18th Workshop on Radiation Monitoring for the International Space Station

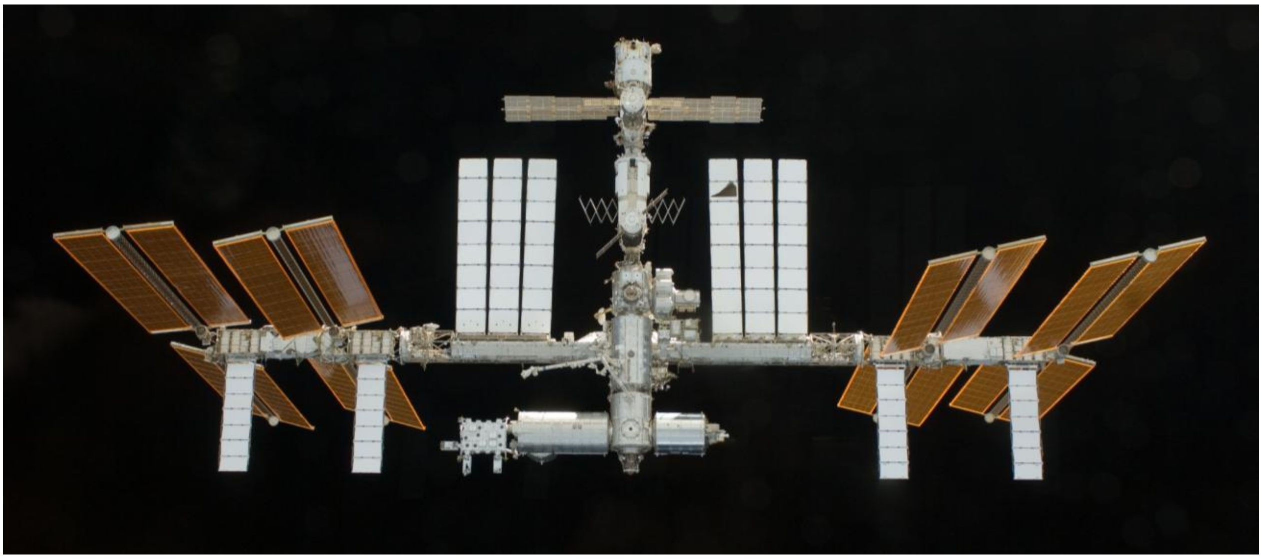
3-5 September 2013, Hotel Novotel Budapest Danube, Budapest, Hungary

The 18th WRMISS is organized by the
Hungarian Academy of Sciences Centre for Energy Research (MTA EK)
and hosted by Hotel Novotel Budapest Danube.

Chairman: **Guenther Reitz, DLR**

Organizing Committee: **Attila Hirn, MTA EK**
Tamás Pázmándi, MTA EK
Péter Szántó, MTA EK

18th Workshop on Radiation Monitoring for the International Space Station



Final Program

Issue: 30th August 2013

Tuesday 3rd Sept

08:00 - 08:45	Registration
08:45 - 09:15	Welcome
09:15 – 10:00	Introductory Talk
10:00 – 11:00	Coffee/Tea Break
11:00 – 12:30	Scientific Session 1
12:30 – 14:00	Lunch
14:00 – 15:30	Scientific Session 2
15:30 – 16:30	Coffee/Tea Break
16:30 – 18:00	Scientific Session 3

Guenther Reitz / (TBD)	Welcome
Attila Hirn	Organizational Issues
Introductory Talk	
Francis Badavi	Evaluation of the new trapped proton model AP9 at ISS Attitudes
Scientific Session 1	
Daniel Matthiä	Calculation of Radiation Exposure Levels in Low Earth Orbit and Beyond
Francis Badavi	Estimates of Cosmic Rays Directional Dose for ISS – Part-II
Ondrej Ploc	Estimation of the dominant ion composition in space using the shape of the deposited energy spectra of Liulin type instruments and PHITS simulations
Scientific Session 2	
Hisashi Kitamura	Status Report of the ICCHIBAN projects
Eric Benton	Ground-based Testing of Bubble Detectors
Satoshi Kodaira	Long-term dose variations in the ISS Piers-module measured by passive dosimeters
Scientific Session 3	
Ramona Gaza	ISS Radiation Area Monitors Measurements at Solar Maximum
Joe Pálfalvi	Passive dosimetry in the PIRS module: 2010-2013
Péter Szántó	Pille Measurements on ISS

Note: Presentation time shall not exceed 30 minutes

Wednesday 4th Sept

08:45 - 10:15	Scientific Session 4
10:15 - 11:15	Coffee/Tea Break
11:15 - 12:45	Scientific Session 5
12:45 - 14:15	Lunch
14:15 - 15:45	Scientific Session 6
15:45 - 16:45	Coffee/Tea Break
16:30 - 18:15	Scientific Session 7
19:00	Workshop dinner (optional, self-paid)

Scientific Session 4	
Tsvetan Dachev	Radiation exposure on BION-M No 1 satellite - First results
Victor Benghin	Results Of The Radiation Monitoring System Measurements On Service Module Of ISS During 2009 -2013
Thomas Berger	The DOSIS and DOSIS-3D experiments: Long term dose monitoring on board the European Columbus module of the International Space Station (ISS)
Scientific Session 5	
Soenke Burmeister	The Dosis And Dosis 3d Experiments Onboard The International Space Station – Results From The Active Dostel Instruments
Attilla Hirn	TRITEL measurements on board the International Space Station
Livio Narici	ALTEA: 2012 radiation measurements in the ISS
Scientific Session 6	
Christer Fuglesang	Relative nuclear abundances LET and dose rates at various locations and configurations in ISS from the ALTCRISS experiment.
Lawrence Pinsky	Update on the Status of the Medipix-Based Radiation Environment on the ISS
Balázs Zábori	BEXUS TECHDOSE stratospheric cosmic radiation experiment
Scientific Session 7	
Tsvetan Dachev	Altitudinal distribution of the Ionizing Radiation Exposure between the Earth Surface and Free Space
Brent Ehresmann	Charged Particle Measurements during Cruise and on Mars with the Radiation Assessment Detector (MSL/RAD).
Cary Zeitlin	Refinement of MSL-RAD Dose Rate Measurements in Cruise and on the Martian Surface

Note: Presentation time shall not exceed 30 minutes

Thursday 5th Sept

08:45 - 10:15	Scientific Session 8
10:15 - 11:15	Coffee/Tea Break
11:15 - 12:45	Scientific Session 9
12:45 - 14:15	Lunch
14:15 - 15:45	Scientific Session 10
15:45 - 16:45	Coffee/Tea Break
16:30 - 18:15	Scientific Session 11 (with conclusion and adjourn)

Scientific Session 8	
Raisa Tolochek	The Results of 4 Sessions of Experimental Study of Local Water Shielding Efficiency to Space Radiation with the Protective Curtain in ISS Crew Cabin
Martin Smith	Neutron Measurements using Bubble Detectors during the ISS-22 to ISS-36 Expeditions
Aiko Nagamatsu	Space radiation dosimetry for the Matroshka-R #1 Experiment onboard the KIBO using PADLES from May - Sep. 2012 (Increment 31/32)
Scientific Session 9	
Slava Shurshakov	Results from MATROSHKA 1 using the HPA dosemeter New Results on Dose Distribution in a Human Body in ISS Compartments Obtained with the Tissue-Equivalent Spherical Phantom
Tsvetan Dachev	Radiation Environment on ISS in 2012- April 2013 According the Data from Liulin-5 Particle Telescope
M. Fragopoulou	The response of a depleted p-MOSFET dosemeter to photons and electrons
Scientific Session 10	
Thomas Berger	The European Crew Personal Active Dosimeter (EuCPAD)
Ryan Rios	Status of the ISS Radiation Assessment Detector
Cary Zeitlin	ISS-RAD Calibration Campaign
Scientific Session 11	
Sunghwan Kim	Overview of Tissue Equivalent Proportional Counter for high LET Radiation Monitoring in Complex Radiation Field
Sándor Deme	The LINTEL, a system for estimating the effective dose of the space stations' crew
Conclusion/Adjourn	All

Note: Presentation time shall not exceed 30 minutes

Venue

The 18th WRMISS is hosted by Hotel Novotel Budapest Danube. This 4-star hotel on the Buda side, between Margaret and Chain Bridge, overlooks the Danube and the Parliament. Free Internet access (ADSL, Wi-Fi) is available throughout the hotel. Hotel is fully accessible for guests with limited mobility.

