

NASA 2016 Plans for Dosimetry in Support of Manned Spaceflight



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NASA Programs

- ISS Program
 - Support to sustain/develop systems to ensure radiation health of ISS crews
 - ISS-TEPC/IV-TEPC, ISS-RAD, Passive Detectors, EV-CPDS, SEDA-AP (JAXA)
- Advanced Exploration Systems (AES)
 - NASA's Advanced Exploration Systems (AES) program is pioneering new approaches for rapidly developing prototype systems, demonstrating key capabilities, and validating operational concepts for future human missions beyond Earth orbit. AES activities are uniquely related to crew safety and mission operations in deep space, and are strongly coupled to future vehicle development.
 - ISS-REM, BIRD, HERA, ANS, Radiation Modeling
 - Multi-year Partnership with AMS 02 (Alpha Magnetic Spectrometer- state of the art particle physics detector). AMS02 data is available. Contract with University of Hawaii to deliver particle flux of protons and He, and other heavy ions.
 - Dr. Veronica Bindi
- Multi-purpose Crew Vehicle (MPCV): Orion
 - Will integrate HERA
 - Personal Active Dosimeter PAD (initial phase of project) to be used for crew personal dosimetry for Orion missions only



Tissue Equivalent Proportional Counters

• ISS-TEPC

- Current on-orbit unit functioning well (since 2007)
- Version first flown in 2000, developed in late 1990s.
- Hardware exceeding design life, no indication of degradation
- Serves at stationary mission reference dosimeter at SM-P327
- IV-TEPC project initiated to Support ISS operations to 2020/24
 - First time 2 TEPCs operating simultaneously on ISS
 - Flight Model (FM) 1 had *flash memory card failure*, replaced by Flight Model (FM) 2
 - FM-2 IV-TEPC started surveying ISS after checkout and comparison with current TEPC but had problems as well



IV-TEPC



ISS IV-TEPC FM-1 unpackaged and placed on SM panel 327 on April 23, 2012

Operated successfully until October 09, 2013

New IV-TEPC (Flight Model 2) delivered to ISS on Orb-2. Deployed on July 28, 2014 at SM P328.



IV-TEPC Problems

- IV-TEPC Flight Unit (FLT2)
 - Launched on Orb2; failed to operate shortly after deployment
 - Dose rate fell to zero
 - Positive 5 Volt Analog Current Flag
 - Ground disabled Pulser Test on startup
 - Large Detector was removed
 - Returned Large Detector on SpX-6
 - Verified that the JFET and the Op Amp not functioning correctly
 - Failure aligns with FLT1 Large Detector
- IV-TEPC Ground Unit (FLT1)
 - Returned from SpX-3 with a failed compact flash (CF) card
 - Reworked, tested, and verified as functional Post CF Card Rework
 - Failed to operate shortly into radiation testing
 - Irregular Dose Rate
 - Positive 5 Volt Analog Current Flag
 - Poor Pulser Response



IV-TEPC Spectrometer with Large Detectors



Large Detector Interior



Repair Options

<u>Summary</u>

- IV-TEPC (FLT2) is currently operating in a degraded state on ISS, which impacts survey capability for real time radiation operations. Only small detector operational.
- Revealed correlation of failures using the returned ground unit (FLT1) and returned Large Detector (FLT2).
- Determined root cause to be a design issue resulting from inadequate grounding.

- 1. Base Option: Redesign / Repair IV-TEPC Fleet
- Interim Solution: Fly Small Detector; mount to FLT2 Redesign / Repair FLT 1
 Alternative Solution: Replace FLT2 with Qual Unit (as is) Redesign / Repair FLT1 and FLT2



