WRMISS in Rome 2023

Final Conference Program

Workshop on Radiation Monitoring on International Space Station

26th WRMISS

5 – 7 September 2023

26^{th} WRMISS Conference Program: Tuesday 5^{th} September 2023

08:45 – 09:15	Registration
0915 – 09:30	Welcome, organizational Issues
09:30 - 09:45	Telespazio- Our hosts profile
09:45 – 10:30	Scientific Session 1
10.30 – 11:15	Coffee/Tea Break
11.15 – 12:15	Scientific Session 2
12:15 – 13:30	Lunch
13:30 – 15:00	Scientific Session 3
15.00 – 16:00	Coffee/Tea Break
16:00 – 17:45	Scientific Session 4

Guenther Reitz , Livio Narici **Flavia D'Amico, Dario Castagnolo (Telespazio)**	Welcome, Organizational Issues
Marco Brancati (Telespazio)	Company Profile

Scientific Session 1

John Norbury	DDFRG: Double differential fragmentation models for light particle production in nuclear reactions for space radiation protection

Scientific Session 2

Marek Sommer	High-energy per-pixel calibration of the Timepix pixel detector with laboratory alpha source
Matthias Meier	Between Sea Level and the ISS: Radiation Measurements in the SAA Region at Flight Altitudes

Scientific Session 3

Martina Luzova	SPRM – compact tissue-equivalent LET spectrometer for space applications – testing at HIMAC (15 min)
Karel Marsalek	$1.6*10^3$ days of data for the DLR RAMIS measurements in LEO and further updates on the DLR M-42 Si-detector family
Stuart George	First Radiation Measurement Results from the Biosentinel Cubesat
Patrik Pinczes	Pille measurements of excess radiation doses in the South Atlantic Anomaly

Scientific Session 4

Martin Smith	Radi-N and Radi-N2: Measurements of Neutron Radiation Using Bubble Detectors (2009 – 2020)
Thomas Berger **Soenke Burmeister**	DOSIS 3D – current status and science updated DOSTEL measurements as part of DOSIS/DOSIS3D: An update
Patrik Princzes	Radiation Measurements with Passive Detectors in the Columbus Module over One Solar Cycle within the DOSIS and DOSIS 3D projects
Ondrej Ploc	SPACEDOS – an open-source PIN diode dosimeter for applications in Space (15 min)

26th WRMISS Conference Program: Wednesday 6th September 2023

09:00 - 10:30	Scientific Session 5
10.30 - 11.15	Coffee/Tea Break
11.15 – 12:15	Scientific Session 6
12.15 - 13:30	Lunch
13:30 – 15:00	Scientific Session 7
15:00 – 16:00	Coffee/Tea Break
16:00 – 17:30	Scientific session 8
20:00 – 23.00	**Conference Dinner:** Trattoria da Teo, Piazza Dei Ponziani 7, Rome

Scientific Session 5

Luca Di Fino	More than 3 years of LIDAL measurement onboard the ISS Columbus Module
Virginia Boretti	New methods for space radiation field characterization: LET and TOF for the first $z2/\beta2$ and kinetic energy spectra
Luca Lunati	Studies on particle energy and directionality of the SAA radiation environment using the LIDAL detector

Scientific Session 6

Cary Zeitlin (Diego Laramore)	7.5 Years of ISS-RAD
Tom Campbell-Rickets	Ten Years of Radiation Environment Monitors on ISS

Scientific Session 7

Martin Losekamm	Update on the RadMap Telescope on the International Space Station: Deployment and First Measurements
Federico Donnini	Precision Measurement of the Monthly Light Ion Fluxes in Cosmic Rays with the Alpha Magnetic Spectrometer on the International Space Station
Benjamin Puzantian	Equivalent dose measurements of astronauts for ISS space missions between 2007-2016

Scientific Session 8 (RadLab)

Livio Narici	DORELI: advances in the flight comparison of three silicon detector in the COLUMBUS modulus of the ISS. Learning lessons
Sylvain Costes **Jack Miller**	The RadLab Project RadLab Demonstration Video from Kirill Grigoriev
Sylvain Costes, Kirill Grigorev, Jack Miller, Livio Narici	The RadLab Working Group - Introduction and Discussion (30 min) RadLab Discussion

26th WRMISS Conference Program: Thursday 7th September 2023

09:00 - 10:30	Scientific Session 9
10.30 - 11.15	Coffee/Tea Break
11.15 – 12:15	Scientific Session 10
12.15 - 13:30	Lunch
13:30 – 1500	Scientific Session 11
15:00 – 16.00	Coffee/Tea Break
16:00 -17:45	Scientific session 12

Scientific Session 9

Ramona Gaza	Overview of Radiation Measurements Performed for Artemis I Science Payloads
Thomas Berger	NASA Artemis, I mission and the MARE experiment
Nicholas Stoffle	Status of Artemis HERA on Space Station

Scientific Session 10

Diego Laramore	Artemis 1 Radiation Analysis, Modeling, and Dose Assessment
Edward Semones	SRAG Activities in Preparation for Artemis II and III

Scientific Session 11

Bent Ehresmann (Don Hassler)	Radiation measurements on Mars on the way to solar maximum
Daniel Matthiae	Model predicted variations in neutron fluence and dose on the surface of Mars
Stuart George	2023 Update on the Compact Electron Proton Spectrometer Project

Scientific Session 12

Eric Benton	Space Tissue Equivalent Dosimeter (SpaceTED)
Michael Ecord	The Linear Energy Transfer Spectrometer (LETS) Payload on NASA's Commercial Lunar Payload Services (CLPS) TO2 Peregrine-1 (15 min)
Alessandro Bartoloni	Advancing Space Radiobiology through interdisciplinary research: Insights from the INFN Roma Sapienza AMS Group
all	Wrap up and Adjurn

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Abstracts:

SESSION 1

DDFRG: Double differential fragmentation models for light particle production in nuclear reactions for space radiation protection

John W. Norbury
NASA Langley Research Center

Double-Differential FRaGmentation (DDFRG) model cross sections for pion, neutron, proton and light ion production from high energy nucleus-nucleus collisions are developed. The pion model employs thermal production from a very hot central fireball source, while the neutron and proton models employ thermal production from the projectile, central fireball and target sources, along with quasi-elastic direct knockout. Light ion (isotopes of Hydrogen and Helium) production cross sections employ a hybrid coalescence model. The models correctly predict a wide range of experimental data with only a small number of parameters. Closed-form analytic formulas for double-differential cross sections are developed, which enable very efficient computation for space radiation transport codes.

