# 7th Workshop on Radiation Monitoring for the International Space Station

## 2-4 September 2002, UIC, Paris, France

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| **Chairman** | **Guenther Reitz, DLR** |
| **Co-Chairman** | **Jean-Francois Bottollier-Depois** |

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

### Preliminary Program

**Monday 2nd Sept**

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| 9.00 - 10.30 | Scientific Session |
| 10.30 - 11.00 | Coffee Break |
| 11.00 - 12.30 | Scientific Session |
| 12.30 - 14.00 | Lunch |
| 14.00 - 15.30 | Scientific Session |
| 15.30 - 16.00 | Coffee/Tea Break |
| 16.00 - 17.30 | Scientific Session |

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| Welcome and Scientific Program/ Organisational Matters<br><br>Protocol Review of last meeting | G.Reitz/<br>J.F.Bottollier-<br>Depois |

**Inflight Measurements**

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|---|---|
| Results from Dose Measurements on Board the International Space Station ISS and from the 2nd ICCHIBAN Irradiation Campaign at NIRS in May 2002, Part 1: Measurements | T. Berger |
| Evaluation of SSNTD stacks exposed onboard of ISS | J. Palfalvi |
| The Determination of the Neutron Component of the Cosmic Radiation Field in Spacecraft using a PADC Neutron Personal Dosemeter | D. Bartlett |
| The DOSMAP experiment on ISS Expedition 2 | G. Reitz |
| Results from the ISS Passive dosimetry System During the Expedition 2 DOSMAP experiment | E. Benton |
| DOSTEL Dosimetry Data as a Part of DOSMAP | R. Beaujean |
| Dose equivalent, Absorbed Dose and Charge Spectrum Investigation in Low Earth Orbit | D. O'Sullivan |
| Radiation Environment Onboard of the Russian Segment of the ISS Measured by the Radiation Monitoring System | V. V. Benghin |
| Nuclear Abundances and Radiation Environment Measurements insideMIR and ISS with Sileye-2 and Sileye-3 experiments | M. Casolino |
| The Martian Radiation Environment Experiment MARIE | C. Zeitlin |
| Round Table discussion | all |

Note: Presentation time shall not exceed 30 minutes

## Tuesday 3rd Sept

| | |
|---|---|
| 9.00 - 10.30 | Scientific Session |
| 10.30 - 11.00 | Coffee Break |
| 11.00 - 12.30 | Scientific Session |
| 12.30 - 14.00 | Lunch |
| 14.00 - 15.30 | Scientific Session |
| 15.30 - 16.00 | Coffee/Tea Break |
| 16.00 - 17.30 | Scientific Session |

### Session Models

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| Silicon Telescope LET Spectrometers – possibilities and Limitations | T. Pazmandi |
| Progress on an Integrated Monte-Carlo Transport Code to Simulate the Space Radiation Environment based on Fluka | L. Pinsky |
| The ESA Space Environment Information System (SPENVIS) | D. Heynderickx |
| Round table Discussion | all |

### Calibration of Instruments

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|---|---|
| Preliminary Results from the First two ICCHIBAN Intercomparisons of Space Radiation Detectors | Y. Uchihori |
| Beam Characterization Measurements for ICCHIBAN | J. Miller |
| Results from Dose Measurements on Board the International Space Station ISS and from the 2nd ICCHIBAN Irradiation Campaign at NIRS in May 2002 Part 2: Calibration | T. Berger |
| Results from the 2nd ICCHIBAN run using different types of TLD's | G. Reitz |
| Preliminary Results from 2nd ICCHIBAN (InterComparision for Cosmic-ray with Heavy-Ion Beams At NIRS) | E. Semones |
| The Potential of Using Optically Stimulated Luminescence from $Al_2o_3$:C Dosimeters for Space Radiation Dosimetry: Behavior to HCP Irradiations | S. McKeever |
| The Response of the a PADC Neutron Personal Dosemeter to HZE | L. Hager |
| Development of a Passive Dosimeter for Life Science Experiments in Space (PADLES) in NASDA | A. Nagamatsu |
| Preliminary Results of ISS Active Radiation Instruments from 1st ICCHIBAN (Intercomparison for Cosmic-Ray with Heavy-Ion Beams at NIRS) | T. Shelfer |

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| Post Flight Calibration of DOSTEL with Heavy Ions During the First ICCHIBAN Run at HIMAC, Chiba | S. Burmeister |
| Measurement of LET-Distributions for Protons from the Loma Linda Synchroton by RRMD-III and Spherical TEPC | T. Doke |
| Lighting Fires – Full interplanetary Radiation Environment Simulation | W. Schimmerling |
| Round Table Discussion | All |

Note: Presentation time shall not exceed 30 minutes

**Wednesday 4th Sept**

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

**New Instrument Development/Operations/Data Base**

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|---|---|
| Status of the ESA Facility MATROSHKA | G. Reitz |
| ISS Radiation Operational Support | M. Weyland |
| U.S. ISS Radiation Instrument Data Processing and Archiving – Status Report | M. Golightly |
| Round table discussion | All |
| **Recommendations/Conclusions** | All |

# ABSTRACTS

## Results from Dose Measurements on Board the International Space Station ISS and from the 2nd Icchiban Irradiation Campaign at Nirs in Mai 2002

Thomas Berger, Michael Hajek, Leopold Summerer, Norbert Vana,
Atominstitute of the Austrian Universities, Stadionallee 2, 1020 Vienna

In this presentation the focus will be laid on the last results from dose measurements on board the International Space Station ISS and on the first results from the intercomparison measurement campaign ICCHIBAN at the Heavy Ion Medical Accelerator Facility (HIMAC) in Chiba, Japan. In the framework of the joint Russian – Austrian project RBO – 2 seven dosemeter packages were exposed from February to November 2001 at 6 different positions onboard the Russian segment of the ISS. The overall exposure time was 248 days. The Austrian dosemeter packages consisted of 5 different types of TLD´s (LiF and $CaF_2$ with different dopands). The results from the ISS will be compared to previous measurements on Space Station MIR ( project PHANTOM). Due to the upcoming project MATROSHKA a short overview about the depth dose dependence in a Phantom (results of the Project PHANTOM) will be given. The second part of the talk will be devoted to the first results from the 2nd ICCHIBAN intercomparison measurements performed at the end of May 2002 at NIRS. For these exposures TLD of the types TLD – 600, TLD – 700 and TLD – 300 as well as CR – 39 track etch detectors were used. Data about the efficiency in dependence on the LET, as well as a first interpretation of the BLIND exposures based on the TLD and CR – 39 data will be presented.

