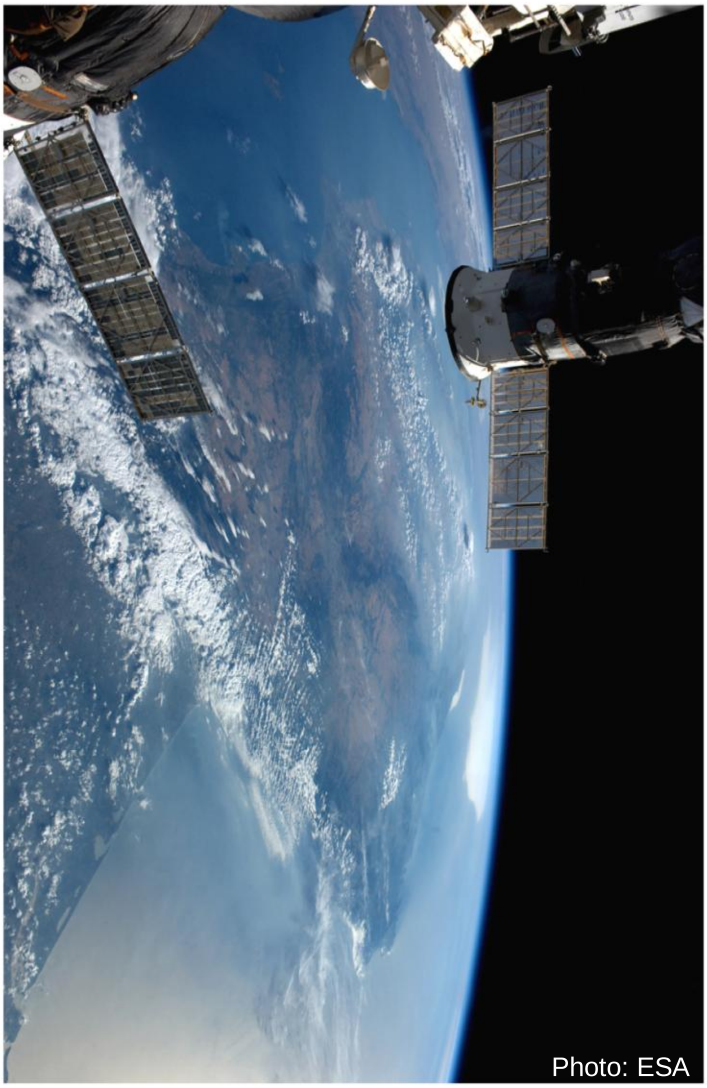

19th WRMISS

WORKSHOP ON RADIATION MONITORING FOR THE INTERNATIONAL SPACE STATION

organized by the Institute of Nuclear Physics Polish Academy of Sciences

Kraków, Poland

9-11 September 2014

Program and Abstracts

19TH WORKSHOP ON RADIATION MONITORING
FOR THE INTERNATIONAL SPACE STATION

Chairman: Günther Reitz, DLR

Local organizer: Paweł Bilski, IFJ

WRMISS-19 is sponsored by

Polish Academy of Sciences

POLSKA AKADEMIA NAUK

City of Kraków

KRAKÓW

krakow.pl

KRK2B

Krakow to business

Tuesday 9th September

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

Günther Reitz Paweł Bilski	Welcome and Organizational Issues

Introductory Talk

Francis F. Badavi	Status of the of Trapped Model AE9/AP9/SPM International Version (IRENE) for the ISS Environment

Scientific Session 1

Samy El-Jaby	Monte Carlo Simulations of the Radiation Environment at Suborbital Altitudes
Myung-Hee Y. Kim	Implementing Badhwar-O'Neill Galactic Cosmic Ray Model for the Analysis of Space Radiation Exposure
Andrey Lishnevskii	Extrapolation Algorithm to Forecast the Dynamics of Accumulation of the Absorbed Dose at the International Space Station, According to the Radiation Monitoring System Data

Scientific Session 2

Paweł Bilski	Investigations of the Relative Efficiency of Thermoluminescent Detectors to Protons at the IFJ PAN in Kraków
Cary Zeitlin	Further Analysis of Thin Silicon Detector Dose to Tissue Dose
Bartos Przybyla	Nuclear Track Etch Detector Evaluation Studies in the Frame of the DOSIS 3D Experiment

Scientific Session 3

Andrea Strádi	Some Aspects of Passive Dosimetry on BION-M1 and Foton-M2 & M3 Satellites
Ramona Gaza	New ISS Radiation Area Monitors Measurements at Solar Maximum
Joe K. Pálfalvi	Passive Dosimetry in the Service (Zvezda) Module: 2010-2014
Aiko Nagamatsu	Comparative Study between Radiation Doses in the MATROSHKA Anthropomorphic Phantom and the Matoroshka-R Spherical Phantom Experiment#1 aboard International Space Station 'KIBO'

Wednesday 10th September

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 – 16.15	Coffee/Tea Break
16.15 – 18.45	Scientific Session 7 – visit to accelerator center at the IFJ PAN

Scientific Session 4

René Demets	Radiation Dosimetry on the ISS: ESA Experiments in 2014
Thomas Berger	The DOSIS and DOSIS 3D Project on-board the International Space Station – Current Status and Science Overview
Soenke Burmeister	The DOSIS and DOSIS 3D Project on-board the International Space Station – Current Status and Results of the DOSTELs as Active Instruments

Scientific Session 5

Daniel Matthiä	Variations in the Radiation Exposure within the Columbus Module of the ISS Measured during the DOSIS and DOSIS 3D Experiments
Attila Hirn	Pille Measurements on ISS (Exp. 35-38)
Livio Narici	ALTEA – shield: an ESA Sponsored ISS-USLab Radiation Survey

Scientific Session 6

Ramona Gaza	ISS Tissue Equivalent Proportional Counter (TEPC) Radiation Measurements
Martin Smith	Neutron Measurements Using Bubble Detectors: ISS-34 to ISS-40
Paweł Olko	Proton Irradiation for Space Research at IFJ PAN Kraków

Scientific Session 7

Visit to the IFJ proton irradiation facility – Bronowice Cyclotron Center (CCB)

Thursday 11th September

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
16.45 – 18.15	Scientific Session 11

Scientific Session 8

Lawrence S. Pinsky	Update of the Results from ~2 Years of Medipix on the ISS and Future Plans for Evolutions of the Medipix Technology
Stuart George	Mapping the Asymmetry in the SAA Fluxes Using the Medipix Particle-by-Particle Directional Information
Raisa V. Tolochek	Study of Dose Distribution in ISS Compartments With Passive Detectors

Scientific Session 9

Brent Ehresmann	Update on Radiation Measurements on the Martian Surface with MSL/RAD
Cary Zeitlin	Recent Results from the MSL-RAD Experiment on the Curiosity Mars Rover
Rachid Machrafi	On the Possibility of Neutron and Gamma Spectrometry with a Single Scintillator

Scientific Session 10

Jaejin Lee	Development of compact Tissue Equivalent Proportional Counter (TEPC) for Monitoring Space Radiation on the ISS, Cubesat and Aircraft
Cary Zeitlin	Status of ISS-RAD
Amir Bahadori	Development of the Battery-operated Independent Radiation Detector (BIRD)

Scientific Session 11

Eddie Semones	NASA Plans for Dosimetry in Support of Manned Spaceflight
Conclusion/Adjourn	All

Note: Presentation time shall not exceed 30 minutes

Venue

19th WRMISS will be held in the building of Polish Academy of Arts and Sciences, Sławkowska st. 17 in Kraków.

