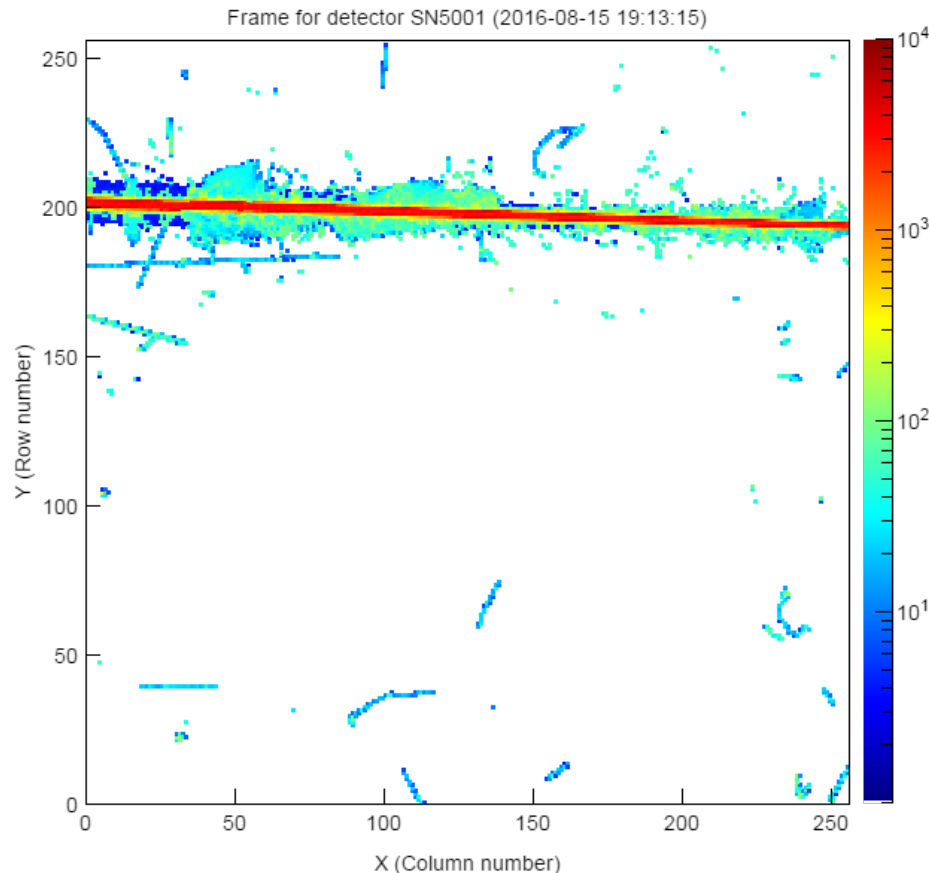




Update on the NASA Plans for Dosimetry in Support of Manned Spaceflight



E. J. Semones, D. Fry, K. Lee, M. Kroupa, N. Stoffle, L. Pinsky, C. Amberboy, R. Gaza, R. Rios, M. Leitgab, K. Beard, John Flores-McLaughlin, C. Zeitlin



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, HERA, FNS (ANS), Radiation Modeling – Solar Particle Event Storm Shelter, Miniaturized Particle Telescope (MPT)**
 - Multi-year Partnership with **AMS 02** (Alpha Magnetic Spectrometer- state of the art particle physics detector). AMS02 data is available. Contract with Dr. Veronica Bindi - University of Hawaii to deliver particle flux of protons and He, and other heavy ions.
- Space Technology Mission Directorate (STMD)
 - rapidly develops, demonstrates, and infuses revolutionary, high-payoff technologies through transparent, collaborative partnerships,
 - Thick Shield Project led by Martha Cloudsley
- Multi-purpose Crew Vehicle (MPCV): Orion
 - Will integrate **HERA**
 - **Crew Personal Active Dosimeter – CPAD (contract in place with Mirion) – to be used for crew personal dosimetry for Orion missions**



NASA Investments in Radiation Protection – 2016/2017

- In addition to NASA Human Research Program investments
 - Primary focus is radiation biology, risk models and radiation transport
- **STMD - thick shield project to determine if there are optimum passive shielding conditions for GCR and provides**
- **AES – focused on delivery of HERA systems for Orion and spiral designs of charged/neutron spectrometer for exploration habitats**
- **Orion - supporting development of COTs derived active crew dosimeter for Orion manned missions**
- **ISS – maintain radiation system for life of ISS while allowing for technical demonstration of exploration hardware. Focus on cost and crew time reductions**



2016-2017 Goals

- Eliminate reliance on any passive detectors for operations
 - Up and down mass + logistics, crew time for installation
 - Requires switch to REM tech demo and CPAD tech demo hardware
- Transition from gas-filled detectors to Si/solid state based dosimeters
 - Stop IV-TEPC surveys (eliminates crew time/power cycles)
 - Focus on RAD software updates/improvements
- Complete HERA Flight model delivery for EM-1
- Fly **3 new** technology demos
 - CPAD, FNS, MPT
- Take delivery of AMS02 H weekly flux data
 - Improve GCR models including modulation



Tissue Equivalent Proportional Counters

- ISS-TEPC

- Current on-orbit unit functioning (since 2007)
- Version first flown in 2000, developed in late 1990s.
- Hardware exceeding design life, indication of degradation in recent excursions
- Serves as 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
- IV-TEPC (FLT2) is currently operating in a degraded state on ISS, which impacts survey measurement capability for real time radiation operations.
- Only small detector operational.



IV-TEPC Options

Summary

- Determined root cause to be a design issue resulting from inadequate grounding.

1. Base Option: ~~———— Redesign / Repair IV-TEPC Fleet~~
2. Alternative Solution: **Replace FLT2 with Qual Unit (as is) – no cost**
~~Redesign / Repair FLT1 and FLT2~~
3. No additional expenditures other than planned detector replamcements