IV-TEPC Flight Model 2 Deployments









Current IV-TEPC Data

ISS IVTEPC 24-HOUR DISPLAY



Cur	rent		GMT Instrument Mode Alarm Status GMT (Set Point: 50 μGy/min) (Last Update) 33:25 Data Acquisition Not In Caution 252/10:32:45														
Current GMT 252/10:33:25			Ins	trumer	nt Mode	Alar	Alarm Status		GMT								
	252/10:33:25			ta Aco	uisition	Not I	Not In Caution		(Last Opdate) 252/10:32:45								
	Primary Detecto Ch 2			Locat	ion I		osition										
	Ch 2			NOD3) F3	Deck											
Cur	rent Dog	80								4 Hours 1-252 33:25 .00 11.26 17.97							
oui	Channel 1 Channel 2																
Dose Rate (µGy/n			/min)	in) 0.000		0.027).027 1 μGy = 0.1		mrad								
Dose Eq. Rate (µSv/mi			'min)	0.00	0	0.027	1 <i>µ</i> Sv = 0.1	mrem									
Cumulative Dose																	
(Since Instrument Yesterday Today Last 24 Hours										;							
Turned On)																	
					18/18	3:48:00	251	252	251-252 10:33:25								
Channel 1 - Dose (µGy)					0.00		0.00	0.00	0.00								
Dose				(µSv)	0	.00	0.00	0.00	0.00								
Channel 2 - Dos			se (µ0	ày)	531	14.01	279.68	158.74	281.26								
		Dos	e Eq	. (μSv)	128	85.44	700.93	372.61	737.97								
Inst	nstrument Status File Status																
	Power	1553 CF	יט ^{Cl} Tr	hassis np (°C)		Start F	I wment Yesterday Today Last 24 Hours 200 251 252 251-252 10:33:25 3:00 251 252 10:33:25 10:33:25 4 0.00 0.00 0.00 0.00 01 279.68 158.74 281.26 44 700.93 372.61 737.97 Status Number Files on Disk 18522 19192 671										
OK OK OK			К	30		1852	2 19192	6	71								
Cha	Channel Statue																
ond	nnel Status Channel 1 Channel 2																
Analog Hardware			C)	0												
Temperature			- ę	96	32												
High Voltage			0)	0												
Detector Hardware			2	2	0												



ISS RAD







Fast Neutron Detector (FND)



Gd Shield

MSL RAD



ISS-RAD Plans





- ISS-RAD delivered for launch!!
- •ISS-RAD manifested on OA-4 scheduled ~ 12/15
- •Long term plan is to have continuous measurement campaign on ISS until 2024.
- •ISS-RAD will be relocated several times per year but not as frequent as IV-TEPC. Base location in USLAB



AES Development Path: putting new sensor technology into operational detector system



ISS REM

Proof-of-concept

• Demonstrates feasibility of Timepix space dosimetry

BIRD (EFT-1)

- Intermediate step
- Stand-alone data acquisition
- Off-line data processing

EM-1,2 HERA

- Springboard
- Significant progress towards operational active area monitoring

EM-3+ HERA

 Operational active radiation area monitoring for Orion MPCV

Use of large portable instruments (i.e. TEPC) not possible for MPCV



• ISS REM

- Continue to collect/analyze data
 - Web server data display and analysis (Webrem)
 - Deploy REM units in BEAM
 - Publications of flight data
- Increase of number of units +3-5 units
- Possible use of dedicated laptop
- BIRD
 - Flight Completed
 - NASA TP Published
 - 2015-218575



• HERA

- Successfully completed SRR-PDR
- Design is progressing
- Possible Tech Demo of HERA prototype on ISS



NASA/TP-2015-218575



Battery-operated Independent Radiation Detector Data Report from Exploration Flight Test 1

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HERA – Instrument Summary

- HERA: Hybrid Electronic Radiation Assessor
 - Measures absorbed dose in real-time
 - Time-resolved absorbed dose rate and flux
 - Provide Caution and Warning signaling and display (EM-2)
 - Provides coarse in-flight binning of particle charge and energy
 - Stores/downlinks raw data for detailed analysis
 - Data usage
 - Operational radiation protection decisions
 - Risk Assessment
- MPCV interfaces
 - Connected to Orion PDU
 - RS-422 data bus
 - 120 VDC input
 - Real-time status telemetry
 - Periodic full data download



HERA – Physical/Functional

- HERA system:
 - 1 HERA Power Unit (HPU)
 - Up to 3 HERA Sensor Units (HSU) per HPU
 - EM-1: detection and recording
 - Will rely on vehicle power
 - Will store all data on the HSU and HPU
 - Capability to be powered on/off by PDU.
 - EM-2: same as EM-1 plus will be tied into Caution
 & Warning system to alert crew to shelter



HERA - Interface Diagram





Current HERA system











Advanced Neutron Spectrometer (ANS) – Mark Christl at MSFC

• Scope

- A compact low-power neutron monitor for future precursor/long duration manned missions
 - Neutrons are generated from steady rate GCR and transient solar event particle fluxes (protons)
 - Habitats and Planetary Surfaces are important sources of secondary neutrons
- Focus on developing a neutron detector that distinguishes neutrons in mixed radiation fields of charged particles (light and heavy nuclei, secondary particles) and neutral particles (neutrons, gamma rays)
- Measure a broad spectrum of neutrons in a fluctuating particle background