The Workshop Dinner

Wednesday, September 10th, 8-11 p.m. at the restaurant Oranżeria (Plac Kossaka 1), located at the top of the Hotel Kossak and known for the beautiful view at the Wawel royal castle and the old city (www.cafeoranzeria.pl)

Local Organizing Committee

Paweł Bilski
Barbara Marczewska
Mariusz Kłosowski
Wojciech Gieszczyk
Michał Sądel
Anna Twardak
Dagmara Wróbel
Jan Gajewski

Status of the of Trapped Model AE9/AP9/SPM International Version (IRENE) for the ISS Environment

Francis F. Badavi[1]

[1]*Old Dominion University, Norfolk*

The production version 1 (V1.0) of the new trapped electron, proton and space plasma model AE9/AP9/SPM was released in United States in the September of 2012. The international version, in evaluation mode, was installed on Space Environment Information System (SPENVIS-4) in the September-October 2013 time frame. The international version named International Radiation Environment for Near Earth (IRENE) includes most but not all of the important capabilities of the new model in mean, percentile, perturbation and Monte Carlo modes. For long duration trajectories (e.g. days), even for a SPENVIS-4 "advance user", IRENE is subject to the web server timeout limitation. The next generation SPENVIS appropriately named SPENVIS-NG will incorporate the lessons learned from the IRENE implementation in SPENVIS-4.

In this talk, for the ISS and a few other Low Earth Orbit (LEO) trajectories, some of the more important features and limitations of IRENE as installed on SPENVIS-4 will be reviewed. For electrons and protons, the quantities of importance such as flux and fluence in differential and integral modes as generated by IRENE will be compared with older environmental models such as AE8/AP8, CRRESELE and CRRESPRO.

Monte Carlo Simulations of the Radiation Environment at Suborbital Altitudes

Samy El-Jaby[1], Richard B. Richardson[1]

[1]*Radiological Protection Research & Instrumentation Branch*
Atomic Energy of Canada Limited

Occupational radiation exposures are well studied and regulated for commercial airline travel and for missions to low-Earth orbit, though not for missions to the intermediary suborbital altitudes. Airline crew, which typically fly at altitudes of 7 to 14 km, may receive 1 to 5 mSv of additional radiation dose annually depending on the routes flown and total flight-time logged. Meanwhile, a single mission to the International Space Station, which orbits between 300 and 400 km, can result in approximately 0.05 to 0.15 Sv of effective dose. Space tourism vehicles are expected to reach suborbital altitudes of approximately 100 km and crews will receive significant occupational doses during repeated transits. The thin atmosphere present at suborbital altitudes makes the radiation environment faced complex and unique. In this paper, simulations of the radiation environment from surface altitudes up to low-Earth orbit are presented with emphasis on the suborbital altitude regime. Using the Monte Carlo radiation transport MCNPX, the Badhwar-O'Neill (2010) galactic cosmic radiation model is transported through a representation of Earth's atmosphere using the NRLMSIS-00 atmospheric density model. Radiation flux distributions, ambient dose equivalent rates, and effective dose equivalent rates in air as a function of altitude and particle type are described.

Implementing Badhwar-O'Neill Galactic Cosmic Ray Model for the Analysis of Space Radiation Exposure

Myung-Hee Y. Kim[1], Patrick M. O'Neill[2], Tony C. Slaba[3]

[1]*Wyle Science, Technology and Engineering, Housto, USA*
[2]*NASA Johnson Space Center, Houston, USA*
[3]*NASA Langley Research Center, Hampton, USA*

For the analysis of radiation risks to astronauts and planning exploratory space missions, accurate energy spectrum of galactic cosmic radiation (GCR) is necessary. Characterization of the ionizing radiation environment is challenging because the interplanetary plasma and radiation fields are modulated by solar disturbances and the radiation doses received by astronauts in interplanetary space are likewise influenced. A model of the Badhwar-O'Neill 2011 (BO11) GCR environment, which is represented by GCR deceleration potential ㅈ , has been derived by using all of the GCR measurements from balloons, satellites, and the newer NASA Advanced Composition Explorer (ACE). In the BO11 model, the solar modulation level is derived from the mean international sunspot numbers with time-delay, which has been calibrated with actual flight-instrument measurements to produce better GCR flux data fit during solar minima. GCR fluxes provided by the BO11 model were compared with various spacecraft measurements at 1 AU and further comparisons were made for the tissue equivalent proportional counters measurements at low-Earth orbits using the high-charge and energy transport (HZETRN) code and various GCR models. For the comparison of the absorbed dose and dose equivalent calculations with the measurements by Radiation Assessment Detector (RAD) at Gale crater on Mars[1], the intensities and energies of GCR entering the heliosphere were calculated by using the BO11 model, which accounts for time-dependent attenuation of the local interstellar spectrum of each element. The BO11 model, which has emphasized for the last 24-solar minima, showed in relatively good agreement with the RAD data for the first 200 sols, but the BO11 model resulted in less agreement near the solar maximum of solar cycle 24, due to subtleties in the changing heliospheric conditions. By performing the error analysis of the BO11 model and the optimization in reducing overall uncertainty, the resultant BO13 model corrects the fit at solar maxima as well as being accurate at solar minima. The BO13 model is implemented to the NASA Space Cancer Risk model for the assessment of radiation risks. Overall cumulative probability distribution of solar modulation parameters represents the percentile rank of the average interplanetary GCR environment, and the probabilistic radiation risks can be assessed for various levels of GCR environment to support mission design and operational planning for future manned space exploration missions.

[1]Kim, M.-H. Y., et al. (2014), *Comparison of Martian surface ionizing radiation measurements from MSL-RAD with Badhwar-O'Neill 2011/HZETRN model calculations*, J. Geophysical Research – Planets, 119(6):1311-1321, doi:10.1002/2013JE004549.

Extrapolation Algorithm to Forecast the Dynamics of Accumulation of the Absorbed Dose at the International Space Station, According to the Radiation Monitoring System Data

A. Lishnevskii[1], V. Benghin[2], A. Gross[3]

[1]*Lomonosov Moscow State University Skobeltsyn, Institute of Nuclear Physics (MSU SINP), Russia*
[2]*Institute for Biomedical Problems RAS, Moscow, Russia*
[3]*FernUniversitat in Hagen, Germany*

The ISS service module is equipped with the radiation monitoring system (RMS) which provides data for the daily estimation of the radiation environment on board the station. The sensitive elements of the RMS are silicon semiconductor detectors and ionization chambers. The data obtained in quiet radiation environment allowed to determine the contribution to the absorbed radiation dose due to galactic cosmic rays and the Earth's inner radiation belt. The corresponding analysis was conducted for the 2005 – 2011 period. As a result empirical relations were obtained allowing to calculate the dose for one crossing of the area of the South Atlantic Anomaly. The initial parameters for the calculation are longitude and altitude on which the ISS trajectory crosses this area. The obtained empirical relations allowed to develop a simple calculation algorithm for the short-term forecasting of the dynamics of accumulation of the radiation dose at the ISS which is based on the assumption that the current level of contribution to the daily dose of galactic cosmic rays and the structure of the Earth's inner radiation belt at the station flight altitude remains unchanged within a few days. The results of the analysis of the ISS RMS data which was conducted using the developed calculation algorithm for the period from 2005 to 2011 (the period in which solar cycle 23 ended and solar cycle 24 began) showed the possibility to implement a short-term (1-2 days) forecast of the dynamics of accumulation of the dose on board the station with an acceptable error rate (of no more than 30 percent). The algorithm developed for forecasting the radiation environment may be used to process and analyse the current RMS information when providing effective radiation safety for the ISS crew.

