6th Workshop on Radiation Monitoring for the International Space Station

12-14 September 2001, Jesus College, Oxford, England

Chairman	**Guenther Reitz, DLR**
Co-Chairman	**David Bartlett, NRBP**

Workshop on Radiation Monitoring for the International Space Station (WRMISS)

Preliminary Program

Wednesday 12th Sept

9.00 - 10.30	Scientific Session
10.30 - 11.00	Coffee Break
11.00 - 13.00	Scientific Session
13.00 - 14.00	Lunch
14.00 - 15.30	Scientific Session
15.30 - 16.00	Coffee/Tea Break
16.00 - 17.30	Scientific Session

Welcome and Scientific Program/ Organisational Matters Memorial for Gautam Badhwar	G.Reitz/D. Bartlett
Session on Recent Measurements	
"Twenty Years of Radiation Measurements in Low-Earth Orbit—What Have We Learned About the Space Radiation Environment?"	M. Golightly
Determination of the Neutron Component of the Radiation Field in Spacecraft using Etched Track Detectors	D T Bartlett
Preliminary TLD results from the DOSMAP experiment on ISS	I. Apathy
Recent Results of Passive Monitoring on the International Space Station	E. Semones
Preliminary Measurements and Calculations in the SM and the Human Research Facility (HRF) in the USlab	W. Atwell
Results of Measurements Obtained in the First Phase of the Radiation Monitoring System Deployment on the Russian Segment of the ISS.	V. V. Benghin
Dosimetric measurements on ISS during quiet and disturbed periods	R. Beaujean
Active Radiation Monitoring on the International Space Station	T. Shelfer
A Conceptual Framework for Utilization of Space Radiation Measurements	W. Schimmerling
Round Table Discussion	all

Note: Presentation time shall not exceed 30 minutes

Thursday 13th Sept

9.00 - 10.30	Scientific Session
10.30 - 11.00	Coffee Break
11.00 - 13.00	Scientific Session
13.00 - 14.00	Lunch
14.00 - 15.30	Scientific Session
15.30 - 16.00	Coffee/Tea Break
16.00 - 17.30	Scientific Session

Session Models

Radiation Environment and Effect Models and Tools in SPENVIS	D. Heynderickx
Integrated Approach for Determining Radiation Quality and Effective Doses Using Physical and Cytogenetic Measurements from ISS.	F.A. Cucinotta
Round table Discussion	all

Session Calibration of Instruments

InterComparison of Cosmic-rays with Heavy Ion Beams At NIRS	Y. Uchihori
, A Solid-State Detector System for Ground-based Intercomparisons	C. Zeitlin
Fast neutron monitor in space using scintillation fiber camera	T. Doke
First Calibration of a New Scintillation Detector at CERF	S.Burmeister
Round Table Discussion	all

Session New Instrument Development/Data Base

MATROSHKA, An ESA-Facility for Radiation Measurements under EVA-Conditions	G. Reitz
"MSREM – Manned Space Flight Radiation Environment Measurements—Database Development Status"	M.J. Golightly
Round Table Discussion	all

Friday 14th Sept

9.00 - 10.30	
10.30 - 11.00	Coffee Break
11.00 - 13.00	Recommendations/Conclusions
13.00 - 14.00	Lunch
14.00	Adjurn

Discussion on scientific and operational eqipment of ISS Dosimetry tasks

Report on NCRP final draft Sc 46-15	D. Bartlett
Round table Discussion	all
Recommendations/Conclusions	all

ABSTRACTS

Preliminary TLD results from the DOSMAP experiment on ISS

G. Reitz[1], S. Deme[2], **I. Apathy[2]**

[1] German Aerospace Center (DLR), Cologne, Germany
[2] KFKI Atomic Energy Research Institute, Budapest, Hungary

Abstract:

The Dosimetric Mapping (DOSMAP) experiment, operated by Expedition Two onboard the ISS attempted to record and map radiation inside Space Station within a four month period. One of the several different types of devices used by DOSMAP was the Passive Dosimeter System (PDS) containing twelve pieces of TLD-PNTD (ThermoLuminescent Dosimeter and Plastic Nuclear Track Detector) kits and an onboard TLD Reader. The TL Dosimeters of the kits, located at different places on ISS were read out and evaluated periodically on board. One TLD was permanently inserted in the Reader and read out every 1.5 hours automatically to achieve an extremely good dose rate time resolution at that location.

