Space Radiation Hazards and Countermeasures: 1990-2004

A Custom Bibliography From the
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Includes radiation environments, tools and techniques for measuring radiation dosage, effects of radiation on humans and animal models, methods for strengthening biological resistance to radiation, and radiation shielding.

July 2004

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JULY 2004

20040020236

Emerging Radiation Health-Risk Mitigation Technologies

Wilson, J. W.; Cucinotta, F. A.; Schimmerling, W.; AIP Conference Proceedings; February 04, 2004; ISSN 0094-243X; Volume 699, no. 1; In English; Space Technology and Applications Internat. Forum-STAIF 2004: Conf. on Thermophys. in Microgravity; Commercial/Civil Next Gen. Space Transp.; 21st Symp. Space Nuclear Power & Propulsion; Human Space Explor.; Space Colonization; New Frontiers & Future Concepts, 8-11 February 2004, Albuquerque, New Mexico, USA; Copyright

Past space missions beyond the confines of the Earth's protective magnetic field have been of short duration and protection from the effects of solar particle events was of primary concern. The extension of operational infrastructure beyond low-Earth orbit to enable routine access to more interesting regions of space will require protection from the hazards of the accumulated exposures of Galactic Cosmic Rays (GCR). There are significant challenges in providing protection from the long-duration exposure to GCR: the human risks to the exposures are highly uncertain and safety requirements places unreasonable demands in supplying sufficient shielding materials in the design. A vigorous approach to future radiation health-risk mitigation requires a triage of techniques (using biological and technical factors) and reduction of the uncertainty in radiation risk models. The present paper discusses the triage of factors for risk mitigation with associated materials issues and engineering design methods. [copyright] 2004 American Institute of Physics

Author (AIP)

Galactic Cosmic Rays; Hazards; Health; Human Factors Engineering; Radiation Effects; Radiation Hazards; Radiation Shielding; Shielding; Solar Corpuscular Radiation; Space Missions; Spacecraft

20040065989 NASA Marshall Space Flight Center, Huntsville, AL, USA

Radiation Hazards and Countermeasures for Human Space Flight

Adams, James H., Jr.; [2004]; In English, 19-22 Apr. 2004, Solvang, CA, USA; No Copyright; Avail: Other Sources

Protection of the astronauts from space radiation is NASA's moral and legal responsibility. There can be no manned deep space missions without adequate protection from the ionizing radiation in space. There are two parts to radiation protection, determining the effects of space radiation on humans so that adequate exposure limits can be set and providing radiation protection that insures those limits will not be exceeded. This talk will review the status of work on these two parts and identify areas that are currently being investigated and gaps in the research that have been identified.

Author

Radiation Hazards; Countermeasures; Manned Space Flight; Extraterrestrial Radiation; Exposure

20040067866 NASA Johnson Space Center, Houston, TX, USA

Charged Particle Dose Measurements by the Odyssey/MARIE Instrument in Mars Orbit and Model Calculations

Cleghorn, T. F.; Saganti, P. B.; Zeitlin, C.; Cucinotta, F. A.; Lunar and Planetary Science XXXV: Exploration and Observations; 2004; In English; Copyright; Avail: CASI

Knowledge of the space radiation environment is crucial both for human space exploration, and robotic space missions. It is likely that human explorers will return to the moon, and then go to Mars within the next thirty years. The radiation environment that they will encounter is a significant obstacle to future exploration, and must be dealt with successfully before longterm human missions outside of the magnetosphere can take place. Shielding technologies and materials must be developed to lower the dose and dose equivalent that human beings will receive on such missions. To begin this development, a fairly complete and accurate understanding of the space environment must be obtained. The major components of the space particle radiation environment that are most hazardous to humans are: galactic cosmic rays (GCR), the particles contained in solar particle events, (SPE), and secondary particles generated in material in the spacecraft itself. The intensity of the GCR varies by roughly a factor of two over the eleven-year solar cycle, inversely with the level of solar activity. These GCR

particles are fully stripped nuclei, predominantly protons and helium, but also significant numbers of heavier ions, including carbon, oxygen, and iron. The MARIE instrument has been described elsewhere.
Derived from text
Charged Particles; Dosage; Extraterrestrial Radiation; Spacecraft Instruments; Planetary Orbits; Mars (Planet); Astronomical Models

20040065985 NASA Marshall Space Flight Center, Huntsville, AL, USA
Radiation Risk Assessment of the Individual Astronaut: A Complement to Radiation Interests at the NIH
Richmond, Robert C.; [2004]; In English, 19 Apr. 2004, Rockville, MD, USA; No Copyright; Avail: Other Sources

Predicting human risks following exposure to space radiation is uncertain in part because of unpredictable distribution of high-LET and low-dose-derived damage amongst cells in tissues, unknown synergistic effects of microgravity upon gene- and protein-expression, and inadequately modeled processing of radiation-induced damage within cells to produce rare and late-appearing malignant cancers. Furthermore, estimation of risks of radiogenic outcome within small numbers of astronauts is not possible using classic epidemiologic study. It therefore seems useful to develop strategies of risk-assessment based upon large datasets acquired from correlated biological models useful for resolving radiogenic risk-assessment for irradiated individuals. In this regard, it is suggested that sensitive cellular biodosimeters that simultaneously report 1) the quantity of absorbed dose after exposure to ionizing radiation, 2) the quality of radiation delivering that dose, and 3) the biomolecular risk of malignant transformation be developed in order to resolve these NASA-specific challenges. Multiparametric cellular biodosimeters could be developed using analyses of gene-expression and protein-expression whereby large datasets of cellular response to radiation-induced damage are analyzed for markers predictive for acute response as well as cancer-risk. A new paradigm is accordingly addressed wherein genomic and proteomic datasets are registered and interrogated in order to provide statistically significant dose-dependent risk estimation in individual astronauts. This evaluation of the individual for assessment of radiogenic outcomes connects to NIH program in that such a paradigm also supports assignment of a given patient to a specific therapy, the diagnosis of response of that patient to therapy, and the prediction of risks accumulated by that patient during therapy - such as risks incurred by scatter and neutrons produced during high-energy Intensity-Modulated Radiation Therapy. Value of assessment of radiogenic outcome for individuals exposed to radiation is suggested to be common to both NASA and NIH.
Author
Radiation Therapy; Extraterrestrial Radiation; Microgravity; Ionizing Radiation; Assessments

20040065983 Eril Research, Inc., San Rafael, CA, USA
Characterization of the Radiation Shielding Properties of U.S. and Russian Extravehicular Activity Suits, Chapter 4
Benton, E. R.; Benton, E. V.; Frank, A. L.; December 2003; In English; No Copyright; Avail: CASI

Reported herein are results from the Eril Research, Inc. (ERI) participation in the JSC-sponsored study characterizing the radiation shielding properties of the two types of space suit that astronauts are wearing during the EVA on-orbit assembly of ISS. Measurements using passive detectors were carried out to assess the shielding properties of the U.S. EMU Suit and the Russian Orlan-M suit during irradiations of the suits and a tissue-equivalent phantom to monoenergetic proton and electron beams at LLUMC. During irradiations of 6 MeV electrons and 60 MeV protons, absorbed dose as a function of depth was measured using TLDs exposed behind swatches of the two suit materials and inside the two EVA helmets. Considerable reduction in electron dose was measured behind all suit materials in exposures to 6 MeV electrons. Slowing of the proton beam in the suit materials led to an increase in dose measured in exposures to 60 MeV protons. During 232 MeV proton irradiations, measurements were made with TLDs and CR-39 PNTDs at five organ locations inside a tissue-equivalent phantom, exposed both with and without the two EVA suits. The EVA helmets produce a 13% to 27% reduction in total dose and a 0% to 25% reduction in dose equivalent when compared to measurements made in the phantom head alone. Differences in dose and dose equivalent between the suit and non-suit irradiations for the lower portions of the two EVA suits tended to be smaller. Proton-induced target fragmentation was found to be a significant source of increased dose equivalent, especially within the two EVA helmets, and average quality factor inside the EMU and Orlan-M helmets was 2% to 14% greater than that measured in the bare phantom head.
Author
Radiation Shielding; Extravehicular Mobility Units; Astronauts; Cosmonauts

20040068092 NASA Johnson Space Center, Houston, TX, USA
Summary and Recommendations for Future Work, Chapter 12
Cucinotta, Francis A.; Shavers, Mark R.; Saganti, Premkumar B.; Miller, Jack; Radiation Protection Studies of International

Space Station Extravehicular Activity Space Suits; See also Doc ID 20040031719; December 2003; In English; No Copyright; Avail: CASI

The safety of astronauts is the primary concern of all space missions. Space radiation has been identified as a major concern for ISS, and minimizing radiation risks during EVA is a principle component of NASA s radiation protection program. The space suit plays a critical role in shielding astronauts from EVA radiation exposures. In cooperation with the JSC Extravehicular Activity Project Office, and the Space Radiation Health Project Office, the NASA EMU and RSA Orlan space suits were taken to the LLUPTF for a series of measurements with proton and electron beams to simulate exposures during EVA operations. Additional tests with material layouts of the EMU suit sleeve were made in collaboration with NASA LaRC at the LBNL 88-inch cyclotron and at the Brookhaven National Laboratory Alternating Gradient Synchrotron.
Derived from text

Astronauts; Extraterrestrial Radiation; Radiation Protection; Radiation Shielding; Space Suits; Recommendations

20040065984 California Univ., Lawrence Berkeley National Lab., Berkeley, CA, USA

Radiation Tests of the Extravehicular Mobility Unit Space Suit for the International Space Station Using Energetic Protons, Chapter 3

Zeitlin, C.; Heilbronn, L.; Miller, J.; Shavers, M.; December 2003; In English

Contract(s)/Grant(s): NASA Order T-5606-W; DE-AC-03076SF00098; No Copyright; Avail: CASI

Measurements using silicon detectors to characterize the radiation transmitted through the EMU space suit and a human phantom have been performed using 155 and 250 MeV proton beams at LLUMC. The beams simulate radiation encountered in space, where trapped protons having kinetic energies on the order of 100 MeV are copious. Protons with 100 MeV kinetic energy and above can penetrate many centimeters of water or other light materials, so that astronauts exposed to such energetic particles will receive doses to their internal organs. This dose can be enhanced or reduced by shielding - either from the space suit or the self-shielding of the body - but minimization of the risk depends on details of the incident particle flux (in particular the energy spectrum) and on the dose responses of the various critical organs. Data were taken to characterize the beams and to calibrate the detectors using the beam in a treatment room at LLUPTF, in preparation for an experiment with the same beams incident on detectors placed in a human phantom within the EMU suit. Nuclear interactions of high-energy protons in various materials produce a small flux of highly ionizing, low-energy secondary radiation. Secondaries are of interest for their biological effects, since they cause doses and especially dose-equivalents to increase relative to the values expected simply from ionization energy loss along the Bragg curve. Because many secondaries have very short ranges, they are best measured in passive track detectors such as CR-39. The silicon detector data presented here are intended to supplement the CR-39 data in regions where silicon has greater sensitivity, in particular the portion of the LET spectrum below 5 keV/micron. The results obtained in this study suggest that optimizing the radiation shielding properties of space suits is a formidable task. The naive assumption that adding mass can reduce risk is not supported by the data, which show that reducing the dose delivered at or near the skin by low-energy particles may increase the dose delivered by energetic particles to points deeper in the body.
Author

Extravehicular Mobility Units; Radiation Shielding; Energetic Particles; Protons

20040065980 Loma Linda Univ., CA, USA

Proton and Electron Threshold Energy Measurements for Extravehicular Activity Space Suits, Chapter 2

Moyers, M. F.; Nelson, G. D.; Saganti, P. B.; December 2003; In English

Contract(s)/Grant(s): NCC9-79; No Copyright; Avail: CASI

Construction of ISS will require more than 1000 hours of EVA. Outside of ISS during EVA, astronauts and cosmonauts are likely to be exposed to a large fluence of electrons and protons. Development of radiation protection guidelines requires the determination of the minimum energy of electrons and protons that penetrate the suits at various locations. Measurements of the water-equivalent thickness of both US. and Russian EVA suits were obtained by performing CT scans. Specific regions of interest of the suits were further evaluated using a differential range shift technique. This technique involved measuring thickness ionization curves for 6-MeV electron and 155-MeV proton beams with ionization chambers using a constant source-to-detector distance. The thicknesses were obtained by stacking polystyrene slabs immediately upstream of the detector. The thicknesses of the 50% ionizations relative to the maximum ionizations were determined. The detectors were then placed within the suit and the stack thickness adjusted until the 50% ionization was reestablished. The difference in thickness between the 50% thicknesses was then used with standard range-energy tables to determine the threshold energy for penetration. This report provides a detailed description of the experimental arrangement and results.
Author

Protons; Electrons; Radiation Measurement; Extravehicular Mobility Units

20040065986 Lockheed Martin Corp., Houston, TX, USA

A Comparison of Model Calculation and Measurement of Absorbed Dose for Proton Irradiation, Chapter 5

Zapp, N.; Semones, E.; Saganti, P.; Cucinotta, F.; December 2003; In English; No Copyright; Avail: CASI

With the increase in the amount of time spent EVA that is necessary to complete the construction and subsequent maintenance of ISS, it will become increasingly important for ground support personnel to accurately characterize the radiation exposures incurred by EVA crewmembers. Since exposure measurements cannot be taken within the organs of interest, it is necessary to estimate these exposures by calculation. To validate the methods and tools used to develop these estimates, it is necessary to model experiments performed in a controlled environment. This work is such an effort. A human phantom was outfitted with detector equipment and then placed in American EMU and Orlan-M EVA space suits. The suited phantom was irradiated at the LLUPTF with proton beams of known energies. Absorbed dose measurements were made by the spaceflight operational dosimetrist from JSC at multiple sites in the skin, eye, brain, stomach, and small intestine locations in the phantom. These exposures are then modeled using the BRYNTRN radiation transport code developed at the NASA Langley Research Center, and the CAM (computerized anatomical male) human geometry model of Billings and Yucker. Comparisons of absorbed dose calculations with measurements show excellent agreement. This suggests that there is reason to be confident in the ability of both the transport code and the human body model to estimate proton exposure in ground-based laboratory experiments.

Author

Extravehicular Mobility Units; Radiation Dosage; Proton Irradiation

20040068089 Loma Linda Univ., CA, USA

In Vitro Studies on Space Radiation-Induced Delayed Genetic Responses: Shielding Effects

Kadhim, Munira A.; Green, Lora M.; Gridley, Daila S.; Murray, Deborah K.; Tran, Da Thao; Andres, Melba; Pocock, Debbie; Macdonald, Denise; Goodhead, Dudley T.; Moyers, Michael F.; December 2003; In English

Contract(s)/Grant(s): NCC9-79; No Copyright; Avail: CASI

Understanding the radiation risks involved in spaceflight is of considerable importance, especially with the long-term occupation of ISS and the planned crewed exploration missions. Several independent causes may contribute to the overall risk to astronauts exposed to the complex space environment, such as exposure to GCR as well as SPES. Protons and high-Z energetic particles comprise the GCR spectrum and may exert considerable biological effects even at low fluence. There are also considerable uncertainties associated with secondary particle effects (e.g. HZE fragments, neutrons etc.). The interaction of protons and high-LET particles with biological materials at all levels of biological organization needs to be investigated fully in order to establish a scientific basis for risk assessment. The results of these types of investigation will foster the development of appropriately directed countermeasures. In this study, we compared the biological responses to proton irradiation presented to the target cells as a monoenergetic beam of particles of complex composition delivered to cells outside or inside a tissue phantom head placed in the USA EVA space suit helmet. Measurements of chromosome aberrations, apoptosis, and the induction of key proteins were made in bone marrow from CBA/CaJ and C57BL/6 mice at early and late times post exposure to radiation at 0, 0.5, 1 and 2 Gy while inside or outside of the helmet. The data showed that proton irradiation induced transmissible chromosomal/genomic instability in haematopoietic stem cells in both strains of mice under both irradiation conditions and especially at low doses. Although differences were noted between the mouse strains in the degree and kinetics of transforming growth factor-beta 1 and tumor necrosis factor-alpha secretion, there were no significant differences observed in the level of the induced instability under either radiation condition, or for both strains of mice. Consequently, when normalized to physical dose, the monoenergetic proton field present inside the helmet-protected phantom produced equivalent biological responses, when compared to unshielded cells, as measured by the induction of delayed genetic effects in murine haematopoietic stem cells.

Author (revised)

Radiation Effects; Radiation Shielding; Proton Irradiation; Mutations

20040031719 NASA Johnson Space Center, Houston, TX, USA

Radiation Protection Studies of International Space Station Extravehicular Activity Space Suits

Cucinotta, Francis A., Editor; Shavers, Mark R., Editor; Saganti, Premkumar B., Editor; Miller, Jack, Editor; December 2003; In English

Report No.(s): NASA/TP-2003-212051; S-904; No Copyright; Avail: CASI

This publication describes recent investigations that evaluate radiation shielding characteristics of NASA's and the Russian Space Agency's space suits. The introduction describes the suits and presents goals of several experiments performed with them. The first chapter provides background information about the dynamic radiation environment experienced at ISS

and summarized radiation health and protection requirements for activities in low Earth orbit. Supporting studies report the development and application of a computer model of the EMU space suit and the difficulty of shielding EVA crewmembers from high-energy reentrant electrons, a previously unevaluated component of the space radiation environment. Chapters 2 through 6 describe experiments that evaluate the space suits' radiation shielding characteristics. Chapter 7 describes a study of the potential radiological health impact on EVA crewmembers of two virtually unexamined environmental sources of high-energy electrons-reentrant trapped electrons and atmospheric albedo or ″splash″ electrons. The radiological consequences of those sources have not been evaluated previously. A detailed computational model of the shielding distribution provided by components of the NASA astronauts' EMU is being developed for exposure evaluation studies. The model is introduced in Chapters 8 and 9 and used in Chapter 10 to investigate how trapped particle anisotropy impacts female organ doses during EVA. Chapter 11 presents a review of issues related to estimating skin cancer risk form space radiation. The final chapter contains conclusions about the protective qualities of the suit brought to light from these studies, as well as recommendations for future operational radiation protection.
Author
Extravehicular Activity; International Space Station; Radiation Protection; Extraterrestrial Radiation; Extravehicular Mobility Units

20040065987 NASA Langley Research Center, Hampton, VA, USA
Shuttle Space Suit: Fabric/LCVG Model Validation, Chapter 8
Wilson, J. W.; Tweed, J.; Zeitlin, C.; Kim, M.-H. Y.; Anderson, B. M.; Cucinotta, F. A.; Ware, J.; Persans, A. E.; Radiation Protection Studies of International Space Station Extravehicular Activity Space Suits; See also Doc ID 20040031719; December 2003; In English; No Copyright; Avail: CASI

A detailed space suit computational model is being developed at the Langley Research Center for radiation exposure evaluation studies. The details of the construction of the space suit are critical to estimation of exposures and assessing the risk to the astronaut on EVA. Past evaluations of space suit shielding properties assumed the basic fabric layup (Thermal Micrometeoroid Garment, fabric restraints, and pressure envelope) and LCVG could be homogenized as a single layer overestimating the protective properties over 60 percent of the fabric area. The present space suit model represents the inhomogeneous distributions of LCVG materials (mainly the water filled cooling tubes). An experimental test is performed using a 34-MeV proton beam and high-resolution detectors to compare with model-predicted transmission factors. Some suggestions are made on possible improved construction methods to improve the space suit's protection properties.
Author
Space Suits; Radiation Protection

20040065988 NASA Langley Research Center, Hampton, VA, USA
Preliminary Shuttle Space Suit Shielding Model, Chapter 9
Anderson, Brooke M.; Nealy, J. E.; Qualls, G. D.; Staritz, P. J.; Wilson, J. W.; Kim, M.-H. Y.; Cucinotta, F. A.; Atwell, W.; DeAngelis, G.; Ware, J.; Persans, A. E.; Radiation Protection Studies of International Space Station Extravehicular Activity Space Suits; See also Doc ID 20040031719; December 2003; In English; No Copyright; Avail: CASI

There are two space suits in current usage within the space program: EMU [2] and Orlan-M Space Suit. The Shuttle space suit components are discussed elsewhere [2,5,6] and serve as a guide to development of the current model. The present model is somewhat simplified in details which are considered to be second order in their effects on exposures. A more systematic approach is ongoing on a part-by-part basis with the most important ones in terms of exposure contributions being addressed first with detailed studies of the relatively thin space suit fabric as the first example. Additional studies to validate the model of the head coverings (bubble, helmet, visors...) will be undertaken in the near future. The purpose of this paper is to present the details of the model as it is now and to examine its impact on estimates of astronaut health risks. In this respect, the nonuniform distribution of mass of the space suit provides increased shielding in some directions and some organs. These effects can be most important in terms of health risks and especially critical to evaluation of potential early radiation effects.
Author
Space Suits; Portable Life Support Systems; Computer Aided Design

20030033907 NASA Langley Research Center, Hampton, VA, USA
Analysis of a Radiation Model of the Shuttle Space Suit
Anderson, Brooke M.; Nealy, John E.; Kim, Myung-Hee; Qualls, Garry D.; Wilson, John W.; March 2003; In English
Contract(s)/Grant(s): RTOP 732-50-00-01
Report No.(s): NASA/TP-2003-212158; NAS 1.60:212158; L-18235; Copyright; Avail: CASI

The extravehicular activity (EVA) required to assemble the International Space Station (ISS) will take approximately 1500 hours with 400 hours of EVA per year in operations and maintenance. With the Space Station at an inclination of 51.6 deg the radiation environment is highly variable with solar activity being of great concern. Thus, it is important to study the dose gradients about the body during an EVA to help determine the cancer risk associated with the different environments the ISS will encounter. In this paper we are concerned only with the trapped radiation (electrons and protons). Two different scenarios are looked at: the first is the quiet geomagnetic periods in low Earth orbit (LEO) and the second is during a large solar particle event in the deep space environment. This study includes a description of how the space suit's computer aided design (CAD) model was developed along with a description of the human model. Also included is a brief description of the transport codes used to determine the total integrated dose at several locations within the body. Finally, the results of the transport codes when applied to the space suit and human model and a brief description of the results are presented.
Author
Radiation Dosage; Space Suits; Radiation Protection; Trapped Particles; Human Beings; Models

20030094706
In vivo and in vitro measurements of complex-type chromosomal exchanges induced by heavy ions
George, K.; Durante, M.; Wu, H.; Willingham, V.; Cucinotta, F. A.; Advances in Space Research; March 2003; ISSN 0273-1177; Volume 31, no. 6; In English; Copyright; Avail: Other Sources

Heavy ions are more efficient in producing complex-type chromosome exchanges than sparsely ionizing radiation, and this can potentially be used as a biomarker of radiation quality. We measured the induction of complex-type chromosomal aberrations in human peripheral blood lymphocytes exposed in vitro to accelerated H-, He-, C-, Ar-, Fe- and Au-ions in the LET range of approximately 0.4-1400 keV/micron. Chromosomes were analyzed either at the first post-irradiation mitosis, or in interphase, following premature condensation by phosphatase inhibitors. Selected chromosomes were then visualized after FISH-painting. The dose-response curve for the induction of complex-type exchanges by heavy ions was linear in the dose-range 0.2-1.5 Gy, while Upsilon -rays did not produce a significant increase in the yield of complex rearrangements in this dose range. The yield of complex aberrations after 1 Gy of heavy ions increased up to an LET around 100 keV/micron, and then declined at higher LET values. When mitotic cells were analyzed, the frequency of complex rearrangements after 1 Gy was about 10 times higher for Ar- or Fe-ions (the most effective ions, with LET around 100 keV/micron) than for 250 MeV protons, and values were about 35 times higher in prematurely condensed chromosomes. These results suggest that complex rearrangements may be detected in astronauts' blood lymphocytes after long-term space flight, because crews are exposed to HZE particles from galactic cosmic radiation. However, in a cytogenetic study of ten astronauts after long-term missions on the Mir or International Space Station, we found a very low frequency of complex rearrangements, and a significant post-flight increase was detected in only one out of the ten crewmembers. It appears that the use of complex-type exchanges as biomarker of radiation quality in vivo after low-dose chronic exposure in mixed radiation fields is hampered by statistical uncertainties.
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EI
Blood; Chelation; Chromosomes; Heavy Ions

20030032352 NASA Johnson Space Center, Houston, TX, USA
Physics of the Isotopic Dependence of Galactic Cosmic Ray Fluence Behind Shielding
Cucinotta, Francis A.; Saganti, Premkumar B.; Hu, Xiao-Dong; Kim, Myung-Hee Y.; Cleghorn, Timothy F.; Wilson, John W.; Tripathi, Ram K.; Zeitlin, Cary J.; February 2003; In English
Report No.(s): NASA/TP-2003-210792; NAS 1.60:210792; S-891; No Copyright; Avail: CASI

For over 25 years, NASA has supported the development of space radiation transport models for shielding applications. The NASA space radiation transport model now predicts dose and dose equivalent in Earth and Mars orbit to an accuracy of plus or minus 20%. However, because larger errors may occur in particle fluence predictions, there is interest in further assessments and improvements in NASA's space radiation transport model. In this paper, we consider the effects of the isotopic composition of the primary galactic cosmic rays (GCR) and the isotopic dependence of nuclear fragmentation cross-sections on the solution to transport models used for shielding studies. Satellite measurements are used to describe the isotopic composition of the GCR. Using NASA's quantum multiple-scattering theory of nuclear fragmentation (QMSFRG) and high-charge and energy (HZETRN) transport code, we study the effect of the isotopic dependence of the primary GCR composition and secondary nuclei on shielding calculations. The QMSFRG is shown to accurately describe the iso-spin dependence of nuclear fragmentation. The principal finding of this study is that large errors (plus or minus 100%) will occur in the mass-fluence spectra when comparing transport models that use a complete isotope grid (approximately 170 ions) to ones that use a reduced isotope grid, for example the 59 ion-grid used in the HZETRN code in the past, however less

significant errors (less than 20%) occur in the elemental-fluence spectra. Because a complete isotope grid is readily handled on small computer workstations and is needed for several applications studying GCR propagation and scattering, it is recommended that they be used for future GCR studies.
Author
Fluence; Galactic Cosmic Rays; Primary Cosmic Rays; Isotopes; Radiation Shielding; Mathematical Models; Radiation Transport; Radiation Absorption

20030060568 NASA Johnson Space Center, Houston, TX, USA
Secondary Neutron Production from Space Radiation Interactions: Advances in Model and Experimental Data Base Development
Heilbronn, Lawrence H.; Townsend, Lawrence W.; Braley, G. Scott; Iwata, Yoshiyuki; Iwase, Hiroshi; Nakamura, Takashi; Ronningen, Reginald M.; Cucinotta, Francis A.; 2002 Microgravity Materials Science Conference; February 2003; In English; No Copyright

