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BOOK OF ABSTRACTS

Radiation monitoring on board the Russian segment of the ISS. The comparison of the dose measurements by "Pille-ISS" and "R-16" service systems

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Thermoluminescent dosimeter "Pille-ISS" consisting of ten autonomic detectors and the onboard compact reader, also as radiometer "R-16" consisting of two ionizing chambers, are part of the radiation control service system of the Russian Segment of ISS. The intercomparison of two mentioned devices has been carried out during flight ISS-8). Two "Pille" detectors, that had been previously nulled, were placed on the body of radiometer "R-16" and were exposed there constantly with periodic measurement on the reader each 30 day approximately. The data from both devices were transferred to the Earth to the IBMP Space Flights Radiating Safety Service, and have been analyzed. The comparative data on 10 sessions of measurements are submitted. The dose measurement results by two service dosimeters systems are well agreed among themselves.The results of personal dose measurements by the "Pille-ISS" dosimeter are submitted also for two EVA missions of crews ISS-8 (26.02.2004) and ISS-9 (01.07.2004).

TL dose measurements on board the Russian segment of the ISS by “Pille” during expedition - 7, -8 and -9

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The most advanced version of a thermo-luminescent (TL) dosemeter system (“Pille-MKS”) developed by the KFKI Atomic Energy Research Institute (KFKI AEKI), consisting of ten $CaSO_4$:Dy bulb dosemeters and a compact reader, was successfully installed on board the ISS in October, 2003. It is applied for the routine and EVA individual dosimetry of astronauts/cosmonauts as part of the service system as well as for onboard experiments and operated by the Institute for Biomedical Problems (IBMP). It is unique providing accurate and high resolution TL dose data already on board the space station which became increasingly important during the suspension of the Space Shuttle flights. In accordance with the common Russian-American working document *ISS 8 IDRD,* seven dosemeters are located at several places of the Russian segment of the ISS and read out per month, two dosemeters are dedicated for EVAs and one dosemeter is kept in the reader and read out automatically every 90 minutes. During particular events like coronal mass ejections, hitting Earth incidental measuring campaigns are intercalated with frequent readouts (twice a day). In this paper we report results of dosimetric measurements made aboard the International Space Station during Expedition-7, -8 and -9 using the Pille portable TLD system.

The use of passive personal neutron dosemeters to determine the neutron component of cosmic radiation fields in spacecraft

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Secondary neutrons are a major contributor to dose equivalent and effective dose inside a spacecraft for the altitude range and inclination of the International Space Station. The exact proportion is very dependent on the amount of shielding of the primary galactic cosmic radiation and trapped particles, but is likely to lie in the range of 10% to 60%. Neutron personal dosemeters of simple design, processed using simple techniques developed for routine personal dosimetry, have been used to determine the neutron component, including the neutron-like interactions of high energy protons. Using results of ICCHIBAN irradiations, it can be shown that for the etch regime employed, the combination of high LET threshold (there is little response below a restricted LET_{200} in PADC of about 30 keV/μm), and poor angle dependence of response to high-energy charged particles, results in a much reduced overall response of the neutron dosemeter to the HZE component of the field in spacecraft and no response to protons of energy greater than about 1 MeV. For the fields in the ISS, an estimated correction of 10 to 30% is necessary to account for the detector HZE response. An accurate correction may be made by carrying out an additional simple chemical etch procedure can be carried out which allows discrimination and subtraction of HZE tracks.

The radiation monitoring system of the Russian segment of the ISS – Current status and results

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Radiation monitoring system (RMS) has worked on board of the International Space Station (ISS) practically continuously since August 2001. The information about performance of device and dose rate data since August 2001 till July 2004 are presented. The data for solar proton events are considered separately. The appreciable dose value during above period observed for solar proton events September 24 and November 4, 2001, October 28 and 29, 2003. It was noted, that for solar proton event of November 4, 2001 the difference between maximum and minimum values of absorbed doses measured by DB-8 units was approximately 30 times.

Results obtained with DB-8 and LIULIN-ISS instruments during ICCHIBAN-5 session at the NIRS HIMAC

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The intercomparison study of the dosimetric instruments used on board the ISS is a part of the international ICCHIBAN project that is realized at the heavy ion medical accelerator (HIMAC) at the National Institute of Radiological Studies (NIRS), Chiba, Japan. The ICCHIBAN-5 studies with DB-8 and Liulin-ISS silicon detector instruments were carried out in the 150 MeV helium ion beam in Jan., 2004. Particle fluxes and dose rates measured with DB-8 and Liulin-ISS instruments agree within 15-20 %. The dose sensitivity of the DB-8 instrument is close to isotropic. The results obtained certify the possibility to use DB-8 and Liulin-ISS instruments for space radiation dosimetry. The authors would like to gratefully acknowledge the NIRS, the HIMAC operation group, and personally Dr. Yu. Uchihori for the good opportunity to use the HIMAC facility in this study.

