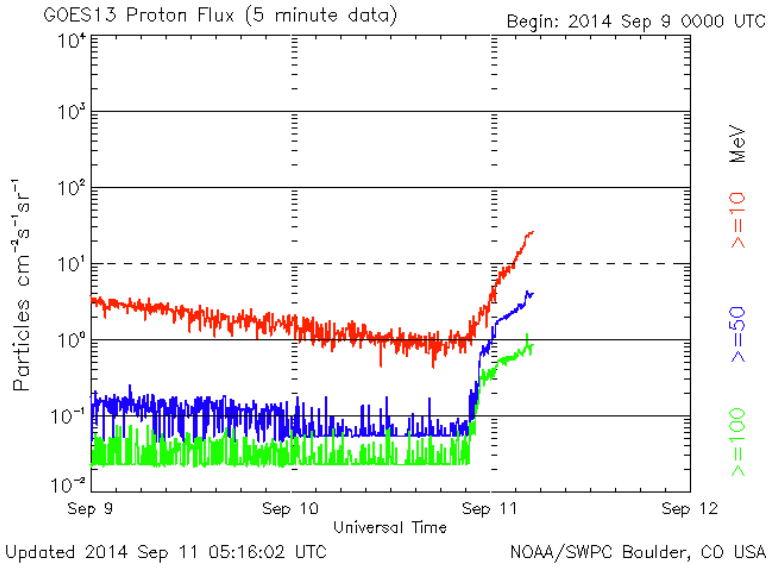
NASA Plans for Dosimetry in Support of Manned Spaceflight



Expedition 40 Lands - Three crew members from the International Space Station returned to Earth Wednesday after 169 days

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

NASA Programs

- ISS Program
  - Support to sustain/develop systems to ensure radiation health of ISS crews
  - **ISS-TEPC/IV-TEPC, ISS-RAD, Passive Detectors (1 year mission requires new effort)**

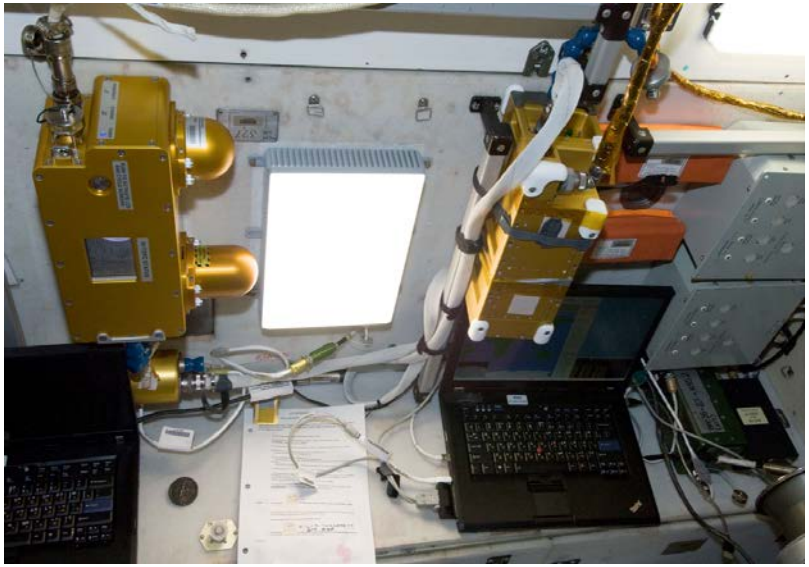
- Advanced Exploration Systems (AES)
  - NASA's Advanced Exploration Systems (AES) program is pioneering new approaches for rapidly developing prototype systems, demonstrating key capabilities, and validating operational concepts for future human missions beyond Earth orbit. AES activities are uniquely related to crew safety and mission operations in deep space, and are strongly coupled to future vehicle development.
  - **ISS-REM, BIRD, HERA, ANS (we call team developing these the REM team)**

  - 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.

Tissue Equivalent Proportional Counters

- ISS-TEPC
  - Current on-orbit unit functioning nominally (since 2007)
  - Version first flown in 2000, developed in late 1990s.
  - Hardware exceeding design life, no indication of degradation
- IV-TEPC project initiated to Support ISS operations to 2020/24
    - Part of new NASA monitoring suite, that will also include ISS RAD
    - 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 will be surveying ISS after checkout and comparison with current TEPC

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 Flight Model 2 Status

Timeline of Events

Jul 18

- Crew successfully assembled / deployed onto SM Panel 328. At ~30 minutes of operation, Dose Rate and Dose Equivalent Rate telemetry from the **Large Detector** (installed on Channel 1) **went to 0.000.**
- BME dumped all available **science/engineering data**, syslog files, and performed a BIT (extended cyclic) dump. The data was passed to Engineering and SRAG for analysis.

Jul 21

- BME switched the device into and out of Standby mode, and then performed a **soft system reset**. This had **no effect** on the data from Channel 1.

Jul 22

- During evening DPC (~1:45CST), the crew was instructed to perform a **hard reset** of the instrument. No effect on the data from Channel 1.
- BME dumped all science/engineering data (contained the results of **three Pulser Tests**) and all configuration files.

Jul 23

- MER-CHeCS drafted a Chit for crew to remove the Large Detector from Channel 1, **inspect** it for obvious signs of damage, then **return it to Channel 1** if no damaged noted.

Jul 24

- BME performed another soft system reset in order to trigger a **fourth Pulser Test**. All science/engineering data files and all syslog files were also downlinked.

Jul 25

- Discussed the forward plan for IV-TEPC troubleshooting. Chit submitted to perform the **Large Detector Inspection**; separate activity to move the Large Detector to Channel 2 should not be pursued until photo analysis is completed.

Channel 1 Summary

Spectrometer

IV 1 failed at 30 minutes

- **IV1 Dose was appropriate before the failure**
- **The failure developed over 2 to 3 minutes**
- **3 power supply currents exhibited abnormal behavior coincident with the failure.**
  - **Relation to failure not understood**

Pulser Tests

- **Initial pulser test on start-up: normal**
- **After failure: No pulser counts registered in first test**
- **Subsequent tests: 2 counts, 438 counts (Normal: 3900 counts)**
- **Failure to register pulser counts is indicative of:**
  - **Fault in the processing circuit (Detector might be OK)**
  - **Fault in Pulser 1 (Detector might be OK)**
  - **Fault in the Detector (interfering with pulser tests)**

Channel 2 Summary

Spectrometer

IV2 Dose rates

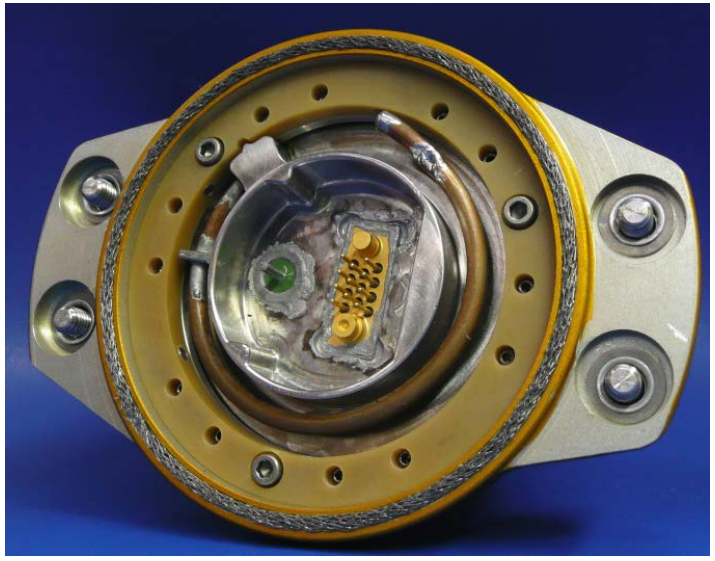
- **All evidence supports FLT2 IV2 as operating properly**

Pulser Tests

- **First two pulser tests: normal**
- **Second two tests:**
  - **Appears that Pulser 2 attenuator is always enabled (altering the pulse magnitudes sent)**
  - **Abnormal pulse count rate**
  - **Abnormal state is understood and acceptable for conducting pulser tests**
- **Channel 2 electronics are operationally normal**