Preliminary results of the TLD measurements are presented in this report. The LET dependence of the TLD efficiency will be corrected using LET spectra recorded by the PNTDs.

Preliminary Measurements and Calculations in the SM and the Human Research Facility (HRF) in the USlab

W. Atwell

Abstract not yet available

Determination of the Neutron Component of the Radiation Field in Spacecraft using Etched Track Detectors

D T Bartlett, L G Hager and R J Tanner

Abstract

Etched track plastic detectors may be used to estimate the neutron component of the galactic cosmic radiation using the same techniques developed for routine neutron personal dosimetry, but with appropriate calibration. Electrochemically etched pits are identified and counted. Read-out procedures are fully automated. HZE particles above a certain LET threshold will also produce an etchable track and be counted as if produced by a neutron and the same response factor applied (about 10 µSv per track) which will over-estimate the HZE component of dose equivalent. However, an additional chemical etch allows discrimination. The response of the etched track detectors is energy and angle dependent and, in general, the interpretation of results requires assumptions in respect to the energy and direction distributions of the field being determined.

Dosimetric measurements on ISS during quiet and disturbed periods

R. Beaujean (1), S. Burmeister (1), F. Petersen (1) and G. Reitz (2)

(1) University Kiel/IEAP, 24098 Kiel, Germany
(2) DLR Köln/Flugmedizin, 51147 Köln, Germany

Abstract:

Two units of the Kiel DOSimetry TELescope DOSTEL have been flown inside the US Laboratory on the International Space Station as part of the DOSMAP experiment. In 2001 during the period DOY 85-201, continous dosimetric measurements were performed. DOSTEL consists of two 315 µm thick Silicon detectors and measures count rates, dose rates and separate LET spectra in the LET range 0.1 –250 KeV/µm (in water) for Galactic Cosmic Rays (GCR) and particles detected during crossings of the South Atlantic Anomaly (SAA). Compared to earlier missions of DOSTEL, the upper limit of the LET range was increased by design changes. During the mission, some solar particle events (e.g. on April 15, 2001) occured and were well detected inside the ISS.

Quiet time measurements yielded a mean dose equivalent of about 500 µSv/d with Q=2.5-2.6 (GCR and SAA values are 350 and 150 µSv/d respectively). In 2001, the mean dose rate in silicon was about 150 µGy/d which is significantly less than the value of about 250 µGy/d measured during Shuttle-to-MIR missions in 1997.

Details of the DOSTEL measurements on GCR, SAA and solar particles will be given.

First Calibration of a New Scintillation Detector at CERF

S. Burmeister, R. Beaujean, E. Böhm, F. Petersen

Institut für Experimentelle und Angewandte Physik, Universität Kiel

Abstract

A new instrument was developed to measure the dose contribution of the neutral component for civil aircrew dosimetry. The detector arrangement consists of a 10x10x5 cm^3 BC-430 plastic scintillator to measure energy spectra of recoil protons from neutrons. This inner detector is surrounded by a 1 cm thick anticoincidence of the same material to discriminate charged particles in a mixed radiation field. The scintillation light of the inner detector is read out by two 2.8x2.8 cm^2 silicon PIN photodiodes. The light pulse of the anticoincidence is detected by twelve 1x2 cm^2 silicon PIN photodiodes. A prototype was recently exposed in the CERF Reference Field at CERN. This detector was found to be able to discriminate neutral particle induced events from charged particle radiation. The low energy detection threshold in the inner detector of recoil protons is 1MeV. Recoil protons of less than 140MeV are absorbed in 10cm of scintillator. Preliminary results will be discussed.