SESSION 2

High-energy per-pixel calibration of timepix pixel detector with laboratory alpha source

M. Sommer[1], Carlos Granja[2], S. Kodaira[3] and O. Ploc[1]

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The spectral response of the pixel detector Timepix at the high per-pixel proportional range is examined and calibrated using a simple technique and alpha particles from a standard laboratory source in air. For the detector used, a Timepix ASIC chip equipped with a 300 μm thick silicon sensor, the spectral range is newly extended up to about 1750 keV per-pixel. This expands the region above 850 keV per pixel which is described and covered by the existing low-energy calibration. The low-energy calibration uses discrete low-energy gamma rays in the range 5–60 keV and is extrapolated over the linear range up to 850 keV/px. Above this level, the per-pixel spectral response changes. At higher energies it undergoes distortion and saturation. The proportional and monotonic response is observed with regions of varying dependence up to nearly 2 MeV. This high-energy region is covered and described by the newly developed calibration method which uses an alpha source of common low activity (kBq level). Data are collected within one day of total measuring time. Measurements are performed in air at various source-to-distance positions and several sensor bias settings. The developed method together with suitable setting of the sensor bias, which determines the extent of charge sharing, expands the spectral response of Timepix to high energy-loss particles such as alpha particles and light ions in a wide energy range. Results are demonstrated on alpha particles, protons and 12C ions. Resulting spectra of deposited energy and cluster pixel height are correctly calibrated and they reproduce expected values.

Between Sea Level and the ISS: Radiation Measurements in the SAA Region at Flight Altitudes

Matthias M. Meier[1], Thomas Berger[1], Thomas Jahn[2], Daniel Matthiä[1], Mona C. Plettenberg[1], Markus Scheibinger[2], Kai Schennetten[1], Michael Wirtz[1]

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The South Atlantic Anomaly (SAA) is a geographical region over the South Atlantic Ocean where the inner Van Allen radiation belt extends down particularly close to Earth. This leads

to highly increased levels of ionizing radiation and related impacts on spacecraft in Low Earth Orbits, e.g., correspondingly increased radiation exposure of astronauts and electronic components on the International Space Station. According to an urban legend, the SAA is also supposed to affect the radiation field in the atmosphere even down to the altitudes of civil aviation. In order to identify and quantify any additional contributions to the omnipresent radiation exposure due to the Galactic Cosmic Radiation at flight altitudes, comprehensive measurements were performed crossing the geographical region of the SAA at an altitude of 13 km in a unique flight mission—Atlantic Kiss. No indication of increased radiation exposure was found.

SESSION 3

SPRM – compact tissue-equivalent LET spectrometer for space applications – testing at HIMAC

M. Lužová[1,2,*], M. Sommer[1], M. Kákona[1], M. Marčišovský[2], H. Kitamura[3], S. Kodaira[3], P. Suchánek[4], P. Brož[4] and O. Ploc[1]

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SPRM (Scintillator with PH32 chips Radiation Monitor) is an advanced hybrid LET spectrometer developed for evaluation of cosmic radiation onboard spacecraft by esc Aerospace company in cooperation with CTU in Prague and NPI of Czech Academy of Sciences. SPRM is a sandwich of a tissue equivalent plastic scintillator surrounded by two pairs of silicon strip detectors. Abilities of the newly constructed detector were tested at the Heavy Ion Medical Accelerator in Chiba (HIMAC).

Energy of used ions is estimated from the scintillator and four layers of strip detectors give angle of the incoming particle and thus length of ion track in the scintillator in between. Measurements were performed for various angles of the detector irradiated by Si, Ar and N beams in the physics room of HIMAC facility. Time synchronization of both types of detectors, energy proportionality and angular accuracy were evaluated from the obtained data.

1.6*10^3 days of data for the DLR RAMIS measurements in LEO and further updates on the DLR M-42 Si-detector family

Karel Marsalek*, Joachim Aeckerlein, Thomas Berger, Moritz Kasemann, Daniel Matthiä, Bartos Przybyla, Markus Rohde, Aleksandra Rutczynska, Michael Wirtz
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The DLR RAMIS detector telescope has been measuring the radiation environment in the Earth's polar orbit at around 600 km altitude since December 2018 within the DLR Eu:CROPIS mission. For almost five years now the measured data cover the last solar minimum in spring 2020 and now the increase of the solar activity towards solar maximum is clearly visible. With

RAMIS we could measure the variation of trapped electrons in the outer radiation belts, the solar cycle variation of the galactic cosmic radiation and in the last months also several solar particle events for the new solar cycle.

In the last years DLR also developed the M-42 radiation detector for the application during the MARE experiment on the NASA Artemis 1 mission end of 2022. The updates on new M-42 family members
(e.g. with increased energy deposition range and recent development of low-power position-sensitive detection technology), future moon landing mission (Astrobotic/Peregrine) and data from meteorological balloon flight campaigns over Finland and during the DLR MAPHEUS sounding rocket mission will be presented.

