Overview of ISS Radiation Monitoring

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CHARGE

- Review radiation detection hardware currently available (flight pedigree) with potential for flight use with minimal modifications
- Review the current state of the art of radiation detection systems/techniques that should be pursued for future development of flight hardware
- Discuss current NASA funded research related to radiation detection/dosimetry to determine if there are opportunities to utilize research results in operational hardware
- Perform gap analysis to determine if there are research areas that need to be pursued to help support operational radiation detection
- Provide a specific list of consensus recommendations of radiation detection/dosimetry systems best suited for procurement and development

Requirements

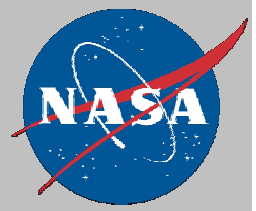
- **Absorbed Dose Monitoring**
  absorbed dose and dose rate from charged particles with LET of 0.2 - 1000 keV/μm, as a function of depth
- **Dose Equivalent Monitoring**
  time-resolved linear/lineal energy transfer (LET, y) used to determine the absorbed dose rate, and LET-based quality factors for determining dose equivalent
- **Charged Particles Monitoring**
  proton and heavy ion ($1 \leq Z \leq 26$) fluence (primary and secondary particles) as a function of energy and time
- **Neutron Monitoring**
  neutron energy fluence spectra/and or ambient dose equivalent in the energy range 1 to 200 MeV, as a function of time.

Why Now?

- Current flight hardware is reaching the end of designed lifetime
- With retirement of Shuttle, there are limited flight opportunities for launching hardware
- Crew Exploration Vehicle (CEV) and Exploration Missions on the horizon
  - ISS would be an excellent test bed for CEV and Exploration radiation detectors
- Currently there are several NASA funded projects that could potentially be used for operational monitoring: Mars RAD, CRaTER, etc.

There is a long lead time for hardware procurement, certification, and manifesting.

Description of ISS Dosimetry



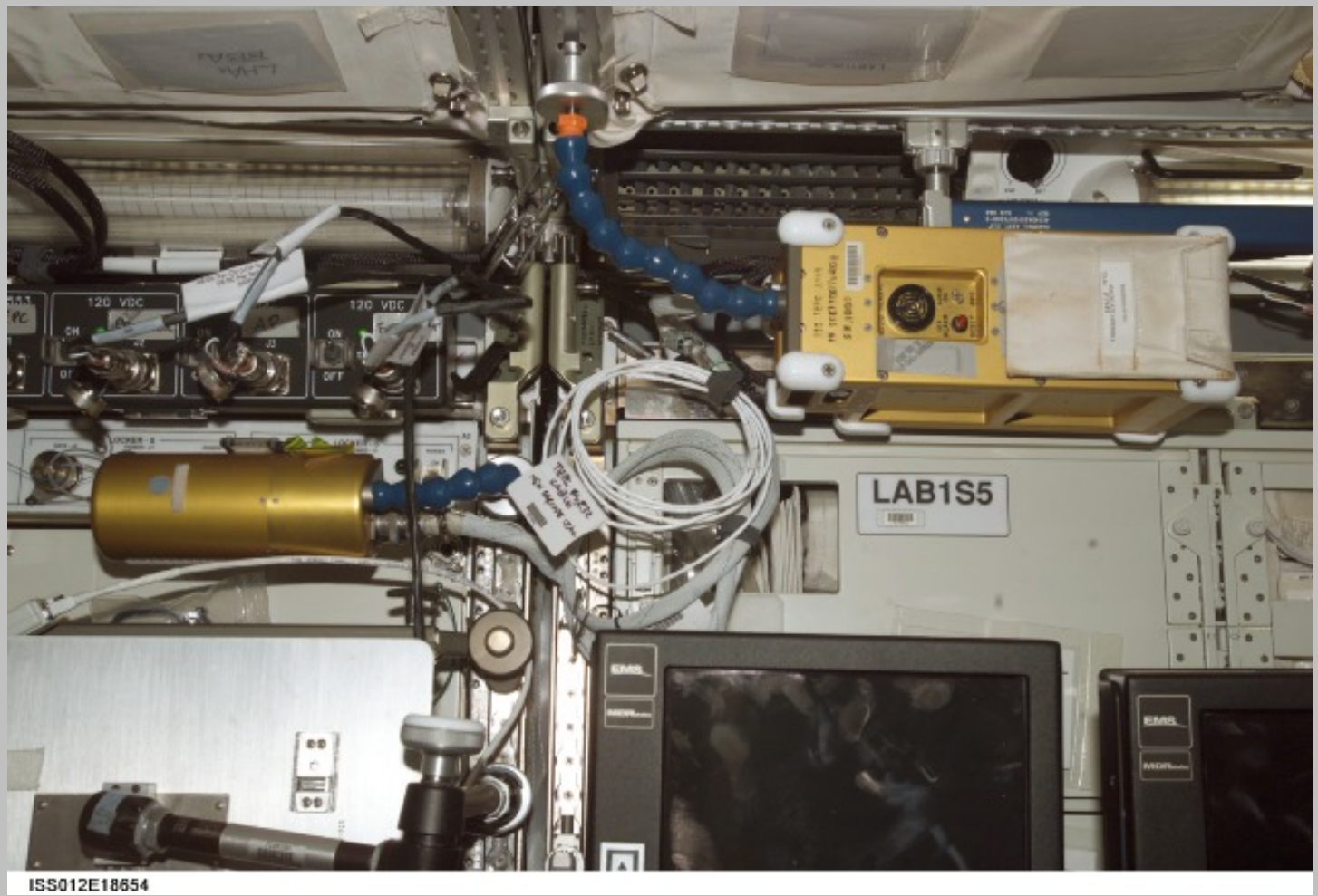
- **1 Crew Passive Dosimeter (CPD)**
  - carried by each crewmember for duration of mission, including EVAs
- **17 Radiation Area Monitors (RAMs)** and High Rate Dosimeters (3)
  - Standard locations in SM, Node, Lab, A/L monitored since 1998, pre Expedition 1.

