# PSI's Space Radiation Instrumentation

## Radiation Detection & Dosimetry Workshop

**6-7 April 2006**

G. E. Galica

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# *PSI Rad Sensor Experience*



- **PSI has developed several generations of charged particle sensors**
  - Space science
  - Spacecraft & microelectronics survivability
  - Spacecraft operations support

- **SDOM [JAXA] – Gen1**
  - 1-200 MeV protons, 0.5-10 MeV electrons, alphas, Heavy ions - 32 particle-energy bins
  - 2 sensors currently flying (GEO & GTO), 1 awaiting launch on JEM
- **LPD [USEF(Japan)] – Gen2**
  - 1-150 MeV protons, 0.3-20 MeV electrons, alphas/heavy ions - 12 particle-energy bins
  - 1 sensor currently flying (1000 km polar), follow-on sensor launch 2007
- **CEM [NASA LWS SET] – Gen2**
  - Modified LPD
  - Launch 2009
- **HIPS [AFRL] – Gen3**
  - LPD derivative
  - High energy electrons and protons, Imaging sensor
  - Development started (launch 2009 on DSX)
- **LIPS [AFRL]**
  - 20-2000 keV protons and electrons
  - Imaging sensor, 12 particle energy bins x 8 angular bins
  - Launch 2009 on DSX

- **PSI has flown >20 instrument and experiments since 1991 on satellites, shuttle and space station**

# *PSI Rad Sensor Design Objectives & Data Quality*



- **PSI GEN1& GEN2 radiation sensors had several performance goals that have now been demonstrated on orbit:**

- **Single sensor to detect protons, electrons, alphas, heavy ions**
- **Large throughput (A$\Omega$) – up to 0.3 cm$^2$ sr**
  - Results in high count rates, efficient detection of small populations of particles, good counting statistics
- **High count rate – up to 200 kcps**
  - Does not saturate during solar storms
- **Good particle discrimination**
  - Cross-contamination between electrons and protons can be a significant problem
  - SDOM & LPD (GEN1&2 sensors) achieved <$10^{-4}$ contamination
  - Achieved through sensor design and on-board processing
- **High accuracy calibration and validated sensor model**
  - Returning fully calibrated data from sensor turn-on
- **Flight proven technology on multiple orbital missions**
- **High quality, calibrated data received from turn-on**

# *LPD – Light Particle Detector (GEN-2)*

NASA_JSC-3

- **Designed for and flying on the SERVIS-1 satellite (Japan)**
  - Space Environment Reliability Verification Integrated System
  - Orbital mission Oct03-present
  - SERVIS-2 follow-on launch 2007
  - CEM for LWS-SET
- **Baseline Energy Range**
  - protons: 1 to 150 MeV (6 bins)
  - electrons:  0.3 to 10 MeV (4 bins)
  - alphas: >12 MeV (1 bin)
  - ions:  >3 MeV/nucleon (1 bin)
- **Large G-factor/high count rate**
  - 0.2 $cm^2$ sr
  - 200 kcps
- **FPGA-based processing**
- **Extensive ground calibration & modeling**
- **Physical parameters**
  - 4 kg (fully redundant)
  - 7 W  (HiRel/RadHard)


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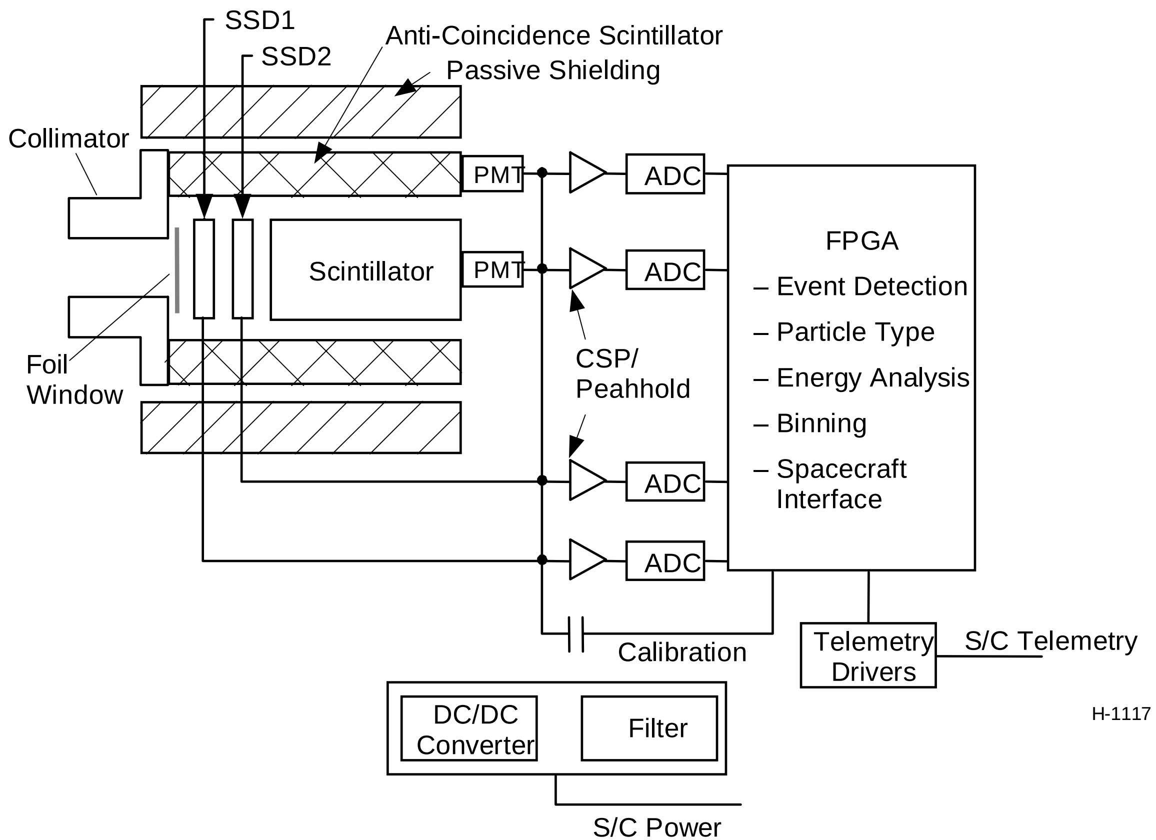
# Generic Block Diagram