Address:
Bem Rakpart 33-34
1027 Budapest
HUNGARY

The Workshop Dinner

The workshop dinner is organized at
Mátyás Pince Restaurant.
Address: Március 15. tér 7.

Directions:

See the map on the next page (the red circles denote the metro stations).

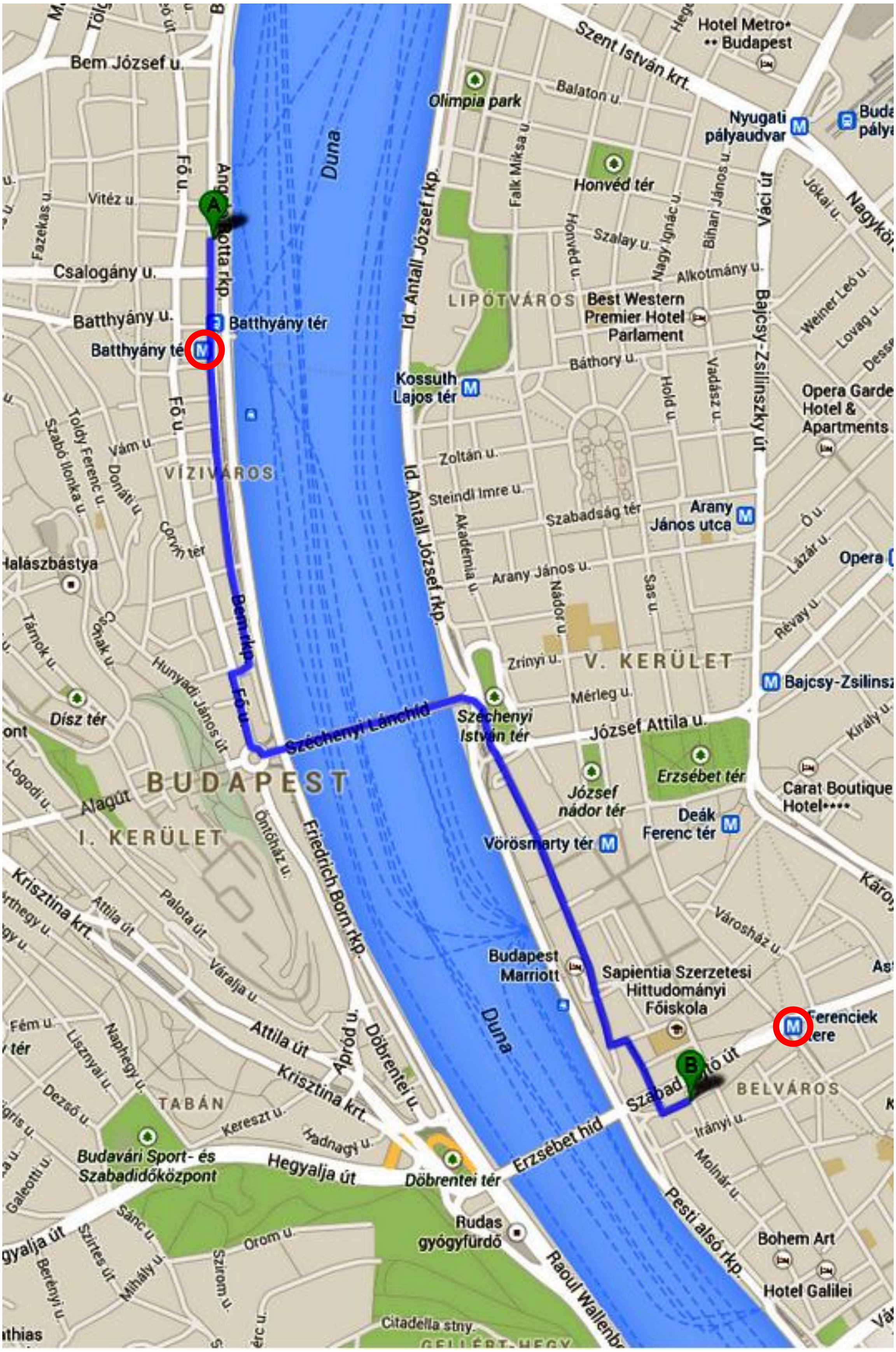
By public transport:
Metro line 2: Batthyány tér → Deák Ferenc tér (two stops)
Metro line 3: Deák Ferenc tér → Ferenciek tere (one stop)

On foot:
30-35 minute walk from the hotel (2.7 km).

Emergency Phone

+36 30 938 5026

This number is available from Sept 1st 8:00 to Sept 5th 20:00.



http://goo.gl/maps/kIOYi

Evaluation of the new trapped proton model AP9 at ISS attitudes

F. Badavi

Traditionally, the radiation exposure estimates for the semiconductor/tissue based components are computed using NASA trapped radiation models AP8/AE8 to obtain estimates of trapped proton and electron populations. These models were developed in the 1970s and 1980s and provide sufficient information for the shield design of a spacecraft. There are however well-known limitations on the validity of AP8/AE8 and over the past few years, in the space radiation community, a broad consensus has been building that the trapped environment as quantified by AP8/AE8 requires a more accurate, comprehensive and up-to-date standards. This is due to the fact that modern design and systems engineering techniques require models with finite time duration probability distributions, error bars, inclusion of a broader energy range (i.e., hot plasma and energetic protons) and a more complete spatial coverage as increasingly complex technologies are flown into the trapped regions (LEO, MEO and GEO) with consideration for missions in non-traditional orbit regimes. To meet the design criteria of future satellites, Aerospace Corporation, Los Alamos National Laboratory (LANL), National Reconnaissance Office (NRO) and Air Force Research Laboratory (AFRL), embarked on a project to produce the next generation trapped radiation belt model, namely the AP9/AE9. This model upgrade offers improvements in terms of specified radiation hazards, spectral and spatial coverage definition, time correlated probability of occurrence definition and statistics accuracy and uncertainty quantification. In this presentation only the proton component (AP9) of the new trapped environment at ISS attitudes will be considered. After an introduction to AP9, comparison between AP8 and AP9 for specific locations onboard ISS will be presented and differences between the two models will be discussed.

Calculation of Radiation Exposure Levels in Low Earth Orbit and Beyond

D. Matthiä, A. I. Mrigakshi, T. Berger, G. Reitz

The radiation exposure in space can be estimated with numerical simulations applying different models for the galactic cosmic rays (GCR) and trapped particles irradiating a defined shielding geometry. A comparison of commonly used GCR models, Badhwar-O'Neill2010, Burger-Usoskin, CREME2009/CREME96, was presented during the 17th WRMISS in 2012 together with the newly developed DLR model. The models were evaluated by comparing spectra of light and heavy nuclei with measurements from various high-altitude balloon and space missions. The differences arising in the calculated radiation exposure by applying these models were quantified in terms of absorbed dose and dose equivalent rates using the GEANT4 Monte-Carlo framework. We expanded this comparison by including the recently released Badhwar-O'Neill 2011 model. The differences in the spectra described by the models result in considerable differences in the estimation of the radiation exposure. The application of the Badhwar-O'Neill 2011 model leads to significantly increased dose rates compared to the previous Badhwar-O'Neill 2010 model, especially during the maximum GCR intensity in 2009.

Results from the Monte-Carlo simulations of the radiation exposure in low Earth orbit and interplanetary space are presented for different time periods and the contribution of different particle types is investigated. The cumulative shielding distribution of the European COLUMBUS module presented at the 17th WRMISS was implemented and used for the calculation of dose rates. The results are compared to different measurements as, for example, the DOSIS/DOSIS 3D experiment. Additionally, the impact of different shielding and irradiation geometries is investigated.

