Conference Program

Workshop on Radiation Monitoring on International Space Station *

24th WRMISS

3 - 5 September 2019

24th WRMISS Conference Program: Tuesday 3rd September 2019

08.30 – 09:00	Registration
09.00 – 10:00	Opening
10.00 – 10:30	Scientific Session 1
10.30 – 11.30	Coffee/Tea Break
11.30 – 13:00	Scientific Session 2
13:00 – 14:00	Lunch
14.00 – 15:30	Scientific Session 3
15.30 – 16:30	Coffee/Tea Break
16:30 – 18.15	Scientific Session 4

Major of Athens, **Ministry of Ministry of digital policy** **Ministry of Ministry of Development and Investment** **President of Hellenic Space Center** **Greek ESA- representative** **NASA Radiation Health Officer: Edward Semones**	Opening speeches
Guenther Reitz, Marianthi Fragopoulou	Welcome and Organisational Issues

Scientific Session 1

Samy El-Jaby	Reviewing ISS-member cancer and non-cancer risk models and their differences for exploration class missions

Scientific Session 2

Xiaojing Xu	Validation of Trapped Proton Environments with EFT-1 Measurements
Claudio Cordi	Solar Modulation, Forbush decreases and Solar Particle Events by AMS onboard ISS
Martha Clowdsley	Validation of NASA's Radiation Analysis Tools with ISS Radiation Environment (REM) Measurements

Scientific Session 3

Pawel Bilski	Fluorescent Nuclear Track detectors based on LiF single crystals
Lawrence Pinsky	The Timepix 2 from the Medipix 2 Collaboration – First results
Valerie Formato	The AMS-02 experiment as a cosmic ray flux and radiation monitor on the ISS

Scientific Session 4

Tsvetan Dachev	GCR flux and dose rates variations observed experimentally by 13 Liulin Type instruments between 1991 and 2019
Attila Hirn	Pille Measurements on ISS (February 2018 –July 2019)
Sylvain Costes	NASA GeneLab space omics database: expanding from space to ionizing radiation data on the ground

24th WRMISS Conference Program: Wednesday 4th September 2019

09:00 - 09:45	Invited Talk
09:45 - 10:30	Scientific Session 5
10.30 - 11.30	Coffee/Tea Break
11.30 - 13:00	Scientific Session 6
13:00 - 14:00	Lunch
14:00 - 15.30	Scientific Session 7
15:30 - 16.30	Coffee/Tea Break
16.30 - 18.30	Scientific Session 8
20:00 - 23.00	**Conference Dinner: TBD**

Invited Talk

Olga Malandraki	Energetic Particles in the Heliosphere: Science and Application

Scientific Session 5

Livio Narici	ERFNet, a network for ground work in radiation mitigation to support deep space exploration.
Ramona Gaza	Twenty years of Passive Radiation Dosimetry on ISS: Ops Radiation Area Monitors Results

Scientific Session 6

Thomas Berger	DOSIS & DOSIS 3D onboard the ISS – Status and Science Overview from 2009 - 2019
Eric Benton	OSU Dosimetric Experiments aboard the ISS
Martin Smith	Recent Bubble-Detector Measurements for Matroshka-R and Radi-N2
Andrea Stradi	Latest Results in the Tritel-RS experiment simultaneous passive and active measurements

Scientific Session 7

Nicolas Stoffle	Recent Measuements of the ISS Environment Using Timepix-based Hardware on ISS
Martin Leitgab	Data Comparison between the ISS-Rad Fast Nuetron Detector and the Advanced Neutron spectrometer and Updates on FND Operational Neutron Dose Equivalent and Energy Spectrum Data
Mari Aida	Overview of JAXA radiation dosimetry and estimation of astronaut doses for future interplanetary missions

Scientific Session 8

Thomas Berger	The RaMIS radiation detector of the DLR Eu:CROPIS mission – data from first month at 600 km orbit
Tsvetan Dachev	Analysis of the radiation environment, obtained in 2018-2019 by Liulin Ten-Koh instrument on the Japanize Ten-Koh satellite
Prem Saganti	Radiation and X-Ray Measurements in Polar Orbit by Ten-Koh 2018 Spacecraft and Comparative Assessment with ISS Measurements
Masayuki Naito	Radiation dose on/around Moon and its protection

24th WRMISS Conference Program: Thursday 7th September 2019

09:00 – 10:30	Scientific Session 9
10:30 – 11:30	Coffee/Tea Break
11.30 – 13:00	Scientific Session 10
13:00 – 14.00	Lunch
14:00 – 15:45	Scientific Session 11
15:45 – 16:45	Coffee Tea Break
16:45 - 18:15	Scientific Session 12

Scientific Session 9

Soenke Burmeister	First Measurements of the radiation Dose on the Lunar Surface with LND Instrument on the Chang'E 4 lander
Bent Ehresmann	Updates from the MSL-RAD investigations and outlook for the future
Cary Zeitlin	A Tale of Two RADs

Scientific Session 10

Jordanka Semkova	Radiation Environment aboard ExoMars Trace Gas Orbiter in Mars science orbit in May 2018-July 2019
Victor Benghin	Comparison of Liulin-MO dosimeter radiation measurements during ExoMars 20166 TGO Mars circular orbit with dose estimations based on galactic cosmic ray models
Boglarga Erdoes	RADTEL charged particle detector for space weater measurements as part of The RadMag system

Scientific Session 11

Marianthi Fragopoulou	Dosimeter System for ORION-MARE
Martin Losekamm	The RadMap Telescope Technology Demonstrator Aboard the ISS
Livio Narici	LIDAL: update of the project, ground tests and perspectives

Scientific Session 12

Kerry Lee	Artemis-2 Full Launch Window Trajectory Analysis and projected Exposures at Radiation Hardware Locations on Artemis Flights
Stuart George	The Hybrid Electronic Radiation Asssessor (HERA) system
Heshan Hussein	Orion Artemis-1 Internal Environement Characterisation: The Matroshka AStroRad Radiation Experiment
	Summary , Discussion, next Location of WRMISS

Friday September 6th , 2019

Island Cruise (departs 7:00; return 19:30 arrival to port and 20.30 on the center of Athens)

Overview of JAXA radiation dosimetry and estimation of astronaut doses for future interplanetary missions

Mari Aida[1], Aiko Nagamatsu[1], Shinichiro Narita[1], Hiroki Furihata[1], Naoki Sato[1], Tatsuhiko Sato[2]

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Based on participation in the International Space Station (ISS) program, and the technology and knowledge cultivated in space science missions, human space exploration of the Moon and Mars is under coordination through international collaboration.

For the Japan Aerospace Exploration Agency (JAXA), participation in the Gateway and sustainable humanspace exploration on the lunar surface entails using Japan's strategic technologies:① Landing technology on gravitional body, ② Surface exploration technology on gravitional body, ③ Humanhabitation technology, and ④ Deep space resupply technology.

However, realizing a healthy and long-term stay on the lunar surface requires space radiation dosimetry that takes into account the effects of radiation exposure on the human body, exposure dose prediction and mission planning in conjunction with space weather, and biological/physical protection techniques.

This presentation describes JAXA's radiation protection technology, which is part of the technology for human habitation in space mentioned in ②. It also presents the simulated results of radiation dose evaluation using an aluminum spherical-shell-like rover to be jointly developed by JAXA and TOYOTA in the future. Particle and Heavy Ion Transport code System (PHITS) developed by the Japan Atomic Energy Agency (JAEA) was used in this calculation.

