22nd WRMISS 2017

Conference Program

5 – 7 September 2017

Thales Alenia Space, Torino, Italy

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22st WRMISS Conference Program: Tuesday 5th September 2017

09.00 – 09.15	Welcome
09.15 – 10.00	Invited Talk
10:00 – 10:30	Scientific Session 1
10.30 – 11.15	Coffee/Tea Break
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12.45 – 14.00	Lunch
14.00 – 15.30	Scientific Session 3
15.30 – 16.15	Coffee/Tea Break
16.15 – 18.00	Scientific Session 4

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Walter Cugno, Cesare Lobascio and Martina Giraudo	Welcome and Organisational Issues

Invited Talk

Roberto Battiston	SPACE RADIATION SUPERCONDUCTING SHIELDS - A NEW APPROACH

Scientific Session 1

Matteo Palermo	Solar modulation, Forbush decreases and Solar Energetic Particles with AMS

Scientific Session 2

Francis F. Badavi	Evaluation of galactic cosmic rays (GCR) models using AMS2 data
Atila Hirn	Results and lessons learned from calibration measurements of the TRITEL 3D silicon detector telescope at the HIMAC accelerator facility
Alessio Parisi	Microdosimetric modeling of the relative efficiency of thermoluminescent detectors exposed to charged particles relevant for space applications

Scientific Session 3

A. Rizzo	Time of Flight measurements on-board the ISS: development of LIDAL (Light Ion Detector for ALTEA) apparatus ”
George P. Stuart	Particle Type and Energy Identification in Single Pixellated Silicon Detectors
Martin Kakona	AIRDOS - an open source dosimeter for measurement on board of aircraft
Marianthi Fragopoulou	The sensitivity of p-MOSFET dosemeter to heavy ions

Scientific Session 4

Iva Ambrožová	Contribution of Different Particles onboard Bion-M1 Estimated by Means of Plastic Nuclear Track Detectors
Andrea Stradi	The "PHOENIX" radiobiological experiment on-board the Russian segment of the ISS supported by passive dosimetry - First results
Alba Zanini	Neutron Spectrometry and Dosimetry on spacecraft with passive detector system
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Thomas Berger	DOSIS & DOSIS 3D: Long term dose monitoring onboard the Columbus Laboratory of the International Space Station (ISS) – Current status and work in progress
Cary Zeitlin	Results from the ISS-RAD Charged Particle Detector and Comparisons to MSL-RAD

Scientific Session 6

Martin Leitgab	One and a Half Years Onboard ISS: Neutron Dose Equivalent and Energy Spectrum Results from the ISS-RAD Fast Neutron Detector
Ramona Gaza	ISS Radiation Environmental Monitor (REM) Transition to Operations: RAM to REM Transition

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Ryan Rios	Comparison of Silicon-based Detectors on ISS
K. Kastev	Results from radiation environment investigations on the International Space Station and interplanetary space with Liulin charged particle telescope
Tsvetan Dachev	Relativistic electron precipitation bands in the outside radiation environment of the International space station

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Samy El-Jaby	Update on Radiation Risks to Crew for a Cis-Lunar Mission: A Benchmark of Codes and Simulation Geometries
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ADJOURN

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SPACE RADIATION SUPERCONDUCTING SHIELDS - A NEW APPROACH

Roberto Battiston[1,2,3], Filippo Ambroglini[4,5], Bertrand Baudouy[6] ,Christophe Berriaud[6], Bernardo Bordini[7], Silvia Brisigotti[8], Romain Bruce[6], William Burger[2,9]; Valerio Calvelli[10], Roberto Destefanis[11], Fabrizio Duo[12], Alberto Franzoso[12], Enrico Gaia[11], Martina Giraudo[11,13], Matteo Grespi[12], Francois Paul Juster[6], Cesare Lobascio[11], Riccardo Musenich[14], Davide Nardelli[8], Giovanna Ober[12], Lucio Rossi[7], Piero Spillantini[15], Filippo Tunesi[12]; Marco Vuolo[16], Francesco Zanetti[12], Davide Pietranera[8], Matteo Tropeano[8], Giovanni Grasso[8], Andrea Tumino[8]

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Deep-space missions will result in extended exposure of astronauts to space radiation, eventually leading them to deal with late and acute effects. Current countermeasures include passive shielding, however, to significantly reduce the effective dose to the crew, large amounts of optimized materials would be necessary and this solution is not compliant with the existing weight restrictions to space missions. The EU FP7 SR2S Project - Space Radiation Superconducting Shield - attempted for the first time to design an active shielding system, using magnets based on MgB2 superconductors. The multidisciplinary design activities have been supported by extensive detailed Geant4 Monte Carlo simulations. The structures and radiation transport through both magnetic fields and materials in a deep-space mission scenario have been considered. The large production of secondary particles arising from the passage of space radiation through the shielding structures was characterized with the intent of minimize it using accurate material selection and proper mass distributions around the habitat. The results of this work and the correlated simulations activities are reported, together with a comparison of the performances between active shielding and mass-equivalent passive ones. We also present results of realistic analysis and experimental studies of some key technologies which are necessary to develop such a shield (superconducting cable, cryogenics, quench protection, heat removal).

Solar Modulation, Forbush Decreases and Solar Energetic Particles with AMS

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Knowledge of the Galactic Cosmic Ray (GCR) fluxes and their time variations within the heliosphere are crucial to predict the radiation exposure during space travels. In addition, particles emitted and accelerated by the Sun contribute to enhance the overall radiation level in space.

The Alpha Magnetic Spectrometer (AMS) on the International Space Station (ISS) has collected since May 2011 more than 100 billion events. AMS has performed precise measurements of the time variation of the proton and helium fluxes during the ascending phase of solar cycle 24 through its maximum and toward its minimum. In this time period, AMS has detected sudden reductions of the GCR intensity —the so-called Forbush decreases (FD). AMS has also measured 26 sudden increases of the proton flux in the low energy interval around 1GV which are related to the most energetic Solar Energetic Particle (SEP) events.

The time evolution of the proton and helium fluxes and some examples of FD and SEP events are presented. The unique features accessible by AMS for these kinds of studies will be highlighted.

Evaluation of Galactic Cosmic Rays (GCR) Models using AMS2 Data

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Traditionally, Galactic Cosmic Rays (GCR) models are used as a boundary condition input to the deterministic or stochastic (i.e. Monte Carlo) based radiation transport codes, with the goal of extracting dosimetric quantities of interest at a desired target point within the spacecraft. To compute such dosimetric quantities, the geometry and mass property of the spacecraft which represent the vehicle structure and radiation detector locations, are defined through a ray-tracing procedure. The transported fluxes are then manipulated to interpolate on the vehicle ray-traced database at different depths of spacecraft defined by its mass model properties to complete the dosimetric computation.