Estimates of Cosmic Rays Directional Dose for ISS – Part-II

F. Badavi

The International Space Station (ISS) provides the proving ground for future long duration human activities in space. Radiation measurements at Low Earth Orbit (LEO) in general, and at ISS in particular, form an appropriate tool for the experimental validation of radiation environmental models and nuclear transport code algorithms. Within the framework of an environment code named GEORAD (GEOmagnetic RADiation), this presentation describes the directional capabilities of GEORAD as applied to the interaction of Galactic Cosmic Rays (GCR) with the geomagnetic field at LEO. The described model is a component of GEORAD which computes directional cutoff rigidity and the corresponding transmission coefficient, both of which are used as input into a deterministic particle transport algorithm for exposure estimation within ISS. The GEORAD capability to compute directional cutoff rigidity and transmission coefficient provides a useful tool to validate GCR exposure measurements by solid state particle telescopes which inherently have directional sensitivity. The presentation concentration is on the directional characteristics of GCR ions at LEO and at quiet solar periods. The presentation is a follow up to a talk given at the 2012 WRMISS-17 meeting which took place in Austin, Texas USA. The presentation provides new simulation results, addresses and answers specific questions that were brought up in the 2012 Austin meeting.

Estimation of the dominant ion composition in space using the shape of the deposited energy spectra of Liulin type instruments and PHITS simulations

T.P. Dachev[1], **O. Ploc[2],** L. Sihver[3,4,5,6,7,8]

[1] *Space Research and Technology Institute, Bulgarian Academy of Sciences, Bulgaria*
[2] *Nuclear Physics Institute, Czech Academy of Sciences, Czech Republic*
[3] *Chalmers University of Technology, Sweden*
[4] *University of Houston, USA*
[5] *Texas A&M University, USA*
[6] *Roanoke College, USA*
[7] *Medical College of Soochow University, Suzhou, China*
[8] *East Carolina University, North Carolina, USA*

A comprehensive study of the shape of the deposited energy spectra obtained by Liulin type spectrometers on spacecraft since 2001 was used to characterize the predominant ion composition, their dose rate and energy spectra in the near Earth radiation environment. In the silicon diode of the Liulin, the galactic cosmic rays (GCRs) generate quasi-linear-falling-shape spectra expressed as absorbed dose distribution per deposited energy. The spectra are characteristic with 2 maxima at 0.5-0.9 MeV and 7-9 MeV of deposited energy. This form of the spectra can be interpreted as superposition of 2 single maximums originating from protons, neutrons, alpha particles and heavier ions. Two similar maxima in the deposited energy spectra were observed inside the inner radiation belt and when passing over the South Atlantic Anomaly (SAA) region. Simulations with the Particle and Heavy Ion Transport code System (PHITS) were used to test the assumption that the shape of the deposited energy spectrum can be used to characterize the dominant ion composition in space. Trapped proton and GCR input spectra were generated by the SPENVIS system using the AP8MIN/AP8MAX and ISO-15390 standard models, respectively, for both minimum and maximum solar conditions. The simulated spectra irradiated isotropically a model of the Liulin device located both inside and outside of an imaginary spacecraft with an effective shielding thickness of 5 g/cm^2 aluminum at an average orbit of the International Space Station.

Status Report of the ICCHIBAN projects

H. Kitamura, S. Kodaira., Y. Uchihori, N. Yasuda, E. Benton, T. Berger, M. Hajek, I. Ambrozova, O. Ploc

Since the 1st ICCHIBAN (Inter-Comparison for Cosmic-rays with Heavy Ion Beams At NIRS) experiment was kicked off in 2002, the ICCHIBAN Working Group (ICWG) has been promoting ground-based and spaceborne experiments using various accelerators and the International Space Station (ISS), respectively. After 2010, we had carried out the proton exposures, named as "Proton ICCHIBAN", for passive detectors such as TLDs, OSLDs and glass dosimeters, which have capability to measure low-LET particles. We carried out the experiments using proton beams with energies of 30, 40, and 70 MeV at the NIRS Cyclotron fasility. Now, we have parmetelized the cynclotron and the transport system for different energy beams: 50, 60, and 80 MeV for proton and 100 MeV ^{4}He. We are planning the next experiments using new beams.

In this presentation, we will show the current status and the future plan of ICCHIBAN experiments. Ground-based Testing of Bubble Detectors

R. Machrafi, **E. Benton**

As a part of ongoing effort to investigate the response of bubble detectors to charged particles, several experiments with bubble detectors were conducted with three different proton energies at Procure proton therapy facility, Oklahoma City, USA. A total of ten bubble detectors, with a similar sensitivity as the detector used aboard the ISS, has been irradiated with 78.2, 162 and 226 MeV energy protons in different configurations. The proton sensitivity has been obtained after exposing the detectors to proton fluences from 2 to 15.10^{7}p cm^{-2}. A bubble detector reader was used for automatic bubble counting. The proton sensitivity has been found to be in the order of 10^{-6} bubbles/p cm^{-2}. Two other irradiations were carried out, one with the detector partially covered with Al and another positioning the detectors behind polyethylene material of different depths. The number of bubbles seen in the covered portion of the detector represents only a small percentage of the number seen in the uncovered portion of the bubble detector. The ratio of the surface dose (on the surface of the polyethylene) to the dose at 17.5 cm depth is ~1.4, similar of what it has been seen in expedition ISS 15 and ISS 16.

Long-term dose variations in the ISS Piers-module measured by passive dosimeters

S. Kodaira, H. Kawashima, Y. Uchihori, H. Kitamura, M. Kurano, N. Yasuda, I. Kobayashi, A. Suzuki, Y. Koguchi, Y.A. Akatov, R.V. Tolochek, T.K. Krasheninnikova, A.D. Ukraintsev, E.A. Gureeva, V.N. Kuznetsov, and V.A. Shurshakov

The measurements of absorbed dose and dose equivalent during manned space missions on the International Space Station (ISS) in low earth orbit (LEO) are important for evaluating the risk to astronaut health and safety when exposed to space radiation. The dosimetric quantities are constantly changing and depend mainly on the level of solar activity and the various spacecraft- and orbit-dependent parameters such as the shielding distribution surrounding the detectors, location of the spacecraft within its orbit relative to the Earth, the attitude (orientation) and altitude. Consequently, continuous monitoring of dosimetric quantities is required to record and evaluate the personal radiation dose for crew members during spaceflight. The constant dose measurement through long-term duration at a fixed location would give a crucial data related with the changes of solar activity and other parameters.

We have measured the absorbed dose and dose equivalent rates using passive dosimeters at Piers-1 module on the ISS through 8 sessions with different durations between 2007 and 2012. The passive dosimeters consisted of a combination of luminescent detectors and CR-39 plastic nuclear track detectors. Each session period has been ranging from 0.5 to 5.5 yrs. In the typical case of less than 1 yr, CR-39 analysis has been carried out with high speed optical microscope system (HSP-1000). The longer exposure samples have been analyzed with atomic force microscope. The gradual and dynamical variations of LET spectra and dose rates were observed, which depend on the solar activity and the other ISS parameters. We present the long-term variations of space radiation environment inside ISS Piers-1 module between 2007 and 2012.

ISS Radiation Area Monitors Measurements at Solar Maximum

R. Gaza[1], A. Bahadori[2], D. Fry[2], K. Lee[2], E. Semones[2]

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A summary of the latest ISS Radiation Area Monitors (RAM) dosimetry results for inside-vehicle radiation monitoring in low Earth orbit at solar maximum conditions performed at the Space Radiation Dosimetry Laboratory will be presented. These solar maximum measurements were performed during 2012-2013 at
397 - 417 km altitude and will be compared with previous solar minimum RAM measurements (2009-2010) at 337-355 km altitude. The comparison results will be discussed in terms of the space radiation environment differences as well as the altitude variations.

The solar maximum RAM suite included two new ISS Tranquillity (Node 3) Module locations (NOD3FD5, NOD3OA2), and three new ISS Cupola Module locations (Cupola, Cupola_2, and Cupola_3). These new radiation monitoring locations were established to satisfy the NASA requirement for Area Radiation Monitoring inside the ISS per the International Space Station Flight Crew Integration Standard (SSP 50005 5.7.2.2.3 B).