Advanced Neutron Spectrometer (ANS)

- Spiral I: ANS Objectives (2012-2014)
 - Develop neutron spectrometer for exploration missions
 - Year1: design, test and demonstrated 1st generation
 - Year2: critical comparison with state of the art techniques
 - Year3: 2nd generation design: 2.3 kg, 4W
- Spiral II: ANS Objectives (2015-2017)
 - ISS test flight demonstration
 - Year1/2: design, fabricate and test ANS-ISS
 - Year2: deploy to ISS
 - Year3: operate and acquire data for analysis
- Spiral III: Operational for Manned Exploration (2018+)

Long term strategy - Combine best features of ANS AND ISS-RAD FND



ANS-ISS Summary

Objectives

- Conduct spaceflight test to mature the ANS measurement technique and design
- Deploy to ISS for 6 month mission
- Transmit data to ground station
- Analyze data to determine the fast neutron spectrum on the ISS
- Compare with ISS-FND
- Evaluate environment background

ANS-ISS Allocation

4 kgs •Mass: 5"x8"x10" •Volume: •Power: 7.5 W •Voltage: 28 VDC Data Link: USB to ISS laptop •Data Rate: 100 kbits/sec •Attachment location: Internal/multiple Attachment method: Velco Mission duration: 6 months Launch configuration: Soft stow •Payload readiness date: June/July2016



 Li-6 doped glass scintillating fiber array (>5000 fibers 120 microns diameter)



- Electronics and Data Acquisition



 Fiber array cast in plastic scintillator detector (1 liter), machined and polished surfaces





ANS Design in Fabrication







ANS GEN-II (3U CubeSat formfactor)

Acquiring neutron data from radioactive AmBe source





FY14 AES HQ Milestone: Conduct benchtop demonstration of ANS September 29, 2014



- The CAD model included updated to all USOS elements
- US-Lab, Columbus, Nodes 1-3, Cupola, JEM, PMAs, Airlock, PMM and SM modules updated and ray traced.
- Continued working on additional Russian modules.
 - Assigned correct densities, converted units and resolved interferences to the MRM1, MRM2,
 - DC1 and FGB models.
 - Assigning correct densities, converted units and resolved interferences of Russian Soyuz and Soyuz/Progress modules.





AMS-02





AMS-02 Data Plans



NASA/TP-2015-218569

•Through collaboration with University of Hawaii – Dr. Veronica Bindi – we have long term collaboration with AMS-02 team to provide to elemental flux to help GCR model development for operation use at NASA: BO-2014 Model updates

•Monthly flux data will be made available for protons and He in the coming year after AMS-02 official publication



Badhwar - O'Neill 2014 Galactic Cosmic Ray Flux Model Description

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AMS-02 Space Radiation Workshop

SOLAR ENERGETIC PARTICLES SOLAR MODULATION AND SPACE RADIATION



NEW OPPORTUNITIES IN THE AMS-02 ERA



OCTOBER 18 - 23, 2015 HONOLULU, HAWAI'I

https://indico.cern.ch/event/390724/

Committee Mirko Boezio Martin A Lee Marius Potgieter Eddie Semones Allan Tylka Ilva Usoskin

Local Organizer Veronica Bindi





edit: NASA/GSFC/SDO

Solar Energetic Particles Solar Observations Solar Flares and Coronal Mass Ejections Solar Modulation of Galactic Cosmic Rays Cosmic Rays Propagation in Heliosphere Earth's Magnetosphere Geomagnetic Cutoff Space Radiation Environment



Summary

- ISS dosimetry remains robust and configuration includes
 - **2 TEPCs** (2-3 separate detectors)
 - ISS-RAD activation and checkout in 2016
 - At least 7-10 **REM** units (hopefully more)
 - Continued use of RAMs and CPDs, 1 year mission mid-year swap out conducted for Kelly ~50% Reduction in overall number of RAMs to reduce logistic impact
 - **ANS** demonstration for supplemental neutron data
 - Outside ISS active data from EV-CPDS to be supplemented with SEDA-AP
- AES
 - New **REM** units (10) to increase number of units on board
 - Continue HERA development
 - Deliver ANS-ISS in 2016 for launch late 2016
- MPCV
 - BIRD provided data critical on MCPV CAD model-trapped radiation
 - HERA project in full swing
 - Personal Active Dosimeter down select



NASA switch to *active* solid state detectors for operational dosimetry requires long lead time to develop analysis tools and use experience. Requires constant reflection...