21st WRMISS 2016

Conference Program

6 – 8 September 2016

ESA-ESTEC, Noordwijk, The Netherlands

21st WRMISS 2016 Conference Program: Tuesday 6th September 2016

09.00 – 09.15	Welcome
09.15 – 10.30	Scientific Session 1
10.30 – 11.15	Coffee/Tea Break
11.15 – 12.45	Scientific Session 2
12.45 – 14.00	Lunch
14.00 – 15.30	Scientific Session 3
15.30 – 16.30	Coffee/Tea Break
16.30 – 18.00	Scientific Session 4

Günther Reitz **René Demets**	Welcome and Organisational Issues
Jason Hatton/ René Demets	Introduction to ESA Activities

Scientific Session 1

Francis F. Badavi	AMS1 secondary proton analysis and its contribution to the ISS dosimetric validation

Scientific Session 2

Myung-Hee Y. Kim	Estimation of Exposure Levels for Consequences of Solar Particle Events
Samy El-Jaby	A generalized approach for modelling deep space radiation exposures
Josef Palfalvi	Utilization of ground experiments for reliable dose estimate in space

Scientific Session 3

Alessio Parisi	Deconvolution study of the glow curves of LiF:Mg,Ti and LiF:Mg,Cu,P
Martin Kakona	Progress report on CANDY silicon detector
Marianthi Fragopoulou	Mosfet used on Space Satellite

Scientific Session 4

Samy El-Jaby	An update on Monte Carlo simulations of the radiation environment at space tourism altitudes
Attila Hirn	Pille Measurements on ISS (April 2015 - Dec 2015)
Martin B. Smith	Matroshka-R and Radi-N2 Experiments using Bubble Detectors: ISS-43/44 and ISS-45/46
Daniel Heynderickx	Construction of Long Term Interplanetary H and He Datasets in the Framework of the ESA Sepem/Eshiem/Sepcalib Projects

21st WRMISS 2016 Conference Program: Wednesday 7th September 2016

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19.00- 22.00	Conference Dinner: De Zeemeeuw, Koningin Wilhelmina Boulevard 108, Noordwijk (opposite the light tower, exit 18 to the beach)

Scientific Session 5

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 – Results of the DOSTEL instruments
Andrey Lishnevskii	Contribution of galactic cosmic rays and of Earth radiation belt into the daily dose aboard the ISS determined by the data of RMS ISS

Scientific Session 6

Tsvetan Dachev	Overview of the ISS radiation environment observed during EXPOSE-R2 mission in 2014-2016
Livio Narici	The energetic Solar Particle Events (SPEs) measured by ALTEA in the ISS during the ALTEA-shield experiment (2011-2012): first 1.5 years long study of SPE radiation inside a space habitat.

Scientific Session 7

Aiko Nagamatsu	Shielding evaluation of the ISS 'KIBO' hull wall for space radiation between radiation dosimetry inside/outside and PHITS simulation
Raisa Tolochek	Radiation protection properties of additional shielding «protective curtain» installed in crew cabin of Russian segment of ISS
Livio Narici	ALTEA Measurements on radiation shielding efficacy of Kevlar, compared to Polyethylene performances, in the International Space Station

Scientific Session 8

Thomas Berger, Ulrich Straube	EuCPAD: First Results from the European Crew Personal Active Dosimeter (OpNom: ESA Active Dosimeter – EAD) onboard the International Space Station (ISS)
Cary Zeitlin	First Results from the ISS-RAD Charged Particle Detector
Martin Leitgab	Preliminary On-Orbit Neutron Dose Equivalent and Energy Spectrum Results from the ISS-RAD Fast Neutron Detector (FND)

21st WRMISS 2016 Conference Program: Thursday 8th September 2016

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16.15 – 18.00	Scientific Session 12
	Adjourn

Scientific Session 9

Kerry Lee	Comparison of RAM dose data with calculated dose using an updated ISS CAD
Eddie Semones	Update on the NASA Plans for Dosimetry in Support of Manned Spaceflight
Tsvetan Dachev	Radiation investigations onboard ExoMars missions. Results for radiation parameters during TGO cruise to Mars

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Cary Zeitlin	Latest Results from the MSL-RAD Experiment
Jingnan Guo	The dependence of Martian surface radiation on atmospheric depth
Daniel Matthiä	Particle spectra on the Martian surface – An update on the comparison of models and MSL-RAD measurements

Scientific Session 11

Razvan Gaza	Orion Exploration Mission 1: Proposed Radiation Measurements in Cislunar Space
Larry Pinsky	Update on MEDIPIX Developments
Tsvetan Dachev	Description of the Liulin-ISS-2 system for personal dosimetric control of Russian cosmonauts inside and outside ISS

Scientific Session 12

Ondrej Ploc	CZENDA – the Czech Experimental Novel Dosimetry Assembly aboard the BION-M2 Russian satellite
Hisashi Kitamura	Status Report of Active Space Radiation Detector, A-DREAMS-2 at NIRS
Attila Hirn	Development of the radiation and magnetic field measurement payload RadMag

Contents

AMS1 secondary proton analysis and its contribution to the ISS dosimetric validation

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The existing Galactic Cosmic Ray (GCR) models (i.e. codes) at 1 AU do not account for the production of downward/upward secondary ions (mostly protons) at Low Earth Orbit (LEO). The source of the secondary ions production is the interaction of the primary GCR ions with the tenuous atmosphere at LEO.

In order to improve the accuracy of the existing GCR models at LEO, data from the Alpha Magnetic Spectrometer 1 (AMS1) detector, flown onboard the space shuttle (circa 1998) are analyzed. For the 10 days duration of AMS1 data acquisition, it is shown that the GCR at LEO can be categorized as being made of a high energy primary and a low energy secondary spectrum. In addition, it is shown that the secondary spectrum is made of downward and upward (splash) ions.

To further verify the existence of secondary ions, AMS1 downward data is correlated with the Payload for Antimatter Matter Exploration and Light-nuclei Astrophysics (PAMELA) data (circa 2006-present), with both detectors showing the existence of secondary downward low energy ions, while maintaining different trajectories at LEO.

Based on the AMS1 data, a parametric model is developed to quantify the secondary ions production in the upward/downward directions. This model can work with the existing GCR codes. The parametric model acts as an additional low energy GCR boundary condition input into any particle transport code at LEO, to compute the required dosimetric quantities of interest at a given target point within ISS, or any other spacecraft flying at LEO.