Results of Measurements Obtained in the First Phase of the Radiation Monitoring System Deployment on the Russian Segment of the International Space Station.

Markov A.V., Panasyuk M.I., Petrov V.M., **Benghin V.V**., et al.

No abstract available

Integrated Approach for Determining Radiation Quality and Effective Doses Using Physical and Cytogenetic Measurements from ISS.

Francis A. Cucinotta, Kerry George, Honglu Wu, and Robin E. Barber, NASA Johnson Space Center Biophysics Laboratory, Houston TX, 77075, U.S.A.

The effective dose received by astronauts on the International Space Station (ISS) cannot be directly measured using physical dosimetry and an integrated approach using physical and biological dosimetry is required. Important issues in determining the astronaut's effective dose are the attenuation of the radiation field by the self-shielding of the human body and the measurement of radiation quality. Limitations in physical dosimetry include efficiency as a function of particle type, limited correlation with the shielding variations of individual astronauts, and the absence of tissue shielding modifications. Biodosimetry using cytogenetic methods includes the vehicle shielding history of the individual and their tissue shielding, however has statistical limitations related to the background frequencies of aberrations, especially at low doses. Lymphocytes respond to protons, heavy ions and neutrons with reasonable efficiency, however there are differences in the relationship between quality factors and relative biological effectiveness factors for specific aberration types as functions of the linear energy transfer (LET). We discuss an integrated model that utilizes space radiation transport models, ISS shielding codes, and ground-based calibration methods in conjunction with physical dosimetry and individual biodosimetry data in order to estimate the organ specific dose equivalent and the effective dose during ISS missions. A preliminary error analysis of our approach is discussed.

Fast neutron monitor in space using scintillation fiber camera

Tadayoshi Doke and Kazuhiro Terasawa

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Abstract

Using monochromatic high energy neutron beams, the fundamental tests were made for two scintillation fiber cameras which were 3 dimensional track detectors. The size

of one camera is 25 mm × 25 mm × 25 mm, consisting of scintillation fibers with the cross section of 250 μm × 250 μm, and that of the other, 50 mm × 50 mm × 50 mm, consisting scintillation fibers with the cross section of 500 μm × 500 μm. From difference in scintillation yield, in the test, we found that the threshold neutron energy of the former for n-γ discrimination was 5 MeV and that for the latter was 10 MeV. In these cameras, the track of proton recoiled by fast neutron was clearly identified from that of heavier particle due to difference in scintillation yield and/or in the range-energy relation as well as n-γ discrimination and the LET distribution along the track of recoiled proton was easily measured. From LET-distribution given by recoiled protons inside the camera, we can easily estimate the absorbed dose and the dose equivalent for only protons recoiled by fast neutrons. From their results and the aid of simulation, also, the total absorbed dose and total dose equivalent for fast neutrons will be estimated. On the basis of these experimental results and the fundamental consideration, a new fast neutron monitor which is sensitive for neutrons with the energy of > 5 MeV was designed.

"MSREM – Manned Space Flight Radiation Environment Measurements—Database Development Status"

[1]**M.J. Golightly**, [2]E.J. Semones, and [2]C.B. Dardano

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The NASA Johnson Space Radiation Analysis Group (SRAG) has continued the development of MSREM—a database of radiation measurements from manned space missions. MSREM is structured to permit searches for data based on mission parameters (altitude, inclination, etc), specific time periods, type of detector (TLD, TEPC, etc), type of measurement (neutron flux, absorbed dose, etc), as well as correlative studies between groups of measurements and/or space environment parameters.

MSREM is designed for multiple levels of access, depending on the need/requirement for accessing the data. Database access levels are currently structured as general public, ISS operational radiological support team, and principle investigators participating in a data exchange program. General public access is limited to pertinent mission parameters and corresponding average total dose and dose equivalent measurements. ISS operational radiological support team members will have access to maximum, minimum, and average values, daily summaries and plots of temporally resolved data. Investigators who agree to abide by a data-sharing agreement and provide data to the database will have full access to all of the database's contents, including predetermined queries.

