

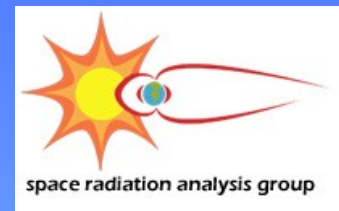
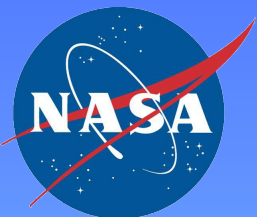
Recent Shuttle and ISS radiation measurements: STS-121, STS-115, STS-116, STS-117 and ISS Expedition 13

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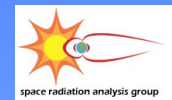
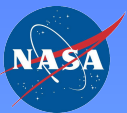


Operational passive dosimetry at SRAG



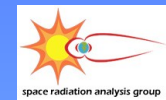
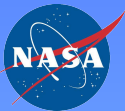
- Monitoring crew members and ISS area locations since May 1999
- Total of 19 passive radiation monitoring increments
- 3035 day continuous crew/area ISS monitoring

- Monitoring crew members and STS area locations since April 1981
- Total of 117 Shuttle Missions flown



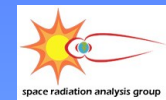
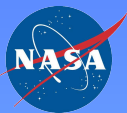
Summary of ISS Expeditions

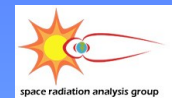
ISS Passive Radiation Monitoring Increments	Module	Duration (days)	Detector Types
05/20/99-05/29/00	Node 1 (3 locations)	375	TLD-100
05/19/00-09/20/00	Node 1 (3 locations)	124	TLD-100, TLD-300 TLD-600, TLD-700
09/08/00-12/11/00	Node 1 (3 locations) Service Module (4 locations)	93	TLD-100, TLD-300 TLD-600, TLD-700
12/01/00-05/01/01	Node 1 (3 locations) Service Module (6 locations)	151	TLD-100, TLD-300 TLD-600, TLD-700
04/19/01-07/24/01	Node 1 (3 locations) Service Module (6 locations) US Lab Module (5 locations)	96	TLD-100, TLD-300 TLD-600, TLD-700
07/12/01-08/22/01	Node 1 (3 locations) Service Module (6 locations) US Lab Module (5 locations) Airlock (2 locations)	40	TLD-100, TLD-300 TLD-600, TLD-700
08/10/01-12/17/01	16 locations	128	TLD-100, TLD-300 TLD-600, TLD-700
12/05/01-04/19/02	16 locations	134	TLD-100, TLD-300 TLD-600, TLD-700
04/08/02-06/19/02	16 locations	71	TLD-100, TLD-300 TLD-600, TLD-700
06/05/02-12/07/02	16 locations	184	TLD-100, TLD-300 TLD-600, TLD-700

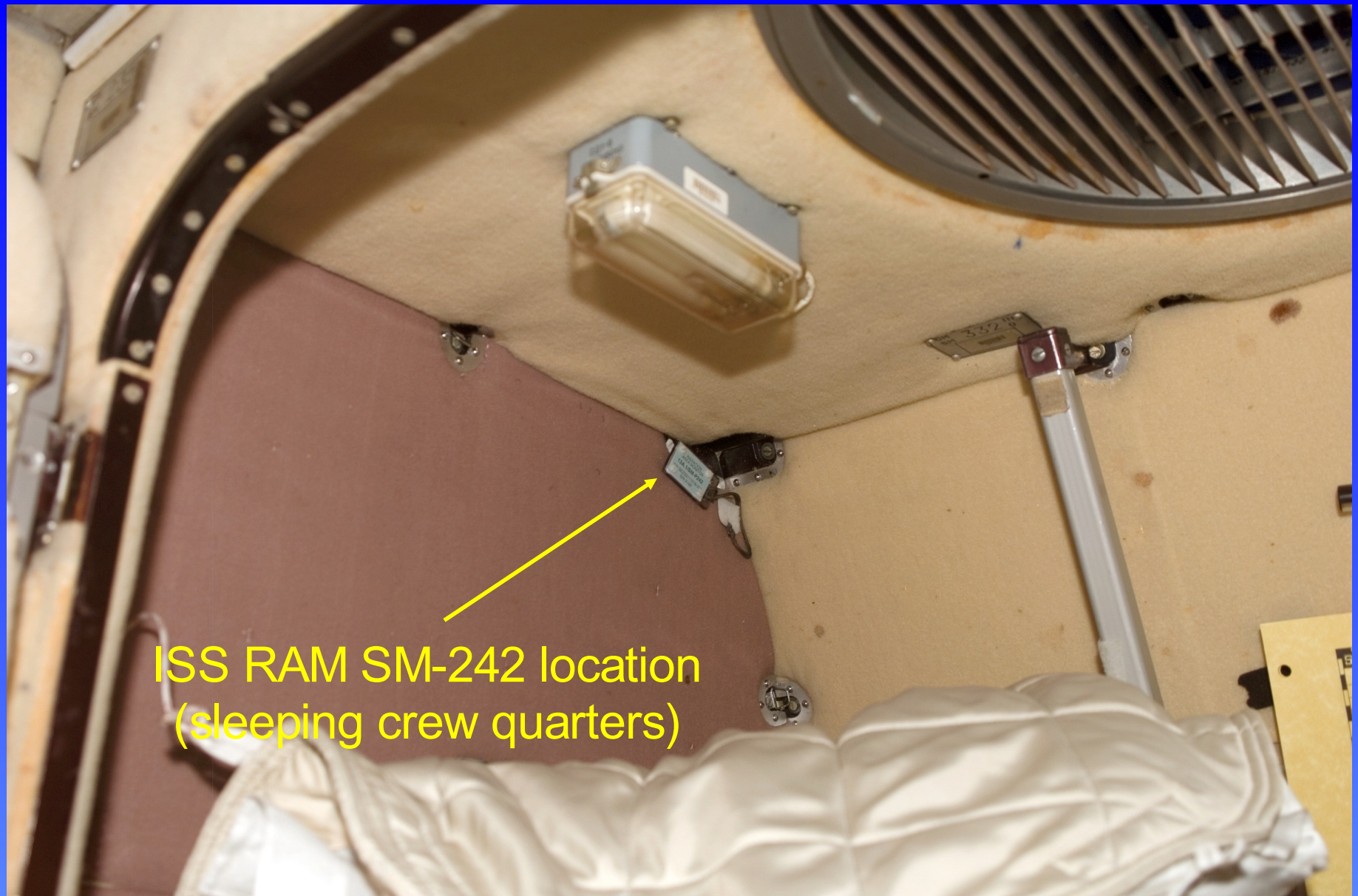


Summary of ISS Expeditions

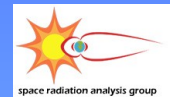
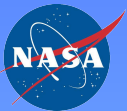
ISS Passive Radiation Monitoring Increments	Module	Duration (days)	Detector Types
11/24/02-05/04/03	16 locations	160	TLD-100, TLD-300 TLD-600, TLD-700
10/18/03-04/30/04	16 locations	195	TLD-100, TLD-300 TLD-600, TLD-700
04/19/04-10/24/04	17 locations –added the TEPC RAM	188	TLD-100, TLD-300 TLD-600, TLD-700
10/14/04-04/24/05	17 locations	192	TLD-100, TLD-300 TLD-600, TLD-700
04/15/05-10/11/05	17 locations	178	TLD-100, TLD-300 TLD-600, TLD-700, Luxel, CR-39
10/01/05-04/08/06	17 locations	189	TLD-100, TLD-300 TLD-600, TLD-700, Luxel, CR-39
03/30/06-09/29/06	18 locations-added extra Lab Module location	182	TLD-100, TLD-300 TLD-600, TLD-700, Luxel, CR-39
09/18/06-08/21/07	18 locations	337	TLD-100, TLD-300 TLD-600, TLD-700, Luxel, CR-39
08/08/07-	18 locations		TLD-100, TLD-300 TLD-600, TLD-700, Luxel, CR-39