Estimation of Exposure Levels for Consequences of Solar Particle Events

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The potential for exposure to large solar particle events (SPEs) with fluxes that extend to high energies is a major concern during interplanetary transfer and extravehicular activities (EVAs) on the lunar and Martian surfaces. Prediction of sporadic occurrence of SPEs is not accurate for near or long-term scales, while the expected frequency of such events is strongly influenced by solar cycle activity. In the development of NASA's operational strategies real-time estimation of exposure to SPEs has been considered so that adequate responses can be applied in a timely manner to reduce exposures to well below the exposure limits. Previously, the organ doses of large historical SPEs had been calculated by using the complete energy spectra of each event and then developing a prediction model for blood-forming organ (BFO) dose based solely on an assumed value of integrated fluence above 30 MeV (Φ_{30}) for an otherwise unspecified future SPE. While BFO dose is determined primarily by solar protons with high energies, it was reasoned that more accurate BFO dose prediction models could be developed using integrated fluence above 60 MeV (Φ_{60}) and above 100 MeV (Φ_{100}) as predictors instead of Φ_{30}. In the current study, re-analysis of major SPEs (in which the proton spectra of the ground level enhancement [GLE] events since 1956 are correctly described by Band functions) has been used in evaluation of exposure levels. More accurate prediction models for BFO dose and NASA effective dose are then developed using integrated fluence above 200 MeV (Φ_{200}), which by far have the most weight in the calculation of doses for deep-seated organs from exposure to extreme SPEs (GLEs or sub-GLEs). The unconditional probability of a BFO dose exceeding a pre-specified BFO dose limit is simultaneously calculated by taking into account the distribution of the predictor (Φ_{30}, Φ_{60}, Φ_{100}, or Φ_{200}) as estimated from historical SPEs. These results can be applied to the development of approaches to improve radiation protection of astronauts and the optimization of mission planning for future space missions.

A generalized approach for modelling deep space radiation exposures

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Efforts are currently underway to understand the radiation exposure to crew during deep space exploratory missions. It is necessary to accurately assess the radiation dose crew will receive as this can impact the number of 'safe days' in space beyond which prescribed dose limits will be exceeded. The primary source of radiation during transits to the Moon and Mars is galactic cosmic radiation (GCR), which is modulated by the level of solar activity. Solar particle events (SPEs), should they occur, represent an additional acute radiation hazard. These primary sources of radiation, in turn, will be modified by vessel and habitat shielding resulting in a secondary scatter environment that is inherently unique. Monte Carlo radiation transport codes provide a means to accurately transport such spectra through complex shielding geometries, but they can be time consuming. Given that several models currently exist for describing the GCR environment throughout a solar cycle, and several methodologies have been proposed to model the energy spectra of SPEs, it is clear that uncertainty exists in our understanding of the deep space radiation environment. Without knowing which model is correct, each source distribution must be transported independently to assess the radiation dose received; additionally, any future iteration of these source spectra must also be transported. Rather than transporting defined source spectra, Monte Carlo radiation transport codes can be used to generate a database of secondary scatter production for incident, mono-energetic radiation exposure scenarios. This database can then be used to assess the dose resulting from any primary spectral distribution quickly and efficiently without the need for further Monte Carlo modelling. This methodology will be demonstrated for sample SPE spectra.

Utilization of ground experiments for reliable dose estimate in space

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The career of astronauts is dependent mostly on the lifetime dose received from primary cosmic rays and secondary particles generated within the structuring materials of a space craft. Since the high energy protons have the highest abundance and significantly contribute to the dose, the study of the response of solid state nuclear track detectors (SSNTDs) to these particles has a great importance. SSNTDs, having been used for dosimetry on the International Space Station (ISS), were exposed to different high energy proton beams at several accelerators (recently at the Proteus cyclotron, IFJ PAN – Krakow and earlier at Loma-Linda, BNL, TSL). The incident high energy protons generate secondary particles as recoils and fragments of the constituent elements of the detector material ($C_{12}H_{18}O_7$) similarly to those forming the human tissue. These secondaries induce latent tracks inside the detector which can be visualized by chemical etching and investigated by optical microscope. The measurable track parameters and appropriate calibration allow to determine the linear energy transfer (LET) spectrum of the fragments and also the absorbed dose in the nearly tissue equivalent detector material. The LET spectra of the different exposures will be presented and compared. Additionally, some LET spectra obtained from the DOSIS-3D and SPD experiments on the ISS will be compared to those obtained from accelerator irradiations.

Deconvolution study of the glow curves of LiF:Mg,Ti and LiF:Mg,Cu,P

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Dose mapping in space, individual monitoring of astronauts and space biological experiments require passive, small, safe and light detectors which are able to measure doses for the whole range of particles and energies. For this, a combination of luminescent and track etch detectors is currently used on spacecraft, although the dose assessment process with track etch detectors is very time consuming, requires specialized equipment and personnel and cannot be performed directly in space.

Aiming to explore the possibility of determining total radiation doses in space with luminescent detectors only, ^{6}LiF:Mg,Ti, ^{7}LiF:Mg,Ti, ^{6}LiF:Mg,Cu,P and ^{7}LiF:Mg,Cu,P detectors were exposed to protons, helium and carbon ions to investigate the relative efficiency LET dependence of the different peaks composing their glow curves. In order to resolve the different peak contributions, computer assisted deconvolution of the glow curves was performed. A general decrease of the relative efficiency with the increase of the LET was found for both LiF:Mg,Ti and LiF:Mg,Cu,P detectors. Exceptions to this trend are represented by the high temperature peaks of LiF:Mg,Ti detectors which appear to be enhanced by high LET radiations. Furthermore, differences in the structure of the LiF:Mg,Ti high temperature peaks between the different isotopic compositions were found and discussed.

Consequently, an analysis of the glow curve peak structure was performed using the high temperature ratio (HTR) method. This method uses the different LET dependence of LiF:Mg,Ti main and high temperature peaks for the determination of the average LET of the incident particles. The goal of this study was to investigate if the use of deconvolution software could improve the performances of the HTR method. It was found that it was possible to obtain two parameters (called A-HTR) using the ratio between the deconvoluted high temperature peaks 6 or 7 over the main peak 5. For detectors irradiated with the same radiation quality, these two A-HTR parameters are characterized by typically 2-3 times lower dispersion in comparison with the classical HTR method.

Progress report on CANDY silicon detector

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CANDY is our humble attempt to develop an open source silicon cosmic ray detector. Reasons for a construction of a novel detector will be discussed. Then some experiments performed on prototypes and their results will be shown. Presented experiments comprise tests aboard commercial aircraft, stratospheric balloon flight and measurements utilizing laboratory sources of ionising radiation. The intention to develop CANDY was introduced at WRMISS 2015. The progress achieved during one year of development and experiments will be reported.