## Evaluation of SSNTD stacks exposed onboard of ISS

J.K. Pálfalvi[1] ,Yu. Akatov[2], J. Szabó[1], L. Sajó-Bohus[3], and I. Eördögh[4]

[1]KFKI-Atomic Energy Res. Institute, POB-49, H-1525 Budapest
[2]Res. Centre for Spacecraft Rad. Safety, Moscow 123182, Russia
[3]University Simon Bolivar, 89000 Caracas, Venezuela
[4]Res. Inst. for Technical Physics and Material Sci. POB-49, H-1525 Budapest

SSNTDs stacks were developed consisting of 3 CR-39 sheets. The 1st and 2nd sheets were separated by Ti foil, the 2nd and 3rd ones sandwiched a Lexan. The stack was wrapped in Al and sealed in a polyethylene bag. The neutron responses on 8 surfaces were studied by MC codes. The proton response was determined by monoenergetic protons. The background on each surface was measured before assembling the stacks, utilizing the pre-etching technique.

6 stacks were delivered to the ISS by the Progress 244 spacecraft on 26th Feb. 2001 and placed in the Russian segment Zvezda. They got back to the Earth on the Sayouz TM-32 on 31st Oct. 2001. Another 15 stacks were exposed at the CERF high energy calibration fields. The detectors were evaluated by the VIRGINIA image analyzer. The dose was obtained by statistical analysis. The investigation of the individual tracks is in progress.

Corresponding author: J.K. Pálfalvi
KFKI-Atomic Energy Research Institute
POB-49, H-1525 Budapest 114, Hungary
Phone: (+361) 392 2222 ext. 1495
Fax: (+361) 395 9162
E-mail: palfalvi@sunserv.kfki.hu

## The Determination of the Neutron Component of the Cosmic Radiation Field in Spacecraft using a PADC Neutron Personal Dosemeter

D T Bartlett , L G Hager and R J Tanner

National Radiological Protection Board, Chilton, Oxon OX11 0RQ, UK

Poly allyl diglycol carbonate (PADC or CR-39®) etched track detectors may be used to estimate the neutron component of the cosmic radiation in spacecraft using simple techniques developed for neutron personal dosimetry. Electrochemically etched pits are identified and counted using fully automated read-out procedures. The neutron and HZE particle components of the radiation field at the location of the dosemeter will produce electrochemically etchable tracks, depending on particle type, energy and angle of incidence. The neutron response of the dosemeter is corrected for the different response to the calculated field in the spacecraft relative to that for a CERF calibration. The response to HZE particles, which produce tracks and are counted as if produced by a neutron, will lead to an over-estimate of the neutron component. A correction can be applied to take account of this or an additional chemical etch carried out which allows discrimination. Recent results for exposures on STS are reported.

## The DOSMAP Experiment on ISS Expedition 2

G. Reitz[1], R. Beaujean[2], E. Benton[3], S. Deme[4], W. Heinrich[5], M. Luszik-Bhadra[6], P. Olko[7] and M. Scherkenbach[8]

[1] DLR, Institut für Luft- und Raumfahrtmedizin, D-51140 Köln
[2] Universität Kiel, Experimentelle und Angewandte Physik, Extraterrestrik, D-24118 Kiel
[3] Eril Research Inc., San Rafael, CA, USA
[4] KFKI Atomic Energy Research Institute, Budapest, Hungary
[5] Universität GH Siegen, Naturwissenschaft I – Physik, D-57076 Siegen
[6] Physikalisch-Technische Bundesanstalt, D-38116 Braunschweig
[7] Institut of Nuclear Physics, Krakow, Poland
[8]M. Scherkenbach, RWTH Aachen, Lehrstuhl für Flugmedizin, D-52057 Aachen

The experiment Dosimetric Mapping flown as part of the science program of NASA's Human Research Facility (HRF) was designed to measure at different locations inside the U.S. Lab integrated total absorbed doses (ionising radiation and neutrons) and heavy ion fluences and its energy, mass and linear transfer (LET) spectra ; time dependant fluence rates of charged particles and their corresponding dose rate

The experiment consists of five nuclear track detector packages (NTDPs) thermoluminescence dosimeters (TLD) and plastic nuclear track detectors), two DOSimetry TELescopes (DOSTEL) using two passive implanted planar silicon detectors per instrument, four Mobile Dosimetry Units (MDUs) with one passive implanted planar silicon detector per unit with an Control and Interface Unit (CIU) and an onboard TLD system consisting of a small weight TLD Reader and twelve TLD-bulbs, which have been reused after each measurement (Fig. 1). In addition, each TLD bulb holder carried three small orthogonal oriented passive nuclear track detector (NTDP) packages. Detectors are spread over the whole US-Lab.

The presentation will give an overview of the results and some comparison of the different systems. Detailed information the Passive Dosimetry System (PDS) and on the DOSTEL ,measurements will then be given in the two following presentations.

**RESULTS FROM THE ISS PASSIVE DOSIMETRY SYSTEM DURING THE EXPEDITION 2 DOSMAP EXPERIMENT**

E. R. Benton, E. V. Benton and A. L. Frank, Eril Research, Inc.
S. Deme and I. Apathy, KFKI Atomic Energy Research Institute
G. Reitz, DLR

Flight verification testing of the ISS Passive Dosimetry System (PDS), jointly developed by Eril Research, Inc., the KFKI Atomic Energy Research Institute, and the NASA Ames Research Center, was carried out as part of the DOSMAP experiment on ISS Expedition 2. A total of twelve PDS dosimeters were deployed throughout the ISS—five in the Unity Node 1 module and seven in the Destiny US Lab module—for a period of 100 days between 3 May 2001 and 9 August 2001. The PDS utilizes the Pille portable TLD system to measure absorbed dose on-orbit and CR-39 plastic nuclear track detectors (PNTD), arranged in three mutually orthogonal directions, to measure the LET spectrum from charged particles of $LET_{\infty}H_2O \geq 5$ keV/μm. Results from the Pille TLDs and CR-39 PNTDs are combined to yield mean total dose rate, mean total dose equivalent rate, and average quality factor.