For humans engaged in long-duration missions in deep space or near-Earth orbit, the risk from exposure to galactic and solar cosmic rays is an important factor in the design of spacecraft, spacesuits, and planetary bases. As cosmic rays are transported through shielding materials and human tissue components, a secondary radiation field is produced. Neutrons are an important component of that secondary field, especially in thickly-shielded environments. Calculations predict that 50% of the dose-equivalent in a lunar or Martian base comes from neutrons, and a recent workshop held at the Johnson Space Center concluded that as much as 30% of the dose in the International Space Station may come from secondary neutrons. Accelerator facilities provide a means for measuring the effectiveness of various materials in their ability to limit neutron production, using beams and energies that are present in cosmic radiation. The nearly limitless range of beams, energies, and target materials that are present in space, however, means that accelerator-based experiments will not provide a complete database of cross sections and thick-target yields that are necessary to plan and design long-duration missions. As such, accurate nuclear models of neutron production are needed, as well as data sets that can be used to compare with, and verify, the predictions from such models. Improvements in a model of secondary neutron production from heavy-ion interactions are presented here, along with the results from recent accelerator-based measurements of neutron-production cross sections. An analytical knockout-ablation model capable of predicting neutron production from high-energy hadron-hadron interactions (both nucleon-nucleus and nucleus-nucleus collisions) has been previously developed. In the knockout stage, the collision between two nuclei result in the emission of one or more nucleons from the projectile and/or target. The resulting projectile and target remnants, referred to as prefragments, then decay by the emission of nucleons, composites, and gamma rays. Recent improvements to the model have incorporated coalescence effects, which effectively tie up single nucleons in the formation of composites during final-state interactions. Comparison of the improved model s predictions with neutron production data near 0 deg in the CA-40+ H reaction at 357 and 565 MeV/nucleon show marked improvement.
Author
Cosmic Rays; Extraterrestrial Radiation; Neutron Sources; Mathematical Models; Particle Interactions

20030006868
Reliability Methods for Shield Design Process
Tripathi, R. K.; Wilson, J. W.; AIP Conference Proceedings; January 28, 2003; ISSN 0094-243X; Volume 654, no. 1; In English; Space Technology and Applications Int. Forum-STAIF 2003: Conf. on Thermophysics in Microgravity; Commercial/ Civil Next Generation Space Transportation; Human Space Exploration, 2-5 February 2003, Albuquerque, New Mexico, USA; Copyright

Providing protection against the hazards of space radiation is a major challenge to the exploration and development of space. The great cost of added radiation shielding is a potential limiting factor in deep space operations. In this enabling technology, we have developed methods for optimized shield design over multi-segmented missions involving multiple work and living areas in the transport and duty phase of space missions. The total shield mass over all pieces of equipment and habitats is optimized subject to career dose and dose rate constraints. An important component of this technology is the estimation of two most commonly identified uncertainties in radiation shield design, the shielding properties of materials used and the understanding of the biological response of the astronaut to the radiation leaking through the materials into the living space. The largest uncertainty, of course, is in the biological response to especially high charge and energy (HZE) ions of the galactic cosmic rays. These uncertainties are blended with the optimization design procedure to formulate reliability-based

methods for shield design processes. The details of the methods will be discussed. [copyright] 2003 American Institute of Physics
Author (AIP)
Aerospace Medicine; Biological Effects; Biophysics; Extraterrestrial Radiation; Radiation Effects; Radiation Protection; Reliability; Shielding; Space Exploration; Spacecraft

20030006869
Development of Collaborative Engineering Environments for Spacecraft Design
Singleterry, Robert C., Jr; Johns, Bradley D.; Fan, Kwok Y.; Cheatwood, F. McNeil; Qualls, Garry D.; Wareing, Todd A.; McGhee, John; Pautz, Shawn; Prinja, Anil K.; Gleicher, Frederick; AIP Conference Proceedings; January 28, 2003; ISSN 0094-243X; Volume 654, no. 1; In English; Space Technology and Applications Int. Forum-STAIF 2003: Conf. on Thermophysics in Microgravity; Commercial/Civil Next Generation Space Transportation; Human Space Exploration, 2-5 February 2003, Albuquerque, New Mexico, USA; Copyright

The hazards of ionizing radiation in space continue to be a limiting factor in the design of missions, spacecraft, and habitats. Shielding against such hazards is an enabling technology in the human and robotic exploration and development of space. If the design of the radiation shielding is not optimal for the mission, then excess mass will be launched, mission costs will be higher than necessary, and useful payload will be reduced. This reduced mission capability scenario can be repeated for other technical design disciplines. These other disciplines can also effect each other's requirements. A collaborative engineering environment can optimize ALL design parameters for cost (or another parameter) producing a spacecraft that will meet all mission requirements at the minimum cost. This paper describes two environments that include space radiation analyses and the inclusion within a larger optimization methodology. [copyright] 2003 American Institute of Physics
Author (AIP)
Computer Aided Design; Ionizing Radiation; Radiation Protection; Shielding; Space Missions; Spacecraft; Spacecraft Design

20030006878
Radiation Shielding Analysis for Deep Space Missions
De Angelis, Giovanni; Clowdsley, Martha S.; Nealy, John E.; Singleterry, Robert C.; Tripathi, Ram K.; Wilson, John W.; AIP Conference Proceedings; January 28, 2003; ISSN 0094-243X; Volume 654, no. 1; In English; Space Technology and Applications Int. Forum-STAIF 2003: Conf. on Thermophysics in Microgravity; Commercial/Civil Next Generation Space Transportation; Human Space Exploration, 2-5 February 2003, Albuquerque, New Mexico, USA
Contract(s)/Grant(s): NCC-1-404; Copyright

An environment for radiation shielding analysis for manned deep space mission scenarios has been developed. The analysis is performed by dividing a mission scenario into three possible different phases, namely the interplanetary cruise phase, the final planetary approach and orbit insertion, and the surface phase. In the first phase only Galactic Cosmic Rays and Solar Events particles are used, in the second phase the effects of trapped radiation belts are also taken into account, and in the third phase also the effect of the planetary environment is considered. Planetary surfaces and atmospheres are modeled based on results from the most recent targeted spacecraft. The dose results are coupled with mission design visualization techniques. [copyright] 2003 American Institute of Physics
Author (AIP)
Aerospace Medicine; Cosmic Rays; Deep Space; Galactic Cosmic Rays; Manned Space Flight; Planetary Atmospheres; Radiation Belts; Radiation Protection; Radiation Shielding; Shielding; Solar Corpuscular Radiation; Solar Radiation; Solar Wind; Space Missions; Spacecraft

20030006879
Gateway/L1 Modeling and Radiation Analysis
Anderson, Brooke M.; Nealy, John E.; Geffre, James R.; Qualls, Garry D.; Krizan, Shawn A.; Troutman, Pat; AIP Conference Proceedings; January 28, 2003; ISSN 0094-243X; Volume 654, no. 1; In English; Space Technology and Applications Int. Forum-STAIF 2003: Conf. on Thermophysics in Microgravity; Commercial/Civil Next Generation Space Transportation; Human Space Exploration, 2-5 February 2003, Albuquerque, New Mexico, USA; Copyright

The radiation environments at Earth-Lunar L1 are vastly different than what has been encountered before by humans, thus analysis of the predicted dose rates will need to be examined if the Gateway scenario is to be properly evaluated. The environments to be considered will be those of deep space. Recently a CAD model of the three vehicles of the Gateway concept was developed to define the shielding properties inherent to the vehicles. The models consist of approximately 50-100

components that describe the directional shielding provided for the astronaut. The goals were to provide simple models so that near real-time analysis can be performed while the solid angles subtended by the modeled elements were compatible with those of the true vehicle models. The analysis will consist of determining the variable dose though out each of the Gateway vehicles. [copyright] 2003 American Institute of Physics
Author (AIP)
Aerospace Medicine; Computer Aided Design; Radiation Protection; Shielding; Spacecraft

20030006880
Deep Space Environment and Shielding
Wilson, J. W.; Nealy, J. E.; de Angelis, G.; Clowdsley, M. S.; Badavi, F. F.; AIP Conference Proceedings; January 28, 2003; ISSN 0094-243X; Volume 654, no. 1; In English; Space Technology and Applications Int. Forum-STAIF 2003: Conf. on Thermophysics in Microgravity; Commercial/Civil Next Generation Space Transportation; Human Space Exploration, 2-5 February 2003, Albuquerque, New Mexico, USA; Copyright

Mission scenarios outside the Earth's protective magnetic shield are being studied. Included are high usage assets in the near-Earth environment for casual trips, for research, for commercial and for operational platforms, in which career exposures will be multimission determined over the astronaut's lifetime. In addition, the exploration beyond these near Earth operational platforms will include single missions of long duration to planets, asteroids, and planetary satellites. The interplanetary environment is evaluated using convective diffusion theory. Local induced environments for each celestial body are modeled by using results from recent targeted spacecraft studies, and integrated into the design environments. Design scenarios are then evaluated for these missions. The underlying assumptions in deriving the model environments and their impact on mission exposures with various shield materials will be discussed. [copyright] 2003 American Institute of Physics
Author (AIP)
Aerospace Environments; Aerospace Medicine; Deep Space; Radiation Effects; Radiation Protection; Shielding; Spacecraft

20030006881
ISS as a Platform for Environmental Model Evaluation
Hugger, Craig P.; Qualls, Garry D.; Wilson, John W.; Cuccinotta, Frank A.; Shavers, Mark R.; Zapp, Neil; AIP Conference Proceedings; January 28, 2003; ISSN 0094-243X; Volume 654, no. 1; In English; Space Technology and Applications Int. Forum-STAIF 2003: Conf. on Thermophysics in Microgravity; Commercial/Civil Next Generation Space Transportation; Human Space Exploration, 2-5 February 2003, Albuquerque, New Mexico, USA; Copyright

The International Space Station provides researchers with a unique opportunity to develop and test radiation environment models and computational procedures. Since having manned missions into space is an ongoing part of NASA exploration of space, it has become necessary to conceive new methods to determine the safety of the astronauts in that environment. One of the major environmental hazards in space is the radiation an astronaut will be exposed to during their mission. NASA Langley Research Center, working in conjunction with Johnson Space Center, is developing a process that accurately simulates the radiation environment in the International Space Station. The environment includes the shielding provided by the ISS and the radiation environment surrounding the ISS. The radiation shielding is modeled using commercial CAD software. Ray-tracing software is used to calculate the shielding thicknesses for the model. A radiation environment is generated from data acquired from the NASA-GSFC National Space Science Data Center and transport codes for heavy ions and electrons. The radiation dose can then be calculated through combining the thickness files and the radiation environment. Various radiation dose experiments were and still are being performed on the International Space Station. Analysis of the radiation shielding environmental model can be compared to data obtained from the ISS, enabling researchers to perfect their methods of predicting radiation environments and allowing them to create a tool that can be applied to future endeavors into space. [copyright] 2003 American Institute of Physics
Author (AIP)
Aerospace Medicine; Computer Aided Design; Environment Models; International Space Station; Radiation Effects; Radiation Protection; Shielding; Spacecraft

20030110897 NASA Johnson Space Center, Houston, TX, USA
Monte Carlo Simulations of the Response of the MARIE Instrument
Andersen, V.; Lee, K.; Pinsky, L.; Atwell, W.; Cleghorn, T.; Cucinotta, F.; Saganti, P.; Turner, R.; Zeitlin, C.; Lunar and Planetary Science XXXIV; 2003; In English; Copyright

The MARIE instrument aboard Mars Odyssey functions as a telescope for the detection of charged, energetic, nuclei. The

directionality that leads to the telescope description is achieved by requiring coincident signals in two designated detectors in MARIE s silicon detector stack for the instrument to trigger. Because of this, MARIE is actually a bi directional telescope. Triggering particles can enter the detector stack by passing through the lightly shielded front of the instrument, but can also enter the back of the instrument by passing through the bulk of Odyssey. Because of this, understanding how to relate the signals recorded by MARIE to astrophysically important quantities such as particle fluxes or spectra exterior to the spacecraft clearly requires detailed modeling of the physical interactions that occur as the particles pass through the spacecraft and the instrument itself. In order to facilitate in the calibration of the MARIE data, we have begun a program to simulate the response of MARIE using the FLUKA [1] [2] Monte Carlo radiation transport code.
Author
Radiation Transport; Monte Carlo Method; Radiation Detectors

20030110994 NASA Johnson Space Center, Houston, TX, USA
Solar Particle Events Observed by the Odyssey MARIE Instrument at Mars: Dose and Model Calculations
Cleghorn, T. F.; Saganti, P. B.; Zeitlin, C. J.; Cucinotta, F. A.; Lunar and Planetary Science XXXIV; 2003; In English; Copyright; Avail: CASI

One of the primary concerns prior to human exploration of Mars is the need to accurately characterize the charged particle radiation environment both for the surface stay, and for the transit period to and from the planet. The Odyssey spacecraft, currently in Mars orbit, includes a charged particle radiation detector, MARIE, which can measure particle fluxes with energies above approx. 30 MeV and charges between 1 and 10. Two classes of particles are of particular interest: the Galactic Cosmic Rays, (GCR), and those charged particles associated with Solar Particle Events, (SPE). The GCR are present continuously throughout the solar activity cycle, and their numbers vary inversely with the level of solar activity. They are characteristically more energetic than those particles originating from solar activity, and hence less influences by the solar magnetic field.
Derived from text
Solar Flares; Solar Magnetic Field; Radiation Counters

20030112873 NASA Marshall Space Flight Center, Huntsville, AL, USA
Multiparametric Determination of Radiation Risk
Richmond, Robert C.; [2003]; In English, 26-28 Feb. 2003, Palo Alto, CA, USA; No Copyright; Avail: Other Sources

Predicting risk of human cancer following exposure to ionizing space radiation is challenging in part because of uncertainties of low-dose distribution amongst cells, of unknown potentially synergistic effects of microgravity upon cellular protein-expression, and of processing dose-related damage within cells to produce rare and late-appearing malignant transformation, degrade the confidence of cancer risk-estimates. The NASA- specific responsibility to estimate the risks of radiogenic cancer in a limited number of astronauts is not amenable to epidemiologic study, thereby increasing this challenge. Developing adequately sensitive cellular biodosimeters that simultaneously report 1) the quantity of absorbed dose after exposure to ionizing radiation, 2) the quality of radiation delivering that dose, and 3) the risk of developing malignant transformation by the cells absorbing that dose could be useful for resolving these challenges. Use of a multiparametric cellular biodosimeter is suggested using analyses of gene-expression and protein-expression whereby large datasets of cellular response to radiation-induced damage are obtained and analyzed for expression-profiles correlated with established end points and molecular markers predictive for cancer-risk. Analytical techniques of genomics and proteomics may be used to establish dose-dependency of multiple gene- and protein- expressions resulting from radiation-induced cellular damage. Furthermore, gene- and protein-expression from cells in microgravity are known to be altered relative to cells grown on the ground at 1g. Therefore, hypotheses are proposed that 1) macromolecular expression caused by radiation-induced damage in cells in microgravity may be different than on the ground, and 2) different patterns of macromolecular expression in microgravity may alter human radiogenic cancer risk relative to radiation exposure on Earth. A new paradigm is accordingly suggested as a national database wherein genomic and proteomic datasets are registered and interrogated in order to provide statistically significant dose-dependent risk estimation of radiogenic cancer in astronauts.
Author
Extraterrestrial Radiation; Ionizing Radiation; Radiogenic Materials; Radiation Dosage

20030111792 NASA Marshall Space Flight Center, Huntsville, AL, USA
Radiation Shielding for Manned Deep Space Missions
Adams, James H., Jr.; [2003]; In English, 28 Sep. - 2 Oct. 2003, Dubna, Russia; No Copyright; Avail: Other Sources

The arrival of the Expedition 1 Crew at the International Space Station represents the beginning of the continuous

presence of man in space. Already we are deploying astronauts and cosmonauts for missions of approx. 6 months onboard the ISS. In the future we can anticipate that more people will be in space and they will be there for longer periods. Even with 6-months deployments to the ISS, the radiation exposure that crew members receive is approaching the exposure limits imposed by the governments of the space- faring nations. In the future we can expect radiation protection to be a dominant consideration for long manned missions. Recognizing this, NASA has expanded their research program on radiation health. This program has three components, bioastronautics, fundamental biology and radiation shielding materials. Bioastronautics is concerned with the investigating the effects of radiation on humans. Fundamental biology investigates the basic mechanisms of radiation damage to tissue. Radiation shielding materials research focuses on developing accurate computational tools to predict the radiation shielding effectiveness of materials. It also investigates new materials that can be used for spacecraft. The radiation shielding materials program will be described and examples of results from the ongoing research will be shown.
Author
Radiation Shielding; Manned Space Flight; Deep Space; Radiation Damage; Radiation Effects

20030111588 NASA Johnson Space Center, Houston, TX, USA
Results from the Martian Radiation Environment Experiment MARIE
Zeitlin, C.; Cleghorn, T.; Cucinotta, F.; Saganti, P.; Andersen, V.; Lee, K.; Pinsky, L.; Atwell, W.; Turner, R.; Lunar and Planetary Science XXXIV; 2003; In English; Copyright; Avail: CASI

One of the three science instruments aboard the 2001 Mars Odyssey spacecraft is the Martian Radiation Environment Experiment, MARIE. MARIE consists of a stack of silicon detectors, augmented by a Cerenkov detector. MARIE is designed to measure a portion of the particle spectrum of the Galactic Cosmic Rays (GCR), as well as the high fluxes of low-energy protons (energies less than about 100 MeV) that are intermittently produced by active regions on the sun in Solar Particle Events (SPE). MARIE is providing the first detailed information about the radiation environment near Mars. MARIE has been operating successfully for nearly a year. Solar particle events of considerable interest have been observed, and data have been obtained that will yield GCR spectra from a novel observation point in the solar system.
Derived from text
Mars Environment; 2001 Mars Odyssey; Spacecraft Instruments; Galactic Cosmic Rays; Extraterrestrial Radiation

20030111264 NASA Johnson Space Center, Houston, TX, USA
Heavy Ion Flux Comparison of MARIE and ACE/CRIS Instruments
Lee, K. T.; Andersen, V.; Atwell, W.; Cleghorn, T.; Cucinotta, F.; Pinsky, L.; Saganti, P.; Turner, R.; Zeitlin, C.; Lunar and Planetary Science XXXIV; 2003; In English; Copyright

The charged particle spectrum for nuclei from protons to neon, (charge Z=10) has been observed during the cruise phase and in orbit around Mars by the MARIE charge particle spectrometer aboard the Odyssey spacecraft. The cruise data was taken between April 23, 2001 and August 11, 2001. The Mars orbit data was taken from March 5, 2002 through December 2002. Both the cruise data set and the orbital data set are compared with the simultaneous observations made by the CRIS instrument aboard the ACE space-craft, located at L1. Any detectable differences between the two spacecraft data sets could lead to the understanding of the radial dependence of solar modulation.
Author
Charged Particles; Neon; Protons; Mars (Planet)

20030066742 NASA Langley Research Center, Hampton, VA, USA
A New Time-dependent Model for the Martian Radiation Environment
DeAngelis, G.; Clowdsley, M. S.; Singleterry, R. C., Jr.; Wilson, J. W.; Sixth International Conference on Mars; 2003; In English; Original contains color illustrations
Contract(s)/Grant(s): NCC1-404; Copyright; Avail: CASI

Manned space activities have been until present time limited to the near-Earth environment, most of them to low Earth orbit (LEO) scenarios, with only some of the Apollo missions targeted to the Moon. In current times most human exploration and development of space (HEDS) activities are related to the development of the International Space Station (ISS), and therefore take place in the LEO environment. A natural extension of HEDS activities will be going beyond LEO, and reach asteroids, Mars, Jupiter, Saturn, the Kuiper belt and the outskirts of the Solar System. Such long journeys onboard spacecraft outside the protective umbrella of the geomagnetic field will require higher levels of protection from the radiation environment found in the deep space for both astronauts and equipment. So, it is important to have available a tool for radiation shielding which takes into account the radiation environments found all along the interplanetary space and at the different bodies

encountered in the Solar System. Moreover, the radiation protection is one of the two NASA highest concerns and priorities. A tool integrating different radiation environments with shielding computation techniques especially tailored for deep space mission scenario is instrumental in view of this exigency. In view of manned missions targeted to Mars, for which radiation exposure is one of the greatest problems and challenges to be tackled, it is of fundamental importance to have available a tool which allows to know which are the particle flux and spectra at any time at any point of the Martian surface. With this goal in mind, a new model for the radiation environment to be found on the planet Mars due to Galactic Cosmic Rays (GCR) has been developed. Solar modulated primary particles rescaled for Mars conditions are transported within the Martian atmosphere, with temporal properties modeled with variable timescales, down to the surface, with altitude and backscattering patterns taken into account. The tool allows analysis for manned Mars landing missions, as well as planetary science studies, e.g. subsurface water and volatile inventory studies. This Mars environmental model is available through the SIREST website, a project of NASA Langley Research Center.
Author
Manned Mars Missions; Environment Models; Mars Environment; Radiation Dosage; Radiation Protection

20040051107 Communications Research Lab., Tokyo, Japan
Research on a System for Monitoring, Analyzing, and Forecasting of the Space Environment
Kikuchi, Takashi; Journal of the Comminications Research Lab. Special Issue on Space Weather Forecast II: Development of Observation and Forecasting Systems and Information Services, Volume 49, No. 4; December 2002; In English; Copyright; Avail: Other Sources

In the 21st century, an age of widespread space-based endeavors, satellite communication, broadcast, and positioning applications have become an essential part of our social and economic activities. Furthermore, opportunities for manned space activities are increasing, such as through the utilization of the International Space Station, and in the future, space tourism may become a reality. Accordingly, the CRL has been pursuing research to develop technologies to monitor, analyze, and forecast variations in numerous space weather phenomena, in order to sustain a high-tech society that relies heavily on satellite technology. An additional goal of such research is to minimize human exposure to radiation during manned space activities. The Special Issue of Space Weather Forecasting I (Sept. 2002 issue) presented the results of research concerning variations in the space environment that interfere with normal satellite operation. The present issue is a compilation of the results of research focusing mainly on the development of technologies for monitoring, analyzing, and forecasting the space weather. This issue consists of two parts: the first deals with the development of technologies relating to the sun and solar winds, the magnetosphere, and the ionosphere and thermosphere; the second deals with the development of technologies to be applied to systems of collecting and distributing space weather information. The section on the sun and solar winds presents the results of optical and radio observations of solar surface phenomena that cause space environment variations, in addition to the results of studies on the methods of predicting the arrival time at the Earth of solar surface disturbances. This section also contains a paper regarding a project involving observation of coronal gas (coronal mass ejections) using solar-orbiting satellites. The section on the magnetosphere consists of a paper on a receiving system for satellites that perform direct observation of solar wind disturbances, another paper on the development of instrumentation and satellite data-acquisition system to observe various magnetospheric phenomena, and a paper on a system for monitoring magnetosphere-ionosphere disturbances using ground magnetometer networks. The section on the ionosphere and the thermosphere presents papers on the technology for total electron content (TEC) of which variations cause errors in positioning, and on the observation of ionospheric variations. The second part of this issue, dealing with information services, consists of papers on a remote control system for ionospheric observation and a system for the distribution of space weather information. We hope that this issue, together with Special Issue I, will contribute to a deeper understanding of the space weather phenomena that occur between the sun and the Earth and of the methods for monitoring, analyzing, and forecasting these phenomena.
Author
Solar Cosmic Rays; Solar Flares; Solar Prominences; Solar Radio Bursts; Forecasting; Information Systems; Satellite Communication

20040051105 Communications Research Lab., Tokyo, Japan
Space Weather Forecast in the Future Manned Space Era
Tomita, Fumihiko; Journal of the Communications Research Lab. Special Issue on Space Weather Forecast II: Development of Observation and Forecasting Systems and Information Services, Volume 49, No. 4; December 2002; In English; Copyright; Avail: Other Sources

Space weather is the conditions of the Sun and in the solar wind, magnetosphere, ionosphere and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems and can endanger human and

animal life or health. In 2050, everyone will be able to enjoy his/her space tour. The space weather research will transform into more and more practical science in that future manned space era.
Author
Space Weather; Manned Space Flight; Weather Forecasting; Aerospace Environments

20030003661 NASA Glenn Research Center, Cleveland, OH USA
Non-Invasive Health Diagnostics using Eye as a 'Window to the Body'
Ansari, Rafat R.; Sixth Microgravity Fluid Physics and Transport Phenomena Conference; November 2002; Volume 1; In English; No Copyright; Avail: CASI

As a 'window to the body', the eye offers the opportunity to use light in various forms to detect ocular and systemic abnormalities long before clinical symptoms appear and help develop preventative/therapeutic countermeasures early. The effects of space travel on human body are similar to those of normal aging. For example, radiation exposure in space could lead to formation of cataracts and cancer by damaging the DNA and causing gene mutation. Additionally, the zero-gravity environment causes fluid shifts in the upper extremities of the body and changes the way blood flows and organ system performs. Here on Earth, cataract, age-related macular degeneration (AMD), diabetic retinopathy (DR), and glaucoma are major eye diseases and are expected to double in next two decades. To detect, prevent, and treat untoward effects of prolonged space travel in real-time requires the development of non-invasive diagnostic technologies that are compact and powerful. We are developing fiber-optic sensors to evaluate the ocular tissues in health, aging, and disease employing the techniques of dynamic light scattering (cataract, uveitis, Alzheimer's, glaucoma, DR, radiation damage, refractive surgery outcomes), auto-fluorescence (aging, DR), laser-Doppler flowmetry (choroidal blood flow), Raman spectroscopy (AMD), polarimetry (diabetes), and retinal oximetry (occult blood loss). The non-invasive feature of these technologies integrated in a head-mounted/goggles-like device permits frequent repetition of tests, enabling evaluation of the results to therapy that may ultimately be useful in various telemedicine applications on Earth and in space.
Author
Aerospace Medicine; Eye Diseases; Radiation Dosage; Biological Effects; Deoxyribonucleic Acid; Cells (Biology); Bioinstrumentation; Space Flight

20020070827 Michigan Univ., Ann Arbor, MI USA
Biosensors for Real-Time Monitoring of Radiation-Induced Biologic Effects in Space
Baker, James R.; Balogh, Lajos; Majoros, Istvan; Keszler, Balazs; Myc, Andrzej; Kukowska-Latallo, Jolanta; Norris, Theodore; delaiglesia, Felix; Beeson, Nicholas W., Compiler; August 2002; In English; Original contains color illustrations
Contract(s)/Grant(s): NAS2-02069
Report No.(s): NAS2-02069-4; No Copyright; Avail: CASI

This work seeks to develop cellular biosensors based on dendritic polymers. Nanoscale polymer structures less than 20 nm in diameter will be used as the basis of the biosensors. The structures will be designed to target into specific cells of an astronaut and be able to monitor health issues such as exposure to radiation. Multiple components can be assembled on the polymers including target directors, analytical devices (such as molecular probes), and reporting agents. The reporting will be accomplished through fluorescence signal monitoring, with the use of multispectral analysis for signal interpretation. These nanosensors could facilitate the success and increase the safety of extended space flight. The design and assembly of these devices has been pioneered at the Center for Biologic Nanotechnology in the University of Michigan. This period, synthesis of the test-bed biosensors continued. Studies were performed on the candidate fluorescent dyes to determine which might be suitable for the biosensor under development. Development continued on producing an artificial capillary bed as a tool for the use in the production of the fluorescence signal monitor. Work was also done on the in vitro multispectral analysis system, which uses the robotic microscope.
Author
Bioinstrumentation; Nanostructures (Devices); Radiation Measuring Instruments; Biological Effects; Polymers

20020073167 NASA Johnson Space Center, Houston, TX USA
Space Radiation Cancer Risk Projections for Exploration Missions: Uncertainty Reduction and Mitigation
Cucinotta, Francis; Badhwar, Gautam; Saganti, Premkumar; Schimmerling, Walter; Wilson, John; Peterson, Leif; Dicello, John; Aug. 01, 2002; In English; Original contains color illustrations
Report No.(s): NASA/TP-2002-210777; NAS 1.60:210777; S-887; No Copyright; Avail: CASI

In this paper we discuss expected lifetime excess cancer risks for astronauts returning from exploration class missions.