Next Steps

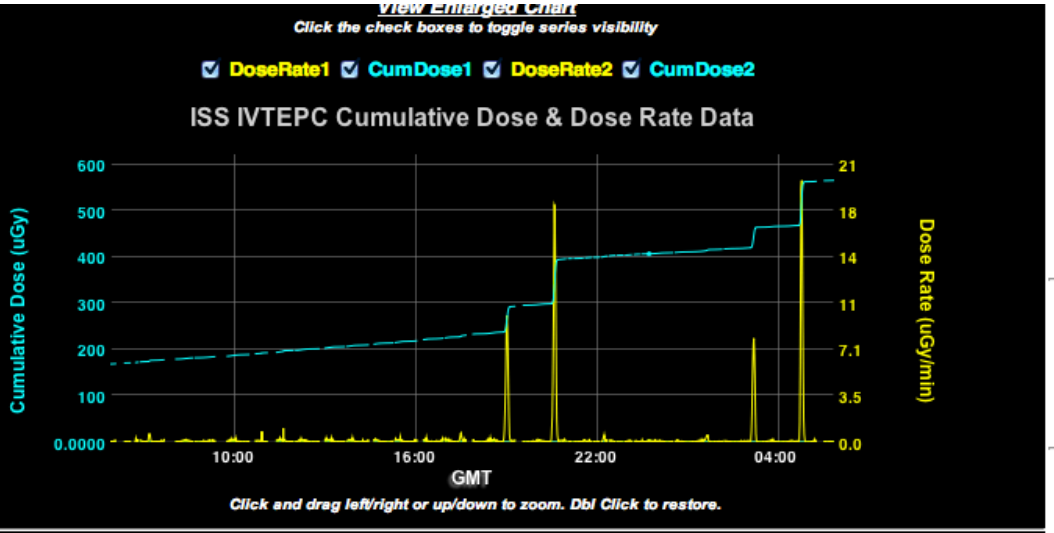
- Crew activity to inspect and photo document the Large Detector and Spectrometer Interface for damage completed
  - no damage was observed, reinstall Large Detector onto Channel 1.
- Currently assessing whether to proceed with next troubleshooting step to swap the detectors – large detector to be placed on Channel 2

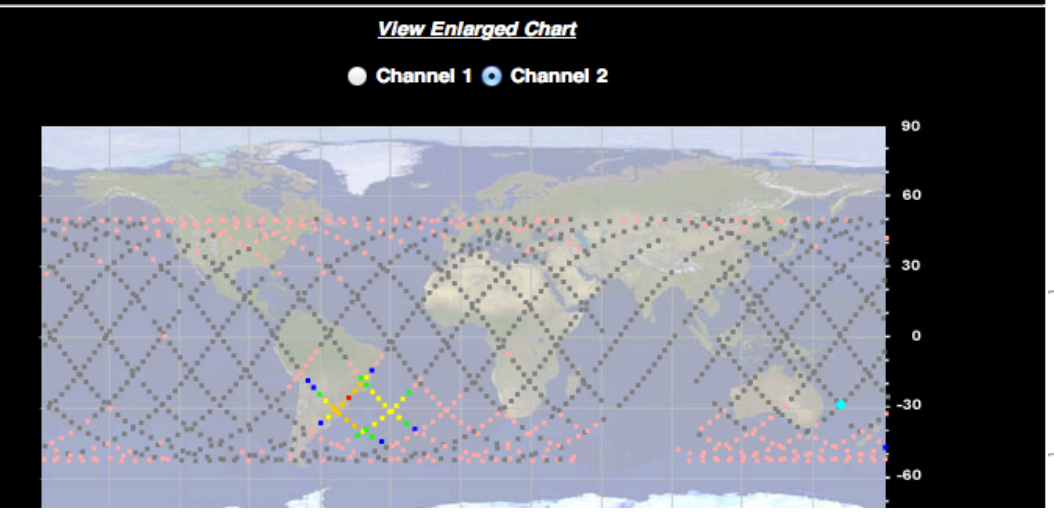


IV-TEPC Plans

- Complete checkout of FM-2
  - Possibly use only single Large Detector until FM-1 (on ground) can be prepared for launch
  - Resume survey of ISS with IV-TEPC , relocating every ~ 4 weeks
- ISS-TEPC will operate until failure – no plans to refurbish at this point

IV-TEPC latest data





Current

Current GMT	Instrument Mode	Alarm Status (Set Point: 50 μGy/min)	GMT (Last Update)
254/05:54:26	Data Acquisition	Not In Caution	254/05:52:04

Primary Detector	Location	Position
Ch 1	SM P328	Port

Current Dose

	Channel 1	Channel 2	
Dose Rate (μGy/min)	0.000	0.056	1 μGy = 0.1 mrad
Dose Eq. Rate (μSv/min)	0.000	0.092	1 μSv = 0.1 mrem

Cumulative Dose

	Total (Since Instrument Turned On)	Yesterday	Today	Last 24 Hours
	1/7:12:00	253	254	253-254 05:54:26
Channel 1 - Dose (μGy)	0.00	0.00	0.00	0.00
Dose Eq (μSv)	0.00	0.00	0.00	0.00
Channel 2 - Dose (μGy)	566.83	404.02	158.08	397.61
Dose Eq. (μSv)	1125.33	845.83	266.02	818.28

Instrument Status

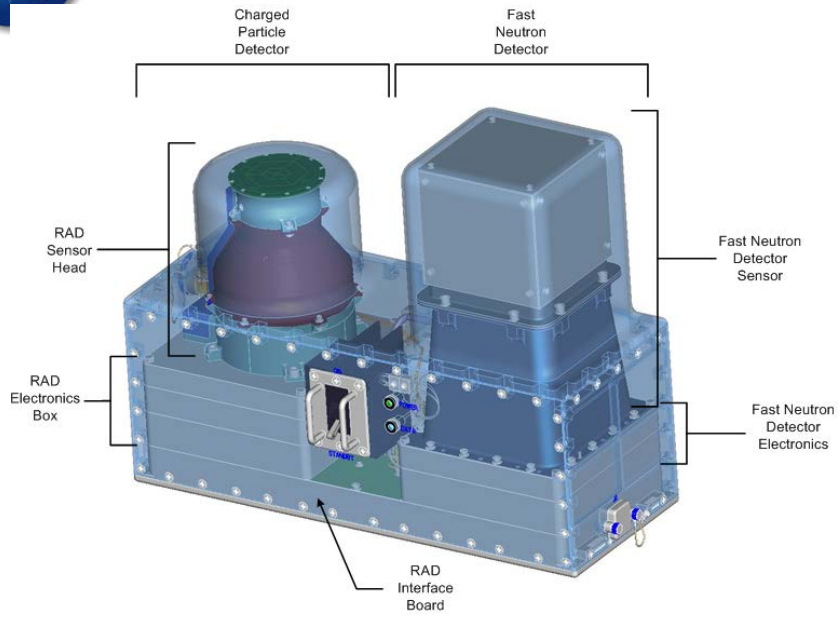
Power	1553	CPU	Chassis Tmp (°C)
OK	OK	OK	32