In addition, updated TLD-100 results from the DOSIS-1, DOSIS-2 and DOSIS-3D (30S) and preliminary results from the DOSIS-3D (32S) will be presented. The ISS measurements for all of the DOSIS Projects were facilitated by the collaboration with the German Space Agency (DLR) and involved passive radiation measurements at 10 different shielding locations inside the ESA Columbus Module.

Passive dosimetry in the PIRS module: 2010-2013.

J.K. Pálfalvi [1], J. Szabó [1], V.A. Shurshakov [2], R. Tolochek [2], I. Ambrozova [3], S. Kodaira [4], T. Berger [5], M. Hajek[6]

[1] *HAS, Centre for Energy Research, Budapest, Hungary*
[2] *RAS, Institute of Biomedical Problems, Moscow, Russian Federation*
[3] *CRAS, Nuclear Physics Institute, Prague, Czech Republic*
[4] *National Institute of Radiological Sciences, Chiba, Japan*
[5] *German Aerospace Center, Cologne, Germany*
[6] *Atomic Institute of the Austrian Universities, Vienna, Austria*

Within the MATROSHKA-R space experiments and the BioTrack program the IBMP conducted passive dosimetry measurements in the PIRS module since 2005. Some results obtained between 2005 and 2009 have already been published [1]. In this presentation we outline the dose measurements made between 2010 and 2013 based on the data provided by the participants by the end of June, 2013.

The participants applied various themoluminescent and solid state nuclear track detectors, different measuring methods and evaluation systems. An effort has been made to highlight the deviations and agreements of the dose quantities obtained by the different participants and by the different systems. Also a trial has been made to analyze the effect of Sun activity, as well as, of the altitude of the ISS on the measured results.

[1] I. Ambrozova et al, Monitoring on board spacecraft by means of passive detectors. Rad. Prot. Dos. 44, 605-610, 2011.

Pille Measurements on ISS

P. Szántó[1], I. Apáthy[1], Yu. A. Akatov[2], V. V. Arkhangelsky[2], I. Nikolaev[3], S. Deme[1], T. Pázmándi[1]

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[2] *State Scientific Center, Institute for Biomedical Problems, Russian Academy of Sciences, Moscow, Russia*
[3] *Rocket Space Corporation Energia, Korolev, Moscow Region, Russia*

The Pille system was developed as the first and to date the only TLD system containing an on-board reader designed specifically for use by cosmonauts and astronauts while traveling in space. Since the first time it was launched in 1980, the Pille system worked on board each space station. It has been continuously used on board the International Space Station since October 2003 under the supervision of the Institute for Biomedical Problems (IBMP) as the service dosimeter system of the Russian Zvezda module. In the past nine years the dosimeter system was utilized for routine dose measurements inside the ISS, and as personal dosimeter system during Extra-vehicular Activities (EVAs).

With the system consisting of a lightweight reader device and a number of TL dosimeters, more than 35 000 read-outs were carried out until now. The Pille system provides monthly dose data from locations of the space station including Matroshka while two dosimeters are dedicated to EVA measurements, and one is read out in every 90 minutes automatically to provide high time resolution data.

Results to be presented: In the present paper the measurement data (including several EVA measurements) from the latest expeditions (Expeditions 31-32 and 33-34, April 2012 – May 2013) obtained by the Pille system is presented. The results are compared with previous measurement results.

Radiation exposure on BION-M No 1 satellite - First results

T.P. Dachev[1], B. Tomov[1], Yu. Matviichuk[1], Pl. Dimitrov[1], N. G. Bankov[1], V. Petrov[2], O.A. Ivanova[2], V. Shurshakov[2], V. Benghin[2], D.-P. Häder[3], M. Lebert[4], M. Schuster[4], G. Reitz[5], G. Horneck[5], O. Ploc[6]

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[2] *State Research Center Institute of Biomedical problems, Russian Academy of Science, Moscow, Russia*
[3] *Neue Str. 9, 91096 Möhrendorf, Germany*
[4] *Friedrich-Alexander-Universität, Institut für Botanik und Pharmazeutische Biologie, Erlangen, Germany*
[5] *DLR, Institute of Aerospace Medicine, Köln, Germany*
[6] *Nuclear Physics Institute, Czech Academy of Sciences, Praque, Czech Republic*

Space radiation has been monitored using the РДЗ-БЗ radiometer-dosimeter on board a recent space flight on the Russian recoverable satellite BION-M No 1. The instrument was mounted inside of the satellite pressurized volume together with biological objects and samples. РДЗ-БЗ instrument is a battery operated version of the spare model of the R3D-B3 instrument developed and built for the ESA BIOPAN-6 facility on Foton M3 satellite in September 2007. Cosmic ionizing radiation has been monitored and separated in 256 deposited energy spectra, which were further used for determination of the absorbed dose rate and flux. Basic data tables were prepared to be used by other BION-M No 1 experiments. The report summarizes the first results for the Earth radiation environment at the altitude (253–585 km) of the BION M No 1 spacecraft.

Results of the RADIATION MONITORING SYSTEM measurements on SERVICE MODULE OF ISS during 2009 -2013

V.V. Benghin[1], V.M. Petrov[1], Panasyuk[3], A.N. Volkov[2], I.V. Nikolaev[2], V.I. Lyagushin[2], O.Yu. Nechaev[3], A.E. Lichnevsky[3], S.G Drobishev[1]

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[2] *Rocket-space corporation "Energiya", Korolev, Russia,*
[3] *Skobeltsyn Institute of Nuclear Physics of Moscow State University Moscow, Russia*

The report presents the data on the radiation monitoring system (RMS) operating and results of dose rate measurements during the period from August 2009 to July 2013 in comparison with more early data. The data of the radiation environment variations onboard the International Space Station (ISS) measured with high-sensitivity dosimeter units DB-8 are analyzed. It was made separation of the ERB and GCR contributions to daily dose for time since 2006 until 2009 year. Very low level of solar activity was observed throughout this time, and no proton events occurred. It is shown that the variations of the mean daily dose rate during this period were caused by ERB variations because of height of the ISS flight variations. The GCR contributions to daily dose correlate well with neutron monitors count rate.

The DOSIS and DOSIS-3D experiments: Long term dose monitoring onboard the European Columbus module of the International Space Station (ISS)

T.Berger[1], S.Burmeister[2], J.Labrenz[2], P.Bilski[3], T.Horwacik[3], M.Hajek[4,5], C.Hofstätter[5], J.Palfalvi[6] ,I.Ambrozova[7], F.Vanhavere[8], R.Gaza[9], E.Yukihara[10], E.Benton[10], Y.Uchihori[11], S.Kodaira[11], H.Kitamura[11], V.Shurshakov[12], A.Nagamatsu[13], M.Boehme[14], G.Reitz[1]

[1] *DLR German Aerospace Center, Cologne, Germany*
[2] *CAU Christian Albrechts Universität zu Kiel, Kiel, Germany*
[3] *IFJ Institute of Nuclear Physics, Krakow, Poland*
[4] *IAEA International Atomic Energy Agency, Vienna, Austria*
[5] *ATI Technical University Vienna, Vienna, Austria*
[6] *CER-HAS Centre for Energy Research, Budapest, Hungary*
[7] *NPI Nuclear Physics Institute, Prague, Czech Republic*
[8] *SCK-CEN Belgian Nuclear Research Center, Mol, Belgium*
[9] *NASA Space Radiation Analysis Group - Houston, United States*
[10] *OSU Oklahoma State University, Stillwater, United States*
[11] *NIRS National Institute of Radiological Sciences, Chiba, Japan*
[12] *IMBP Russian Academy of Sciences, Moscow, Russia*
[13] *JAXA Japan Aerospace Exploration Agency, Tsukuba, Japan*
[14] *OHB System AG - Bremen, Germany*

The radiation environment encountered in space differs in nature from that on earth, consisting mostly of high energetic ions from protons up to iron, resulting in radiation levels far exceeding the ones present on earth for occupational radiation workers.