For the first time we make a quantitative assessment of uncertainties in cancer risk projections for space radiation exposures. Late effects from the high charge and energy (HZE) ions present in the galactic cosmic rays including cancer and the poorly understood risks to the central nervous system constitute the major risks. Methods used to project risk in low Earth orbit are seen as highly uncertain for projecting risks on exploration missions because of the limited radiobiology data available for estimating HZE ion risks. Cancer risk projections are described as a product of many biological and physical factors, each of which has a differential range of uncertainty due to lack of data and knowledge. Monte-Carlo sampling from subjective error distributions represents the lack of knowledge in each factor to quantify risk projection overall uncertainty. Cancer risk analysis is applied to several exploration mission scenarios. At solar minimum, the number of days in space where career risk of less than the limiting 3% excess cancer mortality can be assured at a 95% confidence level is found to be only of the order of 100 days.
Author
Astronauts; Cancer; Galactic Cosmic Rays; Risk; Space Exploration; Planetary Environments; Radiation Hazards

20020051124 NASA Langley Research Center, Hampton, VA USA
Natural and Induced Environment in Low Earth Orbit
Wilson, John W.; Badavi, Francis F.; Kim, Myung-Hee Y.; Clowdsley, Martha S.; Heinbockel, John H.; Cucinotta, Francis A.; Badhwar, Gautam D.; Atwell, William; Huston, Stuart L.; May 2002; In English; Original contains color illustrations
Contract(s)/Grant(s): RTOP 705-30-11-11
Report No.(s): NASA/TM-2002-211668; L-18165; NAS 1.15:211668; No Copyright; Avail: CASI

The long-term exposure of astronauts on the developing International Space Station (ISS) requires an accurate knowledge of the internal exposure environment for human risk assessment and other onboard processes. The natural environment is moderated by the solar wind which varies over the solar cycle. The neutron environment within the Shuttle in low Earth orbit has two sources. A time dependent model for the ambient environment is used to evaluate the natural and induced environment. The induced neutron environment is evaluated using measurements on STS-31 and STS-36 near the 1990 solar maximum.
Author
Low Earth Orbits; Space Transportation System; Mathematical Models; Earth Orbital Environments

20030047019
Nuclear fragmentation cross sections for NASA database development
Zeitlin, C.; Heilbronn, L.; Miller, J.; Fukumura, A.; Iwata, Y.; Murakami, T.; MacGibbon, J.; Pinsky, L.; Wilson, T.; AIP Conference Proceedings; April 02, 2002; ISSN 0094-243X; Volume 610, no. 1; In English; Nuclear Physics in the 21st Century:International Nuclear Physics Conference INPC 2001, 30 Jul-3 Aug 2001, Berkeley. California, USA
Contract(s)/Grant(s): AC03-76SF00098; H31909D; L14230C; NAG8-1658; Copyright

Heavy ions with energies of hundreds to thousands of MeV/nucleon are present in the Galactic Cosmic Rays and will be a source of risk to astronaut health when long-duration crewed missions are undertaken. Nuclear interactions of these GCR ions in shielding materials must be accurately modeled by transport codes in order to estimate the dose and dose equivalent at points inside a spacecraft. Uncertainties in the nuclear fragmentation cross sections are propagated into these estimates, and the overall uncertainties increase as shielding depth increases. A program of fragmentation cross section measurements has therefore been undertaken to reduce these uncertainties, using GCR-like ion species and energies in particle accelerators in the USA, at the Brookhaven National Laboratory's Alternating Gradient Synchrotron (AGS) and in Japan at the National Institute of Radiological Science's Heavy Ion Medical Accelerator in Chiba (HIMAC). An extensive set of data has been obtained with beams ranging from helium to iron and including most of the species that are prominent in the GCR. [copyright] 2002 American Institute of Physics.
Author (AIP)
Biological Effects; Cosmic Rays; Data Bases; Fragmentation; Galactic Cosmic Rays; Heavy Ions; High Energy Interactions; Particle Production; Radiation Effects; Radiation Protection; Relativistic Particles; Shielding

20030047021
Importance of nuclear physics to NASA's space missions
Tripathi, R. K.; Wilson, J. W.; Cucinotta, F. A.; AIP Conference Proceedings; April 02, 2002; ISSN 0094-243X; Volume 610, no. 1; In English; Nuclear Physics in the 21st Century:International Nuclear Physics Conference INPC 2001, 30 Jul-3 Aug 2001, Berkeley. California, USA; Copyright

We show that nuclear physics is extremely important for accurate risk assessments for space missions. Due to paucity of experimental input radiation interaction information it is imperative to develop reliable accurate models for the interaction of radiation with matter. State-of-the-art nuclear cross sections models have been developed at the NASA Langley Research center and are discussed. [copyright] 2002 American Institute of Physics.
Author (AIP)
Biological Effects; Cosmic Rays; Galactic Cosmic Rays; High Energy Interactions; Nuclear Physics; Nuclear Reactions; Radiation Effects; Radiation Protection; Scattering; Shielding; Space Missions; Spacecraft

20020046209 NASA Johnson Space Center, Houston, TX USA
Exploration of the Mars Radiation Environment Using MARIE
Cucinotta, F.; Badhwar, G.; Zeitlin, C.; Cleghorn, T.; Bahr, J.; Beyer, T.; Chambellan, C.; Delaune, P.; Dunn, R.; Flanders, J., et al.; Lunar and Planetary Science XXXIII; April 2002; In English; CD-ROM contains the entire conference proceedings presented in PDF format; No Copyright

One of three science instruments onboard Mars Odyssey is the Mars Radiation Environment Experiment (MARIE), which is described here. MARIE is an energetic particle spectrometer which will characterize the space radiation environment of Mars and determine its risk to human exploration. Additional information is contained in the original extended abstract.
Derived from Text
Planetary Radiation; Mars Environment; Mars Exploration; Radiation Dosage

20020041462 NASA Langley Research Center, Hampton, VA USA
Transport of Space Environment Electrons: A Simplified Rapid-Analysis Computational Procedure
Nealy, John E.; Anderson, Brooke M.; Cucinotta, Francis A.; Wilson, John W.; Katz, Robert; Chang, C. K.; March 2002; In English; Original contains color illustrations
Contract(s)/Grant(s): RTOP 732-50-00-01
Report No.(s): NASA/TP-2002-211448; L-18155; NAS 1.60:211448; No Copyright; Avail: CASI

A computational procedure for describing transport of electrons in condensed media has been formulated for application to effects and exposures from spectral distributions typical of electrons trapped in planetary magnetic fields. The procedure is based on earlier parameterizations established from numerous electron beam experiments. New parameterizations have been derived that logically extend the domain of application to low molecular weight (high hydrogen content) materials and higher energies (approximately 50 MeV). The production and transport of high energy photons (bremsstrahlung) generated in the electron transport processes have also been modeled using tabulated values of photon production cross sections. A primary purpose for developing the procedure has been to provide a means for rapidly performing numerous repetitive calculations essential for electron radiation exposure assessments for complex space structures. Several favorable comparisons have been made with previous calculations for typical space environment spectra, which have indicated that accuracy has not been substantially compromised at the expense of computational speed.
Author
Aerospace Environments; Electron Transfer; Planetary Magnetic Fields; Parameterization; Extraterrestrial Radiation

20020048310 NASA Marshall Space Flight Center, Huntsville, AL USA
Cancer Risk Assessment for Space Radiation
Richmond, Robert C.; Curreri, Peter A., Technical Monitor; [2002]; In English; Spelman College RIMI/Biology Seminar Series, 9 Apr. 2002, Atlanta, GA, USA; No Copyright; Avail: Other Sources

Predicting the occurrence of human cancer following exposure to any agent causing genetic damage is a difficult task. This is because the uncertainty of uniform exposure to the damaging agent, and the uncertainty of uniform processing of that damage within a complex set of biological variables, degrade the confidence of predicting the delayed expression of cancer as a relatively rare event within any given clinically normal individual. The radiation health research priorities for enabling long-duration human exploration of space were established in the 1996 NRC Report entitled ″Radiation Hazards to Crews of Interplanetary Missions: Biological Issues and Research Strategies″. This report emphasized that a 15-fold uncertainty in predicting radiation-induced cancer incidence must be reduced before NASA can commit humans to extended interplanetary missions. That report concluded that the great majority of this uncertainty is biologically based, while a minority is physically based due to uncertainties in radiation dosimetry and radiation transport codes. Since that report, the biologically based uncertainty has remained large, and the relatively small uncertainty associated with radiation dosimetry has increased due to the considerations raised by concepts of microdosimetry. In a practical sense, however, the additional uncertainties introduced

by microdosimetry are encouraging since they are in a direction of lowered effective dose absorbed through infrequent interactions of any given cell with the high energy particle component of space radiation. The biological uncertainty in predicting cancer risk for space radiation derives from two primary facts. 1) One animal tumor study has been reported that includes a relevant spectrum of particle radiation energies, and that is the Harderian gland model in mice. Fact #1: Extension of cancer risk from animal models, and especially from a single study in an animal model, to humans is inherently uncertain. 2) One human database is predominantly used for assessing cancer risk caused by space radiation, and that is the Japanese atomic bomb survivors. Fact #2: The atomic-bomb-survivor database, itself a remarkable achievement, contains uncertainties. These include the actual exposure to each individual, the radiation quality of that exposure, and the fact that the exposure was to acute doses of predominantly low-LET radiation, not to chronic exposures of high-LET radiation expected on long-duration interplanetary manned missions.
Author
Cancer; Radiation Transport; Space Exploration

20020050921 NASA Marshall Space Flight Center, Huntsville, AL USA
Radiation Effect on Human Tissue
Richmond, Robert C.; Cruz, Angela; Bors, Karen; Curreri, Peter A., Technical Monitor; [2002]; In English; 40th American Institute of Aeronautics and Aerospace Sciences Meeting and Exhibit, 15 Jan. 2002, Reno, NV, USA; No Copyright; Avail: Other Sources

Predicting the occurrence of human cancer following exposure of an epidemiologic population to any agent causing genetic damage is a difficult task. To an approximation, this is because the uncertainty of uniform exposure to the damaging agent, and the uncertainty of uniform processing of that damage within a complex set of biological variables, degrade the confidence of predicting the delayed expression of cancer as a relatively rare event within clinically normal individuals. This situation begs the need for alternate controlled experimental models that are predictive for the development of human cancer following exposures to agents causing genetic damage. Such models historically have not been of substantial proven value. It is more recently encouraging, however, that developments in molecular and cell biology have led to an expanded knowledge of human carcinogenesis, and of molecular markers associated with that process. It is therefore appropriate to consider new laboratory models developed to accomodate that expanded knowledge in order to assess the cancer risks associated with exposures to genotoxic agents. When ionizing radiation of space is the genotoxic agent, then a series of additional considerations for human cancer risk assessment must also be applied. These include the dose of radiation absorbed by tissue at different locations in the body, the quality of the absorbed radiation, the rate at which absorbed dose accumulates in tissue, the way in which absorbed dose is measured and calculated, and the alterations in incident radiation caused by shielding materials. It is clear that human cancer risk assessment for damage caused by ionizing radiation is a multidisciplinary responsibility, and that within this responsibility no single discipline can hold disproportionate sway if a risk assessment model of radiation-induced human cancer is to be developed that has proven value. Biomolecular and cellular markers from the work reported here are considered for use in assessing human cancer risk related to exposure to space radiation. This potential use must be integrated within the specified multidisciplinary context in order to create a new tool of molecular epidemiology that can hopefully then realistically assess this cancer risk.
Author
Carcinogens; Radiation Effects; Tissues (Biology); Epidemiology; Human Body

20030003835 NASA Langley Research Center, Hampton, VA USA
Deep Space Design Environments for Human Exploration
Wilson, J. W.; Clowdsley, M. S.; Cucinotta, F. A.; Tripathi, R. K.; Nealy, J. E.; DeAngelis, G.; [2002]; In English, 10-19 Oct. 2002, Houston, TX, USA; Original contains color illustrations; Copyright; Avail: CASI

Mission scenarios outside the Earth's protective magnetic shield are being studied. Included are high usage assets in the near-Earth environment for casual trips, for research, and for commercial/operational platforms, in which career exposures will be multi-mission determined over the astronaut's lifetime. The operational platforms will serve as launching points for deep space exploration missions, characterized by a single long-duration mission during the astronaut's career. The exploration beyond these operational platforms will include missions to planets, asteroids, and planetary satellites. The interplanetary environment is evaluated using convective diffusion theory. Local environments for each celestial body are modeled by using results from the most recent targeted spacecraft, and integrated into the design environments. Design scenarios are then evaluated for these missions. The underlying assumptions in arriving at the model environments and their impact on mission exposures within various shield materials will be discussed.
Author
Space Exploration; Deep Space; Planetary Environments; Manned Space Flight; Mathematical Models

20030014806 NASA Langley Research Center, Hampton, VA USA

Space Radiation Transport Methods Development

Wilson, J. W.; Tripathi, R. K.; Qualls, G. D.; Cucinotta, F. A.; Prael, R. E.; Norbury, J. W.; Heinbockel, J. H.; Tweed, J.; [2002]; In English; World Space Congress 2002, 10-19 Oct. 2002, Houston, TX, USA; Copyright; Avail: CASI

Improved spacecraft shield design requires early entry of radiation constraints into the design process to maximize performance and minimize costs. As a result, we have been investigating high-speed computational procedures to allow shield analysis from the preliminary design concepts to the final design. In particular, we will discuss the progress towards a full three-dimensional and computationally efficient deterministic code for which the current HZETRN evaluates the lowest order asymptotic term. HZETRN is the first deterministic solution to the Boltzmann equation allowing field mapping within the International Space Station (ISS) in tens of minutes using standard Finite Element Method (FEM) geometry common to engineering design practice enabling development of integrated multidisciplinary design optimization methods. A single ray trace in ISS FEM geometry requires 14 milliseconds and severely limits application of Monte Carlo methods to such engineering models. A potential means of improving the Monte Carlo efficiency in coupling to spacecraft geometry is given in terms of reconfigurable computing and could be utilized in the final design as verification of the deterministic method optimized design.

Author

Extraterrestrial Radiation; Manned Space Flight; Space Exploration; Asymptotic Methods; Mathematical Models; Spacecraft Design

20030020808 College of William and Mary, Williamsburg, VA, USA

Predictions for Radiation Shielding Materials

Kiefer, Richard L.; [2002]; In English; Original contains color illustrations

Contract(s)/Grant(s): NCC1-327; No Copyright; Avail: CASI

Radiation from galactic cosmic rays (GCR) and solar particle events (SPE) is a serious hazard to humans and electronic instruments during space travel, particularly on prolonged missions outside the Earth s magnetic fields. Galactic cosmic radiation (GCR) is composed of approx. 98% nucleons and approx. 2% electrons and positrons. Although cosmic ray heavy ions are 1-2% of the fluence, these energetic heavy nuclei (HZE) contribute 50% of the long-term dose. These unusually high specific ionizations pose a significant health hazard acting as carcinogens and also causing microelectronics damage inside spacecraft and high-flying aircraft. These HZE ions are of concern for radiation protection and radiation shielding technology, because gross rearrangements and mutations and deletions in DNA are expected. Calculations have shown that HZE particles have a strong preference for interaction with light nuclei. The best shield for this radiation would be liquid hydrogen, which is totally impractical. For this reason, hydrogen-containing polymers make the most effective practical shields. Shielding is required during missions in Earth orbit and possibly for frequent flying at high altitude because of the broad GCR spectrum and during a passage into deep space and LunarMars habitation because of the protracted exposure encountered on a long space mission. An additional hazard comes from solar particle events (SPEs) which are mostly energetic protons that can produce heavy ion secondaries as well as neutrons in materials. These events occur at unpredictable times and can deliver a potentially lethal dose within several hours to an unshielded human. Radiation protection for humans requires safety in short-term missions and maintaining career exposure limits within acceptable levels on future long-term exploration missions. The selection of shield materials can alter the protection of humans by an order of magnitude. If improperly selected, shielding materials can actually increase radiation damage due to penetration properties and nuclear fragmentation. Protecting space-borne microelectronics from single event upsets (SEUs) by transmitted radiation will benefit system reliability and system design cost by using optimal shield materials. Long-term missions on the surface of the Moon or Mars will require the construction of habitats to protect humans during their stay. One approach to the construction is to make structural materials from lunar or Martian regolith using a polymeric material as a binder. The hydrogen-containing polymers are considerably more effective for radiation protection than the regolith, but the combination minimizes the amount of polymer to be transported. We have made composites of simulated lunar regolith with two different polymers, LaRC-SI, a high-performance polyimide thermoset, and polyethylene, a thermoplastic.

Author

Dosage; Exposure; Galactic Radiation; Hazards; Magnetic Fields; Polyethylenes; Polyimides; Protection; Radiation Protection; Solar Corpuscular Radiation; Thermoplasticity

20010110764 NASA Langley Research Center, Hampton, VA USA
An Improved Analytic Model for Microdosimeter Response
Shinn, Judy L.; Wilson, John W.; Xapsos, Michael A.; September 2001; In English
Contract(s)/Grant(s): RTOP 732-50-00-01
Report No.(s): NASA/TP-2001-211040; NAS 1.60:211040; L-18109; No Copyright; Avail: CASI

An analytic model used to predict energy deposition fluctuations in a microvolume by ions through direct events is improved to include indirect delta ray events. The new model can now account for the increase in flux at low lineal energy when the ions are of very high energy. Good agreement is obtained between the calculated results and available data for laboratory ion beams. Comparison of GCR (galactic cosmic ray) flux between Shuttle TEPC (tissue equivalent proportional counter) flight data and current calculations draws a different assessment of developmental work required for the GCR transport code (HZETRN) than previously concluded.
Author
Dosimeters; Microinstrumentation; Mathematical Models; Radiation Protection; Extraterrestrial Radiation; Energy Transfer

20020026387 California Univ., Lawrence Berkeley National Lab., Berkeley, CA USA
Nuclear fragmentation cross sections for NASA database development
Zeitlin, C. J.; Heilbronn, L. H.; Miller, J.; Fukumura, A.; Iwata, Y.; Aug. 24, 2001; In English
Report No.(s): DE2001-789172; LBNL-48879; No Copyright; Avail: Department of Energy Information Bridge

Heavy ions with energies of hundreds to thousands of MeV/nucleon are present in the Galactic Cosmic Rays and will be a source of risk to astronaut health when long-duration crewed missions are undertaken. Nuclear interactions of these GCR ions in shielding materials must be accurately modeled by transport codes in order to estimate the dose and dose equivalent at points inside a spacecraft. Uncertainties in the nuclear fragmentation cross sections are propagated into these estimates, and the overall uncertainties increase as shielding depth increases. A program of fragmentation cross section measurements has therefore been undertaken to reduce these uncertainties, using GCR-like ion species and energies in particle accelerators in the USA, at the Brookhaven National Laboratory's Alternating Gradient Synchrotron (AGS) and in Japan at the National Institute of Radiological Science's Heavy Ion Medical Accelerator in Chiba (HIMAC). An extensive set of data has been obtained with beams ranging from helium to iron and including most of the species that are prominent in the GCR.
NTIS
Data Bases; Fragmentation; Nuclear Interactions; NASA Programs; Galactic Cosmic Rays; Cross Sections

20010082534 NASA Langley Research Center, Hampton, VA USA
Proton-Nucleus Elastic Cross Sections Using Two-Body In-Medium Scattering Amplitudes
Tripathi, R. K.; Wilson, John W.; Cucinotta, Francis A.; August 2001; In English
Contract(s)/Grant(s): RTOP 101-21-23-03
Report No.(s): NASA/TP-2001-211043; L-18089; NAS 1.60:211043; No Copyright; Avail: CASI

Recently, a method was developed of extracting nucleon-nucleon (NN) cross sections in the medium directly from experiment. The in-medium NN cross sections form the basic ingredients of several heavy-ion scattering approaches including the coupled-channel approach developed at the Langley Research Center. The ratio of the real to the imaginary part of the two-body scattering amplitude in the medium was investigated. These ratios are used in combination with the in-medium NN cross sections to calculate elastic proton-nucleus cross sections. The agreement is excellent with the available experimental data. These cross sections are needed for the radiation risk assessment of space missions.
Author
Nucleon-Nucleon Interactions; Proton Scattering; Scattering Amplitude

20010057226 NASA Johnson Space Center, Houston, TX USA
Integration of the QMSFRG Database into the HZETRN Code
Cucinotta, F. A.; Shavers, M. R.; Tripathi, R. K.; Wilson, J. W.; Microgravity Materials Science Conference 2000; March 2001; Volume 1; In English; CD-ROM contains the entire Conference Proceedings presented in PDF format; No Copyright

Accurate nuclear interaction data bases are needed for describing the transport of space radiation in matter including space craft structures, atmospheres, and tissues. Transport models support the identification and development of new material concepts for human and electronic part protection. Quantum effects are manifested in nuclear reactions in several ways including interference effects between terms in the multiple scattering series, the many-body nuclear wave functions (for e.g. the roles of shell structure and Fermi momentum) and nuclear clustering. The quantum multiple scattering fragmentation

model (QMSFRG) is a comprehensive model for generating nuclear interaction databases for galactic cosmic ray (GCR) transport. Other nuclear databases including the NUCFRG model and Monte-Carlo simulation codes such as FLUKA, LAHET, HETC, and GEANT ignore quantum effects. These codes fail to describe many important features of nuclear reactions and are thus inaccurate for the evaluation of materials for radiation protection. Previously we have shown that quantum effects are manifested through constructive interference in forward production spectra, the effects of Fermi momentum on production spectra, cluster nuclei knockout, and the nuclear response function. Quantum effects are especially important for heavy ions with mass numbers less than 20 that dominate radiation transport in human tissues and for the materials that are expected to be superior in space radiation protection. We describe the integration of the QMSFRG model into the HZETRN transport code. Integration milestones include proper treatment of odd-even charge-mass effects in nuclear fragmentation and the momentum distribution of nucleon production from GCR primary heavy ions. We have also modified the two-body amplitudes in the model to include nuclear medium effects. In order to include a comprehensive description of the GCR isotopic composition in materials, we have described the isotopic composition of the GCR by extending the 59-isotope version of HZETRN to an 120-isotope version. The isotopic composition of most primary GCR elements (including H, He, C, N, O, Ne, Mg, Si, Ar, Ca, Cr, and Fe) are included in the extended model. We discuss results for the high-energy neutron composition inside materials, and the charge and mass distribution for benchmark GCR problems.
Author

Data Bases; Applications Programs (Computers); Galactic Cosmic Rays; Radiation Transport; Nuclear Particles; Nuclear Interactions

20010057333 NASA Langley Research Center, Hampton, VA USA

Improved Spacecraft Materials for Radiation Protection

Wilson, John W.; Cucinotta, Francis A.; Tripathi, Ram K.; Clowdsley, M. S.; Shinn, J. L.; Singleterry, Robert C., Jr.; Thibeault, Sheila Ann; Kim, M.-H. Y.; Heinbockel, John H.; Badhwar, Gautam D., et al.; Microgravity Materials Science Conference 2000; March 2001; Volume 3; In English; CD-ROM contains the entire Conference Proceedings presented in PDF format; No Copyright; Avail: CASI

Methods by which radiation shielding is optimized need to be developed and materials of improved shielding characteristics identified and validated. The galactic cosmic rays (GCR) are very penetrating and the energy absorbed by the astronaut behind the shield is nearly independent of shield composition and even the shield thickness. However, the mix of particles in the transmitted beam changes rapidly with shield material composition and thickness. This results in part from the breakup of the high-energy heavy ions of the GCR which make contributions to biological effects out of proportion to their deposited energy. So the mixture of particles in the radiation field changes with shielding and the control of risk contributions from dominant particle types is critical to reducing the hazard to the astronaut. The risk of biological injury for a given particle type depends on the type of biological effect and is specific to cell or tissue type. Thus, one is faced with choosing materials which may protect a given tissue against a given effect but leave unchanged or even increase the risk of other effects in the same tissue or increase the risks to other adjacent tissues of a different type in the same individual. The optimization of shield composition will then be tied to a specific tissue and risk to that tissue. Such peculiarities arise from the complicated mixture of particles, the nature of their biological response, and the details of their interaction with material constituents. Aside from the understanding of the biological response to specific components, one also needs an accurate understanding of the radiation emerging from the shield material. This latter subject has been a principal element of this project. In the past ten years our understanding of space radiation interactions with materials has changed radically, with a large impact on shield design. For example, the NCRP estimated that only 2 g/sq cm. of aluminum would be required to meet the annual 500 mSv limit for the exposure of the blood forming organs (this limit is strictly for LEO but can be used as a guideline for the Mars mission analysis). The current estimates require aluminum shield thicknesses above 50 g/sq cm., which is impractical. In such a heavily shielded vehicle, the neutrons produced throughout the vehicle also contribute significantly to the exposure and this demands greater care in describing the angular dependence of secondary particle production processes. As such the continued testing of databases and transport procedures in laboratory and spaceflight experiments has continued. This has been the focus of much of the last year's activity and has resulted in improved neutron prediction capability. These new methods have also improved our understanding of the surface environment of Mars. The Mars 2003 NRA HEDS related surface science requirements were driven by the need to validate predictions on the upward flux of neutrons produced in the Martian regolith and bedrock made by the codes developed under this project. The codes used in the surface environment definition are also being used to look at in situ resources for the development of construction material for Martian surface facilities. For example, synthesis of polyimides and polyethylene as binders of regolith for developing basic structural elements has been studied and targets built for accelerator beam testing of radiation shielding properties. Preliminary mechanical tests have also been promising. Improved spacecraft materials have been identified (using the criteria reported by this project at the last conference)

as potentially important for future shielding materials. These are liquid hydrogen, hydrogenated nanofibers, liquid methane, LiH, Polyethylene, Polysulfone, and Polyetherimide (in order of decreasing shield performance). Some of the materials are multifunctional and are required for other onboard systems. We are currently preparing software for trade studies with these materials relative to the Mars Reference Mission as required in the project's final year.
Author
Radiation Protection; Radiation Shielding; Heavy Ions; Aluminum; Liquefied Gases

20010085361 NASA Langley Research Center, Hampton, VA USA
Approach and Issues Relating to Shield Material Design to Protect Astronauts from Space Radiation
Wilson, J. W.; Cucinotta, F. A.; Miller, J.; Shinn, J. L.; Thibeault, S. A.; Singleterry, R. C.; Simonsen, L. C.; Kim, M. H.; Materials and Design; 2001; ISSN 0261-3069; Volume 22; In English; Copyright; Avail: Other Sources

One major obstacle to human space exploration is the possible limitations imposed by the adverse effects of long-term exposure to the space environment. Even before human spaceflight began, the potentially brief exposure of astronauts to the very intense random solar energetic particle (SEP) events was of great concern. A new challenge appears in deep space exploration from exposure to the low-intensity heavy-ion flux of the galactic cosmic rays (GCR) since the missions are of long duration and the accumulated exposures can be high. Since aluminum (traditionally used in spacecraft to avoid potential radiation risks) leads to prohibitively expensive mission launch costs, alternative materials need to be explored. An overview of the materials related issues and their impact on human space exploration will be given.
Author
Aluminum; Energetic Particles; Extraterrestrial Radiation; Galactic Cosmic Rays; Launch Costs; Space Exploration; Radiation Shielding

20020020361 NASA Marshall Space Flight Center, Huntsville, AL USA
Cancer Risk Assessment for Space Radiation
Richmond, Robert C.; Cruz, Angela; Bors, Karen; Curreri, Peter A., Technical Monitor; [2001]; In English; International Workshop on Micro and Mini Dosimetry and Its Applications, 16-20 Dec. 2001, Sydney, Australia; No Copyright; Avail: Other Sources

