redundant system). All units contain Timepix sensor chip.
    - HERA Power Unit (HPU)



    - HERA Sensor Unit (HSU)