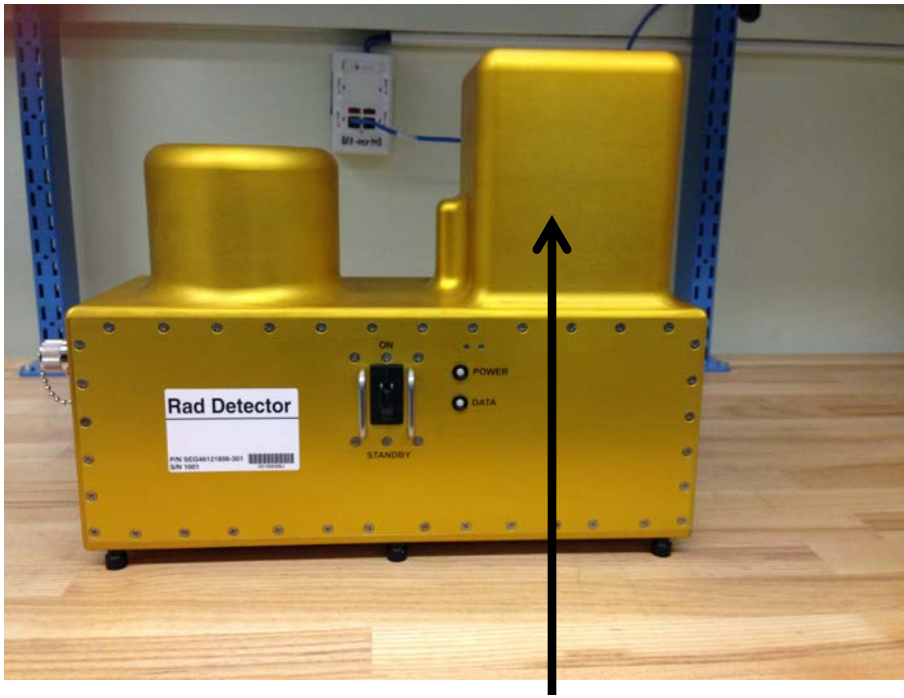
File Status

Start File	End File	Number Files on Disk
2861	4864	744

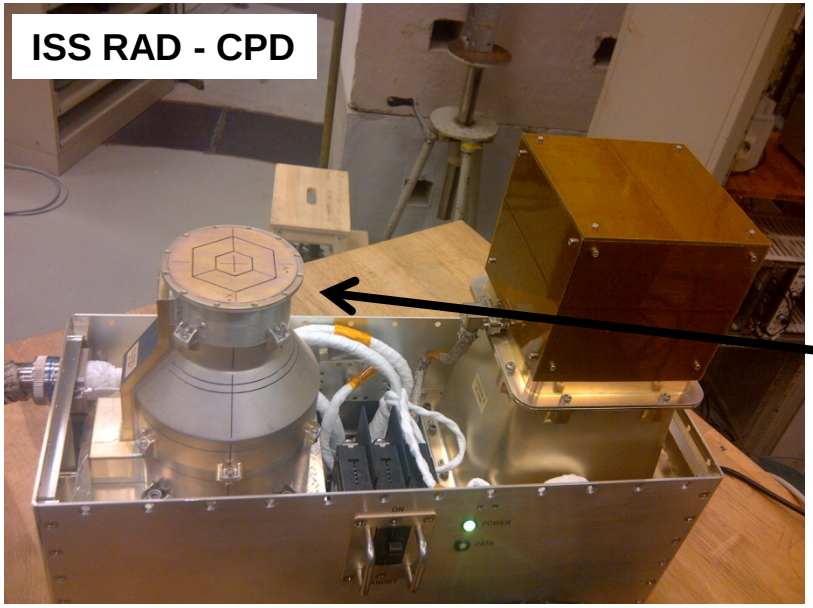
Channel Status

ISS RAD



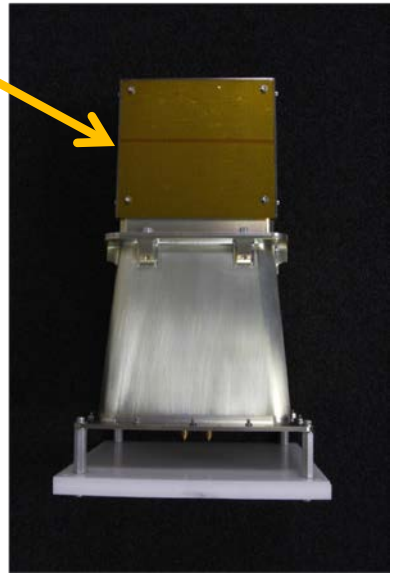


Fast Neutron Detector (FND)



MSL RAD

Gd Shield

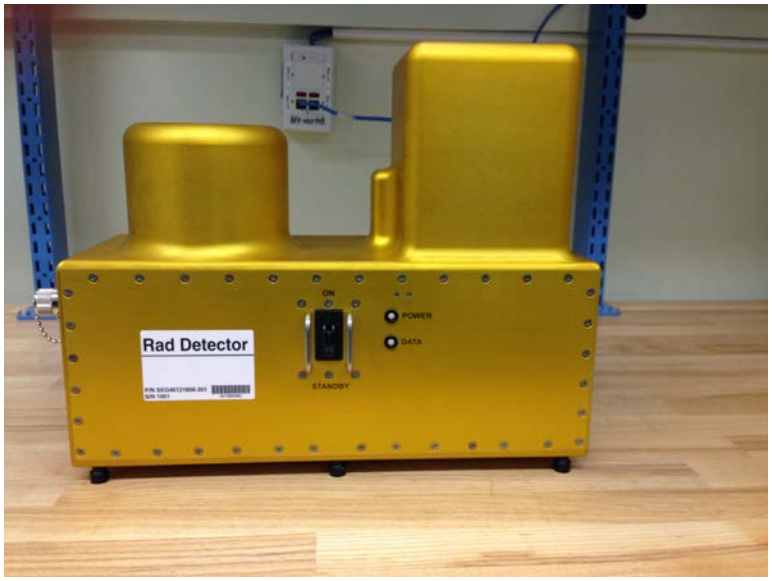


ISS-RAD Status

Major Accomplishments

- Flight Unit Fabrication Completion - 3/28/14
- Certification and Science Testing Performed to date:
  - Vibration & Thermal (at SwRI)
  - 1553 Data and Commanding (at JSC)
  - EMI (at JSC)
  - Science Testing and Calibration (3 runs at NSRL, 1 run at PTB)
  - Cyclotron Testing (8/4-6, at Indiana University)
  - Power Quality (this past week, at JSC)
- FND Rework completed. Delivered to JSC – 7/14. Post FND Repair Testing at SwRI:
  - Repeat Burn-In (24hr)
  - Repeat Thermal Cycle (x2) on Rad Detector
  - New tailored Random Vibration (FND002 only)
- Certification and Science Testing Remaining:
  - Touch Temperature (TBD, at JSC)
  - 1553 RT Validation (TBD, at JSC)
  - SSC Interface (TBD, at JSC)
  - Science and Calibration (10/6 -10, PTB Germany)

ISS-RAD Plans



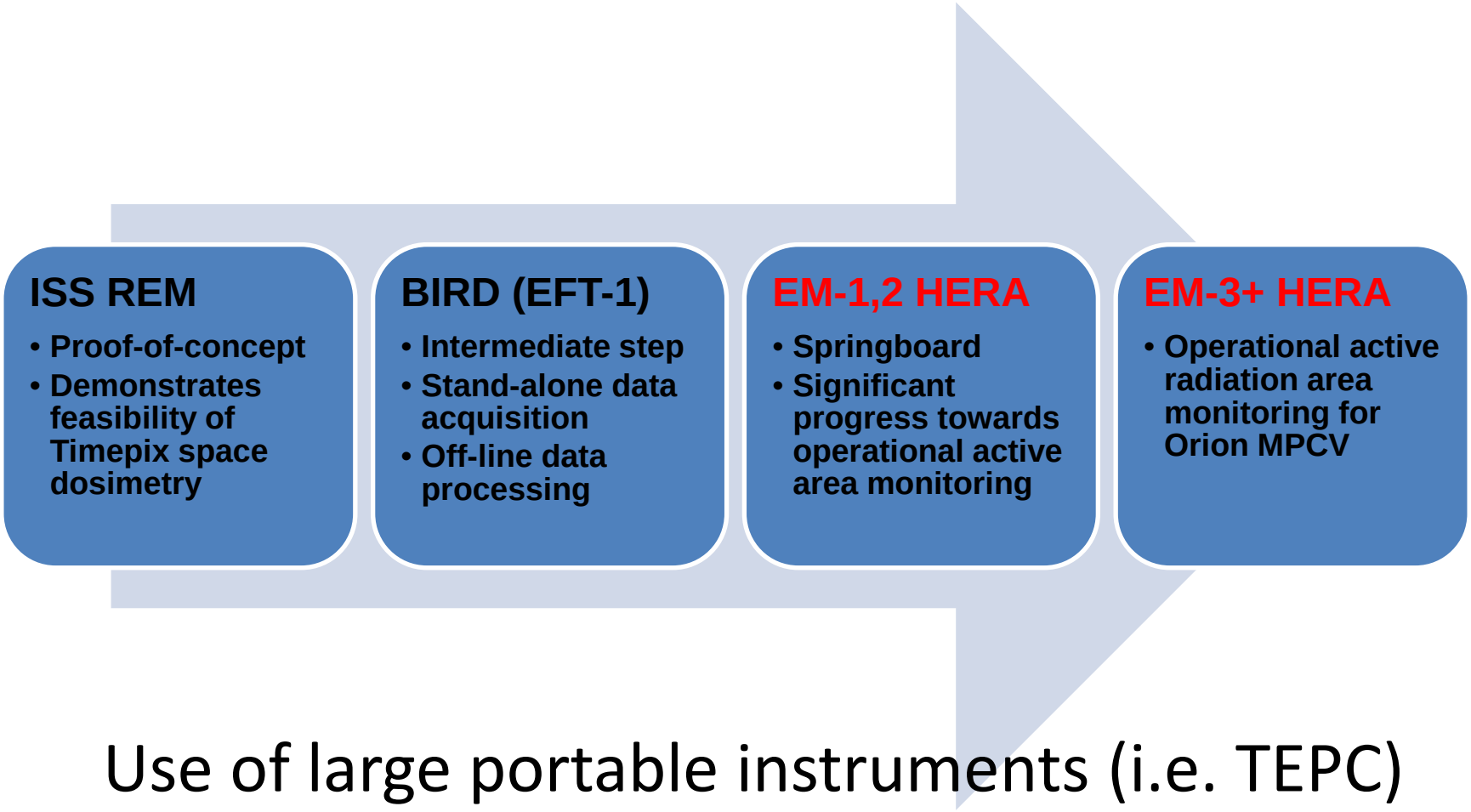
- **ISS-RAD manifest on Orb-4 scheduled ~ 4/15**