- **1 ISS Tissue Equivalent Proportional Counter** (TEPC) – **portable**
  - 2 flight units available; 1 currently on orbit and 1 undergoing troubleshooting

- **1 Intravehicular Charged Particle Directional Spectrometer (**IV-CPDS**)** – **portable**
  - 2 flight units available; 1 currently on orbit and 1 undergoing preliminary certification work

- **1 Extravehicular Charged Particle Directional Spectrometer EV-CPDS 3 CPDS units in one integrated instrument**
  - No flight backup CPDS units for EV-CPDS

Tissue Equivalent Proportional Counter (ISS-TEPC)



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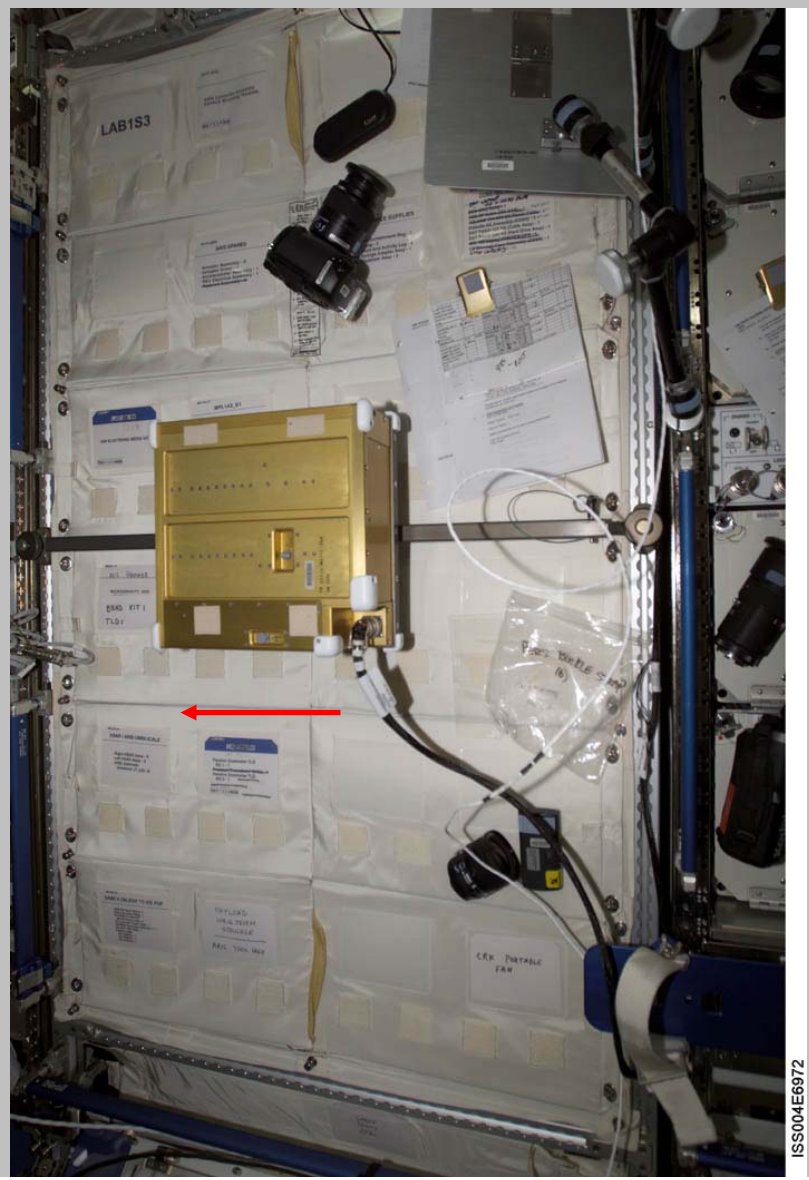
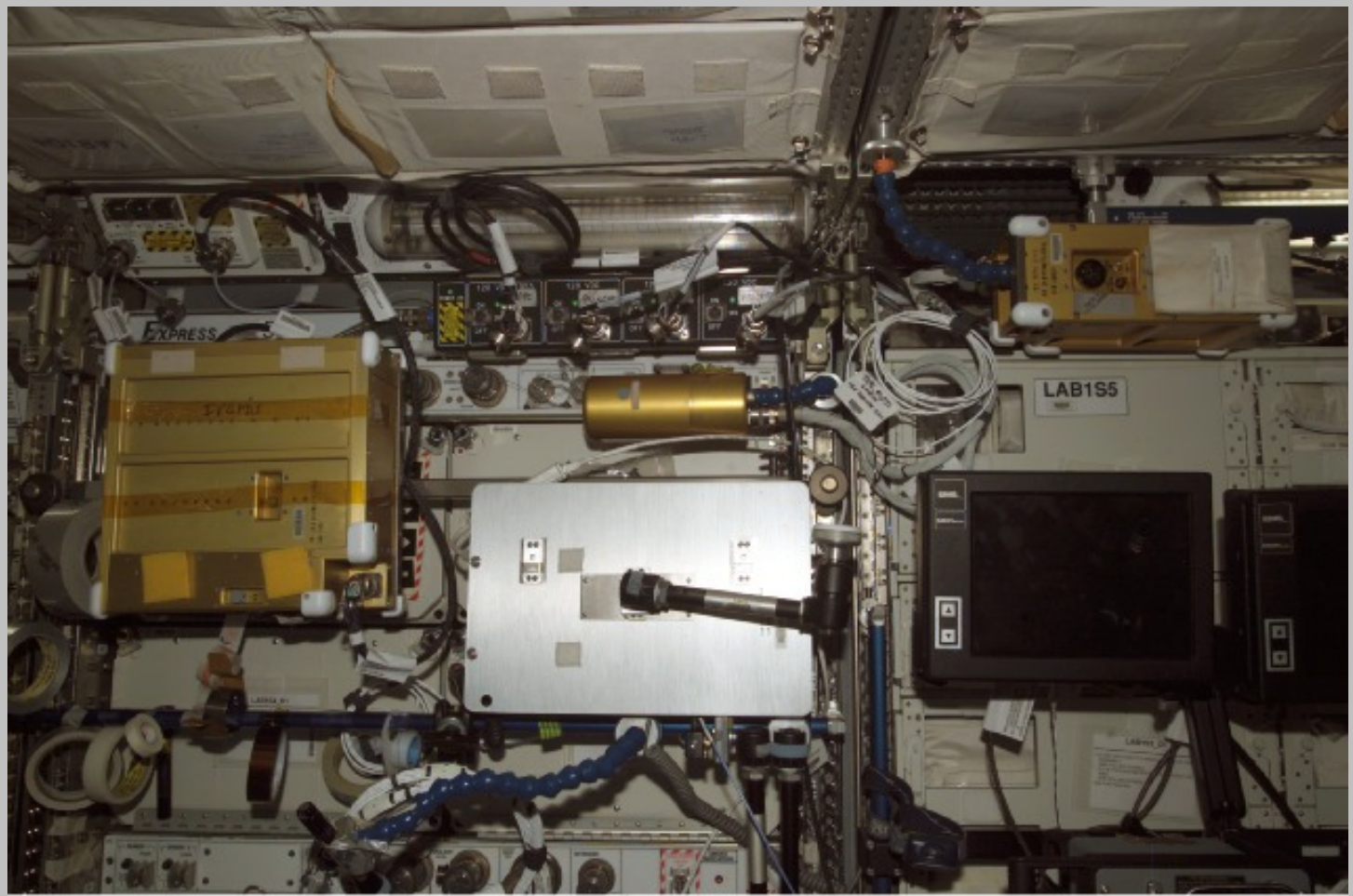
Intra-Vehicular Charged Particle Directional Spectrometer (IV-CPDS)