Investigations of the Relative Efficiency of Thermoluminescent Detectors to Protons at the IFJ PAN in Kraków

P. Bilski[1], M. Sądel[1], J. Swakoń[1], P. Olko[1]

[1]*Institute of Nuclear Physics, Polish Academy of Sciences (IFJ PAN), Kraków, Poland*

Passive dosimetry of cosmic radiation is usually realized with thermoluminescent (TL) and plastic track detectors. It is well known that, the relative thermoluminescent efficiency, which is defined as the ratio of the emitted light intensity per unit dose for a given radiation type, to the same quantity for the reference gamma radiation (usually Cs-137 or Co-60), is not constant and depends on radiation type and energy. This dependence is a result of influence of ionization density on charge carrier trapping/recombination processes, which lead to luminescence emission. Usually the relative efficiency decreases with increasing ionization density, however exceptions from this general trend are known.

In the recent decade a lot of experimental work was done on characterization of properties for heavy ions of TL detectors used in space dosimetry. This was mostly realized exploiting the ion beams of the HIMAC accelerator in Chiba in frame of the ICCHIBAN and other projects. However, somewhat less attention was paid to investigations of the TL efficiency to protons, in spite that protons constitute the major part of cosmic radiation. The difference between TL efficiency to protons and to gamma-rays is obviously much smaller, that in the case of heavy ions, nevertheless these efficiencies cannot be a priori assumed as equal. LiF:Mg,Ti, which are the most commonly applied TL detectors, were several times reported to show efficiency to protons greater than that to gamma-rays, even by as much as 30%. On the other hand, in the literature one can easily find contradicting results, with the relative efficiency close to unity.

At the IFJ Kraków since 2011 the proton radiotherapy of eye tumours is being conducted exploiting the 60 MeV proton beam of the AIC-144 cyclotron. Taking advantage of having a proton beam available on-site, we realized in the last years a project aimed on systematic investigations of the TL efficiency of LiF detectors to protons. The presentation will show among others the data on dependence of the efficiency on proton energy and dose, as well as variability between various detector batches.

This work was supported by the National Science Center (projects No DEC-2012/06/M/ST9/00423 and DEC-2011/01/B/ST2/02450).

Further Analysis of Thin Silicon Detector Dose to Tissue Dose

Cary Zeitlin[1]

[1]*Southwest Research Institute, USA*

A problem frequently encountered in the analysis of flight data is the proper conversion of dose silicon to dose in tissue. Generally, a single multiplicative factor based on the Bethe formula is used. The factor is typically around 1.2. While this ignores energy dependence of the ionization energy loss ratios, it is a reasonable approximation in the case that the measured energy loss distribution is not in any way truncated. However, in the analysis of silicon telescope data, a correlation cut is often made between energy deposits in adjacent detectors; this truncates the tail of the Landau/Vavilov distribution and shifts the mean of the measured distribution to a lower value, closer to the peak (most probable) energy loss value, with a corresponding effect on the silicon-to-tissue dose conversion factor. Furthermore, it will be shown that the mean of the Landau/Vavilov energy loss distribution in a thin silicon detector only reaches the mean value as per the Bethe formula when very large energy deposits are included. These energy deposits correspond to electrons that have sufficient energy to escape the detector and are therefore not actually measured, so that the finite dimensions of the detector acts to truncate the energy loss distribution.

Nuclear Track Etch Detector Evaluation Studies in the Frame of the DOSIS 3D Experiment

B. Przybyla[1], T. Berger[1], S. Kodaira[2], H. Kitamura[2], Y. Uchihori[2], G. Reitz[1]

[1]*Institute of Aerospace Medicine, German Aerospace Centre, Cologne, Germany*
[2]NIRS *National Institute of Radiological Sciences, Chiba, Japan*

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. The 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. In the frame of the DOSIS 3D experiment passive detector packages (PDPs) are positioned at eleven positions inside the Columbus laboratory to measure the spatial distribution of the radiation field. The PDPs use a combination of thermoluminescence detectors and nuclear track etch detectors for the determination of the absorbed dose and the dose equivalent. Detectors are provided by various research groups. One aim of the DOSIS 3D experiment is, besides the measurements on board Columbus, the comparison of data provided by the various research groups. The aim of this work focuses on the different nuclear track etch detector evaluation systems, and their properties related to track identification, measurement and evaluation. The talk will give a first overview of comparisons made between the nuclear track etch detector evaluation systems at DLR, Cologne, Germany and NIRS, Chiba, Japan.

Some Aspects of Passive Dosimetry on BION-M1 and Foton-M2 & M3 Satellites

A. Strádi[1], 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]*Centre for Energy Research of the Hungarian Academy of Sciences (HAS CER)*
[2]*State Scientific Center of Russian Federation Institute of Biomedical Problems, Russian Academy of Science, Russia*
[3]*Nuclear Physics Institute ASCR, Prague, Czech Republic*
[4]*NIRS National Institute of Radiological Sciences, Chiba, Japan*
[5]*DLR German Aerospace Center, Cologne, Germany*
[6]*IAEA International Atomic Energy Agency, Vienna, Austria*

BION-M1 and Foton-M2 & M3 satellites provided possibility to perform different biological experiments within low gravity. Each satellite had exposure platform also at the outer surface of the recoverable capsule which permits exposure of biological samples to the open space environment. To support the biological studies each satellite was equipped with Thermoluminescent detectors (TLD) and Solid state nuclear track detectors (SSNTD) to monitor the radiation environment.

This presentation deals with the results obtained by detector stacks exposed on the outer platforms of each satellite at extremely low shielding levels down to a few mg cm-2.

The main contributors of the space radiation are electrons in the range of 100 keV to 5 eV and some contribution is delivered by the belt protons, mainly with energies up to 30 MeV. Although the HZE particles of galactic origin are always present and can deliver a huge dose locally along their path, their contribution to the traditionally defined absorbed dose is low. The contribution of high energy protons and neutrons is due to the secondary charged particles induced directly in materials and detectors.

The performance of the detectors may be highly influenced by the changing temperature and low air pressure. There will be a trial to explain the differences in the dosimetric results measured on the different satellites and by the different participating groups having detectors under different shielding conditions.