During the DOSMAP experiment, mean total dose rate measured in the PDS dosimeters ranged from 145.2 ± 8.2 μGy/d in the US Lab, above the aft hatch leading to Node 1, to 208.3 ± 8.2 μGy/d above the aft hatch of Node 1. Mean total dose equivalent rate varied from 322.1 ± 19.8 μSv/hr to 417.6 ± 19.0 μSv/hr at these same respective locations. The average quality factor varied from 2.01 ± 0.11 above the aft hatch of Node 1 to 2.38 ± 0.13 on the port side of the US Lab near the aft hatch. The CR-39 plastic nuclear track detector component of the PDS received an additional 26 days (20% of the total on-orbit time) of exposure while stored together in the PDS Supply/Return kit. This added and unforeseen exposure compromised the quality of the data from the CR-39 PNTDs, severely complicating the interpretation of the results and impacting the overall quality of the results. Complete readout of the twelve sets CR-39 PNTDs and Pille TLD dosimeters, and analysis of the LET spectra, mean total dose rates and dose equivalent rates, and average quality factors was completed within 90 days of the receipt of the exposed detectors. LET spectrum measurements made by CR-39 PNTDs are in good agreement with the results from the DOSTEL Si telescope in the LET region in which both instruments are sensitive.

# DOSTEL Dosimetry Data as a part of DOSMAP

**R. Beaujean** [1] , S. Burmeister [1] , F. Petersen [1] , G. Reitz [2]

[1] Universität Kiel/IEAP, 24098 Kiel, Germany [2] DLR Köln/Flugmedizin, 51147 Köln, Germany

Two DOSimetry TELescopes (DOSTELs) were part of the DOSMAP experiment on the International Space Station (ISS) during March 26 th and July 20 th 2001. The two identical thickness of 315 µm each. The distance between the two detectors of about 15 mm yields an opening angle of 120° for the LET spectra where only coincident events are stored. The dose and count rate were measured in both detectors separately without the coincidence requirement. The measured count and dose rates as well as the LET spectra were stored in the internal memory for 5-10 days until the next download. The instruments are able to separate GCR and SAA spectra online by a count rate threshold. Spectra for the northern and the southern magnetic hemisphere were stored separately.

A comparison of pre- and post flight calibration shows no observable differences. The mean dose rate for the given period was 523 µSv/d, the mean quality factor was 2.9. Methods to separate the GCR dose contribution from the contribution of the SAA are presented. Temporal variations (e.g. induced by solar activity) of these values are discussed.

# DOSE EQUIVALENT, ABSORBED DOSE AND CHARGE SPECTRUM INVESTIGATION IN LOW EARTH ORBIT

D. O'Sullivan (1), D. Zhou (1), E. Semones (2), E. Flood (1)
(1) Dublin Institute for Advanced Studies, Astrophysics Section, 5 Merrion Square, Dublin 2, Ireland
(2) Johnson Space Center, Mailcode 23, 2101 Nasa Rd 1, Houston, Texas 77058, USA

Particle intensity, dose equivalent and absorbed dose have been measured on board the space shuttle Endeavour during STS-108 in Dec. 2001. The dose estimates are based on very accurate measurements of recoils produced in CR-39 by cosmic ray primary and secondary protons and heavier nuclei and by secondary neutrons. The corresponding LET spectra were used to determine dose equivalent and absorbed dose values for the mission. Some comparisons are made with preliminary data obtained on STS-98 and other missions using CR-39 detectors and with TEPC measurements on STS-108. Estimates of the total flux of $Z\geq2$ nuclei have been undertaken and a preliminary charge spectrum was measured. The data is compared with predictions of the Siegen group for a MIR mission of similar inclination.

## Radiation environment onboard of the Russian segment of the ISS measured by the radiation monitoring system.

**V**.M. Petrov [1)], V.V. Benghin [1)], V.A. Shurshakov [1)], I.V. Chernykh [1)], A.V. Markov [2)], V.I. Lyagushin [2)], A.N. Volkov [2)], A.P. Aleksandrin, [2)] Yu.L. Germantsev [2)], M.I. Panasyuk [3)], G.Ya. Kolesov [3)], M.V. Tel'tsov [3)], Yu.V. Kutuzov [3)], O.V. Morozov [3)].

[1)] Scientific Research Centre of the RF – Institute for Biomedical Problems, Russian Academy of Sciences.

[2)] Rocket-space corporation "Energiya".

[3)] Skobeltsyn Institute of Nuclear Physics of Moscow State University.

Radiation monitoring system (RMS) has worked on board of the International Space Station (ISS) practically continuously since August, 2001. At the current phase RMS consists of 7 units:

- The R-16 device with 2 ionization chambers filled with argon;
- Four DB-8 sets of dosimeters with semiconductor radiation detectors;
- Utility Unit (UU) and Data Collection Unit (DCU) made for processing and analysis of the data obtained

The dose rate data since August, 2001 till July, 2002 are presented. There are compared the dose rate data measured by the radiation monitoring system detectors installed in different points of Service module of the ISS. A range of the average dose rates was from 135 till 245 microGray/day.

The dose rate data during solar proton events September 24 and November 4, 2001 are considered separately. The dose rate data during solar proton events September 24 and November 4, 2001 are considered separately. 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.

## Nuclear abundances and radiation environment measurements inside Mir and ISS with Sileye-2 and Sileye-3 experiments

V. Bidoli[1], M. Casolino[1], M. P. De Pascale[1], G. Furano[1], A. Morselli[1], L. Narici[1], P. Picozza[1], E. Reali[1], R. Sparvoli[1], A. Galper[2], A Khodarovic[2], M. Korotkov[2], A. Popov[2], N. Vavilov[2], G. Mazzenga[3], M. Ricci[3], G. Castellini[4], S. Avdeev[5], M. Boezio[6], W. Bonvicini[6], A. Vacchi[6], N. Zampa[6], P. Papini[7], P. Spillantini[7], P. Carlson[8], C. Fuglesang[9]

[1] INFN Roma2 and University of Roma Tor Vergata; [2] Moscow Engineering and Physics institute, Moscow, Russia; [3] LNF, INFN, Frascati, Italy; [4] IROE of CNR, Florence, Italy; [5] Russian Space Corporation 'Energia', Korolev, Moscow Region, Russia; [6] INFN and University of Trieste; [7] INFN and University of Florence; [8] Royal Institute of Technology, Stockholm, Sweden; [9] European Astronaut Centre, ESA, Cologne, Germany

In this work we present measurements of cosmic ray nuclear abundances above ≅150 MeV/n performed inside Mir and the International Space Station. Mir data have been obtained with SilEye-2 detector, a 6 plane silicon strip detector telescope designed to measure environmental radiation and investigate on the Light Flash phenomenon. In standalone mode, SilEye-2 is capable to measure LET distribution spectra and identify nuclear species with energy above 100 MeV/n: a total of 100 sessions comprising more than 1000 hours of observation were perfomed in the years 1998-2000, recording also several Solar Energetic Particle (SEP) events. We report on LET measurements and relative abundances from Boron to Iron measured in different regions and at different geomagnetic cutoffs, in solar quiet conditions and during SEP events, showing how the composition varies in these different situations.