- **ISS-RAD to be delivered for launch ~ 12/14**

- **Long term plan is to have continuous measurement campaign in USOS until 2024.**

- **ISS-RAD will be relocated several times per year but not as frequent as IV-TEPC**

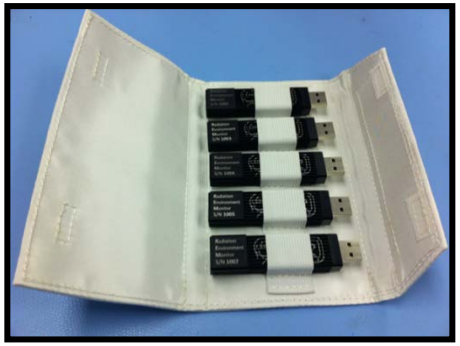
AES Development Path: putting new sensor technology into operational detector system



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

REM Plans

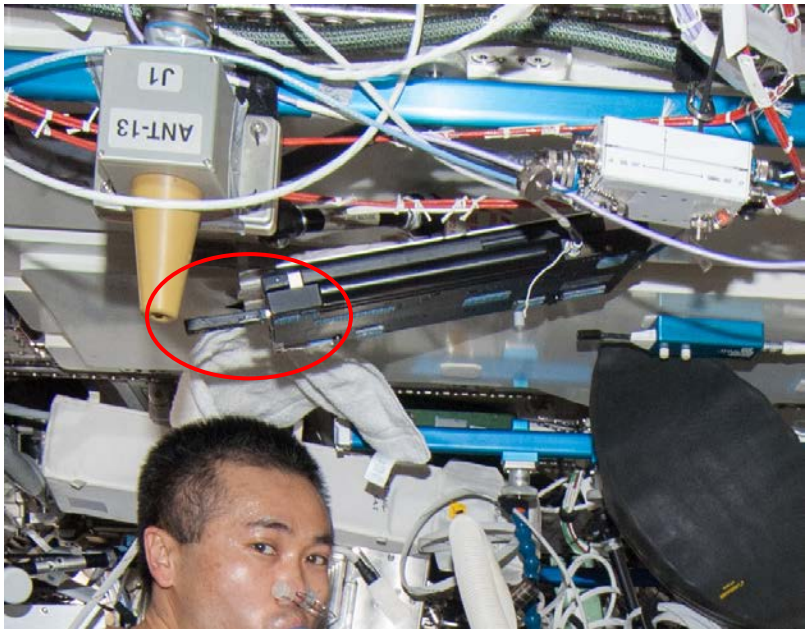
- **ISS REM**
  - Continue to collect/analyze data
    - Web server data display and analysis
    - First quarterly report
    - Deploy REM units in BEAM
  - **Collaboration with LaRC on model comparisons, PI Martha Clowdsley**
  - **Possible increase of number of units +3-5 units**



- **BIRD**
  - Flight hardware in JSC bond
  - Tested S/N 1002 at NSRL
  - Ship to KSC on or before EFT-1 flight
- **HERA**
  - Successfully completed SRR
  - PTRS baseline imminent
  - Design is progressing
  - Table-top review to be held September 30
  - **Possible Tech Demo of HERA prototype on ISS**

REM Data for Modeling

- Data starts midnight GMT Nov 16, 2013 and ends just before midnight GMT Nov 25, 2013
- The REM SN 1005 was located in the US Lab approximately 2 inches from the border between racks 3 & 4 overhead
- Data covers 240 hours minus 2 weekly reboots of ~ 8.5 hrs each
- Total data covers ~223 hrs, with ~187,000 points (~4 sec average interval between data points)

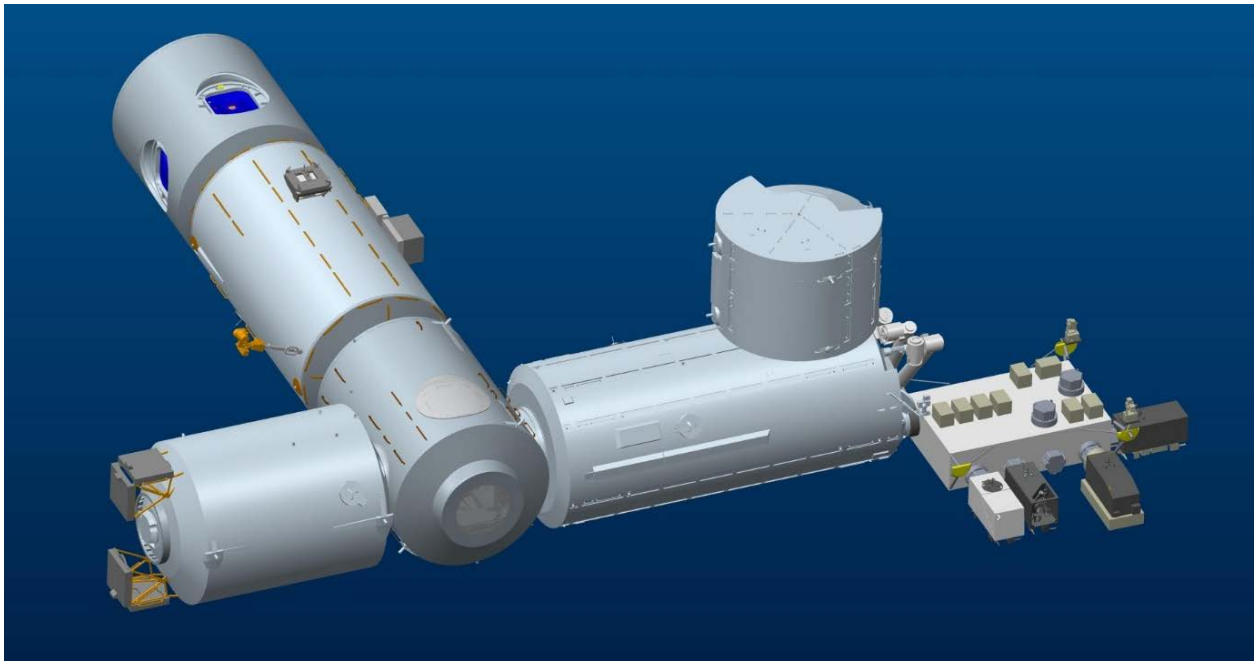


REM Dosimeter location

ISS CAD Model Updates - LaRC

- The CAD model included updated US Lab, Node 1 & 2, and Columbus models (overlapping parts fixed, parts modeled as surfaces removed/fixed, masses correct at the rack or structure level).
- Remaining modules and structures were not updated, but uniform densities were assigned to parts in each module to ensure that total module masses agree with those on the JSC ISS Mass Properties Group website.