Comparison of results from the ICCHIBAN-4 experiment and current status of the proton ICCHIBAN and ICCHIBAN-6 experiments

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The ICCHIBAN-4 Experiment, dedicated to the ground-based intercomparison of passive dosimeters used to measure radiation exposure in space, was conducted in May 2003 at the NIRS HIMAC heavy ion accelerator. A total of ten laboratories in eight countries provided detectors for exposure during the ICCHIBAN-4 experiment. The heavy ion beams used in the exposures consisted of 150 MeV/n ^{4}He, 400 MeV/n ^{12}C, 400 MeV/n ^{20}Ne, and 500 MeV/n ^{56}Fe. In addition, some exposures were made to a ^{60}Co γ-ray source to simulate the low LET component of the space radiation environment. Passive dosimeters were expose to both "known" and "blind" conditions over the course of the experiment. Proton ICCHIBAN, the first ICCHIBAN experiment to be held outside Japan, was conducted in Sept. 2003 using the proton therapy synchrotron at Loma Linda University Medical Center, California, USA. Active detectors from four laboratories in three countries and passive dosimeters from 13 laboratories in nine countries were exposed over the course of the experiment. Monoenergetic proton exposures were made at energies of 70 MeV, 155 MeV, and 230 MeV. In addition, exposures were made to a simulated Solar Particle Event with mixed proton energies from 30 to 210 MeV. The ICCHIBAN-6 Experiment for passive space dosimeters was conducted in June 2004. Heavy ion beams included 135 MeV/n ^{12}C, 500 MeV/n ^{40}Ar, and 400 MeV/n ^{84}Kr. Data from the Proton ICCHIBAN and ICCHIBAN-6 experiments are still being analyzed. NSRL ICCHIBAN, the first ICCHIBAN experiment to be held at the newly opened NASA Space Radiation Laboratory at the Brookhaven National Laboratory, New York, USA, is scheduled for late Sept. 2004. Both passive and active detectors were be included in the experiment. The heavy ion beams for the NSRL ICCHIBAN experiment will include ^{1}H, ^{16}O, and ^{56}Fe, all at energies of 1 GeV/n.

The Matroshka facility – Dose determination during an EVA

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On the 29^{th} of January 2004 the MATROSHKA facility was launched with a Russian Progress to the International Space Station. MATROSHKA is an ESA project that is realized under the direction of the DLR. The project is a cooperation of more than 15 research institutes from all over the world and is currently the biggest international radiation experiment performed ever in space. The facility simulates as exact as possible an astronaut during an extravehicular activity (EVA). It was installed outside the Russian segment “Zvezda” on the 26^{th} February 2004 and will remain there for at least one year exposure period. The MATROSHKA facility basically consists of a human phantom, a Base Structure and a Container. The container is a Carbon fibre structure and forms with the Base Structure, to which the phantom is mounted, a closed volume that contains a dry oxygen atmosphere and acts as a simulation of the space suit with respect to shielding thickness. The phantom body is made of commercial phantom parts, well introduced in the field of radiotherapy. It consists of natural bones, embedded in tissue equivalent plastic of different density for tissue and lung. The Phantom is cut in 33 slices; each of them is equipped with channels and cut-outs to allow the accommodation of active and passive dosemeters and temperature sensors. The phantom is equipped with three active instruments (a silicon detector telescope DOSTEL located at top of the phantom head, a scintillator/silicon device (SSD) with five scintillator sensors each surrounded by 6 silicon detectors for anticoincidence integrated at five organ locations inside the phantom and the NASA MIR TEPC located in front of the belly of the phantom) as well as over 6000 passive dosemeters (TLDs and CR-39). The phantom is dressed with a Poncho and a Hood in order to allow the integration of passive dosemeters for skin dose measurements. The data expected are particle fluence and energy and LET spectra, dose and dose rates outside and throughout the phantom. Since mid April 2004 MATROSHKA was activated. Housekeeping and scientific data were transmitted to ground using a PCMCIA card and the American voice link. Some preliminary scientific data will be presented together with the MATROSHKA status data. After the exposure time of one year the facility will be brought back to inside the RSM, where the passive detectors will be reinstalled and transported back to ground by Soyuz. The facility remains for further use inside the RSM.

TLD results from the recent ICCHIBAN experiments

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The ICCHIBAN project created opportunity to study response of TLDs to high-energy ion beams. During the series of experiments at HIMAC we investigated the TLDs which are currently exposed within the MATROSHKA facility at the ISS. The used TLD types are: standard ^{7}LiF:Mg,Ti (equivalent of TLD-700; denoted MTS-7), high-sensitive ^{7}LiF:Mg,Cu,P (MCP-7) and a newly developed in Kraków version of ^{7}LiF:Mg,Ti with modified activator composition and increased response to high-LET radiation (MTT-7). It is proposed to exploit ratios of responses of these three TLDs for extracting some information about ionization density of the unknown high-LET radiation field. In this way it is possible to correct the under-response of TLDs for such radiation. A brief summary of results obtained during recent ICCHIBAN-6 (preliminary results) and Proton-ICCHIBAN experiments will be presented and compared with the results of previous ICCHIBAN-2 and -4 runs.