Predicting the occurrence of human cancer following exposure to any agent causing genetic damage is a difficult task. This is because the uncertainty of uniform exposure to the damaging agent, and the uncertainty of uniform processing of that damage within a complex set of biological variables, degrade the confidence of predicting the delayed expression of cancer as a relatively rare event within any given clinically normal individual. The radiation health research priorities for enabling long-duration human exploration of space were established in the 1996 NRC Report entitled 'Radiation Hazards to Crews of Interplanetary Missions: Biological Issues and Research Strategies'. This report emphasized that a 15-fold uncertainty in predicting radiation-induced cancer incidence must be reduced before NASA can commit humans to extended interplanetary missions. That report concluded that the great majority of this uncertainty is biologically based, while a minority is physically based due to uncertainties in radiation dosimetry and radiation transport codes. Since that report, the biologically based uncertainty has remained large, and the relatively small uncertainty associated with radiation dosimetry has increased due to the considerations raised by concepts of microdosimetry. In a practical sense, however, the additional uncertainties introduced by microdosimetry are encouraging since they are in a direction of lowered effective dose absorbed through infrequent interactions of any given cell with the high energy particle component of space radiation. Additional information is contained in the original extended abstract.
Derived from text
Cancer; Exposure; Extraterrestrial Radiation; Radiation Dosage; Risk

20010048177 NASA Marshall Space Flight Center, Huntsville, AL USA
Radiation Shielding Materials
Adams, James H., Jr.; Rose, M. Franklin, Technical Monitor; [2001]; In English; AIAA Conference, 9 Jan. 2001, Reno, NV, USA; No Copyright; Avail: Other Sources

NASA has relied on the materials to provide radiation shielding for astronauts since the first manned flights. Until very recently existing materials in the structure of manned spacecraft as well as the equipment and consumables onboard have been taken advantage of for radiation shielding. With the advent of the International Space Station and the prospect of extended missions to the Moon or Mars, it has been found that the materials, which were included in the spacecraft for other reasons, do not provide adequate shielding. For the first time materials are being added to manned missions solely to improve the

radiation shielding. It is now recognized that dual use materials must be identified/developed. These materials must serve a purpose as part of the spacecraft or its cargo and at the same time be good shielding. This paper will review methods for evaluating the radiation shielding effectiveness of materials and describe the character of materials that have high radiation shielding effectiveness. Some candidate materials will also be discussed.
Author
Radiation Shielding; Absorbers (Materials); Electromagnetic Absorption; Electromagnetic Shielding; Reactor Materials

20010066733 Old Dominion Univ., Norfolk, VA USA
A Study of Green's Function Methods Applied to Space Radiation Protection
Heinbockel, John H.; [2001]; In English
Contract(s)/Grant(s): NCC1-320; No Copyright; Avail: CASI

The purpose of this research was to study the propagation of galactic ions through various materials. Galactic light ions result from the break up of heavy ion particles and their propagation through materials is modeled using the one-dimensional Boltzmann equation. When ions enter materials there can occur (i) the interaction of ions with orbital electrons which causes ionization within the material and (ii) ions collide with atoms causing production of secondary particles which penetrate deeper within the material. These processes are modeled by a continuum model. The basic idea is to place a control volume within the material and examine the change in ion flux across this control volume. In this way on can derive the basic equations for the transport of light and heavy ions in matter. Green's function perturbation methods can then be employed to solve the resulting equations using energy dependent nuclear cross sections.
Derived from text
Green's Functions; Light Ions; Radiation Protection; Extraterrestrial Radiation; Heavy Ions

20000105025 NASA Langley Research Center, Hampton, VA USA
Proton-Nucleus Total Cross Sections in Coupled-Channel Approach
Tripathi, R. K.; Wilson, John W.; Cucinotta, Francis A.; October 2000; In English
Contract(s)/Grant(s): RTOP 101-21-23
Report No.(s): NASA/TP-2000-210534; L-17994; NAS 1.60:210534; No Copyright; Avail: CASI

Recently, nucleon-nucleon (N-N) cross sections in the medium have been extracted directly from experiment. The in-medium N-N cross sections form the basic ingredients of several heavy-ion scattering approaches including the coupled-channel approach developed at the Langley Research Center. In the present study the ratio of the real to the imaginary part of the two-body scattering amplitude in the medium was investigated. These ratios are used in combination with the in-medium N-N cross sections to calculate total proton-nucleus cross sections. The agreement is excellent with the available experimental data. These cross sections are needed for the radiation risk assessment of space missions.
Author
Nucleon-Nucleon Interactions; Ionic Collisions; Protons; Absorption Cross Sections; Coupled Modes; Mathematical Models

20000117670 Civil Aeromedical Inst., Oklahoma City, OK USA
Galactic Cosmic Radiation Exposure of Pregnant Aircrew Members, 2
Nicholas, Joyce S.; Copeland, Kyle; Duke, Frances E.; Friedberg, Wallace; OBrien, Keran, III; October 2000; In English
Contract(s)/Grant(s): AM-PHY305
Report No.(s): DOT/FAA/AM-00/33; No Copyright; Avail: CASI

This report is an updated version of a previously published Technical Note in the Journal Aviation, Space, and Environmental Medicine. The main change is that improved computer programs were used to estimate galactic cosmic radiation. The calculations also cover a greater range of altitudes. Small differences in the calculated doses were obtained, but the conclusions are the same. The International Commission on Radiological Protection (ICRP) and the Federal Aviation Administration (FAA) consider aircrews to be occupationally exposed to ionizing radiation. Although the USA has no regulations limiting aircrew exposure to cosmic radiation, the FAA has recommended limits. For pregnant crewmembers, starting when the pregnancy is reported to management, the FAA recommends: (1) a limit of one millisievert to the conceptus for the remainder of the pregnancy, in accordance with the ICRP policy/recommendation, and (2) a monthly limit of 0.5 millisievert to the conceptus, as recommended by the National Council on Radiation Protection and Measurements (NCRP). Here we address, principally, the ICRP policy. The stated ICRP policy is that a standard of radiation protection for any conceptus be broadly comparable with that provided for members of the general public, i.e. a yearly limit of one millisievert. In their 1990 recommendations, the ICRP indicated that this standard could be met by limiting the equivalent dose to the

surface of pregnant women's abdomen to two millisieverts for the remainder of the pregnancy, once declared. They apparently assumed that the equivalent does to the conceptus would be about half the dose to the surface of the abdomen. We tested this assumption with respect to galactic cosmic radiation, the principal ionizing radiation to which aircrews are exposed.
Author
Cosmic Rays; Flight Crews; Ionizing Radiation; Pregnancy; Radiation Dosage; Radiation Protection

20010021704 Civil Aeromedical Inst., Oklahoma City, OK USA, Medical Univ. of South Carolina, Charleston, SC USA, University of Northern Arizona, Flagstaff, AZ USA
Galactic Cosmic Radiation Exposure of Pregnant Aircrew Members II
Nicholas, J. S.; Copeland, K.; Duke, F. E.; Friedberg, W.; OBrien, K., III; Oct. 2000; In English
Contract(s)/Grant(s): AM-PHY305
Report No.(s): PB2001-102921; DOT/FAA/AM-00/33; No Copyright; Avail: CASI

In its 1990 recommendation regarding occupational exposure during pregnancy, the International Commission on Radiological Protection apparently assumed that the equivalent dose to a pregnant woman's abdomen is reduced by half in traversing the body to the conceptus. This assumption was tested with respect to galactic cosmic radiation, the principal ionizing radiation to which aircrews are exposed. We calculated the equivalent dose that would be received at depths of 0, 5, 10, and 15 centimeters in a 30-centimeter thick, soft-tissue slab phantom, at several locations in the atmosphere and on two air carrier flights, and found that the dose was almost the same at all the tissue depths studied. Thus, the assumption of considerable shielding of the conceptus by the woman's body is not valid with respect to galactic cosmic radiation. The effective dose of galactic radiation to the mother was found to be a good estimate of the equivalent dose to the conceptus.
NTIS
Air Transportation; Radiation Protection; Flight Crews; Cosmic Rays; Pregnancy; Galactic Radiation

20000073842 NASA Langley Research Center, Hampton, VA USA
An Improved Elastic and Nonelastic Neutron Transport Algorithm for Space Radiation
Clowdsley, Martha S.; Wilson, John W.; Heinbockel, John H.; Tripathi, R. K.; Singleterry, Robert C., Jr.; Shinn, Judy L.; July 2000; In English
Contract(s)/Grant(s): RTOP 101-21-23
Report No.(s): NASA/TP-2000-210299; L-17971; NAS 1.60:210299; No Copyright; Avail: CASI

A neutron transport algorithm including both elastic and nonelastic particle interaction processes for use in space radiation protection for arbitrary shield material is developed. The algorithm is based upon a multiple energy grouping and analysis of the straight-ahead Boltzmann equation by using a mean value theorem for integrals. The algorithm is then coupled to the Langley HZETRN code through a bidirectional neutron evaporation source term. Evaluation of the neutron fluence generated by the solar particle event of February 23, 1956, for an aluminum water shield-target configuration is then compared with MCNPX and LAHET Monte Carlo calculations for the same shield-target configuration. With the Monte Carlo calculation as a benchmark, the algorithm developed in this paper showed a great improvement in results over the unmodified HZETRN solution. In addition, a high-energy bidirectional neutron source based on a formula by Ranft showed even further improvement of the fluence results over previous results near the front of the water target where diffusion out the front surface is important. Effects of improved interaction cross sections are modest compared with the addition of the high-energy bidirectional source terms.
Author
Neutron Sources; Algorithms; Particle Interactions; Shielding; Boltzmann Transport Equation; Radiation Protection; Extraterrestrial Radiation; Elastic Properties

20010023088 NASA Johnson Space Center, Houston, TX USA
End-To-End Risk Assesment: From Genes and Protein to Acceptable Radiation Risks for Mars Exploration
Cucinotta, Francis A.; Schimmerling, Walter; Concepts and Approaches for Mars Exploration; July 2000, Part 1; In English; No Copyright; Avail: CASI

The human exploration of Mars will impose unavoidable health risks from galactic cosmic rays (GCR) and possibly solar particle events (SPE). It is the goal of NASA's Space Radiation Health Program to develop the capability to predict health risks with significant accuracy to ensure that risks are well below acceptable levels and to allow for mitigation approaches to be effective at reasonable costs. End-to-End risk assessment is the approach being followed to understand proton and heavy ion damage at the molecular, cellular, and tissue levels in order to predict the probability of the major health risk including

cancer, neurological disorders, hereditary effects, cataracts, and acute radiation sickness and to develop countermeasures for mitigating risks.
Derived from text
Mars Exploration; Aerospace Safety; Risk; Assessments; Radiation Hazards

20000057013 NASA Langley Research Center, Hampton, VA USA
Materials for Low-Energy Neutron Radiation Shielding
Singleterry, Robert C., Jr.; Thibeault, Sheila A.; June 2000; In English
Contract(s)/Grant(s): RTOP 101-15-01-51
Report No.(s): NASA/TP-2000-210281; NAS 1,60:210281; L-17773; No Copyright; Avail: CASI

Various candidate aircraft and spacecraft materials were analyzed and compared in a low-energy neutron environment using the Monte Carlo N-Particle (MCNP) transport code with an energy range up to 20 MeV. Some candidate materials have been tested in particle beams, and others seemed reasonable to analyze in this manner before deciding to test them. The two metal alloys analyzed are actual materials being designed into or used in aircraft and spacecraft today. This analysis shows that hydrogen-bearing materials have the best shielding characteristics over the metal alloys. It also shows that neutrons above 1 MeV are reflected out of the face of the slab better by larger quantities of carbon in the material. If a low-energy absorber is added to the material, fewer neutrons are transmitted through the material. Future analyses should focus on combinations of scatterers and absorbers to optimize these reaction channels and on the higher energy neutron component (above 50 MeV).
Author
Alloys; Hydrogen; Technology Assessment; Radiation Shielding

20000031890 NASA Langley Research Center, Hampton, VA USA
An Improved Neutron Transport Algorithm for Space Radiation
Heinbockel, John H.; Clowdsley, Martha S.; Wilson, John W.; March 2000; In English
Contract(s)/Grant(s): RTOP 101-15-01-51
Report No.(s): NASA/TP-2000-209865; NAS 1.60:209865; L-17876; No Copyright; Avail: CASI

A low-energy neutron transport algorithm for use in space radiation protection is developed. The algorithm is based upon a multigroup analysis of the straight-ahead Boltzmann equation by using a mean value theorem for integrals. This analysis is accomplished by solving a realistic but simplified neutron transport test problem. The test problem is analyzed by using numerical and analytical procedures to obtain an accurate solution within specified error bounds. Results from the test problem are then used for determining mean values associated with rescattering terms that are associated with a multigroup solution of the straight-ahead Boltzmann equation. The algorithm is then coupled to the Langley HZETRN code through the evaporation source term. Evaluation of the neutron fluence generated by the solar particle event of February 23, 1956, for a water and an aluminum-water shield-target configuration is then compared with LAHET and MCNPX Monte Carlo code calculations for the same shield-target configuration. The algorithm developed showed a great improvement in results over the unmodified HZETRN solution. In addition, a two-directional solution of the evaporation source showed even further improvement of the fluence near the front of the water target where diffusion from the front surface is important.
Author
Neutrons; Algorithms; Radiation Protection; Mathematical Models; Applications Programs (Computers); Extraterrestrial Radiation

20000097896 NASA Langley Research Center, Hampton, VA USA
Neutrons in Space: Shield Models and Design Issues
Wilson, J. W.; Clowdsley, M. S.; Shinn, J. L.; Singleterry, R. C.; Tripathi, R. K.; Cucinotta, F. A.; Heinbockel, J. H.; Badavi, F. F.; Atwell, W.; [2000]; ISSN 0148-7191; In English; 30th, 10-13 Jul. 2000, Toulouse, France
Report No.(s): SAE Paper 00ICES-377; Copyright; Avail: Other Sources

The normal working and living areas of the astronaut are designed to provide an acceptable level of protection against the hazards of ionizing space radiation. Attempts to reduce the exposures require intervening shield materials to reduce the transmitted radiation. An unwelcome side effect of the shielding is the production of neutrons, which are themselves dangerous particles that can be (but are not always) more hazardous than the particles that produced them. This is especially true depending on the choice of shield materials. Although neutrons are not a normal part of the space environment, this paper focuses on them as principle component of astronaut exposure in the massive spacecrafts required for human space travel and

habitation near planetary surfaces or other large bodies of material in space.
Author
Ionizing Radiation; Shielding; Protection; Neutrons; Exposure; Astronauts

20000083354 NASA Johnson Space Center, Houston, TX USA
Radiation Physics for Space and High Altitude Air Travel
Cucinotta, F. A.; Wilson, J. W.; Goldhagen, P.; Saganti, P.; Shavers, M. R.; McKay, Gordon A., Technical Monitor; [2000]; In English; 11th 11th International Congress on Radiation Res., 11-15 Jul. 2000, Dublin, Ireland; No Copyright; Avail: Other Sources

Galactic cosmic rays (GCR) are of extra-solar origin consisting of high-energy hydrogen, helium, and heavy ions. The GCR are modified by physical processes as they traverse through the solar system, spacecraft shielding, atmospheres, and tissues producing copious amounts of secondary radiation including fragmentation products, neutrons, mesons, and muons. We discuss physical models and measurements relevant for estimating biological risks in space and high-altitude air travel. Ambient and internal spacecraft computational models for the International Space Station and a Mars mission are discussed. Risk assessment is traditionally based on linear addition of components. We discuss alternative models that include stochastic treatments of columnar damage by heavy ion tracks and multi-cellular damage following nuclear fragmentation in tissue.
Author
Radiation Chemistry; Aerospace Environments; High Altitude; Air Transportation; Galactic Cosmic Rays; Hydrogen Ions; Helium Ions; Heavy Ions

20000004258 NASA Langley Research Center, Hampton, VA USA
Universal Parameterization of Absorption Cross Sections
Tripathi, R. K.; Cucinotta, Francis A.; Wilson, John W.; December 1999; In English
Contract(s)/Grant(s): RTOP 111-10-50
Report No.(s): NASA/TP-1999-209726; NAS 1.60:209726; L-17832; No Copyright; Avail: CASI

Our prior nuclear absorption cross sections model is extended for light systems (A less than or equal to 4) where either both projectile and target are light particles or one is a light particle and the other is a medium or heavy nucleus. The agreement with experiment is excellent for these cases as well. Present work in combination with our original model provides a comprehensive picture of absorption cross sections for light, medium, and heavy systems, a very valuable input for radiation protection studies.
Author
Absorption Cross Sections; Mathematical Models; Parameter Identification; Light (Visible Radiation)

20000029485 Johns Hopkins Univ., Baltimore, MD USA
Radiation Effects: Core Project
Dicello, John F.; National Space Biomedical Research Institute; Sep. 30, 1999; In English; No Copyright; Avail: CASI

The risks to personnel in space from the naturally occurring radiations are generally considered to be one of the most serious limitations to human space missions, as noted in two recent reports of the National Research Council/National Academy of Sciences. The Core Project of the Radiation Effects Team for the National Space Biomedical Research Institute is the consequences of radiations in space in order to develop countermeasure, both physical and pharmaceutical, to reduce the risks of cancer and other diseases associated with such exposures. During interplanetary missions, personnel in space will be exposed to galactic cosmic rays, including high-energy protons and energetic ions with atomic masses of iron or higher. In addition, solar events will produce radiation fields of high intensity for short but irregular durations. The level of intensity of these radiations is considerably higher than that on Earth's surface, and the biological risks to astronauts is consequently increased, including increased risks of carcinogenesis and other diseases. This group is examining the risk of cancers resulting from low-dose, low-dose rate exposures of model systems to photons, protons, and iron by using ground-based accelerators which are capable of producing beams of protons, iron, and other heavy ions at energies comparable to those encountered in space. They have begun the first series of experiments using a 1-GeV iron beam at the Brookhaven National Laboratory and 250-MeV protons at Loma Linda University Medical Center's proton synchrotron facility. As part of these studies, this group will be investigating the potential for the pharmaceutical, Tamoxifen, to reduce the risk of breast cancer in astronauts exposed to the level of doses and particle types expected in space. Theoretical studies are being carried out in a collaboration between scientists at NASA's Johnson Space Center and Johns Hopkins University in parallel with the experimental program have provided methods and predictions which are being used to assess the levels of risks to be encountered and to evaluate

appropriate strategies for countermeasures. Although the work in this project is primarily directed toward problems associated with space travel, the problem of protracted exposures to low-levels of radiation is one of national interest in our energy and defense programs, and the results may suggest new paradigms for addressing such risks.
Author
Cancer; Radiation Effects; Biological Effects; Physiological Effects; Aerospace Medicine; Bioastronautics; Health Physics; Radiation Injuries; Countermeasures

20000029496 Johns Hopkins Univ., Baltimore, MD USA
Chemoprevention of Radiation Induced Rat Mammary Neoplasms
Huso, David L.; National Space Biomedical Research Institute; Sep. 30, 1999; In English; No Copyright; Avail: CASI

Radiations encountered in space include protons and heavy ions such as iron as well as their secondaries. The relative biological effect (RBE) of these ions is not known, particularly at the doses and dose-rates expected for planetary missions. Neutrons, are not particularly relevant to space travel, but have been found experimentally to have an increase in their RBE with decreasing dose. If a similar trend of increasing RBE with decreasing dose is present for heavy ions and protons during irradiation in space, the small doses received during space travel could potentially have substantial carcinogenic risk. Clearly more investigation of the effects of heavy ions and protons is needed before accurate risk assessment for prolonged travel in space can be done. One means to mitigate the increased risk of cancer due to radiation exposure in space is by developing effective countermeasures that can reduce the incidence of tumor development. Tamoxifen has recently been shown to be an effective chemopreventive agent in both animal models and humans for the prevention of mammary tumors. Tamoxifen is a unique drug, with a highly specific mechanism of action affecting a specific radiation-sensitive population of epithelial cells in the mammary gland. In human studies, the annual incidence of a primary tumor in the contralateral breast of women with previous breast cancer is about 8 per 1000, making them an exceedingly high-risk group for the development of breast cancer. In this high risk group, treated with tamoxifen, daily, for 2 years, the incidence of a new primary tumor in the contralateral breast was approximately one third of that noted in the non-tamoxifen treatment group. Tamoxifen antagonizes the action of estrogen by competing for the nuclear receptor complex thereby altering the association of the receptor complex and nuclear binding sites. Its effects in reducing the development of breast cancer could be accomplished by controlling clinically undetectable microcancers, arresting preneoplastic lesions, or correcting abnormal environments which predispose to high risk of malignant transformation.
Derived from text
Cancer; Carcinogens; Mammary Glands; Prevention; Radiation Effects; Relative Biological Effectiveness (RBE); Tumors; Neoplasms; Health Physics; Aerospace Medicine

19990070313 NASA Langley Research Center, Hampton,VA USA
Solar Cycle Variation and Application to the Space Radiation Environment
Wilson, John W.; Kim, Myung-Hee Y.; Shinn, Judy L.; Tai, Hsiang; Cucinotta, Francis A.; Badhwar, Gautam D.; Badavi, Francis F.; Atwell, William; September 1999; In English; Original has color illustrations
Contract(s)/Grant(s): RTOP 199-45-16-12
Report No.(s): NASA/TP-1999-209369; L-17780; NAS 1.60:209369; No Copyright; Avail: CASI

The interplanetary plasma and fields are affected by the degree of disturbance that is related to the number and types of sunspots in the solar surface. Sunspot observations were improved with the introduction of the telescope in the seventeenth century, allowing observations which cover many centuries. A single quantity (sunspot number) was defined by Wolf in 1848 that is now known to be well correlated with many space observable quantities and is used herein to represent variations caused in the space radiation environment. The resultant environmental models are intended for future aircraft and space-travel-related exposure estimates.
Author
Extraterrestrial Radiation; Interplanetary Medium; Space Plasmas; Sunspots; Solar Cycles; Cosmic Rays; Solar Activity Effects

19990051001 NASA Langley Research Center, Hampton, VA USA
Contribution of High Charge and Energy (HZE) Ions During Solar-Particle Event of September 29, 1989
Kim, Myung-Hee Y.; Wilson, John W.; Cucinotta, Francis A.; Simonsen, Lisa C.; Atwell, William; Badavi, Francis F.; Miller, Jack; May 1999; In English
Contract(s)/Grant(s): RTOP 199-45-16-12
Report No.(s): NASA/TP-1999-209320; L-17744; NAS 1.60:209320; No Copyright; Avail: CASI

The solar-particle event (SPE) of September 29, 1989, produced an iron-rich spectrum with energies approaching 1 A GeV with an approximate spectral slope parameter of 2.5. These high charge and energy (HZE) ions challenge conventional methods of shield design and assessment of astronaut risks. In the past, shield design and risk assessment have relied on proton shielding codes and biological response models derived from X-ray and neutron exposure data. Because the HZE spectra decline rapidly with energy and HZE attenuation in materials is limited by their penetration power, details of the mass distributions about the sensitive tissues (shielding materials and the astronaut's body) are important determining factors of the exposure levels and distributions of linear energy transfer. Local tissue environments during the SPE of September 29, 1989, with its f= components are examined to analyze the importance of these ions to human SPE exposure. Typical space suit and lightly shielded structures leave significant contributions from HZE components to certain critical body tissues and have important implications on the models for risk assessment. A heavily shielded equipment room of a space vehicle or habitat requires knowledge of the breakup of these ions into lighter components, including neutrons, for shield design specifications.
Author
Solar Flares; Solar Storms; Solar Corpuscular Radiation; Linear Energy Transfer (LET); Ions; Mass Distribution; Absorbers (Materials)

19990035994 NASA Langley Research Center, Hampton,VA USA
A Simple Method for Nucleon-Nucleon Cross Sections in a Nucleus
Tripathi, R. K.; Cucinotta, Francis A.; Wilson, John W.; April 1999; In English
Contract(s)/Grant(s): NCC1-242; RTOP 199-45-16-11
Report No.(s): NASA/TP-1999-209125; L-17791; NAS 1.60:209125; No Copyright; Avail: CASI

A simple reliable formalism is presented for obtaining nucleon-nucleon cross sections within a nucleus in nuclear collisions for a given projectile and target nucleus combination at a given energy for use in transport, Monte Carlo, and other calculations. The method relies on extraction of these values from experiments and has been tested and found to give excellent results.
Author
Nucleon-Nucleon Interactions; Formalism; Absorption Cross Sections

19990036754 NASA Langley Research Center, Hampton,VA USA
Aircraft Radiation Shield Experiments--Preflight Laboratory Testing
Singleterry, Robert C., Jr.; Shinn, Judy L.; Wilson, John W.; Maiden, Donald L.; Thibeault, Sheila A.; Badavi, Francis F.; Conroy, Thomas; Braby, Leslie; Apr. 1999; In English
Contract(s)/Grant(s): RTOP 199-45-16-12
Report No.(s): NASA/TM-1999-209131; L-17764; NAS 1.15:209131; No Copyright; Avail: CASI

In the past, measurements onboard a research Boeing 57F (RB57-F) aircraft have demonstrated that the neutron environment within the aircraft structure is greater than that in the local external environment. Recent studies onboard Boeing 737 commercial flights have demonstrated cabin variations in radiation exposure up to 30 percent. These prior results were the basis of the present study to quantify the potential effects of aircraft construction materials on the internal exposures of the crew and passengers. The present study constitutes preflight measurements using an unmoderated Cf-252 fission neutron source to quantify the effects of three current and potential aircraft materials (aluminum, titanium, and graphite-epoxy composite) on the fast neutron flux. Conclusions about the effectiveness of the three selected materials for radiation shielding must wait until testing in the atmosphere is complete; however, it is clear that for shielding low-energy neutrons, the composite material is an improved shielding material over aluminum or titanium.
Author
Radiation Shielding; Aircraft Structures; Aircraft Construction Materials; Ionizing Radiation; Flight Tests

19990050998 Eril Research, Inc., San Rafael, CA USA
A Survey of Radiation Measurements Made Aboard Russian Spacecraft in Low-Earth Orbit
Benton, E. R.; Benton, E. V.; March 1999; In English
Contract(s)/Grant(s): NAS8-40294
Report No.(s): NASA/CR-1999-209256; M-920; NAS 1.26:209256; No Copyright; Avail: CASI

The accurate prediction of ionizing radiation exposure in low-Earth orbit is necessary in order to minimize risks to astronauts, spacecraft and instrumentation. To this end, models of the radiation environment, the AP-8 trapped proton model and the AE-8 trapped electron model, have been developed for use by spacecraft designers and mission planners. It has been

widely acknowledged for some time now by the space radiation community that these models possess some major shortcomings. Both models cover only a limited trapped particle energy region and predictions at low altitudes are extrapolated from higher altitude data. With the launch of the first components of the International Space Station with numerous constellations of low-Earth orbit communications satellites now being planned and deployed, the inadequacies of these trapped particle models need to be addressed. Efforts are now underway both in the U.S. and in Europe to refine the AP-8 and AE-8 trapped particle models. This report is an attempt to collect a significant fraction of data for use in validation of trapped radiation models at low altitudes.
Author
Radiation Dosage; Extraterrestrial Radiation; Ionizing Radiation; Low Earth Orbits; Particle Energy

19990040264 NASA Johnson Space Center, Houston, TX USA
Evaluation of Spacecraft Shielding Effectiveness for Radiation Protection
Cucinotta, Francis A.; Wilson, John W.; NASA Microgravity Materials Science Conference; February 1999; In English; No Copyright; Avail: CASI