The database is currently populated with all Space Shuttle mission parameters and results from the operational Passive Radiation Dosimeters (PRDs) and Crew Passive Dosimeters (CPDs). Radiation Area Monitoring (RAM) measurements from throughout the International Space Station (ISS) are available for the period May 1999 to Jul 2001, daily ISS Tissue Equivalent Proportional Counter (TEPC) measurements from Nov 2000 through Apr 2001, and daily Russian R-16 data since Aug 2000. Correlative space weather parameters (F10.7, KP, AP, etc.) covering the entire manned space flight era have been added to the database—these values are automatically updated on a daily basis.

Ongoing efforts are underway to assemble, from the published literature, a listing of all known radiation instruments and measurements from the Soyuz, Salyut, Skylab, Mir, Shuttle, and ISS programs. This listing, along with available data and results, will be added to MSREM upon completion of an initial literature survey.

A brief review will also be provided of the problems encountered, instrument status, lessons learned, and plans for the future of ISS operational radiation environment monitoring.

"Twenty Years of Radiation Measurements in Low-Earth Orbit—What Have We Learned About the Space Radiation Environment?"

[1]**M.J. Golightly**, [2]M.D. Weyland, [2]A.S. Johnson, and [2]E. Semones

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[2] Lockheed Martin-NASA Johnson Space Center, Houston, TX 77058

Abstract

The advent of the Space Shuttle program has made possible space radiation environment measurements covering a wide range of altitudes and orbital inclinations over multiple solar cycles. These measurements range from routine integral dose measurements with thermoluminescent dosimeters to particle energy spectra measurements made with a charged particle telescope. This paper will review improved understandings of the space radiation environment gained from this diverse data set. Major findings from these measurements include: detection of an approximately 0.33°/y westward drift of the geographic location of the South Atlantic Anomaly (SAA); evidence for a northward component to the drift in the location of the SAA of approximately 0.07°/y; observation of the formation and decay of a pseudo-stable additional radiation belt following the March 1991 solar particle event and geomagnetic storm with an estimated decay e-folding time of approximately 5 months; observation of a local geomagnetic east-west trapped proton exposure anisotropy with an altitude-dependent east-west flux ratio estimated to be in the range of 1.6-3.3; demonstration that the trapped proton exposure in low-Earth orbit (LEO) can be reasonably modeled as a power-law function of atmospheric density in the SAA region, with best correlations obtained when the exospheric temperature dependence saturates at 938-975ºK; and the actual modulation of trapped proton exposure in LEO is less than predicted by the AP8 model. Long-term, time-resolved proportional counter measurements made aboard the Mir during the same period provide further demonstration of the solar cycle modulation of the trapped protons at low altitudes—the observed modulation is also well described as a power-law function of atmospheric density.

These data and findings have helped to improve the overall accuracy of pre-mission crew exposure projections using various semi-empirical environment models, radiation transport codes, and spacecraft shield models. During the rise phase of

solar cycle 22 (1987-1991), the RMS error between preflight exposure projections and measured crew exposure was 73%. For the rise phase of cycle 23 (1997-2001), the preflight exposure projection RMS error has decreased to 23%.

Radiation Environment and Effect Models and Tools in SPENVIS

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The ESA SPace ENVironment Information System (SPENVIS) provides standardized Access to models of the hazardous space environment through a user-friendly WWW interface. The interface includes parameter input with extensive defaulting, definition of user environments, streamlined production of results (both in graphical and textual form), background information, and on-line help. It is available on-line at http://www.spenvis.oma.be/spenvis/. Intranet versions are also available.

SPENVIS is based on internationally recognised standard models and methods in many domains.It uses an ESA-developed orbit generator to produce orbital point files necessary for many different types of problem. It has various reporting and graphical utilities, and extensive help facilities. SPENVIS includes models of the radiation environment and effects, including NIEL and internal charging. It also contains an active, integrated version of the ECSS Space Environment Standard, and access to in-flight data. Apart from radiation and plasma environments, SPENVIS includes meteoroid and debris models, atmospheric models (including atomic oxygen), and magnetic field models.