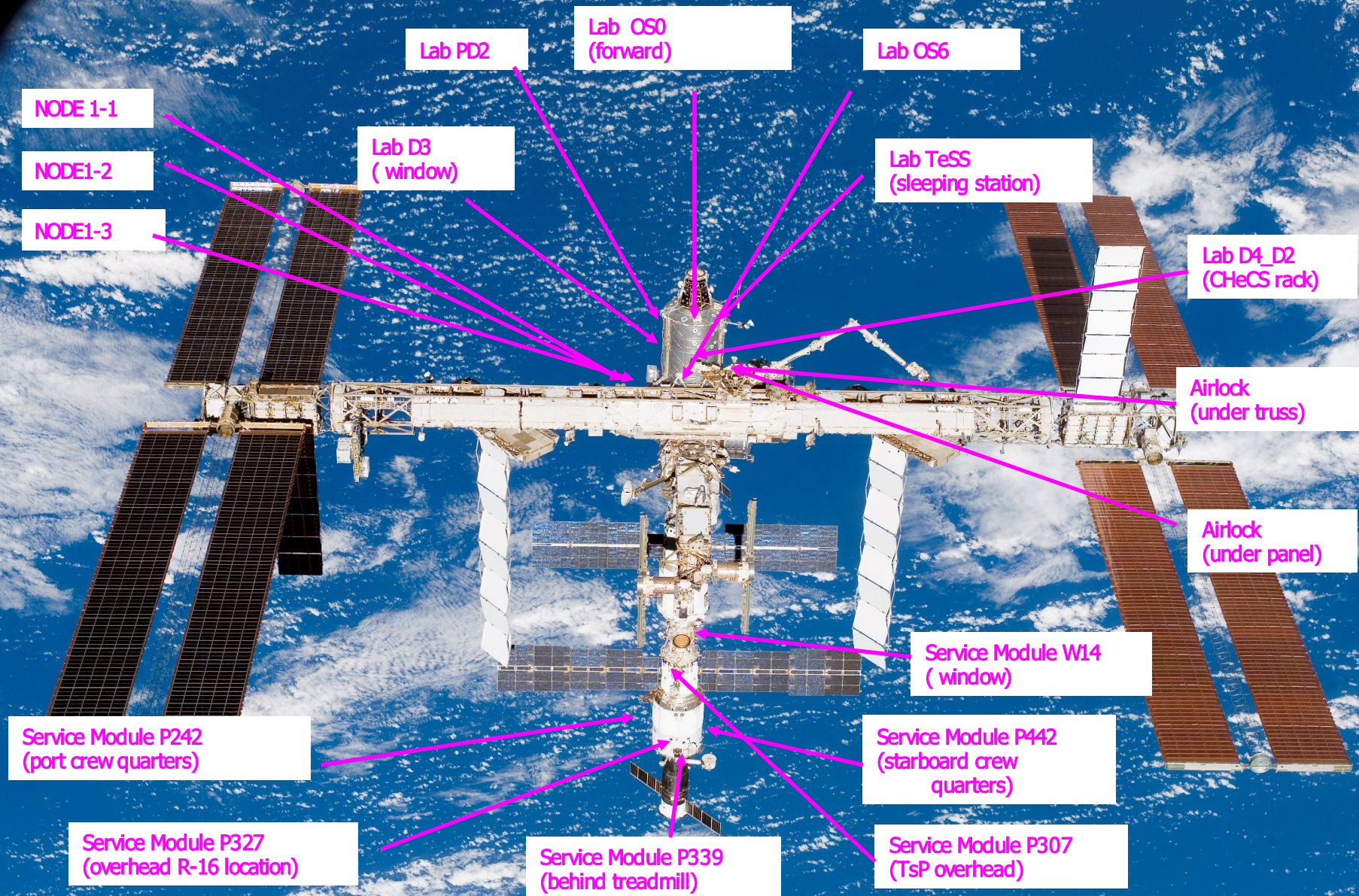




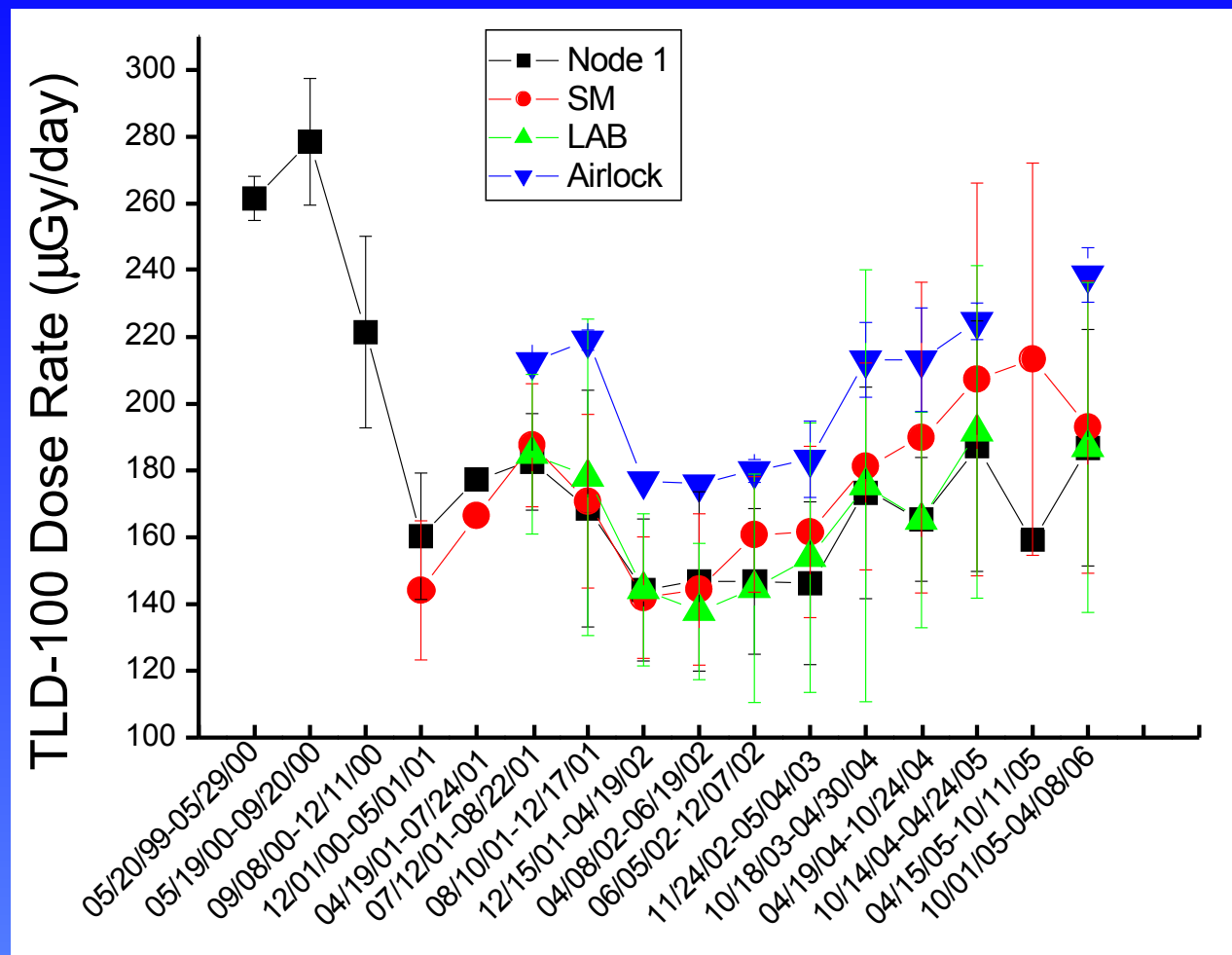
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ISS Radiation Area Monitor (RAM) Locations

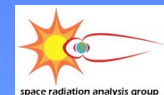
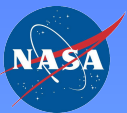