Mosfet used on Space Satellite

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Metal-Oxide-Semiconductor Field Effect Transistor (MOSFET) dosemeters can be successfully applied in space dosimetry. They have numerous advantages such as: low cost, small size and weight, robustness, accuracy of measurement, real-time or delayed direct read-out and information retention with small fading, possibility of integration with other sensors and/or circuitry. In addition they can be used without power supply during irradiation i.e. as passive dosemeters and measure a large dose ranges, which is very important for a dosemeter used in space.

Up to now MOSFET dosemeters have been used in space dosimetry mainly for measurements of protons and electrons, but the neutrons contribution to the total ambient dose equivalent during space mission is not negligible. Neutrons contribute up to 30% of the dose equivalent of the intravehicular crew exposure. Therefore the neutron ambient dose equivalent is an important component to be studied.

The pMOSFETs used has been developed at LAAS (CNRS), Toulouse, France in corporation to Electronics Laboratory, School of Physics, Aristotle University of Thessaloniki (AUTH) Greece. The electronic dosimeter has been irradiated at neutron, photon, heavy ions and proton fields. Regarding the response to high-energy protons irradiations have been performed at HIMAC accelerator (Japan), through the frame of ICCHIBAN (Intercomparison for Cosmic ray with Heavy Ion Beams At NIRS) collaboration.

After calibration the MOSFET dosimeters were participated in FOTON M4 exposures.

An update on Monte Carlo simulations of the radiation environment at space tourism altitudes

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Commercial space tourism companies, such as Virgin Galactic, are anticipated to begin operation in the near future. They will offer the general public voyages to suborbital altitudes, near the edge of space, at approximately 100 km altitude. This unique experience will last several hours from liftoff to touchdown with a brief, few minutes of weightlessness expected in between. It is well known that commercial airline crew flying below 20 km and space crew in low-Earth orbit at 400 km, receive elevated annual radiation doses relative to the general public. The radiation environments of these two regimes are unique and well-studied. The suborbital radiation environment is similarly unique, but remains poorly characterized. Given that crew can expect to repeat these journeys to near space many times throughout a calendar year, it is important to understand the radiation doses they will experience in anticipation of elevated exposure levels. In 2014, Monte Carlo simulations were done of the secondary neutron fields, from surface altitudes to low-Earth orbit produced by galactic cosmic radiation (GCR) interacting with Earth's atmosphere. Included were estimates of the neutron ambient and effective dose equivalent rates as a function of altitude. In that work, the Badhwar O'Neill 2010 GCR model at solar minimum was used to describe the incident space radiation environment. The NRLMSIS-00 atmospheric density model was used to describe Earth's atmosphere. Furthermore, a methodology was devised to accommodate the influence of varying magnetic field strengths on secondary neutron production. In this presentation, revised estimates of the secondary neutron fields will be provided. Additional estimates of the secondary proton and helium nuclei (alpha) fields, for a 5 GV cutoff rigidity, will also be presented.

Pille Measurements on ISS (April 2015 – December 2015)

A. Hirn[1], I. Apáthy[1], V. A. Bondarenko[2], S. Deme[1], I. Fehér[1], O. Ivanova[2], V. Mitrikas[2], I. V. Nikolaev[3], T. Pázmándi[1], V. A. Shurshakov[2], P. Szántó[1], V.V.Tsetlin[2]
A. Hirn[1], I. Apáthy[1], V. A. Bondarenko[2], S. Deme[1], I. Fehér[1], O. Ivanova[2], V. Mitrikas[2], I. V. Nikolaev[3], T. Pázmándi[1], V. A. Shurshakov[2], P. Szántó[1], V.V.Tsetlin[2]

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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 50000 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.

In the present paper the measurement data (including several EVA measurements) obtained by the Pille system from the period between April 2015 – December 2015 are presented. The results are compared with previous measurement results.

Matroshka-R and Radi-N2 Experiments using Bubble Detectors: ISS-43/44 and ISS-45/46

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Radiation protection is a high-priority issue for human spaceflight that becomes more important as both the length of the mission and the distance from Earth increase. Neutrons encountered in low-Earth orbit (LEO), for example on the International Space Station (ISS), are produced predominantly by 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. Over the last decade, bubble detectors have been used to characterise neutron radiation on the ISS for the Matroshka-R, Radi-N, and Radi-N2 experiments. During the ISS-13 (2006) to ISS-42 (2014/15) missions, a series of measurements was performed in both the Russian Orbital Segment (ROS) and the US Orbital Segment (USOS) of the ISS.

The Matroshka-R and Radi-N2 experiments continued to collect data during the recent ISS-43/44 and ISS-45/46 expeditions in 2015/16. The Radi-N2 measurements continued in four modules of the USOS: Columbus, the Japanese Experiment Module, the US Laboratory, and Node 2. The goal of Radi-N2 is to characterise the neutron dose equivalent and energy distribution in these four locations over a prolonged period of time, enabling an assessment of potential influence quantities such as location within the ISS, solar activity, and ISS altitude. The recent Radi-N2 results are not significantly different from the earlier Radi-N and Radi-N2 surveys in the same ISS locations, despite the large variations in solar activity since the Radi-N study started in 2009. Aggregation of all the data from each of the four USOS modules shows that the neutron field in each location is similar.

During ISS-43/44 and ISS-45/46, Matroshka-R measurements in the ROS largely focussed on investigating the effect of shielding materials on the neutron dose equivalent and energy spectrum. Experiments were performed in the Zvezda Service Module to assess the effect of a hydrogenous shield on the neutron field. The results of these measurements are compared to earlier results obtained using the same shield. Surveys were also performed to compare the neutron field in two locations thought to be the least and most shielded in the Service Module, based on empirical and theoretical analysis. The results of these measurements suggest that there is no major difference in the neutron field in these two locations.

CONSTRUCTION OF LONG TERM INTERPLANETARY H AND HE DATASETS IN THE FRAMEWORK OF THE ESA SEPEM/ESHIEM/ SEPCALIB PROJECTS

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During the ESA SEPEM, ESHIEM and SEPCALIB projects, long term (1974-2015) cross-calibrated interplanetary proton and He datasets were constructed using data from the IMP8/GME instrument and the EPS instruments on a series of GOES spacecraft.