First Radiation Measurement Results from the Biosentinel Cubesat

Stuart George, University of Houston

The Biosentinel cubesat launched on Artemis I in November 2022 and was lofted into a heliocentric orbit by the Space Launch System upper stage on its disposal burn. Now some 22 million kilometers from Earth Biosentinel has been sending back continuous radiation data include dose rate and LET spectra since its launch from its Timepix based “LETS” radiation sensor. This talk provides an outline of the Biosentinel cubesat and the LETS radiation sensor and presents initial results including GCR dose rates, LET spectra and quality factors as well as analysis of the 4 solar particle events seen thus far in the mission. The future measurement prospects of Biosentinel are also discussed.

Pille measurements of excess radiation doses in the South Atlantic Anomaly
P. Pinczés[1], A. Hirn[1], I. Apáthy[1], S. Deme[1], O. Ivanova[2], T. Pázmándi[1], V. Shurshakov[2]

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The Pille thermoluminscent passive dosimeter developed by MTA EK is present on the ISS since 2003. Over 21 years of Pille 15- and 90-minutes automatic measurements and 11 years of extra vehicular activity (EVA) dose rates are presented. The 15 minutes long measurements show the possibility to use Pille for spatial mapping of the radiation field and we separate the South-Atlantic Anomaly excess doses from the rest of the orbit. We analyze the results in 3 aspects: the altitude-dose rate correlation, the extra vehicular activity (EVA) excess doses, and the solar cycle caused oscillations in our data.
The results show weak statistical correlation between the altitude and dose rates, and an inverse correlation between dose rates and sunspot numbers. We show that the doses during EVAs are not directly linked to the SAA, and we need to factor in the location of the reference dosimeter inside the ISS and their location on the spacesuits.

SESSION 4

Radi-N and Radi-N2: Measurements of Neutron Radiation Using Bubble Detectors (2009 – 2020)

M.B. Smith[1], H.R. Andrews[1], H. Ing[1], E.M. Johnston[1], S. Khulapko[2,3], M.R. Koslowsky[1], R. Machrafi[4], B. Nicayenzi[5], I. Nikolaev[3], A.M. Norris[1], A.J. Romano[1], V. Shurshakov[2], L. Tomi[5]

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The goal of the Radi-N and Radi-N2 measurements was to characterize the neutron dose equivalent and energy distribution at multiple locations in the US Orbital Segment (USOS) of the International Space Station (ISS) over an extended period of time. The measurements used multiple bubble detectors, which are passive neutron dosimeters based on superheated liquid droplets dispersed in a polymer gel, and an automatic mini reader that counts the bubbles in the detectors. The Radi-N experiments were conducted in 2009 in Columbus, the Japanese Experiment Module, and the US Laboratory. The Radi-N2 measurements began in 2012 in these three ISS modules, later extending to include Node 1, Node 2, Node 3, and the Cupola. For some sessions, one bubble detector was worn by a Canadian astronaut, while a second detector was located in their sleeping quarters. These data provide a comparison of the neutron dose equivalent in the sleeping quarters to that accumulated during daily activities around the ISS.

By the conclusion of the measurements in 2020, 75 week-long sessions had been conducted in the seven USOS locations. In parallel, a similar number of measurements was conducted at various locations in the Russian Orbital Segment of the ISS. The data enable an assessment of the effects of solar activity (and other influence quantities) on the neutron field in the ISS from 2009 to 2020, which corresponds to a full solar cycle. The data suggest that a significant fraction of the neutron dose equivalent is due to neutrons with energy above 15 MeV, which provides motivation for future measurements using a high-energy neutron spectrometer with improved energy resolution.

DOSIS 3D – current status and science updated

Thomas Berger for the DOSIS 3D Science Team
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The radiation environment inside the Columbus Laboratory of the ISS has been measured with active and passive radiation detectors within the frame of the DOSIS (2009 – 2011) and the DOSIS 3D (2012 -) project. Two active Dosimetry Telescopes (DOSTEL) have been mounted at a fixed position beneath the EPM rack in Columbus to enable the long-term measurements of relevant radiation field parameters (dose) and to determine solar cycle variations of the GCR and SAA contributions inside Columbus. Data has been compared with various other active radiation detectors on board the ISS, Moon and Mars. With the eleven passive radiation detector packages (PDPs) placed in Columbus the relevant dose values for six months' time periods have been determined for up to now 26 ISS missions. The talk will give an overview of the current status of DOSIS 3D and the planned future activities.

DOSTEL measurements as part of DOSIS/DOSIS3D: An update

S. Burmeister, T. Berger and D. Matthiä for the DOSIS3D team

In the frame of the DOSIS / DOSIS3D Experiments two DOSTEL units are utilized to measure the radiation environment inside the COLUMBUS module of the International Space Station. DOSIS and its successor DOSIS3D measure the radiation dose induced by Galactic Cosmic Rays, Radiation Belt Particles and Solar Energetic Particles. The instruments are operative for more than 13 years since 2009. This means more than one half of a 22-year solar cycle is covered by the experiment by now. The variation of the radiation field inside the station depends on this solar cycle as well as the geomagnetic shielding by the earth's magnetosphere. The data gathered over this long period of time will be presented as well as the plans for the future.

We are currently preparing DOSTEL3D, a three-axis-telescope for the station. DOSTEL3D shall replace the two DOSTEL instruments by modern electronics to increase the energy- and time resolution. It is planned to operate the current DOSTEL units simultaneously with the new system to have good inflight cross calibration to have a continuous comparable data set. The current status of DOSTEL 3D will be presented as well as its design.

Radiation Measurements with Passive Detectors in the Columbus Module over One Solar Cycle within the DOSIS and DOSIS 3D projects

J. Szabó[1], T. Berger[2], B. Przybyla[2], P. Pinczés[1] for the DOSIS 3D team

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Within the framework of the DOSIS (2009 – 2011) and DOSIS 3D (2012 –) projects the radiation environment in the Columbus module of the International Space Station (ISS) was and is monitored using active and passive radiation detector systems. The experiment is performed by universities and research institutes from several countries under the project and science lead of DLR. The data for the passive radiation detectors has been collected almost continuously since 2009, except for a period of about two years between mid 2010 to mid of 2012. This long mission duration makes it possible to study the effects of the solar activity and the changes of the ISS altitude on the dosimetric quantities.