In this talk, three widely used GCR models are evaluated against published data for proton and helium, from the Alpha Magnetic Spectrometer 2 (AMS2) detector, mounted on the main truss of the International Space Station (ISS). For the three GCR models particular emphasis is put on energy region where GCR peaks (i.e. $E_k \leq 3$ GeV), to evaluate the discrepancies between the three models and the AMS2 data.

Keywords: Galactic cosmic rays (GCR), AMS2

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Results and lessons learned from calibration measurements of the TRITEL 3D silicon detector telescope at the HIMAC accelerator facility

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A three dimensional silicon detector telescope (TRITEL) was developed in the Space Dosimetry Research Group of the Centre for Energy Research, Hungarian Academy of Sciences (MTA EK, the former MTA KFKI AEKI) in the past years. The instrument, comprising three mutually orthogonal, fully depleted, passivated implanted planar silicon detector pairs, is capable of providing the LET spectrum and the average quality factor of the radiation as well as the absorbed dose and dose equivalent. Due to the three orthogonal telescopes an assessment of the anisotropy of the radiation field is also possible.

Several experiment runs have been performed in the recent years with heavy ions of different LET at the NIRS Heavy Ion Medical Accelerator facility (HIMAC) in order to calibrate the TRITEL instrument and check its performance in known high-LET radiation fields.

In our presentation, we are going to give a brief technical overview of the system as well as the measurement setup, and give a comprehensive summary of the results of the heavy ion measurements at HIMAC. Measurement data will be also compared to preliminary results from Monte Carlo simulations. We attempt to give a possible explanation for the LET spectra obtained by TRITEL on the ISS based on the results of the on-ground measurements.

Microdosimetric modeling of the relative efficiency of thermolumi-nescent detectors exposed to charged particles relevant for space applications

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The increasing utilization of lithium fluoride based thermoluminescent detectors in radiation environments as space and hadron therapy beams requires an accurate knowledge of their efficiency for measuring a wide range of charged particles and energies. Hence, in the last decades a lot of effort has been put in assessing the relative efficiency of these detectors by means of calibrated heavy ion exposures at ground based particle accelerators (Berger and Hajek, 2008; Bilski and Puchalska, 2010). At the same time, track structure based models (Waligorski and Katz, 1980; Kalef-Ezra and Horowitz, 1982) have been used to attempt predicting detector efficiencies. This is being done by relating the detector gamma dose response with the radial dose distribution around the heavy charged particle track. An alternative approach making use of the microdosimetric specific energy distributions in nanometer targets has been proposed to model detector efficiencies exposed to heavy charged particles ranging from protons (Z = 1) to oxygen ions (Z = 8) with energies up to 20 MeV/u (Olko et al., 2002).

In this work, a similar model has been developed (Parisi et al., 2017) in order to investigate the validity of the microdosimetric methodology to heavier particles and higher energies. This has been done using the Monte Carlo code PHITS and presents similarities (i.e. microdosimetric specific energies distribution being folded into the gamma dose response function) and differences (i.e. a different dose response function, microdosimetric spectra evaluated in LiF using PHITS, particle slowing down within the detector considered, higher particle energies, different site size) with the work of Olko et al., 2002. The model has been tested for LiF:Mg,Ti (MTS) detectors up to xenon ions (Z = 54) and energies up to 1000 MeV/u. The results are in agreement with the experimental values from Bilski and Puchalska, 2010, Bilski et al., 2011, Gieszczyk et al., 2013 and Sadel et al., 2015 generally within 5%. Furthermore, preliminary results for LiF:Mg,Cu,P (MCP) detectors will be also discussed.

References

Berger, T., & Hajek, M. (2008). TL-efficiency—overview and experimental results over the years. Radiation Measurements, 43(2), 146-156.
Bilski, P., Olko, P., Puchalska, M., Obryk, B., Waligórski, M. P. R., & Kim, J. L. (2007). High-dose characterization of different LiF phosphors. Radiation Measurements, 42(4), 582-585.
Bilski, P., & Puchalska, M. (2010). Relative efficiency of TL detectors to energetic ion beams. Radiation Measurements, 45(10), 1495-1498.
Bilski, P., Berger, T., Hajek, M., & Reitz, G. (2011). Comparison of the response of various TLDs to cosmic radiation and ion beams: Current results of the HAMLET project. Radiation Measurements, 46(12), 1680-1685.
Gieszczyk, W., Bilski, P., Olko, P., Herrmann, R., Kettunen, H., Virtanen, A., & Bassler, N. (2013). Evaluation of the relative thermoluminescence efficiency of LiF: Mg, Ti and LiF: Mg, Cu, P TL detectors to low-energy heavy ions. Radiation Measurements, 51, 7-12.
Kalef-Ezra, J., & Horowitz, Y. S. (1982). Heavy charged particle thermoluminescence dosimetry: track structure theory and experiments. The International Journal of Applied Radiation and Isotopes, 33(11), 1085-1100.
Olko, P., Bilski, P., Budzanowski, M., Waligórski, M. P. R., & Reitz, G. (2002). Modeling the response of thermoluminescence detectors exposed to low-and high-LET radiation fields. Journal of radiation research, 43(Suppl), S59-S62.
Parisi, A., Van Hoey, & Vanhavere, F. (2017). Microdosimetric modeling of the relative luminescence efficiency of LiF:Mg,Ti (MTS) detectors exposed to charged particles. Radiation Protection Dosimetry, submitted.
Sądel, M., Bilski, P., Swakoń, J., Rydygier, M., Horwacik, T., & Weber, A. (2015). Comparative investigations of the relative thermoluminescent efficiency of LiF detectors to protons at different proton therapy facilities. Radiation Measurements, 82, 8-13.
Waligórski, M. P., & Katz, R. (1980). Supralinearity of peak 5 and peak 6 in TLD-700. Nuclear Instruments and Methods, 172(3), 463-470.

Time of Flight measurements on-board the ISS: development of LIDAL (Light Ion Detector for ALTEA) apparatus ”

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LIDAL (Light Ion Detector for ALTEA) is a detector based on scintillators for fast time applications, designed to work paired with three ALTEA Silicon Detector Units (SDU), in order: i) to extend the ALTEA detection capability for the lower Z-part of the radiation spectrum on-board the International Space Station (ISS) and ii) to enhance particle discrimination power by matching the dE/dx measured by ALTEA with the kinetic energy measured by LIDAL through the Time Of Flight (ToF) technique.

The talk is made of three main parts. The first is an overview of the different tasks and timing performances required for LIDAL detector: starting from simulations results, we will show how it is possible to fulfill timing requirements using the on-the-edge available technology.