Summary of ISS RAM Dose Rates



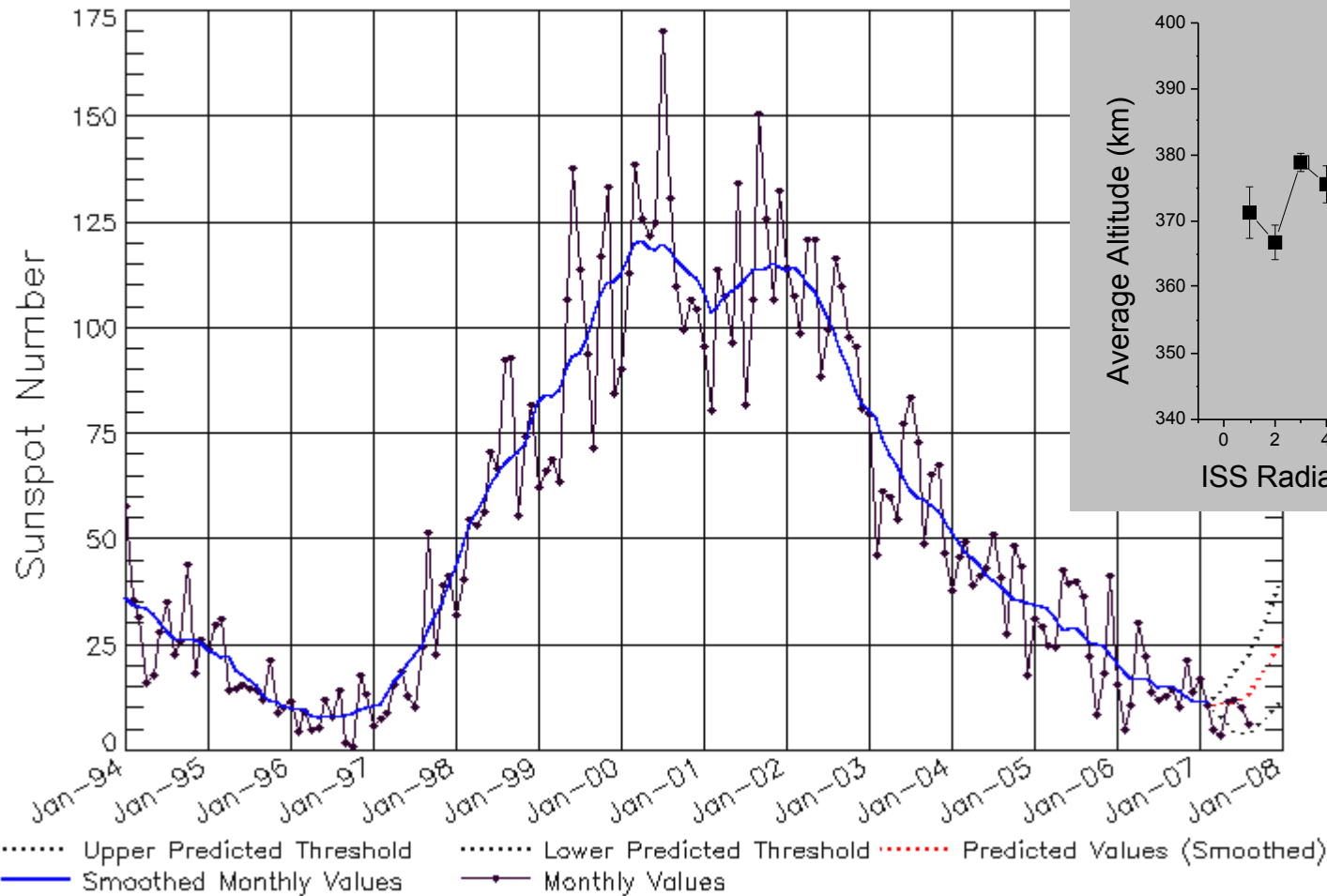
Standard Deviation

- Node1: 10-20 %
- SM: 20-50 %
- US LAB: 25-50 %
- Airlock: 5-15 %



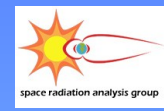
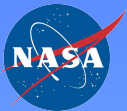
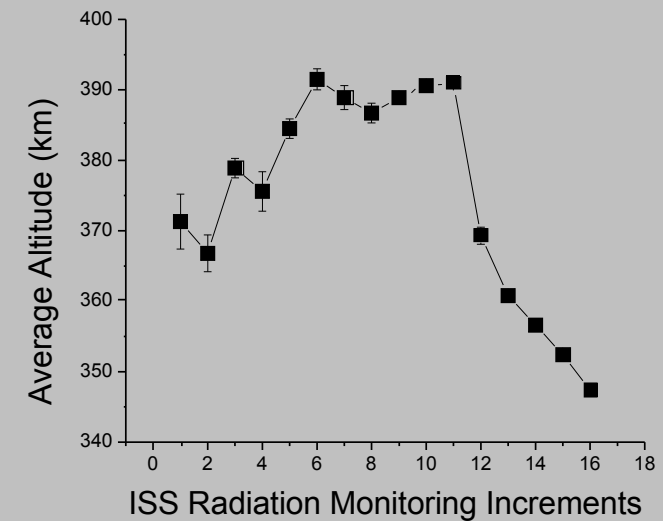
Solar Cycle Progression and Altitude Profile

ISES Solar Cycle Sunspot Number Progression
Data Through 31 Aug 07



Updated 2007 Sep 5

NOAA/SEC Boulder, CO USA



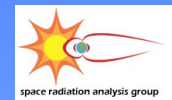
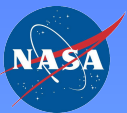
Current SRAG Operational Passive Radiation Measurements

Personal Radiation Monitoring

- each crew member carries a radiation detector for the whole duration of the mission
- TLDs: LiF:Mg,Ti , $\text{CaF}_2\text{:Tm}$
- OSLD: $\text{Al}_2\text{O}_3\text{:C}$ (Luxel)
- PNTD: CR-39

Area Radiation Monitoring

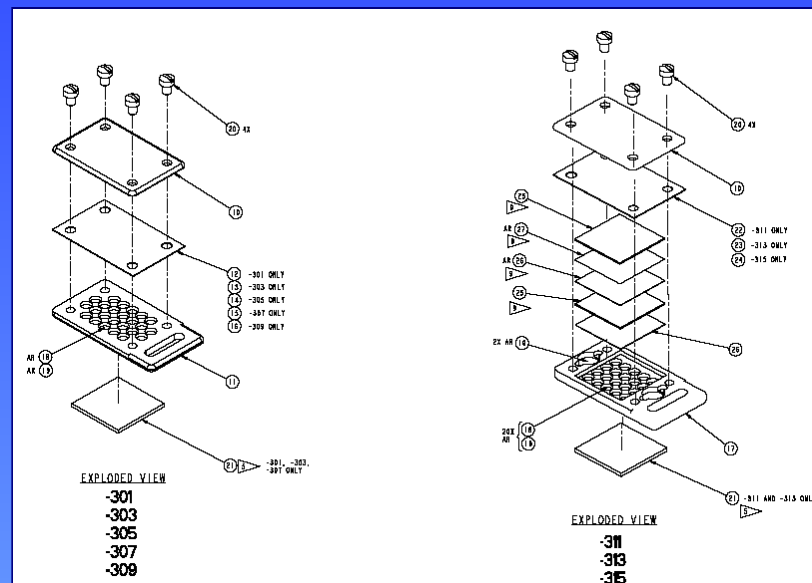
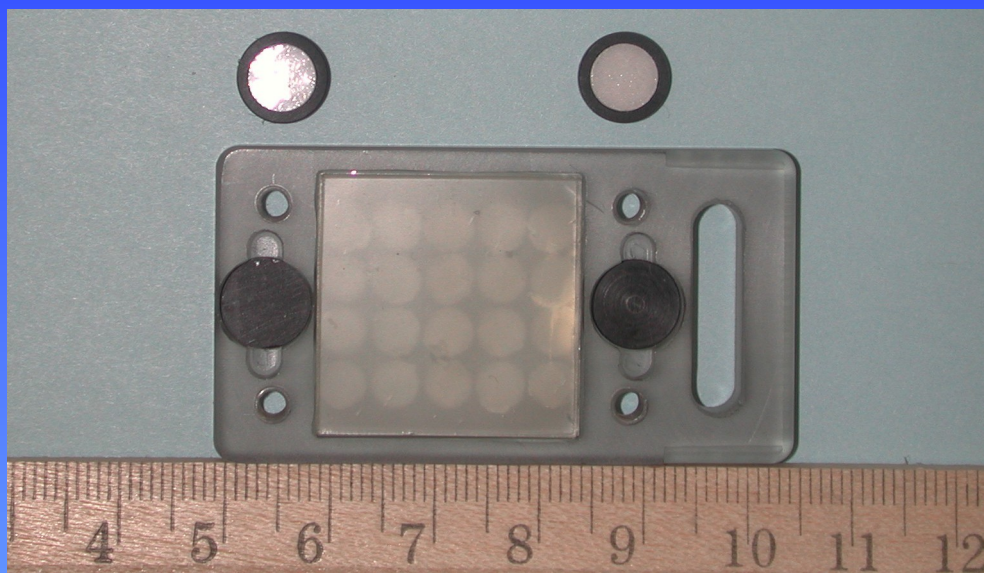
- Passive Radiation Dosimeters (PRDs) to monitor the radiation environment inside the Shuttle (6 locations)
- Radiation Area Monitors (RAMs) to monitor the radiation environment inside ISS (18 locations)