In one mission cycle of human exploration onboard the lunar rover scheduled for launch in 2029, astronauts will stay in the rover for about 40 days. During the activity period, the effects of exposure to galactic cosmic rays (GCR) must always be considered. And in the event of solar activity, the effects of solar energetic particles (SEP) must be fully considered.

In the case of an SEP event occurring, the exposure dose to the human body was simulated, while the rover was running on the lunar surface. PHITS was used in the calculation and then a simple lunar-surface environment was simulated, where an aluminum spherical shell was used as an alternative to the rover. A comparison of the conditions for a 40-day stay in the worst-case GCR environment and the conditions for staying in a single SEP environment revealed that the exposure dose to the human body due to SEP was 5-8 times greater than that due to GCR. Thus, a relatively large difference was obtained. This result quantitatively showed that countermeasures for exposure to SEP are important for a long term stay mission on the lunar surface.

Comparison of Liulin-MO dosimeter radiation measurements during ExoMars 2016 TGO Mars circular orbit with dose estimations based on galactic cosmic ray models

V. Benghin, V. Shurshakov, J. Semkova, T. Dachev, St. Maltchev, B. Tomov, Yu. Matviichuk, P. Dimitrov, R. Kovaleva, K. Kanev, I. Mitofanov, A. Malakhov; M. Mokrousov, A. Sanin, M. Litvak, A. Kozyrev, V. Tretyakov, D. Golovin, S. Nikiforov, A. Vostrukhin, F. Fedosov, N. Grebennikova; S.G. Drobyshev

The Liulin-MO dosimeter onboard ExoMars 2016 TGO had provided new information to compare dose rate estimations based on galactic cosmic ray models. The results obtained over the last years allowed us to combine series of the flux and dose rate data of the galactic cosmic rays near Mars. The analysis was carried out of the TGO attitude influence on the flux measurements. It has been clarified the method of Mars shading effect assessing on the Liulin-MO detectors flux measurements. The data obtained in a circular orbit were recalculated to free space conditions. A comparison of the extended data series with calculated estimations of flux and dose rate has been carried out.

OSU Dosimetric Experiments aboard the ISS

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R. Vaidyanathan[2], K. Herrman[2], Satoshi Kodaira[3], Hisashi Kitamura[3] and B. Gersey[4]

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The Oklahoma State University Radiation Physics Laboratory (OSURPL) continues to carry out dosimetric experiments both inside and external to the ISS. In Summer 2018, the OSURPL tested the Active Tissue Equivalent Dosimeter (ATED), a low-cost, portable tissue equivalent proportional counter, aboard the ISS. We are currently developing several updated versions of the ATED including a model capable of neutron/charged particle discrimination, and several models specifically designed for use in heavy ion accelerators and spallation neutron sources. The OSURPL is also participating in several experiments to test the radiation shielding efficacy of new materials external to ISS as part of the Materials on ISS Experiment (MISSE) program. Preliminary results from the MISSE-9 experiment, recently retrieved from the ISS, will be presented. The radiation shielding properties of one of the candidate materials, SC2020 containing Boron Nitride-loaded ultrahigh molecular weight polyethylene, together with those of baseline materials (polyethylene, aluminum, copper), is currently be exposed on the exterior of the ISS as part of the MISSE-11Experiment.

DOSIS & DOSIS 3D onboard the ISS – Status and Science Overview from 2009 - 2019

Thomas Berger for the DOSIS & DOSIS 3D Team

German Aerospace Center (DLR), Institute of Aerospace Medicine, Linder Hoehe, 51147 Cologne, Germany

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 on-board 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 DOSIS 3D (2012 - ongoing) experiment 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 (DOSTEL) 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 & DOSIS 3D in the years 2009 to 2019. Further on we will describe current ongoing work in terms of data comparison with the CRaTER (Moon) and the MSL-RAD (Mars) instruments and provide new results from GEANT-4 calculations for the ISS and also for a "simulated" Columbus Laboratory flying in free space.

Acknowledgments: At DLR, Cologne, DOSIS 3D was supported by the DLR grant FuE-Projekt ''ISS LIFE'' (Programm RF-FuW, Teilprogramm 475). The participation of the Technische Universität Wien, Atominstitut (ATI), Vienna, Austria in the DOSIS-1 and -2 experiments was supported by the Austrian Space Applications Programme (ASAP) under contract no. 819643. The Polish contribution for the Institute of Nuclear Physics (IFJ), Krakow, Poland was supported by the National Science Center (project No DEC-2012/06/M/ST9/00423). MTA EK greatly acknowledges the possibility to participate in the project to DLR and to the ESA PECS for the financial grant No. PECS4000108464. The participation of the Nuclear Physics Institute of the Czech Academy of Sciences has been supported by the grant of Czech Science Foundation (GACR) No. 15-16622Y. The CAU, University of Kiel was supported by DLR under grants 50WB0826, 50WB1026, 50WB1232 and 50WB1533

The RAMIS radiation detector of the DLR Eu:CROPIS mission – data from first 8 months at 600 km orbit

Thomas Berger, Karel Marsalek, Daniel Matthiä, Bartos Przybyla, Michael Wirtz, Markus Rohde and Joachim Aeckerlein for the Eu:CROPIS team

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At the 3rd December 2018 the DLR Eu:CROPIS satellite) was launched into a 600 km sun synchronous orbit (https://www.dlr.de/dlr/en/desktopdefault.aspx/tabid-11082/. The satellite mission Eu:CROPIS (Euglena gracilis: Combined Regenerative Organic-food Production In Space) is a testbed for investigating the behavior of combined biological life support systems under the influence of altered gravity, here, Lunar and Martian gravity (Hauslage et al. 2018). Eu:CROPIS is also equipped with two silicon detector telescopes (RAMIS) developed and built at the Institute of Aerospace Medicine. The 1st RAMIS (PL3M2) is mounted on the top of the satellite under very low shielding conditions, while the 2nd RAMIS detector (PL1M1) acts as a dosimeter for the biological payload inside the satellite. The two systems were activated on 5th December 2018. The talk will give an overview of the data generated within the first 8 months of the mission, focusing on the contributions from GCR, Electrons of the outer radiation belts and protons from the South Atlantic Anomaly.

Acknowledgments: At DLR, Cologne, Eu:CROPIS was supported by the DLR grant FuE-Projekt ‘‘EuCROPIS’’.

References: Hauslage, J., Strauch, S.M., Eßmann, O., Haag, F.W.M., Richter, P., Kruger, J., Stoltze, J., Becker, I., Nasir, A., Bornemann, G., Müller, H., Delovski, T., Berger, T., Rutczynska, A., Marsalek, K., Lebert, M., (2018). Eu:CROPIS – “Euglena gracilis: Combined Regenerative Organic-food Production in Space” - A Space Experiment Testing Biological Life Support Systems Under Lunar And Martian Gravity Microgravity-Science and Technology, 1-10, https://doi.org/10.1007/s12217-018-9654-1

Fluorescent Nuclear Track Detectors based on LiF single crystals

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Lithium fluoride is a very well-known thermoluminescent material, widely applied in ionizing radiation dosimetry.Besides thermoluminescence, LiF exhibits also another radiation related phenomenon: radio-photoluminescence, i.e.emission of luminescence from radiation-created defects under excitation with light of specific wavelength. This effect was recently successfully exploited for a novel method of imaging tracks of single nuclear particles [1, 2]. LiF single crystals were grown with the Czochralski and micro-pulling-down methods at IFJ PAN in Kraków. The crystalline samples were irradiated with various radiation modalities, including several high-energy ion beams at the HIMAC accelerator in Chiba. Fluorescent images of nuclear particle tracks were then obtained under blue light excitation, using a wide-field fluorescent microscope equipped with a high-sensitive CCD camera. The lateral resolution of the track images was found to be below 0.5 µm, while axial below 1 µm. The intensity of track luminescence depends on ionization density, what gives possibility of LET estimation. The LiF fluorescent track detectors were already exposed on orbit within DOSIS-3D project.