Sileye-3/Alteino results on cosmic rays on board the ISS

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We discuss measurements of cosmic ray nuclear fluxes and abundances above 150 MeV/n inside the International Space Station with the Sileye-3/Alteino experiment. The device has been working during April 2002 in the framework of the Soyuz-34 mission, and is devoted to the study of the Light Flash (LF) phenomenon and the radiation environment on board manned spacecraft. Sileye-3 consists of an electroencephalograph to monitor brain activity of the astronaut during LF perception and a silicon telescope (AST) to measure cosmic rays. The silicon telescope is capable to identify nuclei from B to Ni and to measure LET in the 1keV/mum – 1000 keV/mum range. The detector was located in the PIRS module during the duration of the mission. The orbit of the station has been divided in three regions (polar, equatorial and South Atlantic Anomaly) and nuclear abundances are measured in each section. Results are compared with similar data obtained on Mir with Sileye-2 experiment. We also report on the analysis of pitch angle distributions for galactic and trapped (protons in the South Atlantic Anomaly) component as a function of the orbit, the orientation of the station and the geomagnetic field.

Simultaneous investigation of galactic cosmic rays on aircrafts and on International Space Station

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Galactic cosmic rays component of the space radiation environments at aircraft altitudes and on the International Space Station (ISS) were measured by using of practically equal silicon active detectors in May-August 2001. The aircraft measurements were performed on commercial flights of CSA airlines, while the measurements on the ISS were inside of the "Dosimetric mapping" experiment on ISS. Different cases of comparison are presented in the paper and discussed.

ISS observations of the trapped proton anisotropic effect

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Space radiation measurements were made on the International Space Station (ISS) with the Bulgarian Liulin-E094 instrument, which contains 4 Mobile Dosimetry Unit (MDU), and the NASA Tissue Equivalent Proportional Counter (TEPC) during 2001. Four MDUs were placed at fixed locations: one unit (MDU #1) in the ISS “Unity” Node-1 and three (MDU #2-#4) units were located in the US Laboratory module. The MDU #2 and the TEPC were located in the US Laboratory module Human Research Facility (rack #1, port side). Space radiation flight measurements were obtained during the time period May 11 – July 26, 2001. In this paper we discuss the flight observed asymmetries in different detectors on the ascending and descending parts of the ISS orbits. The differences are described by the shielding differences generated by different geometry between the predominating eastward drifting protons and the orientation and placement of the MDUs within the ISS. Shielding distributions were generated for the combined ISS and detector shielding models. The AP8-MAX and AE8-MAX trapped radiation models were used to compute the daily absorbed dose for the five detectors and are compared with the flight measurements. In addition, the trapped proton incident spectra inside of ISS were calculated using calibration curve of MDU. Spectra maximums were analyzed against L value for the individual passes through the South Atlantic Anomaly.

The DESIRE project: Studies of the Columbus/ISS radiation environment using Geant4

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The DESIRE (Dose Estimation by Simulation of the ISS Radiation Environment) project aims to accurately calculate radiation fluxes and doses to astronauts inside the European Columbus module of the International Space Station using Geant4. Since Geant4 has not been previously used for this type of application it needs to be validated. This will be followed by a detailed evaluation of the incident radiation fields on ISS and culminate with the geometry modelling and full-scale flux and dose simulations for Columbus. Results of Geant4 simulations of the transport of some relevant radiation field components through the hull of a model of Columbus in ISS configuration14A are presented. Geant4 validation studies and comparisons to other tools are briefly presented. The DESIRE project is financed by ESA and the Swedish National Space Board.

TEPC results from ICCHIBAN-5, Proton ICCHIBAN-1, and the KC135 flight environment characterization experiments

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The ICCHIBAN experiments provide a unique opportunity to characterize the response of radiation detection instruments to a variety of high energy charged particles. The ICCHIBAN-5 experiments took place at the Heavy Ion Medical Accelerator (HIMAC) at the National Institute of Radiological Sciences in Chiba, Japan in February 2004. Results from this experiment for the irradiation of a shuttle style Tissue Equivalent Proportional Counter (TEPC) by 144 MeV/nucleon ^{4}He particles at 5 discrete angles of exposure are presented. Proton ICCHIBAN-1 took place at the Loma Linda University Medical Center proton synchrotron, Riverside, CA in September 2004. Preliminary results from this experiment of the response of the TEPC to protons from 70-240 MeV are presented. Modeling results of the TEPC

response function for both of these experiments using the spatially restricted LET model are also presented. The TEPC was flown aboard the KC135 Weightless Wonder in April of 2004 to correlate the response function to changes in the vibration, EMF, and gravitational field present aboard the aircraft. Results from this experiment are also presented.

ICCHIBAN-4 & 6: NRPB results

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Personal neutron dosemeters of simple design, and processed using simple techniques developed for personal dosimetry may be used to estimate the neutron component of the radiation field in spacecraft. Electrochemically etched pits in poly allyl diglycol carbonate (PADC or CR-39®) etched track detectors are identified and counted using fully automated read-out procedures. A calibration factor is applied which is appropriate for the neutron plus neutron-like (high energy proton) component. The tracks observed are produced not only by secondary charged particles from interactions of the neutron and neutron-like component of the radiation field, but also in part by the directly ionizing proton and energetic heavy charged particle components of the radiation field at the location of the dosemeter. This leads to an over-estimate of the neutron component. The efficiency of the etch and read procedures is very dependent on particle type, energy and angle of incidence. The ICCHIBAN series of irradiations has enabled the determination of the restricted LET and angle dependence of detector response, and has also has allowed the development of techniques to identify and subtract the pits caused by HZE particles.