ISS data have been taken in 2002 with Sileye-3/Alteino device during the Soyuz-34 flight of Roberto Vittori. The cosmic ray telescope is similar to Sileye-2 but with 8 planes each of 32 strips. Plans for long term operation of the device are currently under way.

# The Martian Radiation Environment Experiment MARIE

C. Zeitlin

Lawrence Berkeley National Laboratory and National Space Biomedical Research Institute

Detailed measurements of the Martian Radiation Environment are necessary as a precursor to human exploration of Mars. The MARIE, which consists primarily of a stack of silicon detectors, was launched aboard the 2001 Mars Odyssey spacecraft in April 2001. A small data set was acquired during the cruise phase. Odyssey arrived at Mars in October 2001. After a highly successful aerobraking program placed the spacecraft into polar orbit 400 km above the surface, Odyssey's science instruments, including MARIE, began returning data from Mars in March 2002. In addition to detecting high-energy GCR particles, MARIE has also seen several solar particle events. As the Sun-Earth-Mars angle varies over time, MARIE does not necessarily see the same events, or the same aspects of particular events, as are seen by near-Earth detectors such as GOES-8. In addition to the interest generated by the novelty of having an observation point at Mars, the MARIE data are also of interest because the instrument is very similar to the IVCPDS and EVCPDS telescopes now flying on ISS. Techniques for analysis and modeling of MARIE data can readily be adapted for use with the ISS instruments.

## Silicon telescope LET spectrometers - Possibilities and limitations

Tamás PÁZMÁNDI, Sándor DEME

*KFKI Atomic Energy Research Institute (KFKI AEKI), 1525 Budapest, P. O. B. 49, Hungary*
*Phone: +36 1 3922222 / 1361 Fax:+36 1 395 92 93 E-mail: pazmandi@sunserv.kfki.hu*

In space dosimetry LET spectrum is used not only for the determination of the radiation weighting factor and for the evaluation of the equivalent dose, but for the efficiency corrections of the TL measurements as well. Proportional counters and silicon detector telescopes are widely used for the measurement of the LET spectra; the possibilities and limitations of silicon detector telescopes are analysed in this paper.

The main advantages of the silicon detector telescopes are their long-term stability and low signal to noise ratio (i.e. suitability for measuring relativistic particles). However, silicon detectors measure the absorbed energy in the crystal instead of the LET spectra. The absorbed energy depends on the angle of incidence (i.e. the path-length) and the LET values of the particles are changing inside the crystal due to the change of their energy, therefore a complicated spectrum evaluation procedure must be used. It should be taken into account that some particles stop inside the silicon crystal.

A mathematical method for calculating the energy deposition spectrum and our first results are presented in this paper. The response function for isotropic and directional fluxes, the geometric factor and the efficiency for various cases are analyzed. The results of the Monte Carlo calculations are presented as well.

The development of an advanced dosimetry telescope is planned by the DLR (G. Reitz) and the Kiel University (R. Beaujean) in co-operation with the KFKI AEKI, using the method described above.

# Progress on an Integrated Monte-Carlo Transport Code to Simulate the Space Radiation Environment based on FLUKA

V. Andersen, A. Empl, K. Lee, L. Pinsky, and N. Zapp
Physics Department, University of Houston, Houston, Texas

T. L. Wilson
NASA, JSC, Houston, Texas

F. Carminati, E. Futo, I. Gonzalez-Caballero
CERN, Geneva, Switzerland

A. Ferrari, P. Sala
INFN Milan, Italy, and CERN Geneva, Switzerland

A NASA-funded project, FLEUR-S (FLuka Executing Under Root-Space) has been underway for slightly over two years now to develop an integrated Monte-Carlo package based on the FLUKA transport code for use in simulating the Space Radiation Environment. Considerable progress has been made on the primary task of incorporating the capability for simulating nucleus-nucleus inelastic interactions internally within FLUKA. We have succeeded in integrating a version of the DPMJET event generator code into FLUKA to simulate interactions above 3 GeV/A, and that code is now publicly available. We are in the process of providing an interim event generator for use from 3 GeV/A down to the threshold for inelastic interactions based on a version of the QMD event generator. (Note that currently all single stable particle-nucleus interactions are already included across the complete range of energies). We expect to be able to release a version of FLUKA with the capability to simulate the full range of nucleus transport as early as the end of the current calendar year. Other improvements to code have been made as well including the development of a routine to translate geometry descriptions from a GEANT 3.21 format into the required FLUKA input format. Steps have also been taken to transform existing FLUKA data evaluation tools into the ROOT-based infrastructure, and to provide an interim ROOT-based input file creator. Finally, in order to evaluate the performance of this code, we have undertaken a simulation of the ATIC balloon-borne cosmic ray experiment in order to compare our simulated results with their flight data. We have also begun to model the MARIE experiment on the Mars Odyssey spacecraft. That instrument is similar in nature to the EVCPDS and IVCPDS instruments on the ISS. Knowledge gained from that exercise along with the improvements mentioned, should facilitate application of FLEUR-S to a number of aspects of the analysis of the data expected from these ISS measurements.

# THE ESA SPACE ENVIRONMENT INFORMATION SYSTEM (SPENVIS)

D. Heynderickx, B. Quaghebeur, M. Kruglanski

Belgisch Instituut voor Ruimte-Aëronomie, Ringlaan 3, B-1180 Brussel, Belgium
*(D.Heynderickx; B.Quaghebeur; M.Kruglanski)@oma.be*

E.J. Daly, H.D.R. Evans

ESA/ESTEC, Keplerlaan 1, NL-2200 AG Noordwijk, The Netherlands
*(Eamonn.Daly; Hugh.Evans)@esa.int*

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 Is designed to help spacecraft engineers perform rapid analyses of environmental problems and, with extensive documentation and tutorial information, allows engineers with relatively little familiarity with the models to produce reliable results. It has been developed in response to the increasing pressure for rapid-response tools for system engineering, especially in low-cost commercial and educational programmes. It is very useful in conjunction with radiation effects and electrostatic charging testing in the context of hardness assurance. SPENVIS is based on internationally recognized 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 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 implemented by means of the UNILIB library for magnetic coordinate evaluation, magnetic field line tracing and drift shell tracing. The UNILIB library can be downloaded at http://www.magnet.oma.be/unilib/ in the form of a Fortran object library for different platforms.