New ISS Radiation Area Monitors Measurements at Solar Maximum

Ramona Gaza[1,2], Steve Johnson[1,2], Edward Semones[2]

[1]*Lockheed Martin, Houston, USA*
[2]*NASA Johnson Space Center, Houston, USA*

A summary of the latest Radiation Area Monitors (RAM) dosimetry results during ISS Expeditions 31 – 37, for inside-vehicle radiation monitoring in low Earth orbit at solar maximum conditions, performed in the Space Radiation Dosimetry Laboratory at the NASA Johnson Space Center will be presented.

The ISS RAM measurements consisted of a total of 96 RAM units (24 RAMs/ISS Expedition) and were performed during 2012 – 2014 at 398 – 418 km altitude. The RAMs are distributed inside the Node 1, Node 2, Node 3, US Lab, SM, Columbus and JEM Modules. The 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).

Each RAM unit consisted of a suite of thermoluminescence (TL) and optically stimulated luminescence (OSL) detectors and included LiF:Mg,Ti (TLD-100), 6LiF:Mg,Ti (TLD-600), 7LiF:Mg,Ti (TLD-700), Al_2O_3:C (LuxelTM), and CaF_2:Tm (TLD-300). The comparison results will be discussed in terms of the space radiation environment differences as well as the altitude variations.

In addition, TLD-100 results from the DOSIS-3D_34S and the DOSIS-3D_36S exposure (2013 – 2014) will be presented and compared to previous DOSIS-3D measurements (2012 – 2013). 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 11 different shielding locations inside the ESA Columbus Module.

Passive Dosimetry in the Service (Zvezda) Module: 2010-2014

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

[1]*Centre for Energy Research of the Hungarian Academy of Sciences (HAS CER)*
[2]*State Scientific Center of Russian Federation Institute of Biomedical Problems, Russian Academy of Science, Russia*
[3]*Nuclear Physics Institute ASCR, Prague, Czech Republic*
[4]*NIRS National Institute of Radiological Sciences, Chiba, Japan*
[5]*DLR German Aerospace Center, Cologne, Germany*
[6]*IAEA International Atomic Energy Agency, Vienna, Austria*

Since the first astronauts and cosmonauts entered the ISS in 2001, there are dose measurements inside the Zvezda (Service) module (SM) by passive dosimetry systems (SPD). These were organized by the IBMP with international collaboration. The Centre for Energy Research (CER) participated in these studies since the beginning using Solid State Nuclear Track Detectors (SSNTD) and Thermoluminescent Detectors (TLD).

In this presentation we provide details about the dosimeters, evaluation methods and calibration processes. The results of the flux and dose measurements performed at four locations of the SM within the SPD project between 2010 and 2014 (SPD 7, 8, 9 and 10) will be detailed and compared to the measurements performed within the previous BRADOS project, as well as, to the results obtained by the on-board TLD system called Pille.

Comparative Study between Radiation Doses in the MATROSHKA Anthropomorphic Phantom and the Matoroshka-R Spherical Phantom Experiment#1 aboard International Space Station 'KIBO'

A. Nagamatsu[1], T. Sato[2], K. Kitajo[3], K. Shimada[3], K. Takeda[4], T. Ito[1], I. Nikolaev[5], R. Tolochek[6], V. Shurshakov[6], T. Berger[7]

[1]*Japan Aerospace Exploration Agency, Ibaraki, Japan*
[2]*Japan Atomic Energy Agency, Ibaraki, Japan*
[3]*Advanced Engineering Services Co., Ltd, Ibaraki, Japan*
[4]*Research Organization for Information Science and Technology, Ibaraki, Japan.*
[5]*4. S.P. Korolev Rocket and Space Corporation (RSC-Energia)*
[6]*Institute of Biomedical Problems (IBMP), Radiation Safety Department*
[7]*DLR German Aerospace Center, Cologne, Germany*

Since Japanese Experiment Module 'KIBO' was attached to the International Space Station (ISS) in 2008, we have been performing continuous space radiation dosimetry 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 employed for two experiments in the ISS KIBO at JPM1F2 Rack2 location to verify of dose distributions in a human body during space flight. One is 'the MATROSHKA Anthropomorphic Phantom experiment (2B_KIBO experiment)' jointly conducted with ESA/DLR from May 2010 to March 2011. Absorbed doses were measured at 19 organ locations (skin, eye, lung, stomach, kidney, intestine and top of the head) in the human phantom torso.

The other is 'the MATROSHKA-R spherical phantom experiment' with ROSCOSMOS/IBMP/RSC-Energia from May to September 2012. 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). These experiments duration meets on the way to solar cycle 24th upward curve.

Area monitoring at fixed 17 locations in the KIBO part of the Area PADLES experiments were conducted in the same period of each experiment, the period during Area PADLES series #4 covered the MATROSHKA 2B_KIBO experiment and the series #8 over the MATROSHKA-R experiment, respectively.

At this time, we would like to show the preliminary results of a comparative study among two experiments conducted in the same locations of JPM1F2 Rack2 and the area monitoring inside the KIBO. In additions, simulated radiation doses of the two experiments using the Particle and Heavy Ion Transport code System (PHITS) calculations with well developed shielding model of the KIBO and numerical spherical phantom inside will be presented.

Radiation Dosimetry on the ISS: ESA Experiments in 2014

René Demets[1]

[1]European Space Agency, *HE Space for ESA, Noordwijk, the Netherlands*

Introduction:

Two sets of radiation detectors from ESA are currently deployed on the ISS. One is placed inside the Columbus module, the other on an external platform of the Zvezda module. All detectors reside under research dosimetry as no permanent operational dosimetry is foreseen by ESA. This report in focused on the scientific goals and does not include recorded data or scientific results.

Experiments:

The passive and active detectors in the Columbus module are part of the DOSIS-3D experiment (Dose Distribution inside the International Space Station - 3D), lead investigator Thomas Berger. The detectors on the Zvezda platform are provided by Thomas Berger (passive dosimetry) and Tsvetan Dachev (active dosimetry).

Scientific Objectives:

DOSIS-3D deals with area dosimetry and is intended to identify and quantify radiation gradients across the Columbus module. The results will be compared and combined with similar measurements in other modules of the ISS. The active and passive detectors on the Zvezda platform are accommodated inside the ESA Expose-R2 facility to provide radiation dosimetry in support of astrobiological and astrochemical exposure experiments.

Hardware location:

DOSIS-3D consists of eleven passive detector packages, strategically distributed over the cylindrical Columbus module, accompanied by a twin set of active DOSTEL detectors on the Utility Interface Panel of the EPM rack. Expose-R2 is located in open space at the port side of the Zvezda module. The passive detectors are distributed at different shielding depths, the active detector is a Liulin.

Timing:

DOSIS-3D has been in action since May 2012. Since then the passive detector packages have been renewed with every 6-month increment. An extension over the coming years is envisaged. The detectors on Zvezda will be downloaded between October 2015 and February 2016 when the Expose-R2 mission is over.

ESA and industry:

ESA provides the flight opportunity including upload, download and flight operations. The flight hardware is developed, manufactured and financed by the science teams.