Acknowledgements:
This work was supported by the National Science Centre, Poland (Contract No. UMO-2015/17/B/ST8/02180). The data was partly generated in the frame of the HIMAC Research Project 17H374 "Space Radiation Dosimetry – Energetic ParticleDetection with Active and Passive Detector Systems for Space Missions".

[1] P. Bilski, B. Marczewska, W. Gieszczyk, M. Kłosowski, M. Naruszewicz, Y. Zhydachevskyy, S. Kodaira, *Luminescentproperties of LiF crystals for fluorescent imaging of nuclear particles tracks*, Opt. Mater., 90 (2019) 1-6.
[2] P. Bilski, B. Marczewska, W. Gieszczyk, M. Kłosowski, M. Naruszewicz, M. Sankowska, S. Kodaira, *Fluorescent imaging of heavy charged particle tracks with LiF single crystals*, J. Lumin., 213 (2019) 82-87.

RADTEL charged particle detector for space weather measurements as part of the RadMag system

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Understanding space weather and even forecasting it is more and more important for space missions and even for terrestrial systems since it can be hazardous to astronauts, spacecraft and terrestrial systems as well. As a first step toward this goal, a fleet of satellites are needed around the Earth to monitor magnetic field changes and cosmic radiation intensity at several different points in real-time to build up a reliable database. Since over the last-decade, the market of small and micro satellites has undergone tremendous growth, it brought the cost of smaller satellites closer to a realistic budget. That is why the Hungarian Academy of Sciences Centre for Energy Research has been developing a space weather monitoring system called RadMag in the size of a micro satellite. The first technology demonstration of the system will be on board of the RADCUBE 3U CubeSat developed by C3S Electronics Development LLC.

The RadMag system has two main parts, the magnetic field measurement system and the radiation measurement telescope called RADTEL, which is a biaxial silicon semiconductor charged particle detector telescope for measuring protons, electrons, and heavy ions. The first assembly of the detector has just been tested with accelerator generated proton beams and now the system is ready for its next stage. In this talk the current state of the project will be presented.

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First Measurements of the Radiation Dose on the Lunar Surface with the LND instrument on the Chang'E 4 lander

Sönke Burmeister[1], Shenyi Zhang[2,3,4,5], Robert F. Wimmer-Schweingruber[1,2], Jia Yu[1] , Chi Wang[2], Qiang Fu[6], Yongliao Zhou[2], Yueqiang Sun[2,3,5], Chunqin Wang[2,3,5], Donghui Hou[2,3,4,5], Stephan Böttcher[1], Lars Seimetz[1], Björn Schuster[1], Guohong Shen[2,3,5], Bin Yuan[2,3,5], Henning Lohf[1] , Zigong Xu[1], Johan L. Freiherr von Forstner[1], Haitao Xu[2], Changbin Xue[2], Jun Li[2], Zhe Zhang[7], He Zhang[8], Thomas Berger[9], Christine E. Hellweg[9], Xufeng Hou[10], Baoguo Ren[10], Zhen Chang[2,3,5], Binquan Zhang[2,3,5], Yuesong Chen[2], Hao Geng[2], Zida Quan[2,3,5]

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Besides other effects space radiation is one of the most concerning risks for astronauts participating in human exploration missions to the Moon. Astronauts travelling to the moon and staying on its surface are exposed to radiation consisting of galactic cosmic rays and sporadic solar particle events. The interaction of this radiation field with the lunar soil leads to a third component which consists of neutral particles, i.e., neutrons and gamma radiation. On January 3, 2019 at 02:26 UTC the Chinese Chang'E 4 mission landed in the von Karman crater on the far side of the Moon. Immediately after the landing the Lunar Lander Neutrons and Dosimetry (LND) experiment aboard China's Chang'E 4 lander has made the first ever measurements of the radiation exposure to both charged and neutral particles on the lunar surface. An overview of the Chang'E 4 mission and the LND instrument in detail will be presented as well as first dosimetric results of LND instrument.

The CAU contributions are financially supported by BMWi under Grant 50JR1604

Solar modulation, Forbush decreases and Solar Energetic Particles measured by AMS on the ISS

Claudio Corti

University of Hawaii at Manoa
Physics and Astronomy Department
Prof. Veronica Bindi's AMS group

The Alpha Magnetic Spectrometer (AMS), on the International Space Station (ISS) since May 2011, has acquired the largest number of particles ever measured in space by a single experiment, performing the most precise measurement of galactic cosmic rays (GCRs) to-date. The detailed time variation of multiple particle species fluxes measured in the first years of operations will be shown. This period covers the ascending phase of solar cycle 24, the solarm aximum and reversal of the Sun's magnetic field polarity, and the descending phase towards the solar minimum.

For all particles, the high energy spectrum remains stable versus time, while the low-energy range is strongly modulated by the solar activity. In addition, AMS measured several Forbush decreases (FD) and solar energetic particles (SEP) associated with the short term solar activity. AMS data allows us to study the time evolution of the rigidity dependence of these type of events for multiple particle species. Selected FD and SEP events observed by AMS, since the beginning of its mission, will be presented.

Validation of NASA's Radiation Analysis Tools with ISS Radiation Environment Monitor (REM) Measurements

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NASA's Advanced Exploration Systems (AES) RadWorks project supports efforts to validate the computational tools used to evaluate astronaut radiation exposure. These tools include environment models, charge and neutral particle transport codes, and spacecraft shielding models. Measurements made with the Radiation Environment Monitor (REM) detectors, currently onboard the International Space Station (ISS), have provided an opportunity to perform end-to-end validation of the radiation analysis tools, and to evaluate the impact of a number of model and code improvements. Calculated results accurately model the time dependence of the environment within ISS, but underestimate dose resulting from Galactic Cosmic Rays (GCR). Initial calculations performed in 2014 underestimated GCR dose by approximately 25% at high southern/northern latitudes, where the environment is similar to the free space environment, and by approximately 60% in the equatorial region. Since that time, ISS models have been updated, a number of improvements to the environment models have been evaluated, and a new version of the HZETRN space radiation transport code has been developed. Updates to the transport code, a new 3D transport algorithm and coupling of the pion transport to the nucleon transport, had the largest impact on results. These updates reduce the under-prediction in high cutoff rigidity regions in the equatorial region to approximately 40% with smaller improvements in lower cutoff rigidity regions.