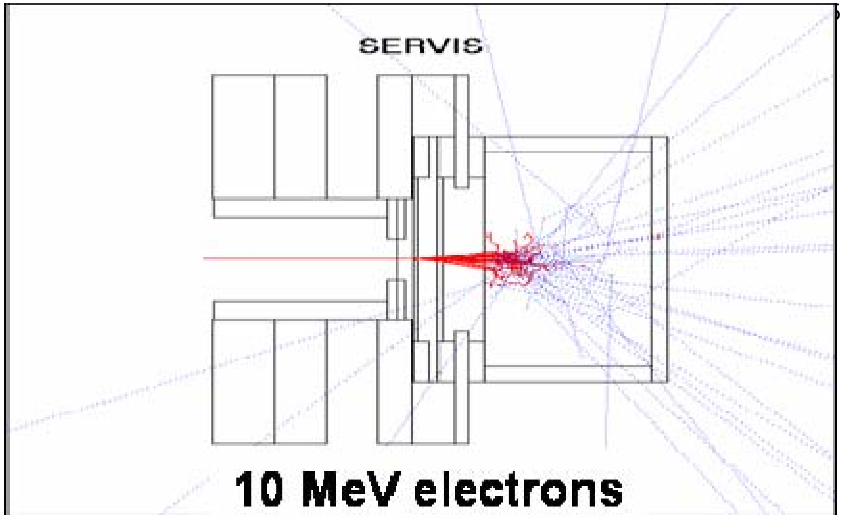


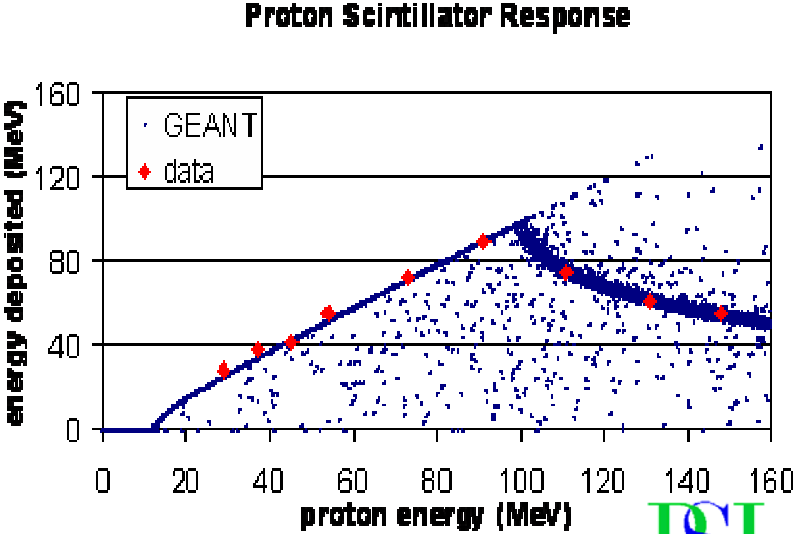
- Combination of multiple detectors: SSDs and scintillator
- AntiCoincidence Scintillator rejects side penetrating particles
- Collimator defines acceptance angle for low energy particles
- High-speed analog circuitry and ADC (12-bit) enables 200 kcps rate
- High-speed, FPGA-based processor reduces data volume



# *Modeling and Calibration*

- **All PSI sensors are modeled using the GEANT4 code**
  - no free parameters
- **The model is validated with calibration data**
  - Sensors are calibrated over nearly their entire particle-energy range
- **We use the model to:**
  - **develop and refine the sensor and algorithm design**
  - **interpolate/extrapolate sensor response to uncalibrated regimes**
  - **predict on-orbit performance**
  - **interpret orbital data**

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# *Sensor Calibration & Modeling*

NASA_JSC-6

- **PSI extensively calibrates its radiation sensors**
  - over nearly their entire particle / energy ranges
- **We develop full 3D sensor models to describe performance**
  - GEANT4 based models
  - No free parameters
- **We validate the models with ground calibration data**
- **Use the models for to interpolate and extrapolate sensor performance to uncalibrated regions**
  - Design phase
  - Interpretation of orbital data

| Particle | Energy (MeV) | Facility |
|---|---|---|
| Proton | 0.03-1.0<br>0.9-1.7<br>7.5-31<br>15-225<br>50-250 | UNT<br>NASA GSFC<br>Yale Wright NSL<br>NPTC<br>IUCF |
| Electron | 0.03-0.4<br>0.5-2.0<br>7-32 | NIST C-W<br>NIST VdG<br>NIST MIRF |
| Alpha | 10-50 | Yale Wright NSL |
| Ion (C) | 15-120 | Yale Wright NSL |