The SPENVIS radiation module features models of the proton and electron radiation belts, as well as solar energetic particle and cosmic ray models. The particle spectra serve as input to models of ionising dose (SHIELDOSE), Non-Ionising Energy Loss (NIEL), and Single Event Upsets (CREME). Material shielding is taken into account for all these models, either as a set of user-defined shielding thicknesses, or in combination with a sectoring analysis that produces a shielding distribution from a geometric description of the satellite system. A sequence of models, from orbit generator to folding dose curves with a shielding distribution, can now be run as one process, which minimizes user interaction and facilitates multiple runs with different orbital or shielding configurations.

MATROSHKA, an ESA-Facility for Radiation Measurements under EVA-Conditions

G. Reitz

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MATROSHKA is designed to allow studies of the depth dose distribution of the different components of the orbital radiation field at different sides of the organs, occurring in men being exposed during an Extra Vehicular Activity (EVA). The MATROSHKA facility basically consists of a human phantom, which is housed in a sealed container providing structural support and fixation of the phantom and protection against e.g. space vacuum, space debris and solar UV (Fig.1). The container, which is a Carbon Fiber Reinforced Plastic(CFRP) monolith structure, as well as the phantom will be mounted to a base structure, which hosts the facility and most of the radiation detectors electronics. The MATROSKA electronic consists of a power conditioning unit to receive, convert and distribute filtered and regulated power to its subsystems and to the detector electronics, a data handling module to communicate with the detectors and the Russian Service Module and for temporally data storage of housekeeping data, a memory module as temporary buffer for scientific date and a sensor module managing information of the housekeeping sensors.

The phantom consists of commercial phantom parts. It is built up by 32 slices composed of natural bones, embedded in tissue equivalent plastics of different density for tissue and lung. The phantom provides spaces for the accommodation of active and passive radiation detector sensors and of housekeeping sensors like temperature and pressure. It carries a Nomex poncho that provide pockets for carrying passive detectors to allow for skin measurements.

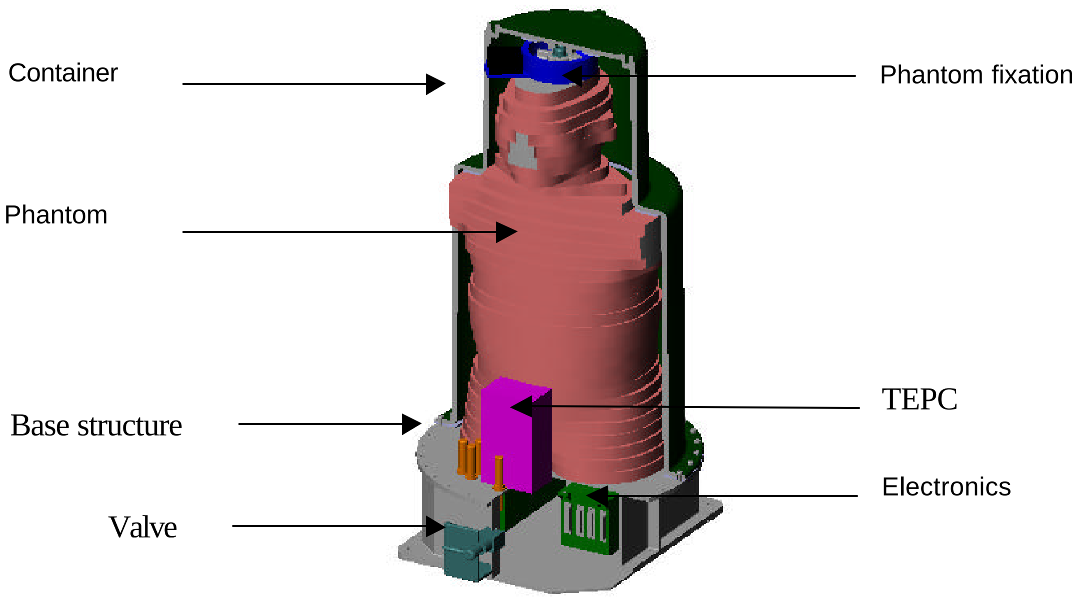

Figure 1 MATROSHKA overview.