The following upgrades are now being implemented:

- interfacing to remote applications, including parameter input, file uploading and results downloading. An interface to MULASSIS (Multi-Layered Shielding Simulation Software), a Geant4 toolkit for particle transport in user-defined geometries, is now in the testing phase.

- A geometric tool to calculate shielding distributions for simple spacecraft geometries is already available. A tool to fold the shielding distribution with ionizing and non-ionizing dose curves is under development
- Damage equivalent fluence models for multi junction solar cells.
- Implementation of multi-segment spacecraft orbits to take into account the evolution of orbit parameters or changes in the orbit specification.
- Upgrades of the internal and external charging codes.
- Upgrades of the neutral atmosphere and ionosphere models.
- JavaScript and C script extensions to simulate “dynamic” pages.
- A new page layout with improved navigation functions.
- Links to the ECSS standards on spacecraft charging and radiation effects, which are under development

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# Preliminary Results from the first two ICCHIBAN Intercomparisons of Space Radiation Detectors

Y. Uchihori

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

The first two sets of controlled exposures of space radiation detectors to heavy ions at the HIMAC were successfully carried out as part of the ICCHIBAN (Intercomparison for Cosmic Rays with Heavy Ion Beams At NIRS) Project. The first ICCHIBAN run, dedicated to the intercomparison of active detectors, was conducted in February 2002. Detectors from eight different institutions, including two NASA JSC TEPCs, the NASA JSC CPDS, the DLR DOSTEL Si telescope, the NASDA RRMD-III Si telescope, and the Liulin Mobile Dosimetry Unit were exposed to beams of 400 MeV/n Carbon and 400 MeV/n Iron. Reference measurements of the HIMAC beam were made using the LBNL Ground Base Detector. The second ICCHIBAN Run, dedicated to passive detectors, was carried out in May 2002 and included TLDs and PNTDs from ten different laboratories in Europe, Russia, the USA and Japan. Passive detectors were exposed to 150 MeV/n Helium, 400 MeV/n Carbon, 490 MeV/n Silicon, and 500 MeV/n Iron. Preparations are currently underway for the 3$^{rd}$ and 4$^{th}$ ICCHIBAN runs tentatively scheduled for February and May 2003.

# Beam Characterization Measurements for ICCHIBAN

J. Miller[1], C. Zeitlin[1], L. Heilbronn[1], Y.Uchihori[2], N.Yasuda[2], E. R. Benton[3]

[1]Lawrence Berkeley National Laboratory, Berkeley, California, USA
[2]National Institute of Radiological Sciences, Chiba, Japan
[3]ERIL Research, Inc., USA

An important element of the ICCHIBAN project for intercomparison of radiation detectors used in space is the characterization of the incident heavy ion beams by primary beam and fragment charge and energy. In the first ICCHIBAN run, for active detectors, this was done using solid state detectors provided by Lawrence Berkeley National Laboratory (LBNL) and the National Institute of Radiological Sciences (NIRS). ICCHIBAN and the NIRS measurements are described elsewhere in this Workshop. Here we will briefly discuss the methods and some results of the LBNL characterization measurements.

## Results from the 2nd ICCHIBAN run using different types of TLD's

G. Reitz[1], P. Olko[2], P. Bilski[2]

[1] DLR, Institut für Luft- und Raumfahrtmedizin, D-51140 Köln

[2] Institut of Nuclear Physics, Krakow, Poland

Several types of TLD's were exposed during the 2nd ICCHIBAN run to He, C, Si and Fe ions at different doses. The TLD dose dependence and the TLD efficiency will be shown as preliminary result of this calibration.

# Preliminary Results from 2nd ICCHIBAN (InterComparision for Cosmic-ray with Heavy-Ion Beams At NIRS)

E. Semones[1], T. Shelfer[1], M. Weyland[1], N. Zapp[1], and M.J. Golightly[2],

1.Lockheed-Martin Space Operations, C23, 2400 NASA Rd 1, Houston, TX77058 USA
+01-(281) 244-5107 esemones@ems.jsc.nasa.gov

2.NASA Johnson Space Center, SF2, Houston, TX 77058 USA

The Space Radiation Analysis Group (SRAG) at the NASA - Johnson Space Center (JSC) participated in the 1st and 2nd InterComparisions for Cosmic-ray with Heavy-Ion Beams At NIRS (ICCHIBAN). During the 1st ICCHIBAN, the active instruments used for US monitoring on the ISS and Shuttle were exposed. The 2nd ICCHIBAN provided for the exposure of passive detectors. The current US passive detectors used on ISS, including previously flown detectors, were exposed during this intercomparison. The detectors were exposed to known fluences of He, C, Si, Fe, and fragment beams to study linearity and LET response. Blind exposures to unknown particle types/fluences were also conducted. Preliminary results from these measurements will be presented.

**THE POTENTIAL OF USING OPTICALLY STIMULATED LUMINESCENCE FROM $Al_2O_3$:C DOSIMETERS FOR SPACE RADIATION DOSIMETRY: BEHAVIOR TO HCP IRRADIATIONS**

Ramona Gaza, Eduardo Yukihara and Stephen McKeever,

Department of Physics, Oklahoma State University, Stillwater,
OK 74078-3072, USA

As part of the recent ICCHIBAN intercomparison of the performance of passive dosimeters in HCP fields, for potential use in space radiation dosimetry, we studied the OSL and TL properties of $Al_2O_3$:C luminescence dosimeters. Two types of $Al_2O_3$ sample were used: single crystal chips (of type TLD-500), and Landauer Luxel™ detectors. Thermoluminescence (TL) and two modes of optically stimulated luminescence (OSL) measurement were carried out. The two OSL modes were CW-OSL, in which the stimulation source is continuous and of fixed intensity, and Pulsed OSL (POSL) in which the stimulation source is pulsed at high power. The differences between these two measurement modes will be explained. In addition, the results obtained for $Al_2O_3$ were compared with TL results from LiF:Mg,Ti (TLD-100). Significant differences were found in the efficiency to HCPs for the two materials and for the different measurement modes. The results are discussed in terms of the gamma dose response and the ionization density surrounding the HCP track. Recommendations regarding space applications are made.