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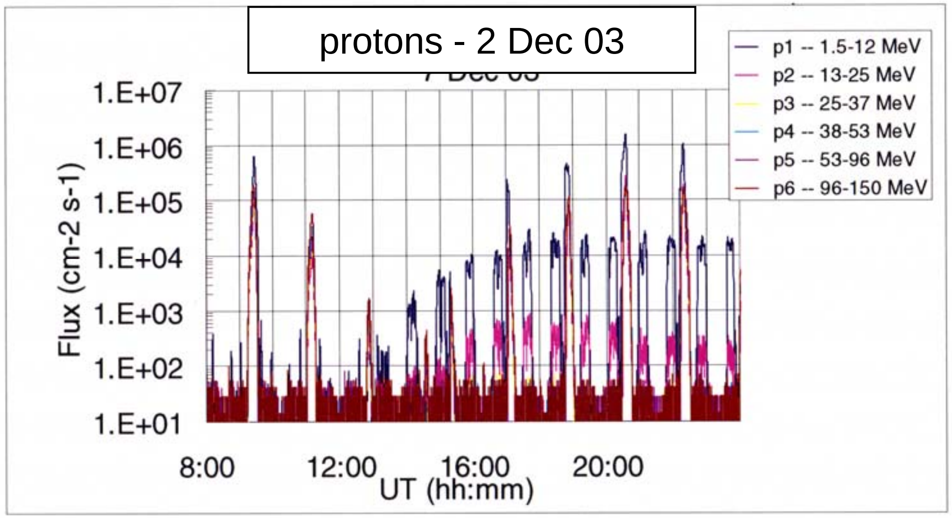
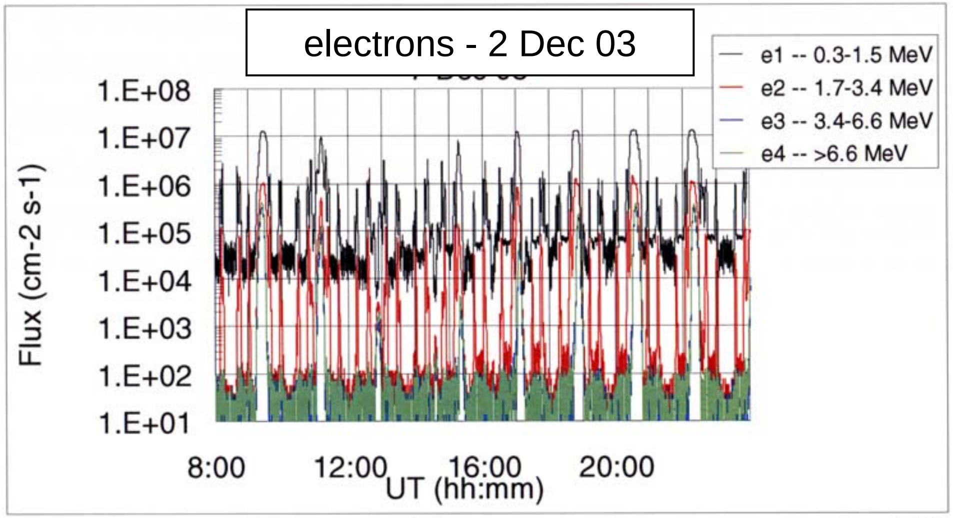
# *SERVIS LPD – 2 Dec 03*

- **On 2 Dec 2003, SERVIS LPD detected a sudden, spatially distinct enhancement of low-energy protons**
- **Low energy protons (1 to 12 MeV) enhanced first**
- **Enhancement in higher energy protons (12 to 25 MeV; 25 to 50 MeV) occurred after a delay**
- **Small changes in electron activity**
- **SAA proton flux was also enhanced**

NASA JSC-7

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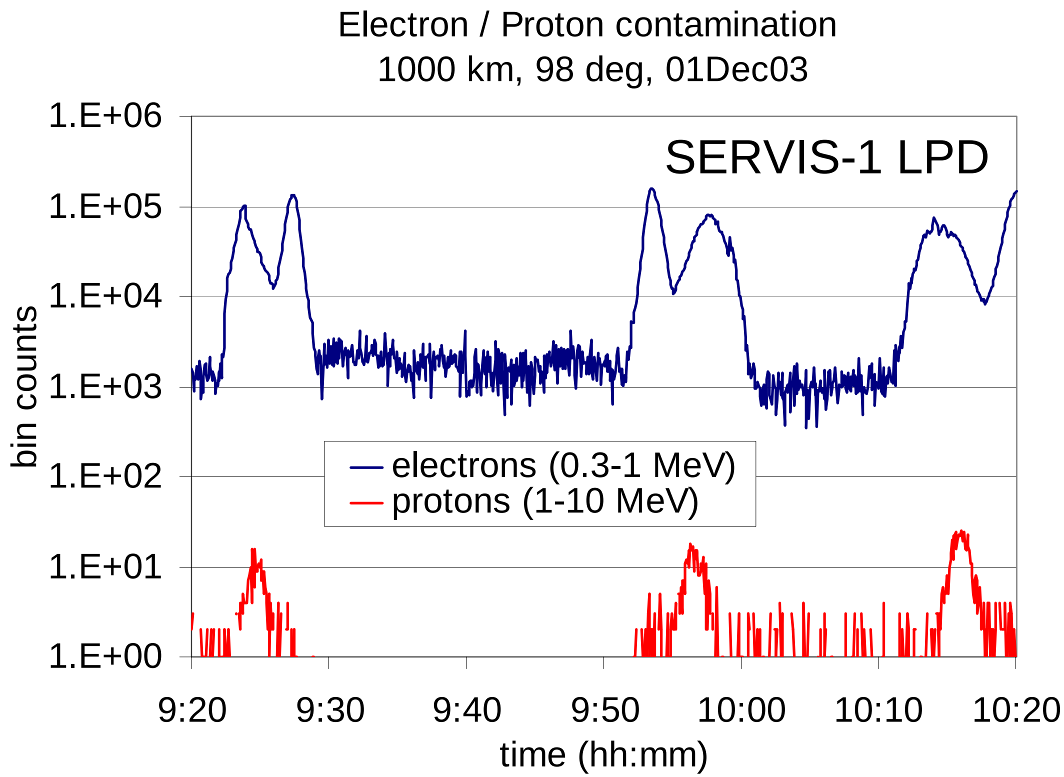
# *Electron / Proton contamination*

NASA_JSC-8

- **LPD and SDOM both exhibit very small amounts of contamination by low energy electrons**