The presentation will focus on the results obtained by the Centre for Energy Research (EK) with solid state nuclear track detectors (SSNTDs) and thermoluminescent dosimeters (TLDs). These are integrated in 11 passive dosimetry packages (PDPs), one of them containing detectors arranged in three orthogonal directions (Triple PDP), which are installed inside Columbus at locations with different shielding conditions. From the huge amount of data gathered until 2022, some selected LET spectra and the variation of the absorbed dose and dose equivalent values will be presented.

SPACEDOS – an open-source PIN diode dosimeter for applications in Space

M. Kákona[1,2,7,*], I. Ambrožová[1], M. Sommer[1], L. Sihver[1], O. Velychko[1,2], J. Kákona[6], J. Chroust[5], H. Kitamura[4], S. Kodaira[4] and O. Ploc[1]

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A new open-source dosimeter - SPACEDOS - for measurement of cosmic radiation onboard spacecraft and small satellites has been developed. Its main advantages are that it is small, lightweight with low power consumption. It can be adjusted for specific applications, e.g. used in pressurized cabins of spacecraft or in vacuum environments in CubeSats and larger satellites. The open-source design enables exceptional portability and reproduction of results which is a big advantage of this device. The calibrations and tests of each individual unit were performed at HIMAC (Heavy Ion Medical Accelerator in Chiba, Japan) and cyclotron U-120M in Rez, Czechia.

SPACEDOS was deployed in three space missions — one 3U CubeSat mission Sokrat-R (NORAD ID 44404) and two measurement campaigns performed on the ISS in the years 2019–21. The obtained results on ISS will be discussed and compared with those measured with other detectors such as thermoluminescent detectors placed in the same location as SPACEDOS. We will also show comparison of energy deposition spectra measured with Liulin on the ISS during another mission (July 2001) to demonstrate and discuss this difference in instrument capabilities.

SESSION 5

More than 3 years of LIDAL measurement onboard the ISS Columbus Module

Luca Di Fino[1], Virginia Boretti[2], Luca Lunati[2], Giorgia Santi Amantini[2] and Livio Naric[i2]
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The LIDAL telescope system has been continuously monitoring the radiation environment within the Columbus module of the International Space Station since January 19th, 2020, with only occasional interruptions attributed to Columbus maintenance, experiment settings, and other ISS operations. Over the span of three years, the LIDAL orientation has undergone several modifications, aligning with one of the three axes of the ISS on each occasion.

.LIDAL (Light Ion Detector for ALTEA) is the first device inside the ISS able to perform time-of-flight (ToF) measurements of charged particles with a time sensitivity (sigma) of about 80 ps, thanks to the two scintillator planes, each equipped with 8 bars, read by fast scintillators and a high-speed electronic read-out system, positioned at both ends of a stack of three SDUs (Silicon Detector Unit) particle telescopes from previous ALTEA detector. Combining the ToF measurement by the scintillator planes with the energy deposition measurement by the silicon detectors, the LIDAL system enables comprehensive measurement and analysis of all charged components present in the radiation environment, encompassing tracking, nuclear identification, and kinetic energy reconstruction. LIDAL, with is narrow field of view, is able to do a unique probe on radiation anisotropies due to ISS shielding.

LIDAL, as of September 2023, has been active inside Columbus for about 1246 days, and detected more than 3 108 particles with a total raw data size of about 1.5 TB.

Within this talk, we will present the daily particle flux and dose along the whole active period for the different geomagnetic regions and the different orientations, highlighting the modulation due to the solar cycle and to the different shielding. For the different geomagnetic regions, we will compare LET spectra for the different orientations, analyzing the effect of the different shielding on the radiation quality.

We will compare these data to the GOES data on proton flux above 100 MeV to show the effects of the solar activity on the radiation flux inside the ISS, with emphasis on the Oct 29th 2021 SPE, the first Ground Level Event recorded on three celestial bodies (Earth, Moon, Mars). In conclusion, this study yields insights into the radiation environment within the ISS and demonstrates LIDAL capabilities in advancing our comprehension of the anisotropy of this environment due to the uneven shielding of the Station.

New methods for space radiation field characterization: LET and TOF for the first $z2/\beta2$ and kinetic energy spectra

Virginia Boretti, Luca Lunati, Luca Di Fino, Giorgia Santi Amantini, Giulia Romoli, Giorgio Baiocco, Alice Mentana, Livio Narici

Studying radiation risks for astronauts and evaluating the proper countermeasures calls for a detailed description of the radiation field to which they will be exposed. This analysis becomes of vital importance in the optics of long-duration human voyages in the solar system where the Geomagnetic Field cannot offer radiation shielding as it partially happens in Low Earth Orbits (LEO) where the International Space Station is in order to obtain information about radiation in the ISS, we used LIDAL (Light Ion Detector for ALTEA), an upgrade of the ALTEA detector system. LIDAL consists of: 3 Silicon

Detector Units, each composed by six silicon planes, enclosed between 2 LIDAL Detector Units, each made of a plane of 8 plastic scintillators bars each 80 x 20 x 4 mm3 with a fast-electronic read-out system, constituting the first Time-of-Flight system to ever fly on board a space habitat. LIDAL's goal is the measurement of the energy released by the particle passing through the Silicon detector (Linear Energy Transfer, LET) together with its Time of Flight (ToF) measured by scintillators. In this talk new algorithms, specifically developed to exploit the single particle information on LET and ToF in order to characterize the radiation field will be presented. These algorithms are applied to LIDAL data and the results are compared to simulations. The output of the algorithm allows a nuclear identification expressed in terms of both charge (z) and kinetic energy of the particle before entering the detector. This analysis results in the first kinetic energy spectrum of particles inside a space habitat, and in the first $z2/\beta2$ spectrum. This ratio is important as it is currently suggested by NASA as a needed parameter for recent radiation risk models, leading also to the computation of an advanced radiation quality factor.