## The Response of the a PADC Neutron Personal Dosemeter to HZE

L G Hager, D T Bartlett and R J Tanner

National Radiological Protection Board, Chilton, Oxon OX11 0RQ, UK

The NRPB neutron personal dosemeter detects charged particles produced by interactions of neutrons in the PADC detector and nylon holder. Tracks of protons of energies less than about 2 MeV (LET in water of about 20 keV $\mu m^{-1}$) and recoil nitrogen, carbon and oxygen are developed by an electrochemical etching process. This gives a number of observed pits which is acceptably linearly proportional to neutron personal dose equivalent over a wide range of neutron energies. The combination of dosemeter, process and read procedures also gives a response to HZE. The results are reported for the ICCHIBAN2 irradiations and also previous irradiations at HIMAC and BNL for both electrochemical and chemical etching. The electrochemical response to HZE depends on particle type and energy, with a strong dependence on angle of incidence, giving a low response in an isotropic field. For normal incidence, the electrochemical etch response to 500 MeV/n $^{56}Fe$ was 90%, about 50% for 490 MeV/n $^{28}Si$, and zero for 400 MeV/n $^{12}C$.

# Development of a Passive Dosimeter for Life Science Experiments in Space (PADLES) in NASDA

Aiko Nagamatsu,[1] Shigeki Kamigaichi, [1] Mitsuyo Maskawa,[1] Hiroko Tawara,[1,2] Takayoshi Hayashi,[3] Hidenori Kumagai,[4] Michiko Masaki,[4] Takayoshi Hayashi,[5] Hiroshi Yasuda,[6] and Nakahiro Yasuda[6]

1.Space Utilization Research Center, NASDA, 2-1-1 Sengen, Tsukuba, Ibaraki, 305-8505, Japan. 2.High Energy Accelerator Research Organization (KEK), 1-1 Oho, Tsukuba, Ibaraki 305-0801, Japan. 3.Advanced Research Institute for Science & Egineering, Waseda University, 3-4-1 Okubo Shinjuku-ku Tokyo 169-8555, JAPAN. 4.Advanced Engineering Services Co., Ltd. Tsukuba Mitsui Building 7th floor, 1-6-1, Takezono, Tsukuba, Ibaraki, 305-0032, Japan. 5.National Institute of Radiological Sciences, 4-9-1 Anagawa, Inage, Chiba 263-8555, Japan.

Biological damage in space arises from the interactions of high-energy heavy-charged particles, ranging from protons to iron nuclei, with DNA, cells and tissues. Investigating biological effects due to space radiation and microgravity thus requires precise measurements of space radiation. The Passive Dosimeter for Life science Experiments in Space (PADLES) analysis system has therefore been developed by NASDA space utilization research center for supporting life science experiments aboard ISS. PADLESs located by biological samples consists of thermoluminescent dosimeters (TLD-MSO) and plastic nuclear track detectors (CR-39). TLDs are used for estimating the absorbed dose in the LET region below 10 keV/μm. CR-39 is used for measuring LET distributions of heavy-charged particles in the LET region above 10 keV/μm. By combining the TLD and CR-39 data, we can obtain the absorbed dose and dose equivalent in the entire LET region.

PADLESs with the biological samples are to be stored at various temperatures from -80□ to 37□ for up to six months inside the Cell Biology Experiment Facility (CBEF) and the Minus Eighty degree celsius Laboratory Freezer for the International space station (MELFI) on JEM. Intensive ground testing of PADLES has been conducted with heavy ion beams from HIMAC in NIRS.* In this workshop, we report the following results obtained from the ground tests:

(1) the dose response of TLD-MSO is linear up to 2 Gy-water for 160MeV-protons and $^{60}$Co-γ rays.

(2) the TL efficiency of TLD-MSO decreases with increasing LET above approximately 10 keV/μm.

(3) the fading tendency of TLD-MSO depends on the storage temperature.

(4) the calibration curves of CR-39 are obtained at various incident angles of the heavy ions from $10^{o}$ to $90^{o}$ .

We will also report the preliminary data from PADLESs aboard the ISS Russian service module, which has been employed for investigating space radiation effects on the high-definition television camera CCD.

(*Research project with Heavy Ions at NIRS-HIMAC)

e-mail : nagamatsu.aiko@nasda.go.jp

# Preliminary Results of ISS Active Radiation Instruments from 1st ICCHIBAN (InterComparision for Cosmic-ray with Heavy-Ion Beams At NIRS)

T. Shelfer[1], E. Semones[1], N. Zapp[1], F. Riman[1], J. Flanders[1], M.J. Golightly[2], M. Weyland[1]

1. Lockheed-Martin Space Operations, C23, 2400 NASA Rd 1, Houston, TX 77058 USA +01-(281) 483-5509 tad.shelfer1@jsc.nasa.gov

2. NASA Johnson Space Center, SF2, Houston, TX 77058 USA

The Space Radiation Analysis Group (SRAG) at the NASA - Johnson Space Center (JSC) participated in the 1st InterComparision for Cosmic-ray with Heavy-Ion Beams At NIRS (ICCHIBAN) by sending three back-up flight instruments. One of the instruments we exposed was the back-up flight ISS Tissue Equivalent Proportional Counter (ISS TEPC). We also exposed the back-up flight Intra-Vehicular Charged Particle Directional spectrometer (IV-CPDS). Finally, we also exposed a flight Shuttle TEPC since many of the Shuttle flights are ISS construction flights and we have collected a great deal of TEPC data from both the Shuttle and ISS instruments while the two vehicles were docked. All of these instruments were exposed to two different beams at the National Institute of Radiological Sciences (NIRS), Chiba, Japan, as part of the 1st ICCHIBAN project. The first beam consisted of 400 MeV Carbon ions, and the second beam was made up of 400 MeV iron ions. The detectors were exposed to the beams in a number of different orientations and translations with respect to the beam line. Preliminary results from these instruments will be presented for each exposure.