IV-CPDS and (ISS-TEPC)



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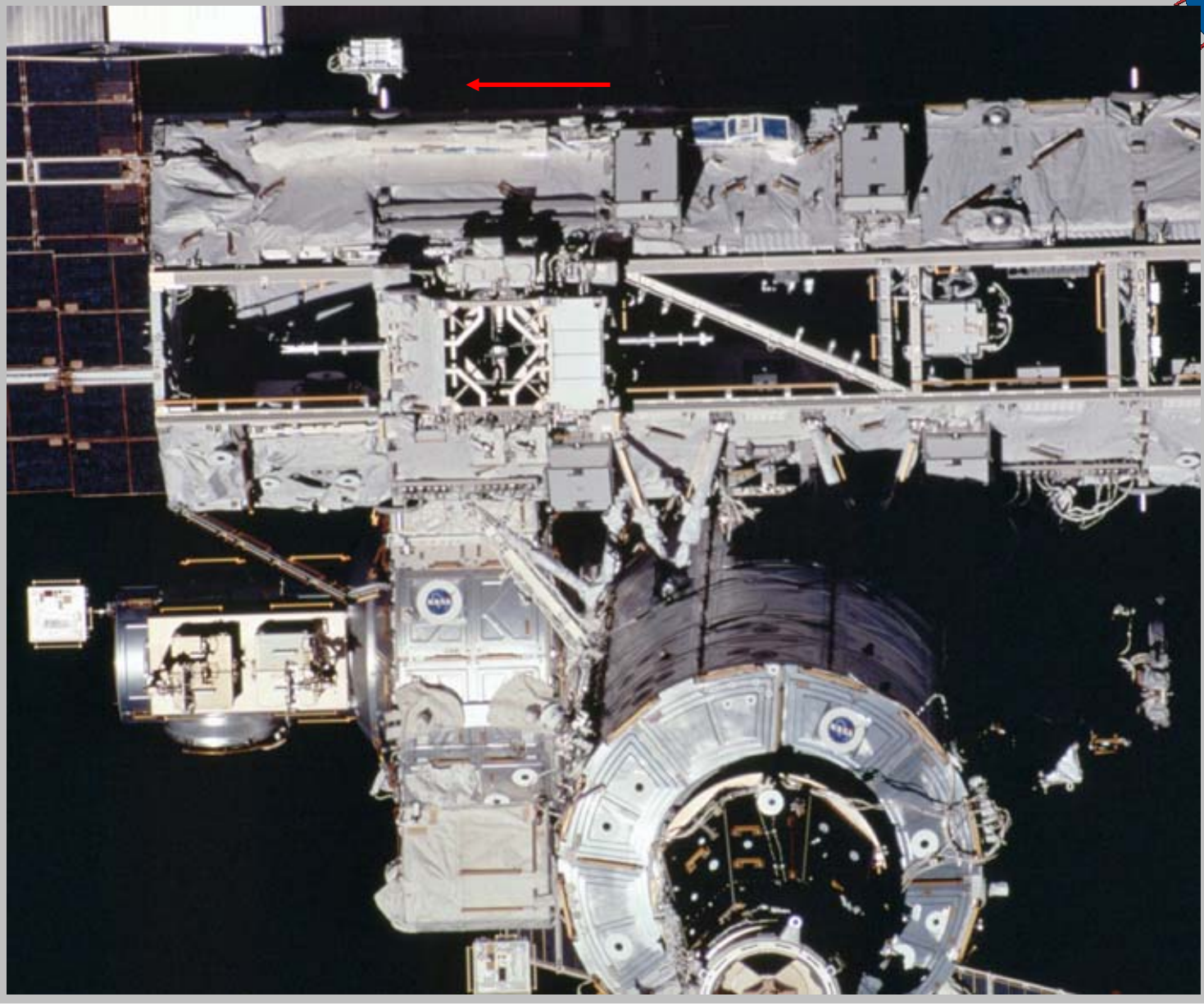
Extra-Vehicular Charged Particle Spectrometer (EV-CPDS)