Keywords: Galactic Cosmic Rays (GCR), International Space Station (ISS), HZETRN

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NASA GeneLab space omics database: expanding from space to ionizing radiation data on the ground

Jack Miller, **Sylvain V. Costes**

NASA Ames Research Center

NASA GeneLab is an open-access repository for omics datasets generated by biological experiments conducted in space or ground experiments relevant to spaceflight (e.g. simulated cosmic radiation, simulated microgravity, bed rest studies). The GeneLab Data Systems (GLDS) version 4.0 will be available on October 1st 2019, and will provide a state-of-the-art bioinformatics platform for the space biology and radiation communities to upload their data into an omics data commons, to process their data with vetted standard workflows and to compare with existing analyses. Started in 2015 as a repository designed to archive omics data from space experiments, GeneLab has expanded its scope to all ionizing radiation omics experiments conducted on the ground and has put considerable effort in providing carefully characterized radiation metadata on all datasets. GeneLab is also providing processed data derived from the raw data covering a large spectrum of omics (genome, epigenome, transcriptome, epitranscriptome, proteome, metabolome) to help users explore important questions: 1) Which genes or proteins are expressed differently in space for various living organisms? 2) What specific DNA mutations or epigenetic changes happen in space or after exposure to ionizing radiation? and 3) How does genetics affect these responses? Processed data available on GeneLab are derived by standard data analysis workflows vetted by hundreds of scientists who volunteered to join one of the four GeneLab Analysis Working Groups (Animal AWG, Plant AWG, Microbe AWG, Multi-Omics AWG). In this presentation, we will discuss how to bridge the gap between irradiation studies performed on earth and biological experiments conducted in space since the early 1990's. We will discuss how radiation dosimetry was estimated for datasets derived from samples collected during the Space Shuttle era, on the International Space Station or on other orbiting platforms. Finally, we will address future strategies regarding dose monitoring in future missions into space, inter-agency efforts to unify data under one umbrella, and knowledge dissemination across the radiation research community and the space biology community.

GCR flux and dose rates variations observed experimentally by 13 Liulin type instruments between 1991 and 2019.

T. Dachev[1], B. Tomov[1], Y. Matviichuk[1], P.Dimitrov[1], J. Semkova[1], R. Koleva[1], N. Bankov[1], M. Jordanova[1], V. Shurshakov[2], V. Benghin[2]

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The paper presents the GCR flux and dose rates variations, observed experimentally by 13 Bulgarian build (Liulin type) spectrometers-dosimeters, which worked in the Earth and interplanetary radiation environment between 1991 and 2019. The existing Liulin type instruments GCR flux and dose rate data, obtained at L values larger than four in low earth orbit (LEO) and during 2 flights outside the Earth magnetosphere from 1991 to 2019 are compared with the monthly values of the modulation parameter (in MV) reconstructed from the ground based cosmic ray data, using the procedure described by (Usoskin et al., 2017). Relatively good agreement between the two data sets is obtained.

Analysis of the radiation environment, obtained in 2018-2019 by Liulin Ten-Koh instrument on the Japanize Ten-Koh satellite

T. Dachev[1]*, P. Dimitrov*[1]*, B. Tomov*[1]*, Y. Matviichuk*[1]*, N. Bankov*[1]*, P. Saganti*[2]*, D. Holland*[3]*, K. Okuyama*[4]*, I. Fajardo*[4]

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On 29 October 2018 was successfully launched, at about 623 km altitude and at 98° inclination, the 23.5-kilogram mass satellite Ten-Koh, developed in Kyushu Institute of Technology by Prof. K. Okuyama. Ten-Koh's primary science instrument is the Charged Particle Detector (CPD) developed at the Prairie View A&M University, and NASA Johnson's Space Center of Houston, TX, USA. The Liulin Ten-Koh instrument is mounted on the top of the CPD. The following three primary radiation sources were expected and recognized in the data obtained with the Liulin Ten-Koh instrument: (i) globally distributed primary GCR particles and their secondary products, (ii) energetic protons in the South Atlantic Anomaly (SAA) region of the inner radiation belt (IRB); (iii) relativistic electrons and/or bremsstrahlung in the high latitudes of the Ten-Koh orbit where the outer radiation belt (ORB) is situated. The data is compared with data from other Liulin type instruments. The aim of the paper is to analyze the total amount off the space radiation data obtained by Liulin Ten-Koh instrument on the Japanize Ten-Koh satellite.

Updates from the MSL-RAD investigation and outlook for the future

B. Ehresmann[1], D. Hassler[1], C. Zeitlin[2], R. F. Wimmer-Schweingruber[3], D. Matthiae[4] , J. Guo[3], H. Lohf[3], G. Reitz[5]

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We will present updates and new findings from the last year of the Mars Science Laboratory – Radiation Assessment Detector (MSL-RAD) investigation that is measuring the radiation environment in Gale crater on Mars on board NASA's Curiosity rover. We will discuss and summarize the results of the 2nd Mars Radiation Modeling Workshop, held in Boulder in October last year. During the workshop different modeling teams presented their calculations of the Martian surface environment, and the results were then compared to the MSL-RAD measurements. We will, furthermore, present analysis of a "radiation shadowing" effect on the Martian surface radiation environment, provided by natural rock formations (buttes) that block out part of the hemisphere above RAD, and thus decrease the incoming radiation. We will also discuss an outlook on MSL's 3rd extended mission expected to start in October 2019, and what to expect for the MSL-RAD measurements in the next few years.

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Reviewing ISS-member cancer and non-cancer risk models and their differences for exploration class missions

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The space exploration community is increasingly focused towards crewed missions to the Moon and beyond. Such missions will present many unique engineering challenges. There are also other challenges involving crew health, including the radiation-induced health risks to crew that will differ from those in low-Earth orbit (LEO).

Radiation-induced health risks include both cancer and non-cancer diseases. Occupational dose limits, however, are typically defined to cap the increased risk of stochastic (cancers) and deterministic (acute effects) to an acceptable level while allowing continued flexibility for exploration; if occupational dose limits become too restrictive, certain mission scenarios simply cannot take place. Currently, International Space Station (ISS) member nations are working on consensus on regulatory dose limits for increased risk of developing cancer during missions beyond low-Earth orbit (BLEO).

For ISS, the Canadian Space Agency (CSA) does not employ gender and age-based career dose limits for Canadian astronauts, and has a single effective dose limit based on recommendations of the International Commission on Radiological Protection (ICRP) [1] . In contrast, the National Aeronautics and Space Administration (NASA) adopts recommendations based on the National Council on Radiation Protection and Measurement (NCRP) that are gender and age dependent [2,3]. This is only one example of differences in addressing radiation risk in space among various agencies.

Non-cancer effects are also a recognized concern. They have the potential to limit the effectiveness of crew during a mission and/or impact the quality of life of crew upon return. They include deterministic effects discussed earlier, but also age-related effects. One such example is cardiovascular disease which can occur for a variety reasons (i.e. lack of gravity) but maybe also a result of radiation damage [4]. To answer this, however, further investigation is needed. To this end, we will also explore the feasibility of setting up next generation cardiovascular tissue organoid model to model the biological effects of ionizing radiation.

The CSA is currently investigating the applicability of their dose limits for ISS to exploration class missions. In support of the CSA's effort, Canadian Nuclear Laboratories (CNL) is conducting a review of current cancer and non-cancer risk models. The objective is to summarize the differences and similarities in these models including under what assumptions they are developed and how they may be applied for future exploration missions. A preliminary summary of the differences identified will be provided during this talk.

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[4] R.L. Hughson et al., "Heart in space: effect of the extraterrestrial environment on the cardiovascular system", Nature Reviews Cardiology, 2017.

Dosimeter System for ORION-MARE

Marianthi Fragkopoulou for HERADO Team

The Orion Multi-Purpose Crew Vehicle (MPCV) is NASA's next generation human rated Exploration-class spacecraft. Orion upcoming flight Artemis-1 formerly known as Exploration Mission-1 is scheduled to launch on 2020. The Artemis-1 is an un-manned flight circumnavigating the moon. This flight presents a unique opportunity for a large scale intravehicular dosimetry Intercomparison, in an environment that has not been explored by human rated spacecraft since the last Apollo mission. Radiation measurements represent an excellent opportunity to improve Astronaut safety. MARE (Matroshka AstoRad Radiation Experiment) is a radiation science payload proposed to fly on Artemis-1 by German Aerospace Center (DLR) and the Israel Space Agency (ISA) and subsequently accepted and manifested by NASA. MARE consists of two female tissue equivalent phantom torsos instrumented with radiation detectors and located inside the Orion. Both phantom torsos are integrated by DLR with active and passive radiation detectors provided by DLR and other international participants. Greece is accepted to participate in these experiments by providing a real time dosimeters system ALMAR for the upcoming flight. The status of the system is going to be presented.