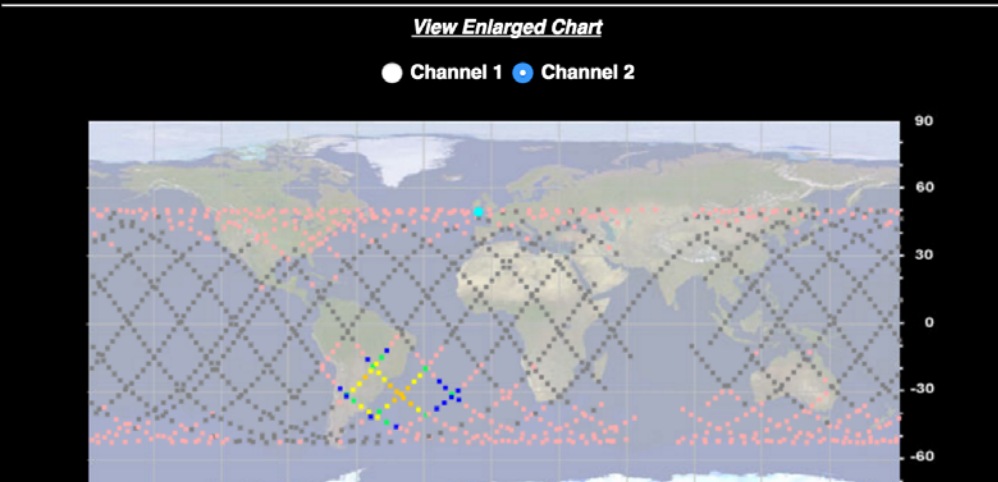
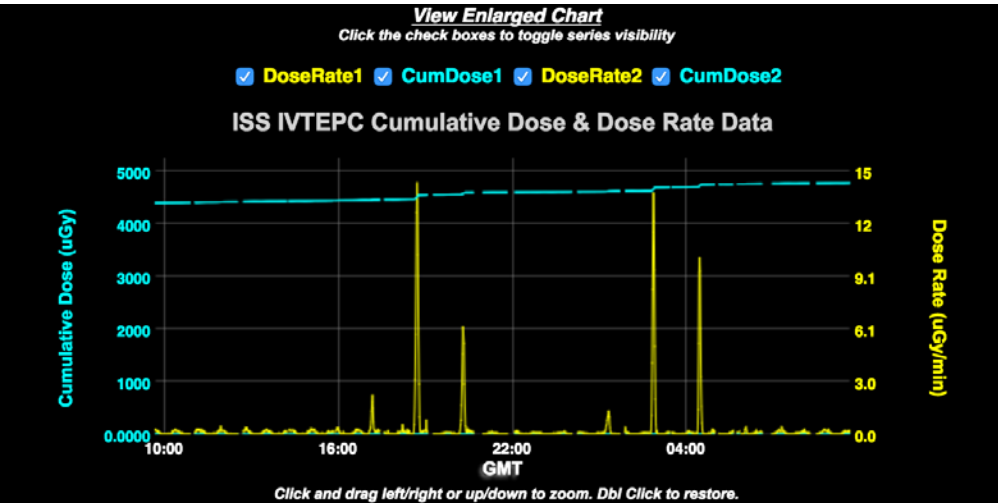


IV-TEPC Flight Model 2 Deployments





Current IV-TEPC Data



Current

Current GMT	Instrument Mode	Alarm Status <small>(Set Point: 50 μGy/min)</small>	GMT <small>(Last Update)</small>
250/09:41:10	Data Acquisition	Not In Caution	250/09:40:31

Primary Detector	Location	Position
Ch 2	SM P328	Port

Current Dose

	Channel 1	Channel 2	
Dose Rate (μ Gy/min)	0.000	0.107	1 μ Gy = 0.1 mrad
Dose Eq. Rate (μ Sv/min)	0.000	0.107	1 μ Sv = 0.1 mrem

Cumulative Dose

	Total <small>(Since Instrument Turned On)</small>	Yesterday	Today	Last 24 Hours
	12/1:18:00	249	250	249-250 09:41:10
Channel 1 - Dose (μ Gy)	0.00	0.00	0.00	0.00
Dose Eq (μ Sv)	0.00	0.00	0.00	0.00
Channel 2 - Dose (μ Gy)	4784.81	379.52	171.38	380.54
Dose Eq. (μ Sv)	10525.25	821.66	363.72	820.46

Instrument Status

Power	1553	CPU	Chassis Tmp ($^{\circ}$ C)
OK	OK	OK	32

File Status

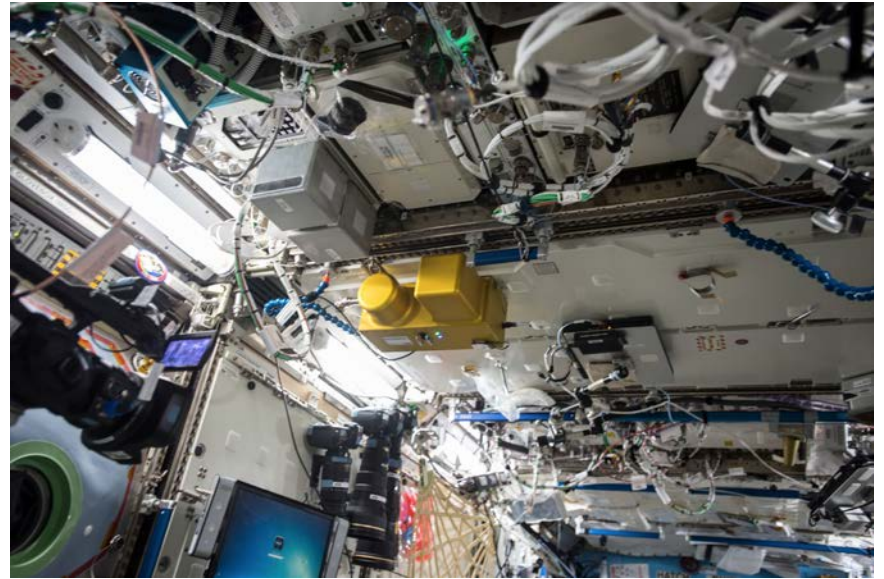
Start File	End File	Number Files on Disk
35651	35941	291

Channel Status

	Channel 1	Channel 2
Analog Hardware	0	0



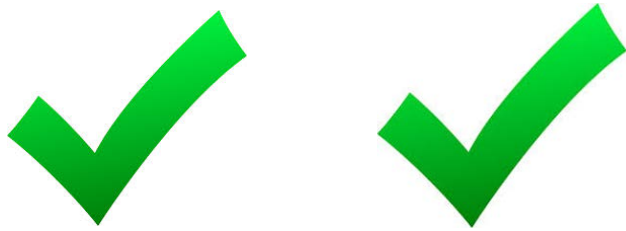
ISS-RAD Plan



- Launched in December 2015
 - Deployed on ISS on 2/1/2016 in US Lab on Lab1O3, pointing forward
- Long term plan is to have continuous measurement campaign on ISS until 2024. Relocated/rotated several times per year
- **Focus is flight software updates/improvements and additional adjustments to analysis chain**



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



REM Plans

- **ISS REM**

- Continue to collect/analyze data
 - Web server data display and analysis (Webrem)
 - Deployed REM units in BEAM
 - Publications of flight data
- **Increase of number of units +3-5 units**
- **Complete BEAM campaign and perform detailed analysis**