GOES/SEM/EPS H and He data from 1974 to end of 2015 were processed to remove data spikes and fill data gaps. IMP8/GME H and He data were also despiked, and data points affected by saturation or dead time effects were removed. Extensive work has been carried out to correct for a failure in the IMP8/GME LED telescope which resulted in significantly increased background. The corrected GME H dataset was used to define mean energies for each of the GOES/SEM/EPS H energy bins (the so-called effective energy). Similarly, the GME He dataset was used to define effective energies for each of the GOES/SEM/EPS He energy bins. The resulting reference datasets take advantage of the benefits of a highly resolved long-term science instrument (GME) and radiation monitor data which does not saturate during large SPEs (EPS).

This analysis has produced consistent and contiguous GOES H and He datasets spanning more than 40 years (the datasets for the individual GOES spacecraft were re-binned to a common set of reference energies). These are now the primary data source for further analysis for deriving SEP models for H, He and heavier ions which can be particularly important for deriving single event effect rates in components and effects on humans in space.

The H dataset was used to compile an SEP event list (305 events in total), which was in turn used to define quiet and disturbed periods for background removal in the He data.

The new datasets and event list will be available on the SEPEM application server for plotting and limited downloads. In addition, the complete datasets have been made available on an ESA download site (ftp://ftp.estec.esa.int/private/pjiggens/anonymous/SEPEM_RDS_v2-00.zip).

DOSIS & DOSIS 3D: Long term dose monitoring onboard the Columbus Laboratory of the International Space Station (ISS) – Current status

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The radiation encountered in space differs in nature from that on Earth, consisting mostly of highly energetic ions from protons up to iron, resulting in radiation levels far exceeding the ones present on Earth for occupational radiation workers. Since the beginning of the space era the radiation exposure during space missions has been monitored with various passive and active radiation instruments. Also onboard the International Space Station (ISS) a number of area monitoring devices provide data related to the spatial and temporal variation of the radiation field in – and outside the ISS. The aim of the DOSIS (2009 – 2011) and the DOSIS 3D (2012 - ongoing) experiment was and is the measurement of the radiation environment within the European Columbus Laboratory of the ISS. These measurements are, on the one hand, performed with passive radiation detectors mounted at eleven locations within Columbus for the determination of the spatial distribution of the radiation field parameters and, on the other hand, with two active radiation detectors mounted at a fixed position inside Columbus for the determination of the temporal variation of the radiation field parameters. Data measured with passive radiation detectors showed that the absorbed dose value inside the Columbus Laboratory follows a pattern with minimum dose values observed in the year 2010 of 195 to 270 µGy/day and maximum values observed in the year 2012 with values ranging from 260 to 360 µGy/day. The absorbed dose is modulated by (a) the variation in solar activity (b) by the changes in ISS altitude as well as (c) by the local shielding within the Columbus Laboratory. The talk will give an overview of the current status of the DOSIS 3D experiment and will present latest results from the passive detectors onboard Columbus.

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The DOSIS and DOSIS 3D experiments on-board the International Space Station – Results from the DOSTEL Instruments

Soenke Burmeister[1], Thomas Berger[2], Johannes Labrenz[1], Matthias Boehme[3], Lutz Haumann[3] and Guenther Reitz[2]

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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 (since 2012) experiment.

The CAU contributions to DOSIS and DOSIS 3D are financially supported by BMWi under Grants 50WB0826, 50WB1026, 50WB1232 and 50WB1533.

Contribution of galactic cosmic rays and of Earth radiation belt into the daily dose aboard the ISS determined by the data of RMS ISS

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We continued analysis of a data array obtained earlier by means of the operational radiation monitoring system of the International space station (RMS ISS) to separate contribution into the daily absorbed dose from the galactic cosmic rays (GCR) and from the inner Earth radiation belt (ERB). We developed a corresponding technique based on dosimetric data obtained by detectors DB-8 of RMS ISS.

We performed data processing for the period from July 2005 to the end of 2010, and the results were included in this report. Contribution into the daily absorbed dose from the GCR varied from 0.08 mGy/day in July 2005 to 0.11 mGy/day in November 2009 followed by decrease to 0.10 mGy/day by December 2010, and it was essentially independent on the shielding of DB-8 detectors. Contribution to the daily dose from the ERB varied from 0.06 mGy/day to 0.14 mGy/day (based on the data from the most shielded DB-8 detector unit) and from 0.15 mGy/day to 0.31 mGy/day (based on the data from the least shielded DB-8 detector unit), and it depended significantly on the detector shielding and on the station orbit altitude.

Also the report includes details on the developed technique of dosimetric data processing that allows separation of the contribution into daily dose from GCR and from ERB for the whole time span of available data from detectors DB-8 of RMS ISS from 2001 up to the end of 2014 that covers the period from the maximum phase of the 23th solar cycle to that of the 24th one.

Overview of the ISS radiation environment observed during EXPOSE-R2 mission in 2014-2016

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The R3DR2 instrument performed measurements in the ESA EXPOSE-R2 platform outside the Russian "Zvezda" module of the ISS in the period 23 October 2014-11 January 2016 at an average altitude of 415 km and 52.6° orbit inclination. R3DR2 is Liulin-type deposited energy spectrometer (DES) (Dachev et al., 2015). Using specially developed software and experimentally derived formulas for the relation between the specific dose and the type of the predominant radiation source the R3DR2 data were sorted into four separate categories: (i) galactic cosmic ray (GCR) particles and their secondary products with a daily average dose rate of 71.6 mGy d^{-1}; (ii) protons in the South Atlantic Anomaly (SAA) region of the inner radiation belt (IRB) with a daily average dose rate of 567 mGy d^{-1}; (iii) relativistic electrons and/or bremsstrahlung in the outer radiation belt (ORB) with a daily average dose of 278 mGy d^{-1} (but it is practically 0 in magnetically quiet periods and reaches almost 3000 mGy d^{-1} in the periods after magnetic storms); (iv) 12 solar energetic proton (SEP) events were observed in the data. During the largest SEP event on 22 June 2015 the hourly dose rate reached more than 5000 mGy h^{-1} (Dachev et al., 2016a).

Dachev, T. P. et al., (2015), Life Sciences in Space Research, 4, 92–114. http://dx.doi.org/10.1016/j.lssr.2015.01.005
Dachev, T. P. et al., (2016a), Radiation Protection Dosimetry, 2016. (accepted paper) http://dx.doi.org/10.1093/rpd/ncw123
Dachev, T. P. et al., (2016b), Life Sciences in Space Research, LSSR_2015_11. available online at http://dx.doi.org/10.1016/j.lssr.2016.03.004

The energetic Solar Particle Events (SPEs) measured by ALTEA in the ISS during the ALTEA-shield experiment (2011-2012): first 1.5 years long study of SPE radiation inside a space habitat.