Studies on particle energy and directionality of the SAA radiation environment using the LIDAL detector

Luca Lunati, Virginia Boretti, Luca Di Fino, Giorgia Santi Amantini, Giulia Romoli, Giorgio Baiocco, Alice Mentana, and Livio Narici

One of the most prominent features of Earth's magnetic field is the South Atlantic Anomaly (SAA), resulting from the tilt (approximately 10°) between Earth's magnetic dipole axis and its rotational axis, along with an offset (about 500 km) between the dipole and Earth's centers. Within the SAA, spacecrafts in LEO (Low Earth Orbit) are exposed to ionizing radiation primarily caused by anisotropic protons trapped within Earth's geomagnetic field. Among the various detectors operating in LEO, LIDAL, deployed on board the International Space Station, crossing the inner belt in the SAA at about 400 km, can play a crucial role in providing insights on the SAA radiation field.

LIDAL is a particle telescope (49 cm long), designed at the University of Rome Tor Vergata, comprising of 18 striped silicon planes stacked in a tower configuration between two segmented arrays of plastic scintillators (8 × 16 cm2) that provides a measure of the particle Time of Flight (ToF) with a resolution better than 100 ps. LIDAL features enable ion discrimination, tracking, and kinetic energy evaluation of all passing through ions. It began acquiring data on January 19th, 2020, and is expected to operate until at least the end of 2024. LIDAL is moved along the three orthogonal axes of the ISS to obtain information on the radiation field from all directions, exploiting its narrow field of view.

The peculiar LIDAL design, combining silicon detectors with scintillators in a long telescope configuration, permits the energy discrimination of detected particles, mostly protons in the SAA. Furthermore, the tracking capability of LIDAL can be used to determine the radiation incident angle. Measurements of SAA proton energy and incident angle are a first within a space habitat.

In this talk, we will present the measured angular distributions of the SAA radiation, the energy modulation in the SAA region, as well as its link with the impinging angle. Particle pitch angle distributions as a function of McIlwain’s L-parameter and energy spectra will also be presented. This study contributes to the description of the SAA radiation environment and highlights the LIDAL capabilities in providing unique parameters to investigate radiation characteristics.

SESSION 6

7.5 Years of ISS-RAD

Cary Zeitlin
Leidos/NASA

We present a summary of results from the ISS-RAD detector. ISS-RAD contains the Charged Particle Detector (CPD) and Fast Neutron Detector (FND) subsystems. It was deployed on Feb. 1, 2016, and has operated almost continuously since then, with an average up-time of 98%. ISS-RAD was deployed in the USLab, JPM, Node 2, Node 3, and Columbus during its survey period from 2017 to 2020. It has been parked in the USLAB at panel 1O6 since May 2020. We will present results for charged particle absorbed dose rates and quality factors, as well as neutron fluence and dose equivalent rates obtained both with the FND and the neutral-particle subsystem of the CPD. Neutron fluence rate measurements from FND (sensitive from 200 keV to 8 MeV) and CPD (sensitive from 4 to about 400 MeV) show reasonable agreement in the region where they overlap, and the combined data span the widest neutron energy range that has been measured on ISS since the Japanese Bonner Ball experiment that operated in 2001.

Ten Years of Radiation Environment Monitors on ISS

Tom Campbell-Rickets, Leidos/NASA

In October 2022, NASA’s Timepix-based Radiation Environment Monitors (REMs) completed their first ten years of service on ISS. Over this period, the REMs, in one form or another, have been continually measuring and recording the radiation field, on an individual particle track by track basis, simultaneously over multiple locations on the ISS. This has provided and continues to yield a unique insight into the radiation environment on ISS, its dependence on orbital location, its variation between ISS modules, and its evolution over, by now, an entire eleven-year solar cycle. We present some of the highlights and findings of this ongoing adventure in space-radiation observation.

SESSION 7

Update on the RadMap Telescope on the International Space Station: **Deployment and First Measurements**

Martin Losekam ,Univ. München, Thomas Berger, DLR

The RadMap Telescope is a new radiation-monitoring instrument operating in the U.S. Orbital Segment (USOS) of the International Space Station (ISS). The instrument was commissioned in May 2023 and will rotate through four locations inside American, European, and Japanese modules over a period of about six months. In some locations, it will take data alongside operational, validated detectors for a cross-check of measurements. RadMap's central detector is a finely segmented tracking calorimeter that records detailed depth-dose data relevant to studies of the radiation exposure of the ISS crew. It is also able to record particle-dependent energy spectra of cosmic-ray nuclei with energies up to several hundred MeV per nucleon. A unique feature of the detector is its ability to track nuclei with omnidirectional sensitivity at an angular resolution of two degrees. In this contribution, we present the design and capabilities of the RadMap Telescope and give an overview of the instrument's commissioning on the ISS. We also show first, preliminary on-orbit measurements

Precision Measurement of the Monthly Light Ion Fluxes in Cosmic Rays with the Alpha Magnetic Spectrometer on the International Space Station

Federico Donnini
INFN Sezione di Perugia

Cosmic rays inside the heliosphere interact with the solar wind and with the interplanetary magnetic field, resulting in a temporal variation of the cosmic ray intensity near Earth for rigidities up to a few tens of GV. Previous AMS results on proton and helium spectra showed that the two fluxes behave differently in time. In this contribution, the precision results of the light ions, from Lithium up to Oxygen, for the first 11 years of data collected by the AMS will be presented inclu-ding detailed temporal variations of the fluxes.