- **HERA**

- Successfully completed SRR-PDR-CDR
- Flight Build is Underway

2 SSC - REM Locations as of Sept 07, 2016

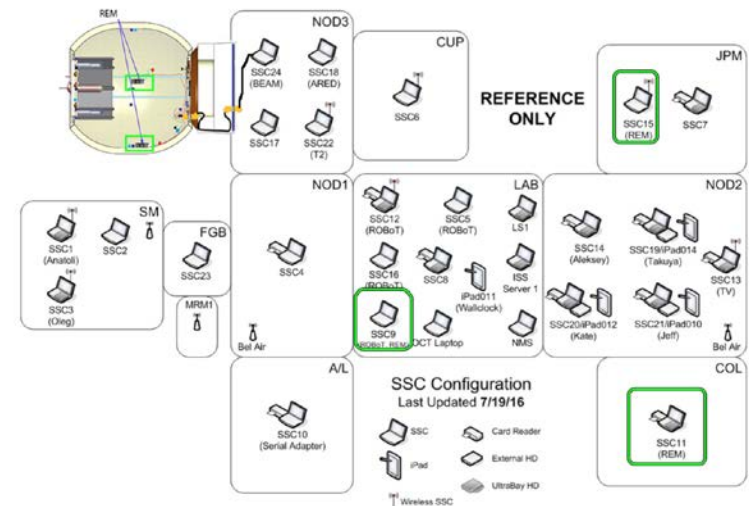
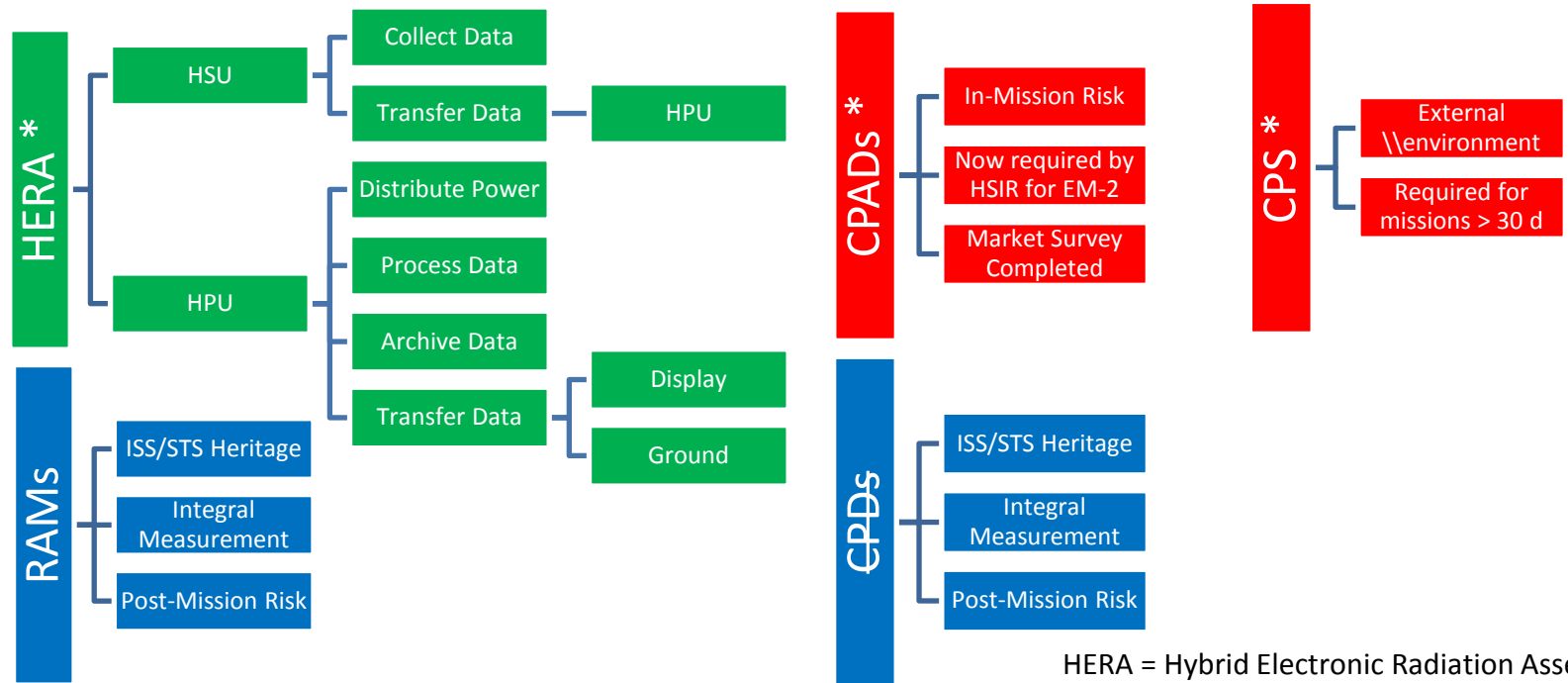


Figure 1: Current SSC configuration for the REM units. Color code based on most recent data received.



MPCV Radiation System



* = Technology needed for EM-2+

HERA = Hybrid Electronic Radiation Assessor
RAM = Radiation Area Monitor
CPD = Crew Passive Dosimeter
CPAD = Crew Personal Active Dosime
CPS = Charged Particle Spectrometer



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 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