Description of ISS Dosimetry: TEPC

- Outer Detector dimensions:
  - 8.5 cm diameter x 21 cm long
- Outer Spectrometer dimensions:
  - 11 cm x 15 cm x 30 cm
- Mass Detector = ~0.9 kg
- Mass Spectrometer = ~3.6 kg
- 5 cm diameter x 5 cm height right circular cylinder, A150 tissue equivalent plastic
- Propane gas fill, simulating 2 μm tissue site
- Power/data cable provides both ISS power and MIL-STD-1553B data interface to the ISS C&DH system

Description of ISS Dosimetry: TEPC

ISS TEPC location is currently in the US Lab, scheduled to be moved to SM-P327

Was in 4 locations in during Expeditions 10, 11, and 12

- Nov 9, 2000: **TEPC 1003 Activated**
- 27 Mar 2002**: new software load to switch to 4 second dose format**
- 28 May 2002**: ISS TEPC high voltage supply failure**
  - Instrument returned to ground on STS-111 (15 Jun 2002)
- Jul 2002**: recommendation made by JSC Space and Life Sciences Directorate to manifest backup TEPC on next available Shuttle mission**
- Aug 2002**: Investigation determined ISS TEPC 1003 failure isolated to single capacitor in high voltage supply**
- 17 Nov 2002**: ISS TEPC 1002 failed. Dose rates dropped to zero and then recovered slightly. Returned to ground for on STS-113, 11A. Analysis of failure still ongoing.**

Description of ISS Dosimetry: TEPC

- 7/9/2004: **Engineering record frequency changed from 30 min to 6 hours to reduce Engineering read related resets**
- Current ISS TEPC (1003) operating nominally
  - Still suffering from rate dependent effects and periodic resets
    - Rate dependent effects impact data analysis and ability to look at doses accumulated over short time periods < 1 hour

Summary of TEPCs flown:

S/N	Flight	Software (dose format)	Monitoring Dates
– TEPC 1003	Flt 1	SW1 2 Second Dose format	Nov 2000 – Mar 26 2002
– TEPC 1003	Flt 1	SW2 4 Second Dose format	Mar 27, 2002 – May 28, 2002*
– TEPC 1002	Flt 1	SW2 4 Second Dose format	Oct 15, 2002 – Nov 17, 2002*
– TEPC 1003	Flt 2	SW3 4 Second Dose format	Feb 2004 – Current

*Hardware failure

ISS TEPC 24-Hour Display

Current

Current GMT	Instrument Mode	Alarm Status (Set Point: 5 mrad/min)
96/03:54:24	Data Acquisition	Nominal

SN Detector/Spectrometer	Location	Position
1003/1003	US Lab	S4

GMT (Last Update)	Dose Rate (mrad/min)	Dose Eq. Rate (mrem/min)
96/03:53:54	0.016	0.032

Cumulative

	Total (Since Instrument Turned On)	Yesterday	Today	Last 24 Hours
	029/03:34:00	95	96	95-96 03:54:24
Dose (mrad)	377.3	12.9	2.8	12.6
Dose Eq. (mrem)	1144.0	39.0	7.0	38.0