The potential for serious health risks from solar particle events (SPE) and galactic cosmic rays (GCR) is a critical issue in the NASA strategic plan for the Human Exploration and Development of Space (HEDS). The excess cost to protect against the GCR and SPE due to current uncertainties in radiation transmission properties and cancer biology could be exceedingly large based on the excess launch costs to shield against uncertainties. The development of advanced shielding concepts is an important risk mitigation area with the potential to significantly reduce risk below conventional mission designs. A key issue in spacecraft material selection is the understanding of nuclear reactions on the transmission properties of materials. High-energy nuclear particles undergo nuclear reactions in passing through materials and tissue altering their composition and producing new radiation types. Spacecraft and planetary habitat designers can utilize radiation transport codes to identify optimal materials for lowering exposures and to optimize spacecraft design to reduce astronaut exposures. To reach these objectives will require providing design engineers with accurate data bases and computationally efficient software for describing the transmission properties of space radiation in materials. Our program will reduce the uncertainty in the transmission properties of space radiation by improving the theoretical description of nuclear reactions and radiation transport, and provide accurate physical descriptions of the track structure of microscopic energy deposition.
Author
Extraterrestrial Radiation; Radiation Transport; Spacecraft Shielding; Radiation Shielding; Radiation Protection

19990040361 NASA Langley Research Center, Hampton, VA USA
Improved Spacecraft Materials for Radiation Shielding
Wilson, J. W.; Shinn, J. L.; Singleterry, R. C.; Tai, H.; Thibeault, S. A.; Simonsen, L. C.; Cucinotta, F. A.; Miller, J.; NASA Microgravity Materials Science Conference; February 1999; In English; No Copyright; Avail: CASI

In the execution of this proposal, we will first examine current and developing spacecraft materials and evaluate their ability to attenuate adverse biological mutational events in mammalian cell systems and reduce the rate of cancer induction in mice harderian glands as a measure of their protective qualities. The HZETRN code system will be used to generate a database on GCR attenuation in each material. If a third year of funding is granted, the most promising and mission-specific materials will be used to study the impact on mission cost for a typical Mars mission scenario as was planned in our original two year proposal at the original funding level. The most promising candidate materials will be further tested as to their transmission characteristics in Fe and Si ion beams to evaluate the accuracy of the HZETRN transmission factors. Materials deemed critical to mission success may also require testing as well as materials developed by industry for their radiation protective qualities (e.g., Physical Sciences Inc.) A study will be made of designing polymeric materials and composite materials with improved radiation shielding properties as well as the possible improvement of mission-specific materials.
Derived from text
Spacecraft Shielding; Radiation Shielding; Spacecraft Construction Materials; Radiation Hazards; Galactic Cosmic Rays

19990041014 NASA Johnson Space Center, Houston, TX USA
Monitoring and Modeling Astronaut Occupational Radiation Exposures in Space: Recent Advances
Weyland, Mark; Golightly, Michael; Proceedings from the 1998 Occupational Health Conference: Benchmarking for Excellence; February 1999; In English; No Copyright; Avail: Other Sources

In 1982 astronauts were declared to be radiation workers by OSHA, and as such were subject to the rules and regulations applied to that group. NASA was already aware that space radiation was a hazard to crewmembers and had been studying and

monitoring astronaut doses since 1962 at the Johnson Space Center. It was quickly realized NASA would not be able to accomplish all of its goals if the astronauts were subject to the ground based radiation worker limits, and thus received a waiver from OSHA to establish independent limits. As part of the stipulation attached to setting new limits, OSHA included a requirement to perform preflight dose projections for each crew and inform them of the associated risks. Additional requirements included measuring doses from various sources during the flight, making every effort to prevent a crewmember from exceeding the new limits, and keeping all exposures As Low As Reasonably Achievable (a.k.a. ALARA - a common health physics principle). The assembly of the International Space Station (ISS) and its initial manned operations will coincide with the 4-5 year period of high space weather activity at the next maximum in the solar cycle. For the first time in NASA's manned program, US astronauts will be in orbit continuously throughout a solar maximum period. During this period, crews are at risk of significantly increased radiation exposures due to solar particle events and trapped electron belt enhancements following geomagnetic storms. The problem of protecting crews is compounded by the difficulty of providing continuous real-time monitoring over a period of a decade in an era of tightly constrained budgets. In order to prepare for ISS radiological support needs, the NASA Space Radiation Analysis Group and the NOAA Space Environment Center have undertaken 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 a high-fidelity space weather simulation system. In addition, significant new real-time space weather data sets, which will enhance the forecasting and now-casting of near-Earth space environment conditions, are being made available through unique NASA-NOAA-USAF collaborations. These new data sets include coronal mass ejection monitoring by the Solar and Heliospheric Observatory (SOHO) and in-situ plasma and particle monitoring at the L1 libration point by the Solar Wind Monitor (SWIM) and Advanced Composition Explorer (ACE) spacecraft. Advanced real-time radiation monitoring data from charged particle telescopes and tissue equivalent proportional counters will also be available to assist crew and flight controllers in monitoring the external and intravehicular radiation environment.
Author
Aerospace Environments; Solar Activity Effects; Radiation Dosage; Radiation Hazards; Solar Radiation

20000020638 California Univ., Lawrence Berkeley Lab., Berkeley, CA USA
Simulation of Clusters of DNA Damage Induced by Ionizing Radiation Encountered in Spaceflight
Chatterjee, A.; Holley, W. R.; Mian, I. S.; Proceedings of the First Biennial Space Biomedical Investigators' Workshop; 1999; In English; No Copyright; Avail: CASI

Energetic Protons and Heavy Charged particles are present in the Galactic Cosmic Rays (GCR). Thus, an assessment of their possible harmful health effects to astronauts in long duration space flights above the earth's magnetic field is of high priority in NASA supported research. The research presented here is from our efforts in the NASA Specialized Center of Research and Training related to Radiation Health. Theoretical modeling of radiobiological effects of charged particles found in the GCR can provide very useful information which may not be obtainable through experiments alone. One such example is the production of clusters of damage by tracks of charged particles interacting with cellular DNA. Based on our general theory of radiation damage to DNA, it has been demonstrated that several damaged sites (base damage, single strand breaks and double strand breaks) can be produced in close proximity, generally within twenty base pairs. The severity of the clustering can vary greatly based on the quality of radiation. One recurring theme in our studies and a feature which distinguishes radiation damage from most other types of insult to DNA is the strong spatial correlations in the damage. The next obvious question is what are the biological consequences of such clustering? Furthermore, since clustering of damaged sites cannot be measured directly, is it possible to correlate theoretical estimates of the frequencies with which certain types of clusters are generated by particle tracks with selected biological end points? In this presentation, we demonstrate our initial efforts in correlating clusters of damage with experimentally measured unrejoined double strand breaks.
Author
Radiation Damage; Simulation; Radiobiology; Mathematical Models; Ionizing Radiation; Health; Estimates; Damage

20000020635 San Francisco Univ., CA USA
Radiation Dosimetry on Manned Space Missions and at Ground-Based Accelerators
Benton, E. V.; Benton, E. R.; Frank, A. L.; Moyers, M. M.; Proceedings of the First Biennial Space Biomedical Investigators' Workshop; 1999; In English; No Copyright; Avail: CASI

Exposure to ionizing radiation of space crews engaged in long-term space missions such as on space stations, Lunar bases and trips to Mars, poses a set of complex scientific and technological problems which are being resolved on the road toward achieving adequate radiation protection. At the same time, both space and ground-based radiobiological experiments, and

radiation sensitive biomedical experiments require adequate dosimetric support. In both areas, passive radiation detectors have in the past and are now playing an important role. Recently we have been conducting two separate but related experiments involving environmental radiation measurements aboard the Russian Mir Space Station and ground-based accelerators aimed at clarifying the role of proton-induced target fragmentation.
Author
Radiation Detectors; Ionizing Radiation; Sensitivity; Radiobiology; Radiation Protection

19990111741 NASA Langley Research Center, Hampton, VA USA
Accurate Universal Parameterization of Absorption Cross Sections, 3, Light Systems
Tripathi, R. K.; Cucinotta, F. A.; Wilson, J. W.; Nuclear Instruments and Methods in Physics Research B: Beam Interactions With Materials and Atoms; 1999; ISSN 0168-583X; Volume 155; In English; Copyright; Avail: Other Sources

Our prior nuclear absorption cross sections model is extended for light systems (A less than or equal to 4) where either both projectile and target are light particles or one is light particle and the other is medium or heavy nucleus. The agreement with experiment is excellent for these cases as well. Present work in combination with our original model provides a comprehensive picture of absorption cross sections for light, medium and heavy systems. As a result the extended model can reliably be used in all studies where there is a need for absorption cross sections.
Author
Absorption Cross Sections; Nuclear Models; Accuracy

20000020634 California Univ., Lawrence Berkeley Lab., Berkeley, CA USA
Comparison of Gamma and Iron Particle Irradiation Induced Remodeling of Extra Cellular Matrix in Murine Liver
Barcellos-Hoff, M. H.; Wang, C.; Ravani, S. A.; Proceedings of the First Biennial Space Biomedical Investigators' Workshop; 1999; In English; No Copyright; Avail: CASI

Cells in tissues exist in complex microenvironments that mediate phenotype and cell interactions. Microenvironments, which includes the insoluble extracellular matrix (ECM) and soluble cytokines, also modulate cellular response to stimuli, which in turn may modify the microenvironment. Our studies have demonstrated rapid and global remodeling of the microenvironment in irradiated murine mammary gland and have identified characteristics of the High ionizing high energy particles (HZE)-irradiated remodeling that are distinct from those following sparsely ionizing radiation. The hypothesis is that certain effects of HZE particles cause specific modifications of tissue microenvironment as compared to reference gamma-radiation. This in turn is postulated to contribute to the functional and carcinogenic cellular effects of HZE exposure. Identification of HZE-induced changes in the microenvironment will provide insight into how fundamental cellular effects are integrated into multicellular tissue responses. The goal of this study was to evaluate early (1 hr - 7 day) temporal and spatial changes in the composition of the irradiated liver microenvironment as a function of radiation quality and dose or particle fluence. Comparison of liver to mammary gland in terms of microenvironment remodeling may provide insight into mechanisms. Tissue-dependent changes are most likely to be the result of particular cellular response to radiation and may reveal specific mechanisms that underlie tissue sensitivity to radiation of various qualities important to the environment in space.
Author
Gamma Rays; Iron; Irradiation; Radiation Effects; Particle Energy; Exposure; Dosage

20000020631 California Univ., Lawrence Berkeley Lab., Berkeley, CA USA
Radiation Session Summary
Kronenberg, Amy; Miller, Jack; Huso, David L.; Proceedings of the First Biennial Space Biomedical Investigators' Workshop; 1999; In English; No Copyright; Avail: CASI

The National Academy of Sciences (NAS) has identified radiation hazards as one of the potential ″show stoppers″ for long term human exploration of space. NASA supports a multi-disciplinary research effort encompassing diverse fields including radiation physics and transport, basic research in radiation carcinogenesis and research on behavioral effects. To supplement the current research effort, the National Council on Radiation Protection and Measurements (NCRP) has assembled Scientific Committee 1-7 (SC 1-7) to provide recommendations on further information that is required to develop radiation protection guidelines for manned missions beyond low earth orbit. Townsend presented an update on the recent activities of NCRP SC 1-7, and reviewed the knowledge base that will be required to accurately assess the risks to humans from exposure to the radiation environment of space. The presentations in the Radiation Session addressed the critical research needs identified by the NAS and the NCRP. These included: (1) characterization of the space radiation environment, (2) modeling and

ground-based measurement of the fragmentation properties of heavy charged particles as they interact with shielding and tissue equivalent materials, (3) biodosimetry in astronauts, (4) ground- and flight-based studies to elucidate the mechanisms of biological response to space radiation (and potential interactions with microgravity), and (5) ground-based studies to quantify the risks of carcinogenesis and other damage to normal tissues that may ensue after exposure to different components of the space radiation environment.
Author
Biological Effects; Carcinogens; Damage; Exposure; Extraterrestrial Radiation; Physiological Responses; Radiation Dosage; Radiation Hazards

19990103940 NASA Marshall Space Flight Center, Huntsville, AL USA
A Novel Technique for Performing Space Based Radiation Dosimetry Using DNA-Results from GRaDEx-I and the Design of GRaDEx-II
Ritter, Joe; Branly, R.; Theodorakis, C.; Bickham, J.; Swartz, C.; Friedfeld, R.; Ackerman, E.; Carruthers, C.; DiGirolamo, A.; Faranda, J.; [1999]; In English, Sep. 1999, Annapolis, MD, USA
Contract(s)/Grant(s): NAS8-40836; SVT96-45100; RTOP 451-102; No Copyright; Avail: CASI

Because of the large amounts of cosmic radiation in the space environment relative to that on earth, the effects of radiation on the physiology of astronauts is of major concern. Doses of radiation which can cause acute or chronic biological effects are to be avoided, therefore determination of the amount of radiation exposure encountered during space flight and assessment of its impact on biological systems is critical. Quantifying the radiation dosage and damage to biological systems, especially to humans during repetitive high altitude flight and during long duration space flight, is important for several reasons. Radiation can cause altered biosynthesis and long term genotoxicity resulting in cancer and birth defects etc. Radiation damage to biological systems depends in a complex way on incident radiation species and their energy spectra. Typically non-biological, i.e. film or electronic monitoring systems with narrow energy band sensitivity are used to perform dosimetry and then results are extrapolated to biological models. For this reason it may be desirable to perform radiation dosimetry by using biological molecules e.g. DNA or RNA strands as passive sensors. A lightweight genotoxicology experiment was constructed to determine the degree to which in vitro naked DNA extracted from tissues of a variety of vertebrate organisms is damaged by exposure to radiation in a space environment. The DNA is assayed by means of agarose gel electrophoresis to determine damage such as strand breakage caused by high momentum particles and photons, and base oxidation caused by free radicals. The length distribution of DNA fragments is directly correlated with the radiation dose. It is hoped that a low mass, low cost, passive biological system to determine dose response relationship (increase in strand breaks with increase in exposure) can be developed to perform radiation dosimetry in support of long duration space flight, and to predict negative effects on biological systems (e.g. astronauts and greenhouses) in space. The payload was flown in a 2.5 cubic foot Get Away Special (GAS) container through NASA's GAS program. It was subjected to the environment of the space shuttle cargo bay for the duration of the STS-91 mission (9 days). Results of the genotoxicology and radiation dosimetry experiment (GRaDEx-1) as well as the design of an improved follow on payload are presented.
Author
Deoxyribonucleic Acid; Ribonucleic Acids; Radiation Damage; Radiation Dosage; Dosimeters; Electrophoresis

20000101087 NASA Johnson Space Center, Houston, TX USA
GCR Transport in the Brain: Assessment of Self-Shielding, Columnar Damage, and Nuclear Reactions on Cell Inactivation Rates
Shavers, M. R.; Atwell, W.; Cucinotta, F. A.; Badhwar, G. D., Technical Monitor; [1999]; In English; 10th 10th Annual Space Radiation Health Investigator's Workshop, 12-16 Jun. 1999, Upton, NY, USA
Contract(s)/Grant(s): NAS9-2000; No Copyright; Avail: Other Sources

Radiation shield design is driven by the need to limit radiation risks while optimizing risk reduction with launch mass/expense penalties. Both limitation and optimization objectives require the development of accurate and complete means for evaluating the effectiveness of various shield materials and body-self shielding. For galactic cosmic rays (GCR), biophysical response models indicate that track structure effects lead to substantially different assessments of shielding effectiveness relative to assessments based on LET-dependent quality factors. Methods for assessing risk to the central nervous system (CNS) from heavy ions are poorly understood at this time. High-energy and charge (HZE) ion can produce tissue events resulting in damage to clusters of cells in a columnar fashion, especially for stopping heavy ions. Grahn (1973) and Todd (1986) have discussed a microlesion concept or model of stochastic tissue events in analyzing damage from HZE's. Some tissues, including the CNS, maybe sensitive to microlesions or stochastic tissue events in a manner not illuminated by either conventional dosimetry or fluence-based risk factors. HZE ions may also produce important lateral damage to adjacent

cells. Fluences of high-energy proton and alpha particles in the GCR are many times higher than HZE ions. Behind spacecraft and body self-shielding the ratio of protons, alpha particles, and neutrons to HZE ions increases several-fold from free-space values. Models of GCR damage behind shielding have placed large concern on the role of target fragments produced from tissue atoms. The self-shielding of the brain reduces the number of heavy ions reaching the interior regions by a large amount and the remaining light particle environment (protons, neutrons, deuterons. and alpha particles) may be the greatest concern. Tracks of high-energy proton produce nuclear reactions in tissue, which can deposit doses of more than 1 Gv within 5 - 10 cell layers. Information on rates of cell killing from GCR, including patterns of cell killing from single particle tracks. can provide useful information on expected differences between proton and HZE tracks and clinical experiences with photon irradiation. To model effects on cells in the brain, it is important that transport models accurately describe changes in the GCR due to interactions in the cranium and proximate tissues. We describe calculations of the attenuated GCR particle fluxes at three dose-points in the brain and associated patterns of cell killing using biophysical models. The effects of the brain self-shielding and bone-tissue interface of the skull in modulating the GCR environment are considered. For each brain dose-point, the mass distribution in the surrounding 4(pi) solid angle is characterized using the CAM model to trace 512 rays. The CAM model describes the self-shielding by converting the tissue distribution to mass-equivalent aluminum, and nominal values of spacecraft shielding is considered. Particle transport is performed with the proton, neutron, and heavy-ion transport code HZETRN with the nuclear fragmentation model QMSFRG. The distribution of cells killed along the path of individual GCR ions is modeled using in vitro cell inactivation data for cells with varying sensitivity. Monte Carlo simulations of arrays of inactivated cells are considered for protons and heavy ions and used to describe the absolute number of cell killing events of various magnitude in the brain from the GCR. Included are simulations of positions of inactivated cells from stopping heavy ions and nuclear stars produced by high-energy ions most importantly, protons and neutrons.
Author

Biophysics; Bones; Brain; Central Nervous System; Damage Assessment; Dosage; Dosimeters; Nuclear Models; Nuclear Reactions; Radiation Shielding

20000109673 NASA Johnson Space Center, Houston, TX USA

Three-Dimensional, Transgenic Cell Models to Quantify Space Genotoxic Effects

Gonda, S. R.; Sognier, M. A.; Wu, H.; Pingerelli, P. L.; Glickman, B. W.; Dawson, David L., Technical Monitor; [1999]; In English, 1-5 Jun. 1999, Pasadena, CA, USA; No Copyright; Avail: Other Sources

The space environment contains radiation and chemical agents known to be mutagenic and carcinogenic to humans. Additionally, microgravity is a complicating factor that may modify or synergize induced genotoxic effects. Most in vitro models fail to use human cells (making risk extrapolation to humans more difficult), overlook the dynamic effect of tissue intercellular interactions on genotoxic damage, and lack the sensitivity required to measure low-dose effects. Currently a need exists for a model test system that simulates cellular interactions present in tissue, and can be used to quantify genotoxic damage induced by low levels of radiation and chemicals, and extrapolate assessed risk to humans. A state-of-the-art, three-dimensional, multicellular tissue equivalent cell culture model will be presented. It consists of mammalian cells genetically engineered to contain multiple copies of defined target genes for genotoxic assessment,. NASA-designed bioreactors were used to coculture mammalian cells into spheroids, The cells used were human mammary epithelial cells (H184135) and Stratagene's (Austin, Texas) Big Blue(TM) Rat 2 lambda fibroblasts. The fibroblasts were genetically engineered to contain -a high-density target gene for mutagenesis (60 copies of lacl/LacZ per cell). Tissue equivalent spheroids were routinely produced by inoculation of 2 to 7 X 10(exp 5) fibroblasts with Cytodex 3 beads (150 micrometers in diameter). at a 20:1 cell:bead ratio, into 50-ml HARV bioreactors (Synthecon, Inc.). Fibroblasts were cultured for 5 days, an equivalent number of epithelial cells added, and the fibroblast/epithelial cell coculture continued for 21 days. Three-dimensional spheroids with diameters ranging from 400 to 600 micrometers were obtained. Histological and immunohistochemical Characterization revealed i) both cell types present in the spheroids, with fibroblasts located primarily in the center, surrounded by epithelial cells; ii) synthesis of extracellular matrix; and iii,, mitotic cells located throughout the spheroids. Spheroidal integrity and cell viability were retained for the 30-day test period after removal of spheroids from the bioreactor. Potential utility of this three-dimensional, transgenic model for genotoxicity was initially assessed by exposure of spheroids to 0-2 Gy neon at dose rates of 0.3 to 1.5 Gy/min (National Institute of Radiological Sciences, Chiba, Japan). Quantification of mutation at the lacl gene revealed a linear dose response for mutation induction. Limited sequencing analysis of mutant clones revealed higher frequencies of deletions and multiple base sequence changes with increasing dose. These results suggest that our three-dimensional, transgenic model is applicable to a wide variety of studies involving the quantification, identification, and characterization of genotoxicity incurred in space and on Earth. This model uniquely allows investigation of the interaction of relevant factors, namely cell-to-cell interactions and the mechanistic interaction of microgravity with radiation insults and DNA repair. Using this three-dimensional model will allow us to obtain dual genotoxic information (i.e., mutation rate plus

chromosome aberration data) from the same system so that one endpoint can be used to reference the other, thereby increasing the fidelity of the data set. Moreover, the tissue-equivalent nature of the three-dimensional model provides high confidence for relevance of risk assessment, i.e., the establishment of quality factors directly applicable to the microgravity environment.
Author
Cells (Biology); Chromosomes; Deoxyribonucleic Acid; Genes; Mutagens; Genetics; Aerospace Environments; Bioastronautics

20000024852 NASA Langley Research Center, Hampton, VA USA
Shielding from Solar Particle Event Exposures in Deep Space
Wilson, John W.; Cucinotta, F. A.; Shinn, J. L.; Simonsen, L. C.; Dubey, R. R.; Jordan, W. R.; Jones, T. D.; Chang, C. K.; Kim, M. Y.; Radiation Measurements; 1999; ISSN 1350-4487; Volume 30; In English; Copyright; Avail: Other Sources

The physical composition and intensities of solar particle event exposures of sensitive astronaut tissues are examined under conditions approximating an astronaut in deep space. Response functions for conversion of particle fluence into dose and dose equivalent averaged over organ tissues are used to establish significant fluence levels and the expected dose and dose rates of the most important events from past observations. The BRYNTRN transport code is used to evaluate the local environment experienced by sensitive tissues and used to evaluate bioresponse models developed for use in tactical nuclear warfare. The present results will help to clarify the biophysical aspects of such exposure in the assessment of RBE and dose rate effects and their impact on design of protection systems for the astronauts. The use of polymers as shielding material in place of an equal mass of aluminum would provide a large safety factor without increasing the vehicle mass. This safety factor is sufficient to provide adequate protection if a factor of two larger event than has ever been observed in fact occurs during the mission.
Author
Shielding; Solar Corpuscular Radiation; Solar Cosmic Rays; Solar Flares; Solar Storms

20000094309 NASA Johnson Space Center, Houston, TX USA
Initial Biological Damage from Space Radiation: Implications for Development of Biological Countermeasures
Cucinotta, Francis A.; Paloski, William H., Technical Monitor; [1999]; In English, 14-18 May 2000, Houston, TX, USA; No Copyright; Avail: Other Sources

Astronauts are exposed to high-energy nuclear particles originating from the galactic cosmic rays, high-energy protons trapped in the Earth's magnetic field or solar particle events, and secondary radiation produced by nuclear reactions. Important differences between conventional radiation including X-rays or gamma-rays, and high-energy nuclei occur at the level of initial damage to DNA and other potential biological target molecules, and to tissues. Such differences include a large fraction of the initial damage from high charge and energy (HZE) nuclear particles manifested as irreparable lesions including small- and large-scale DNA deletions. Also, low dose-rate exposures in space result in a heterogeneous population of damaged cells distinct from energetic photon irradiation of tissue. We present an overview of the initial biological damage and dose and dose-rate effects produced by ionizing radiation using track structure and nuclear reaction models. Implications of the differences in cellular and tissue damage between conventional radiation and space radiation for the development of biological countermeasures are discussed.
Author
Deoxyribonucleic Acid; Extraterrestrial Radiation; Radiation Damage; Radiation Injuries; Aerospace Environments; Aerospace Safety; Bioastronautics

19990064359 NASA Johnson Space Center, Houston, TX USA
Medium Modified Nucleon-Nucleon Cross Sections in a Nucleus
Tripathi, R. K.; Cucinotta, F. A.; Wilson, J. W.; Nuclear Instruments and Methods in Physics Research B; 1999; ISSN 0168-583X; Volume 152; In English
Contract(s)/Grant(s): NCC1-242; Copyright; Avail: Other Sources

A simple reliable formalism is presented for obtaining nucleon-nucleon cross sections within a nucleus in nuclear collisions for a given projectile and target nucleus combination at a given energy for use in transport, Monte Carlo and other calculations. The method relies on extraction of these values from experiments and has been tested for absorption experiments to give excellent results.
Author
Nucleon-Nucleon Interactions; Particle Collisions; Nucleon-Nucleon Scattering; Atomic Collisions; Nuclear Particles; Atomic Excitations

20000020653 NASA Langley Research Center, Hampton, VA USA

Impact of Track Structure Effects on Shielding and Dosimetry

Wilson, J. W.; Cucinotta, F. A.; Schimmerling, W.; Kim, M. Y.; Proceedings of the First Biennial Space Biomedical Investigators' Workshop; 1999; In English; No Copyright; Avail: CASI

Galactic cosmic rays (GCR) consisting of nuclei of all the known elements with kinetic energies extending from tens to millions of MeV pose a significant health hazard to future deep space operations. Even half of the radiation exposures expected in ISS will result from GCR components. The biological actions of these radiations are known to depend on the details of the energy deposition (not just linear energy transfer, LET, but the lateral dispersion of energy deposition about the particle track). Energy deposits in tissues are dominated by the transfer of tens to hundreds of eV to the tissue's atomic electrons. In the case of low LET radiations, the collisions are separated by large dimensions compared to the size of important biomolecular structures. If such events are also separated in time, then the radiation adds little to the background of radicals occurring from ordinary metabolic processes and causes little or no biological injury. Hence, dose rate is a strong determinant of the action of low LET exposures. The GCR exposures are dominated by ions of high charge and energy (HZE) characterized by many collisions with atomic electrons over biomolecular dimensions, resulting in high radical- density events associated with a few isolated ion paths through the cell and minimal dose rate dependence at ordinary exposure levels. The HZE energy deposit declines quickly laterally and merges with the background radical density in the track periphery for which the exact lateral distribution of the energy deposit is the determinant of the biological injury. Although little data exists on human exposures from HZE radiations, limited studies in mice and mammalian cell cultures allow evaluation of the effects of track structure on shield attenuation properties and evaluation of implications for dosimetry. The most complete mammalian cell HZE exposure data sets have been modeled including the C3H10T1/2 survival and transformation data of Yang et al., the V79 survival and mutation data of various groups, and the Harderian gland tumor data of Alpen et al. Model results for the Harderian gland tumor data in comparison with data from Alpen et al. The Harderian target cell initiation cross section compares closely with the transformation cross section found for the C3H10T1/2 cell transformation data of Yang et al. The most notable feature of the cross sections are the multivalued cross sections for a given LET which implies the corresponding relative biological effectiveness (RBE) is dependent not only on the LET but also the ion type. This fact is at variance with the latest ICRP recommended quality factor which is a defined function of only the LET.