Updated Modules-LaRC

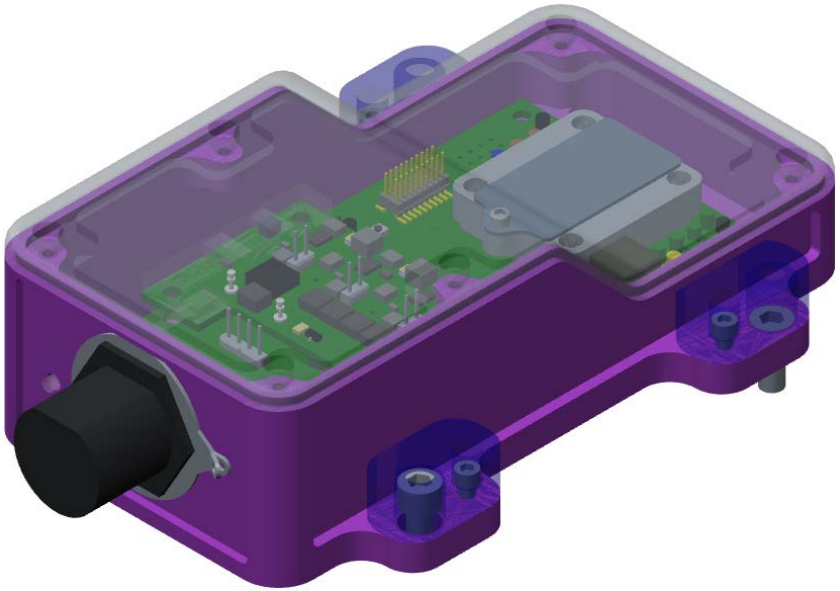


High Fidelity models in LaRC Test assembly

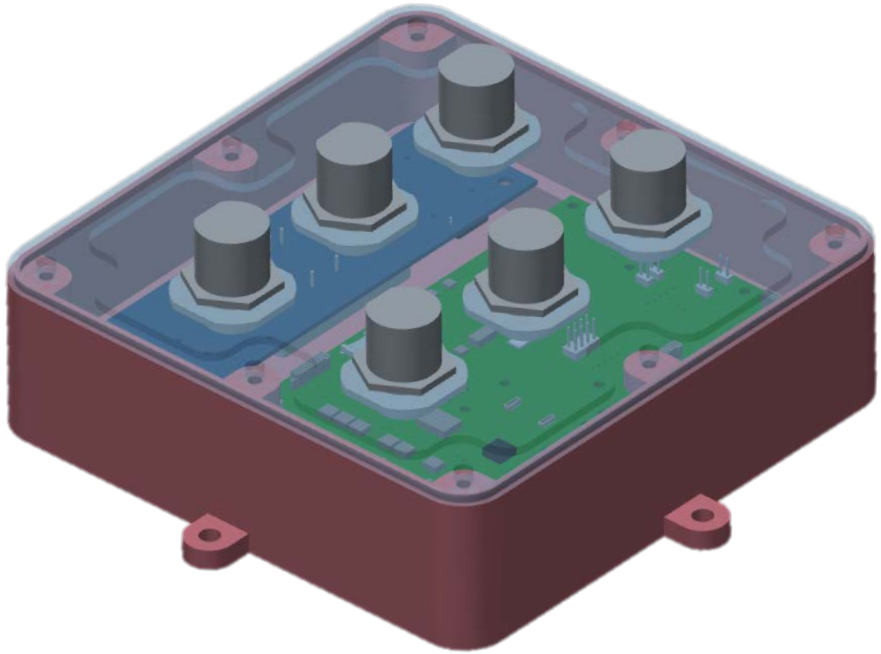
HERA – Instrument Summary

- 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
  - Periodic full data download

HERA – HSU and HPU



HERA Sensor Unit (HSU)
CAD Representation



HERA Power Unit (HPU)
CAD Representation

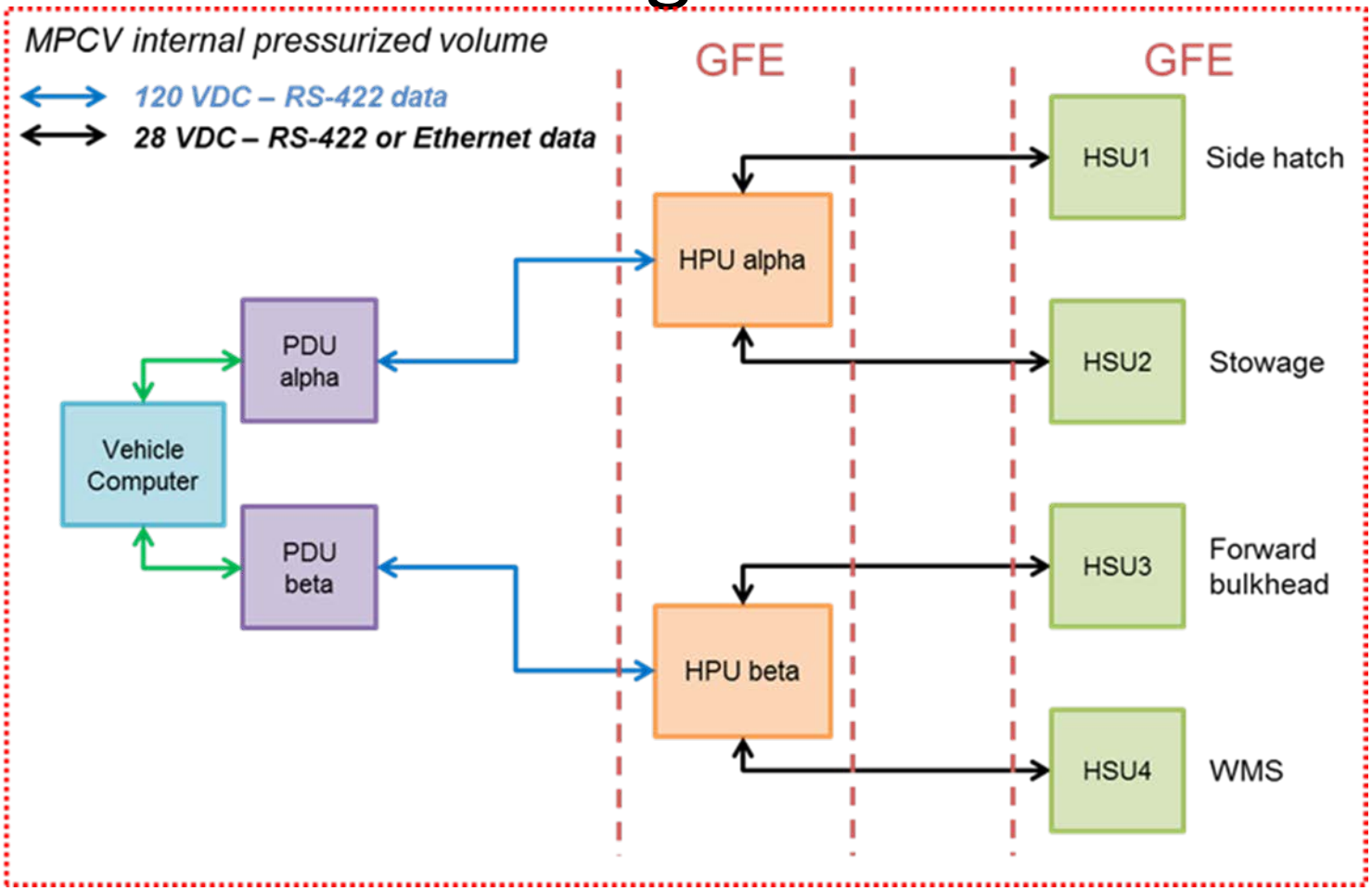
HERA – Instrument Summary

- 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
  - 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