The BRADOS intercomparison ("Space ICCHIBAN") experiment onboard ISS – First results

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The BRADOS intercomparison experiment onboard the Russian Segment of the International Space Station (RS-ISS) was initiated in the course of the successful tradition of the ICCHIBAN intercalibration programme. The participating organizations included the National Institute of Radiological Sciences (NIRS, Japan), the Institute of Biomedical Problems (IMBP, Russian Federation), Eril Research Inc. (ERI, USA), the Oklahoma State University (OSU, USA), and the Atominstitute of the Austrian Universities (ATI, Austria). Detector packages comprised different thermolumines-cence dosemeter (TLD) materials and plastic nuclear track detectors (PNTDs) of the type CR-39. The Austrian side used TLD-300 (CaF_2:Tm), TLD-600 (^{6}LiF:Mg,Ti), TLD-700 (^{7}LiF:Mg,Ti), and TLD-700H (^{7}LiF:Mg,Cu,P) in its detector stack; 0.9 mm-thick Fukubi (former Harzlas) TD-1 PNTD foils, equivalent to a shielding thickness of 0.12 g/cm², served as both radiation sensors and absorber/moderator materials. The detector stack consisted of 28 PNTD sheets in total, with 10 intersecting TLD layers. The detector assemblies of all groups were stored in the same BRADOS containment which was mounted in panel ? 443 (commander sleeping quarter) for an overall exposure duration of 91.5 days from February 1 to April 30, 2004. First results reveal a weak gradient of dose rate, with the highest dose determined in proximity of the spacecraft skin. By analyzing the high-temperature TL emission in TLD-600 and TLD-700, the measured absorbed doses could be corrected for TL efficiency, mainly an overresponse to low-LET protons. The recorded dose values are in good agreement with data from previous measurements in the same panel. The evaluation of the PNTDs is currently under progress.

The radiation assessment detector (RAD) for Mars

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The Radiation Assessment Detector (RAD) is a simple, 1 kg energetic particle spectrometer proposed for the Mars Science Laboratory (MSL) to detect and analyze ALL relevant energetic particle species (p, n, He, CNO, Fe, etc.) incident on the Martian surface, including direct and indirect radiation created both in the atmosphere and the regolith. Fully characterizing and understanding the radiation environment on Mars is fundamental to quantitatively assessing the habitability of the planet, and essential for future manned Mars missions. The RAD instrument consists of a solid-state detector stack and CsI calorimeter with active coincidence logic to identify charged energetic particles using the dE/dx vs E method. RAD also uses a separate plastic scintillator and anti-coincidence shell to detect neutrons and gamma rays. Each of these techniques and components have been used for radiation detection in space since the 1960s, but combined in this way for the first time with RAD. Finally, RAD's simple, compact, and lightweight design make it ideally suited for other future space missions as well (both manned and unmanned), where full characterization of the local radiation environment is required.

Calculation of local doses with account for realistic ISS configuration

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In flight International Space Station is exposed to high-energy cosmic radiation – protons and electrons of Earth radiation belts, solar energetic particles and galactic cosmic rays. To provide the safety of ISS crew and reliable operation of equipment it is very important to calculate correctly the equivalent and absorbed doses during the whole mission and at its different phases at different places of Station. The task is solved using the method of spatial integration on three-dimensional ISS model (ISS 3D-model) of the function which represents the dependence of equivalent and absorbed doses value on the shield thickness in spherically symmetric geometry, a so called sectoring method. Logically the task interface is divided into two basically different parts: (1) Computation procedure and representation of local equivalent and absorbed doses and mass distribution values in digital and graphic forms. The main idea of the part is to apply the client-server technology to interactive control of the computation process. The main application (client) is "Microsoft Excel 2000" into which the initial data are loaded by the user and server – "3D Studio MAX 6.0" in which ISS 3D-model (simulated by the NASA data) is allocated. The results of computation using program languages Visual Basic and Maxscript are shown in output Excel-tables. The initial tables define the dependence of equivalent and absorbed doses on the spherically symmetrical shield thickness. Besides, the table is defined listing spatial coordinates of ISS local points where doses are computed as well as the table with data on physical properties of ISS structure material. Output Excel-tables contain computation results of local doses and mass distribution for chosen local places. In addition it is possible to compute both the total dose and the contribution by different radiation types. (2) Autonomous 3D-observation in "3D Studio MAX" format of mass distribution for each chosen local place. The distribution is represented in the form of colored 3D-sphere (the color intensity depends on the shield thickness in the given direction). Besides, simple observation of each sphere the user can produce different important operations in interactive mode, in particular, quickly determine the shield thickness in any interested direction by simple clicking the mouse button. The report presents the results of the local doses computation at different ISS places.