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Radiation risk mitigation during planetary human exploration requires 'ad hoc' SPE forecasting. Understanding the parameters of the SPE that produce events leading to higher health risks for the astronauts in deep space is a first priority issue, and a needed information for the construction of an optimized forecasting tool. In principle this can be simulated, however it is difficult to define a 'typical' realistic spectrum of a SPE and even more difficult to model the amount and the dynamic of the shielding mass distribution to produce a meaningful transport simulation.

Measurements of SPE effects with active devices inside the ISS can also be used for this purpose. They are limited by the detector performances (acceptance window in kinetic energy, rate, energy transferred, etc.), and refer to a specific detector positions in the ISS (for which we have qualitative knowledge of the mass distribution around the detector), but they produce valid information for the specific SPEs measured, in those circumstances. Active detectors can select data from specific geo-magnetic regions along the orbits, choosing orbital tracts best mimicking deep space radiation.

ALTEA is an active detector system with tracing and spectrometric capability. The data presented here were collected in the USLab and in Columbus in 2010 - 2012 (ALTEA shield experiment sponsored by ESA).

In the studied period ALTEA has measured effects from 18 SPEs (all of the SPEs in the NOAA catalog when ALTEA was in operation). These effects and their relation to the GOES proton flux, as well as to the qualitative knowledge of the shielding and to the modulation due to the Earth geomagnetic field, will be presented and discussed. Some of the characteristics of the measurements that are not fully understood and not simply linkable to those parameters will be underlined.

Finally, an upgrade of the ALTEA detector system, due to be launched in the ISS in 2017-18, will be shortly presented.

Shielding evaluation of the ISS 'KIBO' hull wall for space radiation between radiation dosimetry inside/outside and PHITS simulation

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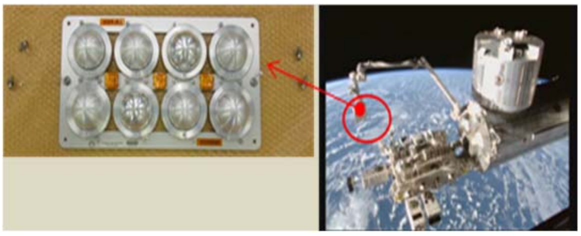
Various study and technology development demonstration related to radiation health management have been conducted on the international space station (ISS) as testbed towards human space flight beyond the LEO. Since shielding effects of each ISS module have not been looked at so far, instead results inside and outside the orbiters in LEO/BLEO are used for verification of ISS hull wall shielding contribution and a benchmark study to develop existing simulation codes and space radiation models, EVA risk assessment, and shielding the design of future space vehicles toward future interplanetary missions.



Configuration of Free Space PADLES experiment on the MPEP

For this purpose, we have conducted Free-Space PADLES experiments outside of Japanese experimental module 'KIBO' part of the ISS for consecutive 14 days from 1 June to 14, 2015 in total flight duration for 240 days from 15 April to 11 December, 2015. The Free-Space PADLES equipment was installed on the Multi-Purpose Experiment Platform (MPEP) facing to the AFT, in a tip of the JEM Remote Manipulator System (JEMRMS) in the measurement position for the Free-Space PADLES outside of the ISS (See Figure 1). After being exposed ISS outside, they are transported inside through the hatch of the 'KIBO' airlock and recovered to the ground. Each shielding case has two sets of PADLES dosimeter and two thermal loggers (CRES305/Maxim integrated Co.). Each PADLES dosimeter includes 4 CR-39 plastic nuclear track detectors (PNTDs) measuring for higher LET regions >10 keV/μm and 7 TLD thermoluminescent dosimeters for lower LET regions ≤10 keV/μm. The thermal loggers recorded the temperature every 15 minutes. Each case condition kept in 1 atm with dry air due to an O-ring seal.

This work will be expected to evaluate the shielding effect of ISS hull walls by direct comparative and simultaneous study with inside and outside measurement results. To obtain dose reduction rate under thinner shielding condition than inside the ISS 'KIBO', we designed the Free-Space PADLES equipment as follows, - 8 sealed and hemisphere shielding case with varying thickness between 0 to 4 mm in aluminum and those bases are 3 mm in aluminum.
The temperature obtained by 16 thermal loggers inside shielding case shows good agreement each other, in the range of -12 to 27.5 ℃ (average temperature: -1 ℃) for 14 days outside of the ISS 'KIBO'. The β angle for the 14 days varied at +74 ° to +18 ° from the beginning. Before and after exposure, the Free-Space PADLES equipment was kept under room temperature inside the ISS 'KIBO' experiment rack, with flight-control PADLES dosimeter stored inside the experiment rack for 240 days. Under vacuum environment, the track formation sensitivity for space radiation particles of the CR-39 PNTDs is decreasing with the change of gas pressure. Therefore dosimeter case held at 1 atm inside and outside the ISS.

On this occasion, we will present preliminary date with actual measurements. Also we will report the status of benchmark study with PHITS code which is incorporated in the well-developed 'KIBO' geometry (computational projections) and the shielding construction of Free-Space PADLES equipment.

RADIATION PROTECTION PROPERTIES OF ADDITIONAL SHIELDING «PROTECTIVE CURTAIN» INSTALLED IN CREW CABIN OF RUSSIAN SEGMENT OF ISS

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According to radiation monitoring crew cabins in the Russian segment of International Space Station (ISS) are known to be less protected against space radiation comparing to neighboring compartments. Special additional shielding “Protective curtain” was designed and delivered to ISS in 2010 year. Protective curtain is a tissue bag, where unused hygienic wipes and towels were stored in 4 layers. Protective curtain was installed along outer wall, the less protected location of crew cabin of RS ISS. The thickness of outer wall is estimated as 1.5 g/cm^2 and the thickness of protective curtain is about 6 g/cm^2 thus protective curtain is considered to have tangible effect against radiation.

Measurements of absorbed and equivalent dose levels in were done with thermoluminescent (TLD) and plastic nuclear track (PNTD) detectors. 6 packages were located on the protective curtain surface, another 6 packages were installed on other side or on the crew cabin well aside. TLD and PNTD were exposed during 6 sessions in period of 2010 – 2016 years. Additional sessions of measurements were done with “Bubble-detector” and “Pille-ISS” detector. Results of TLD and PNTD measurements shows that ratio between dose in protected locations and unprotected ($D_{protected}/D_{unprotected}$) varies from 53 to 93 % for absorbed doses and 52 to 97 % for equivalent dose. Measurements by “Bubble-detector and Pille-ISS” are presented and are in good agreement with TLD and PNTD results. It is shown that properly mounted local shielding can effectively mitigate the radiation dose in space station compartments.