Author

Galactic Cosmic Rays; Dosimeters; Energy Transfer; Exposure; Hazards; Mutations; Radiation Dosage; Relative Biological Effectiveness (RBE)

20000020650 ANSER Corp., Arlington, VA USA

Risk Management Strategies During Solar Events

Turner, Ron; Proceedings of the First Biennial Space Biomedical Investigators' Workshop; 1999; In English; No Copyright

The natural radiation from galactic cosmic rays (GCR) and solar particle events (SPEs) will pose a serious health risk to humans during missions to Mars or the Moon. The opportunities and limitations of astronauts on these missions will be constrained by the radiation environment and NASA's response to it. NASA recognizes both an ethical and legal responsibility to minimize the acute and long-term risks to astronauts during space flight. There is an extensive program underway to collect statistically meaningful data to understand the fundamental biological impacts of the radiation environment. These data can be directly related to the well-characterized incident, slowly varying, galactic cosmic ray flux. There is greater uncertainty in predicting and characterizing the rapidly changing solar particle radiation which, over time periods of hours to days, can produce particle fluences comparable to mission-long GCR fluence. Work by this investigator in an earlier grant (NAGW-4166) systematically identified the types of solar particle events (SPEs), the stages of a human Lunar or Mars mission when the events may occur, and the methods used to detect and forecast these events. Alternative scenarios were identified that represented the range of architectures that could be employed to mitigate SPE risk. The advantages and disadvantages of each scenario were discussed. Based on the earlier results, we initiated a program to continue this research through a sequence of additional phases that will progressively add to NASA's ability to develop a comprehensive SPE risk management strategy. These subsequent phases examine in more detail the science, engineering, and operational requirements. The focus in each phase is to identify the key issues and general approaches to address these issues, rather than to attempt to specify a particular solution. This presentation will include a short review of the physics of SPEs and the current ability to forecast SPEs. It will then cover techniques to observe SPEs and the solar precursers to SPEs.

Author

Galactic Cosmic Rays; Solar Storms; Data Acquisition; Health; Legal Liability; Solar Flares

20000021265 Hampton Univ., VA USA
Closing Report for NASA Cooperative Agreement NASA-1-242
Maung, Khin Maung; [1999]; In English
Contract(s)/Grant(s): NAS1-242; No Copyright; Avail: CASI

Reliable estimates of exposures due to ionizing radiations are of paramount importance in achieving human exploration and development of space, and in several technologically important and scientifically significant areas impacting on industrial and public health. For proper assessment of radiation exposures reliable transport codes are needed. An essential input to the transport codes is the information about the interaction of ions and neutrons with the matter. Most of the information about this interaction is put in by nuclear cross section data. In order to obtain an accurate parameterization of cross sections data, theoretical input is indispensable especially for the processes where there is little or no experimental data available. In the grant period reliable data base was developed and a phenomenological model was developed for the total absorption cross sections valid for any charged/uncharged light, medium and heavy collision pairs valid for the entire energy range. It is gratifying to note the success of the model. The cross sections model has been adopted and is in use in NASA cosmic ray detector development projects, the radiation protection and shielding programs and several DoE laboratories and institutions. A list of the publications based on the work done during the grant period is given below and a sample copy of one of the papers is enclosed with this report.
Author
Phenomenology; Absorption Cross Sections; Scattering Cross Sections; Nucleon-Nucleon Scattering; Particle Collisions

20000020649 Tennessee Univ., Knoxville, TN USA
Information Needed to Make Radiation Protection Recommendations for Travel Beyond Low-Earth Orbit
Townsend, Lawrence W.; Proceedings of the First Biennial Space Biomedical Investigators' Workshop; 1999; In English; No Copyright

Scientific Committee 1-7 (SC 1-7) of the National Council on Radiation Protection and Measurements (NCRP) has been assembled for the purpose of providing recommendations to NASA concerning the information needed to make radiation protection guidelines for manned space missions beyond low-Earth orbit. Current space radiation limits pertain only to missions in low-Earth orbit and are not considered relevant for future deep space missions. SC 1-7 has met numerous times over the past three years to review the current status of scientific knowledge relevant to this task. The committee is currently formulating a set of recommendations for additional research needed to provide the data necessary to establish astronaut radiation limits for exomagnetospheric missions, such as a Lunar base or mission to Mars. In this presentation, the procedures followed by the NCRP for making recommendations are briefly discussed. The composition of SC 1-7 and the scope of its efforts and activities are presented. Brief overviews of the current status and shortcomings of scientific knowledge of the space radiation environment, radiation physics and transport, radiation biology, dosimetry and radiation risk are presented. However, formal recommendations of research necessary to establish radiation limits for deep space missions will not be presented since they have not been developed by the committee or approved by the Council.
Author
Extraterrestrial Radiation; Formulations; Low Earth Orbits; Manned Space Flight; Radiation Protection

20000020648 Texas A&M Univ., Houston, TX USA
Quantitation of Radiation Induced Deletion and Recombination Events Associated with Repeated DNA Sequences
Sinden, Richard R.; Ford, John R.; Braby, Leslie A.; Proceedings of the First Biennial Space Biomedical Investigators' Workshop; 1999; In English; No Copyright; Avail: CASI

Manned exploration of space exposes the explorers to a complex and novel radiation environment. The galactic cosmic ray component of this environment is relatively constant, and the variations with the solar cycle are well understood and predictable. However, a significant fraction of the dose may be delivered by solar particle events which vary dramatically in dose rate and incident particle spectrum. When these radiations interact with spacecraft materials and added shielding they produce a spectrum of secondary particles which depends on the spectrum of the incident particles as well as the shielding material. The different particle types and energies result in different patterns of energy deposition at the molecular and cellular level. Differences in these energy deposition patterns significantly alter the ability of cellular systems to repair the resulting damage. It is likely that these differences also effect the spatial distribution of damage within the DNA of the interphase cell nucleus and produce corresponding differences in endpoints related to health effects. Nearly one-third of the human genome is composed of DNA repeats, which include simple mono-, di-, tri-, and tetranucleotide repeats; widely separated small and large repeats; and inverted repeats. Mutations associated with repetitive DNA are a source of many genetic diseases and cancer. In fact, the vast majority of mutations leading to human disease likely result from replication errors involving

misalignment between repeated DNAs. Therefore, understanding how the various kinds of repeats contribute to the disease burden and understanding the impact of DNA damage on repeat-associated genomic instability is important for human health. DNA damage from ionizing radiation induces DNA structures and DNA repair events that can promote errors associated with repeated DNA sequences. Such repeated DNA sequences are likely to be very prone to mutation following exposure to high-Z high-energy (HZE) particles during space flight. Cells in the direct line of the HZE particle sustain a high dose of energy while cells surrounding the primary tract sustain a lower dose of energy from the energetic delta rays (electrons) produced by HZE particles. Therefore, the nature and pattern DNA damage to cells in tissue upon irradiation with HZE particles is particularly complex. It is important to understand the types of mutational changes induced by both the HZE particles as well as the delta rays.
Author
Quantitative Analysis; Irradiation; Deoxyribonucleic Acid; Damage; Deletion; Dosage; Energy Transfer; Genetics; Ionizing Radiation

20000020647 California Univ., Lawrence Berkeley Lab., Berkeley, CA USA
Non-Rejoined DNA Double-Strand Breaks in Human Cells. A Shift in RBE versus LET for HZE Iron Particles in Comparison with Low Energy Helium Particles
Rydberg, B.; Cooper, P. K.; Proceedings of the First Biennial Space Biomedical Investigators' Workshop; 1999; In English; No Copyright; Avail: CASI

DNA double-strand breaks (dsbs) are likeley to be the most important lesions produced by ionizing radiation. Among the dsbs, those that are either misrejoined or remain unrejoined a long time after induction are probably the most relevant for a variety of biological endpoints. We present here results of unrejoined dsbs in human fibroblasts 16 hrs after irradiation with Energy Heavy Ions (HZE) Fe particles with LETs of 190 and 150 keV/micron and compare this with similar results with He particles in the Linear Energy Transfer (LET) range of 65-160 keV/micron.
Author
Deoxyribonucleic Acid; Linear Energy Transfer (LET); Cells (Biology); Relative Biological Effectiveness (RBE); Particle Energy; Ionizing Radiation

20000083882 NASA Johnson Space Center, Houston, TX USA
On The Development of Biophysical Models for Space Radiation Risk Assessment
Cucinotta, F. A.; Dicello, J. F.; [1999]; In English
Contract(s)/Grant(s): RTOP 111-50-50-01; No Copyright; Avail: CASI

Experimental techniques in molecular biology are being applied to study biological risks from space radiation. The use of molecular assays presents a challenge to biophysical models which in the past have relied on descriptions of energy deposition and phenomenological treatments of repair. We describe a biochemical kinetics model of cell cycle control and DNA damage response proteins in order to model cellular responses to radiation exposures. Using models of cyclin-cdk, pRB, E2F's, p53, and GI inhibitors we show that simulations of cell cycle populations and GI arrest can be described by our biochemical approach. We consider radiation damaged DNA as a substrate for signal transduction processes and consider a dose and dose-rate reduction effectiveness factor (DDREF) for protein expression.
Author
Biophysics; Models; Biochemistry; Cells (Biology); Damage; Deposition; Dosage; Energy Transfer; Extraterrestrial Radiation; Radiation Dosage; Risk

19990080045 Boeing Co., Huntington Beach, CA USA
New Trapped Proton Model
Huston, Stuart L.; Pfitzer, Karl A.; 1999; In English, 28-30 Sep. 1999, Albuquerque, NM, USA
Contract(s)/Grant(s): NAS8-98218
Report No.(s): AIAA Paper-99-4595; Copyright; Avail: Other Sources

The space radiation environment is of crucial importance to all manned and unmanned space activities. As spacecraft and their systems and instruments have become more sophisticated, they have also become more susceptible to the space radiation environment. New requirements for the radiation models have made it evident that the existing models are now inadequate. NASA, ESA, and other agencies are consequently working to develop new models. In particular, under NASA's Space Environments and Effects (SEE) program, a new model has been developed which correctly models the solar cycle variations in the trapped proton flux at low altitudes. This model is now being merged with the U.S. Air Force model based on data from

the CRRES satellite; the resulting model will be a replacement for the current models. In this paper we discuss the models currently available and their drawbacks. We also discuss the development of the new model and present some preliminary results.
Author
Aerospace Environments; Protons; Extraterrestrial Radiation; Models; Flux (Rate); Radiation Dosage

20000112935 Utah Univ., Salt Lake City, UT USA
[Radiation Anticarcinogenesis by Thiazolidine Pro-drug]
Warters, Raymond L.; Roberts, Jeanette C.; Fain, Heidi; [1999]; In English
Contract(s)/Grant(s): NAG5-4452; No Copyright; Avail: CASI

The original goal of this work was to determine the capacity of selected aminothiols to modulate radiation induced cytotoxicity, mutagenesis and carcinogenesis in a human mammary epithelial cell line. The conclusions from this work are that WR-1065 is the ″gold standard″ for protection against radiation induced cytotoxicity, mutagenesis and carcinogenesis. While a potent radiation protector, WR-1065 is cytotoxic in vitro and in vivo. Our rationale for a study of the thiazolidine pro-drugs was that these compounds are neither toxic in vitro or in vivo. The results obtained during this funding period indicate that the thiazolidine pro-drugs are as potent as WR-1065 as protectors against radiation induced mutation induction, and thus presumably against radiation induced carcinogenesis. Our results indicate that the thiazolidine prodrugs are excellent candidates to test as non-toxic anticarcinogens for protecting astronauts from cancer induction during space travel.
CASI
Cancer; Carcinogens; Mutations; Protection; Toxins and Antitoxins; Radiation Hazards

20000020643 California Univ., Lawrence Berkeley Lab., Berkeley, CA USA
Accelerator-Based Studies of Heavy Ion Interactions Relevant to Space Biomedicine
Miller, J.; Heilbronn, L.; Zeitlin, C.; Proceedings of the First Biennial Space Biomedical Investigators' Workshop; 1999; In English
Contract(s)/Grant(s): NASA Order L-14230-C; DE-AC03-76SF-00098; No Copyright; Avail: CASI

Evaluation of the effects of space radiation on the crews of long duration space missions must take into account the interactions of high energy atomic nuclei in spacecraft and planetary habitat shielding and in the bodies of the astronauts. These heavy ions (i.e. heavier than hydrogen), while relatively small in number compared to the total galactic cosmic ray (GCR) charged particle flux, can produce disproportionately large effects by virtue of their high local energy deposition: a single traversal by a heavy charged particle can kill or, what may be worse, severely damage a cell. Research into the pertinent physics and biology of heavy ion interactions has consequently been assigned a high priority in a recent report by a task group of the National Research Council. Fragmentation of the incident heavy ions in shielding or in the human body will modify an initially well known radiation field and thereby complicate both spacecraft shielding design and the evaluation of potential radiation hazards. Since it is impractical to empirically test the radiation transport properties of each possible shielding material and configuration, a great deal of effort is going into the development of models of charged particle fragmentation and transport. Accurate nuclear fragmentation cross sections (probabilities), either in the form of measurements with thin targets or theoretical calculations, are needed for input to the transport models, and fluence measurements (numbers of fragments produced by interactions in thick targets) are needed both to validate the models and to test specific shielding materials and designs. Fluence data are also needed to characterize the incident radiation field in accelerator radiobiology experiments. For a number of years, nuclear fragmentation measurements at GCR-like energies have been carried out at heavy ion accelerators including the LBL Bevalac, Saturne (France), the Synchrophasotron and Nuklotron (Dubna, Russia), SIS-18 (GSI, Germany), the Alternating Gradient Synchrotron at Brookhaven National Laboratory (BNL AGS) and the Heavy Ion Medical Accelerator (HIMAC) in Chiba, Japan. Until fairly recently most of these experiments were done to investigate fundamental problems in nuclear physics, but with the increasing interest in heavy charged particles on the part of the space flight, radiobiology and radiotherapy communities, an increasing number of experiments are being directed at these areas. Some of these measurements are discussed in references therein. Over the past several years, our group has taken cross section and fluence data at the AGS and HIMAC for several incident beams with nuclear charge, Z, between 6 and 26 at energies between 290 and 1050 MeV/nucleon. Iron (Z = 26) has been studied most extensively, since it is the heaviest ion present in significant numbers in the GCR. Targets have included tissue-equivalent and proposed shielding materials, as well as a variety of elemental targets for cross section measurements. Most of the data were taken along the beam axis, but measurements have

been made off-axis, as well. Here we present selected data and briefly discuss some implications for spacecraft and planetary habitat design.
Author
Heavy Ions; Research; Biomedical Data; Damage; Human Body; Incident Radiation; Ion Accelerators; Spacecraft Design; Spacecraft Shielding

20000109863 Utah Univ., Salt Lake City, UT USA
Radioprotection of Human Cell Nuclear DNA by Polyamines: Radiosensitivity of Chromatin is Influenced by Tightly Bound Spermine
Warters, Raymond L.; Newton, Gerald L.; Olive, Peggy L.; Fahey, Robert C.; Radiation Research; 1999; ISSN 0033-7587; Volume 151; In English
Contract(s)/Grant(s): NAGW-4914; NIH-NCI-CA-35982; NIH-5P30-CA-42014; Copyright; Avail: Other Sources

The polyamines putrescine (PUT) and spermine (SPM) were examined for their ability to protect human cell Deoxyribonucleic Acid (DNA) against the formation of radiation-induced double-strand breaks (DSBs). As observed previously, under conditions where polyamines were shown to be almost completely absent, association with nuclear matrix protein into a nucleoid, and organization into chromatin structure, protected DNA from induction of DSBs by factors of 4.5 and 95, respectively. At concentrations below 1 mM, PUT or SPM provided equivalent levels of protection to deproteinized nuclear DNA, consistent with their capacity to scavenge radiation-induced radicals. At constant ionic strength, 5 mM SPM protected deproteinized DNA and nucleoid DNA and DNA in nuclear chromatin by factors of 100 and 26, respectively. At 5 mM, SPM provided 15 times greater protection of deproteinized DNA than did PUT. Under physiologically relevant conditions, 5 mM SPM protected DNA in the intact nucleus from the induction of DSBs by a factor of 2 relative to DNA in the absence of SPM. Studies of SPM binding during cellular fractionation revealed that a significant fraction of the cellular SPM is tightly bound in the nucleus but can be removed by extended washing. Thus the association of SPM with nuclear chromatin appears to be a significant contributor to the resistance of the cell's DNA to the induction of DSBs.
Author
Radiation Protection; Cells (Biology); Human Beings; Deoxyribonucleic Acid

20000020641 Colorado State Univ., Fort Collins, CO USA
Mutagenic Effects of Fe-56 Radiation on Cultured Mammalian Cells
Lenarczyk, M.; Ueno, A.; Vannais, D.; Warters, R.; Roberts, J.; Kronenberg, Amy; Hei, T.; Waldren, C.; Proceedings of the First Biennial Space Biomedical Investigators' Workshop; 1999; In English; No Copyright; Avail: CASI

Travelers in space will almost certainly be exposed to various kinds of ionizing radiation especially high linear energy transfer (LET) particles such as HZE Fe. Such exposures can cause mutations in somatic cells that can increase the risk of developing such genetic diseases as cancer. We have, therefore, measured the mutagenic potency of HZE Fe in culture mammalian cells and begun experiments to determine if mutagenicity can be reduced by radioprotective chemicals like WR-1065 and RibCys, a prodrug of L-cysteine.
Author
Radiation Effects; Radiation Protection; Cells (Biology); Exposure; Ionizing Radiation

20000020640 California Univ., Lawrence Berkeley Lab., Berkeley, CA USA
Genetic Regulation of Charged Particle Mutagenesis in Human Cells
Kronenberg, Amy; Gauny, S.; Cherbonnel-Lasserre, C.; Liu, W.; Wiese, C.; Proceedings of the First Biennial Space Biomedical Investigators' Workshop; 1999; In English
Contract(s)/Grant(s): NASA Order T-864-W; No Copyright; Avail: CASI

Our studies use a series of syngeneic, and where possible, isogenic human B-lymphoblastoid cell lines to assess the genetic factors that modulate susceptibility apoptosis and their impact on the mutagenic risks of low fluence exposures to 1 GeV Fe ions and 55 MeV protons. These ions are representative of the types of charged particle radiation that are of particular significance for human health in the space radiation environment. The model system employs cell lines derived from the male donor WIL-2. These cells have a single X chromosome and they are hemizygous for one mutation marker, hypoxanthine phosphoribosyltransferase (HPRT). TK6 and WTK1 cells were each derived from descendants of WIL-2 and were each selected as heterozygotes for a second mutation marker, the thymidine kinase (TK) gene located on chromosome 17q. The HPRT and TK loci can detect many different types of mutations, from single basepair substitutions up to large scale loss of heterozygosity (LOH). The single expressing copy of TK in the TK6 and WTKI cell lines is found on the same copy of

chromosome 17, and this allele can be identified by a restriction fragment length polymorphism (RFLP) identified when high molecular weight DNA is digested by the SacI restriction endonuclease and hybridized against the cDNA probe for TK. A large series of polymorphic linked markers has been identified that span more than 60 cM of DNA (approx. 60 megabasepairs) and distinguish the copy of chromosome 17 bearing the initially active TK allele from the copy of chromosome 17 bearing the silent TK allele in both TK6 and WTKI cells. TK6 cells express normal p53 protein while WTKI cells express homozygous mutant p53. Expression of mutant p53 can increase susceptibility to x-ray-induced mutations. It's been suggested that the increased mutagenesis in p53 mutant cells might be due to reduced apoptosis.
Author
Mutagens; Mutations; Deoxyribonucleic Acid; Extraterrestrial Radiation; Genetics; Health; Polymorphism

20000020639 NASA Johnson Space Center, Houston, TX USA
NSBRI Radiation Effects: Carcinogenesis in Sprague-Dawley Rats Irradiated with Iron Ions, Protons, or Photons
Dicello, J. F.; Cucinotta, F. A.; Gridley, D. S.; Howard, S. P.; Novak, G. R.; Ricart-Arbona, R.; Strandberg, J. D.; Vazquez, M. E.; Williams, J. R.; Zhang, Y.; Zhou, H.; Huso, D. L.; Proceedings of the First Biennial Space Biomedical Investigators' Workshop; 1999; In English; No Copyright; Avail: CASI

Our ability to confidently develop appropriate countermeasures for radiations in space in terms of shielding and design of a spacecraft, the mission scenario, or chemoprevention is severely limited by the uncertainties in both the risk itself and the change in that risk with intervention. Despite the fact that the risk of carcinogenesis from exposures of personnel to radiations on long-term missions is considered one of the worst hazards in space, only a limited amount of in-vivo data exist for tumor induction from exposures to protons or energetic heavy ions (HZEs) at lower doses. The most extensive work remains the landmark study. for tumor development in the harderian gland of the mouse. The objective of this study is to characterize the level of risk for tumor induction in another relevant animal model. Subsequent experiments are designed to test the hypothesis that the level of risk can be reduced by pharmaceutical intervention in the promoting and progressing stages of the disease rather than in the initiating stage. The work presented here results from a cooperative effort on the part of investigators from two projects of the Radiation-Effects Team of the National Space Biomedical Research Institute (NSBRI). The collaborating projects are the Core Project which is investigating the risk of carcinogenesis in Sprague-Dawley rats and the Chemoprevention Project which is investigating the ability of Tamoxifen to reduce the number of malignant tumors in the irradiated animals. Research at the cellular and subcellular levels is being conducted in two other projects of the Radiation-Effects Team, Cytogenetics with J. R. Williams as Principal Investigator and Mutations from Repeated DNA Sequences. Results for these other projects also are being presented at this Workshop.
Author
Radiation Effects; Carcinogens; Rats; Iron; Irradiation; Ionizing Radiation; Photons; Protons; Countermeasures

19990047933 Brookhaven National Lab., Upton, NY USA
Low doses of ionizing radiation to mammalian cells may rather control than cause DNA damage
Feinendegen, L. E.; Bond, V. P.; Sondhaus, C. A.; Altman, K. I.; Dec. 31, 1998; In English
Report No.(s): DE99-001520; BNL-65902; No Copyright; Avail: Department of Energy Information Bridge

This report examines the origin of tissue effects that may follow from different cellular responses to low-dose irradiation, using published data. Two principal categories of cellular responses are considered. One response category relates to the probability of radiation-induced DNA damage. The other category consists of low-dose induced metabolic changes that induce mechanisms of DNA damage mitigation, which do not operate at high levels of exposure. Modeled in this way, tissue is treated as a complex adaptive system. The interaction of the various cellular responses results in a net tissue dose-effect relation that is likely to deviate from linearity in the low-dose region. This suggests that the LNT hypothesis should be reexamined. This paper aims at demonstrating tissue effects as an expression of cellular responses, both damaging and defensive, in relation to the energy deposited in cell mass, by use of microdosimetric concepts.
NTIS
Ionizing Radiation; Mammals; Deoxyribonucleic Acid; Radiation Protection; Radiation Dosage; Radiation Damage; Biological Effects

19990062139 Los Alamos National Lab., NM USA
Nutritional supplements as radioprotectors -- A review and proposal
Muscatello, A. C.; Dec. 31, 1998; In English
Report No.(s): DE99-002283; LA-UR-98-3405; No Copyright; Avail: Department of Energy Information Bridge

The scientific literature contains several reports that show nutritional substances, such as vitamins, minerals, and phytochemicals (plant chemicals), provide substantial radioprotective effects in animal studies. Incorporating these substances to the human diet, already voluntarily practiced by a large segment of the population, in addition to providing other favorable health effects, may also provide a radioprotective effect. This potential radioprotective effect would be very useful in mitigating the effects of occupational radiation exposure to astronauts (especially future Mars explorers), airline crews, nuclear workers, both commercial and government, and populations exposed to nuclear accidents, e.g. Chernobyl. This paper reviews the existing evidence of radioprotective effects by nutritional supplements and proposes that their efficacy be evaluated, first with animal studies, followed by human tests with astronauts and cosmonauts on long-term missions, such as to the Mir space station and the International Space Station (ISS).
NTIS
Radiation Protection; Nutrition

19990117061 Department of Energy, Washington, DC USA
Theory of RBE
Katz, R.; Oct. 31, 1998; In English
Report No.(s): DE99-002803; DOE/ER/60634-T6; No Copyright; Avail: Department of Energy Information Bridge
The report begins with a historical survey of research activity. Next summaries of research accomplishments in the following areas are given: (1) Radiation Dose Distribution; (2) The 1-Hit Detector: Action Cross Sections; (3) Many Hit Detectors; (4) Biological Cells; (5) Implications for Radiation Protection; and (6) Implications for Radiation Oncology with Heavy Ion Beams.
NTIS
Relative Biological Effectiveness (RBE); Heavy Ions; Ion Beams; Particle Tracks; Radiation Effects; Radiation Dosage

19990047477 NASA Langley Research Center, Hampton, VA USA
Parameterizations of Pion Energy Spectrum in Nucleon-Nucleon Collisions
Cucinotta, Franics A.; Wilson, John W.; Norbury, John W.; October 1998; In English
Contract(s)/Grant(s): RTOP 199-45-16-11
Report No.(s): NASA/TM-1998-208722; NAS 1.15:208722; L-17650; No Copyright; Avail: CASI
The effects of pion (PI) production are expected to play an important role in radiation exposures in the upper atmosphere or on the Martian surface. Nuclear databases for describing pion production are developed for radiation transport codes to support these studies. We analyze the secondary energy spectrum of pions produced in nucleon-nucleon (NN) collisions in the relativistic one-pion exchange model. Parametric formulas of the isospin cross sections for one-pion production channels are discussed and are used to renormalize the model spectrum. Energy spectra for the deuteron related channels (NN yields dPi) are also described.
Author
Nucleon-Nucleon Interactions; Pions; Radiation Transport; Charged Particles; Particle Collisions; Nucleon-Nucleon Scattering; Atmospheric Radiation; Galactic Cosmic Rays

19990100602 Department of Energy, Washington, DC USA
Innovative technology summary report: Sealed-seam sack suits
Sep. 30, 1998; In English
Report No.(s): DE98-007490; DOE/EM-0377; No Copyright; Avail: Department of Energy Information Bridge
Sealed-seam sack suits are an improved/innovative safety and industrial hygiene technology designed to protect workers from dermal exposure to contamination. Most of these disposable, synthetic-fabric suits are more protective than cotton suits, and are also water-resistant and gas permeable. Some fabrics provide a filter to aerosols, which is important to protection against contamination, while allowing air to pass, increasing comfort level of workers. It is easier to detect body-moisture breakthrough with the disposable suits than with cotton, which is also important to protecting workers from contamination. These suits present a safe and cost-effective (6% to 17% less expensive than the baseline) alternative to traditional protective clothing. This report covers the period from October 1996 to August 1997. During that time, sealed-seam sack suits were demonstrated during daily activities under normal working conditions at the C Reactor and under environmentally controlled conditions at the Los Alamos National Laboratory (LANL).
NTIS
Seams (Joints); Seals (Stoppers); Protective Clothing

19980237093 NASA Langley Research Center, Hampton, VA USA

Track Structure Model for Radial Distributions of Electron Spectra and Event Spectra from High-Energy Ions

Cucinotta, F. A.; Katz, R.; Wilson, J. W.; Sep. 1998; In English

Contract(s)/Grant(s): RTOP 199-45-16-11

Report No.(s): NASA/TP-1998-208707; L-17655; NAS 1.60:208707; No Copyright; Avail: CASI

An analytic method is described for evaluating the average radial electron spectrum and the radial and total frequency-event spectrum for high-energy ions. For high-energy ions, indirect events make important contributions to frequency-event spectra. The method used for evaluating indirect events is to fold the radial electron spectrum with measured frequency-event spectrum for photons or electrons. The contribution from direct events is treated using a spatially restricted linear energy transfer (LET). We find that high-energy heavy ions have a significantly reduced frequency-averaged final energy (yF) compared to LET, while relativistic protons have a significantly increased yF and dose-averaged lineal energy (yD) for typical site sizes used in tissue equivalent proportional counters. Such differences represent important factors in evaluating event spectra with laboratory beams, in space- flight, or in atmospheric radiation studies and in validation of radiation transport codes. The inadequacy of LET as descriptor because of deviations in values of physical quantities, such as track width, secondary electron spectrum, and yD for ions of identical LET is also discussed.

