MPCV NASA Space Exploration Active Measurements and Future Operations

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Outline

- EFT-1 BIRD Results
- HERA Integration into MPCV
- Contingency Operations for MPCV during an SPE
BIRD Summary

- EFT-1 presented a unique opportunity
  - First measurements in Orion MPCV
  - Information about EM-2
- Detector operation
  - Met all expectations
  - No apparent data corruption
- Data
  - Two peaks caused by spectral changes
  - Max absorbed dose rate about 1 mGy/min
  - Absorbed dose 1000x ISS TEPC
Introduction

- Timepix chip
  - Single energy threshold
  - 55 µm pixels
  - 256 x 256 pixels
  - Active area ~2 cm²
  - Silicon detection element

L. Pinsky and J. Chancellor
*IEEE* (2007)

Introduction

- Timepix detection at NASA
  - ISS Radiation Environment Monitor (REM)
    - Technical demonstration
    - USB communication with laptop
  - BIRD
    - Flew on Orion MPCV in December 2014
    - Independent of vehicle systems
  - Hybrid Electronic Radiation Assessor (HERA)
    - Integrated system
    - Distributed monitoring
Copper bonding strip positioned to contact an alodined surface.
BIRD Overview

- Oct. 2014: Flight hardware shipped to KSC
- Nov. 2014: Installed into EFT-1 vehicle
- 5 Dec. 2014: EFT-1 Launch
- 9 Dec. 2014: Recovered from vehicle
- Feb. 2015: Data report delivered to HQ

Hardware post flight
Concept of Operations

Pre-flight
- Functional check
- Enter sleep mode
- Install in Orion MPCV

Flight
- Begin data acquisition upon launch
- Terminate once voltage drops below threshold
- Graceful shutdown

Post-flight
- De-install from Orion MPCV
- Transfer data from BIRD
- Analyze and distribute data
Acceleration

L + 2 min
SS #1
SS #2
Parachute deploy
Frame Occupancy and Rate

Left Detector

Right Detector
Absorbed Dose Rates

Left Detector

Right Detector

ISS TEPC alarm

ISS SAA max
Cumulative Absorbed Dose

<table>
<thead>
<tr>
<th></th>
<th>BIRD [mGy]</th>
<th>RAM [mGy]</th>
<th>ISS-TEPC [mGy]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left</td>
<td>17.9</td>
<td>15.1 ± 0.3</td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>15.7</td>
<td>13.5 ± 0.2</td>
<td>0.015</td>
</tr>
</tbody>
</table>
Dose Equivalent Rates

Left Detector

Right Detector
**AP9/AE9 Comparison**

Spherical shell
No solar modulation
AP9/AE9 transport

![Graph](image-url)
Detector Comparison
Rates vs. Altitude and Time
Rates vs. Latitude/Longitude

[Map showing radiation rates varying with latitude and longitude.]
Trapped proton environment below about 2000 km is known to be anisotropic.
EFT-1 Summary

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- Data
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MPCV simplified representations mass (lbm)

<table>
<thead>
<tr>
<th>Simplified Reps</th>
<th>CAD Mass (lbm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAD_SM</td>
<td>10925.05</td>
</tr>
<tr>
<td>RAD_CM_INT</td>
<td>5553.85</td>
</tr>
<tr>
<td>RAD_CM_EXT</td>
<td>4427.75</td>
</tr>
<tr>
<td>RAD_TPS</td>
<td>5825.42</td>
</tr>
<tr>
<td>RAD_Stowage/crew</td>
<td>1472.52</td>
</tr>
</tbody>
</table>

Total mass ~ 28k lbm

- Due to the complexity and size of the MPCV CAD model, it was broken down into 5 simplified representations
- Each simplified representation includes parts and assemblies that have common purpose
- The total of the simplified reps. Equal to the entire MPCV CAD model
Scenario 0: (Crew Seated)

<table>
<thead>
<tr>
<th>Crew Position</th>
<th>Crew #1</th>
<th>Crew #2</th>
<th>Crew #3</th>
<th>Crew #4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective Dose E (mSv)</td>
<td>260</td>
<td>244</td>
<td>273</td>
<td>254</td>
</tr>
</tbody>
</table>

- Crew members’ effective doses for August 1972 King SPE environment
- Human-Systems Integration Requirements (HSIR) not-to-exceed exposure limit is $E = 150 \text{ mSv}$
## SPE Contingency Plan: Scenario 2 (Ideal stowage configuration)

<table>
<thead>
<tr>
<th>Crew Position</th>
<th>Crew #1</th>
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<th>Crew #3</th>
<th>Crew #4</th>
</tr>
</thead>
<tbody>
<tr>
<td>SRAG Bench mark (mSv) Contingency</td>
<td>114</td>
<td>117</td>
<td>119</td>
<td>113</td>
</tr>
<tr>
<td>SRAG Optimized (mSv) Contingency</td>
<td>85</td>
<td>102</td>
<td>100</td>
<td>98</td>
</tr>
</tbody>
</table>
SPE Contingency Plan Scenarios: (Effective Dose due to King '72 SPE)

**Scenario 1:**
D&E stowage on top

- Crew1: 114 mSv
- Crew2: 117 mSv
- Crew3: 119 mSv
- Crew4: 113 mSv

**Scenario 2:**
Ideal stowage configuration

- Crew1: 85 mSv
- Crew2: 102 mSv
- Crew3: 100 mSv
- Crew4: 98 mSv

**Scenario 3:**
D&E stowage in 8 boxes on top

- Crew1: 109 mSv
- Crew2: 122 mSv
- Crew3: 111 mSv
- Crew4: 106 mSv

**Scenario 4:**
D&E stowage in 16 boxes on top

- Crew1: 105 mSv
- Crew2: 117 mSv
- Crew3: 106 mSv
- Crew4: 98 mSv

**Scenario 5:**
18 boxes on top and 20 canisters in WMS

- Crew1: 95 mSv
- Crew2: 110 mSv
- Crew3: 106 mSv
- Crew4: 98 mSv
Aspects of the Orion SPE contingency plan.

1. Use of umbilical from pressurized suits for air flow in bays
2. Mass risk for stowage restraints
3. HITL (Human in the Loop) testing
It fits