ALTEA Measurements on radiation shielding efficacy of Kevlar, compared to Polyethylene performances, in the International Space Station

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Passive radiation shielding is a mandatory element in the design of an integrated solution to mitigate the effects of radiation during long deep space voyages. Understanding and exploiting the characteristics of materials suitable for radiation shielding during space flights is therefore of primary importance in human space exploration. In particular Kevlar, which features several useful properties such as protection against space debris, has shown interesting characteristics as passive radiation shield in ground tests.

We present here the first complete space test of the radiation shielding capability of Kevlar performed onboard the ISS (Columbus) during the ALTEA – shield ESA sponsored program.

Kevlar results are compared with Polyethylene results acquired during the same program. Polyethylene is a known material widely used for radiation shielding and therefore an excellent baseline to be used as comparison. Kevlar shows radiation shielding performances similar, if not better, to the Polyethylene ones, reaching a dose equivalent reduction of about a factor 2 for a shield of 10 g/cm2.

Comparisons with previously published ground based measurements are also presented.

EuCPAD: First Results from the European Crew Personal Active Dosimeter (OpNom: ESA Active Dosimeter – EAD) on board the International Space Station (ISS)

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Over the last decade human presence in space has increased significantly. Extended missions lasting half a year or more became "standard" scenarios. Challenges to human health and wellbeing are though still significant, increasing with mission length and workload. Expanding 'medical' demands are not a solely characteristics of upcoming mission scenarios. Challenges to efficiently utilize the fully operational science platform ISS are immense. Understanding, accepting and approaching those circumstances ESA-HSO did choose a particular pass of implementation this current development with the EuCPAD project. The European Crew Active Dosimetry (EuCPAD) (OpNom: EAD) hardware shall enable advanced personal dosimetry capabilities in real time. It provides a differentiated set of exposure data, supports risk assessment and dose management. It´s final goal is the verification of the system capabilities at highest standards enabling for operational use and medical monitoring in the future. The system consists of several small portable Personal Active Dosimeters (MU = Mobile Unit´s) as well as a rack mounted docking station called "Personal Storage Device (PSD)". The PSD provides data read-out data and advanced display capabilities as well as data storage and telemetry. The PSD contains a Tissue Equivalent Proportional Counter (TEPC) and an internal MU (iMU) for advanced analysis of the complex radiation environment in the space station and to ensure means of cross calibrations. A first technology demonstration activity (launching two Mobile Units to the ISS) was performed during the Short Duration Mission (SDM) in September 2015. On July 18th 2016 the full hardware set was launched with Space-X 9 to the ISS and started operation in Columbus on July 28th 2016. The presentation will give an insight into the technical system and provide an overview of the relevant space radiation data generated till September 2016.

Acknowledgements: The EuCPAD development was carried out with funding from the ESA GSTP program under ESA contract No. 4200023059/09/NL/CP (Technical Project Management: Matthias Dieckmann ESA-ESTEC).

First Results from the ISS-RAD Charged Particle Detector

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The Charged Particle Detector (CPD) subsystem of the ISS-RAD detector has been making measurements of high-energy charged and neutral particles since the unit was deployed on Feb. 1, 2016. The CPD is nearly identical to the MSL-RAD instrument, but onboard data processing has been significantly modified to meet ISS requirements. We will present dose rates and LET spectra obtained over the first six months of operations, as well as preliminary results obtained from the limited sample of pulse-height analyzed raw data that has been telemetered to Earth.

Preliminary On-Orbit Neutron Dose Equivalent and Energy Spectrum Results from the ISS-RAD Fast Neutron Detector (FND)

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The ISS-RAD instrument was activated on ISS on February 1st, 2016. Integrated in ISS-RAD, the Fast Neutron Detector (FND) performs, for the first time on ISS, routine and precise direct neutron measurements between 0.5 and 8 MeV. Preliminary results for neutron dose equivalent and neutron flux energy distributions from online/on-board algorithms and offline ground analyses will be shown, along with comparisons to simulated data and previously measured neutron spectral data. On-orbit data quality and pre-launch analysis validation results will be discussed as well.

Comparison of RAM dose data with calculated dose using an updated ISS CAD model

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The Space Radiation Analysis Group (SRAG) maintains CAD models of the entire International Space Station that includes details such as the pressure shell, module structure, and fairly detailed approximations for the internal racks. Recently, these models have been improved to match the as-flown vehicle mass at the rack level. Shielding distributions have been calculated for various ray configurations from points along the central axes of all the modules as well as locations where Radiation Area Monitor (RAM) measurements have been made. These distributions are presented here as well as comparisons with measured and calculated doses based on the HZETRN 2015 radiation transport code for the LEO environment.

Update on the NASA Plans for Dosimetry in Support of Manned Spaceflight

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NASA has updated the active monitoring suite for ISS operations and is now developing new systems to support exploration missions. 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 has developed a neutron spectrometer called the Fast Neutron Spectrometer (FNS) that will be flown and tested on ISS in the coming year. In addition to the hardware developments, a comprehensive comparison of the ISS Medipix-based Radiation Environment Monitors (REM) measurement data with modelled results from current NASA radiation transport codes and updated shielding distributions has been carried out by the RadWorks team. A new source of heavy ion data for GCR model improvement from the AMS-02 experiment is now available via the University of Hawaii (AMS-02 collaborators) in partnership with RadWorks.

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

Radiation investigations onboard ExoMars missions. Results for radiation parameters during TGO cruise to Mars.

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Presented are the scientific objectives and instrumentation for investigation of the radiation environment onboard the ExoMars 2016 and 2020 missions to Mars. Described are: 1) The charged particle telescope and the experiment Liulin-MO for measurement the radiation environment onboard the ExoMars 2016 Trace Gas Orbiter (TGO) satellite as a part of the Fine Resolution Epithermal Neutron Detector (FREND) and 2) Liulin-ML experiment and instrument for investigation of the radiation environment on Mars as a part of the active detector of neutrons and gamma rays ADRON-EM on the Surface Platform for ExoMars 2020 mission. The preliminary results for the radiation quantities obtained during the TGO cruise to Mars will be discussed.

Latest Results from the MSL-RAD Experiment

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The RAD instrument aboard the Curiosity rover, now in its fourth year of operation on Mars, continues to return dosimetric and spectral data to characterize the radiation environment in Gale Crater. Several updates to the flight software and configuration have been implemented, leading to improvements in both data quality and volume. We will review these changes, as well as presenting updated dosimetry results and a new method for determining neutral particle dose rates.