The second part is dedicated to the LIDAL prototype-0 deployed at University of Tor Vergata: the different realization steps, like the scintillator assembly, wrapping and light tight procedures, are briefly shown and discussed. Results from first tests with cosmic muons are also shown.

The third part is dedicated to the prototype characterization performed at TIFPA proton beam line at Trento. The results are presented and discussed.

The status of the development of the detector and its utilization program will be finally discussed.

Particle Type and Energy Identification in Single Pixellated Silicon Detectors

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Timepix silicon pixel detectors have been used by NASA for space radiation dosimetry since 2012. These detectors produce a detailed track at 55um resolution of radiation passing through the active silicon layer. This information is currently used to calculate the track geometry which together with the deposited energy can be used to measure the LET and in turn calculate the dose.

This talk discusses the calibration of the Timepix detector up to very high energies and LET values, and how the information gathered by the Timepix detector can be further used for particle and energy identification. Our approach focuses on long tracks at high polar angles where an individual track is sampled many times along its length. In this way the Timepix can be thought of as acting like a 'single layer silicon telescope'.

In this case this detailed information can be used in many ways, especially for the task of separating different ion species with the same stopping power. Sample quantities that can be computed include measuring energetic delta electrons, which can be used as a kinetic energy veto and computing the stopping power profile along the track, which can be used to discriminate between slowing and stopping light ions and higher Z fast ions. This detailed information also allows many simultaneous measurements of dE/dX for a single charged particle, which can be used to estimate particle energies with much greater precision than a single dE/dX based lookup table.

These algorithms have been tested on ground and space based data, and a subset of them is planned for implementation in the HERA system for Orion EM-2.

Finally we discuss future potential avenues to exploit the information provided by the Timepix and similar silicon detectors.

AIRDOS - an open source dosimeter for measurement on board of aircraft

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We introduce a new dosimeter AIRDOS developed for measurement on board of aircraft. This dosimeter is based on CANDY project [Kákona et al., WRMISS 2015, WRMISS 2016] and represents our effort for an open source platform for measurement in low intensity mixed field of ionising radiation. The main parts of the AIRDOS device are detector unit - the PIN diode, electronics for conversion of the signal to the pulse-height spectra, GPS module, memory and batteries for one-month continues monitoring. We'll present calibration method for evaluation of dosimetric quantities with AIRDOS, results from several experiments (e.g. from CERF, HIMAC, stratospheric balloon, and aircraft), and comparison with Liulin exposed to the same radiation fields.

The sensitivity of p-MOSFET dosemeter to heavy ions

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The p-MOSFET dosimeter studied in this work has been manufactured at LAAS-CNRS Laboratory in Toulouse France, for applications in personal and space dosimetry. They are proposed for proton, neutrons, heavy ions, electron and photon dose measurements. The current study investigates the sensitivity of the p-MOSFET electronic dosimeter to heavy ions regarding to be used in space applications. Irradiations to heavy ions have been performed at HIMAC accelerator. Two types of p-MOSFETs, with LiF and without LiF converter have been studied. The irradiations were performed in two doses, 10 mGy and 25 mGy and energies ranging from 150 MeV/n to 500 MeV/n.

Contribution of Different Particles onboard Bion-M1 Estimated by Means of Plastic Nuclear Track Detectors

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Cosmic radiation is very complex; it is composed of primary high-energy galactic and solar particles, particles trapped in Earth's radiation belts, and also of secondary particles created in nuclear interactions of primary radiation when passing through spacecraft walls or material load. The contribution of the secondary particles to total radiation exposure can be comparable with that of the primary field. To separate different components of the radiation onboard spacecraft, plastic nuclear track detectors (PNTD) can be used. We will present a method to discriminate high-energy primary ions and secondary particles according to their range in the detector's material. Tracks corresponding to primary high-energy heavy ions are supposed to have a long range, so they can penetrate deep into the detector. On the other hand, tracks corresponding to the secondary component and low-energy particles are visible over a limited thickness only. The exposed detectors are etched several times and the same area of the detector is carefully analyzed after each etching and paired tracks are compared. Tracks of short-range particles become over-etched after long etching.

The method is demonstrated using detectors exposed onboard biological satellite BION-M1, both inside and outside the capsule. The absorbed dose and dose equivalent measured with PNTD outside the capsule are about four times and two times higher, respectively, than inside the satellite. Outside the capsule there is clearly higher contribution of lower-LET particles. Preliminary results show that primary high-energy ions with long range represent more than 80% of all detected particles outside the satellite, whereas inside it is only about 60%. Their contribution to the absorbed dose and dose equivalent is about 80% and 60% for external detector and 56% and 51% for internal detector.

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The "PHOENIX" radiobiological experiment on-board the Russian segment of the ISS supported by passive dosimetry - First results

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In the on-going PHOENIX project absorbed dose rates are measured in the direct vicinity of dried lymphocytes and bone marrow cell samples in three differently shielded modules in the Russian segment of the ISS. In the initial experiment the applied passive dosimeter packages were recovered after four half-year-long sessions, which aimed at tracking the changes in the composition of the radiation field during the decreasing phase of the 24th solar cycle. As a result of the first 199-day session between the end of 2014 and the beginning of 2015, we obtained higher doses than it was published for the same locations in a quieter solar period. These observations will be interpreted taking into account the complex effect caused by the changing solar activity and altitude of the ISS. In addition to the dosimetric results several differences were revealed regarding the evaluation processes applied by the participating laboratories. The details of the above mentioned findings will be covered in the presentation.

Neutron Spectrometry and Dosimetry on spacecraft with passive detector system

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The experimental measurements of neutron dose equivalent are usually complex to perform because of the strong dependence of flux-to-dose conversion factors from neutron energy. Thus the neutron energy spectrum is required, to evaluate accurately the neutron dose.

On board of spacecraft, neutrons are produced as secondary radiation from primary protons and HZE interacting with the shielding, so their energy cover a wide interval, from thermal energies to hundreds of GeV. Neutron energy spectrum and neutron ambient dose equivalent have been measured onboard of Endeavour Shuttle. A set of passive dosimeters was chosen (bubble dosimeters BDT and BD-PND and a Bi209 fission bismuth stack) characterized by a simple set-up and no need of power support, i.e. no interference with the on board electronic. The obtained results in the neutron energy interval from 0.025 eV to 10 GeV are presented and discussed.