- **<$10^{-4}$ contamination of low-energy protons by electrons**

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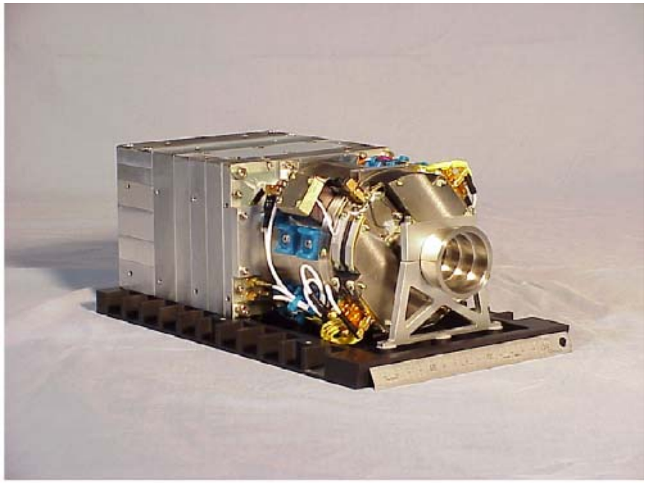
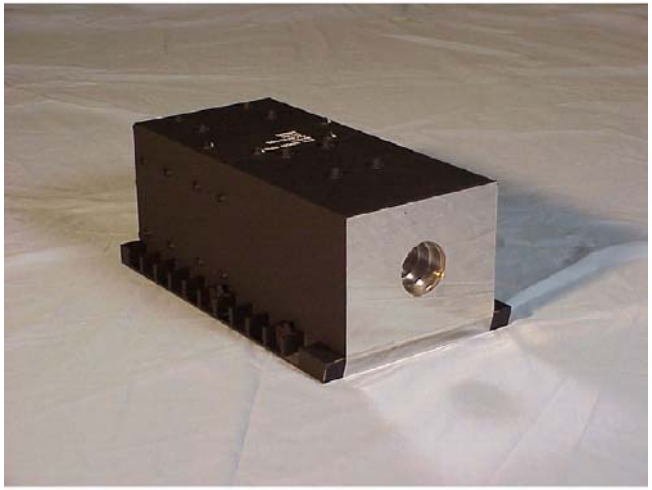
# *SDOM – Standard Dose Monitor (GEN-1)*

NASA_JSC-9

- **PSI and MELCO developed a charged particle spectrometer**
- **Delivered 3 flight units for NASDA (Japan) satellites**
  - MDS1: GTO
  - DRTS: GEO
  - JEM: LEO
- **Characterizes the higher energy orbital radiation environment**
  - protons: 1 to 200 MeV, 12 bins
  - electrons: 0.4 to 20 MeV, 5 bins
  - alphas: 7 to 150 MeV, 4 bins
  - ions: >1.5 MeV/nucleon
- **High count rate**
- **Excellent rejection of Lo-E electrons**





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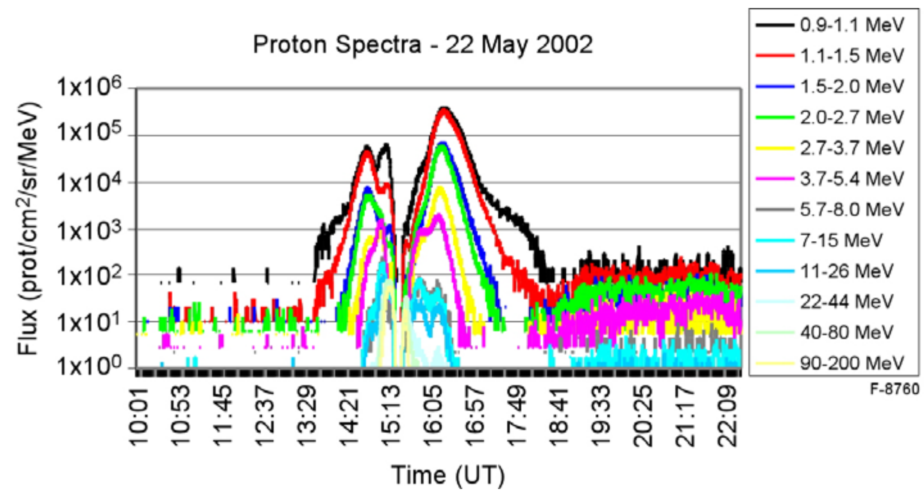
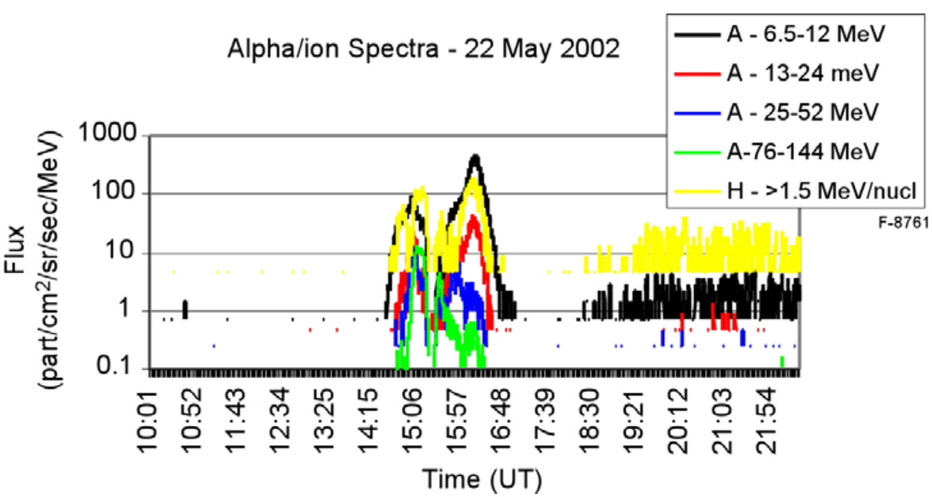
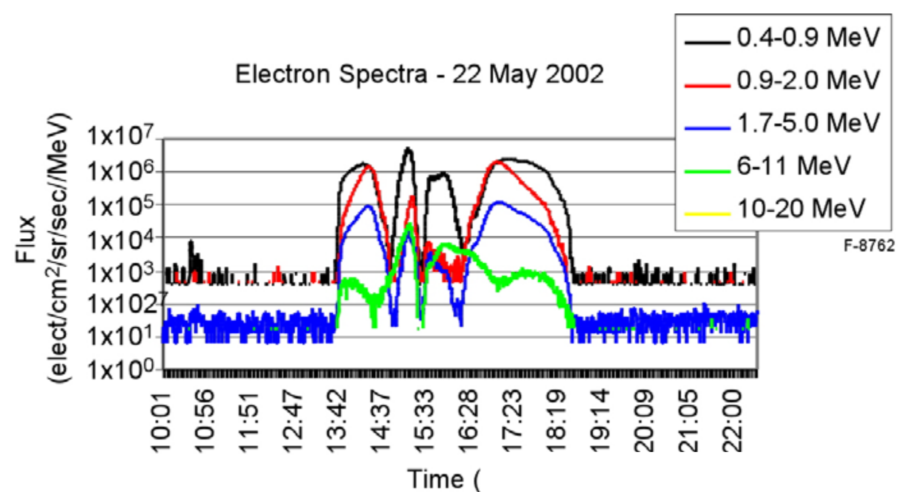
# *MDS1 SDOM Data*