The dependence of Martian surface radiation on atmospheric depth

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The energetic particle environment on the Martian surface is influenced by solar modulations and changes in the local atmospheric pressure (or column depth). The Radiation Assessment Detector (RAD) on board Mars Science Laboratory (MSL) rover Curiosity on the surface of Mars has been measuring this effect for over four years. The anti-correlation between the recorded surface Galactic Cosmic Rays (GCRs) induced dose rates and pressure changes has been investigated by Rafkin et al. (2014) and the long-term solar modulations have also been empirically analyzed and modeled by Guo et al. (2015).

This work employs the newly updated HZETRN2015 code to model the Martian atmosphere shielding effect of the accumulated dose rates and the change of this effect under different solar modulations and atmospheric conditions. The modeled results are then compared with the most up-to-date observations of the RAD instrument on the surface of Mars. Both models and measurements agree with each other reasonably well in supporting the atmospheric shielding effect under small solar modulations and the decline of this effect as solar modulations become stronger.

Particle spectra on the Martian surface – An update on the comparison of models and MSL-RAD measurements

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Since the landing of the curiosity rover on Mars on August 6th 2012 the MSL-RAD instrument has measured the radiation environment on the surface. MSL-RAD has been the first instrument that has provided detailed information about charged and neutral particle spectra and dose rates on the Martian surface. In this work, several numerical radiation transport models are used to predict the radiation environment caused by galactic cosmic rays on Mars in order to validate them with the experimental results. The goal is to identify models suitable for providing information about the radiation environment complementing the measurements of particle spectra and the radiation exposure on the Martian surface. Such models can be used to predict dose rates for future manned missions to Mars or other celestial bodies as well as for performing shield optimization studies.

With proper choices of input parameters and physical models, in many cases a good agreement was found for GEANT4, PHITS and HZETRN/OLTARIS simulations with the MSL-RAD results. This indicates an applicability of these models to more detailed studies on how the radiation environment is influenced by the solar modulation, the Martian atmosphere and soil, and changes due to the Martian seasonal pressure cycle. By extending the range of the calculated particle spectra with respect to the experimental data additional information about the radiation environment is gained, and the contribution of different particle species to the dose is estimated.

In a recent workshop the inter-comparison was extended to other simulation packages with a newer set of RAD measurements.

Orion Exploration Mission 1: Proposed Radiation Measurements in Cislunar Space

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The Orion Multi-Purpose Crew Vehicle (MPCV) is NASA's next generation human rated Exploration-class spacecraft, designed and built by a contractor team led by Lockheed Martin. Orion's first mission - Exploration Flight Test 1 (EFT-1) - was successfully executed on December 5, 2014. The EFT-1 trajectory included a high eccentricity / high re-entry energy orbit with an apogee of 3600 miles. During the flight, the spacecraft traversed the core of the inner (proton) van Allen belts and was exposed to energetic protons of fluence rate peaking at more than 2E+4 p/cm2-s at E>50 MeV. Six GFE passive dosimeter kits (Radiation Area Monitors RAMs) were flown inside the Crew Module. Radiation analysis performed pre-flight predicted dose at these locations to be in the range of 9.52–22.8 mGy. The predictions were found to agree with measurements within ratios of 0.96-1.4, exceeding expectations in the context of uncertainties inherent in the AP-8 proton belt environment model. During the proton belt transit, the increased proton flux caused on-board video cameras to exhibit visual effects commonly observed in high radiation environments such as patient monitoring during radiotherapy procedures, and referred to as "snow and streaks". Post-processed images containing radiation induced noise will be presented for different mission phases and correlated with the predicted proton flux.

Orion's upcoming flights are referred to as Exploration Mission 1 (EM-1), and Exploration Mission 2 (EM-2), and are scheduled for September 2018, and August 2021, respectively. EM-1 is an unmanned test flight to cislunar space, designed to prove crewed flight readiness of the Orion Spacecraft. This flight presents a unique opportunity for a large scale intravehicular dosimetry intercomparison, in an environment that has not been explored by a human rated spacecraft since the last Apollo mission 46 years before. Lockheed Martin is presenting to the NASA customer and the international radiation dosimetry science community a status on options under consideration and is inviting feedback. Proposed options include flying tissue equivalent anthropomorphic radiation phantoms inside the Orion Crew Module. This approach leverages the MATROSHKA ISS heritage, the radiation dosimetry expertise of the WRMISS community, and the successful track record of DLR for integration of science data. Additional objectives under consideration include assessment of radiation protection strategies complementary to the Orion baseline crew radiation protection scenario. Such solutions include the AstroRad individual radiation shield, currently under development by Lockheed Martin and StemRad in anticipation of future Exploration Missions performed by expanded architectures including additional elements such as Deep Space Habitats. Radiation measurements represent an excellent opportunity to maximize science return of EM-1 at minimal impact to the Program, and ultimately to improve Astronaut safety.

Update on Medipix Developments

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The Timepix3 chip from the Medipix3 Collaboration has continued to be evaluated. It has shown exceptional speed capabilities with a modest USB2 interface, and a new USB3 interface that should reach 50% of the design rate capability (continuous ~81 MHz pixel hits with no dead-time) with no dead time. On the Medipix2 front, the timepix2, the replacement for the current Timepix, had completed the design phase and the first chips should be available in Q1 2017. That chip will have a new large dynamic range front end to enable seeing the full range of energy depositions from minimum ionizing particles through stopping fe particles. In addition the Timepix2 will have both TDC-Time-Of-Arrival (TOA) and ADC-Time-Over-Threshold (TOT) readouts with 28 bits available for data storage in each pixel. The Timepix2 will also have a number of additional useful features, and will be almost control compatible with existing Timepix interfaces.

The Medipix4 Collaboration has just formed, and is in the early stages of defining the capabilities to be included in the next generation of detector chips with the latest chip fabrication technologies. These will combine the strengths of both the current Timepix/Timepix2 and the Timepix3 chips with a number of power-saving modes to allow prolonged low power operation with reduced capability, with high-speed switching to full-power modes. The first Timepix4 chips are likely to be available for initial testing and evaluation in late 2018.

