NASA Crew Personal Active Dosimeters (CPADs)
Leveraging Novel Terrestrial Personal Radiation Monitoring Capabilities for Space Exploration

TCC Radiation Technologies Event
9/21/16  Martin Leitgab
1) Novel Capabilities in Terrestrial Personal Radiation Dosimeters Yet Unused in Space

- Currently used NASA personal dosimeters (ISS): Passive dosimeters
  * To be returned to ground upon mission completion for analysis
  * No in-flight exposure information
  * Integral exposure information over entire mission, no time resolution

- Novel capabilities in terrestrial personal dosimeters:
  * Active dosimeters: configurable/autonomous recording of radiation exposure and
    internal storing of data
  * Displays for immediate user exposure feedback
  * Wireless data transmission

Opportunities to enhance Crew personal dosimetry with new features in terrestrial dosimeters
2) Technology Need for Exploration Mission 2 and Beyond

- **Requirements**: Need for wearable personal **active dosimetry**, capable of:
  1) Measuring **time resolved** and time integrated absorbed dose
  2) Operating for 30 days without being charged or requiring data download
  3) Being read out by the crew via a **display on the dosimeter**

Requirement not met with existing NASA radiation hardware (passive dosimeters)

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Space Radiation Analysis Group (SRAG, SD2) develops
**COTS-based Crew Active Personal Dosimeters (CPADs)** to meet requirements

- Derived requirements from intent of basic requirements:
  a. **Minimum impact to Crew mission operations**
     @ To minimize health risk projection uncertainties, CPADs to be worn at all times
     @ CPADs need to be changed in all garment changes
     @ Any additionally required Crew interaction to be avoided (e.g. data Xfer, power)
  b. **Accurate detection of space radiation environment (charged particles)**

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3) Market Survey/Technology Downselect

- Use COTS products/base to minimize resource footprint of project
  
  * Conduct Market Survey and Technology Downselect:
    @ Review COTS radiation detection technology options
    @ Identify most suitable radiation detection technology/implementation and vendor

- Apply basic selections to *identify/downselect COTS candidate dosimeters*:

  **Action a)** Identify dosimeters with needed features *(keeps development gap small)*:
  
  @ Ready-to-purchase, packaged products (no research papers/components)
  @ Battery powered
  @ Capable of record time-stamped dose
  @ Readout via common interface to laptop
  @ Small (<100 cm^3) & lightweight (<100g)
### Candidate Detection Technology

<table>
<thead>
<tr>
<th>Candidate Detection Technology</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silicon diodes</td>
<td>Established (30 yrs), low power, small size, rugged; calibration potentially LET/energy dependent; used by IPs (ESA, JAXA)</td>
</tr>
<tr>
<td>Direct Ion Storage (DIS)</td>
<td>Established (20 yrs), low power, small size, rugged; used by IPs (ESA)</td>
</tr>
<tr>
<td>CsI(Ti) crystals</td>
<td>Too high power consumption, charged particle response probably not adequate</td>
</tr>
<tr>
<td>GM tubes</td>
<td>Only counter, charged particle response not adequate</td>
</tr>
<tr>
<td>Ionization chambers</td>
<td>Too large, too high power</td>
</tr>
<tr>
<td>MOSFET</td>
<td>No packaged product available; sensitivity probably not adequate; used by IPs (ESA)</td>
</tr>
</tbody>
</table>

### Selected Company, Product

<table>
<thead>
<tr>
<th>Selected Company, Product</th>
<th>Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mirion, Instadose 1</td>
<td>DIS</td>
</tr>
<tr>
<td>Mirion, Instadose 2</td>
<td>DIS</td>
</tr>
<tr>
<td>Mirion, DMC 3000</td>
<td>Si diode</td>
</tr>
<tr>
<td>Thermo Fisher Scientific, EPD</td>
<td>Si diode</td>
</tr>
<tr>
<td>Fuji Electric Co, NRF-30</td>
<td>Si diode</td>
</tr>
</tbody>
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3) Market Survey/Technology Downselect