# Postflight Calibration of DOSTEL with Heavy Ions During the First ICCHIBAN Run at HIMAC, Chiba

**S. Burmeister** [1] , R. Beaujean [1] , F. Petersen [1] , G. Reitz [2]

[1] Universität Kiel/IEAP, 24098 Kiel, Germany [2] DLR Köln/Flugmedizin, 51147 Köln, Germany

After the return of the two DOSimetry TELescopes (DOSTELs) from the DOSMAP mission they were irradiated with heavy ions at the Heavy Ion Medical Accelerator in Chiba (HIMAC), Japan. The HIMAC provided 400 MeV/nuc 12 C and 400MeV/nuc 56 Fe. The carbon ions deposit about 5.8 MeV within 315 µm silicon and the iron ions deposit about 126 MeV within the detector. These ion beams were used to verify the pre flight calibration of the two DOSTEL Units and to investigate changes due to the exposition in a space radiation field during the DOSMAP experiment period.

Results of Monte Carlo calculations by GEANT 3 using the preflight calibration data are compared to calibration data yielded by the heavy ion irradiation. The two calibrations before and after the DOSMAP mission do not show observable differences and the intercomparison with the four MDUs shows a good agreement.

# Measurement of LET-distributions for protons from the Loma Linda synchrotron by RRMD-III and spherical TEPC

T. Doke[1], T. Fuse[1], K. Hara[1], S. Suzuki[1], K. Terasawa[1], S. Takagi[2], T. B. Borak[3], S. Guetersoloh[3], P. Taddei[3], C. J. Zeitlin[4] and S. Reitner[5]

[1] Advanced Research Institute for Science and Engineering, Waseda University, Kikuicho-17, Shinjyuku-ku, Tokyo 162-0044, Japan
[2] Safty Engineering and Technology Department, Mitsubishi Research Institute, INC., Otemachi 2-3-6, Chiyoda-ku, Tokyo 100-8141, Japan
[3] Department of Environmental and Radiological Health Sciences, Colorado State University, Ft. Collins, CO 80523, USA
[4] Lawrence Berkeley National Laboratory, 1 Cyclotron road, Berkeley, CA 94720, USA
[5] Loma Linda University Medical Center, Loma Linda, CA 92354, USA

In the STS-91, a large discrepancy between dose equivalents obtained by a cylindrical TEPC and by RRMD-III inside the Space Shuttle of STS-91 was found. In particular, it in the SAA region reached the factor of 2. To investigate the cause of such a discrepancy, the responses of spherical TEPC and RRMD-III for proton beam with various energies were measured at Loma Lind University Medical Center. From their results, φ(LET) and f(y), LETφ and yf(y) are obtained for each proton energy ranging from 40 MeV to 180 MeV, where LET is linear energy transfer obtained by RRMD-III and y is lineal energy for TEPC. Comparison between the mean values obtained from these distributions is made and their discrepancies are discussed.

# LIGHTING FIRES – FULL INTERPLANETARY RADIATION ENVIRONMENT SIMULATION

Walter Schimmerling and Francis A. Cucinotta
NASA

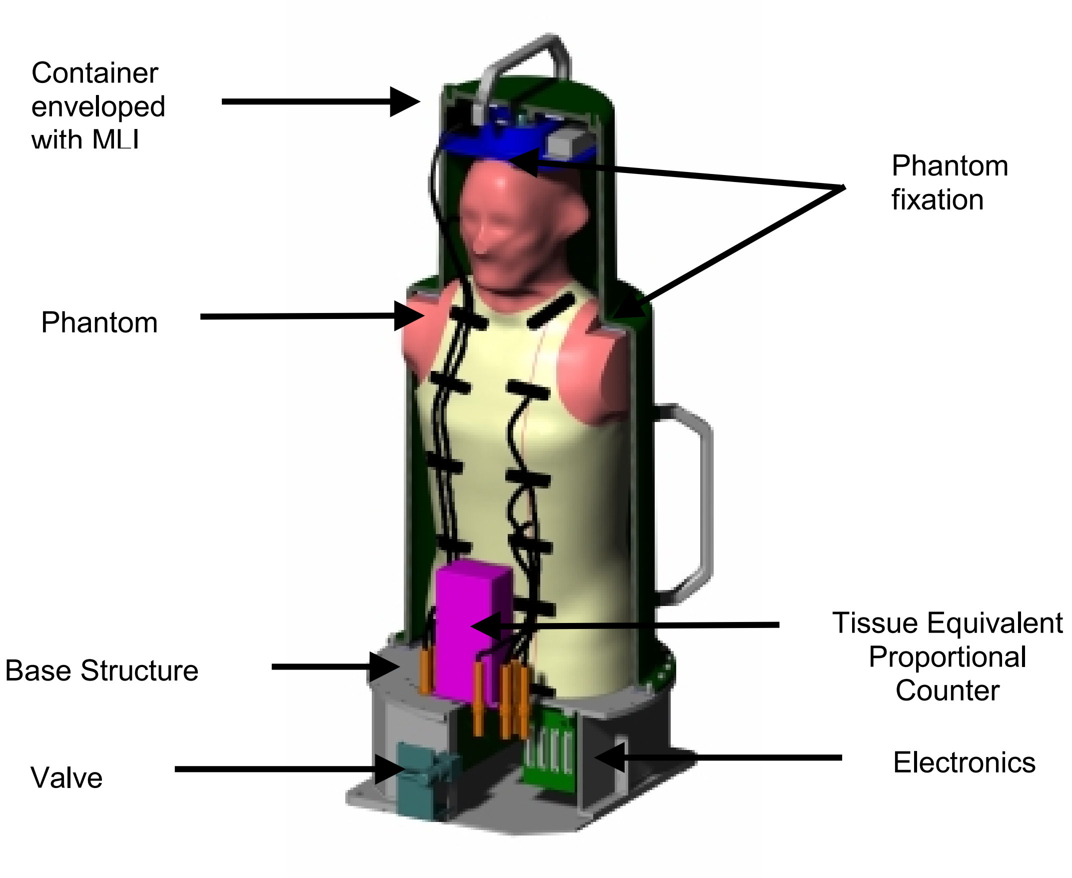
The space radiation environment can be simulated to a large extent by using high energy proton and heavy ion accelerator beams as sources of charged particles of the kinds and energies present in space. The Alternating Gradient Synchrotron (AGS) and the Booster Applications Facility (BAF) at Brookhaven National Laboratory (BNL) in Long Island, New York constitute the mainstay of NASA radiation research. These efforts will be supplemented by the continuing contribution of international accelerator centers. Using particle accelerators, research into the physics and biology of the interaction of radiation with materials, instruments, cells, tissues and organs can be performed on the ground at a higher level of statistical significance, and at a substantially lower cost, than would be possible in space. The current status of the BNL facilities will be discussed in the context of the NASA Radiation Initiative and the imminent commissioning of BAF.