- **Two SDOM units currently on orbit**
  - MDS1: GTO
  - DRTS: GEO
- **PSI involved in orbital data analysis**
- **Currently 3 years of DRTS data; 27 months of MDS1 data**

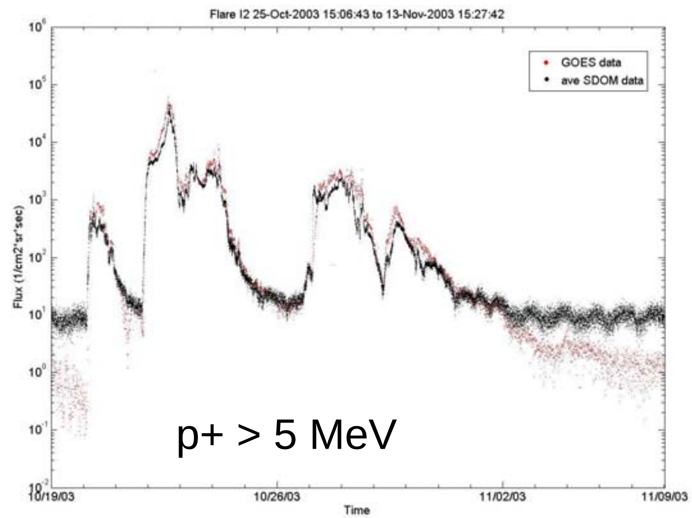


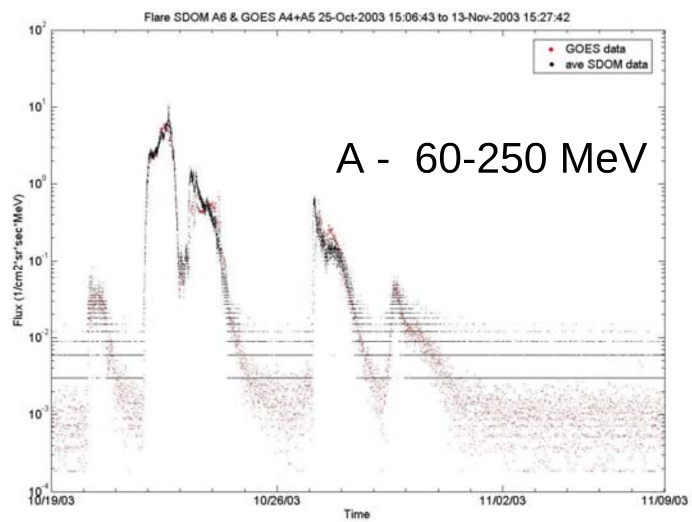



# *DRTS SDOM – GOES Intercomparison*

- **Compared DRTS-SDOM data to GOES data for complete Oct/Nov 2003 Flare**
  - Start time: 25 Oct 2003 15:06:43
  - End time: 13 Nov 2003 15:27:42
- **Mapped SDOM bins onto GOES bins**
  - Sum over SDOM energy bins
  - Time average SDOM data
- **Quantitative comparison between GOES and SDOM is quite good**
- **SDOM not saturated during flare**
- **SDOM low-energy electron bins not contaminated by high energy protons**
- **SDOM provides better energy and temporal resolution**