MATROSHKA will be launched early 2003 and exposed during 1 year outside the Russian Service Module. Once activated MATROSHKA will provide permanently house keeping and scientific data. The amount of data generated is 5.1 MB per day which will be stored in the mass memory of an onboard computer. Under nominal operations, data are downlinked each day, but this data amount is limited to 5 MB a week. Further measurements are planned inside the Service Module with MATROSHKA when it is brought back after the outside exposure.

MATROSHKA uses different sensors which allow measurements of dose rate, particle flux and spectra and linear energy spectra. Various types of thermoluminescence detectors (TLDs) are distributed throughout the phantom body and also at the phantom surface. In addition, it is planned to integrate TLDs in the outer layer of the Multi-layer Insulation. Five passive detector packages (80x40x25 mm) are located at sides of organs of interest inside the phantom (brain, lung kidney, stomach, intestine) and one is located at top of the phantom head. They are built up from plastic nuclear track detectors (PNTD) like CR39, polycarbonate and cellulose nitrate and personal dosimeter packages. The latter ones consists of CR-39 detectors combined with three converter foils and of Makrofol detectors each welded in a radon-tight aluminum/polyethylene pouch and packed inside an albedo dosimeter capsule consisting of boron loaded polyurethane. In front of the phantom body a tissue equivalent proportional counter (TEPC) is mounted which uses a cylindrical low pressure ionization chamber surrounded by 1.9 mm tissue equivalent A-100 plastic material. On top of the phantom head a dosimetry telescope (DOSTEL) sensor is mounted using three silicon detectors in a telescope arrangement. Inside the phantom five silicon/scintillator detectors (SSDs) sensors (36x26x25 mm) are located at sites of the brain, lung, kidney, stomach and intestine. Each detector consists of a plastic scintillator cube surrounded by six silicon detectors acting as anticoincidence detectors. The electronics for the two latter instruments are located in the base structure in the electronics module, which also houses the High-LET Radiation spectrometer (HiLRS). The HiLRS is composed of solid state microelectronics that measure the energy deposited (in terms of pulse-height spectra) when energetic charged particles traverse p-n junctions having dimensions comparable to biological cells.

Following investigators and labs are involved in the investigations: : Dr. Bill Atwell, Boeing, Houston, USA; Dr. G. Badhwar, NASA, Johnson Spaceflight Center, Houston, USA; Dr. M. Luszik-Bhadra, PTB, Braunschweig, Germany; Dr. R. Beaujean, University Kiel, Germany; Dr. S. Deme, KFKI Atomic Energy, Research Institute, Budapest; Prof. W. Heinrich, Universität GH Siegen, Germany; Dr. J. Miller, LBL, Berkeley, California, USA; Dr. P. Olko, Institute of Nuclear Physics, Krakow, Poland; Dr. Petrov, IBMP, Moscow, Russia; Dr. E.G. Stassinopoulos, NASA, Goddard Space Flight Center, USA.

A Conceptual Framework for Utilization of Space Radiation Measurements

Walter Schimmerling and Francis A. Cucinotta

NASA HQ and NASA Houston

Abstract

The information obtained from multiple measurements of space radiation is essential for a proper assessment of dose and implementation of ALARA. The variety of instruments optimized for different energy regions and radiation qualities ensures that the space radiation field is fully characterized for radiation protection. Multiple measurements provide field data by sampling the radiation field at different points so that radiation monitoring data can be properly interpreted. However, proper utilization of the data requires resolution of a number of important questions. Among these are: how to decide between conflicting measurements? How to compare different results? How to communicate and share the data? What is a "dosimeter"? What data to use for radiation records? How much radiation monitoring is "enough"? This contribution develops a framework around the concept of a reference dosimeter, whose output is used to determine crew radiation exposures for archival risk assessment, according to a certification protocol. Likely requirements for achieving such a framework are discussed, including the role of experiments not designed for reference dosimetry, specification of "housekeeping" information related to the proper interpretation of measurements, and use of data resulting from experiments.