Author

Radial Distribution; Radiation Transport; Photons; Linear Energy Transfer (LET); Frequency Distribution; Electrons; Electron Spectroscopy; Dosage; Atmospheric Radiation

19980211473 NASA Langley Research Center, Hampton, VA USA

Extraction of In-Medium Nucleon-Nucleon Amplitude From Experiment

Tripathi, R. K.; Cucinotta, Francis A.; Wilson, John W.; Jul. 1998; In English

Contract(s)/Grant(s): NCC1-242; RTOP 199-45-16-12

Report No.(s): NASA/TP-1998-208438; NAS 1.60:208438; L-17674; No Copyright; Avail: CASI

The in-medium nucleon-nucleon amplitudes are extracted from the available proton-nucleus total reaction cross sections data. The retrieval of the information from the experiment makes the estimate of reaction cross sections very reliable. Simple expressions are given for the in-medium nucleon-nucleon amplitudes for any system of colliding nuclei as a function of energy. Excellent agreement with experimental observations is demonstrated in the ion-nucleus interactions.

Author

Nucleon-Nucleon Interactions; Cross Sections; Quantum Mechanics; Nuclear Chemistry

19980210482 San Francisco Univ., CA USA

Environmental Radiation Measurements on the Mir Space Station, Program 1, Internal Experiment Program

Benton, E. V.; Frank, A. L.; Benton, E. R.; May 12, 1998; In English

Contract(s)/Grant(s): NCC2-893; No Copyright; Avail: CASI

As part of the NASA/Mir Phase 1B Science Program, the ionizing radiation environment inside and outside the Russian Mir's Space Station was monitored using a combination of Thermoluminescent Detectors (TLD) and CR-39 Plastic Nuclear Track Detectors (PNTD). Radiation measurements inside the Mir station were carried out using six Area Passive Dosimeters (APD), four located inside the Mir Base Block and two located inside the Kvant 2 module, during the NASA-2/Mir-21, NASA-3/Mir-22 and NASA-4/Mir-23 missions. The radiation environment under low shielding was measured using an External Dosimeter Array (EDA) mounted on the outer surface of the Kvant 2 module. The external radiation environment and a location inside the Kvant 2 roughly corresponding to the location of the EDA were monitored for 130 days during the NASA- 4/Mir-23 and NASA-5/Mir-24 missions. Dose rates measured by APD TLDs ranged from 271 to 407 microGy/d during the NASA-2/Mir-21 mission, from 265 to 378 microGy/d during the NASA-3/Mir-22 mission, and from 287 to 421 microGy/d during the NASA-4/Mir-23 mission. APD PNTDs have been analyzed and LET spectra have been Cenerated for the five APDs exposed on the NASA-2/Mir-21 mission and for two APD PNTDs exposed on the NASA-3/Mir-22 mission. Dose equivalent rates on the NASA-2/Mir-21 mission ranged from 513 microSv/d in the Kvant 2 module to 710 microSv/d on the floor of the Base Block. Dose as a function of shielding depth in TLDs has been measured in the thin TLD stacks including in the EDA. EDA dose range from 72.5 Gy under 0.0146 g/sq cm to 0.093 Gy under 3.25 g/sq cm of shielding. Readout and analysis of the reaming PNTDs form the NASA-3/Mir-22 mission and PNTDs from the NASA-4/Mir-23 mission (including those from the EDA) is ongoing and will be completed during the final year of this experiment. Dose equivalent rates for the NASA-3/Mir-22 and NASA-4/Mir-23 APDs will then be determined and comparisons will be made with both model calculations and with results from similar measurements.

Author

Environment Pollution; Radiation Measurement; Mir Space Station; Radiation Shielding

19990019278 NASA Langley Research Center, Hampton, VA USA

Assessment and Requirements of Nuclear Reaction Databases for GCR Transport in the Atmosphere and Structures

Cucinotta, F. A.; Wilson, J. W.; Shinn, J. L.; Tripathi, R. K.; Advanced Space Research; 1998; ISSN 0273-1177; Volume 21, No. 12; In English; Copyright; Avail: CASI

The transport properties of galactic cosmic rays (GCR) in the atmosphere, material structures, and human body (self-shielding) are of interest in risk assessment for supersonic and subsonic aircraft and for space travel in low-Earth orbit and on interplanetary missions. Nuclear reactions, such as knockout and fragmentation, present large modifications of particle type and energies of the galactic cosmic rays in penetrating materials. We make an assessment of the current nuclear reaction models and improvements in these model for developing required transport code data bases. A new fragmentation data base (QMSFRG) based on microscopic models is compared to the NUCFRG2 model and implications for shield assessment made using the HZETRN radiation transport code. For deep penetration problems, the build-up of light particles, such as nucleons, light clusters and mesons from nuclear reactions in conjunction with the absorption of the heavy ions, leads to the dominance of the charge Z = 0, 1, and 2 hadrons in the exposures at large penetration depths. Light particles are produced through nuclear or cluster knockout and in evaporation events with characteristically distinct spectra which play unique roles in the build-up of secondary radiations in shielding. We describe models of light particle production in nucleon and heavy ion induced reactions and make an assessment of the importance of light particle multiplicity and spectral parameters in these exposures. Author

Assessments; Galactic Cosmic Rays; Nuclear Reactions; Data Bases; Evaporation; Radiation Transport

19990045892 NASA Johnson Space Center, Houston, TX USA

Radial Distribution of Electron Spectra from High-Energy Ions

Cucinotta, Francis A.; Katz, Robert; Wilson, John W.; Radiat. Environ. Biophys.; 1998; Volume 37; In English; Copyright; Avail: Other Sources

The average track model describes the response of physical and biological systems using radial dose distribution as the key physical descriptor. We report on an extension of this model to describe the average distribution of electron spectra as a function of radial distance from an ion. We present calculations of these spectra for ions of identical linear energy transfer (LET), but dissimilar charge and velocity to evaluate the differences in electron spectra from these ions. To illustrate the usefulness of the radial electron spectra for describing effects that are not described by electron dose, we consider the evaluation of the indirect events in microdosimetric distributions for ions. We show that folding our average electron spectra model with experimentally determined frequency distributions for photons or electrons provides a good representation of radial event spectra from high-energy ions in 0.5-2 micrometer sites.

Author

Linear Energy Transfer (LET); Energy Spectra; Ions; High Energy Electrons; Electron Irradiation; Ion Irradiation

19990116958 NASA Langley Research Center, Hampton, VA USA

Transport of Light Ions in Matter

Wilson, J. W.; Cucinotta, F. A.; Tai, H.; Shinn, J. L.; Chun, S. Y.; Tripathi, R. K.; Sihver, L.; Advances in Space Research; 1998; ISSN 0273-1177; Volume 21, No. 12; In English; No Copyright; Avail: CASI

A recent set of light ion experiments are analyzed using the Green's function method of solving the Boltzmann equation for ions of high charge and energy (the GRNTRN transport code) and the NUCFRG2 fragmentation database generator code. Although the NUCFRG2 code reasonably represents the fragmentation of heavy ions, the effects of light ion fragmentation requires a more detailed nuclear model including shell structure and short range correlations appearing as tightly bound clusters in the light ion nucleus. The most recent NTJCFRG2 code is augmented with a quasielastic alpha knockout model and semiempirical adjustments (up to 30 percent in charge removal) in the fragmentation process allowing reasonable agreement with the experiments to be obtained. A final resolution of the appropriate cross sections must await the full development of a coupled channel reaction model in which shell structure and clustering can be accurately evaluated.

Author

Light Ions; Mathematical Models; Extraterrestrial Radiation; Beam Interactions; Nuclear Models; Radiation Transport

20000107152 Joint Inst. for Nuclear Research, Dubna, USSR

Cytogenetic effects of heavy ions in human lymphocytes

Krasavin, E. A.; Govorun, R. D.; Repin, M. V.; Druzhinin, S. V.; Fedorenko, B. S.; Dec. 31, 1997; In English; 8th, 1997, Upton, NY, USA

Report No.(s): DE98-618172; JINR-E-19-97-170; No Copyright; Avail: Department of Energy Information Bridge

One of the important tasks in space radiobiology is the evaluation of the genetic risk of galactic heavy charged particles. Cytogenetic analysis of the cosmonauts' lymphocytes after space flight missions (the duration of missions was 117 - 515 days) reveals the increase of the frequency of different types of unstable chromosomal aberrations. This effect can reflect the action of space radiation and foremost the galactic space radiation on the genetic structures. In this connection it is important to study the peculiarities of the induction of stable chromosomal aberration in human lymphocytes by different types of ionizing radiation. The technique of fluorescence in situ hybridization (FISH) with chromosome-1-specific DNA probe was used to analyse the chromosomal damages after irradiation by nitrogen ions (50 MeV/nucleon) and (gamma)-rays (Cs-137). It is shown that the number of cells with aberrations of chromosome-1 increases and reaches 75% after nitrogen ion and (gamma)-ray irradiation at 3 Gy and 7 Gy, respectively. The total number of aberrations and the frequency of chromosome-1 translocations increase nonlinearly with the dose of (gamma)-rays and linearly after heavy ion irradiation. The high frequency of chromosome-1 deletions was revealed in experiment with heavy ions. The values of the relative biological effectiveness (RBE) of nitrogen ions were (approx)3 on the frequency of chromosome-1 translocations.
NTIS
Heavy Ions; Cytogenesis; Extraterrestrial Radiation; Radiation Effects; Radiobiology; Lymphocytes; Relative Biological Effectiveness (RBE)

19980006777 NASA Langley Research Center, Hampton, VA USA
Galactic and Solar Cosmic Ray Shielding in Deep Space
Wilson, John W.; Cucinotta, Francis A.; Tai, H.; Simonsen, Lisa C.; Shinn, Judy L.; Thibeault, Shelia; Kim, M. Y.; Dec. 1997; In English
Contract(s)/Grant(s): RTOP 199-45-16-11
Report No.(s): NASA-TP-3682; NAS 1.60:3682; L-17634; No Copyright; Avail: CASI

An analysis of the radiation hazards in support of NASA deep space exploration activities is presented. The emphasis is on materials required for radiation protection shielding. Aluminum has been found to be a poor shield material when dose equivalent is used with exposure limits for low Earth orbit (LEO) as a guide for shield requirements. Because the radiation issues are cost related-the parasitic shield mass has high launch costs, the use of aluminum as a basic construction material is clearly not cost-effective and alternate materials need to be developed. In this context, polyethylene is examined as a potentially useful material and demonstrates important advantages as an alternative to aluminum construction. Although polyethylene is useful as a shield material, it may not meet other design criteria (strength, stability, thermal); other polymer materials must be examined.
Author
Galactic Cosmic Rays; Shielding; Solar Cosmic Rays; Radiation Hazards; Deep Space; Aluminum; Low Earth Orbits; Cost Effectiveness; Radiation Protection; Polyethylenes

19980137598 NASA Langley Research Center, Hampton, VA USA
Shielding Strategies for Human Space Exploration
Wilson J. W., Editor; Miller, J., Editor; Konradi, A., Editor; Cucinotta, F. A., Editor; Dec. 1997; In English; FROM, 6-8 Dec. 1995, Houston, TX, USA
Contract(s)/Grant(s): RTOP 199-45-16-11
Report No.(s): NASA-CP-3360; L-17661; NAS 1.55:3360; No Copyright; Avail: CASI

A group of twenty-nine scientists and engineers convened a 'Workshop on Shielding Strategies for Human Space Exploration' at the Lyndon B. Johnson Space Center in Houston, Texas. The provision of shielding for a Mars mission or a Lunar base from the hazards of space radiations is a critical technology since astronaut radiation safety depends on it and shielding safety factors to control risk uncertainty appear to be great. The purpose of the workshop was to define requirements for the development and evaluation of high performance shield materials and designs and to develop ideas regarding approaches to radiation shielding. The workshop was organized to review the recent experience on shielding strategies gained in studies of the 'Space Exploration Initiative (SEI),' to review the current knowledge base for making shield assessment, to examine a basis for new shielding strategies, and to recommend a strategy for developing the required technologies for a return to the moon or for Mars exploration. The uniqueness of the current workshop arises from the expected long duration of the missions without the protective cover of the geomagnetic field in which the usually small and even neglected effects of the galactic cosmic rays (GCR) can no longer be ignored. It is the peculiarity of these radiations for which the inter-action physics and biological action are yet to be fully understood.
Author (revised)
Solar Radiation Shielding; Aerospace Environments; Galactic Cosmic Rays; Space Exploration; Spacecraft Shielding; Astronauts; Space Flight; Radiation Protection

19970036323 NASA Langley Research Center, Hampton, VA USA

Comparison of Stopping Power and Range Databases for Radiation Transport Study

Tai, H.; Bichsel, Hans; Wilson, John W.; Shinn, Judy L.; Cucinotta, Francis A.; Badavi, Francis F.; Oct. 1997; In English

Contract(s)/Grant(s): RTOP 199-45-16-11

Report No.(s): NASA-TP-3644; NAS 1.60:3644; L-17588; No Copyright; Avail: CASI

The codes used to calculate stopping power and range for the space radiation shielding program at the Langley Research Center are based on the work of Ziegler but with modifications. As more experience is gained from experiments at heavy ion accelerators, prudence dictates a reevaluation of the current databases. Numerical values of stopping power and range calculated from four different codes currently in use are presented for selected ions and materials in the energy domain suitable for space radiation transport. This study of radiation transport has found that for most collision systems and for intermediate particle energies, agreement is less than 1 percent, in general, among all the codes. However, greater discrepancies are seen for heavy systems, especially at low particle energies.

Author

Particle Energy; Radiation Shielding; Ion Accelerators; Ions; Extraterrestrial Radiation; Stopping Power

19970036446 NASA Langley Research Center, Hampton, VA USA

Exposures to Solar Particle Events in Deep Space Missions

Wilson, John W.; Shinn, Judy L.; Simonsen, Lisa C.; Cucinotta, Francis A.; Dubey, R. R.; Jordan, W. R.; Jones, T. D.; Chang, C. K.; Kim, M. Y.; Oct. 1997; In English

Contract(s)/Grant(s): RTOP 199-45-16-11

Report No.(s): NASA-TP-3668; NAS 1.60:3668; L-17616; No Copyright; Avail: CASI

The physical composition and intensities of exposures to solar particle events of sensitive astronaut tissues are examined under conditions approximating an astronaut in space. Response functions for conversion of particle fluence into dose and dose equivalent are used to establish significant fluence levels and the expected dose and dose rates of the most important events from past observations. The BRYNTRN transport code is used to evaluate the local environment experienced by sensitive tissues and is used to evaluate bioresponse models developed for use in tactical nuclear warfare. The present results will help to clarify the biophysical aspects of such exposure in the assessment of relative biological effectiveness (RBE) and dose rate effects and their impact on the design of protection systems for the astronauts. The use of polymers as shielding material in place of an equal mass of aluminum would provide a large safety factor without increasing the vehicle mass. This safety factor is sufficient to provide adequate protection if an event a factor of 2 larger than has ever been observed occurs during the mission.

Author

Exposure; Solar Storms; Relative Biological Effectiveness (RBE); Fluence; Biophysics; Astronauts

19980000422 Armed Forces Radiobiology Research Inst., Bethesda, MD USA

AFRRI Reports

Aug. 1997; In English

Report No.(s): AD-A329318; No Copyright; Avail: CASI

This volume contains AFRRI Scientific Reports SR97-1 through SR97-10 for January-June 1997. The following topics are discussed: The antioxidant trolox enchances the oxidation of 1', 7'-dichlorofluorescin to 2', 7'-dichlorofluorescein; Effects of ondansetron and ICS 205-930 on radiation-induced hypothermia in rats; Regional differences in glial cell modulation of synaptic transmission; Synthetic trehalose dicorynomycolate (S-TDCM), human behavioral effects and radioprotection; Premature chromosome condensation assay for biodosimetry, studies with fission-neutrons; Thiol WR-1065 and disulphide WR-33278, two metabolites of the drug Ethyol (WR-2771), protect DNA against fast neutron-induced strand breakage; Radiomodification by caffeine alone and its combitation with phosphorothioates, In vivo and cell-free studies; MDRl/p-glycoprotein function, (1) Effect of hypotonicity and inhibitors on 123 exclusion, and (2) Effect of hypotonicity and inhibitors on Cl(-) efflux and volume regulation; and Effects of nitrogen mustard alone and in combination with ionizating radiation on guanine.

CASI

Radiobiology; Radiation Protection

19970023530 NASA Langley Research Center, Hampton, VA USA
Calculation of Heavy Ion Inactivation and Mutation Rates in Radial Dose Model of Track Structure
Cucinotta, Francis A.; Wilson, John W.; Shavers, Mark R.; Katz, Robert; Jul. 1997; In English
Contract(s)/Grant(s): RTOP 199-45-16-11
Report No.(s): NASA-TP-3630; L-17579; NAS 1.60:3630; No Copyright; Avail: CASI

In the track structure model, the inactivation cross section is found by summing an inactivation probability over all impact parameters from the ion to the sensitive sites within the cell nucleus. The inactivation probability is evaluated by using the dose response of the system to gamma rays and the radial dose of the ions and may be equal to unity at small impact parameters. We apply the track structure model to recent data with heavy ion beams irradiating biological samples of E. coli, B. subtilis spores, and Chinese hamster (V79) cells. Heavy ions have observed cross sections for inactivation that approach and sometimes exceed the geometric size of the cell nucleus. We show how the effects of inactivation may be taken into account in the evaluation of the mutation cross sections in the track structure model through correlation of sites for gene mutation and cell inactivation. The model is fit to available data for HPRT (hypoxanthine guanine phosphoribosyl transferase) mutations in V79 cells, and good agreement is found. Calculations show the high probability for mutation by relativistic ions due to the radial extension of ions track from delta rays. The effects of inactivation on mutation rates make it very unlikely that a single parameter such as LET (linear energy transfer) can be used to specify radiation quality for heavy ion bombardment.
Author
Biophysics; Heavy Ions; Mutations; Ion Irradiation; Linear Energy Transfer (LET); Radiation Protection

19970022375 NASA Langley Research Center, Hampton, VA USA
New Parameterization of Neutron Absorption Cross Sections
Tripathi, Ram K.; Wilson, John W.; Cucinotta, Francis A.; Jun. 1997; In English
Contract(s)/Grant(s): RTOP 199-45-16-11
Report No.(s): NASA-TP-3656; NAS 1.60:3656; L-17598; No Copyright; Avail: CASI

Recent parameterization of absorption cross sections for any system of charged ion collisions, including proton-nucleus collisions, is extended for neutron-nucleus collisions valid from approx. 1 MeV to a few GeV, thus providing a comprehensive picture of absorption cross sections for any system of collision pairs (charged or uncharged). The parameters are associated with the physics of the problem. At lower energies, optical potential at the surface is important, and the Pauli operator plays an increasingly important role at intermediate energies. The agreement between the calculated and experimental data is better than earlier published results.
Author
Absorption Cross Sections; Neutron Cross Sections; Neutrons; Protons; Collisions

19970024855 San Francisco Univ., CA USA
Environmental Radiation Measurements on MIR Station, Program 1, Internal Experiment
Benton, E. V.; Frank, A. L.; Benton, E. R.; Apr. 15, 1997; In English
Contract(s)/Grant(s): NCC2-893
Report No.(s): NASA-CR-205067; NAS 1.26:205067; No Copyright; Avail: CASI

Environmental radiation levels on the Russian space station Mir are being monitored under differing shielding conditions by a series of six area passive dosimeters (APDs) placed at individual locations inside the Core and Kvant 2 modules, and by an External Dosimeter Array (EDA) to be deployed on the exterior surface of the Kvant 2 module. Each APD and the EDA contains CR-39 plastic nuclear track detectors (PNTDs) for measurement of LET spectra and TLDs for absorbed dose measurements. Two of the missions, NASA-2/Mir-21 and NASA-3/Mir-22 have been completed and the six APDs from each mission returned to Earth from Mir. This report covers progress to date on the analysis of TLDs and PNTDs from these two missions. For NASA-2/Mir-21, average mission absorbed dose rates varied from 271 to 407 micro-Gy/d at the APDS. For NASA-3/Mir-22, average mission absorbed dose rates varied from 265 to 421 micro-Gy/d.
Author
Terrestrial Radiation; Radiation Measurement; Radiation Dosage; Aerospace Environments

19970016813 NASA Langley Research Center, Hampton, VA USA
Astronaut Protection from Solar Event of August 4, 1972
Wilson, John W.; Cucinotta, Francis A.; Jones, T. D.; Chang, C. K.; Apr. 1997; In English
Contract(s)/Grant(s): RTOP 199-45-16-11
Report No.(s): NASA-TP-3643; NAS 1.60:3643; L-17590; No Copyright; Avail: CASI

The dose rates in the blood-forming organ of a typical astronaut for four space shielding conditions are used to study the astronaut health effects of the solar particle event which began on August 4, 1972. This event was chosen as it was the most hazardous event for which detailed measurements have been made and for which dire predictions of the potential health effects have at times been suggested. The code used for health effects is the biological model developed for tactical nuclear weapons warfare survival of young adults in a 1 g environment. We find the risks of early lethality to be very small especially if appropriate medical action (antibiotics and blood transfusions) is taken soon after the exposure. The primary concern would then be for the development of cancer later in life. Although leukemia could occur relatively soon after the exposure, the risk of solid tumors might be best controlled by using mature individuals for the mission, and thereby offset cancer risk by balancing life span remaining against the long latency periods associated with solid tumors. Use of genetic selection criteria could further reduce health risks during the mission. A possible space experiment to evaluate synergistic effects of the microgravity environmental stress and other space-related stress factors is discussed.
Author
Shielding; Astronauts; Dosage; Radiation Effects; Aerospace Medicine; Exposure; Radiation Dosage; Lethality; Organs

19970011098 NASA Langley Research Center, Hampton, VA USA
Universal Parameterization of Absorption Cross Sections
Tripathi, R. K.; Cucinotta, Francis A.; Wilson, John W.; Jan. 1997; In English
Contract(s)/Grant(s): RTOP 199-45-16-11
Report No.(s): NASA-TP-3621; NAS 1.60:3621; L-17580; No Copyright; Avail: CASI

This paper presents a simple universal parameterization of total reaction cross sections for any system of colliding nuclei that is valid for the entire energy range from a few AMeV to a few AGeV. The universal picture presented here treats proton-nucleus collision as a special case of nucleus-nucleus collision, where the projectile has charge and mass number of one. The parameters are associated with the physics of the collision system. In general terms, Coulomb interaction modifies cross sections at lower energies, and the effects of Pauli blocking are important at higher energies. The agreement between the calculated and experimental data is better than all earlier published results.
Author
Absorption Cross Sections; Parameterization; Nuclear Interactions; Particle Collisions

19980024372 NASA, Washington, DC USA, International Academy of Astronautics, Paris, France, Universities Space Research Association, Houston, TX USA
Operational Aspects of Space Radiation
12th Man in Space Symposium: The Future of Humans in Space. Abstract Volume; 1997; In English; No Copyright; Avail: CASI

In this session, Session FA4, the discussion focuses on the following topics: Solar Particle Events and the International Space Station; Radiation Environment on Mir and ISS Orbits During the Solar Cycle; New approach to Radiation Risk Assessment; An Industrial Method to Predict Major Solar Flares for a Better Protection of Human Beings in Space; Description of the Space Radiation Control System for the Russian Segment of ISS; Orbit Selection and Its Impact on Radiation Warning Architecture for a Human Mission to Mars; and Space Nuclear Power - Technology, Policy and Risk Considerations in Human Missions to Mars.
CASI
Aerospace Environments; Radiation Effects; Mars Exploration; Solar Flares; Solar Corpuscular Radiation; Extraterrestrial Radiation; Aerospace Medicine; Radiation Damage; Radiation Protection

19980024368 NASA, Washington, DC USA, International Academy of Astronautics, Paris, France, Universities Space Research Association, Houston, TX USA
Biological Bases of Space Radiation Risk
12th Man in Space Symposium: The Future of Humans in Space. Abstract Volume; 1997; In English; No Copyright; Avail: CASI

In this session, Session JP4, the discussion focuses on the following topics: Hematopoiesis Dynamics in Irradiated Mammals, Mathematical Modeling; Estimating Health Risks in Space from Galactic Cosmic Rays; Failure of Heavy Ions to Affect Physiological Integrity of the Corneal Endothelial Monolayer; Application of an Unbiased Two-Gel CDNA Library Screening Method to Expression Monitoring of Genes in Irradiated Versus Control Cells; Detection of Radiation-Induced DNA Strand Breaks in Mammalian Cells By Enzymatic Post-Labeling; Evaluation of Bleomycin-Induced Chromosome

Aberrations Under Microgravity Conditions in Human Lymphocytes, Using ″Fish″ Techniques; Technical Description of the Space Exposure Biology Assembly Seba on ISS; and Cytogenetic Research in Biological Dosimetry.
CASI
Aerospace Medicine; Radiation Effects; Extraterrestrial Radiation; Galactic Cosmic Rays; Radiation Damage; Exobiology; Physiological Effects; Biological Effects; Aerospace Environments; Irradiation; Mammals; Mathematical Models

20000112938 Utah Univ., Salt Lake City, UT USA
Modulation of Radiation-Induced Apoptosis by Thiolamines
Warters, R. L.; Roberts, J. C.; Wilmore, B. H.; Kelley, L. L.; International Journal of Radiation Biology; 1997; ISSN 0955-3002; Volume 72, No. 4; In English
Contract(s)/Grant(s): NAGW-4914; NIH-5R29GM44785; 5P30-CA42401; Copyright; Avail: Other Sources

Exposure to the thiolamine radioprotector N-(2-mercaptoethyl)-1,3-propanediamine (WR-1065) induced apoptosis in the mouse TB8-3 hybridoma after 60-minute (LD(sub50) = 4.5mM) or during a 20-hour (LD(sub50) = 0.15 mM) exposure. In contrast, a 20-hour exposure to 17 mM L-cysteine or 10 mM cysteamine was required to induce 50 percent apoptosis within 20 hours. Apoptosis was not induced by either a 60-minute or 20-hour exposure to 10 mM of the thiazolidime prodrugs ribose-cysteine (RibCys) or ribose-cysteamine (RibCyst). Thiolamine-induced apoptosis appeared to be a p53-independent process since it was induced by WR-1065 exposure in human HL60 cells. Exposure to WR-1065 (4mM for 15 minutes) or cysteine (10mM for 60 minutes) before and during irradiation protected cells against the induction of both DNA double-strand breaks and apoptosis, while exposure to RibCys (10 mM for 3 hours) did not. Treatment with either WR-1065, cysteine, RibCys or RibCyst for 60 minutes beginning 60 minutes after irradiation did not affect the level of radiation-induced apoptosis. In contrast, treatment with either cysteine, cysteamine or RibCys for 20 hours beginning 60 minutes after irradiation enhanced radiation-induced apoptosis. Similar experiments could not be conducted with WR-1065 because of its extreme toxicity. Our results indicate that thiolamine enhancement of radiation-induced apoptosis is not involved in their previously reported capacity to reduce radiation-induced mutations.
Author
Radiation Effects; Irradiation; Modulation; Apoptosis; Radiation Protection