NASA-SRAG Passive Radiation Detector

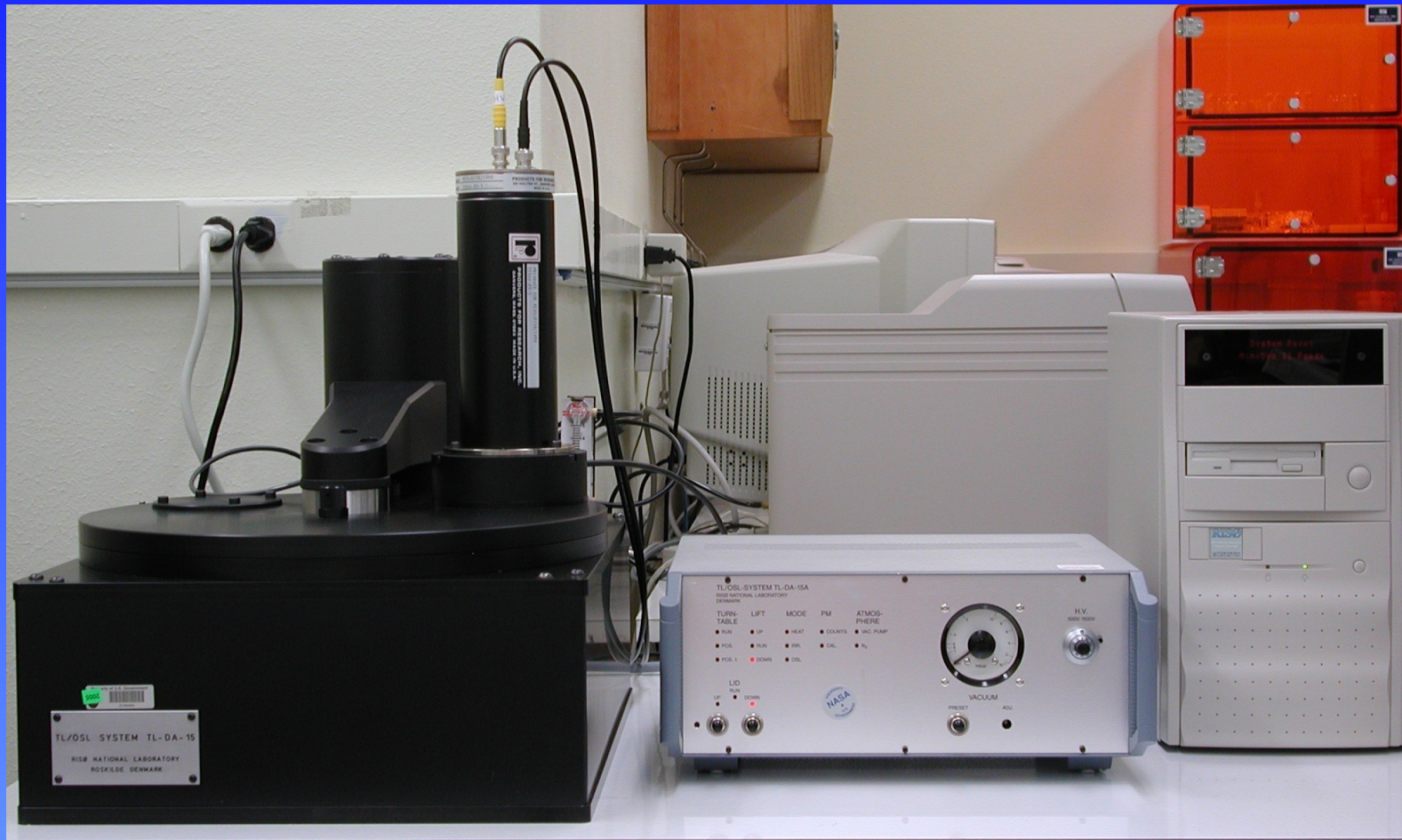


- Crew Passive Dosimeters (CPDs)
- Radiation Area Monitors (RAMs)
- Passive Radiation Dosimeters (PRDs)
 - TLD-100 (8 detectors)
 - TLD-300 (6 detectors)
 - TLD-600 (2 detectors)
 - TLD-700 (2 detectors)
 - OSLD/Luxel (6 detectors)
 - CR-39 (2 detectors)



NASA-SRAG Radiation Detection Lab Equipment

Risø TL/OSL-DA-15C/D Reader



NASA-SRAG Radiation Detection Lab Equipment

Two (semi-automatICAL and manual) Optical
Microscopes



NASA-SRAG Radiation Detection Lab Equipment

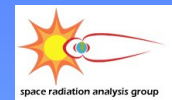
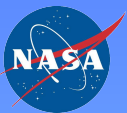
Two Harshaw 5500 TL Readers



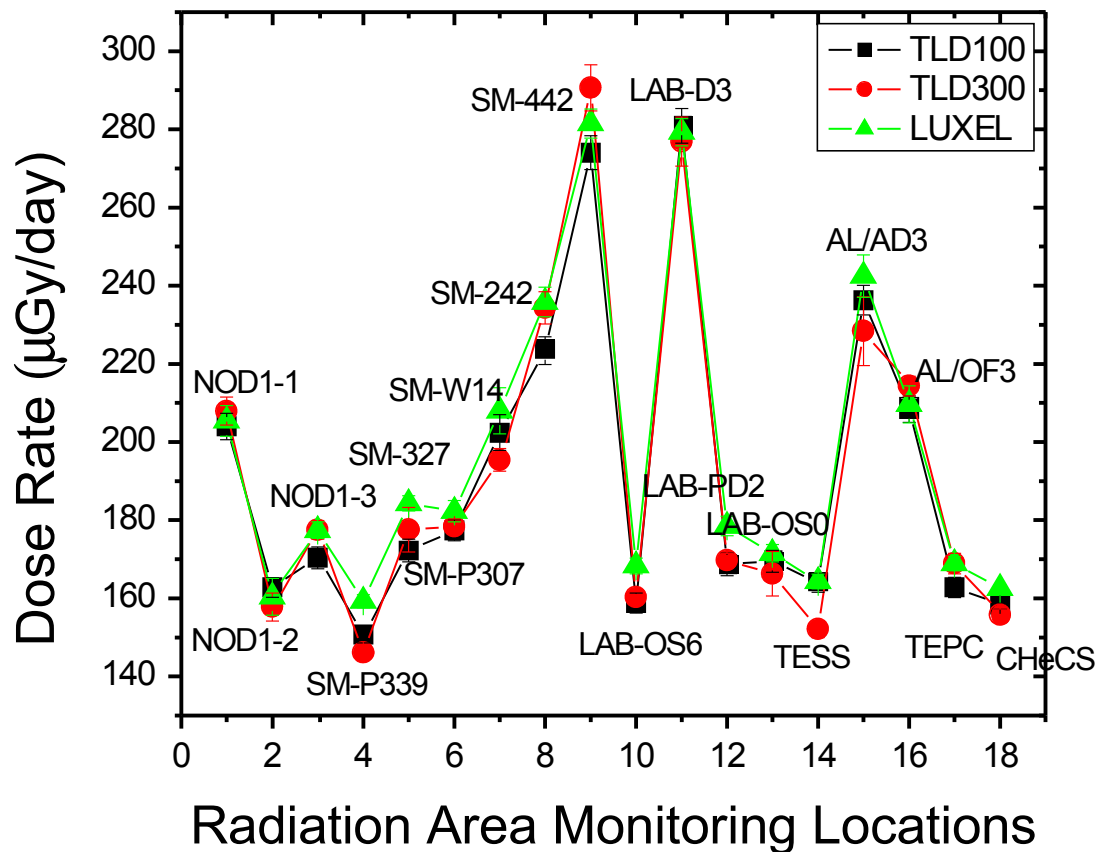
ISS Expedition 13/12S Missions Parameters