DOSIS-3D	T. Berger (DE)	Inside the ISS (Columbus)	yes	yes
DOSIS-Expose		Outside the ISS (Zvezda)	no	yes
R3D-R2	T. Dachev (BG)		yes	no

The DOSIS and DOSIS 3D Project on-board the International Space Station – Current Status and Science Overview

T. Berger[1], S. Burmeister[2], P. Bilski[3], T. Horwacik[3], A. Twardak[3], B. Przybyla[1], M. Hajek[4,5], C. Hofstätter[5], J. Palfalvi[6], A. Hirn[6], J. Szabo[6], I. Ambrozova[7], F. Vanhavere[8], O. Van Hoey[8], W. Schoonjans[8], R. Gaza[9,15], E. Semones[9], E. Yukihara[10], E. Benton[10], J. Labrenz[2], Y. Uchihori[11], S. Kodaira[11], H. Kitamura[11], V. Shurshakov[12], R. Tolochek[12], V. Benghin[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]*MTA-EK 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*
[15]*Lockheed Martin Exploration & Mission Support, Houston, United States*

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 "Dose Distribution Inside the ISS" (DOSIS), 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 eleven locations inside Columbus for the measurement of the spatial variation of the radiation field and two active DOSTELs with a Data and Power Unit (DDPU) in a dedicated nomex pouch mounted at a fixed location beneath the EPM rack 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 – 2014) 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 CAU contributions to DOSIS and DOSIS 3D are financially supported by BMWi under Grants 50WB0826, 50WB1026 and 50WB1232.

The DOSIS and DOSIS 3D Project on-board the International Space Station – Current Status and Results of the DOSTELs as Active Instruments

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

[1]*Institute for Experimental and Applied Physics, Kiel University, Kiel, Germany*
[2]*German Aerospace Center, DLR, Institute of Aerospace Medicine, Cologne, Germany*
[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 has been 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 (Dosimetry Telescopes = 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 were operational 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 and provides continuous data since this activation.

The presentation will focus on the latest results from the two DOSTEL instruments as absorbed dose, dose equivalent and the related LET spectra gathered within the DOSIS (2009 - 2011) and DOSIS 3D (2012 - 2014) experiment.

The CAU contributions to DOSIS and DOSIS 3D are financially supported by BMWi under Grants 50WB0826, 50WB1026 and 50WB1232.

Variations in the Radiation Exposure within the Columbus Module of the ISS Measured during the DOSIS and DOSIS 3D Experiments

D. Matthiä[1], T. Berger[1], S. Burmeister[2], the DOSIS & DOSIS 3D Science Team

[1]*German Aerospace Center, DLR, Institute of Aerospace Medicine, Cologne, Germany*
[2]*Christian-Albrechts-Unitersität zu Kiel (CAU), Kiel, Germany*

The radiation exposure within the Columbus module of the International Space Station (ISS) has been measured in the frame of the DOSIS and DOSIS 3D experiments since July 2009 with passive and active instrumentation. In December 2009 during the prolonged period of very low solar activity a maximum of galactic cosmic ray intensity was reached. Since then the solar activity has increased and the corresponding galactic cosmic ray (GCR) intensity has dropped. Radiation exposure from both galactic cosmic rays and charged particles trapped in the radiation belt are expected to have been decreased with increasing solar activity; the former because of the increased shielding provided by the interplanetary magnetic field and the latter because of the augmented loss processes in the atmosphere.

While the solar activity increased, the ISS was elevated from an altitude of about 350 km in the year 2009 to about 420 km in 2013. In contrast to the radiation exposure from galactic cosmic rays which is expected to be almost independent of the altitude on such a scale, the contribution of trapped particles during crossings of the South Atlantic Anomaly (SAA) is expected to increase significantly with altitude. Using the results of the two DOSTEL instruments from the DOSIS & DOSIS 3D experiments an analysis of the altitude and solar cycle dependence of the dose rates within the SAA and from GCR is presented. The reverse effects of increasing altitude and increasing solar activity on radiation exposure in Columbus are studied.

Pille Measurements on ISS (Exp. 35-38)

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

[1]*MTA Centre for Energy Research, Budapest, Hungary*
[2]*Institute for Biomedical Problems, Russia*
[3]*Rocket Space Corporation "Energia", Moscow, 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 43000 read-outs were carried out until now. The Pille system provides monthly dose data from locations of the space station 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 35-36 and 37-38, April 2013 – May 2014) obtained by the Pille system is presented. The results are compared with previous measurement results.

ALTEA – shield: an ESA Sponsored ISS-USLab Radiation Survey

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

Department of Physics University of Rome Tor Vergata, and INFN sect Tor Vergata, Rome, Italy

ALTEA is a six-detector system (striped-silicon telescopes) developed with ASI grants. Each detector is able to measure ions within 3 keV/µm ≤ LET(Si) ≤ 800 keV/µm, measuring the energy deposited on each of the six silicon planes (constituting one detector) and determining also their individual trajectories. Complete nuclear and energy discrimination (for ions with Z≥3) is feasible in favorable cases. Therefore with ALTEA is possible to fully characterize the "quality of radiation" providing the needed information for a reliable risk assessment as well as for model validation. In several experiments (ASI – ESA – NASA sponsored) the detector system has been used from 2006 to 2012 about four years of radiation measurements.

In this talk we will focus on the project ALTEA-shield, ESA sponsored, running from 2010 to 2012. Data selection criteria leading to the study only of specific orbital segment will be discussed. High latitude passages radiation mimic well the deep space radiation environment. The selection criteria, able to automatically filter out, for example, the radiation in the SAA is therefore quite useful to construct a radiation database for deep space models and spacecraft CAD models validation, providing also essential information to develop proper radiation countermeasures.

Radiation environment in four sites in the USLab and also in one Columbus site will be discussed in function of time and shielding characteristics of the specific ISS site (see also table below for mean values). Slow flux variations as well as larger transient events such as those associated with SPEs will be shown in detail. Influence of SAA passages on the daily radiation as well as of the altitude changes will be presented. 3D characteristics of the radiation, mostly due to the ISS mass distributions, will be underlined.

	USLab				**Columbus**
	P1	P2	P3	P4	P5
Flux (n/cm^2 sr s)	0.0064±0.0002	0.0064±0.0002	0.0056±0.0002	0.0055±0.003	0.0048±0.0003
Dose rate (nGy/s)	0.58±0.02	0.53±0.02	0.42±0.02	0.43±0.02	0.51±0.03
Dose Eq. rate (nSv/s)	3.9±0.3	2.9±0.2	2.0±0.2	2.2±0.2	3.8±0.3

ISS Tissue Equivalent Proportional Counter (TEPC) Radiation Measurements

R. Gaza[1,2], S. Johnson[1,2], E. Semones[2]

[1]*Lockheed Martin, Houston, USA*
[2]*NASA Johnson Space Center, Houston, USA*

The Tissue Equivalent Proportional Counter (TEPC) instrument has been used by the NASA Johnson Space Center for the International Space Station (ISS) intra-vehicular radiation monitoring since the beginning of the Space Station Program.