Equivalent dose measurements of astronauts for ISS space missions between 2007-2016

Benjamin Puzantian[1,2], Lindsay Beaton-Green[1,2], and Ruth C. Wilkins[1,2]

[1]Ionizing Radiation Health Science Division, Consumer and Clinical Radiation Protection Bureau, Health Canada, ON, Canada

[2]Department of Physics, Carleton University, ON, Canada

Biological dosimetry is a technique used to obtain dose estimates for individuals exposed to radiation based on the biological response at the cellular level. These dose estimates are obtained by scoring chromosomal damage such as dicentrics or translocations and matching the damage to dose response calibration curves. This damage is a result of misrepair after DNA double strand breaks in lymphocytes. Calibration curves are produced by ex vivo irradiation of blood samples with known doses using a radiation. A common method to assess radiation damage from protracted low-dose exposure, which astronauts are exposed to during space travel, is by stable translocation analysis using Fluorescent in situ Hybridization (FISH). For each astronaut, a pre-flight blood sample is drawn and irradiated in-house with the 250 kVp X-ray to produce a personalized translocation calibration curve. This curve is then used as a reference to convert stable translocations induced during the flight to the dose to which the astronaut was exposed during their mission. Health Canada's biodosimetry programme has used this method to assess the dose receive by 11 astronauts after missions to the International Space Station (ISS) between 2007 and 2019.

While FISH is particularly useful for protracted exposures to low radiation doses, it is limited to calibration curves generated by a single radiation source available in a laboratory. Therefore, Health Canada has been exploring the use of Monte Carlo programs, such as TOPAS-nBio, to produce mixed radiation calibration curves that more accurately reflect the complex space radiation environments that astronauts encounter. NASA's deterministic radiation assessment tool package, OLTARIS, was used to calculate equivalent doses and particle fluxes inside different ISS components. We found, between 2007 – 2016, astronauts were exposed to daily equivalent dose rates from 0.35mSv/day to 0.49mSv/day from galactic cosmic rays (GCR) and trapped particle (TP) sources. Comparing these results to the biodosimetry obtained results as a proof-of-concept showed variations. Therefore, we propose that mixed radiation calibration curves be produced using particle fluxes from GCRs and TPs as source inputs in Monte Carlo radiobiology codes to assess the accuracy of the biodosimetry. This could provide more precise exposure specific dose estimates leading to a better understanding of the effects of ionizing radiation on astronauts during space travel.

SESSION 8 (RadLab)

Tha RadLab Project

Sylvain Costes

The RadLab Project, initiated by the Open Science Data Repository (OSDR) for Space Biology at NASA Ames Research Center (osdr.nasa.gov), aims to be an ongoing compilation of radiation data relevant to human space flight. Sponsored by the NASA Human Research Program, RadLab serves as the latest database in this domain. RadLab is intended to serve the needs of both the space radiation detector and space radiation biology communities. The RadLab architecture is being designed to accommodate data both from low Earth orbit (LEO) and beyond low Earth orbit (BLEO).

Our long-term vision entails the establishment of a sustainable database receiving continuous updates through APIs connecting to other databases, as well as individual investigator contributions via a RadLab submission portal, modeled on the OSDR (https://osdr.nasa.gov/bio/submission-sso-login.html). In addition to serving as a resource for space biologists and space radiation physicists, such a database would facilitate the deployment of AI algorithms to study the impact of location in space and within spacecraft on the ambient space radiation field. The ultimate goal is to develop predictive dosimetry algorithms for future BLEO missions.

RadLab Demonstration

Kirill Grigorev (Introduced by Jack Miller)

We will demonstrate the RadLab user interface, focusing on the time-dependent data entered so far, including its utility for detector intercomparisons and studying how solar particle events affect different locations in the ISS.

DORELI: advances in the flight comparison of three silicon detector in the COLUMBUS modulus of the ISS. Learning lessons modulus of the ISS. Learning lessons

Livio Narici for the DORELI collaboration:

URTV: Livio Narici, Virginia Boretti, Luca Lunati, Giorgia Santi Amantini
ASI: Luca Di Fino
NASA SRAG: Nic Stoffle, Stuart George, Thomas Campbell-Ricketts
DLR: Thomas Berger, Daniel Matthiae
CAU: Sönke Burmeister

Performing concurrent measurements of the same space radiation environment with different detectors is extremely important as the detectors can be cross calibrated, cross checked, and the refined measurements serve to produce a more complete panorama of the radiation environment itself that is more independent from the detectors’ peculiarities.

About 2 years ago we started a collaboration aimed at cross calibrating LIDAL (University of Rome Tor Vergata, URTV), REM (NASA-JSC/SRAG), DOSTEL-1 & -2 (DLR, CAU), exploiting the good colocation of the 4 detectors (COLUMBUS laboratory, ISS).
The four detectors are all silicon detectors, but with very different characteristics.
LIDAL is a telescope (18 striped silicon planes + 2 segmented scintillators planes, 8 x 16 cm2) 49 cm long.

DOSTEL is a dosimeter/telescope using two Canberra PIPS (Passivated Implanted Planar Silicon) round detectors (6.93 cm2) at 1.5 cm distance. In this presentation data from one single detector from each DOSTEL will be used.

REM is a hybrid silicon pixel detector (Timepix) containing a matrix of 256 x 256 pixels at a 55 micron pitch for a total sensing area of 1.982 cm2. The REM detector is positioned flat on one of the lids of the LIDAL detector, in its field of view, so it follows all the rotations of LIDAL, which is periodically positioned along the three ISS directions X, Y, Z. The two DOSTEL detectors are positioned beneath the nearby EPM rack with telescope viewing directions fixed in the X and Y ISS directions.Today, with 2-4 years of measurements, we are ready to present results and discussions on these data.