Accurate knowledge of the physical characteristics of the space radiation field in dependence on the solar activity, the orbital parameters and the different shielding configurations of the International Space Station ISS is therefore needed. For the investigation of the spatial and temporal distribution of the radiation field inside the European Columbus module the experiment DOSIS (Dose Distribution Inside the ISS), under the project and science lead of DLR, was launched on July 15th 2009 with STS-127 to the ISS. The DOSIS experiment consists of a combination of passive detector packages (PDP) distributed at 11 locations inside Columbus for the measurement of the spatial variation of the radiation field and two active radiation detectors (DOSTELs) with a DDPU (Data and Power Unit) in a dedicated nomex pouch (DOSIS MAIN BOX) mounted at a fixed location beneath the European Physiology Module rack (EPM) for the measurement of the temporal variation of the radiation field parameters. The DOSIS experiment suite measured during the lowest solar minimum conditions in the space age from July

2009 to June 2011. In July 2011 the active hardware was transferred to ground for refurbishment and preparation for the follow up DOSIS-3D experiment. The hardware for DOSIS-3D was launched with Soyuz 30S to the ISS on May 15th 2012. The PDPs are replaced with each even number Soyuz flight starting with Soyuz 30S. Data from the active detectors is transferred to ground via the EPM rack which is activated once a month for this action. The presentation will give an overview of the DOSIS and DOSIS 3D experiment and focus on the results from the passive radiation detectors from the DOSIS-3D experiment (2012 – 2013) in comparison to the data of the DOSIS experiment (2009 – 2011).

The Polish contribution was supported by the National Science Centre (No DEC-2012/06/M/ST9/00423).

The DOSIS and DOSIS 3D Experiments onboard the International Space Station – Results from the Active DOSTEL Instruments

S. Burmeister[1], J. Labrenz[1], J. Marquardt[1], R. Beaujean[1], T. Berger[2], M. Boehme[3], L. Haumann[3], G. Reitz[2]

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[3] *OHB System AG, Bremen, Germany*

Besides the effects of the microgravity environment, and the psychological and psychosocial problems encountered in confined spaces, radiation is the main health detriment for long duration human space missions. The radiation environment encountered in space differs in nature from that on earth, consisting mostly of high energetic ions from protons up to iron, resulting in radiation levels far exceeding the ones encountered on earth for occupational radiation workers. Accurate knowledge of the physical characteristics of the space radiation field in dependence on the solar activity, the orbital parameters and the different shielding configurations of the International Space Station ISS is therefore needed.

For the investigation of the spatial and temporal distribution of the radiation field inside the European COLUMBUS module the experiment DOSIS (Dose Distribution Inside the ISS) under the lead of DLR was launched on July 15th 2009 with STS-127 to the ISS. The experimental package was transferred from the Space Shuttle into COLUMBUS on July 18th. It consists of a combination of passive detector packages (PDP) distributed at 11 locations inside the European Columbus Laboratory and two active radiation detectors (DOSTELs) with a DDPU (DOSTEL Data and Power Unit) in a Nomex pouch (DOSIS MAIN BOX) mounted at a fixed location beneath the European Physiology Module rack (EPM) inside COLUMBUS.

The active components of the DOSIS experiment have been active from July 18th 2009 to June 16th 2011. After refurbishment the hardware has been reactivated on May 15th 2012 as active part of the DOSIS 3D experiment.

Data is transferred from the DOSTEL units to ground via the EPM rack which is activated approximately every four weeks for this action. The latest data download has been performed on August 14th 2013 and contained data till August 8th for DOSTEL-1 and till August 12th for DOSTEL-2 respectively.

The presentation will focus on the results as absorbed dose, dose equivalent and the related LET spectra from the two DOSTEL instruments gathered within the DOSIS (2009 - 2011) and DOSIS 3D (2012 - 2013) experiment.

TRITEL measurements on board the International Space Station

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In cooperation with BL-Electronics Ltd. a three-dimensional silicon detector telescope (TRITEL) was developed at MTA Centre for Energy Research (MTA EK, the former MTA KFKI AEKI) in the past years. The main objective of the instrument was to measure not only the absorbed dose in the cosmic radiation field, but also the linear energy (LET) spectrum of the charged particles and their average quality factor in three mutually orthogonal directions in order to give an estimation of the equivalent dose, too.

In the frame of the EC project SURE the TRITEL system was delivered to the European Columbus Laboratory of the International Space Station (ISS) in October 31, 2012 and it was operated there between November 6, 2012 and May 10, 2013. In cooperation with the State Scientific Center, Institute for Biomedical Problems, Russian Academy of Sciences another version of the system was delivered to ISS. Dosimetry measurements have been performed in the Russian Segment since April 5, 2013.Our presentation addresses the main characteristics of the TRITEL dosimetry system and the first measurement results obtained on board ISS.

The TRITEL-SURE experiment is co-funded by the EC project SURE, contract number RITA-CT-2006-026069 and by the Government of Hungary through ESA Contracts 98057 and 4000108072/13/NL/KML under the PECS (Plan for European Cooperating States).

ALTEA: 2012 radiation measurements in the ISS

L. Di Fino, M. Larosa, V. Zaconte, M. Casolino, P. Picozza, **L. Narici**

Radiation risks mitigation is a mandatory step for the future long space voyages for human exploration. Radiobiology studies are showing risks that strongly depend on the specific characteristic of the radiation. Knowing the radiation environment where the astronauts are going to spend their time is therefore of paramount importance for a proper risk assessment. This knowledge will be provided by detailed simulation and modeling. These must be carefully validated, and the ISS is the best test platform for this purpose, featuring the closest replica available of deep space radiation (at least for high latitude passages). ISS radiation measures can also be used to test the correctness of the CAD models, mostly to study the effects of the limited knowledge of the total shielding distribution in the radiation risk assessments, providing also essential information to develop proper radiation countermeasures.

ALTEA is a six-detector system (striped-silicon telescopes) able to get the full "quality of radiation" parameters needed (for ions with $Z \geq 3$). It is able to measure ions with 3 keV/μm $\leq$ LET(Si) $\leq$ 800 keV/μm, determining each trajectory and permitting in favorable cases complete nuclear and energy discrimination. In several experiments (ASI – ESA – NASA) the detector system has been used from 2006 to 2012 for more than three years of radiation measurements.

In this talk we will focus on 2012 showing radiation features extracted from the ability of looking only at data coming from different orbital segments (and different rigidity cutoff). Slow flux variations as well as larger transient events such as those associated with SPEs will be shown in detail. 3D characteristics of the radiation, mostly due to the ISS mass distributions, will be underlined.

For a complete dosimetric assessment ALTEA needs to cover also the full energy spectrum of light ions ($Z \leq 3$). An upgrade of ALTEA, has been favorably reviewed by ASI and it should be financed possibly next year. This upgrade (Light Ion Detector for ALtea: LIDAL) is based on a Time Of Flight system (TOF) which uses highly performing Silicon Photo-Multiplier (SiPM) and thin segmented scintillators. The new configuration of the ALTEA silicon telescopes, together with this new detector, provides the requested information on all ions, and can measure directly the kinetic energy spectra of the different radiation components.

Relative nuclear abundances, LET and dose rates at various locations and configurations in ISS from the ALTCRISS experiment.

C. Fuglesang, O. Larsson

Over the years many devices, using different technologies and various locations, have been used - and still are in use - on the International Space Station, ISS, to measure and map the radiation and cosmic particle flux which astronauts as well as sensitive electronics are exposed to. This presentation presents recent analyses and results from the Alteino/SilEye-3 detector during the ESA-sponsored project ALTCRISS. Comparisons are made with published data from other experiments, such as ALTEA and DOSIS. Alteino is an Si-strip detector, developed from the two SilEye detectors that were operated on Mir, in particular for studies of the Light Flash phenomena. Alteino was used at several locations, and orientations, in the Russian segment of ISS from late 2005 through 2007. Many of the data sets were obtained with a shielding of 5 g/cm2 polyethylene in front of the detector. Data on nuclei from C to Fe in the energy range above ≃ 60 MeV/n show an increase in relative abundance for odd Z inside ISS compared to the outside, due to fragmentation in the hull. Fluxes and relative abundances vary with location and shielding, where the material of the station itself plays a major role. The difference in flux can be as much as 50%. LET spectra - which are not restricted to single particle events - show similar tendencies, though when converted to equivalent dose rates the effect of the polyethylene is somewhat pronounced. Comparison with ALTEA data shows slightly higher dose rates for Alteino in the Russian segment, which can be expected due to that ALTEA operated in the US lab Destiny with more station material around it. As expected, the response of CR39 in terms of equivalent dose rate is higher than Alteino, due to the smaller acceptance energy range of the latter.