Bubble-Detector Measurements for Matroshka-R and Radi-N2: ISS-47/48 and ISS-49/50

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Neutrons encountered in low-Earth orbit, for example on the 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. Since 2006, bubble detectors have been used to characterise neutron radiation on the ISS for the Matroshka-R, Radi-N, and Radi-N2 experiments. These ongoing measurements are conducted 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 accumulate data during the recent ISS-47/48 and ISS-49/50 expeditions in 2016/17. The goal of Radi-N2 is to characterise the neutron dose equivalent and energy distribution in multiple USOS 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. Prior Radi-N2 measurements took place in four modules of the USOS: Columbus, the Japanese Experiment Module, the US Laboratory, and Node 2. During ISS-47/48 and ISS-49/50, surveys were conducted in Columbus, the US Laboratory, and Node 2, and a fifth ISS module, Node 3, was explored for the first time. The Radi-N2 data collected in the US Laboratory are compared to data collected using NASA's ISS-RAD, a scintillator-based neutron detector that was co-located with the bubble detectors at the time of the measurements. The recent Radi-N2 results are not significantly different from the earlier Radi-N and Radi-N2 data from 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 USOS modules suggests that the neutron field in each location is similar.

During ISS-47/48 and ISS-49/50, Matroshka-R measurements in the ROS focussed on surveys in the Pirs docking module, the Mini Research Modules, MRM1 and MRM2, and the Zvezda Service Module. The ISS-47/48 experiments in MRM1 were performed using the Matroshka-R phantom, a sphere of tissue-equivalent material used to simulate the human body. The measurements suggest that the dose equivalent inside the phantom is approximately 70% of the dose equivalent at its surface, confirming the results of earlier investigations using the same phantom.

Pille Measurements on ISS (June 2016 – April 2017)

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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 14 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 53000 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 June 2016 – April 2017 are presented. The results are compared with previous measurement results. Some information on the latest developments are also shared with the audience.

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

Thomas Berger for the DOSIS & DOSIS 3D science team

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The radiation environment 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. The talk will give an overview of the current results of the data evaluation performed for the passive and active radiation detectors for DOSIS and DOSIS 3D and further focus on the work in progress for data comparison with the active radiation detectors (as for example with ALTEA, DB-8 and REM).

Acknowledgments:

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Results from the ISS-RAD Charged Particle Detector and Comparisons to MSL-RAD

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We present new results from the Charged Particle Detector (CPD) subsystem of the ISS-RAD detector. ISS-RAD was deployed on Feb. 1, 2016, and first results were shown at last year's Workshop. The CPD is nearly identical to the MSL-RAD instrument, and many quantities can be directly compared, revealing clear similarities as well as some subtle differences between the ISS and Mars surface environments. Charged particle fluxes, dose rates, and LET spectra will be shown and compared to MSL-RAD data and also to measurements made by other instruments on ISS. Preliminary results for neutral particles will also be presented.

One and a Half Years Onboard ISS: Neutron Dose Equivalent and Energy Spectrum Results from the ISS-RAD Fast Neutron Detector

Martin Leitgab, on behalf of the ISS-RAD Science Team

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The International Space Station Radiation Assessment Detector (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 of neutron energy. Neutron dose equivalent and energy spectrum results covering 1.5 years of operation in the US-Laboratory, Node 3 and the Japanese Experiment Module-Pressurized Module (JEM-PM) will be discussed, as well as comparisons to simulation results and other experimental measurement results on ISS.

ISS Radiation Environmental Monitor (REM) Transition to Operations: RAM to REM Transition

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The ISS Radiation Environmental Monitor (REM) instrument is based on radiation imaging Timepix technology developed by the Medipix2 Collaboration at CERN. Timepix technology has been well characterized over the years with applications primarily in the medical field (Jakubek, et al., 2008).

For space applications, Timepix technology is used for ISS area radiation measurements as part of the Radiation Environmental Monitor (REM) proof-of-concept technology demonstration starting in 2012 (Stoffle et al., 2015, Pinsky et al., 2011) and for NASA Exploration Missions radiation measurements starting in 2014 (Bahadori et al., 2015). The Battery-operated Independent Radiation Detector (BIRD) is the first iteration of Timepix-based instruments to fly on the Orion MPCV and was successfully tested during EFT-1 (Gaza et al., 2017). The Hybrid Electronic Radiation Assessor (HERA), based on Timepix technology and developed at NASA, will fly on EM-1, EM-2 and subsequent Orion MPCV flights (Kroupa et al., 2015).

There are currently 4 REM units deployed and active on ISS, covering the Columbus, JEM and BEAM modules. Each REM device is powered, controlled and read via USB connection by SSC laptops on Station. The silicon based Timepix hybrid pixel detector is a 256 x 256 array of individual readout pixels, each pixel includes its own front-end electronics. Two different sensor layer thicknesses have been used: 300 µm and 500 µm. A detailed REM comparison study has been performed with the current passive Radiation Area Monitors using in-space measurements and ground accelerator exposures. To facilitate this comparison 2 RAM detectors have been attached to 2 REM units for Increments 46, 48 and 50.

This presentation will include REM/RAM intercomparison results from space and ground measurements as well as a REM transition to operations progress status.

References:

A. Bahadori, E.J. Semones, R. Gaza, M. Kroupa, N. Stoffle, R. Rios, T. Campbell-Ricketts, L. Pinsky, D. Turecek, 2015. Battery-operated Independent Radiation detector data report from Exploration flight Test 1. NASA Technical Publication, NASA/TP-2015-218575.

R. Gaza, M. Kroupa, R. Rios, N. Stoffle, E. Benton and E. Semones, 2017. Comparison of novel active semiconductor pixel detector with passive radiation detectors during the NASA Orion Exploration Flight Test 1 (EFT-1). Radiat. Meas. (in press).
https://doi.org/10.1016/j.radmeas.2017.03.041

J. Jakubek, A. Cejnarova, T. Holy, S. Pospisil, J. Uher, and Z. Vykydal, Pixel detectors for imaging with heavy charged particles, 2008. Nucl. Instr. Meth. Phys. Res. A 591 (1), 155–158.

M. Kroupa, A. Bahadori, T. Campbell-Ricketts, A. Empl, S. Hoang, J. Idarraga-Munoz, R. Rios, E. Semones, N. Stoffle, L. Tlustos, D. Turecek, L. Pinsky, 2015. A semiconductor radiation imaging pixel detector for space radiation dosimetry Life Sc. Sp. Res. 6, 69-78.

L.S. Pinsky, A. Empl, A. Gutierrez, J. Jakubek, H. Kitamura, J. Miller, C. Leroy, N. Stoffle, S. Pospisil, Y. Uchihori, N. Yasuda, C. Zeitlin, 2011. Penetrating heavy ion charge and velocity discrimination with a Timepix-based Si detector (for space radiation applications). Nucl. Inst. Meth. Phys. Res. A 633, S190–S193.N.

Stoffle, L. Pinsky, M. Kroupa, S. Hoang, J. Idarraga, C. Amberboy, R. Rios, J. Hauss, J. Keller, A. Bahadori, E. Semones, D. Turecek, J. Jakubek, Z. Vykydal, S. Pospisil, 2015. Timepix-based radiation environment monitor measurements aboard the International Space Station. Nucl. Instr. Meth. Phys. Res. A 782, 143-148.