This talk will highlight the differences in the detectors (mostly field of view and energy acceptance) that can strongly affect the data and therefore matters in this comparison.
The agreement is remarkable especially when considering the GCR (excluding the data acquired in the South Atlantic Anomaly, SAA). Remaining differences can be mostly accounted for by the shielding distribution around the detectors.

The SAA is a region where radiation is mostly directional and the energy modulation within the area is peculiar. This produces measurements strongly dependent by field of view and energy acceptance, leading to remarkably different results among the detectors, especially between LIDAL and the other three. Data (fluxes and dose rates) versus time and versus the McIllwain’s magnetic coordinate L will be presented and discussed.

Finally, it will be underlined that DORELI represent a perfect use case for the RadLab effort, an initiative within the Open Science Data Repository (OSDR) for Space Biology at NASA Ames Research Center which will be discussed elsewhere in this workshop.

The RadLab Working Group - Introduction and Discussion

Sylvain Costes, Kirill Grigorev, Jack Miller, Livio Narici

The RadLab Working Group (RWG) is intended to promote collaboration and efficient communication among researchers. Its functions would also include identifying detectors and data to be included in the RadLab database, normalizing data formats and incorporating new features based on feedback from working group members and the community at large.

SESSION 9

Overview of Radiation Measurements Performed for Artemis I Science Payloads

Ramona Gaza [1,2] on behalf of the Space Radiation Analysis Group

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The first major spaceflight of NASA's Artemis program, the Artemis I uncrewed mission, has been flown successfully November 16 – December 11, 2022, for a total mission duration of 25.5 days.

The Space Radiation Analysis Group (SRAG) at NASA Johnson Space Center (JSC) has provided active instruments and passive radiation detectors in support of multiple Artemis I science payloads:

i. Commander “Moonikin” Campos was equipped with (Qty 2) Crew Active Dosimeters (CAD).
ii. Matroshka AstroRad Radiation Experiment (MARE) was equipped with (Qty 18) Crew Active Dosimeters (CAD) and (Qty 3,000) Thermoluminescence Dosimeters (TLD); in addition to contributions from the German Aerospace Center (DLR) and the DOSIS team.
iii. BioExpt-1: was equipped with (Qty 4) Crew Active Dosimeters (CAD) and (Qty 4) Radiation Area Monitors (RAM).

In addition, SRAG provided radiation detection hardware in support of the Orion vehicle operations, namely the Hybrid Electronic Radiation Assessor (HERA) (3 locations) and the Radiation Area Monitors (RAM) (6 locations).

This presentation will include an overview of the Commander Campos, MARE, and BioExpt-1 results and their comparison with Orion vehicle ops measurements.

NASA Artemis I mission and the MARE experiment

Thomas Berger for the MARE Team
German Aerospace Center (DLR), Köln, Germany, thomas.berger@dlr.de

After years of planning the NASA Artemis I mission flying with the Orion spacecraft to the Moon and back made its journey from 16 November to 11 December 2022. Part of the secondary science payloads inside Orion was the MARE experiment (Matroshka AstroRad Radiation Experiment). MARE was an international endeavour flying two female anthropomorphic phantoms (Helga & Zohar) to the moon and back. Zohar was equipped with a newly by StemRad developed radiation protection vest (AstroRad). Both phantoms were equipped with a suite of active and passive radiation detectors to determine skin and organ doses for the two phantoms. The talk will give an overview of the MARE hardware and will provide a first view on the data evaluation and science gathered within the experiment.

Status of Artemis HERA on Space Station

N. Stoffle, Leidos/NASA

The Artemis Hybrid Electronic Radiation Assessor on Space Station (AHoSS) is an Artemis HERA flight system adapted to operate on-board the ISS. The system was deployed in the USLab in March of 2021 and proved system capabilities in preparation for the upcoming Artemis II mission which is expected to launch in late 2024. Following completion of the primary and secondary flight objectives for the payload in 2021, the system continues to operate well and is transitioning from payload to ISS systems hardware to augment existing radiation monitoring capability on ISS. The AHoSS system can provide per-minute real-time telemetry through the ISS delay tolerant network system and sub-minute resolution science data records through daily Station Support Computer downlinks. An update on the operational status of AHoSS will be provided and data from the last year of operation will be presented.

SESSION 10

Artemis 1 Radiation Analysis, Modeling, and Dose Assessment

Diego Laramore, Leidos/NASA

The successful completion of the Artemis 1 mission has provided NASA with a significant volume of space radiation dosimetry data that can be used to verify the accuracy of current operational SRAG dose computation models and methods for Beyond LEO missions. High-Fidelity CAD models of the Artemis 1 MPCV Orion were raytraced in 10,000 directions per sensor location, including the location of Artemis HERA sensors, Artemis RAMs (TLDs), and the crew active dosimetry (CADs). The full Artemis 1 mission was modelled using the as-flown trajectory, Ap9-Ae9 IRENE providing the VAB trapped proton and electron environment, and the Badhwar-O'Neill 2020 model providing the freespace GCR environment. IGRF 12 was used to compute cutoff rigidities for the GCR environment in LEO. 1DHZETRN was used to estimate point doses at each sensor position. Computed RAM doses were within 10% of measured values. The computed VAB transit and freespace GCR dose rates showed good qualitative agreement with measured HERA values. An estimate of normalized mean effective dose for a hypothetical male crew member on Artemis 1 using current standard operational methods was computed to be 22.3 mSv.

SRAG Activities in Preparation for Artemis II and III

Edward Semones, NASA/JSC SRAG

Abstract TBD

SESSION 11

Radiation measurements on Mars on the way to solar maximum

Bent Ehresmann and the MSL-Rad team

We present measurements of the radiation environment on the Martian surface conducted with the Radiation Assessment Detector (RAD) aboard NASA's Curiosity rover. We will show updated measurements from the past 12 months that show the influence of the changing solar activity, as well as radiation shielding provided by natural terrain on the Martian surface.