The aerage qality fctors by TEPC for carged prticles

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The quality factor used in radiation protection is defined as a function of LET, $Q_{ave}(LET)$, however tissue equivalent proportional counters (TEPC) measure the average quality factors as a function of lineal energy (y), $Q_{ave}(y)$. A model of the TEPC response for charged particles considers energy deposition as a function of impact parameter from the ion's path to the volume, and describes the escape of energy out of sensitive volume by d-rays and the entry of d-rays from the high-density wall into the low-density gas-volume. A common goal for operational detectors is to measure the average radiation quality to with an accuracy of 25%. We show using our TEPC response model and the NASA space radiation transport model that this accuracy is obtained by a properly calibrated TEPC. However, the individual contributions from trapped protons and galactic cosmic rays (GCR) by TEPC; the average quality factor is overestimated for trapped protons and underestimated for GCR by about 30%, i.e., a compensating error. We find that TEPC's values for trapped protons for $Q_{ave}(y)$ range from 1.99-2.58 for average quality factors, however, $Q_{ave}(LET)$ ranges from 1.5-1.65 as depth increases from low to high spacecraft shielding. The average quality factors for trapped protons on STS-89 demonstrate that the model of the TEPC response is in good agreement with flight TEPC data for $Q_{ave}(y)$, and thus that $Q_{ave}(LET)$ for trapped proton is overestimated by TEPC. Preliminary comparisons for the complete GCR spectra show that $Q_{ave}(LET)$ for GCR is approximately 3.2-4.1, while TEPC's measure 2.9-3.4 for $Q_{ave}(y)$, and thus that $Q_{ave}(LET)$ for GCR is underestimated by TEPC.

Evaluation of neutron radiation environment inside the International Space Station based on the Bonner ball neutron detector experiment

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In order to evaluate the neutron radiation environment inside the International Space Station (ISS), a Bonner Ball Neutron Detector (BBND) experiment was conducted on the US Laboratory Module of the ISS as part of the science program of NASA's human Research Facility(HRF). The neutron energy spectra from thermal energy up to 15 MeV in 22 bins, and dose-equivalent evaluated by using the ICRP-74 conversion coefficients were obtained with 1-minute temporal resolution over eight months from Mar. 2001 through Nov. 2001 corresponding to solar-activity maximum period. The discussion of the neutron radiation environment in this presentation will be on the average results through the BBND experiment, differences between two locations inside the ISS due to the relocation of the BBND instruments during the experimental period, and comparison with the former results obtained by the BBND pre-cursor experiment on the STS-89 in 1998 corresponding to solar-activity less-quiet period. A few solar flares associated with large proton events occurred during the BBND experiment, which induced more severe radiation environment on the ISS orbit. The influences of solar events on the neutron radiation environment will be also discussed

The high energy response of the electronic neutron/photon PTB dosemeter DOS-2002

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Over the last few years, PTB has developed the electronic dosemeter DOS-2002. It is of an especially simple design (1 silicon detector) and detects the photon and neutron personal dose equivalent with a low detection threshold of 0.016 µSv and 10 µSv, respectively. Its dosimetric characteristics have been determined in neutron fields with energies ranging from thermal to 15 MeV and in photon fields with mean energies ranging from 65 keV to 7 MeV. The dosemeter is intended for use on the trunk of the Matroschka phantom inside the international space station, the mean goal being the determination of the personal dose equivalent from neutrons. Inside the space station, broad neutron spectra peaked at about 1 MeV and 100 MeV are expected similar to those found behind thick shieldings at accelerators or in the atmosphere at aircraft flight attitudes. Therefore, the dosemeter needs to be calibrated in fields with a similar spectral distribution and characterized with respect to its high energy neutron response. The first high energy neutron measurements were performed at UCL in Belgium by irradiating the dosemeter attached to an PMMA slab phantom in neutron fields with peak intensities at 35 MeV and 61 MeV. These calibration fields consist of broad energy distributions with roughly one third of the fluence in the peak region and two third in the lower energy region. The monoenergetic response of the DOS-2002 for high energy neutrons was determined by unfolding techniques taking into account the full knowledge of the spectral distributions of these calibration fields as determined by time-of-flight techniques.

Results from recent ground based (HIMAC) and space (ISS) exposures using TL and OSL dosimeters

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We use optically stimulated luminescence (OSL) from Al_2O_3:C samples irradiated in ground-based experiments at HIMAC to test the hypothesis that a “mean efficiency” can be extracted from the shape of the OSL decay curve using a suitable algorithm. This approach resembles the “high-temperature ratio, HTR” method of Vana and colleagues when using LiF:Mg,Ti TL detectors. It is observed that the methods can be used to estimate absorbed dose for unknown single-ion exposures, or for mixed-ion exposures when the total dose is dominated by the low-LET component. When the mixed field exposure contains strong contributions from high-LET components, however, large errors can be introduced (up to 10%). Additional errors are introduced when attempting to estimate dose equivalent.
We use this information to interpret the results from recent exposures on the ISS for the dosimetry of the experiments MESSAGE and MOBILIZATION and, more recently, BRADOS. Different TL and OSL detectors (LiF:Mg,Ti, LiF:Mg,Cu,P, and Al_2O_3:C) were used in these experiments. The data are interpreted using the LET spectrum determined from exposure of plastic nuclear track detectors (PNTDs) and on the efficiency data for heavy charged particles reported by various groups participating to date in the ICCHIBAN intercomparison. The results are important to understand the origin of the differences in doses given by the various dosimeters, and highlight the importance of the correction procedures to be used with TL and OSL to determine the absorbed dose for the low LET (<10 keV/µm) part of the space radiation spectrum.