Mission Delivery to ISS: 12S (Soyuz TMA-8)	Date: 03/29/06	Average Orbit Altitude (km): 349.3
Mission Return from ISS: 12S (Soyuz TMA-8)	Date: 09/28/06	Inclination (deg): 51.6
Expedition Duration (d): 182 days 23 hours 44 minutes		

- 18 RAM locations
- TLD/OSL/CR-39 included
- CHeCS RAM at location for 86 days



Results: Dose rate for ISS RAM locations



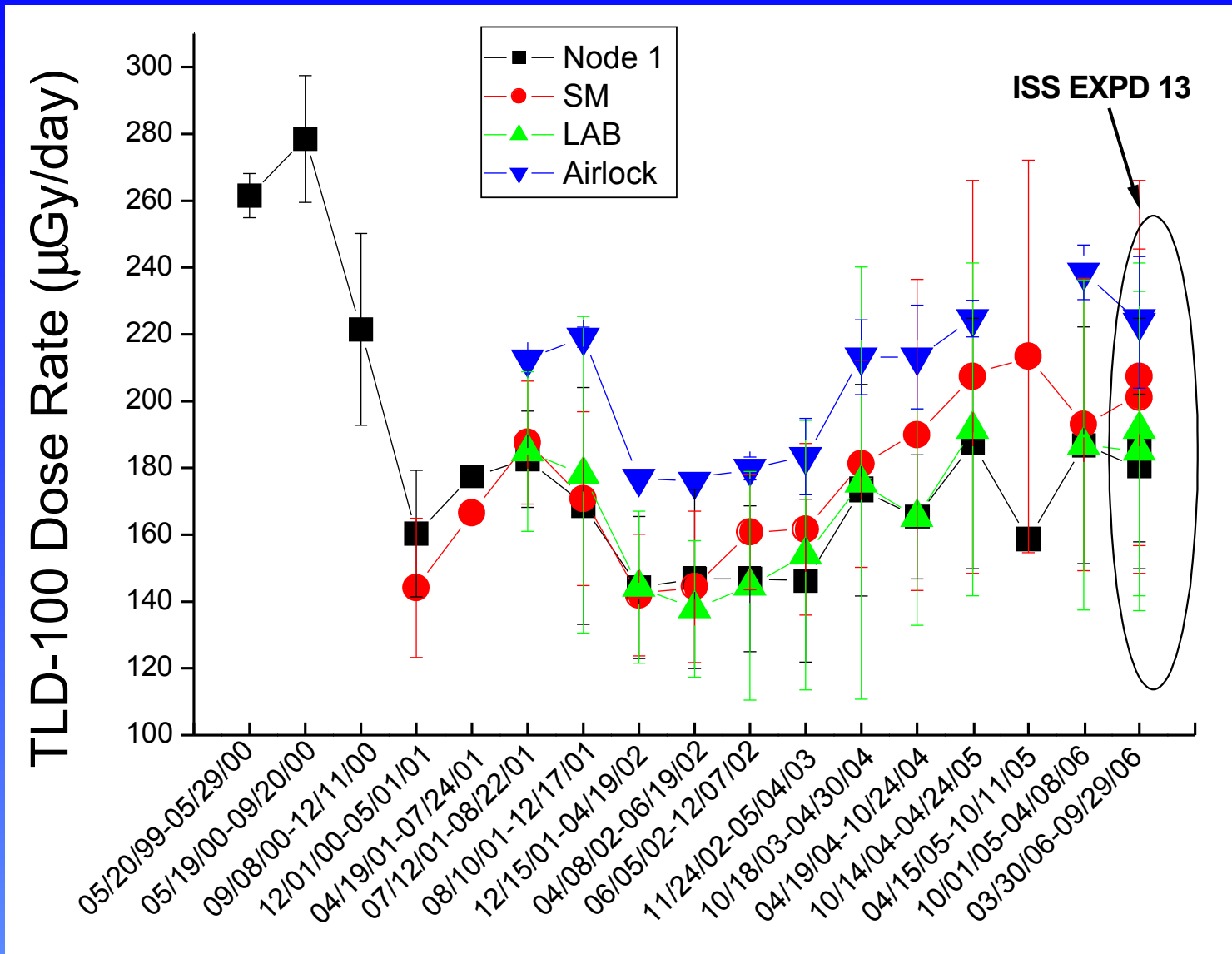
Highest:

- SM-P442 – sleeping crew quarters
- LAB-D3 – window

Lowest

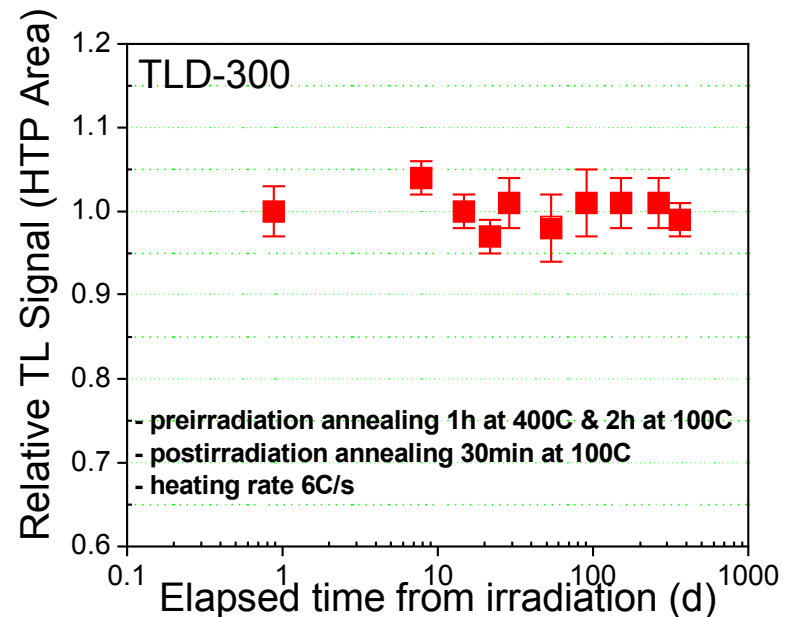
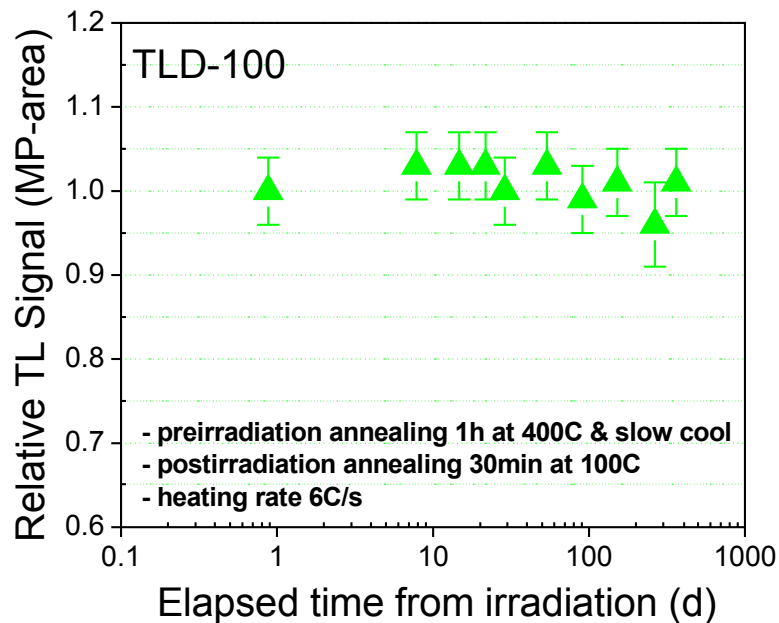
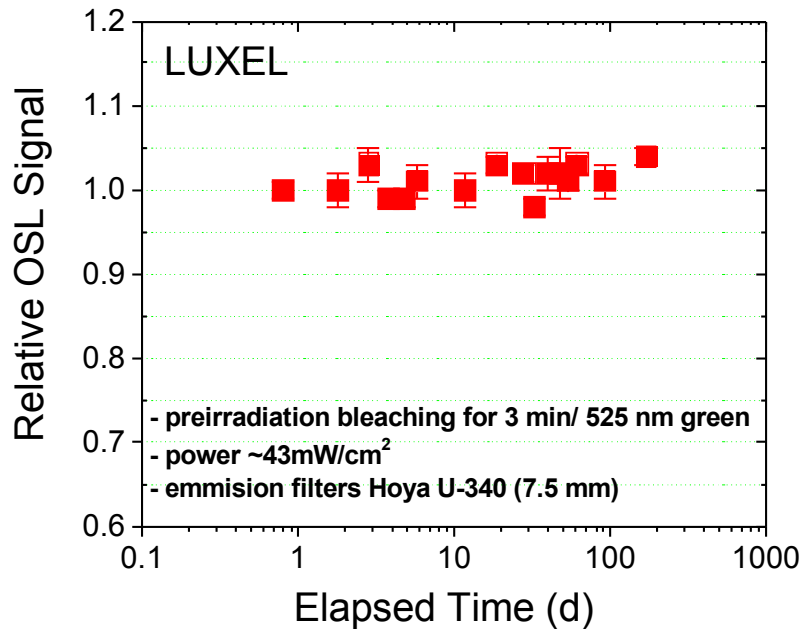
- TESS – US sleeping station
- TEPC – RAM at TEPC location
- CheCS – pharmaceuticals rack