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The AMS-02 experiment as a cosmic-ray flux and radiation monitor on the ISS

Valerio Formato
INFN-Sezione di Roma2

The Alpha Magnetic Spectrometer (AMS) experiment has been continuously measuring cosmic rays since May 2011, on board the International Space Station (ISS). This allows for a precise measurement of cosmic ray fluxes, and of their long-term variation with time and rigidity during the whole ascending phase of solar cycle 24, through the reversal of the Sun's magnetic field polarity and the current solar minimum.

We present AMS differential flux measurements for several cosmic ray species, and their time and rigidity variations, as observed in the period between May 2011 and May 2018 at rigidities below 60 GV. The results will be discussed together with the prospects to also exploit the instrument low-level data, and to use AMS to provide a low-latency monitoring of the cosmic ray flux intensities outside the as well as to identify Solar Particle Events and trigger radiation enhancement alarms to the ISS crew.

Twenty Years of Passive Radiation Dosimetry on ISS: Ops Radiation Area Monitors Results

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Monitoring space radiation is of vital importance for risk reduction strategies in human space exploration. Passive radiation detectors have been used for personal and ambient space radiation measurements since the Mercury and Gemini programs, throughout the Space Shuttle and International Space Station (ISS) programs, including the Orion Multipurpose Crew Vehicle (MPCV), Exploration Flight Test 1 (EFT-1) flight. On the ISS, the Radiation Area Monitors (RAM) used for operational space radiation dosimetry include a combination of thermally and optically stimulated luminescence dosimeters (TLD/OSLD) to measure the low-LET region (LET<10 keV/µm in water) of the space radiation spectrum and plastic nuclear track detectors (PNTDs) for the high-LET region (LET>10 keV/µm in water), per the National Council on Radiation Protection recommendation to comply with the ALARA radiation protection principle (NCRP, 2004). This combination of radiation detectors has been successfully implemented at NASA Johnson Space Center (JSC) to measure the ISS crewmembers' exposure and provide vehicle monitoring inside all habitable modules.

Even though passive detectors are well understood and capable of providing accurate cumulative dose measurements, they do not provide the time-resolved data needed for long-term Exploration Missions (i.e., Lunar, Mars). Thus, the Space Radiation Analysis Group at NASA/JSC investigated several real-time instruments for personal and area radiation monitoring, culminating with the transition from the passive RAM to the active Radiation Environment Monitors (REM) as ISS operational instruments in June 2019.

In addition, the Crew Active Dosimeter (CAD), a Direct Ion Storage device developed for NASA applications by Mirion Technologies, Inc., has been investigated as a potential replacement for the ISS Crew Passive Dosimeter (CPD).

The first part of the presentation will involve an overview of the last 20 years of RAM operational measurements on ISS, to include the detailed Node 2 Crew Quarters radiation dose mapping performed in 2017-2018. The second part of the presentation will include updates to the current status of the CAD Transition to Operations on ISS.

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The Hybrid Electronic Radiation Assessor (HERA) system

Stuart George

University of Houston/NASA JSC

This talk discusses the qualification campaign and measurement capabilities of the Artemis 2 (A-2) Hybrid Electronic Radiation Assessor (HERA) system. HERA is NASA's active radiation monitoring system for the Orion Multi-Purpose Crew Vehicle (MPCV). Each HERA string consists of a HERA Processing Unit connected to three Timepix pixel detectors, one local and two on remote HERA Sensor Units distributed throughout Orion. Compared to the HERA system on Artemis 1, A-2 HERA features minor hardware changes and a significant software upgrade that provides HERA with baseline spectroscopic capability.

This talk discusses the results of the recently completed qualification campaign for the HERA A-2 system and the production and certification of the first three of seven planned flight units. This includes validation of dosimetry capability at Chicago Proton Center and particle energy and charge binning at the Nasa Space Radiation Laboratory.

Pille Measurements on ISS (February 2018 – July 2019)

A. Hirn[1], I. Apáthy[1], V. A. Bondarenko[2], S. Deme[1], O. Gorokhova[3], O. Ivanova[2], V. Mitrikas[2], I. V. Nikolaev[3], V. A. Shurshakov[2], A. Strádi[1], V.V. Tsetlin[2]

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[3]Rocket and Space Corporation, Energia, Russia

The Pille system was developed as the first and to date the only TLD system containing an on-board reader designed specifically for use by cosmonauts and astronauts while traveling in space. Since the first time it was launched in 1980, the Pille system worked on board each space station. It has been continuously used on board the International Space Station since October 2003 under the supervision of the Institute for Biomedical Problems (IBMP) as the service dosimeter system of the Russian Zvezda module. In the past 15 years the dosimeter system was utilized for routine dose measurements inside the ISS, and as personal dosimeter system during Extra-vehicular Activities (EVAs).

The Pille system consists of a lightweight reader device and a number of TL dosimeters ($CaSO_4$:Dy). It 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 June 2018, a new Pille reader (with 5 additional dosimeters) was delivered to ISS to replace the "old" reader operating on board since 2003. Commissioning of the new system started in July 2019 including cross-comparison measurements with the "old" system.

In the present paper the measurement data (including several EVA measurements) obtained by the Pille system from the period between February 2018 – July 2019 are presented. The results are also compared with previous measurement results.

In the present paper the measurement data (including several EVA measurements) obtained by the Pille system from the period between February 2018 – July 2019 are presented. The results are also compared with previous measurement results.

Orion Artemis-1 Internal Environment Characterization: The Matroshka AstroRad Radiation Experiment

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Artemis-1, formerly known as Exploration Mission-1, will be the first integrated test of NASA's deep space exploration systems. The first in a series of increasingly complex missions, Artemis-1 will be an uncrewed flight test that will provide a foundation for human deep space exploration and demonstrate the continued commitment and capability to extend human existence to the Moon and beyond. During this mission, the Orion spacecraft will launch on the most powerful rocket in the world and fly farther than any spacecraft built for humans has ever flown. Artemis-1 is scheduled to launch in 2020 and will reach cislunar space for a total mission duration of about three weeks. The spacecraft will be exposed to ionizing radiation environments, including Van Allen belts, galactic cosmic rays (GCR), and potentially solar energetic particle (SEP) events. Biological effects on the human body depend upon the extravehicular environments as modulated by the spacecraft as well as body self-shielding, leading to complex radiation exposure patterns of various organs and tissues. Accurate radiation risk assessment requires knowledge of this internal dose deposition map due to different biological susceptibilities of various organs.