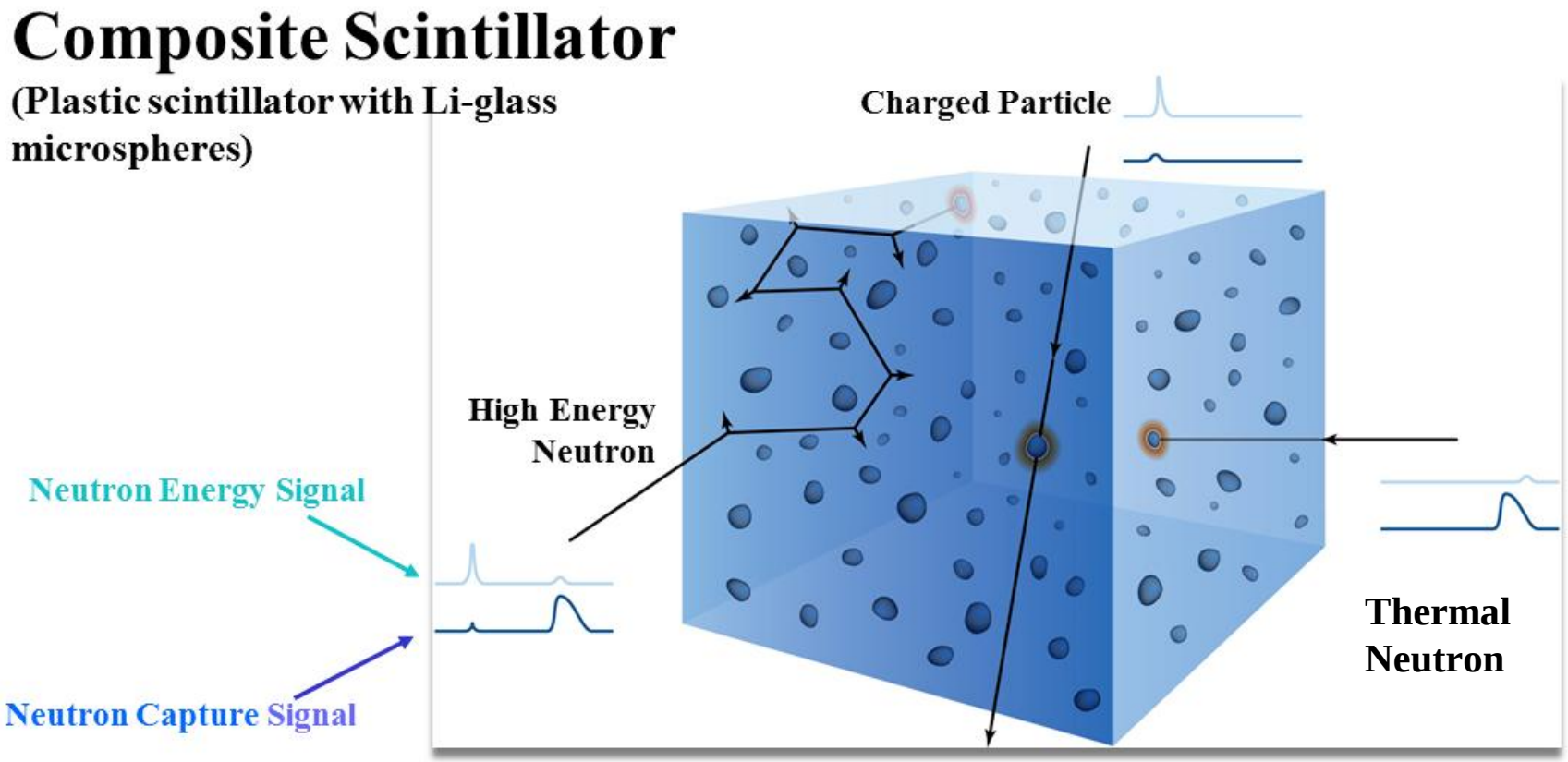
HERA Year in Review - Interface Diagram



Advanced Neutron Spectrometer (ANS) – Mark Christl at MSFC

- **Objectives**
  - 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
  - Alarming capability for SPEs
  - In FY14 develop a second generation prototype of the ANS, measure key performance parameters and demonstrate measurement performance

Gate and Capture Technique for neutrons

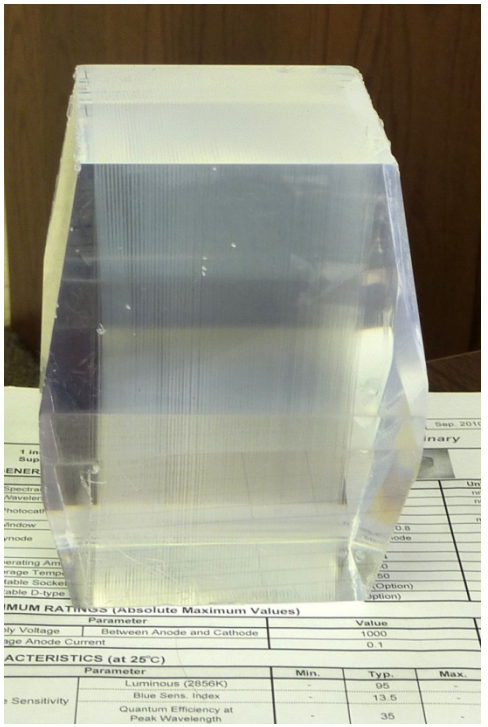


FY14 ANS Accomplishments

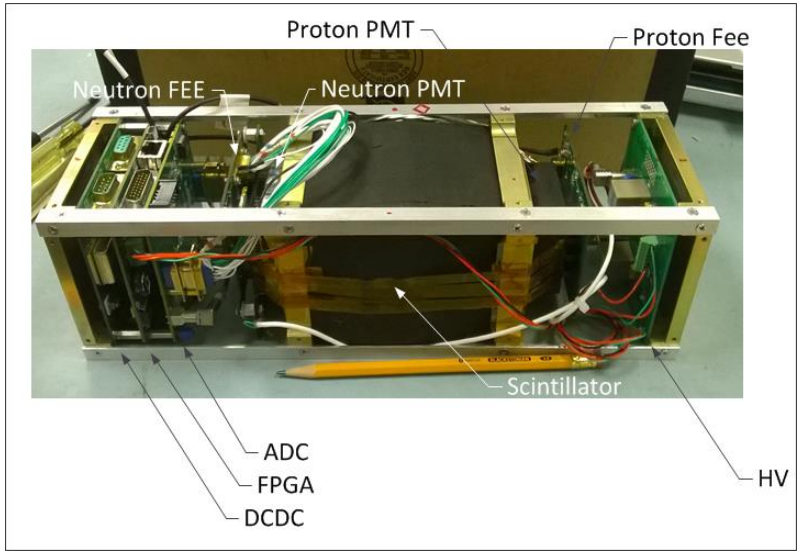
- Completed second generation ANS design and fabrication
- System level functional testing completed; long term testing continues
- Calibrated signal response of the photomultplier tubes using pulsed laser and 200 MeV primary protons
- Measured and simulated collection efficiency and response uniformity for the composite scintillator
- Exposed ANS to mixed field radiation environment at IUCF using 100 MeV protons incident on a aluminum target to produce neutrons, gamma, and other radiation components
- Developed spectral un-folding technique and compared with incident beam
- Supporting neutron measurements at Oak Ridge with tagged neutron source for assessment of detector efficiency and response simulations
- Preliminary environmental testing: vibration and radiation
- Achieved key performance parameters:
  - **Mass 2.3 kg; Power 5.3 W; Energy range: 0.5<E<50 MeV**

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

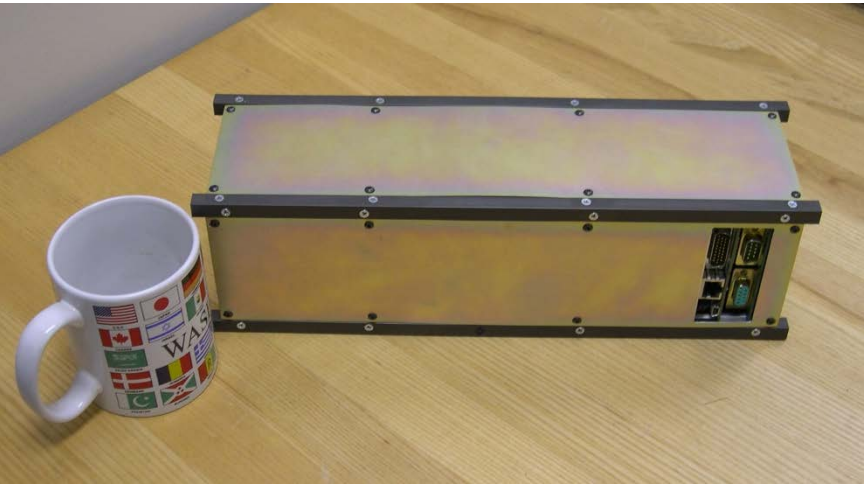
- Fiber array cast in plastic scintillator detector (1 liter), machined and polished surfaces



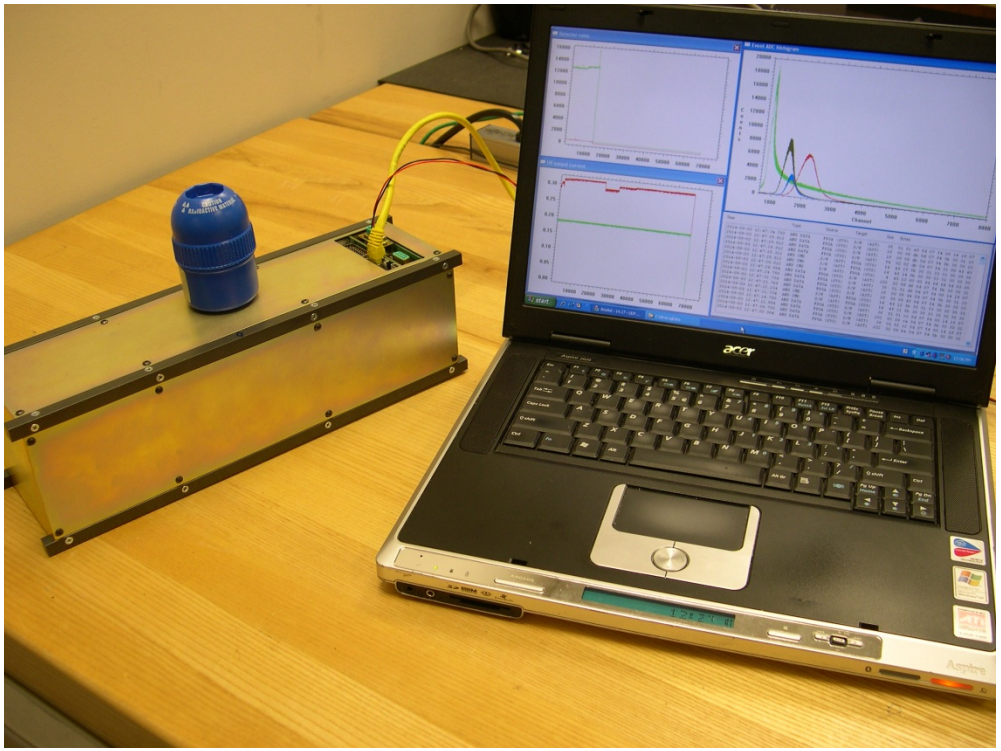
- Electronics and Data Acquisition



ANS GEN-II
(3U CubeSat formfactor)