Comparison of Silicon-based Detectors on ISS

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The DOSIS 3D (Dose Distribution inside the ISS 3D), REM (Radiation Environment Monitor), and ISS-RAD (Radiation Assessment Detector) are Silicon-based solid state detectors currently deployed and operating on the International Space Station. Results will be shown for multiple comparisons using these instruments, specifically: absorbed doses and energy loss distributions for DOSTEL (DOSimetry TELescope), a sub-detector of DOSIS 3D, and REM covering multiple years of co-location in the Columbus laboratory; and absorbed doses for ISS-RAD's CPD (Charged Particle Detector) and REM while co-located in the Destiny laboratory (US Lab).

Results from radiation environment investigations on the International Space Station and interplanetary space with Liulin charged particle telescope

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The space radiation environment of the Earth is complex, composed of galactic cosmic rays, trapped particles of the Earth's radiation belts, solar energetic particles, albedo particles from Earth's atmosphere and secondary radiation produced in the space vehicle shielding materials. Dose characteristics of the near-Earth space radiation environment also depend on many other parameters such as the orbit parameters, solar cycle phase and current helio- and geophysical conditions. Radiation characteristics in the interplanetary medium are determined by the dynamics of the cosmic rays. In the period from 2007 to 2015 the Liulin-5 charged particle telescope has been observing the radiation characteristics on board the ISS. In this paper attention is drawn to the obtained results for the dose rates, particle fluxes and dose equivalent rates from the galactic cosmic rays, trapped protons and the registered solar energetic particle events. Compared are the dosimetric doses obtained at the deep minimum of solar activity between the 23-th and the 24-th solar cycles and close to the maximum of 24-th cycle. These results also are compared with data obtained during the ExoMars 2016 mission. The implications for human space flights are discussed.

Relativistic electron precipitation bands and relativistic electrons in Earth's inner radiation belt

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Radiation risk radiometer-dosimeter (R3DR2) performed active dosimetry measurements outside the International space station (ISS) during the ESA EXPOSE-R2 missions from October 24, 2014 until January 11, 2016. The 10 seconds resolution flux and dose rate data were used to find, identify and classify the relativistic electron precipitation bands (PB) (Blake et al., 1996) in the outside radiation environment of the ISS. PBs were identified as rapid (for 10-40-s) dose rate enhancement from the normal (20-200 mGy h^{-1}) outer radiation belt (ORB) level and similar fast return to the same low level. Only PB that have in the time profile dose rates larger than 10,000 mGy h^{-1}, identical to flux larger than 4,000 $cm^{-2}s^{-1}$, for 10 or more seconds were selected. 16 PB were studied. The largest selected PB delivered in the R3DR2 detector, which was behind 0.3 g cm^{-2} shielding, a dose of 464 mGy for 70 seconds. The later was larger than the ORB daily average dose rates for 366 days out of 442 days measurements during the analyzed period. The daily average doses inside of the ISS were measured using the DOSTEL instrument at an average level of 194 µGy d^{-1} (Reitz et al., 2005). This indicates that only for 70-s, the cosmonaut/astronaut, being on extra vehicular activity (EVA), where they are shielded only by their space suits, will accumulate the equivalent of about 2.5-days dose inside of the ISS. Only 1 PB was identified during the ESA EXPOSE-E mission on ISS in the period February 17, 2008 - September 3, 2009, while in the more active geo-magnetically EXPOSE-R mission in 2010 6 PB were registered. Although the obtained PB doses do not pose extreme risks for cosmonauts/astronauts health, being on EVA, they have to be considered as a possible extremely high dose rate source, which requires additional comprehensively investigation.

Similarly to Claudepierre et al. (2017) and Turner et al. (2017) we start to record penetration of the relativistic electrons below L=2.5 on 18 March 2015. In the period March 18-28 the lower boundary of L=2 was reached. Then the relativistic electrons at low L disappeared on March 28th. The storm on June 25th generated again fluxes of the ORB relativistic electrons at L values below 2.5 and they are clearly seen in Fig. 2. The ORB enhancement on 4 of July 2015 emphasised them again but at this case the minimal L values reached was L=1.6 (For more details please see next part of the paper). Almost all disturbances in Dst from July 11th, 2015 until January 1st, 2016 generated new portion of relativistic electrons in the range of L values between 1.6 and 2. They existed for 1-2 days and disappeared until the next Dst disturbance.

References:

Claudepierre, S. G., et al., 2017. The hidden dynamics of relativistic electrons (0.7-1.5 MeV) in the inner zone and slot region, J. Geophys. Res. Space Physics, 122, http://dx.doi.org/10.1002/2016JA023719.

Reitz, G., Beaujean, R., Benton, E., Burmeister, S., Dachev, T., Deme, S., Luszik-Bhadra, M., Olko, P., 2005. Space radiation measurements on-board ISS-The DOSMAP experiment, Radiat. Prot. Dosim. 116 (1-4), 374-379.

Turner, D. L., et al., 2017. Investigating the source of near-relativistic and relativistic electrons in Earth's inner radiation belt, J. Geophys. Res. Space Physics, 122, 695–710, doi:10.1002/2016JA023600.

Studies of SPEs as measured in the ISS in 2011-2012

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The effects of Solar Particle Events (SPEs) inside a space habitat are key information to understand how these events may affect the astronauts' health, to validate SPE & transport models, and finally to provide insights on the SPE parameters- as inputs for optimizing the now-casting capabilities (now-casting: ability to predict the risk associated to an SPEs from the very first radiation precursors).

In this paper we focus on the SPEs measured by ALTEA, an active silicon detector system orbiting in Low Earth Orbit (LEO) in the International Space Station (ISS), during 2011 – 2012. During these two years a total of twenty SPE events are listed by the NOAA catalogue (ftp://ftp.swpc.noaa.gov/pub/indices/SPE.txt). ALTEA was in operation during fifteen of them.

As ISS is shielded by the Earth geomagnetic field with a modulation from a minimal effect at high latitude to a maximal over the equator, ALTEA observed SPEs are quite different from those detected outside Earth's atmosphere by e.g., GOES, the Geostationary Operational Environmental Satellite.

These measurements by ALTEA are therefore aimed at: i) providing experimental results of actual SPEs detected within a space habitat, also trying to extrapolate these results to deep space; ii) understanding the interaction between the geomagnetic field and the radiation field from the sun.

Results from the major SPEs will be shown correlating the ALTEA data with data coming from other in-situ detectors, such as GOES and EPHIN taking into account the time-and spatial- dependent geomagnetic field cutoffs. We will also investigate the reasons of different ALTEA responses to similar SPEs.