Operational passive dosimetry at SRAG:ISS



Fading properties

- TLD-100 (363 days)
- TLD-300 (363 days)
- Luxel (168 days)



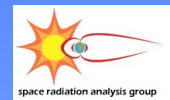
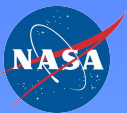
Dose Equivalent and Quality Factor Calculated with the TLD/OSLD/CR-39 combination

$$H = \sum_i H_i = \sum_i D_i \times Q(L_i)$$

- NCRP 142, 2002 Recommendation 11, Equation 6.1:

$$H = Q D_{OSLD/TLD} + \int Q(L) D_{PNTD}(L) dL$$

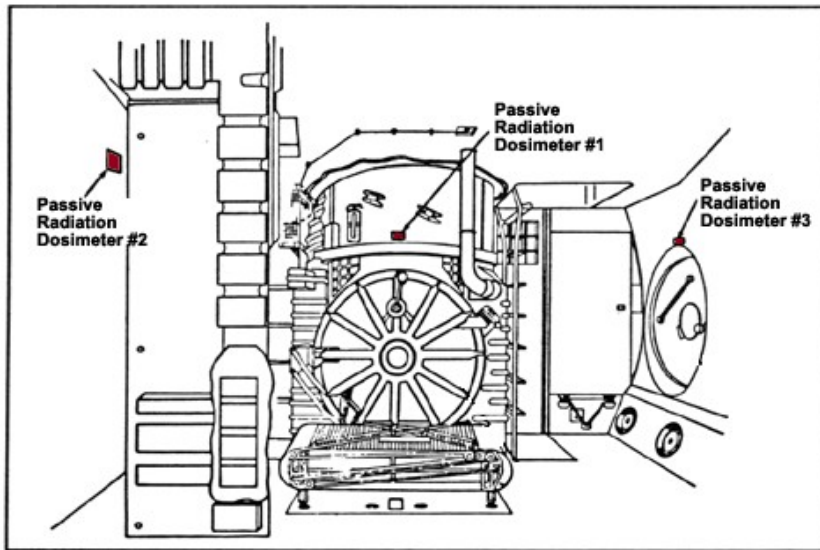
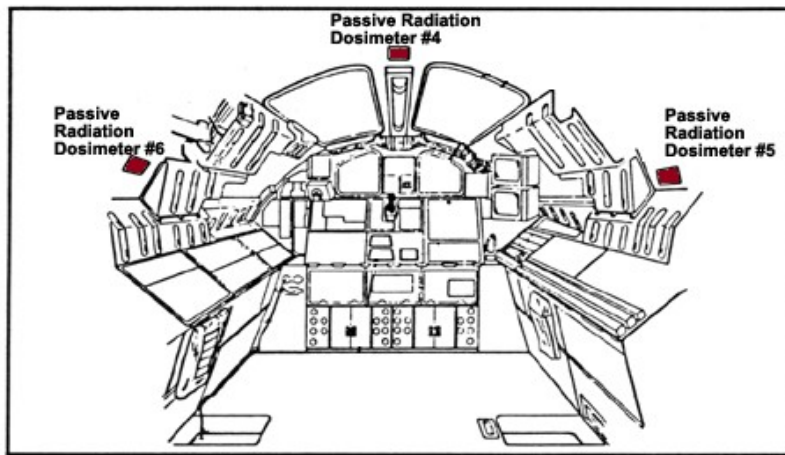
$$Q = \frac{H_{total}}{D_{total}} = \frac{H_{LET < 10 \text{ keV}/\mu\text{m}}^{OSLD/TLD} + H_{LET > 10 \text{ keV}/\mu\text{m}}^{CR-39}}{D^{OSLD/TLD} + (1 - \varepsilon_{ave}) D_{LET > 10 \text{ keV}/\mu\text{m}}^{CR-39}}$$



Dose equivalent for ISS RAM locations

Detector Location	Detector Type	TL/OSL Measured Dose (mGy)	Dose Low-LET (<10 keV/ μm water) Q=1 (mGy)	Dose CR-39 High-LET (>10 keV/ μm water) Q>11 (mGy)	Total Dose (mGy)	Dose Equivalent (mSv)	Quality Factor
SM-P442/ Inside Starboard SM Crew Quarters	TLD-100	50.14 ± 0.79	45.02	8.70 ± 0.88	53.72 ± 1.19	147.00 ± 10.39	2.74
	TLD-300	53.17 ± 1.08	46.50		55.20 ± 1.41	148.49 ± 10.41	2.69
	LUXEL	51.51 ± 0.68	46.52		55.22 ± 1.13	148.51 ± 10.38	2.69
TESS/ Inside the Polyethylene lined Sleep Station	TLD-100	30.00 ± 0.44	27.06	5.57 ± 0.41	32.63 ± 0.57	92.48 ± 4.83	2.83
	TLD-300	27.84 ± 0.38	23.59		29.16 ± 0.57	89.01 ± 4.83	3.05
	LUXEL	30.06 ± 0.35	26.95		32.51 ± 0.57	92.37 ± 4.83	2.84
TEPC/ Attached to TEPC detector	TLD-100	29.79 ± 0.47	26.55	5.62 ± 0.30	32.17 ± 0.58	92.79 ± 3.56	2.88
	TLD-300	30.92 ± 0.48	26.67		32.29 ± 0.58	92.90 ± 3.56	2.88
	Luxel	30.92 ± 0.33	27.74		33.36 ± 0.42	93.97 ± 3.54	2.82

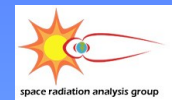
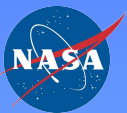
STS Passive Radiation Dosimeter (PRD) Locations



- Crew Passive Dosimeters (CPDs) – 6-7 crew members
- Passive Radiation Dosimeters (PRDs) – 6 locations