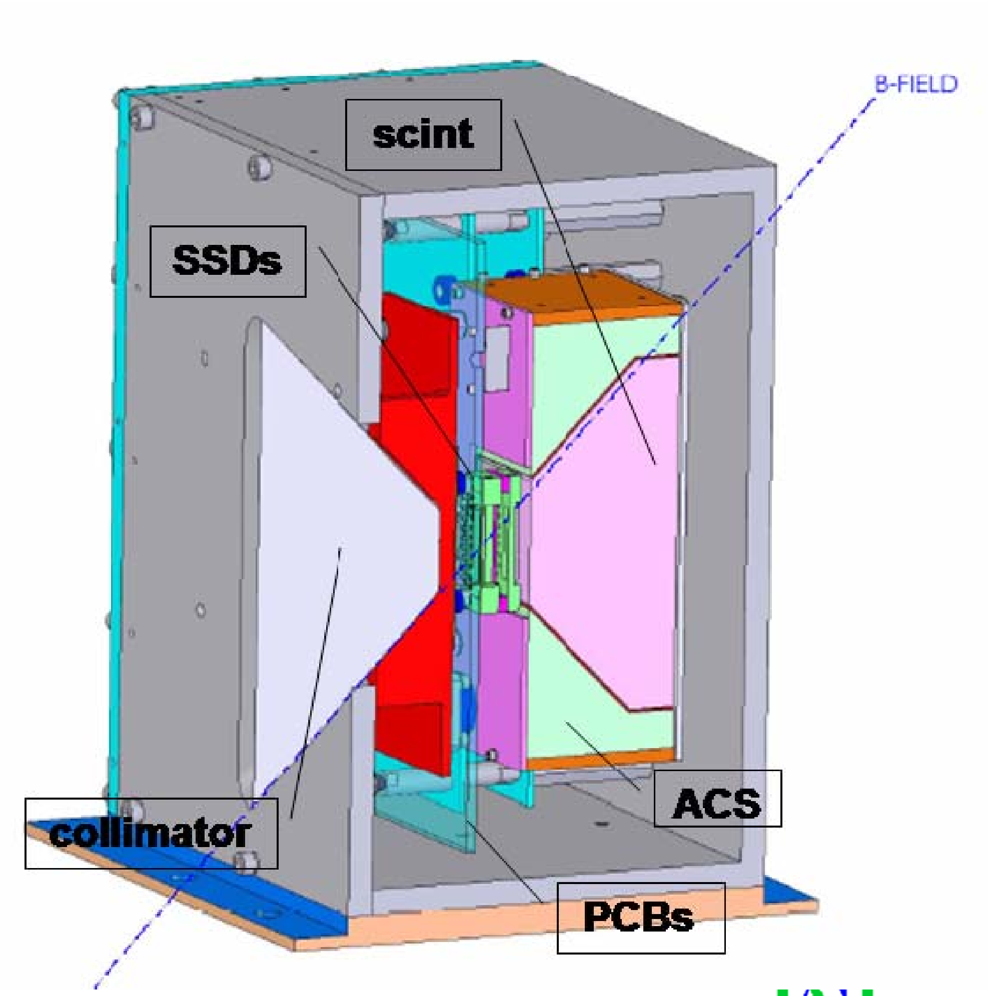


# *DSX HIPS (GEN-3)*



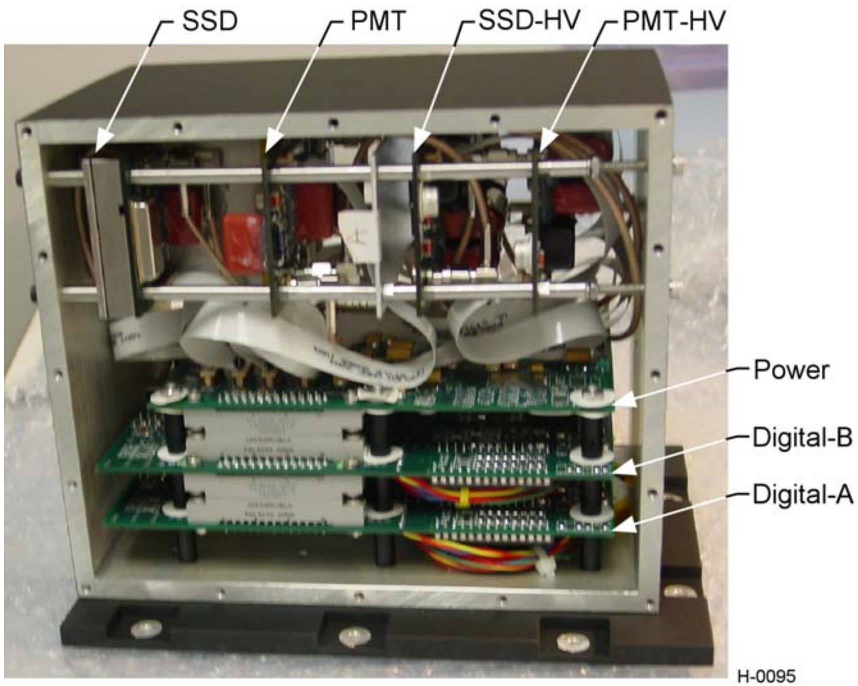
- **High-energy Imaging Particle Spectrometer**
  - Under development for AFRL – DSX mission (COTR: M. Golightly)
  - Currently in EM phase
  - 2007 delivery; 2009 launch
- **Energy Range**
  - Protons 10 - 300 MeV (8 bins)
  - Electrons 0.5 - 30 MeV (12 bins)
- **Pitch angle distribution measurement**
  - 7 x 90 deg FOV
  - 16 pixels
- **Physical**
  - 200 x 210 x 120 mm3
  - 10.5 W
  - 5 kg
  - 740 bytes/sec



# *Modular Configuration*

NASA_JSC-13

- **LPD is designed around flight-proven detector and electronics modules**
- **Modular design enables rapid development of new sensors**
  - alter energy ranges by changing detectors
  - alter bin configuration
- **Working bench model enables rapid prototyping, calibration and validation of new designs**
- **Redundant and non-redundant configurations available**
- **Easily configure redundant systems**

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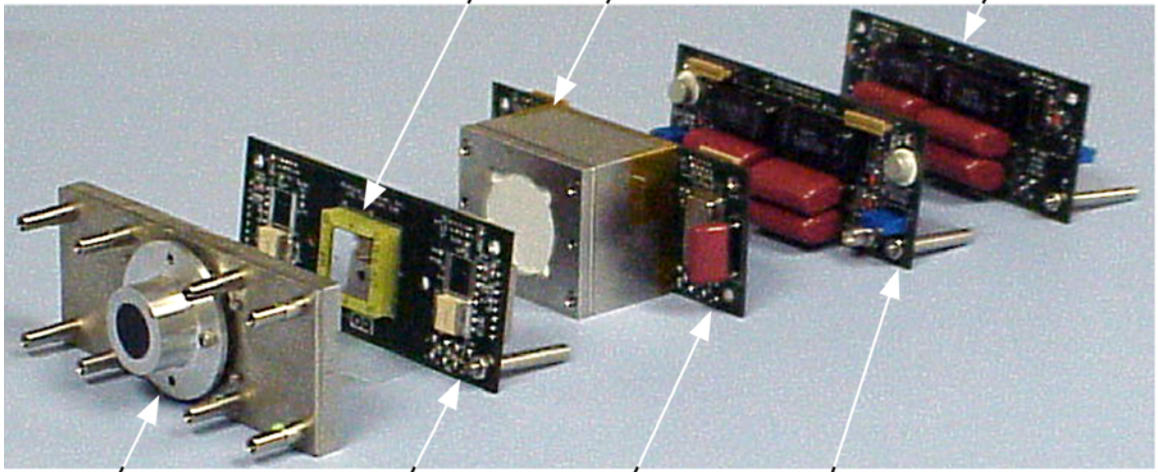
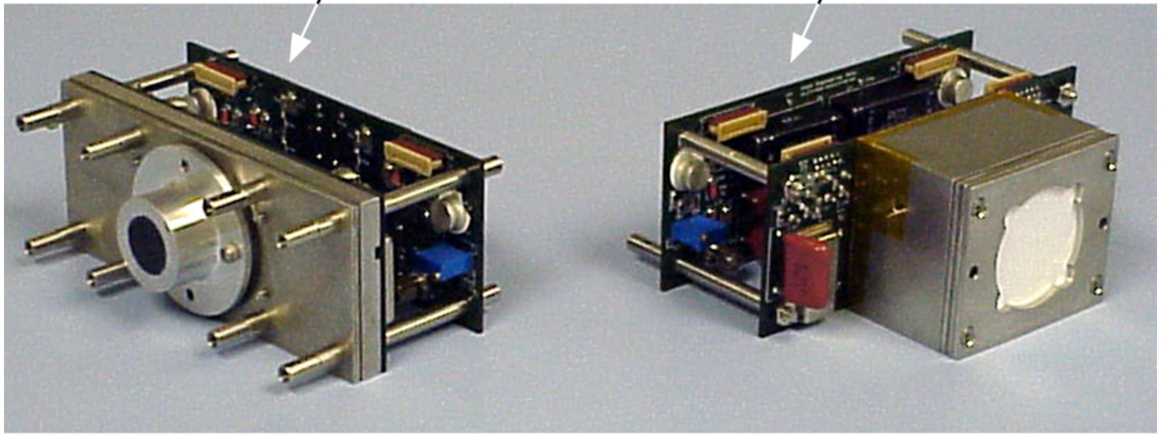
# LPD Modules