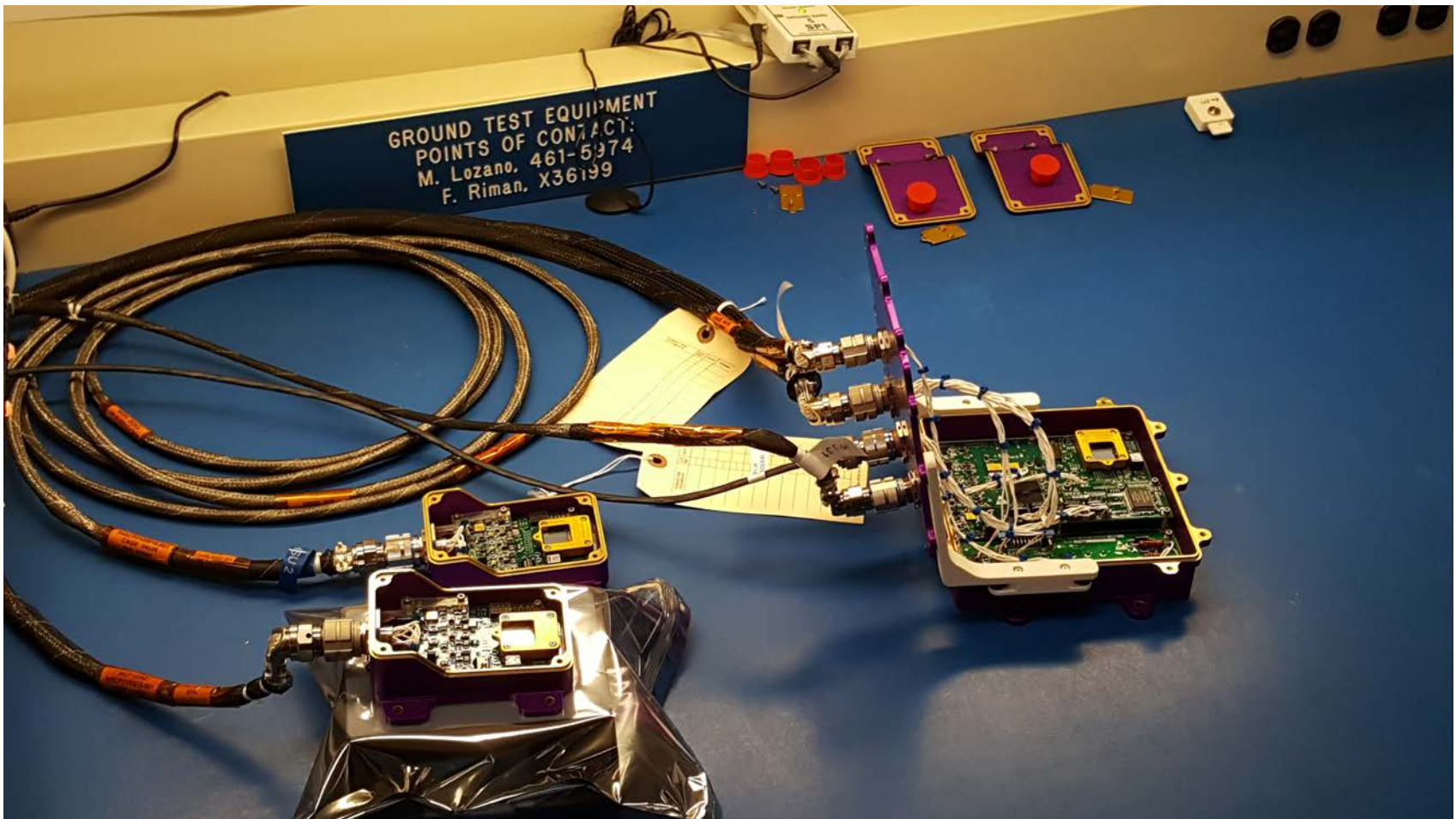


HERA – Physical/Functional

- 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



Current HERA Qualification system





Crew Personal Active Dosimeters (CPADs) Project Flow

-Project Lead is Martin Leitgab-SRAG

a) Analysis Phase
2015-2016

Completed

a.1 Market Survey

a.2 Technology Downselect

b) Development Phase
2016-2017

Current

b.1 CPAD Development

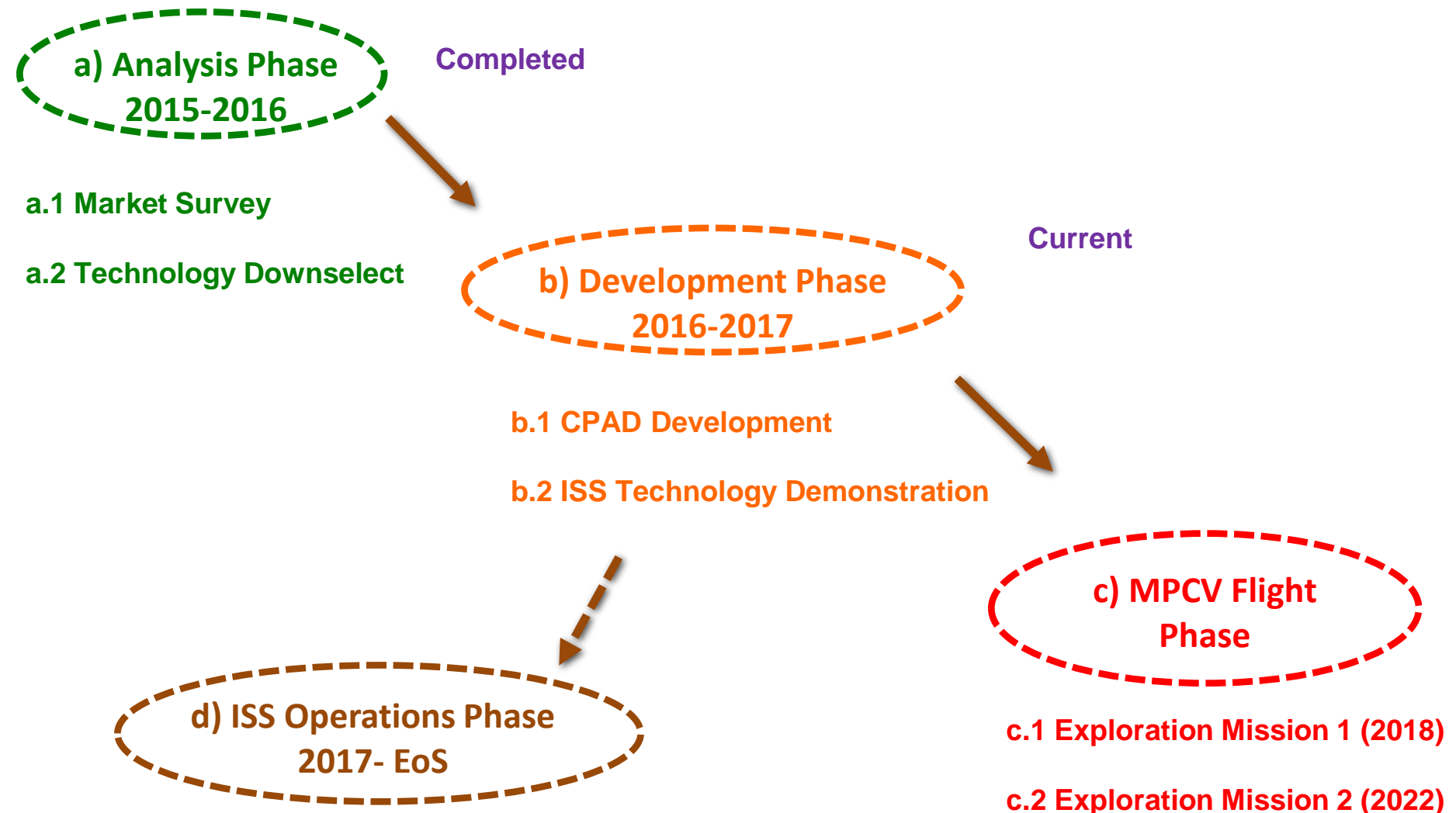
b.2 ISS Technology Demonstration

d) ISS Operations Phase
2017- EoS

**c) MPCV Flight
Phase**

c.1 Exploration Mission 1 (2018)

c.2 Exploration Mission 2 (2022)