Dosimetry for space radiation in ISS lifescience experiments using AUTO PADLES (temporary)

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JAXA's Space Utilization Research Center has developed a Passive Dosimeter for Life-Science Experiments in Space (PADLES) system. The dosimetric data obtained by the PADLES system are provided principally for biological experiments aboard the Japanese Experiment Module Kibo of the International Space Station (ISS), investigating biological effects in a space radiation environment. A full understanding of biological effects in a space radiation environment requires quantitative measurements of radiation doses of biological samples and quality of radiation (species and energies). In order to investigate the correlation between the biological effects and dosimetric quantities, dosimeters must be analyzed promptly just after their recovery from the ISS. Biological researchers expect to detect some variation such as gene mutation due to space radiation exposure using fresh samples. The PADLES system is constructed for routine analysis of many PADLES packages recovered from ISS every 3 (or 6) months. High-speed and semi-automatic analysis of CR-39 by the PADLES system drastically reduces the maximum analysis time to about two weeks for each experiment. Data will be offered to biological researchers from 2008. For prompt and synthetic analysis, the PADLES system which is under development integrates two software programs, TLD PADLES and AUTO PADLES: (1) TLD PADLES individual data of TLD elements, such as controls calibration factors and history of use, TL readouts in flight experiments. In case of preparation for next flight experiment, it's possible to make up the number from all available TLD elements group which shows regular dose response and select most appropriate elements automatically. (2) AUTO PADLES is made up of three functions: (i) the CR-39 processing section processes many microscope images and measure the major axis and minor axis after an ellipse fitting of the etch pit opening shape; (ii) the dose estimation section calculates the absorbed dose, dose equivalent and LET distributions from the combined TLD-MSO and CR-39 data; (iii) the experiment data-base section controls a subject and background of life science experiments, flight information, dose analysis and so on. The automatic etch-pit shape detection function of the CR-39 processing section employs a pit-fit algorithm to shorten the microscope image analysis time. The algorithm was developed by SEIKO Precision and National Institute of Radiological Science (NIRS). The basic dose estimates of AUTO PADLES are based on an evaluation of combined of TLD-MSO and CR-39 data by Doke et.al (1995). TLD and CR-39 response data for heavy ions as determined from ground-based experiments with HIMAC are also installed in the AUTO PADLES database. JAXA has been providing the PADLES packages for several space experiments so far. In long-term experiments from June 2001 to November 2002on the ISS Russian segment, which were conducted for investigating white defects of HDTV CCD elements due to space radiation, We confirmed that the bubbles on etched surfaces of the CR-39 recovered from the ISS Russian segment, which were probably caused by protons increasing gradually in proportion to the number of days of exposure. This is an important problem o be solved for automatic analysis of CR-39 provided for long-term space experiments. PADLES is to be used for four ISS biological research experiments proposed in the international announcements of opportunity and the first KIBO utilization solicitation. We will report on the JAXA life-science experiments with the PADLES system and problems to be solved in space radiation measurements on ISS using the PADLES system.

ALTEA: calibration and status of the project

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The ALTEA project is aimed at i) studying the radiation environment inside the ISS and ii) studying the possible functional damages to the Central Nervous System (CNS) due to particle radiation in space environment. The project is an international and multi-disciplinary collaboration, and it is financed by ASI and INFN. The hardware is scheduled to be positioned in the ISS in 2005. ALTEA is a helmet-shaped device that hosts six active particle telescopes, one Electro Encephalo Graph (EEG) and a visual stimulator. ALTEA permits to study concurrently the passage of cosmic radiation through the brain, the functional status of the visual system and the electrophysiological dynamics of the cortical activity. The basic instrumentation includes also a pushbutton. The telescopes are able to detect the passage of each particle measuring its energy and trajectory identifying nuclear species. The ALTEA hardware can be used separately or in any combination, permitting several different experiments. Calibrations of the Engineering and Flight telescopes have been performed at GSI in Darmstadt (Germany) in November 2003 and April 2004, using C and Ti ions at several energies. We performed complete beam scans of the telescopes to check functionality and homogeneity of all strips of silicon detector planes. We also used different thickness of Aluminium and Plexiglas to study fragmentations. Results showing the good linearity and flexibility of the telescopes will be presented, as well as the results from the fragmentation runs. ALTEA is scheduled also for the next NSRL-ICCHIBAN run at the end of September. Possible further experiment with the ALTEA hardware will be sketched.

Precursor radiation activities for the ESA exploration programme

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As early preparation for the full-scale ESA Exploration Programme and the radiation-related R&D activities planned therein, a number of activities have been started in collaboration with various institutes in Europe. These currently include the DESIRE and RadVIS projects for ISS/Columbus dose calculations and Virtual Reality dose visualization, the REMSIM project for radiation exposure and mission strategies planning for interplanetary flight, the IONMARSE and GEANT4-DNA activities for the development of particle transport codes for radiobiological purposes, and the RESTEC, ATMOCOSMICS and MAGNETOCOSMICS developments for detailed modeling of the Martian radiation environment. In this presentation, a brief overview of these projects is given. Activities planned to be started in the 2004-2005 timeframe will also be outlined.