Recent Results of Passive Monitoring on the International Space Station

Edward Semones, Steve Johnson, Mark Weyland and Mike Golightly

Space Radiation Analysis Group, Johnson Space Center, Houston, Texas 77058, USA

The radiation exposure on board the International Space Station (ISS) has been measured since May 1999 with thermoluminescent dosemeters (TLDs), utilizing TLD-100, TLD-300, TLD-600, and TLD-700. We will discuss measurements taken at three locations in the US built Node 1 and six locations in the Russian built Service Module, and five locations in the US Lab. The ISS area measurements also overlapped with three ISS crew personal dosemeter measurements and provide an estimate of crew absorbed dose. The results show dose rates ranging from 0.14 $mGy{\bullet}d^{-1}$ to 0.30 $mGy{\bullet}d^{-1}$ in the Node 1 and 0.12 $mGy{\bullet}d^{-1}$ to 0.21 $mGy{\bullet}d^{-1}$ in the Service Module. The US Lab results Comparisons with ISS active detector results from the Russian R16 and US TEPC will also be presented.

Active Radiation Monitoring on the International Space Station

Tad Shelfer, Steve Johnson, Mark Weyland and Mike Golightly

Space Radiation Analysis Group, Johnson Space Center, Houston, Texas 77058, USA

Abstract

The radiation environment in and around the International Space Station (ISS) will be measured using a set of three active radiation monitoring instruments: the ISS Tissue Equivalent Proportional Counter (TEPC), the Intra-Vehicular Charged Particle Directional Spectrometer (IV-CPDS), and the Extra-Vehicular Charged Particle Directional Spectrometer (EV-CPDS). The ISS TEPC was activated in November, 2000 and the IV-CPDS was activated in April, 2000. EV-CPDS is currently planned to launch with the S0 Truss segment in February, 2002. Measurements made by the ISS TEPC and the IV-CPDS instruments to date will be discussed. In addition, the difficulties involved with real-time hardware operations within the world of the manned space flight construct will be discussed.

InterComparison of Cosmic-rays with Heavy Ion Beams At NIRS

Yukio Uchihori

International Space Radiation Laboratory, National Institute of Radiological Sciences, Chiba, Japan

Abstract

Ground-based intercomparison of active and passive radiation measurement and dosimetry instruments has been identified at previous WRMISS meetings as an important component in international efforts to carry out crew dosimetry aboard the International Space Station. In keeping with this finding, we have initiated the InterComparison of Cosmic-rays with Heavy Ion Beams At NIRS (ICCHIBAN) program utilizing the HIMAC heavy ion accelerator at the National Institute of Radiological Sciences, Japan. The objectives of the ICCHIBAN program are: 1) To establish and characterize a heavy ion "reference standard" against which space radiation instruments can be calibrated, 2) to determine the response of space radiation dosimeters to heavy ions of charge and energy similar to that found in the galactic cosmic radiation (GCR) spectrum, and 3) to aid in reconciling differences in measurements made by various radiation instruments during space flight. A preliminary set of exposure conditions and test criteria have been established and will be assessed using a limited number of both active and passive detectors during the first set of exposures, scheduled for early 2002.

A Solid-State Detector System for Ground-based Intercomparisons

C. Zeitlin

Lawrence Berkeley National Laboratory

A detector system optimized for heavy ions has been successfully operated with a variety of GCR-like beams and energies for shielding and nuclear fragmentation experiments. The same detectors and electronics will be used in the upcoming ICCHIBAN run at HIMAC, in which several spaceflight dosimeters will be tested. The system and its performance will be described in detail.