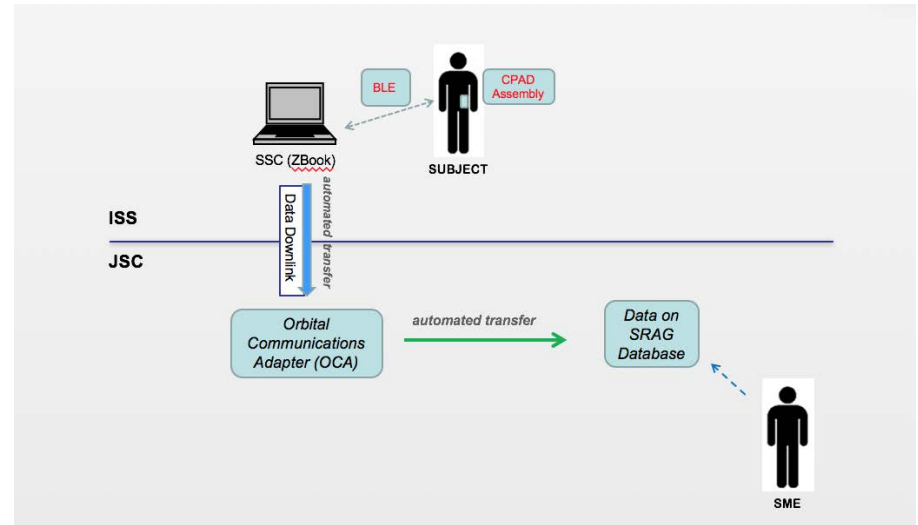
CPAD Technology Down select Results

- In summary, DIS technology was selected as DIS dosimeters fulfilled all requirements for all particle types successfully
- Mirion Technologies holds patents on DIS technology and was selected as sole source vendor



=

CPAD





Fast Neutron Spectrometer (FNS) – 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



Fast Neutron Spectrometer (FNS)

- Spiral I: FNS 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: FNS Objectives (2015-2017)
 - ISS test flight demonstration
 - Year1/2: design, fabricate and test **FNS-ISS**
 - Year2: deploy to ISS
 - Year3: operate and acquire data for analysis
- Spiral III: Operational for Manned Exploration (2018+)
 - Combine best features of FNS AND ISS-RAD FND



FNS-ISS Summary

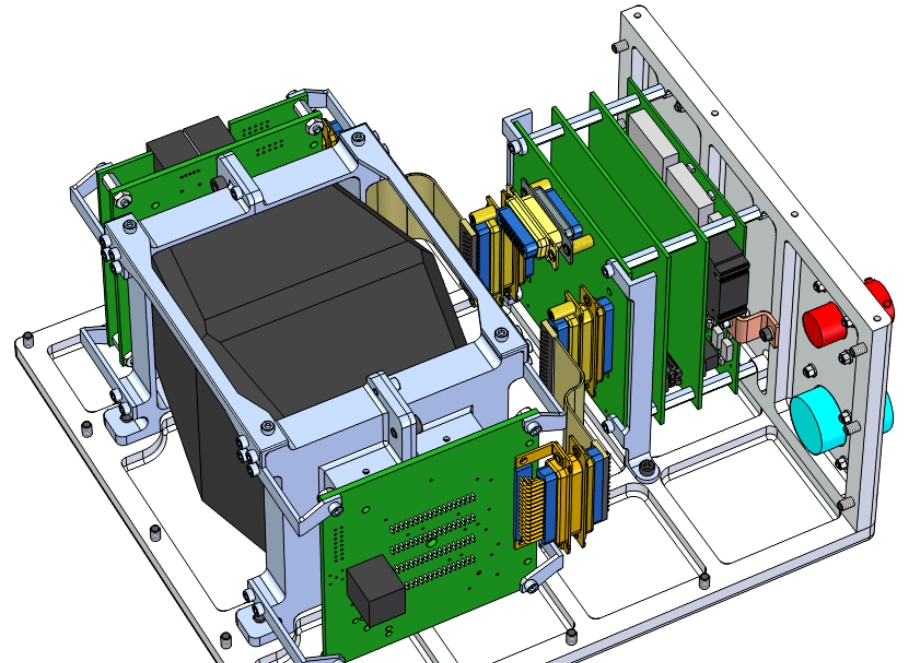
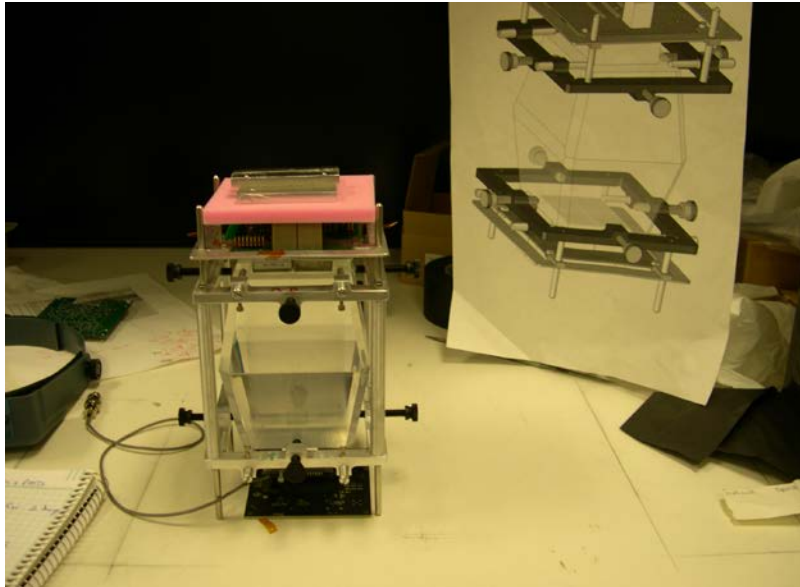
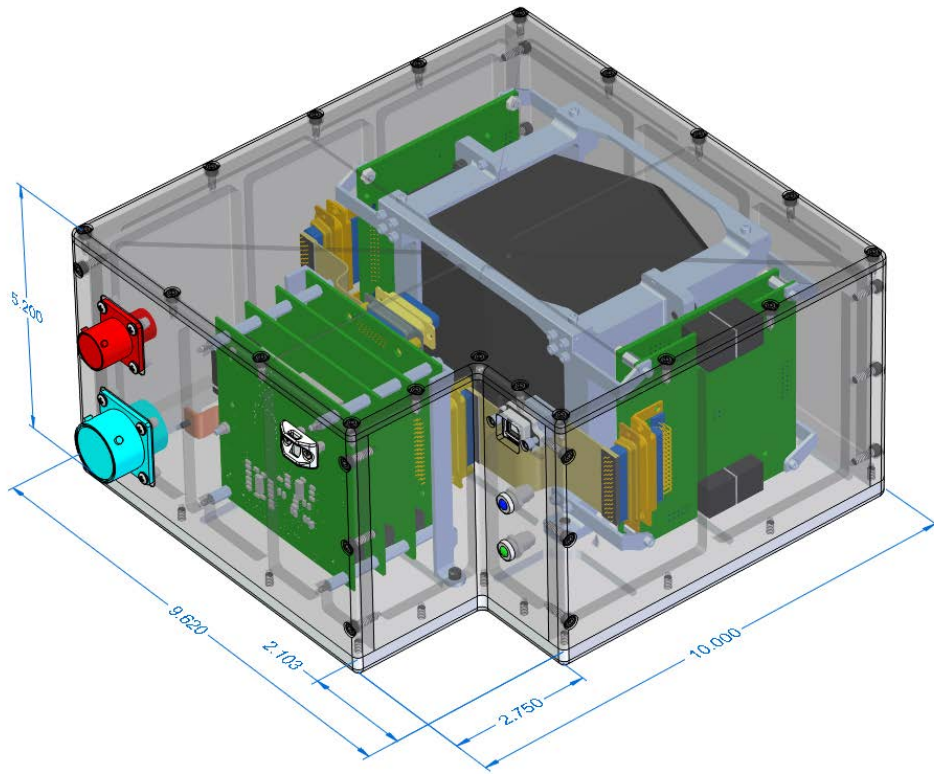
Objectives