D_{st} index induced variations of the ISS inner radiation belt SAA region

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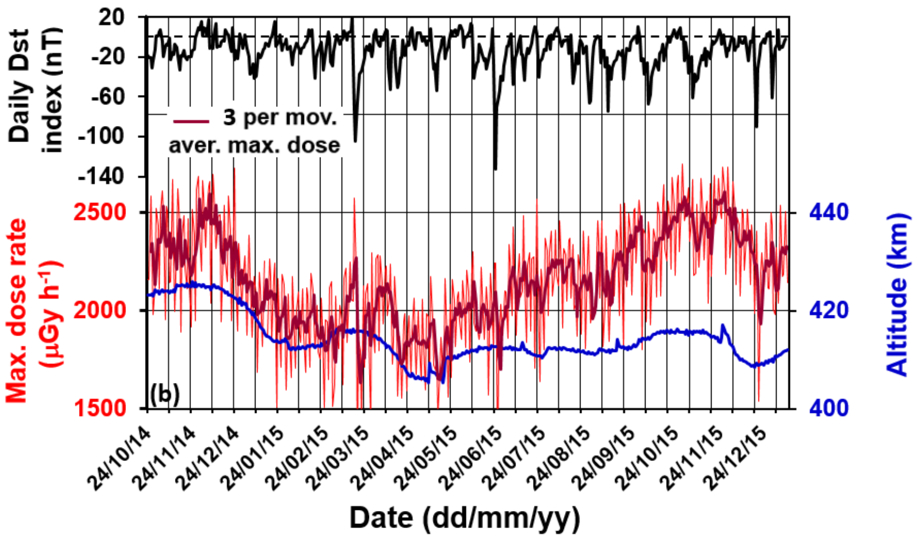
The analysis of the inner radiation belt (IRB) south atlantic anomaly (SAA) region data from the Radiation risk radiometer-dosimeter (R3DR2) obtained outside the International space station (ISS) during the ESA EXPOSE-R2 missions from October 24, 2014 until January 11, 2016 shows strong dependence from the geomagnetic activity, represented with the (Disturbance Storm Time) Dst index (http://wdc.kugi.kyoto-u.ac.jp/index.html) or solar wind variations. The figure illustrates these dependencies. There are 3 curves in the figure. The curve in the top represents the daily averaged variations of the Dst index. The light red line in the middle of the figure shows the maximal observed per day dose rates in the SAA region of the IRB, which are measured during the ascending parts of ISS orbits through the SAA region. The explanation is that the R3DR2 detector, which was located on the left side of the ISS "Zvezda" module opposite the ISS vector of velocity, was shielded more by the "Zvezda" module body on the descending orbits from west to east drifting inner belt protons, when the ISS was in the nominal "XVV" orientation (http://spaceflight.nasa.gov/station/flash/iss_attitude.html). The heavy dark red line is the 3 per moving average of the maximal dose. The ISS daily average altitude at the locations of the SAA measurements (heavy blue line in the bottom) correlates well and explains the long-time variations of the maximal dose rate. The short-time variations of the maximal dose rate (heavy dark red line) follows well the Dst index daily variations with strong depletions of the maximal dose rate coinciding with the depletions of the Dst index during magnetic storms and substorms. Well seen are also enhancements in the maximal dose rate, which occurred during the sudden commencement (SC) period before the main phase of the magnetic storm. The decrease of the proton flux and the maximal dose rate, respectively, near the center of SAA is caused by the enhanced frequency of Coulomb collision between the IRB trapped protons and enhanced atmospheric neutral density during the storm, resulting to the extra losses of the inner belt protons.



ESA Active Dosimeter [EAD] – Status report on the ESA Tech Demo Activity

Ulrich Straube[1] and Thomas Berger[2] for the EAD team

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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. The ESA Active Dosimeter [EAD] hardware shall enable advanced personal dosimetry capabilities in real time. 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. The MU can be applied for personal dosimetry as well as used for area monitoring purposes throughout the station. On July 18th 2016 the full EAD hardware was launched with Space-X 9 to the ISS and started operation in Columbus on July 28th 2016. The presentation will give an overview of the relevant data generated within the first year of operation onboard the ISS.

Results From Radiation Environment Measurements onboard Exomars Trace Gas Orbiter During the Transit and in High Eliptic Mars Orbit

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Since April 2016 the dosimeter Liulin-MO has been conducting radiation environment investigations aboard the Trace Gas Orbiter of the joint ESA-Roscosmos mission ExoMars. Liulin-MO is a module of the Fine Resolution Epithermal Neutron Detector aboard TGO. Presented are data for the radiation dose rates, particle fluxes and dose equivalent rates of the ionizing charged particles measured in the interplanetary space and in high elliptic Mars orbit from 22.04.2016 to 07.03.2017 in the phase of declining solar activity of 24-th solar cycle. Data obtained are compared to the data of other radiation measurements in the interplanetary space.

A similar to Liulin-MO module, called Liulin-ML for investigation of the radiation environment on Mars' surface as a part of the active detector of neutrons and gamma rays ADRON-EM on the Surface Platform is under preparation for ExoMars 2020 mission.

Comparison of Liulin-MO dosimeter radiation measurements during ExoMars 2016 TGO cruise to Mars and dose estimations based on galactic cosmic ray model.

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Flux and dose rate estimations on board ExoMars 2016 TGO had been made based on ISO/DIS 15390 galactic cosmic ray model and a model developed recently in the Skobeltsyn Institute of Nuclear Physics of Moscow State University allowing to take into account the heliocentric distance of the observation point. The estimations were compared with the measurements of the Liulin-MO dosimeter, part of the FREND device. The model of the Liulin-MO detectors shielding was created for calculations. The effect of solar activity variations on the dose rate was evaluated. The effect on the dose rate on board of the flight altitude above the Martian surface was analysed. The effect of Mars' "shadowing" on the magnitude of the particle flux and dose rate was observed at altitudes of less than 3000 km. The decreasing of the flux and dose rate reached 30% in the pericenter region.

Latest Updates from the MSL-RAD Experiment

Cary Zeitlin on behalf of the MSL-RAD Science Team

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The RAD instrument aboard the Curiosity rover has been operating on Mars for nearly 5 years. The instrument continues to return dosimetric and spectral data to characterize the radiation environment in Gale Crater. The weakening of solar modulation as cycle 24 heads towards minimum is clearly visible in the rising dose rates seen on the Martian surface. Since the last WRMISS meeting, RAD has also observed, for the first time, shielding effects of the local terrain as Curiosity traversed the Murray Buttes area. New analysis of LET spectra has been performed, and correlations of <Q> with atmospheric column depth generally show the expected trends. Work in progress to verify the normalization of neutral particle spectra will also be presented.