Update on the status of the MEDIPIX-based Radiation Environment Monitors on the ISS.

L. Pinsky, S. Hoang, J. Idarraga, M Kroupa, N. Stoffle, A. Bahadori, E. Semones, H. Kitamura, Y. Uchiori, S. Pospisil, J. Jakubek, Z. Vykydal

The 5 MEDIPIX-based REM units have been operating onboard the ISS since Oct. 16, 2012, and comparisons with the TEPC show reliable performance in terms of dose and dose equivalent measurement comparisons. A number of analysis improvements have been implemented during this period, and a relatively stable configuration has been achieved.

Battery-based hardware for use on the EFT-1 mission has also been prepared, and the development of hardware for operational use within the Orion Module is proceeding.

BEXUS TECHDOSE stratospheric cosmic radiation experiment

B. Zábori, A. Hirn, T. Pázmándi, P. Szántó, S. Deme, M. Korsós

Commercial airplanes are flying at higher and higher altitudes and the frequency of manned space flights is increasing faster nowadays than before. These facts justify the importance of cosmic radiation and dosimetric measurements with advanced instruments and techniques. Several measurements have been performed on the cosmic radiation field from the surface of the Earth up to the maximum altitudes of research airplanes (the lower limit of the stratosphere). However the cosmic radiation field is not well known between 15 km and 30 km. The main scientific goal of our experiment was to give an assessment of the cosmic radiation field at the altitude of the BEXUS balloon and the main technical goal was to develop a balloon technology platform for advanced cosmic radiation and dosimetric measurements.

To fulfil the scientific and technological objectives several different dosimeter systems were used: TRITEL silicon detector telescope, Geiger-Müller counters, Pille thermoluminescent passive dosimeters with portable reader and Solid State Nuclear Track Detectors (SSNTDs). The evaluated deposited energy spectra measured with the TRITEL instrument were compared with the count rates measured with the GM-counters to calibrate them for dose rate in the cosmic radiation field at the altitude of the stratospheric balloons. The Linear Energy Transfer (LET) spectra, the average quality factor of the cosmic radiation as well as the absorbed dose and the dose equivalent for the flight of the BEXUS-14 and from the SSNTD results the contribution of thermal neutrons were determined.

The results obtained in the TECHDOSE experiment will be compared with the data measured on board the BEXUS-12 balloon in the frame of the CoCoRAD experiment as well as with data provided by the Hungarian Heliophysical Observatory to detect possible effects by the change in the solar activity.

Altitudinal distribution of the Ionizing Radiation Exposure between the Earth Surface and Free Space

T.P. Dachev

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Since 2000 scientists from the former Solar-Terrestrial Influences Institute at the Bulgarian Academy of Sciences contributed Bulgarian-build instruments to a number of experiments for measurements of the incoming space radiation fluxes and dose rates from the Earth surface up to the free space and 100 km Moon orbit. The purpose of this paper is to summarize the data obtained by different instruments on the ground and in aircraft, balloon, rocket, and on spacecraft. Special attendance was given to the altitudinal dependences obtained at the ISS. Dose rate, flux and specific dose (SD) data are analyzed, compared and plotted. The result is a unified picture how the different ionizing radiation sources contribute and build the space exposure altitudinal profile from the Earth surface to the free space.

Charged Particle Measurements during Cruise and on Mars with the Radiation Assessment Detector (MSL/RAD)

B. Ehresmann, D.M. Hassler, C. Zeitlin,R.F. Wimmer-Schweingruber, and the MSL Science Team

The Radiation Assessment Detector (RAD), part of the Mars Science Laboratory (MSL), has been successfully measuring the energetic particle radiation on the Martian surface since the landing of the Curiosity rover in Gale crater. Furthermore, RAD was already operating for large parts of the ~250-day cruise to Mars, measuring the radiation environment inside the spacecraft.

Detailed knowledge of particle-type-dependent energy spectra is important for several reasons. E.g., for one measured differential particle fluxes can be used to validate and evaluate transport models currently used to estimate the radiation exposure on the Martian surface. Another important point of knowing the energy spectra of individual ion species is their differing biological effectiveness in terms of assessing radiation exposure risks for future manned missions to Mars.

Here, we will present differential fluxes for different ion species, both for the cruise and the surface phase. As the energy range of these spectra is limited by the maximum energy with that a particle can stop in one of RAD's detectors, we will show integral fluxes for energies above these upper limits where the total energy of the detected particle is not known.

Refinement of MSL-RAD Dose Rate Measurements in Cruise and on the Martian Surface

C. Zeitlin and the MSL-RAD Science Team

The MSL-RAD detector took data for most of MSL's cruise to Mars, starting ten days after launch (Dec. 6, 2011) and turning off on July 14, 2012. Measurements of GCR were made under complex shielding, with some paths into the detector shielded by more than 80 g cm^{-2} while other paths were lightly shielded. Dose rates were measured using one of the silicon detectors and one of the plastic scintillators in the RAD sensor head. These detectors were triggered by particles regardless of the direction of incidence and the dose rates obtained from them may include contributions from neutral particles. In particular, the plastic scintillator is sensitive to neutrons with energies above about 5 MeV via the production of recoil protons. Prior to launch, data were taken with the fully integrated spacecraft including the radioisotope thermoelectric generator (RTG) that supplies power to the Curiosity rover through the decay of ^{238}Pu. The pre-launch data show that a significant dose is deposited in the silicon detector used for dosimetry, but the dose in the plastic scintillator was negligible. The dose in the silicon detector induced by the RTG appears to be dominantly due to electrons, which can be the end products of several different reaction paths.

The same detectors that were used for dosimetry during the trip to Mars are also being used for dosimetry on the surface. On the surface of a large, airless body, we would expect a factor of two lower dose rate compared to interplanetary space simply from geometric considerations. RAD data taken on the Martian surface show a reduction by more than a factor of two, because the atmosphere above Gale Crater is sufficiently thick to provide some shielding. The dose equivalent rate is reduced even more, relative to the cruise, due to attenuation of heavy ion fluxes by the atmosphere. We will report on recent results from the surface and a re-evaluation of cruise data which has been undertaken with the goal of reducing the uncertainties associated with calibration and conversion of silicon dose to tissue dose.

The Results of 4 Sessions of Experimental Study of Local Water Shielding Efficiency to Space Radiation with the Protective Curtain in ISS Crew Cabin

R. Tolochek, V. Shurshakov, I. Kartsev, E. Yarmanova, I. Nikolaev, S. Kodaira, H. Kitamura, H. Kawashima, Y. Uchihori, I. Ambrozova

Crew cabins in the ISS Service Module are known to be less shielded from space radiation as compared with the neighboring compartments. To increase the crew cabin shielding a special protective curtain was designed and then delivered to ISS in 2010. The hygienic wipes and towels containing water are stored inside protective curtain in 4 layers thus creating an additional shielding thickness. Total mass of the curtain with wipes and towels is 65 kg. The protective curtain was installed along the outer wall of the starboard crew cabin. To study the radiation shielding effect 12 passive detector packages with thermoluminescent detectors (TLD) and solid state track detectors (SSTD) are used. 6 packages are installed on the protective curtain surface and the other 6 packages are installed directly on the crew cabin wall behind or aside the curtain. The passive detector packages were exposed in the Service Module starboard crew cabin during 4 sessions: 149 days from July 4 to November 29, 2010; 160 days from December 15, 2010 to May 24, 2011; 311 days from July 21, 2011 to April 27, 2012; 188 days from May 15 to November 19, 2012. Results of both TLD and SSTD are presented here. The average radiation shielding effect of the protective curtain is varying from 13 to 90 % for absorbed dose. It is shown that properly mounted local shielding can effectively mitigate the radiation dose in space station compartments.