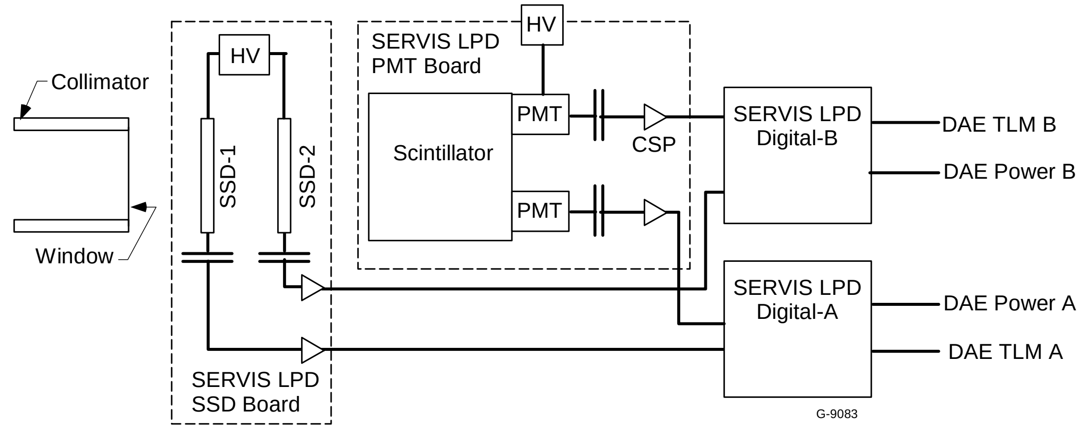

SSD A&B
Scintillator
PMT-HV
Telescope
SSD Board
PMT Board
SSD-HV
H-0099


SSD Module
Scintillator Module
H-0096

# *Reconfiguration of Redundant Systems*

NASA_JSC-15

- **EM modular processors available for rapid prototyping**
- **We create a sensor with greater capability by reconfiguring the basic redundant system**
- **2 detectors → 3 detectors**
- **1 processor → 2 processors**




**SERVIS LPD**

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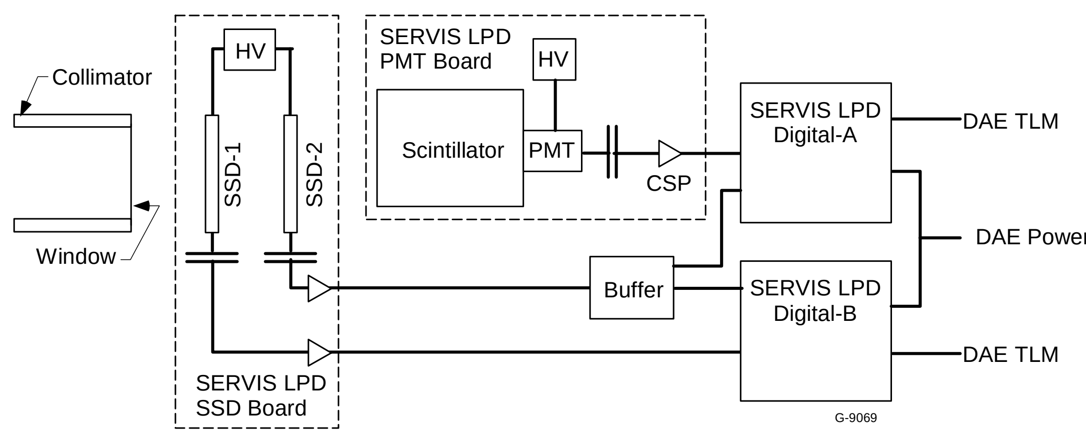
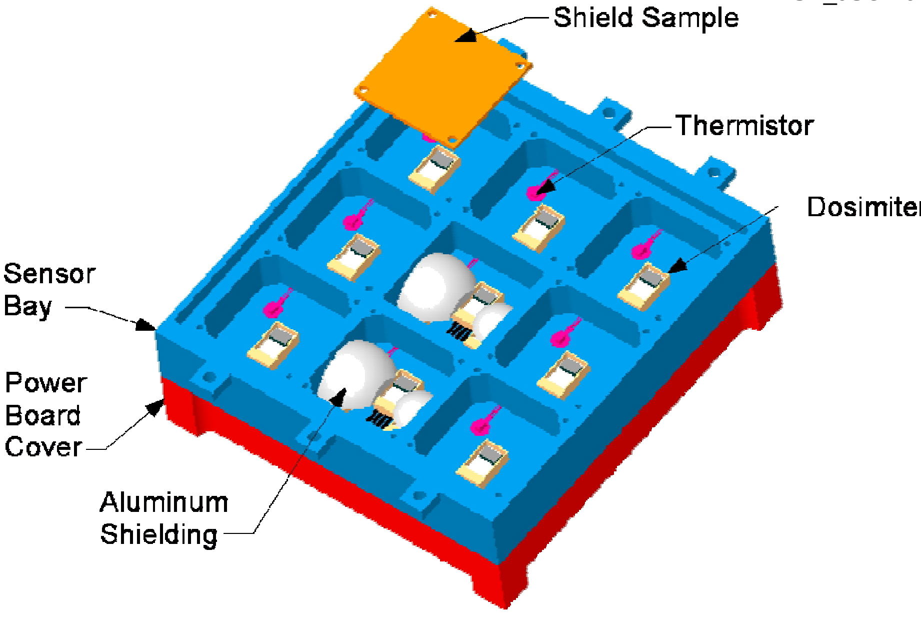
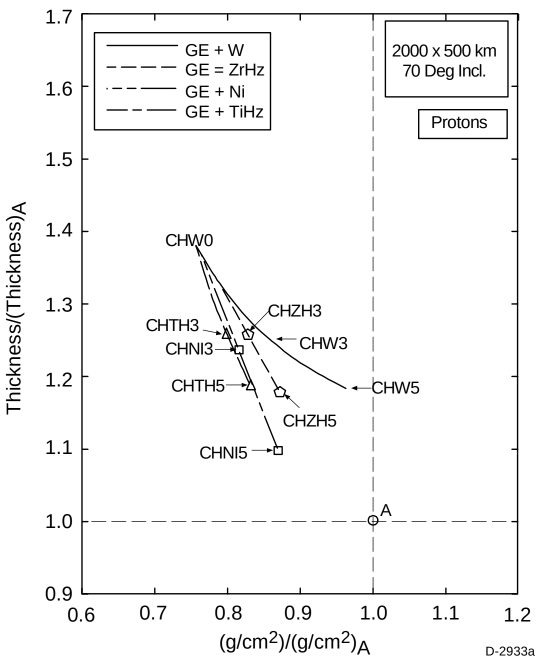