Acquiring neutron data from radioactive AmBe source

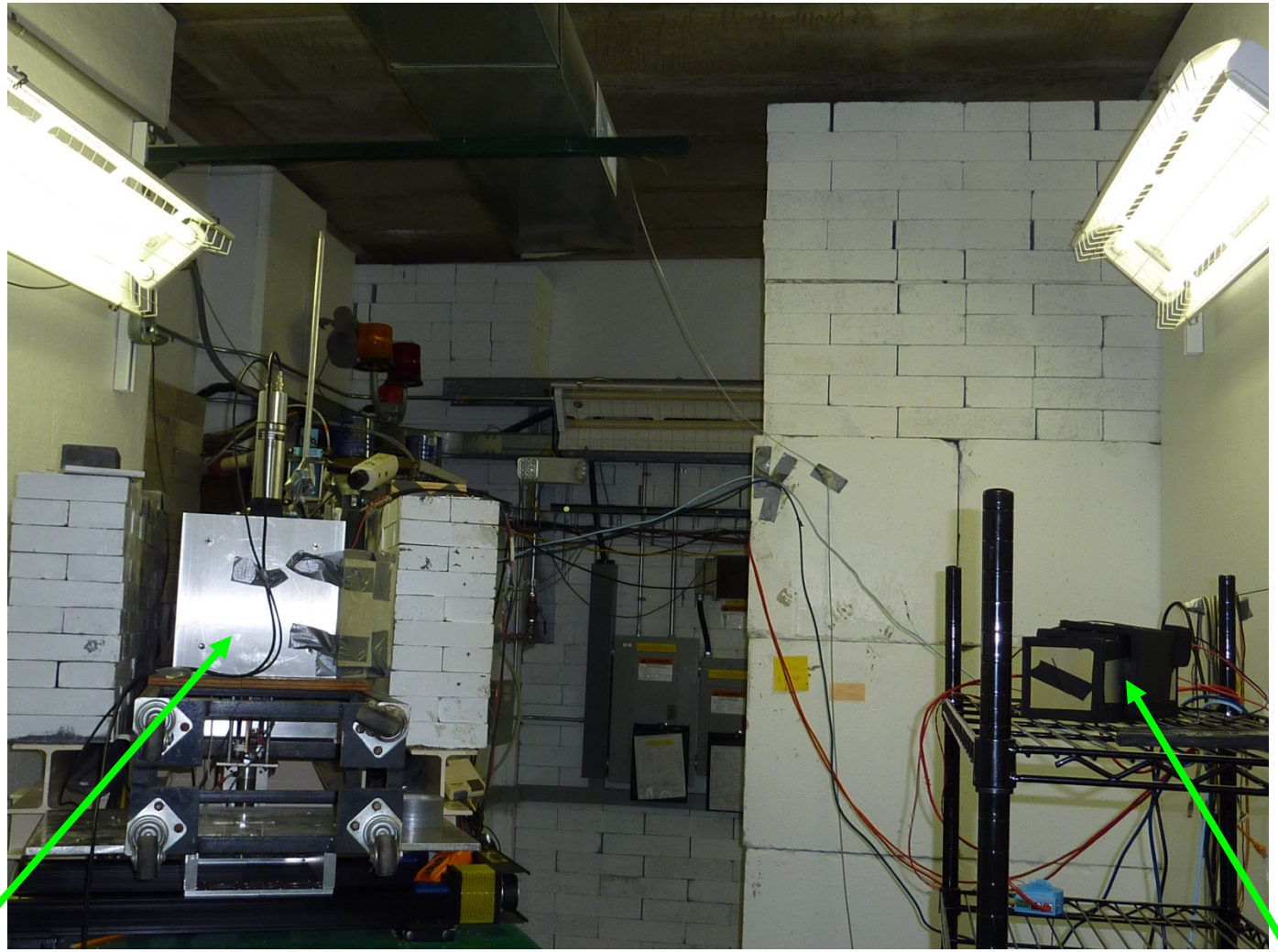


FY14 HQ Milestone: Conduct benchtop demonstration of ANS September 29, 2014

ANS Development Plans

- Phase-I Technology Advancement (2012-2014)
  - Develop an advanced neutron detector design for measuring neutrons in mixed radiation fields
  - Verify critical measurement features
  - Compare performance to state-of-the-art
  - Advance TRL to full-size proto-type
  - Achieve key performance parameters
  - Environmental test and qualification of detector
  - Document measurement performance and data analysis
- Phase-II Spaceflight Demonstration (2015-2017)
  - **Develop plan and schedule for ISS test flight (will compare to ISS-RAD FND)**
  - Identify ISS interfaces: mechanical, power and telemetry
  - Design and fabricate ISS version of ANS
  - Complete environmental testing
- Phase-III Operational (2018+)
  - Develop operational and technical requirements to support manned exploration mission