Neutron Measurements using Bubble Detectors during the ISS-22 to ISS-36 Expeditions

M.B. Smith, S. Khulapko, H.R. Andrews, V. Arkhangelsky, H. Ing, B.J. Lewis, R. Machrafi, I. Nikolaev, V. Shurshakov, L. Tomi

Radiation protection associated with human spaceflight is an important issue which becomes more vital as the length of the mission or the distance from Earth increase. Neutrons encountered in low-Earth orbit (for example, on the ISS) are produced by interactions of galactic cosmic rays or trapped protons with the walls and interior components of the spacecraft, or by neutron albedo after cosmic rays are incident on the Earth's atmosphere. Previous measurements (on recoverable Russian satellites, the Mir space station, the space shuttle, and the ISS) have shown that neutrons contribute significantly to the radiation dose received by astronauts.

As part of the ongoing Matroshka-R experiment, bubble detectors have been used to characterize the neutron dose and energy spectrum on the ISS. Two types of bubble detectors have been used for these measurements, namely space personal neutron dosimeters (SPNDs) and the space bubble-detector spectrometer (SBDS). The SBDS is a set of six detectors with different energy thresholds, which is used to determine the neutron energy spectrum. During the ISS-22 to ISS-33 expeditions (2009 – 2012) two SPNDs and a SBDS were used in the Russian segment of the ISS. These measurements included a comparison of the neutron dose on either side of a water shield. The Radi-N2 experiment, a repeat of the 2009 Radi-N measurements, was conducted during ISS-34. Measurements were performed using a SBDS in four ISS modules: Columbus, the Japanese Experiment Module, the US Laboratory, and Node 2. During each of the SBDS measurements (which typically last one week) one SPND was worn by Canadian astronaut Chris Hadfield, while a second SPND measured the dose in his sleeping quarters. Some of the Radi-N2 measurements have been repeated during ISS-35 and ISS-36, and these experiments will continue after ISS-36.

The energy spectra measured using the SBDS are in good agreement with previous measurements and do not show a strong dependence on location inside the station. Furthermore, the Radi-N2 results are not significantly different from the Radi-N results collected in the same ISS locations, despite the large difference in solar activity between 2009 and 2013. Results of the dose and spectral measurements, which reinforce the importance of neutrons to the dose received on the ISS, will be presented and discussed.

Space radiation dosimetery for the Matoroshka-R #1 Experiment onboard the KIBO using PADLES from May - Sep. 2012 (Increment 31/32)

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[2] *Advanced Engineering Services,Co.Ltd (AES), Future Development Division*
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[4] *S.P. Korolev Rocket and Space Corporation (RSC-Energia)*

Since Japanese Experiment Module 'KIBO' was attached to the International Space Station (ISS) in 2008, we have been performing continuous space radiation dosimetery using a PADLES (Passive Dosimeter for Life-Science Experiments in Space) consisting of CR-39 PNTDs (Plastic Nuclear track detectors) and TLD-MSOs (Mg_2SiO_4:Tb), which includes various PADLES experiments onboard the 'KIBO'.

The PADLESs are also employed for MATROSHKA-R experiments using a spherical phantom, which have been conducted based on the research agreement of IMPLEMENTATION OF THE MATROSHKA-R JOINT EXPERIMENT WITH PADLES ON BOARD THE JAPANESE EXPERIMENT MODULE, KIBO. The first experiment onboard the KIBO at JPM1F2 Rack2 location was conducted over 114 days from 21 May to 12 September 2012 (the installation time in the phantom). This location was also used for ESA (DLR) / ROSCOSMOS/JAXA joint MATROSHKA experiments (2B_KIBO experiment) from May 2010 to March 2011.

The MATROSHKA-R spherical phantom consists of tissue equivalent material covered by a poncho jacket with 32 pockets on the surface. 20 container rods with dosimeters can be struck into the spherical phantom. Its diameter is 370 mm and it is 32 kg in weight.

In the first experiments, 16 PADLES packages were deployed into 16 poncho pockets on the surface of the spherical phantom. Another 12 PADLES packages were deployed inside 4 rods (3 packages per rod in the outer, middle and inner side). Area monitoring in the KIBO was conducted in the same period (Area PADLES series #8 from 15 May to 16 September, 2012). Absorbed doses were measured at 17 area monitoring points in the KIBO and 28 locations (16 packages in poncho pockets and 12 inside 4 rods) in the phantom. The maximum value measured with the PADLES in the poncho pockets on the surface of the spherical phantom facing the outer wall was 0.43 mGy/day and the minimum value measured with the PADLES in the poncho pockets on the surface of the spherical phantom facing the KIBO interior was 0.30 mGy/day. We estimate the difference between averaged doses obtained from dosimeters facing the outer wall and dosimeters facing the KIBO interior to be approximately 13%.

The maximum absorbed doses measured inside rods was 0.28 mGy/day and the minimum value was 0.19 mGy/day. This indicates doses measured from the dosimeters placed in the outer side of each rod are relatively high compared to the doses placed in the center of rod. At this time, we would like to show the dosimetry results of first Matroshka-R experiment onboard the KIBO and are monitoring at 17 fixed locations on the way to solar cycle 24th upward curve.

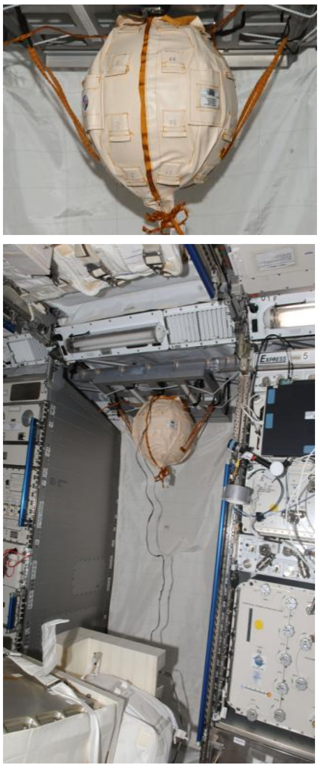

Fig.1: Matroshka-R spherical phantom onboard the KIBO at JPM1F2 Rack2

New Results on Dose Distribution in a Human Body in ISS Compartments Obtained with the Tissue-Equivalent Spherical Phantom

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The tissue-equivalent spherical phantom of space experiment MATROSHKA-R (32 kg mass, 35 cm diameter and 10 cm central spherical cave) has been used on board the ISS for more than 8 years. Due to the specially chosen phantom shape and size, the chord length distributions of the detector locations are attributed to self-shielding properties of the critical organs in a real human body. Originally the spherical phantom was installed in the star board crew cabin of the ISS Service Module, then in the Piers-1 and MIM-2 modules of the ISS Russian segment. Recently, new results in MIM-1 module and JAXA Kibo module were also obtained. Total duration of the detector exposure is more than 1700 days in 8 sessions. In the first phase of the experiment with the spherical phantom the dose measurements were realized with only passive detectors (thermoluminescent and solid state track detectors). The detectors are placed inside the phantom along the axes of 20 containers and on the phantom outer surface in 32 pockets of the phantom jacket. After each session the passive detectors are returned to the ground. The results obtained show the dose difference on the phantom surface as much as a factor of 2, the highest dose being observed close to the outer wall of the compartment, and the lowest dose being in the opposite location along the phantom diameter. Maximum dose rate measured in the phantom is obviously due to the galactic cosmic ray (GCR) and Earth' radiation belt contribution on the ISS trajectory. Minimum dose rate is caused mainly by the strongly penetrating GCR particles and is observed behind more than 5 g/cm2 tissue shielding. Critical organ doses, mean-tissue and effective doses of a crew member in the ISS compartments are also estimated with the spherical phantom data. The estimated effective dose rate is found to be from 10 % to 15 % lower than the averaged dose on the phantom surface as dependent on the attitude of the critical organs.