**WINDS Option 2**

# Advanced Radiation Shielding Materials SBIR

- **Develop composites that provide more shielding per gram than Al**
- **Tailor composition to enhance *e* or *p* shielding for specific mission**
- **20-30% improvement in shielding**
- **thermal & mechanical properties**
- **Sponsor: AFRL Materials**




- **Commercial partner : Space Systems Loral**
- **Phase 3 Flight Validation**
- **Geosynchronous telecom satellite: Estrela Do Sul (2003-present)**
- **6 material samples, Al standards, 13 RadFET dosimeters**

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# Radiation Shielding Composites



## The Goal:

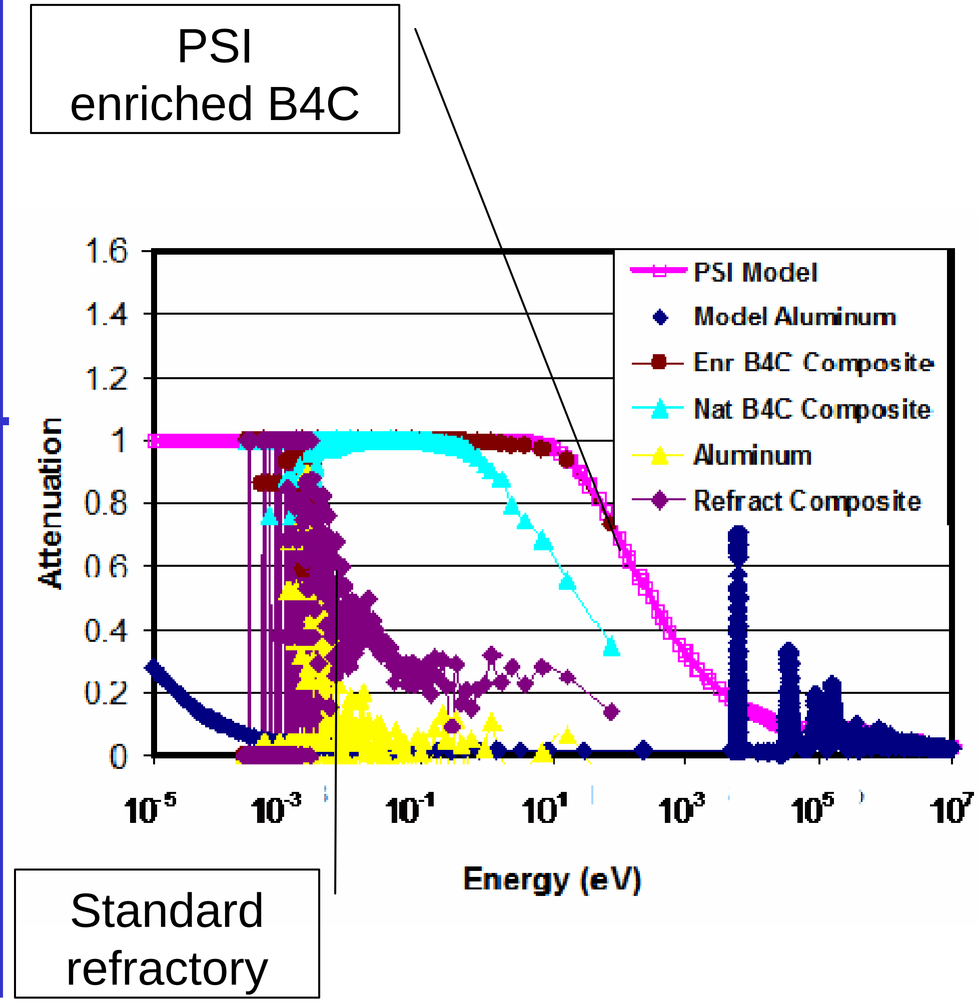
Replace Al, Ti and Be alloys with composite structures that:

- Provide enhanced shielding to x-rays and neutrons.
- Provide comparable strength for direct replacement in structural applications with no weight penalty.
- Can be integrated into multifunctional structures.

## Advantages

- Light weight/High strength
- High temperature performance
  High volume fraction of radiation absorbing materials
- Composite architecture
- Economical production process

## Neutron shielding



# *Summary*



- **PSI has several generations of charged particle instrumentation with flight pedigree**

- **PSI's radiation instrumentation may be able to support the human exploration requirements**

- **Modular design and redundancy enable easy reconfiguration of LPD to serve multiple measurement requirements**
  - energy range & particle types
  - G-factor & count rate
  - number of bins
  - Processing algorithms
  - multiple-axis

- **LPD test model (-TM) at PSI enables rapid and efficient breadboarding test and calibration of new configurations**

- **PSI's advanced shielding materials may be relevant for human exploration applications**