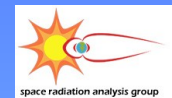
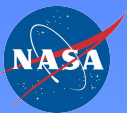
Recent Shuttle Radiation Measurements

Mission	Launch Date (GMT)	Landing Date (GMT)	Duration	Inclination	Total Crew	Intl Crew	EVAs #
STS-121	7/4/2006 18:38	7/17/2006 13:14	12d 18h 36min	51.6	7	1	3
STS-115	9/9/2006 15:14	9/21/2006 10:21	11d 19h 6min	51.6	6		3
STS-116	12/10/2006 1:47	12/22/200 6 22:32	12d 20h 45min	51.6	7	1	4
STS-117	6/8/2007 23:38	6/22/2007 19:49	13d 20h 10min	51.6	7		4

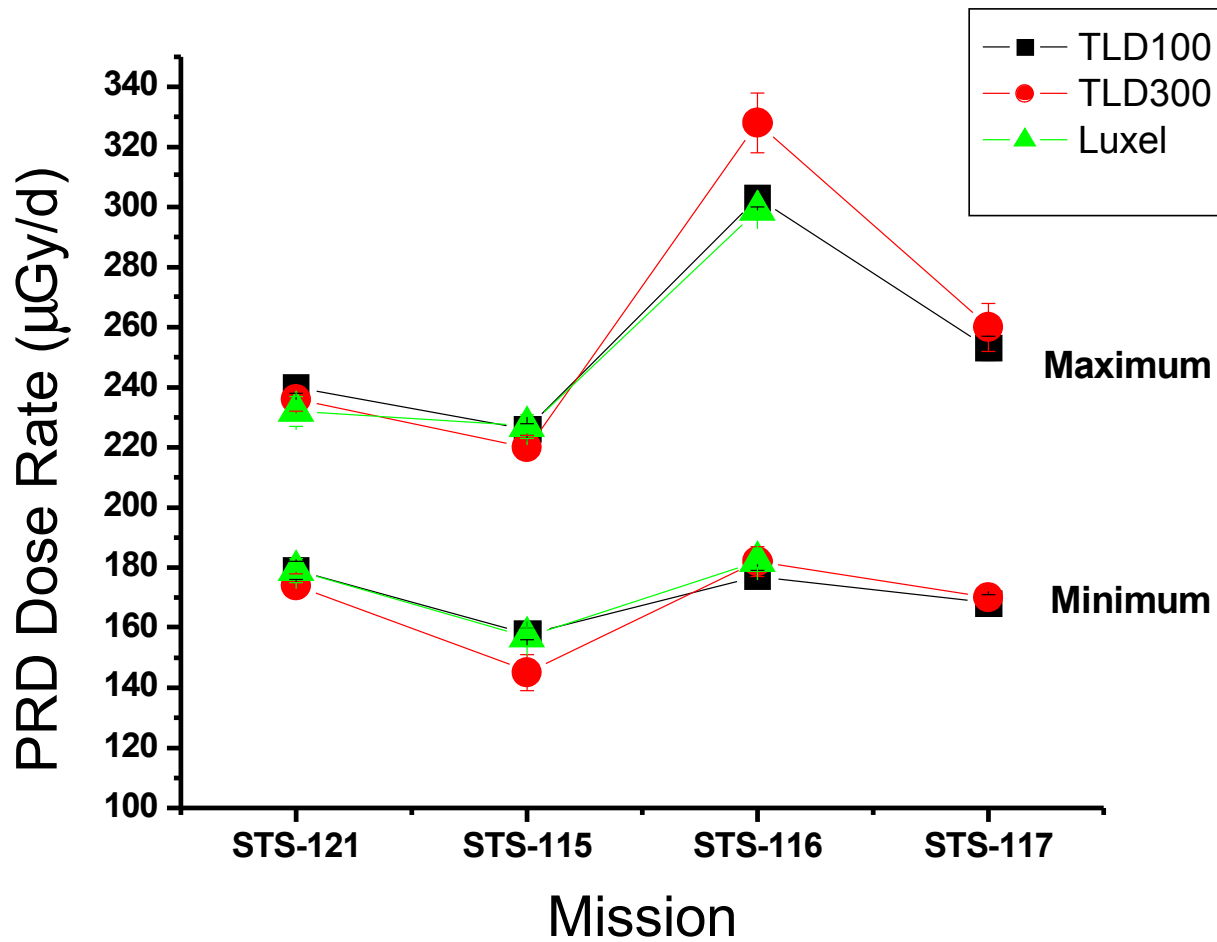


Recent Shuttle Radiation Measurements: Dose Rate ($\mu\text{Gy/d}$)

	Detector	PRD1	PRD2	PRD3	PRD4	PRD5	PRD6
STS-121	TLD-100	187 ± 2	240 ± 2	240 ± 4	179 ± 3	228 ± 3	205 ± 3
	TLD-300	186 ± 4	236 ± 4	230 ± 7	174 ± 4	236 ± 5	194 ± 6
	Luxel	179 ± 4	232 ± 5	216 ± 5	180 ± 4	211 ± 5	196 ± 4
STS-115	TLD-100	158 ± 2	174 ± 3	226 ± 2	184 ± 3	192 ± 2	187 ± 2
	TLD-300	145 ± 6	165 ± 5	220 ± 4	180 ± 4	188 ± 4	172 ± 3
	Luxel	157 ± 3	177 ± 4	227 ± 4	182 ± 4	187 ± 4	185 ± 4
STS-116	TLD-100	177 ± 2	294 ± 3	303 ± 3	191 ± 2	252 ± 3	220 ± 2
	TLD-300	182 ± 5	313 ± 8	328 ± 10	191 ± 5	284 ± 9	234 ± 6
	Luxel	182 ± 2	295 ± 4	299 ± 2	192 ± 2	258 ± 4	222 ± 2
STS-117	TLD-100	168 ± 3	253 ± 4	251 ± 4	183 ± 4	195 ± 5	193 ± 4
	TLD-300	170 ± 3	254 ± 6	260 ± 8	184 ± 4	203 ± 4	194 ± 4
	Luxel	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed



Shuttle Maximum and Minimum Dose Rates

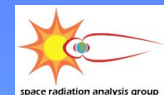
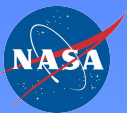
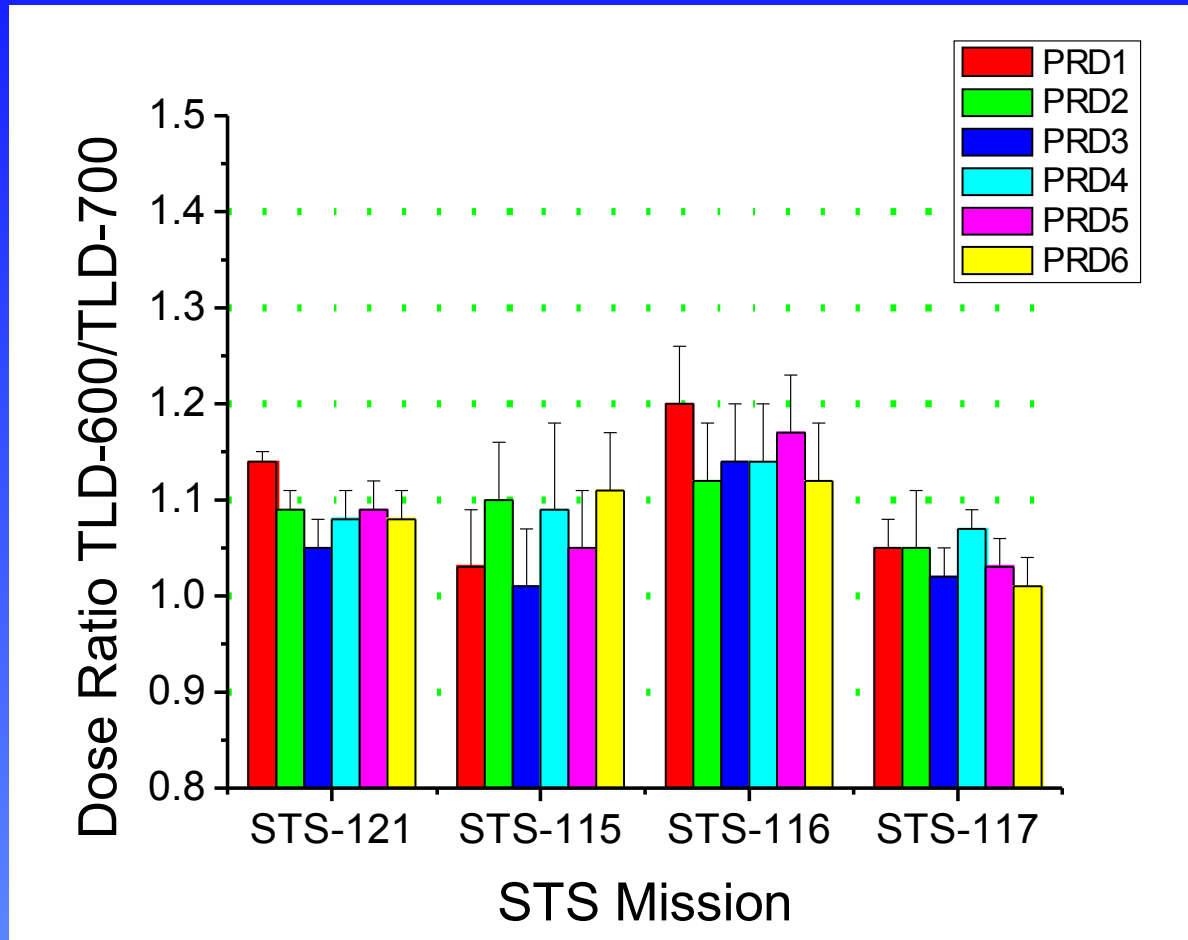