The ISS TEPC is a portable, active radiation detection device consisting of a spectrometer unit and a detector unit that measures the absorbed dose and dose equivalent in complex radiation fields. TEPC collects data as a function of time by making spectral measurements of the lineal energy transfer, y (0.4 – 1000 keV/μm) deposited by the radiation as it passes through the detector volume. The omni-directional detector is surrounded by a tissue equivalent plastic and the detector gas (propane) provides an energy deposition response similar to human tissue. The TEPC instrument is primarily used on ISS as a survey instrument for the low-Earth orbit (LEO) radiation environment at different ISS shielding configurations, with the dual capability to locally store the data and to provide near real-time data telemetry to ground during solar particle events. The custom build TEPC software has the capability of separating the galactic cosmic rays (GCR) dose and the trapped particles (SAA) dose components of the total absorbed dose based on a predetermined dose threshold.

A summary of the latest ISS TEPC radiation measurements in terms of total absorbed dose and dose equivalent, GCR dose and SAA dose will be provided. In addition, the 2009 – 2012 summaries of the TEPC radiation measurements inside the ESA Columbus module and the JAXA KIBO module will be presented.

Neutron Measurements Using Bubble Detectors: ISS-34 to ISS-40

M.B. Smith[1], S. Khulapko[2,3], H.R. Andrews[1], V. Arkhangelsky[2], H. Ing[1], M.R. Koslowsky[1], B.J. Lewis[4], R. Machrafi[4], I. Nikolaev[3], V. Shurshakov[2]

[1]*Bubble Technology Industries, Ontario, Canada*
[2]*State Scientific Centre, Institute for Biomedical Problems, Russian Academy of Science, Moscow, Russia*
[3]*Rocket Space Corporation "Energia", Moscow, Russia,*
[4]*Faculty of Energy Systems and Nuclear Science, University of Ontario Institute of Technology, Oshawa, Ontario, Canada*

Radiation protection associated with human spaceflight is an important issue that becomes more vital as both the length of the mission and the distance from Earth increase. Neutrons encountered in low-Earth orbit, for example on the ISS, are produced predominantly by nuclear interactions of galactic cosmic rays (GCRs) and trapped protons with various elements in the walls and interior components of the spacecraft, and by neutron albedo from GCRs incident on the Earth's atmosphere. Previous investigations, using bubble detectors and other instruments, have shown that neutrons contribute significantly to the total radiation dose received by astronauts.

Bubble detectors have been used to characterize neutron radiation on the ISS since 2006 as part of the ongoing Matroshka-R experiment. Two types of bubble detectors have been used for these experiments, namely space personal neutron dosimeters 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-34 to ISS-40 expeditions (2012 – 2014) bubble detectors were used in both the US Orbital Segment (USOS) and the Russian segment of the ISS. The Radi-N2 experiment, a repeat of the 2009 Radi-N investigation, started during ISS-34 and included repeated measurements in four USOS modules: Columbus, the Japanese Experiment Module, the US Laboratory, and Node 2. Parallel experiments using a second set of detectors in the Russian segment included the first characterization of the neutron spectrum inside the tissue-equivalent Matroshka-R phantom.

The Radi-N2 dose and spectral measurements 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 the present time. The experiments with the phantom in the Russian segment suggest that the dose inside the phantom is approximately 70% of the dose at its surface, while the spectrum inside the phantom contains a larger fraction of high-energy neutrons than the spectrum outside the phantom. Results of the ongoing measurements, which reinforce the importance of neutrons on the ISS, will be presented and discussed.

Proton Irradiation for Space Research at IFJ PAN Kraków

P. Olko[1], J. Swakoń[1]

[1]*Institute of Nuclear Physics, Polish Academy of Sciences (IFJ PAN), Kraków, Poland*

Cosmic radiation is mainly composed of energetic protons. Despite the fact that the cosmic energy range is extremely broad the largest radiological hazard and the impact on electronics is produced by relatively low energy protons, mainly below few hundreds of MeV.

Recently, the first proton therapy center in Poland with 230 MeV Proteus C-235 cyclotron, two scanning gantries, eye-line and experimental hall was put in operation at the Institute of Nuclear Physics PAN in Kraków. In addition to patient treatment, the centre is operated as a research facility where experiments in nuclear physics, and development projects in radiation physics, radiobiology and materials engineering are conducted. The experimental hall is almost 100 m^2, 5 m in height with horizontal proton beam 1.5 m above the floor level. Two biology labs are located by the experimental hall to prepare and handle biological samples for irradiations. International Advisory Committee advises on the priorities of the access to the beam.

In addition Institute offers 60 MeV therapeutic proton beam from cyclotron AIC-144 with fully equipped dosimetry and positioning system as well as 2 MeV proton beam from Van de Graaff accelerator with possibilities of single proton irradiation. The photon irradiation can be performed using 300 kVp X-rays, Theratron 780 Co-60 therapeutic beam, 1.5 keV X-ray microbeam and Cs-137 at the calibration room.

The IFJ PAN proton facilities are regularly used for research in the field of radiation biology, microdosimetry and detector development. We are opened for the new proposals in the field of comic ray dosimetry.

Update of the Results from ~2 Years of Medipix on the ISS and Future Plans for Evolutions of the Medipix Technology

L.S. Pinsky, A. Empl, S. George, J. Idarraga, M. Kroupa, S. Hoang, N. Stoffle, D. Turecek, C. Amberboy, A.A. Bahadori, E. J. Semones, S. Pospisil, J. Jakubek, Z. Vykydal

Physics Department, University of Houston, USA

The Medipix-based Radiation Environment Monitors (REM) units were activated onboard the ISS in October, 2012, giving us close to 2 years of data with this technology. We have been able to evaluate units with 300 and 500 μm Si sensors. The unique ability to assess the details for each individual traversing particle, allows us to evaluate the correction from individual LET in Si to that in tissue on a track-by-track basis. This capability also allows us to report on the mean LET based on the determination from each track, and that data is available for the full coverage of the ISS orbits. Directional analysis of the incident particles is also possible, especially during individual SAA passes (which will be described in a separate abstract).

The current technology deployed on the ISS is based on the Timepix chip from the Medipix2 Collaboration. The next generation of the comparable Medipix technology that is now available from the Medipix3 Collaboration is the Timepix3 chip, which uses a data-driven continuous readout scheme allowing continuous close to dead-free operation, and the initial results from runs at NSRL will be reported. In addition the Medipix2 Collaboration has initiated a redesign to produce an updated and revised version of the current Timepix chip, which will attempt to maximize commonality with the existing interfaces. Reports on the status of both projects will be presented.

Mapping the Asymmetry in the SAA Fluxes Using the Medipix Particle-by-Particle Directional Information

S. George, A. Empl, S. Hoang, J. Idarraga, M. Kroupa, N. Stoffle, D. Turecek, C. Amberboy, A.A. Bahadori, E. J. Semones, S. Pospisil, J. Jakubek, Z. Vykydal, L. Pinsky

CERN Geneva, Switzerland

The Medipix-based Radiation Environment Monitors (REM) units have he unique ability to assess the details for each individual traversing particle, which allows us to evaluate directional information on a particle-by-particle basis. This directional analysis of the incident particles is especially interesting during individual SAA passes. While the absolute orientation of the REM units is uncertain, the profound directionality observed is clearly demonstrable with appropriate visualization graphics. A brief review of this analysis will be presented.