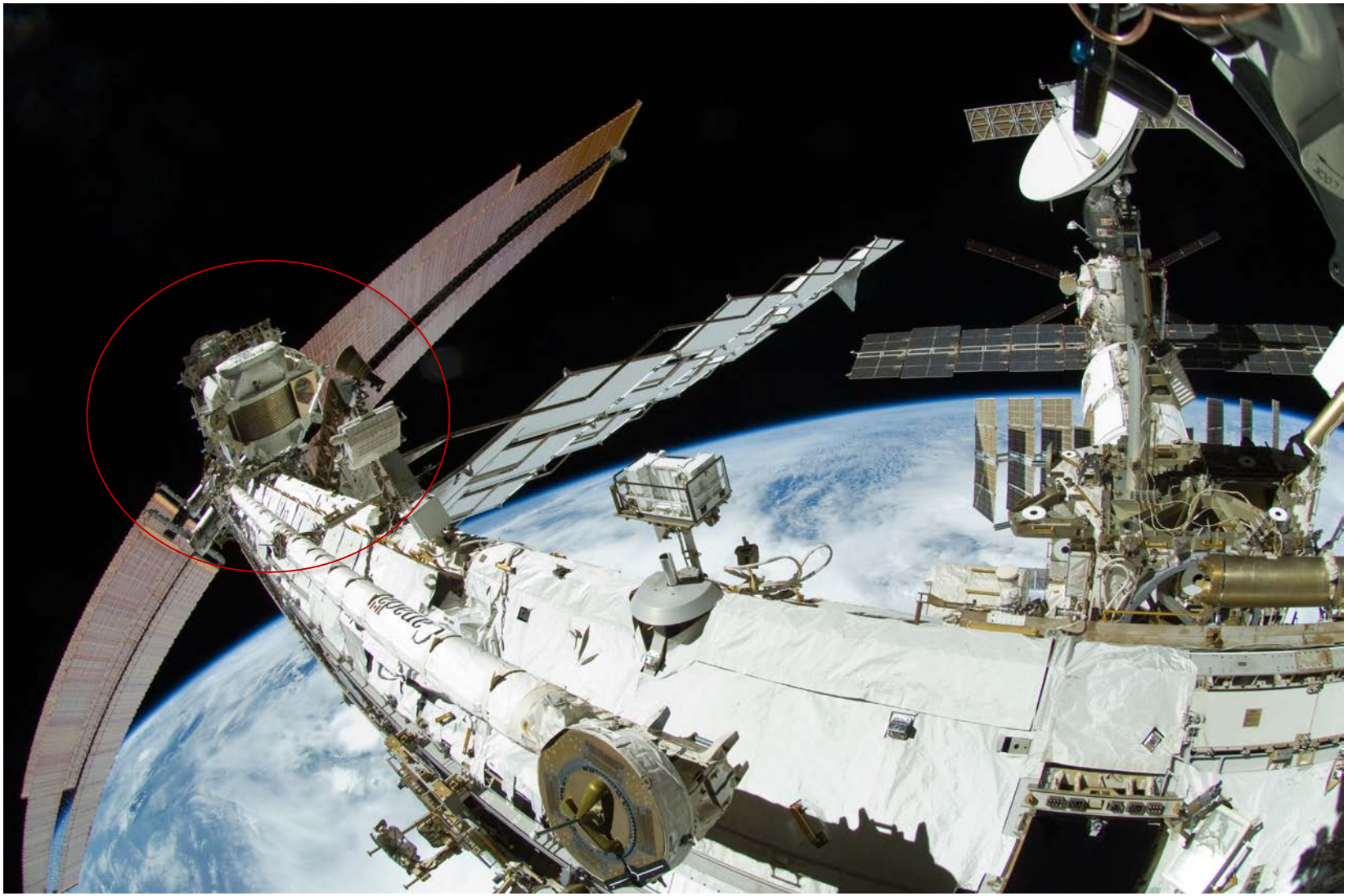
ANS Testing



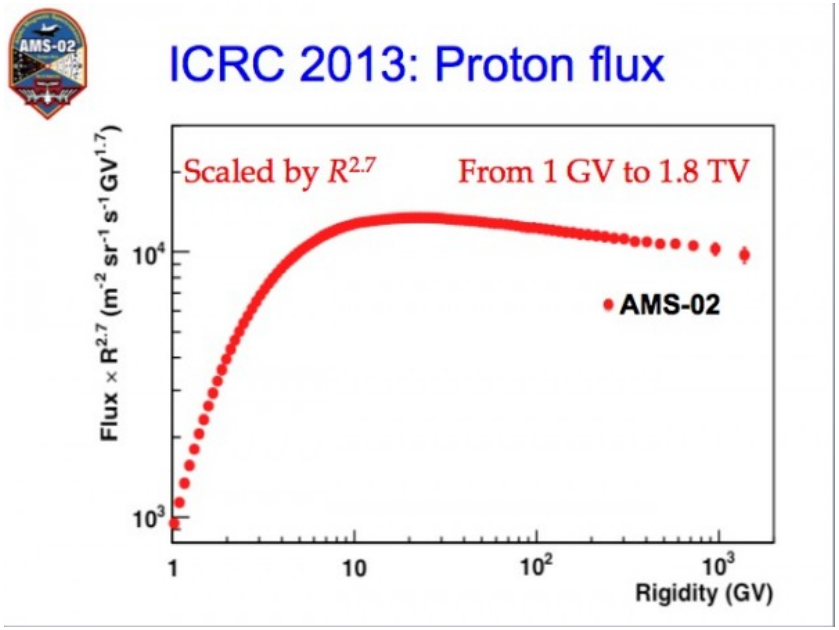
Proton particle beam and aluminum target

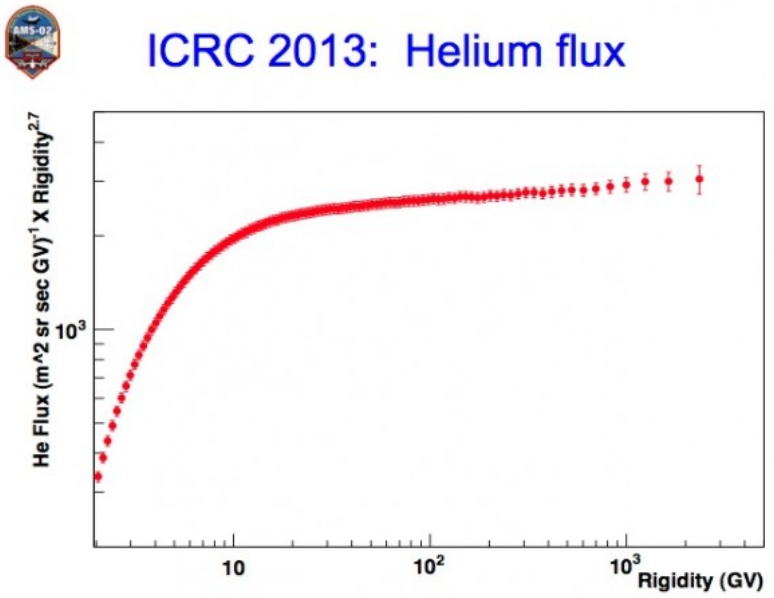
ANS GEN-II

AMS-02



AMS-02 Data Plans





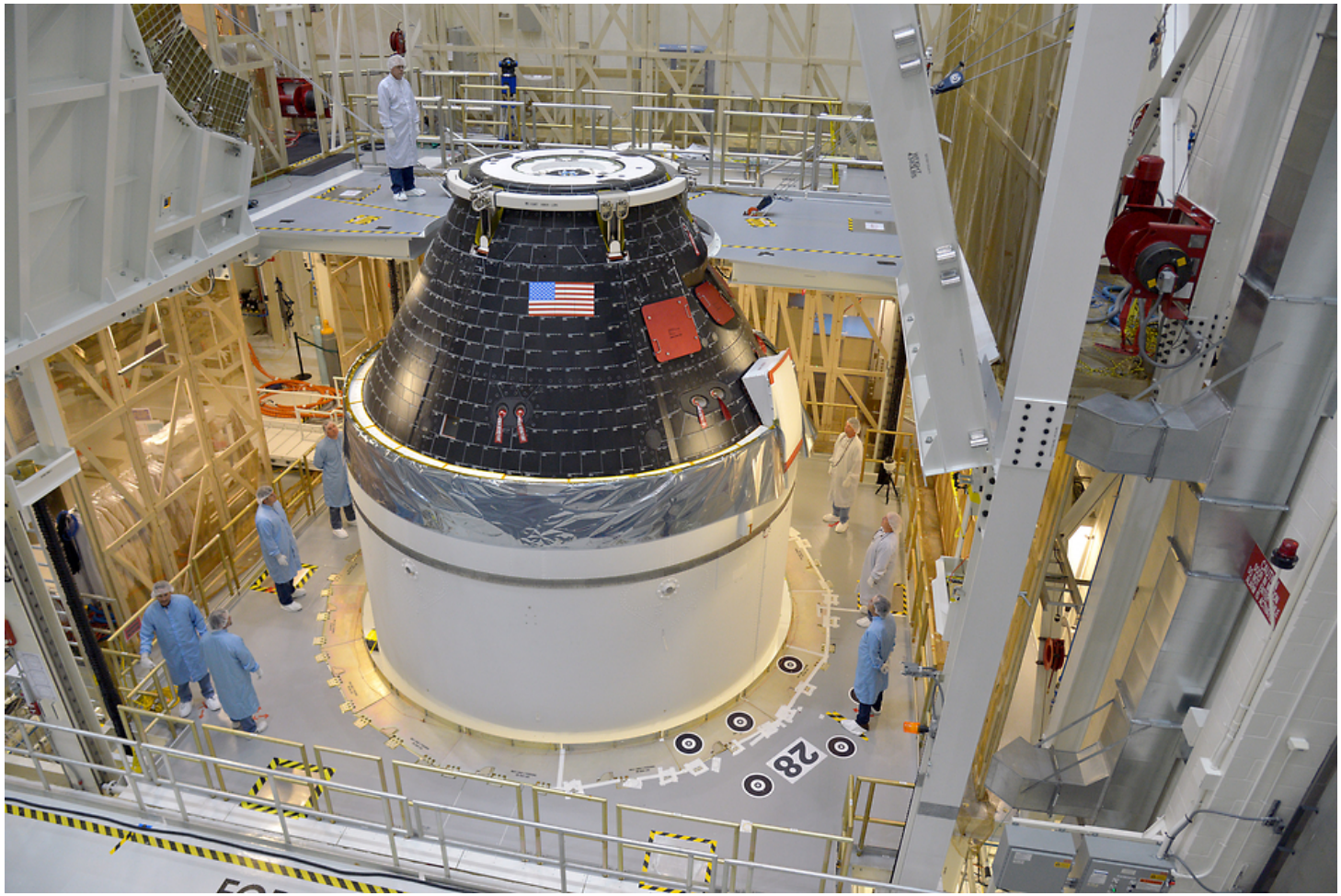
- **Through collaboration with University of Hawaii – Dr. Bindi – developing long term collaboration with AMS-02 team to provide to elemental flux to help GCR model development for operation use at NASA: BO-2013 Model updates**

- **Data will be made available for protons and He in the coming year**

Summary

- ISS dosimetry remains robust and configuration includes
  - 2 TEPCs (3 separate detectors)
  - ISS-RAD – charged particle and neutron spectrometer
  - At least 5 REM units (hopefully more)
  - Continued full use of RAMs and CPDs, 1 year mission will use mid-year swapout
  - ANS demonstration for supplemental neutron data

- MPCV
  - BIRD will provide data critical on MCPV CAD model-trapped radiation
  - HERA project in full swing
  - HERA will be able adapt to improvement in Timepix detectors
  - NASA fully committed to developing systems based on Timepix technology to support future exploration missions



NASA switch to solid state detectors for operational dosimetry requires long lead time to develop analysis tools and use experience. We still have long way to go….