The Matroshka AstroRad Radiation Experiment (MARE) is a science secondary payload manifested aboard Artemis-1. MARE aims to characterize the body internal radiation exposure using human torso analogs instrumented with radiation detectors. MARE is an international experiment lead by the German Aerospace Center (DLR), Israel Space Agency (ISA) and NASA as co-principal investigators and supported by industry contractors. The payload leverages heritage from the Matroshka series of experiments led by DLR on board the International Space Station (ISS), but it expands upon its original scope. On Orion Artemis-1 not one, but two radiation phantoms referred to as Helga and Zohar are located inside the pressurized cabin at seat positions #3 and #4. Zohar is fitted with the AstroRad radiation shielding garment produced by a research and development (R&D) collaboration between Lockheed Martin and StemRad, Israel; thus, a radiation mitigation solution is validated in parallel with the nominal environment characterization. The Matroshka AstroRad Radiation Experiment is designed to provide a comprehensive picture of the radiation environment beyond Earth orbit specific to the Orion spacecraft and internal to human body analogs. This paper presents a detailed description of the MARE payload and the integration status on board of Orion spacecraft,including the suite of radiation detectors, the radiotherapy phantoms used as body analogs, and the AstroRad vest.

The experiment is co-managed by DLR and ISA, with NASA participation as a co-PI. StemRad and Lockheed Martin contribute to the development of AstroRad science objectives. Numerous research groups on three continents participate as co-Is, including ESA. Lockheed Martin personnel facilitate payload integration in the spacecraft. MARE will provide valuable environment characterization specific to the Orion vehicle, validate a protection solution, and ultimately help enable longer mission durations and improve crew safety.

Artemis-2 Full Launch Window Trajectory Analysis and Projected Exposures at Radiation Hardware Locations on Artemis Flights

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Artemis-1 is planned to launch in October of 2020 and there will be several radiation measurement devices for operations that will be tested on this mission. This includes the passive RAMs and the active HERA instrument. There will be 6 RAMs and 3 HERA devices at various locations within the Artemis-1 vehicle. We will use the nominal Artemis-1 trajectory, shielding models of the spacecraft, and the radiation environment models to predict the expected dose and dose rates that will be observed by these instruments.

Artemis-2, the first crewed mission, is planned to launch in October of 2022. There is a finite time window in which the first crewed Artemis mission can launch in order to successfully reach the Moon. The various times of launch dictates where the vehicle passes through the trapped radiation belts. We have used 168 trajectories that span the full range of potential azimuthal launch angles for the Artemis-2 trajectory and show which launch angle corresponds to the best and worst case scenarios with respect to radiation exposure at a specific internal point of the vehicle.

Title: Data Comparison between the ISS-RAD Fast Neutron Detector and the Advanced Neutron Spectrometer and Updates on FND Operational Neutron Dose Equivalent and Energy Spectrum Data

Martin Leitgab, on behalf of the ISS-RAD and ANS Teams

SRAG, NASA JSC, Houston

Abstract: The International Space Station Radiation Assessment Detector (ISS-RAD) instrument was activated on ISS on February 1, 2016. Integrated within ISS-RAD, the Fast Neutron Detector (FND) performs direct neutron measurements between 0.2 and 8.75 MeV of neutron energy, for the first time aboard ISS as a NASA ISS Radiation System operational instrument. A summary of FND neutron dose equivalent and flux spectra results over 3 years of operations will be given.
The Advanced Neutron Spectrometer (ANS) started operations as a technology demonstration on ISS on December 2, 2016, measuring fast neutrons over a similar and wider energy range than the FND detector. The ANS and FND instruments were co-located from October 2018 to January 2019 in the US Lab. A comparison of neutron dose equivalent and flux spectra results between ANS and FND will be shown.

The RadMap Telescope Technology Demonstrator Aboard the ISS

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ABSTRACT

Protecting astronauts against the space radiation environment is one of the major challenges of human space flight. Especially in future missions to the Moon, Mars, and other deep-space destinations with no or minimal natural protection, mitigating radiation effects through shielding and other measures will be critical to mission success. Hence, detailed knowledge about the composition of the radiation environment and its temporal variations is a prerequisite for the design of new spacecraft, habitats, surface vehicles, and space suits. Real-time information about radiation levels inside a spacecraft or habitat is also required for moving astronauts to safety during brief but intense solar-radiation events.

The RadMap Telescope is a technology-demonstration experiment whose main objective is to validate new radiation-sensing concepts for applications in manned and unmanned spacecraft. It is scheduled for deployment to the International Space Station (ISS) in 2020. Currently, the radiation environment aboard the ISS is monitored by a suite of active and passive dosimeters, particle telescopes, and small spectrometers. The RadMap Telescope combines several capabilities of these sensor types in one device and may even expand some of them. Due to its novel design, it also has new, unique capabilities; for example, the ability to monitor the radiation environment omnidirectionally without having to turn or relocate the sensor. The instrument comprises technologies that have only become sufficiently mature for large-scale applications in the past few years. These technologies enable the construction of compact yet highly capable radiation monitors. Much of the data is pre-analyzed on the instrument before being downlinked to the ground for detailed analysis. The centerpiece of this on-line pre-analysis is a framework of machine-learning algorithms that ensures the most important information, such as the radiation dose, is available with as little delay as possible.

In this contribution, we present the overall design of the instrument, how it will be integrated into the ISS environment, and how it addresses the need for detailed studies of the space radiation environment. We show results from proof-of-principle ground tests that we performed during the development of the instrument and outline how we intend to use data from operational radiation sensors for validation. If proven to work as expected, the technology demonstrated in the RadMap Telescope may be used in new radiation detectors and help to reduce the number of sensors required in future spacecraft while increasing measurement capabilities at the same time.

Invited Talk (Wednesday 9:00 am)

Energetic Particles in the Heliosphere: Science and Applications

Olga E. Malandraki

IAASARS, National Observatory of Athens, GR-15236 Penteli, Greece

Energetic particle populations in the heliosphere will be reviewed with emphasis on Solar Energetic Particles (SEPs),that constitute an important contributor to the characterization of the space environment. SEP events pose a threat to modern technology strongly relying on spacecraft and are a serious radiation hazard to humans in space, and are additionally of concern for avionics and commercial aviation in extreme circumstances. Two real-time prediction tools developed in the framework of the HESPERIA HORIZON 2020 project i.e. HESPERIA UMASEP-500 and HESPERIA REleASE, providing > 500 MeV and 30-50 MeV proton predictions, respectively, will be presented. Both forecasting tools are operational under the HESPERIA server maintained at the National Observatory of Athens (http://www.hesperia.astro.noa.gr). Furthermore, expected advances in view of the unique measurements provided by the Parker Solar Probe mission and the upcoming Solar Orbiter mission in the inner heliosphere will be briefly discussed.

Radiation dose on/around the Moon and its protection

Masayuki Naito, Nobuyuki Hasebe, Satoshi Kodaira

Recently, the Moon and its surround is considered as a promising planetary body developed for future manned activities in space. The radiation environment on/around the Moon are severe comparing to the Earth which is shielded by the atmosphere and magnetic field since high energy particles such as galactic cosmic rays (GCRs) and solar energetic particles (SEPs) are directly projected. It is essentially important for future manned missions to evaluate the radiation dose on/around the Moon and estimate its shielding by materials. In this study, the effective dose equivalent due to the GCR particles from H to Fe (GCR dose) was obtained by numerical simulations. The radiation shielding by some materials were also evaluated from the aspect of some physical parameters.

The GCR doses around the Moon become ~87 mSv/y at solar maximum phase and ~240 mSv/y at solar minimum phase in the case of no radiation shielding. Those on the Moon increase up to ~95 mSv/y and ~260 mSv/y, respectively, because of secondary neutrons from lunar surface although the secondary dose is trivial comparing to the GCR primary dose. It is obvious that the radiation shielding is essential for long term manned missions. The particle contributions to GCR dose during solar minimum phase are ordered as H (23%), Fe (16%), He (10%), O (10%) … To attenuate the GCR dose by radiation shielding, it is effective to decrease charge and energy of heavy particle; i.e., Fe. If the GCR dose due to 1 GeV/n Fe can be attenuated 90% by radiation shielding, the decrease of total GCR dose is up to ~40%. It means that the restriction of mission length from the aspect of astronaut dose becomes ~1.7 times longer. This radiation shielding corresponds to ~25 g/cm^2 polyethylene.