Study of Dose Distribution in ISS Compartments With Passive Detectors

R.V. Tolochek[1], V.A. Shurshakov[1], I.V. Nikolaev[2]

[1]*State Scientific Center of Russian Federation Institute of Biomedical Problems, Russian Academy of Science, Russia*
[2]*Rocket Space Corporation "Energia", Moscow, Russia*

The SPD (Set of Passive Detectors) experiment is a part of ongoing space experiment MATROSHKA-R monitoring the dose level in compartments of Russian segment of ISS. The first session of SPD experiment started in 2004 year and at the moment 10 sessions already have been finished. SPD experiment is a set of 6 boxes installed in different locations of Russian segment of ISS compartments such as crew cabins, docking port "Pirs", Multipurpose Laboratory Module. The typical duration of SPD session is half a year, there are also exposures varying from 92 days up to 606 days. The size of each box is 118x63x42 mm, and each box contains biological samples (seeds) and different kinds of passive detectors including thermoluminescent detectors (TLD), optically

stimulated luminescence (OSL) detectors, solid state track detectors (SSTD). The purpose of the experiment is the study of dose dependence on shielding conditions, ISS altitude and solar activity. 6 locations represent different shielding conditions and show the dose distribution on-board ISS, while 10 sessions demonstrate the dose dynamic with in ISS altitude and solar activity covering almost a solar cycle. In current presentation only TLD data obtained by IBMP is analysed and represented.

Update on Radiation Measurements on the Martian Surface with MSL/RAD

B. Ehresmann, C. Zeitlin, J. Koehler, D. M. Hassler, R. F. Wimmer-Schweingruber, D. E. Brinza, S. Rafkin, J. K. Appel, E. Boehm, S. Boettcher, S. Burmeister, J. Guo, C. Martin, G. Reitz, the MSL Science Team

Southwest Research Institute, USA

The Radiation Assessment Detector (RAD) on board the Mars Science Laboratory has been measuring the radiation on the surface of Mars since the successful landing of the Curiosity rover on 6 August 2012.

Besides its capability of measuring important dosimetric quantities, such as radiation dose and Linear Energy Transfer (LET) spectra, RAD further provides particle fluxes for a wide range of particle species and energies. Due to its design RAD is for example able to construct separate spectra for neutrons and gamma rays from its measurements, as well as identify different ion species and isotope spectra.

RAD has further directly detected several Solar Energetic Particle (SEP) events, as well as indirect influences of those SEP events in the form of Forbush decreases.

Current analysis shows that the radiation environment on the Martian surface is influenced by several factors: long-term changes in the inducing Galactic Cosmic Ray (GCR) flux due to the Solar cycle; changes of atmospheric pressure above Gale crater due to the Martian seasons, as well as diurnal changes of the pressure due to the daily thermal tide.

Here, we present an update on the recent findings and the state of analysis of the measured MSL/RAD data.

Recent Results from the MSL-RAD Experiment on the Curiosity Mars Rover

C. Zeitlin[1], D.M. Hassler[1], B. Ehresmann[1], R. Wimmer-Schweingruber[2], J. Appel[2], E. Böhm[2], S. Böttcher[2], D.E. Brinza[3], S. Burmeister[2], J. Guo[2], J. Köhler[2], H. Lohf[2], C. Martin[2], A. Posner[4], S. Rafkin[1], G. Reitz[5]

[1]*Southwest Research Institute, USA*
[2]*Christian Albrechts University, Kiel, Germany*
[3]*Jet Propulsion Laboratory, California Institute of Technology, USA*
[4]*NASA Headquarters, USA*
[5]*German Aerospace Agency, Germany*

The MSL-RAD instrument continues to operate flawlessly on the surface of Mars, having now accumulated data for more than a full Mars year (687 Earth days). We will summarize recent results, including analyses of these and other topics: diurnal and seasonal influences of the Martian atmosphere on the surface dose rate; neutron contributions to dose and dose equivalent; Forbush decreases; comparisons with terrestrial neutron monitor data; and the three weak SEP events seen so far.

On the Possibility of Neutron and Gamma Spectrometry with a Single Scintillator

R. Machrafi, A. Miller, N. Khan

Faculty of Energy Systems and Nuclear Science, University of Ontario Institute of Technology, Oshawa, Ontario, Canada

A recently developed new scintillator, CLYC, has been investigated for possible use as a dual detector for neutron and gamma spectrometry. Two versions of the scintillator with different concentrations have been investigated. In addition to gamma radiation, the output of neutron reactions with two constituents of the sensor i.e. ^{6}Li(n,α) and ^{35}Cl(n,p), provides the possibility of neutron detection for both thermal and fast neutrons, respectively. The sensor has been mounted on a photomultiplier tube controlled with a miniature electronics board and irradiated in different fields of neutrons and gamma radiation.

A series of experiments has been carried out with mono-energetic neutrons as well as well with different gamma energies and the pulse height spectra have been measured. In addition the response function of the detector has been simulated using Monte Carlo N-Particle MCNPX code for gamma-rays and neutrons of different energies. In this paper, the data of the investigation will be presented and discussed.

Development of Compact Tissue Equivalent Proportional Counter (TEPC) for Monitoring Space Radiation on the ISS, Cubesat and Aircraft

Jaejin Lee[1], Uk-won Nam[1], Jeonghyun Pyo[1], Sunghwan Kim[2], Won-Kee Park[1], Bongkon Moon[1], Hisashi Kitamura[3], Shingo Kobayashi[3]

[1]*Korea Astronomy and Space Science Institute, South Korea*
[2]*Cheongju University, South Korea*
[3]*National Institute of Radiological Science*

In this presentation, we briefly describe the compact TEPC developed by Korea Astronomy and Space Science Institute (KASI) and show the calibration results performed with HIMAC at NIRS, Japan. Originally, our spherical type TEPC is designed to measure the LET in the range of 0.2 – 500 keV/µm in the ISS. The digital pulse processing technique is applied to set low and high gain mode for wide dynamic range. The detector is made of tissue equivalent plastic, A-150 which outer diameter is 40 mm, and the inner diameter is 30 mm and filled by tissue equivalent gas, pure propane (C_3H_8). The center electrode is a stainless steel wire with a diameter of 30 µm. We obtained successfully LET spectra of He (150 MeV/u), C (135 MeV/u) and He (400 MeV/u) with HIMAC facility. While this TEPC detector was designed for monitoring space radiation on ISS, we have concentrated on reducing the volume and mass to install on a Cubesat that will be launched in next year, 2015. This experiment is expected to reveal radiation environment on low altitude orbit of 700 km when solar energetic proton event occurs. In addition, we are modifying this instrument to measure the effective dose for aircrew on aircraft altitude. The measurements of aircraft radiation will be compared to the modeled data that will be calculated with GEANT-4.

Status of ISS-RAD

C. Zeitlin[1], Y. Tyler[1], S. Escobedo[1], E. Semones[2], R. Rios[2], K. Beard[2], M. Leitgab[2], M. Kroupa[2], G. Weigle[3], K. Kaufmann[3]

[1]*Southwest Research Institute, USA*
[2]*NASA Johnson Space Center, USA*
[3]*Big Head Endian Software, LLC, USA*

The Flight Model (FM) ISS-RAD has been completed and has been extensively calibrated over the first half of 2014. Beam data have been taken with high-energy protons and high-energy heavy ions including helium, carbon, silicon, and iron, at the NASA Space Radiation Laboratory. Calibration data with quasi-monoenergetic neutron fields were obtained at PTB in Germany. The complexity of the instrument and its on-board data processing software has challenged the science and engineering teams, but all components are now working well. Delivery to ISS should occur early in 2015.