- 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

FNS-ISS Allocation

- Mass: 4 kgs
- Volume: 5"x8"x10"
- 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:
Sept - 2016

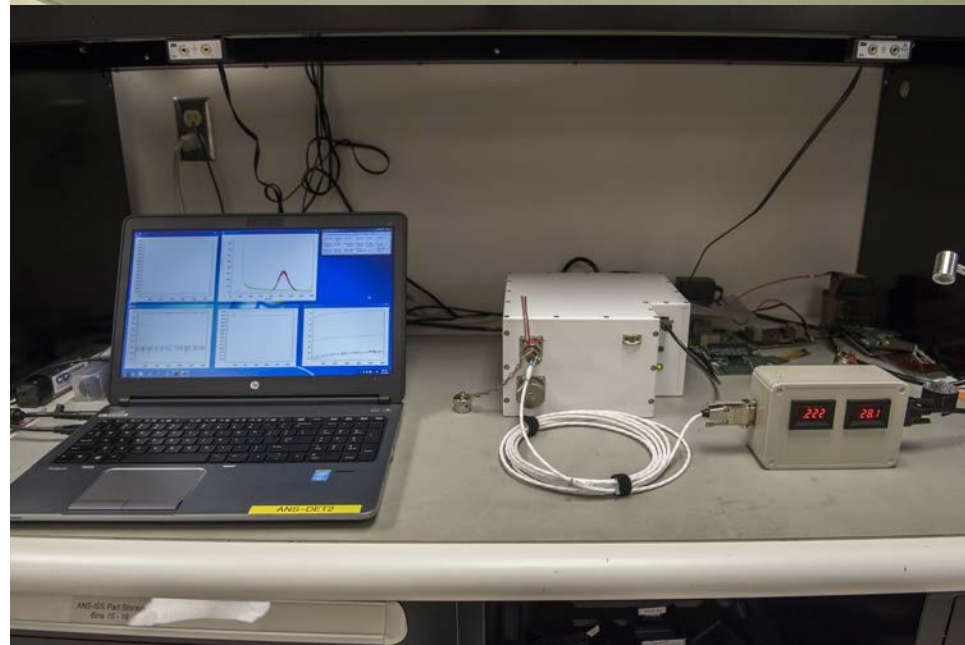
FNS Design in Fabrication





FNS Flight Model Delivered to JSC just last week

FNS will be moving to OA-5 launching September 29th

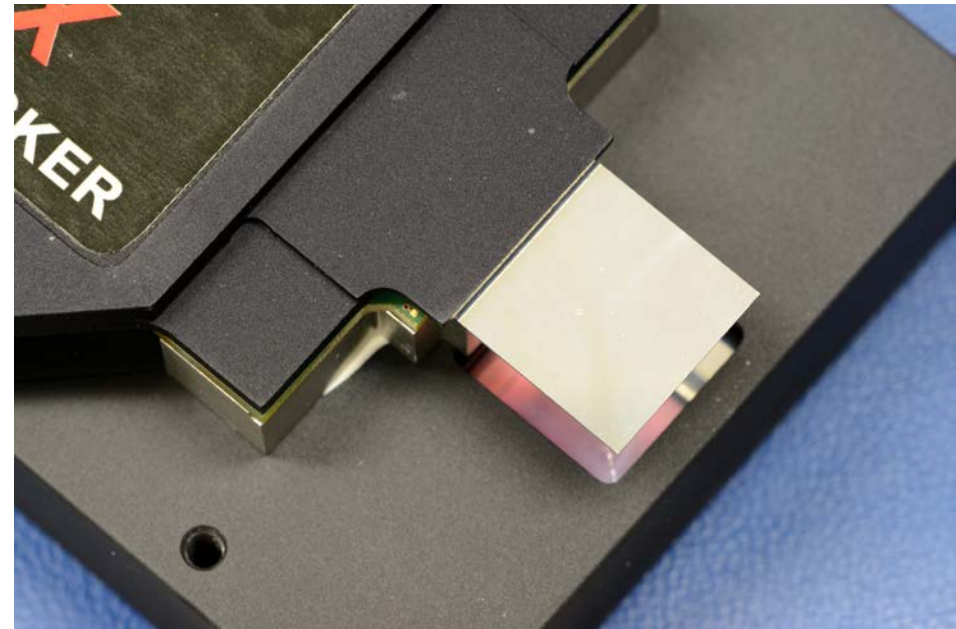
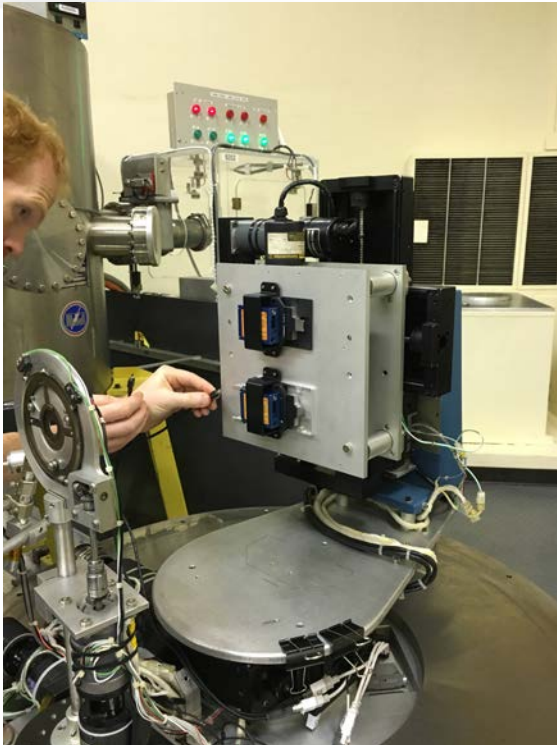