The stopping power of shielding material per mass depends on A_T/Z_T where A_T and Z_T are total atomic mass and charge of target material, respectively. Yield of secondary particle per material mass depends on $\sigma_T/\rho \propto Z_{Tave}^{2/3}/A_{Tave}$ where σ_T, ρ, $Z_{Tave}^{2/3}$ and A_{Tave} are target cross section, density, average charge and atomic mass, respectively. It is found that hydrogen rich materials show high stopping power and cross section. However, we have to be careful that these parameters are those per mass. The most effective material is not always best for shielding material for manned space missions since there are restrictions in both mass and volume for launch. High density material such as aluminium allows to save space in spite of its low shielding efficiency per mass. Some composite materials such as CFRP (carbon fiver reinforced plastic) and SiC composite plastic which is also available to construct fixtures in spacecraft may be promising from the aspect of density and efficiency.

When manned activity on the Moon is considered, materials and structures on the lunar surface are also available for radiation shielding. Especially, the lunar structure is effective, allowing decrease the GCR primary dose by solid angle. For example, it decreases up to ~1/2 by standing on crater deeper than one’s height since the GCR exposure from lateral direction is suppressed.

LIDAL: update of the project, ground tests and perspectives

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LIDAL (Light Ion Detector for ALTEA) is a detector based on scintillators for fast time applications. It is designed to work paired with three ALTEA Silicon Detector Units (SDUs) as a single detector system.
Its major addition to the ALTEA features are the capability to perform Time of Flight (ToF) measurements for passing through particles, and to provide a low Linear Energy Transfer (LET) trigger to the LIDAL-ALTEA system. This last feature allows to extend the LIDAL-ALTEA system detection capability up to relativistic protons and helium ions.
The ToF information significantly enhance particle identification capability already provided by the deposited energy measured by the ALTEA SDUs.
As the new LIDAL system is seen by the ALTEA electronics as part of the ALTEA system, the orbit to ground data routing will be the same as the one used for ALTEA. Real time observation and analysis will therefore be possible.
This presentation will first provide an overview of the LIDAL-ALTEA detector system and then the results of the ground tests performed on the Flight Model of the detector time resolution at TIFPA (Trento, Italy) with protons and at CNAO (Pavia, Italy) with Carbon ions, where the time resolution of the ToF system well below the 100 ps has been confirmed.
The detector system has been handed over to NASA in the week of July 29th 2019. It is manifested to fly next October 2019 on the NG12.
Status of the detector and of the final tests will also be provided.

ERFNet, a network for ground work in radiation mitigation to suppor deep space exploration.

Livio Narici for the ERFNet collaboration

The international research and technological efforts aimed at mitigating radiation risks during exploration class missions is broad and includes activities in many interdisciplinary areas. Several facilities in Europe devoted to space exploration research are supporting these works, by simulating, for example, radiation environment and / or space habitats. Increasingly larger efforts in several relevant scientific teams and panels have been put in the development and validation of risk models, to be able to quantify the radiation effects on the crew.
The researcher, technologist or R&D member of a space firm approaching these issues should navigate through the many related interdisciplinary areas to quantify the relevance of a possible new idea, and, whenever needed, to design the best strategy for its exploitation. This often relies on personal contacts, leading to non-optimal approaches and possibly lower efficacy.
To improve and support these endeavours and to provide upgrading strategies for the relevant facilities, ESA has financed the feasibility work for the European Radiation Facilities Network (ERFNet).
The ERFNet concept has been presented at the 23rd WRMISS in Tsuruga (JP) and now, also supported by the many responses and suggestions given at the WRMISS, the feasibility work has ended.
We are now in the process of providing inputs to ESA for the next development steps, that might start in September 2019.
In this talk an account of the status of the ERFNet work will be given, also to possibly gather further suggestions from all the WRMISS audience.

Lawrence Pinsky

Physics Department, University of Houston

The Timepix2 From The Medipix2 Collaboration—First Results

The CERN-based Medipix2 collaboration has produced the Timepix2, an updated and improved design as the potential successor of the venerable Timepix hybrid radiation-imaging pixel detector chip. Designed in TSMC 130 nm technology, the Timepix2 has the same active area as the Timepix and the same matrix of 256 x 256 with 55 μm square pixels. The Timepix2 can use the same sensors as the Timepix, however the solder-bump pads on the top of the chip have just 25 μm diameters. The Timepix2 pixels can be operated in a variety of modes making different uses of 28-bit pseudorandom output shift-register including simultaneous Time-Over-Threshold (TOT) ADC and Time-of-Arrival (TOA) TDC capability. Another upgrade over the Timepix is the revised charge-sensitive frontend preamp with dynamic feedback that is designed to have a nominally linear response up >106 electrons. In addition, there is suppression for events in pixels that occur prior to the frame being opened where the discriminator is still high, and for continuing to count active TOT's after the frame ends. Other counting modes are possible with continuous (~dead-time free) readout by splitting the output register. Results from several runs with the new Timepix2 in heavy ion beams at the HIMAC facility in Japan, have validated most of the design goals, including the potential ability to use the "Backside Pulse" (monitoring the current flow in the sensor bias voltage) to supplement the LET measurement capability out to > 500 KeV/mm. Future plans for the Timepix2 characterization will be discussed.

Radiation and X-Ray Measurements in Polar Orbit by Ten-Koh 2018 Spacecraft and Comparative Assessment with ISS Measurements

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A light weight and a low power radiation measuring device with multiple sensors was developed for Solar and Heliospheric Assessment of Radiation Particles (SHARP) - Charged Particle Detector (CPD) [SHARP-CPD], and it was launched as part of the Ten-Koh Spacecraft of Kyushu Institute of Technology, KIT-Japan, for Earth's Polar Orbit on October 29, 2018 by JAXA, Japan. This unique payload is comprised of six radiation sensors, two x-ray detectors, and one particle spectrometer.

This radiation payload has the following seven main features: (1) the Liulin particle spectrometer of the Bulgarian Academy of Sciences (BAS) for radiation dose measurement along with the PVAMU's CMOS sensors for assessing radiation transport; (2) a set of two sensors covered with polyethylene spheres to study shielding effectiveness over time; (3) a set of two sensors covered with polystyrene for assessing dose measurement over time; (4) a set of two open sensors for ambient radiation measurements; (5) a pioneering design with a set of two sensors with scintillating material for detecting x-rays in the polar orbit; (6) the entire frame structure was built with PEKK material for low-static electrical interference; and (7) in-flight command control capability, to manage data collection protocols of any sensor independently.

The design and development of this payload was accomplished as a collaborative effort of the Texas A&M University (TAMU) Chancellor's Research Initiative (CRI) at Prairie View A&M University (PVAMU), Radiation Institute for Science and Engineering (RaISE), and NASA Johnson Space Center, for the Ten-Koh spacecraft of the Kyushu Institute of Technology (KIT).

The Ten-Koh spacecraft of KIT-Japan has been in Earth's Polar Orbit at 93 degrees at an altitude of ~ 600 km. We are receiving very valuable data as of this abstract preparation and preliminary results will be presented.

Ref. https://www.pvamu.edu/raise/space-payload/charged-particle-detector-2018/).