Development of the Battery-operated Independent Radiation Detector (BIRD)

A. A. Bahadori, M. Kroupa, T. Sweet, R. Moore, M. Gruseck, J. Idarraga, S. Wheeler, R. Hagen, A. Alvarez-Hernandez, S. Hoang, N. Stoffle, L. Pinsky, C. Amberboy, R. Gaza, E. J. Semones

NASA Space Radiation Analysis Group, Johnson Space Center, USA

The Battery-operated Independent Radiation Detector (BIRD) will fly in December 2014 on the first test flight of the Orion Multi-Purpose Crew Vehicle (MPCV). Exploration Flight Test 1 (EFT1), which will launch from Kennedy Space Center in Florida, will take the Orion MPCV through the trapped radiation belts with one lower altitude orbit, followed by a highly elliptical orbit with a maximum altitude of nearly 6000 km. EFT1 provides a unique opportunity to measure the intravehicular radiation environment through the trapped radiation regions transited by the Orion MPCV.

The BIRD consists of two redundant subsystems, each utilizing a Timepix chip coupled with a 300 μm silicon sensor. The Timepix chip is subsegmented into an array of 256 by 256 pixels; each pixel is a square with side length 55 μm. As indicated by the name, batteries will power the two subsystems. The acquisition time of each frame of data will be controlled by an algorithm using the number of illuminated pixels in previous frames. All raw and engineering data will be saved to on-board storage for post-mission retrieval.

The BIRD was developed as a part of the Advanced Exploration Systems (AES) RadWorks Radiation Environment Monitor (REM) project. It represents the second step in a multi-phase approach, with the ultimate goal being operational implementation of the Timepix technology for space radiation monitoring. The data gathered from the BIRD will be used for comparison with model predictions and to gain knowledge for design and testing of future Timepix-based space radiation detection systems.

NASA Plans for Dosimetry in Support of Manned Spaceflight

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

NASA Space Radiation Analysis Group, Johnson Space Center, USA

NASA is completing its update of the active monitoring suite for ISS operations and developing new systems to support exploration missions. The update includes to the Tissue Equivalent Proportional counter and a new charged particle-neutron spectrometer: the ISS-RAD. NASA's Advanced Exploration Systems (AES) RadWorks Project is developing systems incorporating hybrid pixel detector technology from the Medipix family of chips into a series of instruments for use on ISS and on the Multi-Purpose Crew Vehicle (MPCV). The RadWorks project is developing a neutron spectrometer for use in precursor missions or long duration exploration missions. In addition, a comprehensive comparison of the ISS Medipix-based Radiation Environment Monitors (REM) measurement data with modeled results from current NASA radiation transport codes and updated shielding distributions will be carried out by the RadWorks team. In addition to the development of new instruments, a new source of data for GCR model improvement from the AMS-02 experiment will be available in be near future.

The combination of new instrument capabilities, detailed model comparisons, and new GCR data will be reviewed in context of NASA's overall plans for dosimetry improvements for manned spaceflight.

List of Participants

Iva Ambrozova	Nuclear Physics Institute ASCR, Prague, Czech Republic
Francis F. Badavi	Old Dominion University, Norfolk, USA
Amir Bahadori	NASA Space Radiation Analysis Group, Johnson Space Center, USA
Thomas Berger	Institute of Aerospace Medicine, German Aerospace Centre, Cologne, Germany
Paweł Bilski	Institute of Nuclear Physics, Polish Academy of Sciences (IFJ PAN), Kraków, Poland
Soenke Burmeister	IEAP, Kiel University, Germany
René Demets	European Space Agency, Noordwijk, the Netherlands
Bent Ehresmann	Southwest Research Institute, USA
Samy El-Jaby	Atomic Energy of Canada Limited
Jan Gajewski	Institute of Nuclear Physics, Polish Academy of Sciences (IFJ PAN), Kraków, Poland
Ramona Gaza	Lockheed Martin & NASA Johnson Space Center, Houston, USA
Stuart George	CERN, Geneva, Switzerland
Wojciech Gieszczyk	Institute of Nuclear Physics, Polish Academy of Sciences (IFJ PAN), Kraków, Poland
Anastasia Gross	Fern Universitat in Hagen, Hagen, Germany
Attila Hirn	MTA Centre for Energy Research (MTA EK), Budapest, Hungary
Tomasz Horwacik	Institute of Nuclear Physics, Polish Academy of Sciences (IFJ PAN), Kraków, Poland
Myung-Hee Y. Kim	Wyle Science, Technology and Engineering, Houston, USA
Jaejin Lee	Korea Astronomy and Space Science Institute
Andrey Lishnevskii	Lomonosov Moscow State University Skobeltsyn Institute of Nuclear Physics, Moscow, Russia
Rachid Machrafi	University of Ontario Institute of Technology, Canada
Barbara Marczewska	Institute of Nuclear Physics, Polish Academy of Sciences (IFJ PAN), Kraków, Poland
Karel Marsalek	Institute of Aerospace Medicine, German Aerospace Centre, Cologne, Germany
Daniel Matthiä	Institute of Aerospace Medicine, German Aerospace Centre, Cologne, Germany
Aiko Nagamatsu	Japan Aerospace Exploration Agency "JAXA" , Tsukuba, Japan
Livio Narici	University of Roma Tor Vergata & INFN Tor Vergata, Italy
Paweł Olko	Institute of Nuclear Physics, Polish Academy of Sciences (IFJ PAN), Kraków, Poland
Joe K. Pálfalvi	Centre for Energy Research of the Hungarian Academy of Sciences (HAS CER), Budapest, Hungary
Lawrence Pinsky	University of Houston, USA

Bartos Przybyla	Institute of Aerospace Medicine, German Aerospace Centre, Cologne, Germany
Günther Reitz	Institute of Aerospace Medicine, German Aerospace Centre, Cologne, Germany
Michał Sądel	Institute of Nuclear Physics, Polish Academy of Sciences (IFJ PAN), Kraków, Poland
Eddie Semones	NASA Space Radiation Analysis Group, Johnson Space Center, USA
Martin Smith	Bubble Technology Industries, Chalk River, Ontario, Canada
Andrea Strádi	Centre for Energy Research of the Hungarian Academy of Sciences (HAS CER), Budapest, Hungary
Ulrich Straube	European Space Agency, Cologne, Germany
Raisa Tolochek	State Scientific Center of Russian Federation Institute of Biomedical Problems, Russia
Leena Tomi	Canadian Space Agency
Anna Twardak	Institute of Nuclear Physics, Polish Academy of Sciences (IFJ PAN), Kraków, Poland
Olivier Van Hoey	SCK-CEN, Belgium
Dagmara Wróbel	Institute of Nuclear Physics, Polish Academy of Sciences (IFJ PAN), Kraków, Poland
Cary Zeitlin	Southwest Research Institute, USA