The spherical phantom proved its effectiveness to measure the critical organ doses together with the effective dose in-flight and if supplied with active dosimeters can be recommended for future exploratory manned missions to monitor continuously the effective dose.

Radiation Environment on ISS in 2012- April 2013 According the Data from Liulin-5 Particle Telescope

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The Liulin-5 charged particle telescope observes the radiation characteristics in the spherical tissue-equivalent phantom of MATROSHKA-R project on ISS since June 2007. From January 2012 to April 2013 measurements were conducted in and outside the phantom located in the MIM1 module of ISS. In this paper attention is drawn to the obtained results for dose rates and particle fluxes in and outside the phantom and on GCR dose rates changing during that period. Particularly discussed are the results for radiation characteristics in the phantom during the solar particles events (SPE) occurred in March and May 2012. Discussed are the linear energy transfer spectra and quality factors obtained during and after the SPE. Compared are data from Liulin-5 and other particle detectors in space during the SPEs. Compared are data from Liulin-5 dose rate and particle fluxes during SPEs in 2012 and data from Liulin dosemeter measurements on Mir Space station during SPEs in 1989-1991.

The response of a depleted p-MOSFET dosemeter to photons and electrons

M. Fragopoulou, S. Stoulos, M. Zamani, E. Benton , D. O'Sullivan, S. Siskos, T. Laopoulos, V. Konstantakos and G. Sarrabayrouse

The p-MOSFET dosimeter studied in this work has been manufactured at LAAS-CNRS Laboratory in Toulouse France, for applications in personal and space dosimetry. They are proposed for proton, heavy ions and electron and photon dose measurements. The current study investigates the sensitivity of this new type of Metal-Oxide-Semiconductor field effect transistor (MOSFET) to electrons and gamma radiation. The sensitivity of the new MOSFET based dosemeters to electrons is comparable that of photons and present a linear response for wide dose ranges. The influence on the dosemeters response of the bias applied to the source of the p-MOSFET, during measurement, is also investigated.

The European Crew Personal Active Dosemeter (EuCPAD) System

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In Low Earth Orbit (LEO) humans are exposed to primary radiation of cosmic and solar origin, particles trapped in the earth radiation belts as well as secondary radiation produced by particle interactions with matter, as the hull of the International Space Station (ISS). The radiation field in space is the most complex natural radiation environment humans can encounter. The annual exposure levels applicable for radiation workers on Earth are exceeded in extended space missions on ISS. In consequence ESA - as the responsible agency - is executing a Radiation Health Program for their astronauts. The "European Crew Personal Active Dosimeter for Astronauts (EuCPAD)" project aims at the development and manufacturing of an active (powered) dosimeter system to document the astronaut's exposures, to support risk assessment and to provide a complete data set for space crew dose management. The final goal is the verification of the systems capabilities for medical monitoring at highest medical and technical standards. The EuCPAD project is part of ESA´s Radiation Protection Initiative and Activity initiated by ESA Medical Operations HSO-UM in cooperation with ESA-TEC. The project is led by ESA and contracted to a European consortium which is led by DLR as ESA's prime contractor. The EuCPAD system consists of several small portable Personal Active Dosemeters (MU = Mobile Unit´s) and a fixed mounted docking station "Personal Storage Device (PSD)" for MU storage, data read out, and telemetry. Additionally, the PSD contains a Tissue Equivalent Proportional Counter (TEPC) and an internal MU (iMU) to allow an as precise as possible measurement of the radiation exposure. The presentation will give an overview of the current development status of the hardware as well as results from calibration measurements with neutrons, gamma radiation and heavy ions and show data from first flight measurements on-board aircraft.

The EuCPAD project is carried out under ESA CONTRACT NO. 4200023059/09/NL/CP, Technical Project Management, System Engineering and Budgeting: Matthias Dieckmann, ESA-ESTEC, The Netherlands. Project Manager for Crew-Medical Operational Issues: Ulrich Straube on behalf of ESA-EAC, Cologne, Germany

Status of the ISS Radiation Assessment Detector

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On behalf of the ISS RAD Team

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The International Space Station (ISS) Radiation Assessment Detector (RAD) is an intra-vehicular energetic particle detector designed to measure a broad spectrum of charged particle and neutron radiation unique to the ISS radiation environment. RAD consists of two main detectors – the Charged Particle Detector (CPD) and the Fast Neutron Detector (FND). The CPD consists of four detectors used in measuring the spectroscopy of charged particles – A, B, C, and D; high-energy neutral particles are measured in E; and the last detector – F – is an antic-coincidence detector. A, B, and C are made from Si; D is made from BGO; E and F are made from EJ260XL plastic scintillator. The FND consists of a Boron loaded plastic scintillator (EJ254XL); flashes in the scintillator are detected by a photomultiplier tube (PMT).

A summary of the general status of the ISS RAD project, future plans, and preliminary radiation measurements made with an engineering model prior to and after the delivery of the unit to Johnson Space Center (e.g. testing with neutrons from ^{241}AmBe) will be presented.

ISS-RAD Calibration Campaign

C. Zeitlin, and the ISS-RAD Team

An Engineering Model version of the ISS-RAD detector was completed in early 2013 and has undergone extensive testing and calibration in the following months. The instrument consists of two major subsystems, the CPD (charged particle detector) and FND (fast neutron detector). The CPD is almost identical to the MSL-RAD detector aboard the Curiosity rover, with a few modifications and improvements. Charged particle data for CPD calibration were obtained at the NSRL facility at Brookhaven National Laboratory, and neutron data for calibration of the FND have been obtained at the PTB facility in Braunschweig, Germany, as well as at the RARAF facility in New York. We will present an overview of these activities. The PTB data have been used to construct an initial estimate of the FND response function, as will be explained in detail. For the CPD, expected responses can be calculated from first principles. Results from the charged particle beam runs will be compared to the expected responses.

Overview of Tissue Equivalent Proportional Counter for high LET Radiation Monitoring in Complex Radiation Field

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A portable dosimeter for monitoring cosmic radiation in the range of 0.2~300 keV/μm has been developed. The dosimeter consists of a spherical tissue equivalent proportional counter(TEPC) with inside diameter of 30 mm and wall thickness of 5mm to measure isotropic response and can simulate a 2μm of site diameter for micro-dosimetry. The constructed TEPC has been tested with a standard alpha source (^{241}Am, 5.5 MeV) and 40 MeV proton source. Also, the calibration of the TEPC was performed by using the ^{252}Cf neutron standard source and the calibration factor was Kf = 3.59 x 10^{-7} mSv/R. In a qualification model under development, the RADFET dosimeter will be added in order to measure the total dose as well as the linear energy transfer for space radiation. In this paper, some activities and results of our TEPC development as well as its utilization will be presented.

The LINTEL, a system for estimating the effective dose of the space stations' crew

S. Deme, I. Apáthy, A. Csőke, A. Hirn, O.A. Ivanova, I.V. Nikolaev, T. Pázmándi, G.A. Shmatov, V.A. Shurshakov, P. Szánto, B. Zábori

It is mainly the space stations' crew for whom cosmic radiation might cause considerable dose. The Centre for Energy Research, Hungarian Academy of Sciences continues the activity of the former Central Research Institute for Physics (KFKI) and the Atomic Energy Research Institute (AEKI) in development of space dosimetry systems. The Pille system based on thermoluminescent dosimeters was dedicated for measuring the absorbed dose. The next step was the development of the three dimensional silicon detector system TRITEL; besides the absorbed dose and absorbed dose rate it is capable of measuring the dose equivalent and the dose equivalent rate, too.

The main objective of the development is to elaborate a system for estimating the effective dose of astronauts. The method that will be applied is the measurement of dose equivalent for 4 critical organs (testis, blood forming organs (BFO), central nervous system (CNS), gastro-enteric system (GES) based on the depth distribution of LET spectra. It means that the device named LINTEL (LINear TELescope system) uses several thin, fully depleted silicon detectors located behind absorbers of proper thicknesses and measures the energy deposition of heavy charged particles (mainly protons and α-particles) penetrating through both the gating and measuring detectors.

The presentation will address the principle and the main geometrical parameters of the LINTEL system, as well as shielding properties and measurement ranges.

List of Participants

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