Radiation environment aboard ExoMars Trace Gas Orbiter in Mars science orbit in May 2018-July 2019

Semkova J.[1], Koleva R.[1], Krastev K.[1], Benghin V.[3], Matviichuk Yu.[1], Tomov B.[1], Dachev T.[1], Maltchev S.[1], Dimitrov P.[1], Bankov N. [1], Mitrofanov I.[2], Malakhov A.[2], Mokrousov M.[2], Sanin A.[2], Litvak M.[2], Kozyrev A.[2], Tretyakov V.[2], Golovin D.[2], Nikiforov S.[2], Vostrukhin A.[2], Drobyshev S.[3], Shurshakov V. [3]

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We present recent results from measurements of the charged particle fluxes, dose rates and estimation of quality factor and dose equivalent rates at ExoMars Trace Gas Orbiter (TGO) science orbit (400 km circular orbit from Mars, 74^0 inclination), provided by Liulin-MO dosimeter of FREND instrument aboard TGO. The obtained data from May 2018 to July 2019 show that 1) Slight increase of the dose rate and flux is observed, which corresponds to the increase of GCR intensity during the declining of the solar activity. Short term modulations of GCR fluxes by interaction with solar wind are observed; 2) A strong dependence of the measured fluxes on the part of the field of view shadowed by Mars is observed; 3) There is a slight dependence of the flux distribution on the Martian latitude and longitude; 4) Measurements in two perpendicular directions show that the flux is about 93% (3.06, 3.16 $cm^{-2}s^{-1}$), dose rate is 87% (360.5±36, 374.9±37 μGy day^{-1}), dose equivalent rate is 72% (1.6±0.34, 1.7±0.35 mSv day^{-1}) of that in February-March 2017 in high elliptic Mars orbit; 5) A reasonable agreement between GCR count rates from Liulin-MO and Oulu neutron monitor is observed.

Recent Bubble-Detector Measurements for Matroshka-R and Radi-N2

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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 characterize neutron radiation on the ISS for the Matroshka-R, Radi-N, and Radi-N2 activities. These ongoing measurements are conducted in both the Russian Orbital Segment (ROS) and the US Orbital Segment (USOS) of the ISS.

Matroshka-R and Radi-N2 continued to accumulate data during the recent ISS-55/56 and ISS-57/58 increments in 2018/19, and the current ISS-59/60 expedition. The primary goal of Radi-N2 is to characterize 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. This presentation reports on surveys conducted during ISS-55/56 and ISS-57/58 in the US Laboratory, the JEM, Node 2, and Node 3. Experiments during ISS-59/60 have extended the Radi-N2 activity to include two new locations in the USOS, namely Node 1 and the Cupola. For some measurement sessions, one bubble detector was worn by Canadian astronaut David Saint-Jacques, while a second detector was located in his sleeping quarters. These data provide a comparison of the neutron dose equivalent in the sleeping quarters to that accumulated during daily activities around the space station. The recent Radi-N2 results are compared with the earlier Radi-N and Radi-N2 data from the same locations to assess potential influences on the neutron radiation field across the full solar cycle since the Radi-N experiments in 2009.

During ISS-55/56, ISS-57/58, and ISS-59/60, Matroshka-R experiments in the ROS focussed on the Functional Cargo Block (FGB) and Mini Research Module 1 (MRM1). The measurements in MRM1 continued the study of the neutron distribution in and around a tissue-equivalent phantom, which previously suggested that the dose equivalent in the phantom is ~70% of the value at the phantom surface. The recent Matroshka-R data are compared to earlier results in order to assess variations in the neutron dose equivalent and energy distribution within the ROS.

Recent Measurement of the ISS Environment Using Timepix-based Hardware

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Timepix is a hybrid-pixel read-out chip consisting of 65536 individual pixels. When combined with a silicon detector layer, the Timepix is a low mass, low-power particle detector capable of providing dose measurements as well as information on the spatial energy deposition of individual ionizing radiation tracks.

Several Timepix-based devices are currently on-board the International Space Station (ISS) along with the nominal compliment of operational radiation monitoring instrumentation. Previously flown as a payload investigation, an updated iteration of the Radiation Environment Monitor hardware has been certified for flight and has recently transitioned to operational status for area monitoring on station. As of the return of the last set of Radiation Area Monitors on 57S, the Radiation Environment 2 (REM2) hardware units have replaced the passive dosimetry area monitoring system utilized aboard ISS.

In addition, a flight-spare for the Artemis-1 Hybrid Electronic Radiation Assessor (HERA) system was recently certified and flown as an ISS payload experiment. The system operated continuously for over 30 days in a successful effort to demonstrate system readiness for exploration-class missions.

A summary of the Timepix-based detectors on ISS will be presented, with data comparisons of Timepix data and data from other ISS instrumentation. Interesting features observed in the collected data will also be discussed.

Abstract

Latest results in the Tritel-RS experiment - simultaneous passive and active measurements

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The cosmic radiation environment consists of different types of components covering a wide range of energy and biological effectiveness, thus a measurement system which is able to differentiate these components is vital in order to design the most effective shielding in space habitats occupied by humans.

A complex dosimetry system was developed at the Hungarian Academy of Sciences, Centre for Energy Research (formerly know as the KFKI Atomic Energy Research Institute).

Tritel is an active, three-dimensional silicon detector telescope complemented by a combined passive detector stack comprising of thermoluminescent and plastic nuclear track detectors. This system allows us to measure in a wide LET (linear energy transfer) range in all spatial dimensions.

Results obtained in the Russian segment of the International Space Station between October 2017 and February 2018 will be presented.

Validation of Trapped Proton Environments with EFT-1 Measurements

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The Advanced Exploration Systems RadWorks team has performed a number of new calculations for comparison with EFT-1 measurements in order to identify trapped proton environment models which can be used for evaluating astronaut exposure on Orion missions. The first test flight of Orion, the Exploration Flight Test-1 (EFT-1) was launched on December 5, 2014. Onboard Orion, the Battery-operated Independent Radiation Detector (BIRD) measured the inside-vehicle space radiation throughout the EFT- 1 mission. The BIRD system has two completely isolated and identical radiation instruments, which are about five inches apart. Each instrument contains a Timepix carrier board and is housed in the same mechanical enclosure. Three trapped proton models, namely AP9 and two adaptations of AP8, were used to simulate the geomagnetically trapped proton particle flux along the EFT-1 trajectory at the flight time.

Using the geometric definition of EFT-1, Orion's mass shielding for each BIRD instrument, and model simulated trapped proton flux as boundary conditions, the HZETRN transport code was applied to calculate the dose at the instrument locations. The calculated doses were compared with the BIRD measurements.

This work shows that an accurate modeling of the Earth's magnetic field for a given date is essential for a reasonable simulation of the trapped particle environment. Locations with $L<1.5$ and $100 \text{ km} < H_{min} < 2000 \text{ km}$ see the largest absolute difference between solar minimum and solar maximum. This shows that the suitability of the trapped environment model is highly dependent on location.

Keywords: Battery-operated Independent Radiation Detector (BIRD), Exploration Flight Test-1 (EFT-1), Trapped particle environment

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Cary Zeitlin

NASA JSC

A Tale of Two RADs

Data from the ISS-RAD and MSL-RAD detectors will be compared in detail. Charged particle results will be emphasized, but comparisons between the high-energy neutral particle spectra and dose rates seen in the two environments will be included. Data from the CRaTER instrument aboard the Lunar Reconnaissance Orbiter will also be part of the comparison.

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