Description of the Liulin-ISS-2 system for personal dosimetric control of Russian cosmonauts inside and outside ISS

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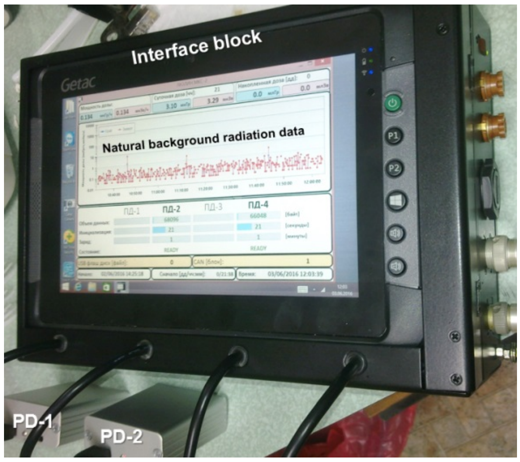

Under a contract between Space Research and Technology Institute, Bulgarian Academy of Sciences, Institute of Biomedical problems, Russian Academy of Sciences and S.P. Korolev Rocket and Space Corporation Energia an engineering model of new system named “Liulin-ISS-2” for personal dosimetric control of Russian cosmonauts inside and outside ISS was developed. It is expected that the new system will replace the Liulin-ISS system, launched to ISS in 2005. The "Liulin-MKS-2" priority is focused on the active measurement with 10 seconds resolution of the dose rate dynamics from galactic cosmic rays (GCR), protons from internal and energetic electrons from external radiation belts, and solar energetic particles (SEP) inside ISS modules and during the extravehicular activity (EVA) of Russian and international cosmonauts. The significance of dose measurements for EVA was formulized during the analysis of the large and rapid variations in space and time of the doses obtained simultaneously at two different locations outside the ISS (Dachev, 2013). Liulin-ISS-2 system consists of 4 portable dosimeters (PD) and interface block (IB) with internal dosimeter. The PD with size 64x60x30 mm is based on the traditional Liulin type DES (Dachev et al., 2015) block diagram with 2 cm^2 0.3 mm PIN diode. The analysis of the obtained deposited energy spectra will be performed according the ideas for intelligent crew personal dosimeter (Dachev et al., 2011) and new experience obtained during the data analysis from the R3DR2 instrument outside ISS in the period October 2014-January 2016 (Dachev et al., 2016a and 2016b). SAFT prismatic lithium-Ion rechargeable battery, endorsed for space use, is used in the PD and allows more than 7 days independent work of the PD with 10 sec resolution. Thermostat and manageable heater are implemented to keep the temperature of the PIN diode not smaller than -20 °C during EVA when in the external spacesuit pocket. The PD can work independently from ID trough USB connection and special software with any other PC. The interface block with size 250x180x80 mm is based on a Getac T800 (http://www.getac.com/) fully rugged tablet PC in compliance with the requirements and procedures of MIL-STD-810G, and under Windows-8 operational system. Through 8 ports industrial USB hub the PC manage the system and data transfer toward CAN interface and/or flash memory stick. Continuously the last 90 minutes data, obtained with the internal dosimeter are visualized on the screen of the PC.

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CZENDA – the Czech Experimental Novel Dosimetry Assembly aboard the BION-M2 Russian satellite

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The BION-M2 satellite will be launched for duration of 30 days in 2021. Purposes of the Bioradiation experiments organized by IBMP RAS are (1) study of biologically significant characteristics of space ionizing radiation and effects of its impact on biological objects in open space and inside the satellite, and (2) research and testing of new methods and means of space dosimetry for their subsequent use in advanced space missions.

CZENDA is the Czech device composed of passive dosimeters (TLDs, track etched detectors, nuclear track emulsions), active dosimeters and radiation field monitors (CANDY, Timepix), lichens and algae equiped with the fluorescence detector, and dry plasmids. In the paper, we'll introduce our plans of several experiments within the CZENDA project:

1. Implementation of the open-source novel dosimetry with the CANDY detector; realtime data will be available for general public during the mission; stratospheric balloon equiped with CANDY will be launched, aircraft and high-mountain measurements with CANDY are planned at the same time,
2. Online quantum-imaging dosimetry of the mixed radiation field in the immediate spacecraft environment focused on wide-dynamic range and high-resolution of: dose rate, dE/dx, LET spectra.
3. Compact particle micro-tracker for directional mapping of energetic charged particles inside the spacecraft module. Enhanced with wide field-of-view and high angular resolution including option to embed (biological) sample for precise tracking of high-LET particles across sample.
4. Accurate assessment of dosimetric quantities (absorbed dose, equivalent dose, the spectra of linear energy transfer - LET) using advanced and well tested passive dosimetry methods throughout the flight.
5. Intercomparison and verification of radiation detection techniques and technologies at LEO.
6. Identification of relativistic nuclei GCR fluxes using a stack of nuclear emulsions (NE); Investigation of the possibility of detection of hypothetical dark matter particles by detecting recoil from the NE material.
7. Study of the biological effects of cosmic radiation on subcellular structure of DNA via exposure of dry plasmids.

To use lichens and algae such as bio-indicators and to test how they withstand the radiation conditions in orbit within the space complex via real-time fluorescence measurements.

Status Report of Active Space Radiation Detector, A-DREAMS-2 at NIRS

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For real time radiation monitoring in space environment, active radiation dosimeters, A-DREAMS have been developed in QST-NIRS. They have silicon semi-conductor detectors and electric circuits to obtain LET distribution of space radiation from protons to iron ions in space radiation. A-DREAMS-2 (AD2), the current version of the A-DREAMS series, was constructed based on the former version, A-DREAM-1. It has two silicon semi-conductor detectors and a coincidence circuit between them to observe space radiation with limited solid angle and limited pass length. We have carried out beam experiments for AD2 with high energy protons and heavy ions accelerated by the NIRS-Cyclotron and the HIMAC in QST-NIRS. From the results of them, the performance of AD2 has been evaluated to be used for the MATROSHKA-III experiment as the future plan.

Development of the radiation and magnetic field measurement payload RadMag

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The research on space weather and its effects will be more and more important in the near future, as a continuous increase in human presence is in progress in the Near-Earth region and the technology dependency of the human civilization has become higher than ever mainly in the fields of energy and telecommunication systems. In 2016, the development of a new space radiation and magnetic field measuring instrument package (RadMag) got underway in the Centre for Energy Research, Hungarian Academy of Sciences to study space weather effects, monitor cosmic radiation and the magnetic field environment, and provide inputs for space weather databases.

The development is realized in the frame of the RADCUBE project of ESA's General Support Technology Programme. By having a compact design following CubeSat standards, monitoring of the cosmic radiation and magnetic field environment will be possible with sufficient statistics in the Near-Earth region on-board a fleet of CubeSats. Additionally the RadMag instrument to be developed can provide a low-cost alternative for supporting radiation damage analysis commercially for future satellite missions as well. The technology demonstration of the system is due in 2019 on board the RADCUBE 3U CubeSat to be developed by C3S Electronics Development LLC.