Miniaturized Particle Telescope (MPT)



- Stack of two chips
- Full Al enclosure
- Up to 850 frames/s
- Integrated bias
- Si sensors 500 μm thick
- Vacuum compatible
- 2x USB port
- Industrial USB connectors
- 1 mm thick Al windows on both sides (up and bottom)
- Fully powered via USB





Early MPT Testing - 20 MeV protons



FY16 Accomplishments – ISS CAD Models

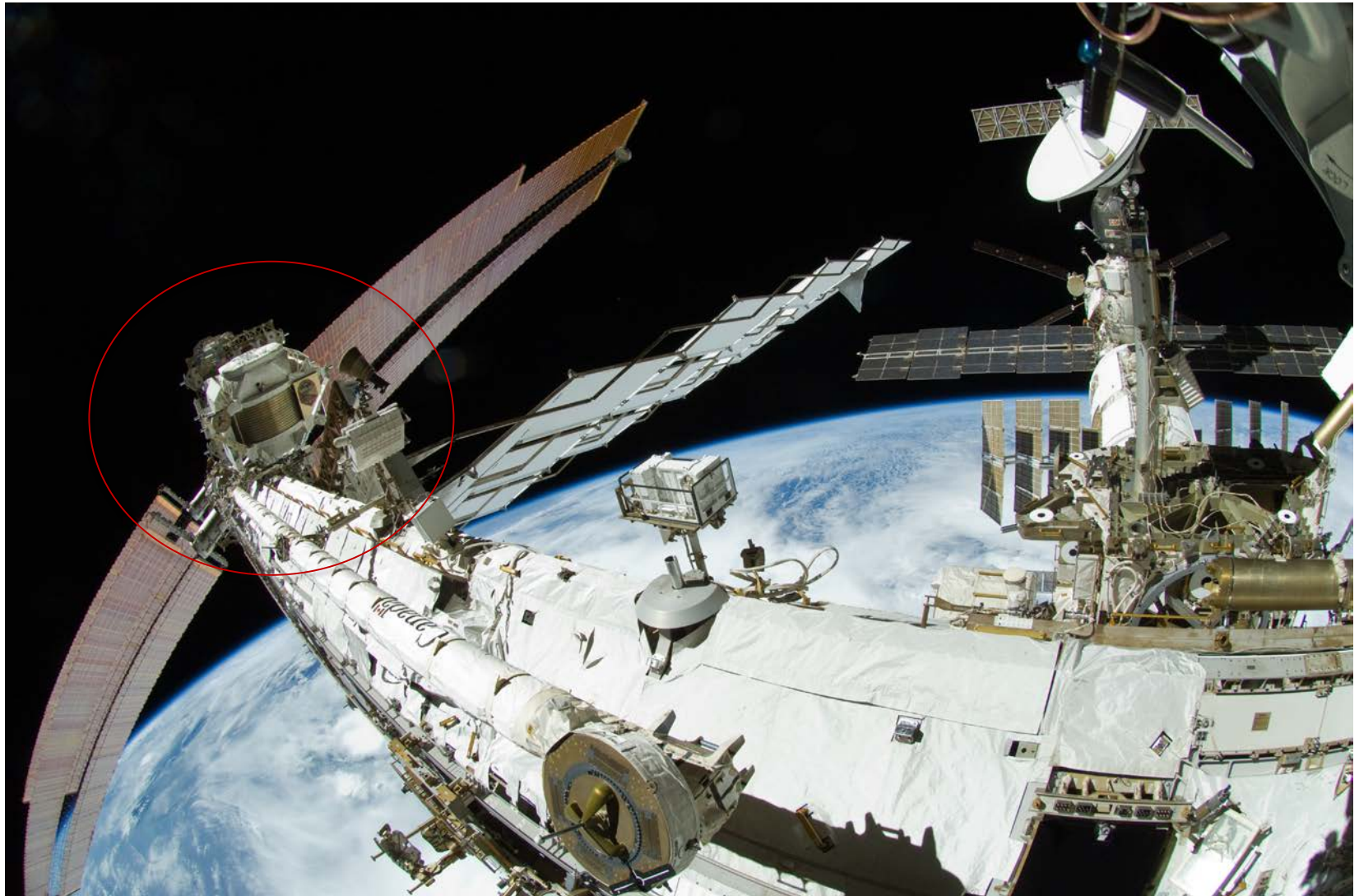
1. Completed updates to all ISS modules and delivered to SRAG
 - Updates to Russian modules and truss structures performed in FY16
 - Overlapping parts fixed, holes removed, surfaces converted to volumetric parts, and masses updated with best available information
2. Began effort to create ray-traces for all detector locations
 - Supports ongoing JSC SRAG operations monitoring radiation dose
 - Supports HRP effort developing improved methods for predicting astronaut exposure
 - Will be used in testing of 3DHZETRN