MSL-RAD Summary of model calculations and comparison to RAD data

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The radiation environment at the Martian surface is, apart from occasional solar energetic particle events, dominated by galactic cosmic radiation, secondary particles produced in their interaction with the Martian atmosphere and albedo particles from the Martian regolith. The highly energetic primary cosmic radiation consists mainly of fully ionized nuclei creating a complex radiation field at the Martian surface. This complex field, its formation and its potential health risk posed to astronauts on future manned missions to Mars can only be fully understood using a combination of measurements and model calculations. In this work the outcome of a dedicated workshop held in June 2016 in Boulder, CO, USA is presented. Experimental results from the Radiation Assessment Detector (RAD) of the Mars Science Laboratory (MSL) are compared to model results from GEANT4, HETC–HEDS, HZETRN, MCNP6, and PHITS. Charged and neutral particle spectra and dose rates measured between 15 November 2015 and 15 January 2016 and model results calculated for this time period are investigated. Based on the calculated and measured data further investigations have been performed on the neutron doses in dependence of detector sizes. Additionally a newly developed parameterized DLR model of the radiation exposure at the Martian surface is presented and the results are compared to RAD data.

A generalized approach to model the SEP/GCR spectra and radiation dose rate on the surface of Mars

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For future human missions to Mars, it is important to study the surface radiation environment during extreme and elevated conditions. In the long term, it is mainly Galactic Cosmic Rays (GCRs) modulated by solar activity that contributes to the radiation on the surface of Mars, but intense solar energetic particle (SEP) events may induce acute health effects. Such events may enhance the radiation level significantly and should be detected as immediately as possible to prevent severe damage to humans and equipment.

However, the energetic particle environment on the Martian surface is significantly different from that in deep space due to the influence of the Martian atmosphere, and, to a lesser extent, the regolith. Depending on the intensity and shape of the original solar particle spectra as well as particle types, the surface spectra may induce entirely different radiation effects. For instance, an intense SEP event with a soft spectrum that would be hazardous on the lunar surface may, in contrast, induce only low levels of radiation on the Martian surface that would be well within human health tolerances. In order to give immediate and accurate alerts while avoiding unnecessary ones, it is important to model and well understand the atmospheric effect on the incoming SEPs including both protons and helium ions. In this paper, we have developed a generalized approach to quickly model the surface response of any given incoming proton/helium ion spectra and have applied it to a set of historical large solar events, thus providing insights into the possible variety of surface radiation environments that may be induced during SEP events.

The PERSEO Project: PErsonal Radiation Shielding for intErplanetary missiOns

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The PERSEO project, funded by ASI - the Italian Space Agency, led to the development of the first prototype of a radiation protection garment to shield astronauts' more radiosensitive organs in case of exposure to a solar particle event. The garment is conceived to protect astronauts during intra-vehicular activities in a space habitat, in case they need to perform emergency operations outside a radiation shelter. The prototype was designed and built to be filled with water on board the ISS, and is going to be tested for wearability by the ESA astronaut Paolo Nespoli, during Expedition 52/53 – mission VITA. Water is chosen as shielding material, and can be recycled after use for filling the garment, thus optimizing the use of available resources. PERSEO opens new perspectives for the development of innovative personal radiation protection devices based on the use of resources available in the space vehicle or habitat for deep space long duration missions.

On behalf of the PERSEO collaboration, I will present the design of the prototype, including preliminary results on the achievable dose reduction to sensitive organs, describe the main steps in the realization of the garment and the features of the final model.

PERSEO is coordinated by the University of Pavia and involve scientists from Thales Alenia Space – Italia, SMAT, AVIOTEC, ALTEC, University of Roma Tor Vergata, Kayser Italia and ARESCOSMO.

ROSSINI 2 – Study Results

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Passive shielding remains the simplest countermeasure to protect astronauts for space radiation exposure in long-term space missions.

In the ROSSINI 2 study the effectiveness of materials used for shielding spacecraft has been calculated through Monte Carlo codes and results have been compared to experimental data.

Different materials have been selected, among them: Mars and lunar soils, multilayer barriers for inflatable space modules, epoxy resins, lightweight hydrides, shielding doped with nanomagnetic particles and many others.

Dose attenuation, primary beam attenuation and production of secondary neutrons have been measured in radiation accelerators facilities: GSI Darmstadt (heavy ions), HIT Heidelberg (carbon ions and protons), NSRL-BNL (heavy ions), TIFPA Trento (protons).

The ROSSINI2 study has been supported by European Space Agency (ESA) under the contract RFP IPLPTE/LF/mo/942.2014 and with the generous support of NASA and BNL to the proposal E-56 ROSSINI.

MARE: International Science aboard Orion EM-1 (Matroshka AstroRad Radiation Experiment)

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Orion is America's next generation vehicle designed by NASA for human exploration of deep space. Orion's upcoming test flight Exploration Mission 1 (EM-1) is scheduled to launch in 2019. EM-1 is an un-manned flight circumnavigating the moon. Matroshka AstroRad Radiation Experiment (MARE) is a radiation science payload proposed to fly on EM-1 by the Israel Space Agency (ISA) and the German Aerospace Center (DLR) and subsequently accepted and manifested by NASA. The MARE payload team includes Lockheed Martin personnel co-located with the Orion program to efficiently assist in the experiment integration. MARE consists of two female tissue equivalent torsos instrumented with radiation detectors and located inside the Orion Crew Module for the flight. One torso is fitted with a light poncho to provide reference nominal crew exposure in the cabin. The other torso is fitted with the AstroRad personal protective equipment radiation vest, manufactured by StemRad, to provide measurements to quantify the protection added by the vest. Both torsos are integrated by DLR with active and passive radiation detectors provided by DLR and other international participants such as the DOSIS 3D and ISS Matroshka science community. After the flight DLR, StemRad, and LM will perform data analysis to characterize the cis-lunar radiation environment and the shielding provided by the vehicle, the AstroRad vest, and simulated tissue. Organ-specific radiation exposure can tehn be used to refine predictions of health effects such as long term cancer probability. This paper presents current MARE development status including the baseline radiation detector suite and vehicle integration progress, and solicits feedback from the community toward maximization of the science benefit provided by MARE and enabling safe space exploration by humans.

Update on Radiation Risks to Crew for a Cis-Lunar Mission: Impact of Shielding Thickness on Decision Making Criteria

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A primary goal of any space exploration mission is the safety of the crew. With future missions being planned to go further into deep space and last for longer durations, the challenges that must be overcome have increased significantly. Astronauts accepting such missions will have to contend with daily, low-dose galactic cosmic radiation (GCR) exposure and the potentially high-dose and high dose-rate from a single, or multiple solar particle events (SPEs). Unlike the GCR environment, the onset of SPEs are difficult to predict, difficult to model and, therefore, difficult to prepare for. Consequently, space agencies have pursued historical 'worst case' SPE design spectra to help drive engineering and mission design.