Instrument Status

Power	1553	CPU	MCA	Display	Memory
OK	OK	OK	OK	OK	OK

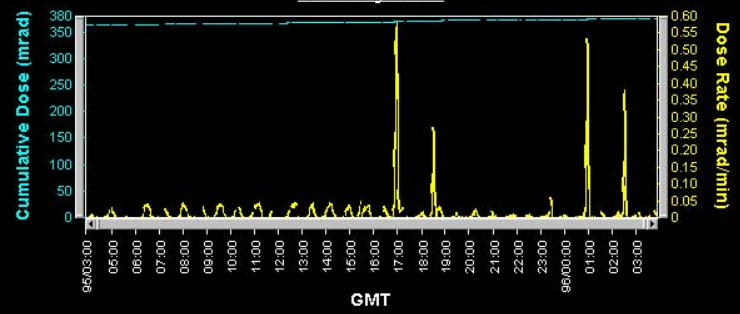
File Status

First File	Last File	Current File
1	9	10

Real Time Monitor

Code	Descripton
111	AcquireCmndExecuted

View Enlarged Chart



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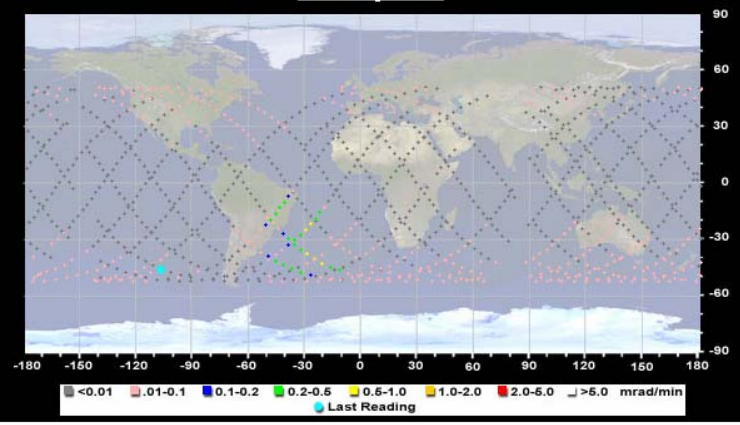

Description of ISS Dosimetry: IVCPDS

IVCPDS location is currently US Lab S4, looking forward

- April 2001: **Initial activation and checkout of S/N 1001**
- Oct 2001: **software upgrade uploaded into IV-CPDS**
  - Allow adjusting detector bias voltage/threshold via ground commands
- Jan 2002: **IV-CPDS dose rate goes up by factor of 2-3**
- Mar 2002: **IV-CPDS dose rate returns to normal on its own**
- May 2002: **IV-CPDS detector bias voltage (A1) successfully adjusted by ground commanding**
- May 2002: **IV-CPDS detector thresholds (A1,A2) successfully adjusted by ground commanding**
- Oct 2002: **software upgrade uploaded into IV-CPDS**
- Nov 23, 2002 – May 3, 2003: **EVARM intercomparison during Expedition 6**
- IVCPDS currently operating nominally
  - Only measuring a limited portion of radiation field
  - Need to modify software to allow correct time/date stamping of data

Description of ISS Dosimetry: EVCPDS

- Apr 2002: EV-CPDS launched and deployed: mounted on S0 Truss
  - EV1 (forward looking CPDS) locked up in the end of April 2003, not recoverable
    - Options to recover EV1 are limited to an EVA task (currently unplanned)
  - EV2 and EV3 still operating nominally

Note: Pre-flight radiation certification testing was not adequate to characterize performance of *any* of the CPDS instruments. This caused the units to be flown without meeting original design specifications.

Description of ISS Dosimetry: Russian Hardware

- 1 Pressurized Ion Chamber: R16
  - Comprised of 2 detectors, D1 and D2
  - Launched with SM (*hardmounted*) behind P327
  - Served as primary Mission Reference Exposure (MRE) detector
    - Used to track Expedition crews' weekly doses
- 4 DB8 Single element Si detectors (1 shielded and 1 unshielded detector in each DB8 unit.
  - Launched with SM (*hardmounted*)
  - Provides dose measurements as a function of shielding in SM only
- Russian Pille
  - Up to 12 TLD bulb dosimeters deployed in SM
  - Similar to our CPDs and RAMs, but readout on-orbit
  - Can provide EVA specific dosimetry
- Russian Luilin
  - 4 portable units, they are basically battery operated version of DB8

Note: The majority of Russian hardware is specific to SM. To date, only Pille dosimeters have made measurements outside SM.