Secondary neutron and cosmic ray studies on the ISS using SSNTD stacks, BRADOZ-1 and 3 projects, 2001-2003

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The BRADOZ projects were organised by the Russian Space Agency (RAZA) between 2001 and 2003. The aim was to study the contribution of the primary galactic cosmic rays and of the secondary particles to the dose of the crew of the International Space Station (ISS). Two different stacks, composed of solid state nuclear track detectors (SSNTD), were constructed and exposed inside the Service Module, Zvezda, in 2001 and 2003. The calibrations were made at the high energy neutron reference field named CERF(Geneva, Swiss) and at a high energy proton accelerator in Loma Linda (CA, USA). Applying a multiple track etching technique (2 to 20 h etching time) and an image analyser which can measure the necessary etched track parameters, the secondary neutron dose and the LET spectra were deduced. The composition of stacks, the evaluation methods and the results will be presented together with comparisons to measurements made by other laboratories.

The status of FLUKA within the NASA space radiation shielding modelling consortium, and its application to ISS and related ground-based measurements

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As reported 2 years ago at the WRMISS meeting in Paris, FLUKA is one of the transport codes participating within NASA's Space Radiation Shielding Consortium. Significant progress has been made in the intervening period in addition to the continuing updates to the physics. These include the development of new data visualization tools and internal improvements in the geometry input format. Current work is focused on continuing to improve the physics accuracy, especially in the area of heavy ion interactions, and on increasing the availability of GUI-based tools. FLUKA has been used to evaluate the MARIE data, and that experience is directly applicable to the analysis of the EV & IVCPDS instruments on the ISS. FLUKA will also be used to simulate the ALTEA Light Flash Experiment on the ISS, including the use of the VOXEL geometry capability of FLUKA to simulate the detailed anatomy the astronaut's eyes, head and body. On the ground, FLUKA will be used to simulate the accelerator cross section measurements at the HIMAC and at NSRL, and as such it can be readily adapted to simulate other accelerator set-ups as well.

MATROSHKA-R experiment on board the ISS: Current status and preliminary results

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The spherical tissue equivalent phantom (35 cm diameter and 10 cm central spherical hole) was installed in the crew quarters of the ISS Service Module in Feb. 2004. This phantom is a multi-user experimental facility that was specially designed for the in-flight radiation measurements onboard the Russian segment of the ISS as part of the Matroshka-R project. The spherical phantom as compared with the anatomical one is known to be more suitable for operational usage onboard the space station. There are a total 20 cylindrical channels inside the phantom body for detector container placement. The phantom has a special jacket made from artificial skin that serves as protection against flammability; the jacket has 32 pockets on its outer surface for detectors. TLD and CR-39 detectors are located in containers in the phantom that can be attributed to critical organs of a human body. Phantom disassembling is not required for detector container retrieval. The detector containers were returned to the ground in April 2004. The containers with new detectors for the Matroshka-R experiment were delivered onboard the ISS in late August 2004. These detectors will be exposed to space radiation until April 2005. Preliminary analysis of the data demonstrates an approximate 15% difference in dose in the phantom body when compared to the surface dose. The data obtained are useful for estimating the dose to critical organs as well as the effectiveness of additional water-filled or polyethylene shielding to be located along the walls of the crew quarters during solar minimum

Energetic solar cosmic ray surveyor and monitor

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The angular distribution of the most energetic Solar Cosmic Rays strongly depends by their energy and evolves with time. Its knowledge is nowadays very important in view of the programs of exploration of the Solar System either in the planning of the distribution of shielding systems, or on the project of the structure of an interplanetary spacecraft, or for the radiation protection of possible orbiters or landers. For a reliable forecasting it must be systematically studied, with correlated information on energies, evolution with the time, etc. in correspondence of the different topologies of energetic solar events and of their frequency. A small mass (<5 kg) and low consumption (<5 W) instrument, based on the two well established techniques of tracking by multistrip silicon detectors and precise charge and timing measurements by scintillation counters, can supply enough precise data up to about 500 MeV/nucleon. It could be part of the payload of a future general-purpose interplanetary probe. If inserted in a Martian orbit it can register in real time the sudden increase and arrival direction evolution of the early arriving electron component, alarming other devices, such as other Mars orbiters, or landers, of the soon arrival (at least half an hour) from a determined direction of the dangerous proton and nuclei storm, greatly simplifying the countermeasure actions. Owing the tenuous Mars atmosphere and the vulnerability of the landed instruments, this is extremely important in planning the robotic exploration, also before a possible human exploration of the planet.

Dosimetry and microdosimetry onboard space vehicles and related topics: Results of Czech participants, 2002-2004

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The contribution will present a review of results obtained by our team within the scope of WRMISS in the period 2002-2004. Basically passive detectors are used: thermoluminescent detectors, Si-diodes as passive fast neutron detectors and track-etch detectors (TED). In space, they were used in the period mentioned during: (i) 3 long term exposures onboard ISS; (ii) Shuttle SST 112 flight, resp. radiobiological experiments MESSAGE and MOBILIZATION. On Earth, the detectors were exposed: (i) during ICCHIBAN 2, ICCHIBAN 4, ICCHIBAN 6, and ICCHIBAN proton runs; (ii) at high energy charged particle beams in JINR, Dubna, Russia; and (iii) at CERF high-energy radiation fields. The results of these and some other related studies are presented, analysed and discussed. Particular attention is devoted to: (i) new methodological achievement with all these detectors; (ii) the analysis of the use of these detectors in space, their advantages and limits, and, (iii) the estimation of neutron component onboard spacecraft deduced from TED based LET spectrometer.
Perspectives of further activities will be also outlined.