ISS Russian Modules and Truss Structures 25



AMS-02

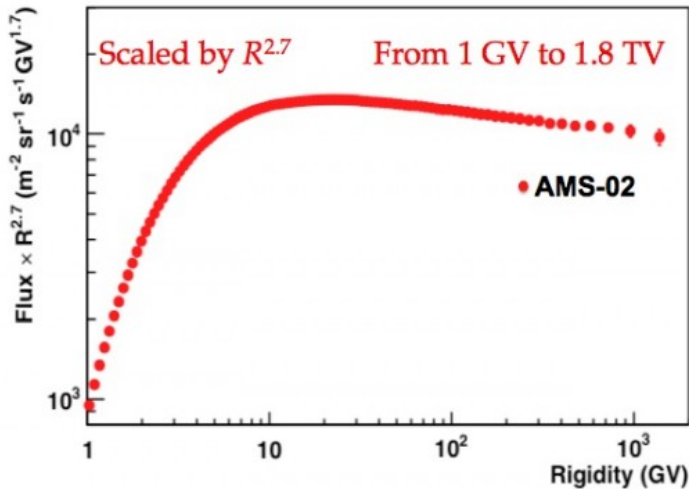




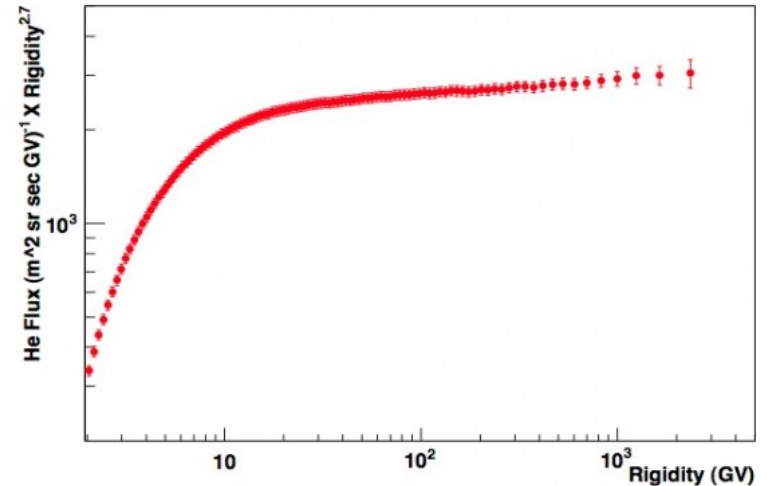
AMS-02 Data Plans



ICRC 2013: Proton flux



ICRC 2013: Helium flux



NASA/TP-2015-218569



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

P. M. O'Neill
NASA Johnson Space Center, Houston, Texas 77058, USA

S. Golge†
University of Houston, Houston, Texas 77004, USA

T. C. Slaba
NASA Langley Research Center, Hampton, Virginia 23681, USA

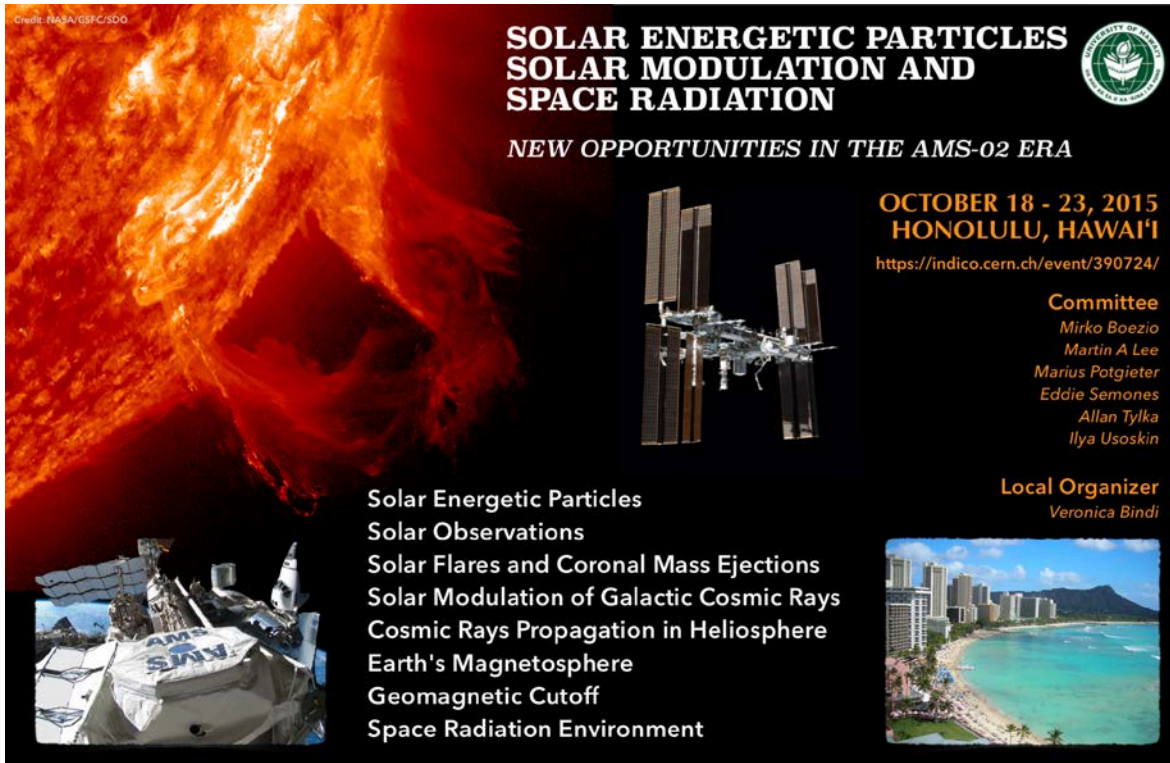
- Through collaboration with University of Hawaii – Dr. Veronica Bindi – we have long term collaboration with AMS-02 team to provide to elemental flux to help GCR model development for operation use at NASA: BO-2014 Model updates

- Monthly flux data will be made available for protons and He in the coming year



AMS-02 Space Radiation Workshop #2

Will be held in Washington DC Area -
April 23 to 27, 2017



AMS-02

**SOLAR ENERGETIC PARTICLES
SOLAR MODULATION AND
SPACE RADIATION**

NEW OPPORTUNITIES IN THE AMS-02 ERA

**OCTOBER 18 - 23, 2015
HONOLULU, HAWAII**

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

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

Local Organizer
Veronica Bindi

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

AMS-02



Summary

- ISS dosimetry remains robust and configuration includes
 - **2 TEPCs** (2 separate detectors for as long as possible)
 - **ISS-RAD** – activation and checkout on-going, will complete in 2016
 - Initiate software updates ASAP
 - At least 5-7 **REM** units total operational
 - **CPD,FNS, MPT** demonstration for will be conducted 2016-2017
 - Outside ISS active data from EV-CPDS to be supplemented with **SEDA-AP**
 - **2 neutron spectrometers** on ISS in 2016!
- AES
 - Complete HERA flight delivery
 - Start Spiral Design of charged particle/neutron spectrometers for habitats
- MPCV-Orion
 - Crew Personal Active Dosimeter down select completed to DIS
 - The first delivery of six CPADs is scheduled for 2/15/17, the remaining 14 CPADs of the development contract are delivered on 3/10/17.