Model predicted variations in neutron fluence and dose on the surface of Mars

Daniel Matthiä[1], Sven Löffler [2], Cary Zeitlin[3], Bent Ehresmann[4], MSL-RAD Science Team
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The interactions of primary cosmic radiation with matter create a complex neutron field with energies ranging over many orders of magnitude. The result is a non-negligible contribution of neutrons to the exposure on planetary surfaces or in spacecraft. The measurement of neutrons is complex and an accurate assessment of the neutron dose is a challenge, especially under the existing restrictions in space flight and model calculations can provide valuable information supplementing the measurements.

This work presents model-predicted variations caused by solar modulation and atmospheric shielding in the neutron fluence on the Martian surface and corresponding dose rates for different dosimetric quantities. The work is going to support an on-going effort to revise the methodology of neutron measurements of the Radiation Assessment Detector (RAD) of the Mars Science Laboratory. Neutral particle spectra can be derived from RAD measurements using an inversion technique on energy deposition spectra in sensitive detector parts with an additional anti-coincidence condition in the surrounding parts of the detector and resulting neutron and gamma energy spectra on the surface of Mars have been published earlier. The method is currently revised with the goal to publish an update on measured neutron and gamma spectra and to provide a comprehensive picture of the results for the environmental conditions RAD has experienced up to date. These environmental conditions were used to derive boundary conditions for the model calculations. The model calculations were performed using the PLANETOCOSMICS tool for Geant4 using primary galactic cosmic ray spectra from hydrogen to iron. The results can be used to estimate the expected variations in the experimental data and can be benchmarked against RAD results. The model calculated dose rates allow to compare different dose quantities and to estimate the relative contribution of the experimentally accessible part of the neutron spectra to the total.

2023 Update on the Compact Electron Proton Spectrometer Project

Stuart George, University of Houston

The Compact Electron Proton Spectrometer is a miniaturized space weather early warning system. The major technical innovation in CEPS is the combination of a 1mm thick CdTe pixelated sensor with a Timepix2 ASIC for readout. The high stopping power of CdTe enables spectroscopic measurement of electrons up to 2 MeV and the pixelated nature of the sensor allows for accurate high-fidelity separation of protons and electrons. The Timepix2 allows for measurements over a very wide input flux regime. All of these properties make this instrument very advantageous for space weather monitoring, both for human protection and more general Heliophysics applications.

This talk outlines the need for space weather early warning measurements, how the CEPS detector can meet this goal and the progress in the development of this instrument over the past year. This includes an overview of the avionics development and beam tests of CdTe Timepix2 assemblies in both proton, electron and heavy ion environments. The future prospects and applications of the CEPS instrument are also discussed.

SESSION 12

Space Tissue Equivalent Dosimeter (SpaceTED)

Eric Benton, Tristen Lee, Conner Heffernan, Martin Yang, Garrett Thornton and Buddy Gersey
Physics Dept., Oklahoma State University, Stillwater, Oklahoma USA

The Space Tissue Equivalent Dosimeter or SpaceTED is a low-cost, portable radiation dosimeter that is scheduled to be demonstrated aboard the ISS beginning in December 2023 after launch aboard SpaceX-29. SpaceTED implements a number of lessons learned from our ATED instrument flown on ISS in 2018. A spherical tissue equivalent proportional counter (TEPC) is used to measure the lineal energy spectrum of particles with LET >1 keV/μm, including secondary particles produced in neutron interactions with the tissue equivalent plastic of the ionization cavity. Particles with LET <1 keV/μm are detected by a Si PIN photodiode. All data is stored locally on a Raspberry-Pi computer and data from the two detectors are combined to yield total absorbed dose and dose equivalent rates as functions of time. The TEPC head has been redesigned to reduce sensitivity to microphonic noise and to provide better electronic equilibrium. This type of two-detector instrument is also being flown aboard aircraft and high-altitude balloons in the form of the Atmospheric Ionizing Radiation Tissue Equivalent Dosimeter (AirTED) as part of a NASA funded effort to measure ionizing radiation aboard high latitude flights.

The Linear Energy Transfer Spectrometer (LETS) Payload on NASA's Commercial Lunar Payload Services (CLPS) TO2 Peregrine-1.

Michael Ecord, Leidos/NASA

Abstract (TBD)

Advancing Space Radiobiology through interdisciplinary research: Insights from the INFN Roma Sapienza AMS Group

Alessandro Bartoloni on behalf of the AMS INFN Roma Sapienza research group
INFN Roma, CERN & Moon Village Association alessandro.bartoloni@cern.ch

Space radiobiology is a multidisciplinary field that investigates the biological effects of ionizing radiation on astronauts engaged in space missions. Understanding the health risks associated with human space exploration is crucial for mitigating damages caused by Galactic Cosmic Rays (GCRs) and solar radiation. GCRs pose a significant radiation exposure risk in space, making it imperative to assess the potential health risk resulting from GCR particle exposure.

The INFN Roma Sapienza Alpha Magnetic Spectrometer research group is at the forefront of research in this area, actively studying the risk evaluation induced by GCR radiation and this talk will make the point of the last 5 years of research.

It will be presented the enabling research that we did on the dose effects models and relationship as well as theoretical framework for modelling the non-target effects due to the space radiation, a crucial topic to assess the carcinogenic risk in space due to space exploration of the deep space.

The roles of the data collected by the astroparticle experiments operating in space will be clarified, with a particular focus on mid and heavy nuclei components of space radiation.

Recently also a collaboration with different research institute is arising to notice is the one with the National Institute for Laser, Plasma, and Radiation Physics (INFLPR) in Bucharest to explore the potentiality to reproduce space radiation conditions through ground experiments is explored by employing Laser Plasma Accelerators. These devices can generate a diverse array of particle beams, including electrons, protons, neutrons, ions, and photons, by tuning various parameters.