Radiation dosimetry for a microbial experiment in the space station using different track-etch and luminescent detectors

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The laboratory of Microbiology at SCK-CEN, in collaboration with different universities, participates in several ESA programs with bacterial experiments in space. The research program MESSAGE (Microbial Experiments in the Space Station About Gene Expression) studies the effect of space conditions on micro-organisms in general using some well-known model bacteria. The main objective of this program is to study the effects of space conditions such as microgravity and cosmic radiation on board the ISS on metabolic processes in 2 model bacteria. The MESSAGE 2 experiment was part of the experiments performed by the Spanish astronaut Pedro Duque on board the International Space Station (ISS) during the taxi flight in October 2003. The experiment was in space for 10 days, of which 8 were in the service module of the ISS. To measure the radiation doses received by the bacteria in the MESSAGE 2 experiment, different detectors accompanied the microbiological samples. This dosimetry experiment was a collaboration between different institutes, so that the doses could be estimated by different techniques. For the high LET doses (>10 keV/μm), two types of track etch detectors were flown. The low LET part of the spectrum, was measured by three types of thermoluminescent detectors (^{7}LiF:Mg,Ti; ^{7}LiF:Mg,Cu,P; Al_2O_3), and by the optically stimulated luminescence technique with Al_2O_3:C detectors, both in continuous and pulsed mode. The high LET results were of the order of 0.13 mGy or 2.4 mSv and LET spectra were obtained. For the low LET radiation, small differences between different techniques and detectors were observed, ranging between 1.5 and 1.9 mGy, but the general agreement was good. The differences may be generally understood from the different efficiencies of the different methods for HCPs.

Development of a diamond detector as a tissue equivalent semiconductor detector for space radiation

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A synthetic diamond radiation detector has been developed for measurement of charged particles of type and energy found in the galactic cosmic radiation spectrum. Because of the wide band gap of diamond, the detector is expected to exhibit low noise at high temperature and a low sensitivity to visible light. Since diamond is pure carbon and has an atomic number close to the average atomic number (~7.2) of human tissue, the diamond detector has a response to charge particles similar to that of tissue. For this reason, the diamond detector may be used as a tissue equivalent semiconductor detector. The diamond detector has been in development by our group for several years. An energy resolution of 15.4 keV to 5.5 MeV α particles from an Am source has been achieved. In addition, the detector has been exposed to heavy ion beams at HIMAC where it was demonstrated that it could be used as a spectroscopic detector. The capability of the diamond detector corresponds well to silicon semiconductor detectors and it may be possible to produce a personal radiation monitor based on diamond. The remaining challenges of the diamond detector are effective area and cost. New developments in the production of synthetic diamond material will overcome these problems in the near future.

Comparison of results from the ICCHIBAN-3 experiment and current status of the ICCHIBAN-5 experiment

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The ICCHIBAN-3 experiment for active space radiation detectors was conducted in February 2003. Five active radiation detectors from four countries, plus a ground-based charged particle spectrometer and several passive detectors were exposed to heavy ion beams at the NIRS HIMAC. The heavy ion beams consisted of 800 MeV/n ^{28}Si, 500 MeV/n ^{56}Fe and 400 MeV/n ^{12}C. The comparison results from active detector exposures during the ICCHIBAN-3 experiment are reported. The ICCHIBAN-5 experiment for active space radiation detectors was performed in February 2004. Six active detectors from five countries were exposed to heavy ion beams in Biology Exposure Room of HIMAC. Wide (10 cm diameter), uniform beams were used to ensure that the entire sensitive area of each detector was exposed. The current status of the analysis of these exposures are presented.

Intercomparison of passive radiation monitors in Russian segment of ISS (Space intercomparison/BRADOS)

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We conducted an intercomparison experiment for passive radiation dosimeters, the BRADOS/Space ICCHIBAN-0 Experiment, aboard the Russian segment of the International Space Station in early 2004. We plan a future experiment of larger scope to include passive dosimeters from all laboratories participating in the ICCHIBAN project. For the Space ICCHIBAN-0 Experiment, passive dosimeters from five laboratories in four countries were contained within a standard BRADOS box. The BRADOS box was exposed on the wall of the Flight Engineer's sleeping quarters in the Russian Service Module for a period of 91.5 days in early 2004. Dosimeters included LiF TLD, MSO TLD, Al_20_3:C OSLD, CR-39 PNTD, and Glass detector. Preliminary data from MSO TLD, Glass detector, and OSL in the NIRS detector packages are presented as a function of depth. Preliminary LET spectra from CR-39 PNTD are also presented.

Calculations of measurement quantities in support of Matroshka

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The MATROSHKA experiment consists of a well-instrumented phantom torso assembly placed within a thing capsule on the exterior of the International Space Station. One application of this data can be to compare and contrast the results of these measurements with calculated analogs using typical space toolsets. We present here the results of such calculations, including the calculated results, as well as a brief discussion of strengths and weaknesses of the current set of available tools, and comparison to measurements where available.