A study is underway to determine if occupational dose limits already in place for low-Earth orbit (LEO), are applicable to cis-lunar missions. In an effort to address this question, a sensitivity analysis was performed to assess the impact of aluminum wall thickness on the decision making criteria. Aluminum is commonly used to represent ISS shielding and was therefore simulated for this study. A spherical aluminum shell, with internal diameter of 3.8 m, was adopted as the reference spacecraft and all calculations were performed using the Monte Carlo radiation transport code MCNPX (Monte Carlo N-Particle eXtended) version 2.7.0 [1]. The effective dose equivalent, expressed in Sievert (Sv), and organ gray-equivalent (Gy-Eq) from historical SPEs published in literature have been calculated for shield thicknesses of 2, 4, 6, 8 and 10 cm. The effective dose equivalent for GCR exposure, assuming the GCR environmental model in deep space proposed by Matthia in 2013 [2,3] at 1997 solar minimum conditions, has also been calculated for shield thicknesses of 0.5, 2, 4, 8, 10, and 15 cm.

It was demonstrated that an optimal shield thickness exists, for minimizing GCR dose, near 16 g cm-2 (approximately 6 cm of Al shielding). This reaffirms previously published results that showed similar values near 20 g cm-2 [4]. Additionally, however, the choice of which SPE would be considered as the 'worst case' scenario will be shown to be dependent on the wall thickness. While no conclusions will be drawn as to which SPE parametric model should be adopted for cis-lunar missions, the impact of this study emphasizes shielding effects that need to be considered for the mission design.

References

1. "MCNPX 2.7.0 Extension Technical Report LA-UR-11-02295," Los Alamos National Laboratory, 2011.
2. Matthia, D., Berkger, D., Mrigakshi, A. I., Reitz, G. " A ready-to-use galactic cosmic ray model", Adv. Space Res., 51, 329-338, 2013.
3. "OLTARIS, the On- Line Tool for the Assessment of Radiation in Space," National Aeronautics and Space Administration, [Online]. Available: https://oltaris.nasa.gov/.
4. Slaba, T., Bahadori, A., Reddell, D., Singleterry, R., Clowdsley, M., Blattnig, S. "Optimal shielding thickness for galactic cosmic ray environments", Life Sciences in Space Research, 12, 1-15, 2017.

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Update on Radiation Risks to Crew for a Cis-Lunar Mission: A Benchmark of Codes and Simulation Geometries

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Radiation transport codes are relied upon to study the interaction of the space radiation environment with shielding and complex geometries. In the absence of measurements, such codes serve as useful tools for modelling exposure scenarios that are poorly understood. The results obtained are then typically used to help design the necessary shielding requirements for radiation protection of the crew. Depending on the complexity of the problems being examined and the modelling assumptions made, however, the results obtained using such codes can vary. Consequently, it is important to understand these differences and ensure that they are incorporated into the design of the shielding. In the process of developing a cis-lunar mission scenario, multiple exposure scenarios were studied using MCNPX (Monte Carlo N-Particle eXtended) version 2.7.0 [1] and OLTARIS, which is based on the deterministic transport code HZETRN [2, 3, 4]. Solar particle event (SPE) spectra and galactic cosmic radiation (GCR) spectra were transported through both 'slab' and 'spherical' geometries using a variety of source definitions. In this paper, the secondary scatter environments produced by these simulations will be compared with the differences between codes and exposure scenarios highlighted. The objective is to illustrate how modelling assumptions can impact results.

References

1. "MCNPX 2.7.0 Extension Technical Report LA-UR-11-02295," Los Alamos National Laboratory, 2011.
2. R. C. Singleterry Jr., S. R. Blattnig, M. S. Clowdsley, G. D. Qualls, C. A. Sandridge, L. C. Simonsen, J. W. Norbury, T. C. Slaba, S. A. Walker, F. F. Badavi, J. L. Spangler, A. R. Aumann, E. N. Zapp, R. D. Rutledge, K. T. Lee and R. B. Norman, "OLTARIS: On-Line Tool for the Assessment of Radiation in Space (NASA/TP-2010-216722)," National Aeronautics and Space Administration (NASA), 2010.
3. "OLTARIS, the On- Line Tool for the Assessment of Radiation in Space," National Aeronautics and Space Administration, [Online]. Available: https://oltaris.nasa.gov/.
4. J. W. Wilson, F. F. Badavi, F. A. Cucinotta, J. L. Shinn, G. D. Badhwar, R. Silberberg, C. H. Tsao, L. W. Townsend and R. K. Tripathi, "HZETRN: Description of a free-space ion and nucleon transport and shielding computer program," NASA Technical Paper 3495, 1995.

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Portable, Low-cost Proportional Counters for Space, Atmospheric and Ground based Applications

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The tissue equivalent proportional counter (TEPC) has a long history in ionizing radiation monitoring since it was originally developed by Failla and Rossi. We are developing a series of proportional counters that make use of the same type of low-pressure cavity found in the Rossi design, but that also incorporates all the support electronics (HVPS, preamplifier, amplifier and spectrometer), together with a microcontroller-based computer and secure digital storage, in a low-cost, compact, portable unit. To reduce costs and increase ease of construction, the ionization cavity is made of acrylic. These proportional counters are designed for use in a number of differing environments, including space, the atmosphere and a variety of ground-based applications. In space, such TEPCs can be used aboard both manned and unmanned spacecraft, including on compact satellites such as Cubesats. In the atmosphere, TEPCs can be used for aircrew dosimetry aboard commercial, business, and military aircraft. A low-cost TEPC is also suitable for student experiments aboard near-space high-altitude balloon flights. Ground-based applications of the TEPC include neutron and charged particle dosimetry in proton and carbon beam radiotherapy, and neutron dosimetry around particle accelerator facilities. The cost target positions the instruments for widespread data accumulation in support of small exposure risk analysis. Our instrument, under the name of Active Tissue Equivalent Dosimeter, is scheduled for delivery to the International Space Station in January 2018 for a six month experiment.

Advanced Radiation Monitoring on Exploration Mission 1 and beyond: The HERA System

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The Hybrid Electronic Radiation Assessor (HERA) is a vehicle-integrated, near-real-time active ionizing radiation monitor designed for the habitable volume of the Orion Multi Purpose Crew Vehicle (MPCV). Data from the instrument will be used for operational radiation protection decisions and in post-mission risk assessments to estimate radiation impact on crew health.

An overview will be given on the underlying Timepix technology and HERA system design and integration into the vehicle, including requirements on the system. Science verification results and project status for Exploration Mission 1 are discussed, as well as crew Concept of Operations, crew display and extended measurement capability development status for Exploration Mission 2. A development path for future Exploration Missions will be outlined.

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