Dose equivalent for STS-116 and STS-121

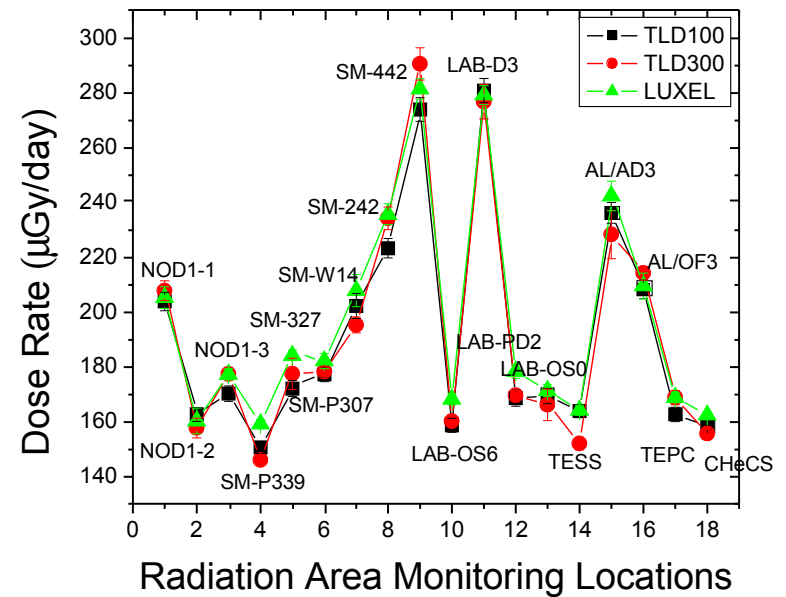
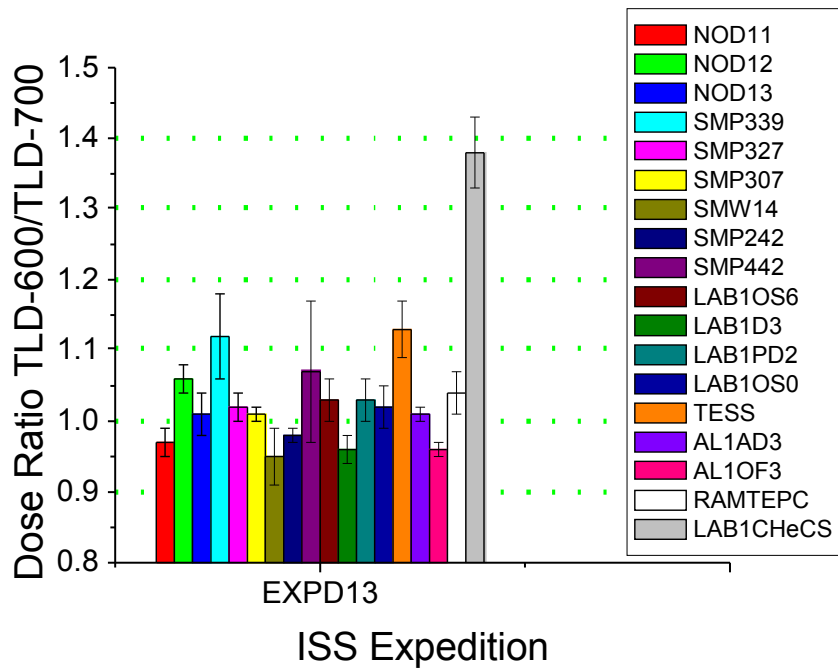
STS-116 Detector Location	Detector	TL/OSL Dose All LET (mGy)	Dose LowLET Q=1 (mGy)	Dose CR-39 High LET Q>10 (mGy)	Total Dose All LET (mGy)	Total Dose Equi. All LET (ICRP 60) (mSv)	Q All LET
PRD-1	TLD-100	2.28 ± 0.03	2.06	0.37 ± 0.04	2.43 ± 0.05	6.41 ± 0.48	2.64
	TLD-300	2.34 ± 0.06	2.06		2.43 ± 0.07	6.41 ± 0.48	2.64
	Luxel	2.34 ± 0.02	2.13		2.50 ± 0.04	6.48 ± 0.48	2.59
PRD-2	TLD-100	3.79 ± 0.04	3.47	0.54 ± 0.04	4.01 ± 0.06	9.51 ± 0.48	2.37
	TLD-300	4.03 ± 0.10	3.61		4.15 ± 0.11	9.65 ± 0.49	2.32
	Luxel	3.80 ± 0.05	3.49		4.04 ± 0.06	9.53 ± 0.48	2.36

STS-121 Detector Location	Detector	TL/OSL Dose All LET (mGy)	Dose LowLET Q=1 (mGy)	Dose CR-39 High LET Q>10 (mGy)	Total Dose All LET (mGy)	Total Dose Equi. All LET (ICRP 60) (mSv)	Q All LET
PRD-1	TLD-100	2.39 ± 0.03	2.18	0.36 ± 0.04	2.54 ± 0.05	6.44 ± 0.47	2.53
	TLD-300	2.38 ± 0.05	2.10		2.47 ± 0.06	6.37 ± 0.47	2.58
	Luxel	2.29 ± 0.05	2.08		2.45 ± 0.06	6.35 ± 0.47	2.59
PRD-2	TLD-100	3.07 ± 0.03	2.79	0.49 ± 0.06	3.28 ± 0.07	8.53 ± 0.68	2.60
	TLD-300	3.01 ± 0.05	2.64		3.13 ± 0.08	8.38 ± 0.68	2.68
	Luxel	2.97 ± 0.06	2.70		3.19 ± 0.08	8.44 ± 0.68	2.65

Qualitative Neutron Contribution: Dose ratio TLD-600/TLD-700



Qualitative Neutron Contribution: Dose ratio TLD-600/TLD-700



Future Work

- Addition of extra ISS RAM detectors at several locations inside the Node 2, European Columbus Module and Kibo Japanese Experimental Module
- Investigate the feasibility of using Blue OSL stimulation of the Al_2O_3 detectors which can lead to shorter post-flight measurement times
- Continue to evaluate the efficiency of the current SRAG's Passive Radiation Detector package and chose the best configuration for the passive radiation monitoring of the next generation space vehicles
- Continue to be part of international collaborations such as Matroshka, Icchiban, etc.