RUSSIAN HARDWARE ISSUES

- Russian hardware deployment/use has been very systematic
  - The plan laid out early in ISS assembly has been carried out faithfully
  - Software upgrade is planned and Luilin use not clearly defined, will not become

- We have good relationship with Russian counterparts and access to flight data is frequent
  - SRAG gets weekly updates of R16 and DB8 of daily dose rate data
  - Time resolution is not sufficient for Solar Particle Event (SPE) monitoring
  - So far, not able to get spectral information

- Hardware has proven to be dependable, however
  - Response change in R16 has been observed by SRAG starting in Nov, 2003
    - Have discussed issue with Russian counterparts and they are investigating the problem
  - Recent hardware discrepancy in DB8 data was reported at RHWG meeting
    - Potential factor of 1.5 increase in reported dose/dose rate

- DATA NOT AVAILABLE FOR USOS
- RESPONSE TO INQUIRIES NOT TIMELY

ISS Radiation Monitoring Hardware Capability Comparison: As Flown

Capability (MORD Rev C Req. #)	TEPC	TLDs and CR-39	IV-CPDS	EV-CPDS	Russian R-16	Russian Pille	Russian DB8
Time Resolved LET Spectra (7.5.3.2.1.1)	Yes 0.3-1200 keV/μm	Yes 10-1000 keV/μm	Yes ~0.5-38 keV/μm	Yes ~0.5-38 keV/μm	No	No	Yes ~0.5-50 keV/μm
Active Radiation Monitoring 7.5.3.2	Yes	No	Yes	Yes	Yes	No	Yes
Charged Particle Monitoring (7.5.3.2.1.2)	No	No	Yes	Yes	No	No	No
Alarm Capability (7.5.7)	Yes	No	No	No	No	No	No
Crew Read Out Capability	Yes	No	Yes	No	No	Yes	No
Neutron Sensitivity (7.5.3.2.1.3)	Yes	Yes	No	No	No	No	No
ISS Surveying Capability (7.5.5)	Yes	Yes	Yes	No	No	Yes	No
ISS Locations Covered	ALL	ALL	USOS ONLY	External	RS ONLY	RS ONLY	RS ONLY

Tasks we can complete without Procurement

1. Complete certification testing of backup TEPC and IVCPD
   - No backup units available/certified for current operational suite: Tissue Equivalent Proportional Counter (TEPC), IntraVehicular Charged Particle Directional Spectrometer (IV-CPDS).

2. ISS TEPC software modification and upload
   - TEPC has incorrect dose rate information for short time intervals (< 1 hour), due to rate dependent effects. This makes data analysis cumbersome and very time consuming.
3. Swapout of current flight IVCPDS with modified backup IVCPDS
   - Identify a flight now and request manifesting
   - Complete additional radiation characterization of backup IVCPDS
   - Post-flight characterization of current flight IVCPDS at multiple facilities to allow for improved flight data analysis of 3 years of operational data

ISS Dosimetry Near Term Plan

Continue with ISS dosimetry near term tasks:

- Complete acceptance testing of backup TEPC and have instrument ready to fly.
- Complete the acceptance testing on backup IV-CPDS . Utilize recent Japan data as driver for IV-CPDS flight unit improvements and data analysis.
  - characterize thresholds, correct gain change and other issues as documented. Recent Japan data will provide insight to overall status of backup IV-CPDS.
- Modify IVCPDS flight software to allow correct time stamping of data
- Modify EV-CPDS software load to have the unit communicate before doing the disk scrub at power on. This would greatly the chance of losing the ability to communicate with EV2 and 3.

ISS TEPC Failure Contingency Plan

- If current ISS TEPC fails in orbit
  - Return failed unit to the ground on earliest possible return flight
  - Without radiation monitoring information during solar particle event, SRAG will have to recommend conservative crew actions during *predicted* higher dose rate periods during IVA and EVA operations
  - Expedite acceptance testing/certification/launch of current backup TEPC
    - accelerate certification of new replacement TEPC if backup TEPC anomalies are not resolved in a timely fashion (<3 months)
  - Continue to improve hardware/software settings of in-flight IVCPDS using data obtained during testing of backup IVCPDS to increase confidence in cyclic dose reporting
    - Set flight parameter change is currently in work to modify dose factor used to derive cyclic dose information
- What SRAG will be missing
  - Instrument/data used for Mission Reference Exposure
  - ISS TEPC is the only radiation instrument on board with a local alarm
    - Provides reliable visible/audible alarm when dose rates exceed 5 mrad/min
    - If energetic solar particle event occurs, alarm will potentially activate and crew will take action without additional delay
  - Ability to track dose equivalent and location specific information on quality factor