Result a) Selected 2 Direct Ion Storage and 3 Silicon Diode COTS dosimeter candidates
4) Technology Downselect

Action b) Test dosimeter candidates in space-relevant charged particle radiation fields

Radiation Testing @ TRIUMF, NSRL

Result b) Tests selected Mirion DIS as sole feasible COTS technology & implementation

- Mirion Technologies holds patents on DIS technology
  -> Selected as sole source vendor

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5) CPAD Development Requirements

- **MPCV Operations Needs**

<table>
<thead>
<tr>
<th>Requirements Category</th>
<th>Flowed Down Requirement</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size/form factor, weight</td>
<td>Within 20% of Instadose 1: &lt; 3 x 1 x 0.6”; &lt; 50 g</td>
<td>Close to existing ID-1 product</td>
</tr>
<tr>
<td>Battery</td>
<td>Life 30+90 days, capacity &lt; 200mAh</td>
<td>Exceeded by existing ID-2 product</td>
</tr>
<tr>
<td>Data storage</td>
<td>&gt;= 4500 points</td>
<td>Exceeded by existing ID-2 product</td>
</tr>
<tr>
<td></td>
<td>‘Dynamic read’: only record dose if beyond 20 muGy resolution (at most once per minute)</td>
<td>New feature (exists in industry)</td>
</tr>
<tr>
<td>Data Transfer</td>
<td>Bluetooth wireless data transmission disable feature (for mission duration): Implement reset buttons for BLE processor</td>
<td>Close to existing ID-2 product</td>
</tr>
<tr>
<td>Non-shatterable display</td>
<td>Display cumulative absorbed dose since mission start and dose over last 10 minutes (‘rate’)</td>
<td>New feature (exists in industry)</td>
</tr>
</tbody>
</table>

- Approach: **Enhance existing COTS features** with additional **new features** to meet all CPAD requirements
6) Leveraging Synergy between NASA ISS and MPCV Programs

- **ISS currently uses** passive dosimeters for Crew personal radiation monitoring

- **Benefits for ISS Program** from use of adoption of CPADs as operational personal dosimeters:
  * Reduced ground processing cost/time
  * Reduced up-down logistics
  * Near real-time data availability

- **Benefits for MPCV Program**: ISS agreed to fund **2017 Technology Demonstration Mission**

**ISS Additional Operations Needs**

<table>
<thead>
<tr>
<th>Category</th>
<th>Flowed Down Requirement</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery compartment</td>
<td>Tool-free accessibility</td>
<td>New feature (exists in industry)</td>
</tr>
<tr>
<td>Battery</td>
<td>Life 8 months, capacity &lt; 200mAh</td>
<td>Exceeded by existing ID-2 product</td>
</tr>
<tr>
<td>Bluetooth Wireless Data</td>
<td>Autonomous data transfer to webserver, transmission quality</td>
<td>Exceeded by existing ID-2 product</td>
</tr>
<tr>
<td>Transmission</td>
<td>assurance, database framework</td>
<td></td>
</tr>
</tbody>
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7) Summary and Future Activities

- **MPCV Crew Personal Active Dosimeters** will bring novel capabilities in COTS personal radiation monitoring to space exploration

- CPADs have operational use option for ISS increasing efficiency and reducing cost contingent on success of Technology Demonstration mission

- **Accelerated schedule** due to use of COTS base:
  * **August 2016** Contract start date
  * September 2016 Deliverables due- basic board schematics and layouts
  * December 2016 Deliverables due- pre-production drawings, bill of materials
  * **February/March 2017** Delivery of CPAD hardware and software; acceptance testing
  
  * **June/July 2017** ISS Technology Demonstration Mission target (SpX-12 or similar)

  * **Fall 2017** Preparation for operational use of CPADs on ISS if Tech Demo Mission successful

  * **2018 Flight on MPCV Exploration Mission 1**

  * **2022 Flight on MPCV Exploration Mission 2**