## Status of the ESA-Facility MATROSHKA

G.Reitz

DLR, Institut für Luft- und Raumfahrtmedizin, D-51140 Köln

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. At the outside as part of the upper MLI 5 pockets are provided to allow measurements behind very low shielding thickness.

The critical design review will be held in September this year. Beginning of November first tests with a Technical Model (TM) will be performed. The TM delivery is planned in March 2003, the flight model delivery in August 2003. To undergo the EM test technical models of the experiments shall be available end 2002. Flight experiments integration shall be started in April 2003. MATROSHKA will be launched end 2003 and exposed during 1 year outside the Russian Service Module. Once activated MATROSHKA will provide permanently house keeping and scientific data.

Following investigators and labs are involved currently in the investigations:
Dr. R. Beaujean, University Kiel, Germany; E. Benton, Eril Research, San Francisco, USA; Dr. F. Cucinotta, NASA, Johnson Spaceflight Center, Houston, USA; Dr. S. Deme, KFKI Atomic Energy Research Institute, Budapest, Hungary; Prof. W. Heinrich, Universität GH Siegen, Germany; Dr. M. Luszik-Bhadra, PTB, Braunschweig, Germany; Dr. J. Miller, LBL, Berkeley, California, USA; Dr. P. Olko, Institute of Nuclear Physics, Krakow, Poland; Dr. J. Palvalvi, , KFKI Atomic Energy Research Institute, Budapest, Hungary; Dr. Petrov, IBMP, Moscow, Russia; Dr. E.G. Stassinopoulos, NASA, Goddard Space Flight Center, Greenbelt, USA; Prof. N. Vana, Atominstitute of the Austrian Universities, Vienna, Austria

## ISS Radiation Operational Support

M. Weyland[1], M.J. Golightly[2], C. Dardano[1], J. Garza[1], T. Shelfer[1], E. Semones[1], S. Johnson[1], N. Zapp[1], G. Smith[2]

1. Lockheed-Martin Space Operations, C23, 2400 NASA Rd 1, Houston, TX 77058 USA
+01-(281) 483-6190 mailto:mweyland@ems.jsc.nasa.gov
2. NASA Johnson Space Center, SF2, Houston, TX 77058 USA

This presentation will walk through the day-to-day nominal and contingency operations of the Space Radiation Analysis Group (SRAG) support, and highlight how new tools are being utilized. The Space Radiation Analysis Group (SRAG) was established at the NASA - Johnson Space Center (JSC) in 1962. The SRAG provided 24-hour continuous support for all manned missions from the JSC Mission Control Center (MCC) until 1994. Upgrades to operational support, thanks to rapidly advancing technologies and improved space environment/transport codes, allowed SRAG to move to daily and on-call status at that time. International Space Station (ISS) operations has been a challenge primarily due to the permanent manned presence in space and managing many new active instruments in an operational environment which is different than what was envisioned. The problem of protecting crews is compounded by the difficulty of providing continuous real-time monitoring over a period of a decade. In order to prepare for ISS radiological support needs, SRAG and the NOAA Space Environment Center (SEC) undertook a multiyear effort to improve and automate ground-based space weather monitoring systems and real-time radiation analysis tools. These improvements include a coupled, automated space weather monitoring and alarm system--SPE exposure analysis system, an advanced space weather data distribution and display system, and the Solar Active Region Display System (SARDS). Several other tools have been developed and integrated into an advanced web based application suite.

## “U.S. ISS Radiation Instrument Data Processing and Archiving—Status Report”

M.J. Golightly[1], C. Dardano[2], J. Garza[2], T. Shelfer[2], E. Semones[2], F. Riman[2], S. Johnson[2], J. Flanders[2], and N. Zapp[2]

1. NASA Johnson Space Center, SF2, Houston, TX 77058 USA +01-(281)483-6190
mgolight@ems.jsc.nasa.gov
2. Lockheed-Martin Space Operations, C23, 2400 NASA Rd 1, Houston, TX 77058 USA

Since the last update in Sep 2001, the U.S. radiation monitoring system for ISS has continued to expand and evolve. The Tissue Equivalent Proportional Counter (TEPC) operated nearly continuously from Sep 2001 to Jun 2002, when the instrument’s high-voltage detector bias unexpectedly failed. The Intra-Vehicular Charged Particle Directional Spectrometer (IV-CPDS) also operated nearly continuously throughout the period. The Extra-Vehicular Charged Particle Spectrometer (EV-CPDS) was launched and attached to the ISS in April 2002 and has been operated only for short periods while completing its activation and checkout process. Cyclic telemetry, including absorbed dose rate, measurement time, instrument status, and vehicle location, are automatically captured and stored in a database: TEPC cyclic telemetry has been captured since Oct 2001 and IV-CPDS telemetry since Nov 2001. These data are being used to drive operational support data displays via the Space Radiation Analysis Group’s (SRAG’s) internal website including: dose rate and integral dose versus time; dose rate versus vehicle location; relative dose rate enhancement versus vehicle location (“tiger plots”); and dose rate versus L-shell. The cyclic data are also used in automatically generated email messages to operational support personnel providing the daily absorbed dose (TEPC, IV-CPDS) and dose equivalent (TEPC only). Periodically, all science data acquired by the instruments are “dumped” from the instruments’ memory to the Mission Control Center-Houston (MCC-H) where it is collected, processed, and archived by SRAG. Routine integral absorbed dose measurements using various thermoluminescent dosimeters (TLDs) are being made at 16 locations throughout the Service Module, U.S. Node 1, U.S. Lab, and Joint Airlock. Results from the first seven TLD monitoring sets, spanning the period 20 May 1999 to 17 Dec 2001, are also posted on SRAG’s internal web site. The increasing quantity of ISS radiation instrument data and growth in the number of operational processes and users is leading to the need to upgrade SRAG’s data processing and archive system. Plans are underway to procure a new high-capacity NT server and migrate the instrument database from Microsoft Access to SQL Server. The new server will be established outside NASA’s firewall to allow increased access to operational radiation instrument data by ISS International Partner radiological support personnel.