19970037440 Southwest Research Inst., San Antonio, TX USA
Energetic Proton Dose-Response: The Relative Biological Effectiveness of Energetic Protons in the Induction of Head and Neck Tumors in Rats
Wood, David H.; Trotter, Ronald W.; Hardy, Kenneth A.; Cox, Ann B.; Salmon, Yolanda L.; 1997; In English; Original contains color illustrations
Contract(s)/Grant(s): NAG9-528; NAGw-3912
Report No.(s): NASA-CR-205150; NAS 1.26:205150; No Copyright; Avail: CASI

In previous lifespan studies sponsored jointly by The National Aeronautics and Space Administration and the USA Air Force, rhesus monkeys that were given total body surface exposures of high energy protons experienced an unusual incidence of malignant brain tumors /1/. To investigate the risk of similar tumor occurrence subsequent to solar radiation exposures in humans, 1100 Fischer-344 rats, aged 70 days, were exposed to uniformly distributed head-only doses of spread Bragg Peak protons. They were divided into five dose groups of 200 animals each, with an additional 100 animals for disease control sentinels. The dose groups were zero (sham-irradiated), 2, 4, 8.5 and 18 Gy. Every subject that completed the study received a post-mortem examination including serial sections of the brain for histological verification of tumor occurrence and type. After the proton study was completed, five additional group of rats of the same age, sex and strain was exposed to head-only Co-60 gamma-radiation on the same dose and dose rate schedule as the proton-exposed rats and they were maintained and observed under the same conditions. The five dose groups each consisted of 40 animals, with an additional 20 disease control sentinels, for a total of 220 rats. Total head and neck tumor incidence for both types of radiation in the dose range of 0-8.5 Gy displayed a linear dose-response. The exposed rats had a greater incidence of tumors, especially pituitary chromophobe adenomas, epithelial tumors and mesenchymal cell tumors, than the unexposed controls, but the excessive occurrence of malignant gliomas that had previously been observed in proton-irradiated monkeys was absent in the rats. The hypothesis that the relative biological effectiveness (RBE) of protons in the induction of head and neck tumors was unity could not be rejected; however, a significant increase in precancerous squamous metaplasia was observed in the proton-exposed rats, but not in the Co-60-exposed animals. We conclude that the occurrence of radiation-induced brain tumors in the rhesus monkeys can be

explained by the Bragg Peak dose distribution in susceptible tissues rather than by a high RBE of protons for brain tumor induction.
Author
Rats; Tumors; Biological Effects; Protons; Dosage; Relative Biological Effectiveness (RBE); Cobalt 60; Gamma Rays; Radiation Dosage; Solar Radiation; Proton Energy

19970017845 Moscow State Univ., Russia
Long-term variations of the radiation doses on board Mir Space Station
Panasyuk, M. I.; Teltsov, M. V.; Shumshurov, V. I.; Bashkirov, V. F.; Dec. 1996; In English; No Copyright; Avail: CASI

Prolonged dose measurements inside the Mir space station were used to study long term dose variations induced by galactic cosmic rays, six-month dose variations due to radiation belt electrons and protons and sporadic dose variations associated with solar proton events. The magnitudes of the dose variations associated with the 11-year solar cycle and 6-month seasonal dose variations can be as large as 50 percent. The daily averaged doses during the winter minimum of the 22nd solar cycle are significantly greater than the predicted dose values. The data are compared with the doses simultaneously measured onboard the Interball satellite.
Author (ESA)
Galactic Cosmic Rays; Radiation Dosage; Mir Space Station

19970018678 Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Cologne, Germany
Radiation biology in space
Reitz, G.; Dec. 1996; In English; No Copyright; Avail: CASI

Work carried out in relation to the effects of radiation and the orbital radiation environment is reviewed. Radiation constitutes one of the most important hazards for man in long term space missions. The results from various space probes demonstrate greater radiation levels in orbit than on the earth's surface, and a change in the nature of the radiation field, including the addition of a heavy ion component. Radiation protection activities are an integral part of the mission. It is considered that the highest priority has to be given to the study of heavy ion effects so that the risk of deterministic and stochastic effects can be estimated with confidence, and that the effect of spaceflight parameters such as microgravity on the expression of radiation effects needs to be investigated. The results from spaceborne experiments and ground-based experiments are reviewed, and the interaction of the spaceflight environment and radiation is discussed. The future ground-based and spaceborne research required is considered.
Author (ESA)
Radiation Hazards; Long Duration Space Flight; Earth Orbital Environments; Radiation Effects

19970018684 Kayser Threde G.m.b.H., Munich, Germany
Space Exposure Biology Assembly (SEBA): Results of the phase A definition study
Schulte, W.; Hofman, P.; Rank, P.; Koenig, H.; Dec. 1996; In English
Contract(s)/Grant(s): ESA-11541/95/NL/JS; No Copyright; Avail: CASI

The space exposure biology assembly (SEBA), designed for installation as an external payload onboard the International Space Station, is presented. In its baseline configuration, SEBA consists of two experimental units: the sun exposed experiment unit designed for photobiology and photoprocessing experiments, and an experiment unit for the simulation of the long term extravehicular activities through the use of a model of the human head and torso equipped with sensors for radiation dosimetric experiments. The facility is designed to provide resources to accommodate self-standing biological or dosimetric add-on experiments. The accommodation of the facility on the space station, the flight operations and the configuration of the two experiment units, called Expose and Matroshka respectively, are described.
Author (ESA)
Bioastronautics; Spaceborne Experiments; Space Station Payloads; Extravehicular Activity; Aerospace Medicine; Exobiology; International Space Station

19970025391 California Univ., Berkeley. Lawrence Berkeley Lab, CA USA
Biological Responses to Exposure to the Space Radiation Environment
Kronenberg, Amy; Astrobiology Workshop: Leadership in Astrobiology; Dec. 1996; In English; No Copyright; Avail: Other Sources

The environment in space is different from that on Earth in many ways. One of the environmental factors that is unique

is the space radiation environment. This environment may play an ongoing role in the evolution of life in the universe in addition to being an important consideration for human exploration in space. The radiation environments encountered in space are different from the natural background radiation on Earth and are complex in nature. Both bacteria and eukaryotes have evolved a series of mechanisms to respond to similar damages on Earth.
Author
Aerospace Environments; Biological Effects; Damage; Eukaryotes; Extraterrestrial Radiation; Physiological Responses; Spacecrews

19970026971 Institute of Space Medico, Beijing, China
Space Medicine and Medical Engineering, Volume 9
Wei, J.; Dec. 1996; In Mixed Languages; Portions of this document are not fully legible
Report No.(s): PB97-142731; No Copyright; Avail: National Technical Information Service (NTIS)

Contents include the following: A Space Ergonomic Data Base System with Dynamic Human Body Model (in English); Study on P300 of Selective Response to Visual Signals with Half to Half Probability (in English); Changes in Bone Noncollagenous Proteins and Bone Mineral Redistribution in Tail - Suspended Rats (in English); Selection of Fine Bifidobacterium by Flight Onboard Recoverable Satellite; The Utility of RAPD Markers for Detection of Tomato DNA Mutation Induced by Space Flight; A Preliminary Study on the Biological Effects of the High Energy Heavy Ions; A Study on Absorption of Microwave Radiation Energy by Rhesus Monkeys under Different Polarization Directions; A Study on Maximum Allowable Concentration of 3 - methylindole in Closed Environment; Effect of Vestibular Stimulation on Urinary Cortisol, Aldosterone and Arginine Vasopressin in Pilots; Development of A Small Biocabin for Recoverable Satellite; Development of an Automatic Storage and Transmission System for Blood Pressure Measurement; Assessment of Gz(+) Protection with a New Type Capstan Anti - G Equipment; Comparison of Diagnosis Values Among Different ECG Parameters on Myocardial Ischemia.
NTIS
Aerospace Medicine; Data Bases; Human Body; Human Factors Engineering

19970016628 European Space Agency, Paris France
European Symposium on Life Sciences Research in Space
Kaldeich-Schuermann, Brigitte, compiler; European Symposium on Life Sciences Research in Space; Oct. 1996; In English; 6th, 16-20 Jun. 1996, Trondheim, Norway; Original contains color illustrations
Report No.(s): ESA-SP-390; Copyright; Avail: CASI

Biological research in space and biological aspects of space flight are reported on. The following topics are considered: plant biology; microgravity effects on vestibulo-ocular functions and movement control; space motion sickness; radiation biology; cell biology and gravireceptors; the effects of microgravity on the development of organisms; the bone and muscular system; biotechnology, and the cardiovascular and respiratory systems.
Author (ESA)
Microgravity; Spaceborne Experiments; Weightlessness; Gravitational Effects; Aerospace Medicine; Gravireceptors; Astronaut Performance; Conferences

19970016653 Institute of Biomedical Problems, Moscow, USSR
Biomedical Aspects of Light Flashes Observed by Astronauts during Space Flights
Akatov, Yu.; Arkhangelsky, V.; Petrov, V.; Trukhavnov, K.; Avdeev, S.; Ozerov, Yu.; Popov, A.; Fuglesang, C.; European Symposium on Life Sciences Research in Space; Oct. 1996; In English; No Copyright; Avail: CASI

Work carried out into the phenomena of flashes observed by astronauts and the results of this work are reviewed with emphasis on the biomedical aspects. The phenomenon mechanisms proposed are presented and some new mechanisms are proposed. These mechanisms involve the impingement of energetic particles on the eye. The types of flashes reported are described and categorized. The white, colorless nature of the flashes is considered.
Author (ESA)
Light (Visible Radiation); Visual Perception; Extraterrestrial Radiation

19970016654 Moscow Physical-Engineering Inst., Russia
SilEye on Mir: First Active Detector for the Study of Light Flashes in Space
Galper, A.; Ozerov, Yu.; Popov, A.; Zemskov, V.; Zverev, V.; Alexandrov, A.; Avdeev, S.; Fuglesang, C.; Shabelnikov, V.; Carlson, P.; dePascale, M.; Morselli, A.; Picozza, P.; Sparvoli, R.; Adriani, O.; Castellini, G.; Spillantini, P.; Barbiellini, G.; Boezio, M.; Vacchi, A.; Oct. 1996; In English; No Copyright; Avail: CASI

Work carried out in relation to the phenomena of flashes observed by astronauts with the aim of identifying the sources of these flashes is reported. The silicon eye (SilEye) project which uses a silicon detector mounted as a telescope in front of an astronaut's eye is presented. The system is designed to detect, in real time, the particles which traverse the eye. A pilot version was used onboard the Mir space station and the results are presented and analyzed. Protons and ions are seen. It is considered that at least one light flash event is correlated with a known particle, and that heavy ions are the main cause of the light flash events.
Author (ESA)
Light (Visible Radiation); Visual Perception; Extraterrestrial Radiation; Silicon Radiation Detectors; Heavy Ions

19970001683 NASA, Hampton, VA USA
Study of Analytic Statistical Model for Decay of Light and Medium Mass Nuclei in Nuclear Fragmentation
Cucinotta, Francis A.; Wilson, John W.; Oct. 1996; In English
Contract(s)/Grant(s): RTOP 199-45-16-11
Report No.(s): NASA-TP-3594; NAS 1.60:3594; L-17542; No Copyright; Avail: CASI

The angular momentum independent statistical decay model is often applied using a Monte-Carlo simulation to describe the decay of prefragment nuclei in heavy ion reactions. This paper presents an analytical approach to the decay problem of nuclei with mass number less than 60, which is important for galactic cosmic ray (GCR) studies. This decay problem of nuclei with mass number less than 60 incorporates well-known levels of the lightest nuclei (A less than 11) to improve convergence and accuracy. A sensitivity study of the model level density function is used to determine the impact on mass and charge distributions in nuclear fragmentation. This angular momentum independent statistical decay model also describes the momentum and energy distribution of emitted particles (n, p, d, t, h, and a) from a prefragment nucleus.
Author
Galactic Cosmic Rays; Heavy Ions; Nuclei (Nuclear Physics); Fragmentation; Statistical Analysis

19960053833 Institute of Space Medico, Beijing, China
Relationship between Particle Fluence and Dose in Cabin of Recoverable Satellite
Qi, Zhang-nian; Chen, Mei; Li, Xianggao; Jia, Xianghong; Space Medicine and Medical Engineering; Aug. 15, 1996; Volume 9, No. 4; In Chinese; No Copyright; Avail: CASI

Radiation doses in the cabin of a recoverable satellite measured by personal dosimeters and LiF thermoluminescent dosimeters are presented. The relationship between the particle fluence calculated from the instrument display and the measured doses was studied. It shows that the particle fluence can be directly calculated from the measured dose with a transformation coefficient which is not obviously affected by shielding around the measuring site. The estimated average energy of the particles in the cabin is on the level of galactic cosmic radiation.
Author
Cosmic Rays; Dosimeters; Galactic Radiation; Radiation Shielding; Thermoluminescence; Fluence

19970016450 Armed Forces Radiobiology Research Inst., Bethesda, MD USA
Estimation of Radiation Risk Based on the Concept of Individual Variability of Radiosensitivity
Kovalev, E. E.; Smirnova, O. A.; Jun. 1996; In English
Contract(s)/Grant(s): DNA001-93-C-0152
Report No.(s): AD-A310666; AFRRI-CR96-1; No Copyright; Avail: CASI

This report was prepared for the Defense Nuclear Agency under contract number DNA001-93-C-0152. A description and analysis of mathematical models developed for two critical systems, the hematopoietic and intestinal systems, are presented. The models, based on modem theories of regulation of the hematopoietic and intestinal epithelium systems, describe the dynamics of these systems in nonirradiated mammals and in mammals exposed to acute and chronic radiation. The first model uses the radiosensitivity indices of hematopoietic cells as its principal parameters. The key parameter of the second model is the radiosensitivity index of precursors of principal crypt cells. The variable parameters of the models are represented by the dose of acute radiation and the dose rate of chronic radiation. These models can be used for quantitative prediction of the effects of acute and chronic radiation on the hematopoietic and intestinal systems of mammals.
DTIC
Hematopoietic System; Radiation Tolerance; Radiobiology; Biological Effects; Mathematical Models; Intestines; Radiation Effects

19960020623 NASA Johnson Space Center, Houston, TX USA

Estimate of Space Radiation-Induced Cancer Risks for International Space Station Orbits

Wu, Honglu; Atwell, William; Cucinotta, Francis A.; Yang, Chui-hsu; Mar. 1996; In English

Report No.(s): NASA-TM-104818; NAS 1.15:104818; S-806; No Copyright; Avail: CASI

Excess cancer risks from exposures to space radiation are estimated for various orbits of the International Space Station (ISS). Organ exposures are computed with the transport codes, BRYNTRN and HZETRN, and the computerized anatomical male and computerized anatomical female models. Cancer risk coefficients in the National Council on Radiation Protection and Measurements report No. 98 are used to generate lifetime excess cancer incidence and cancer mortality after a one-month mission to ISS. The generated data are tabulated to serve as a quick reference for assessment of radiation risk to astronauts on ISS missions.

Author

Cancer; Radiation Protection; Risk; Computerized Simulation; International Space Station; Extraterrestrial Radiation

19950057278

Theoretical model of HZE particle fragmentation by hydrogen targets

Townsend, L.W.; Cucinotta, F. A; Bagga, R.; Tripathi, R. K.; Advances in Space Research; 1996; ISSN 0273-1177; 17, 2; In English; Copyright; Avail: Other Sources

The fragmenting of high energy, heavy ions (HZE particles) by hydrogen targets is an important, physical process in several areas of space radiation research. In this work quantum mechanical optical model methods for estimating cross sections for HZE particle fragmentation by hydrogen targets are presented. The cross sections are calculated using a modified abrasion-ablation collision formalism adapted from a nucleus-nucleus collision model. Elemental and isotopic production cross sections are estimated and compared with reported measurements for the breakup of neon, sulphur, and iron, nuclei at incident energies between 400 and 910 Mev/nucleon. Good agreement between theory and experiment is obtained.

Author (Herner)

Atomic Collisions; Fragmentation; Heavy Ions; Hydrogen; Isotopes; Nuclear Interactions

19970022263 Armed Forces Radiobiology Research Inst., Bethesda, MD USA

AFRRI Reports

Jan. 1996; In English

Report No.(s): AD-A321315; No Copyright; Avail: CASI

Table contents: Effect of chloral hydrate on in vivo KCl-induced striatal dopamine release in the rat. Effect of ionizing radiation on in vivo striatal release of dopamine in the rat. Transient and persistent experimental infection of nonhuman primates with Helicobacter pylori: Implications for human disease. Indomethacin attenuation of radiation-induced hyperthermia does not modify radiation-induced motor hypoactivity. Behavioral toxicity and radioprotective efficacy of WR-15l327 in combination with adenosine receptor antagonists. Chromatographic and mass spectral analysis of the radioprotector and chemoprotector S-3-(3 -methylaminopropylamino)propanethiol (WR- 15t326) and its symmetrical disulfide (WR-25595501). Mechloretharnine-induced enhancement of radiation sensitivity of guanine.

DTIC

Ionizing Radiation; Radiation Effects; Rats; Toxicity

19950057274 NASA Langley Research Center, Hampton, VA, USA, NASA Lyndon B. Johnson Space Center, Houston, TX, USA

Light ion components of the galactic cosmic rays: Nuclear interactions and transport theory

Cucinotta, F. A.; Townsend, L. W.; Wilson, J. W.; Shinn, J. L.; Badhwar, G. D.; Dubey, R. R.; Advances in Space Research; 1996; ISSN 0273-1177; 17, 2; In English; Copyright; Avail: Other Sources

Light nuclei are present in the primary galactic cosmic rays (GCR) and are produced in thick targets due to projectile or target fragmentation from both nucleon and heavy induced reactions. In the primary GCR, He-4 is the most abundant nucleus after H-1. However, there are also a substantial fluxes of H-2 and He-3. In this paper we describe theoretical models based on quantum multiple scattering theory for the description of light ion nuclear interactions. The energy dependence of the light ion fragmentation cross section is considered with comparisons of inclusive yields and secondary momentum distributions to experiments described. We also analyze the importance of a fast component of lights ions from proton and neutron induced target fragementation. These theoretical models have been incorporated into the cosmic ray transport code HZETRN and will

be used to analyze the role of shielding materials in modulating the production and the energy spectrum of light ions.
Author (Herner)
Energy Spectra; Fragmentation; Galactic Cosmic Rays; Light Ions; Nuclear Interactions; Nuclear Scattering; Radiation Shielding; Radiation Transport

19950057273
Neutron yields from interactions of GCR-like beams in stopping targets
Heilbronn, L.; Advances in Space Research; 1996; ISSN 0273-1177; 17, 2; In English; Copyright; Avail: Other Sources

In order to accurately determine the radiation risk to astronauts from Galactic Cosmic Rays (GCR), the nature of the secondary radiation field created by the fragmentation of GCR in shielding and tissue must be understood. Due to their high penetrabilities, neutrons are an important component of the secondary radiation field, especially for astronauts protected by thick shielding on lunar or Martian bases. Neutron yields from 435A MeV and 272A MeV Nb stopping in Nb and Al targets are presented, along with some preliminary analysis of neutron yields from 155A MeV C stopping in Al. Energy spectra and angular distributions are shown for neutron energies above 20 MeV. The data provides some information about the dependence of the neutron yield on projectile energy ad target mass. Comparisons of the data with BUU calculations are also shown.
Author (Herner)
Energy Spectra; Fragmentation; Galactic Cosmic Rays; Neutrons; Nuclear Interactions; Radiation Hazards; Radiation Shielding; Solar Flares

19950057272 NASA Langley Research Center, Hampton, VA, USA
Overview of nuclear fragementation models and needs
Townsend, L. W.; Cucinotta, F. A.; Advances in Space Research; 1996; ISSN 0273-1177; 17, 2; In English; Copyright; Avail: Other Sources

It has been known for some time that adequate assessment of spacecraft requirements and concomitant estimates of astronaut radiation exposures from galactic cosmic radiation requires accurate, quantitative methods for characterizing these radiation fields as they pass through thick absorbers. The main nuclear interaction processes involved are nuclear elastic an inelastic collisions, and nuclear breakup (fragmentation) and electromagnetic dissociation (EMD). Nuclear fragmenation and EMD are important because they alter the elemental and isotopic composition of the transported radiation fields. At present, there is no suitable accurate theory for predicting nuclear fragmentation cross sections for all collision pairs and energies of interest in space radiation protection. Typical cross-section differences between theory and experiment range from about 25 percent to a factor of two. The resulting errors in transported flux, for high linear energy transfer (LET) particles, are compared to these cross-sections errors. In this overview, theoretical models of heavy ion fragmentation currently used to generate input data bases for cosmic-ray transport and shielding codes are reviewed. Their shortcomings are discussed. Further actions needed to improve their accuracy and generality are presented.
Author (Herner)
Atomic Collisions; Electromagnetic Interactions; Fragmentation; Galactic Cosmic Rays; Nuclear Interactions; Radiation Shielding; Radiation Transport

19950057268 NASA Langley Research Center, Hampton, VA, USA
Shielding against galactic cosmic rays
Schimmerling, W.; Wilson, J. W.; Nealy, J. E.; Thibeault, S. A.; Cucinotta, F. A.; Shinn, J. L.; Kim, M.; Kiefer, R.; Advances in Space Research; 1996; ISSN 0273-1177; 17, 2; In English; Copyright; Avail: Other Sources

Ions of galactic origin are modified but not attenuated by the presence of shielding materials. Indeed, the number of particles and the absorbed energy behind most shield materials increases as a function of shield thickness. The modification of the galactic cosmic ray composition upon interaction with shielding is the only effective means of providing astronaut protection. This modification is intimately conntected with the shield transport porperties and is a strong function of shield composition. The systematic behavior of the shield properties in terms of microscopic energy absorption events will be discussed. The shield effectiveness is examined with respect to convectional protection practice and in terms of a biological endpoint: the efficiency for reduction of the probability of transformation of shielded C3H1OT1/2 mouse cells. The relative advantage of developing new shielding technologies is discussed in terms of a shield performance as related to biological effect and the resulting uncertainty in estimating astronaut risk.
Author (Herner)
Efficiency; Energy Absorption; Galactic Cosmic Rays; Ion Atom Interactions; Radiation Shielding; Risk; Transport Properties

19950057266 NASA Lyndon B. Johnson Space Center, Houston, TX, USA

Galactic cosmic radiation model and its applications

Badhwar, G. D.; O'Neill, P. M.; Advances in Space Research; 1996; ISSN 0273-1177; 17, 2; In English; Copyright; Avail: Other Sources

A model for the differential energy spectra of galactic cosmic radiation as a function of solar activity is described. It is based on the standard diffusion-convection theory of solar modulation. Estimates of the modulation potential based on fitting this theory to observed spectral measurements from 1954 to 1989 are correlated to the Climax neutron counting rates and to the sunspot numbers at earlier times taking into account the polarity of the interplanetary magnetic field at the time of observations. These regression lines then provide a method for predicting the modulation at later times. The results of this model are quantitatively compared to a similar Moscow State University (MSU) model. These model cosmic ray spectra are used to predict the linear energy transfer spectra, differential energy spectra of light (charge less than or = 2) ions, and single event upsets rates in memeory devices. These calculations are compared to observations made aboard the Space Shuttle.
Author (Herner)

Energy Spectra; Galactic Cosmic Rays; Interplanetary Magnetic Fields; Modulation; Single Event Upsets; Solar Activity

19950057265 NASA Lyndon B. Johnson Space Center, Houston, TX, USA

Near-earth radiation environment including time variations and secondary radiation; Meetings F2.6 and F2.7, COSPAR Scientific Assembly, 30th, Hamburg, Germany, July 11-21, 1994

Shea, M. A., editor; Heinrich, W., editor; Badhwar, G. D., editor; Advances in Space Research; 1996; ISSN 0273-1177; 17, 2; In English; See also A95-88865 through A95-88891; Copyright; Avail: Other Sources

Both man and technological equipment must survive the near-earth space radiation environment, which can, under specific conditions, be extremely severe. This conference produced 17 papers on the dynamic space radiation environment covering: galactic, solar and trapped particles; nuclear fragmentation; nuclear interactions and transport theory; solar proton events; radiation shielding; and heavy ion fluences. Several papers present results from the recent SAMPEX mission.
Herner

Conferences; Extraterrestrial Radiation; Galactic Cosmic Rays; Radiation Belts; Radiation Shielding; Radiation Transport; Solar Corpuscular Radiation; Trapped Particles

19980222660 Arkansas Univ., Fayetteville, AR USA

Galactic Cosmic-Ray-Produced Thermoluminescence Profiles in Meteorites Lunar Samples and a Terrestrial Analog

Benoit, Paul H.; Chen, Yongheng; Radiation Measurements; 1996; ISSN 1350-4487; Volume 26, No. 2; In English
Contract(s)/Grant(s): NAGw-3479; NSF DPP-91-15521; Copyright; Avail: Other Sources

The long-term radiation shielding properties of common extraterrestrial materials are poorly known, although these materials are the most likely structural elements on airless worlds such as the Moon. We report on radiation dose profiles in meteorites and lunar soil cores using specific minerals as naturally-occurring ″dosimeters″. We find that radiation profiles are fairly flat in typical meteoroid bodies (less than 85 cm radius) and drop by only about 40% through about 2.5 m of lunar soil. These profiles are produced by primary galactic cosmic rays and the secondary proton cascade but with a significant contribution by secondary neutrons at depths of about 2 m (300 g/sq cm).
Author

Galactic Cosmic Rays; Thermoluminescence; Meteorites; Lunar Rocks

19960020566 Institute of Space Medico, Beijing, China

Possibility of Application of the Principles of Differentiation and Treatment of Common Syndromes of the Traditional Chinese Medicine in Manned Spaceflight

Jinhe, Wei, Editor; Tiande, Yang, Editor; Jianfeng, Fan, Editor; Duansheng, Huang, Editor; Zheng, Xu, Editor; Yincheng, Lu, Editor; Xueqi, Yang, Editor; Zhijun, Xiao, Editor; Yong, Liu, Editor; Space Medicine and Medical Engineering; Dec. 1995; In English; No Copyright; Avail: Other Sources

For the purpose of enhancing the application of the traditional Chinese medicine in the area of spaceflight,the physiological effects of spaceflight environment(including microgravity, radiation,isolated narrow- small space, change of biological rhythm) on the human body were discussed and reviewed. Changes in the beginning period of spaceflight are considered as excess syndrome,and its differentiation of syndromes are chaotic meridian Qi and blood, abnormal ascend and descend of the visceral Qi and blood. The principles of its treatment are to ascend the Lucid Yang, to keep the Turbid-Yin downwards, and to promote flow of Qi and blood circulation. Changes in the middle and later stage are considered as

deficiency syndrome complicated with excess, and its differentiaton is deficiency of the liver-Yin and the kidney-Yin,complicated with stagnation of Qi and blood stasis. The principles of its treatment are to nourish the kidney-Yin and the liver-Yin, to invigorate the spleen, replenish Qi and to activate blood circulation.
Author
Aerospace Medicine; Signs and Symptoms; Physiological Effects; Gravitational Effects; Microgravity; Manned Space Flight

19960007435 College of William and Mary, Williamsburg, VA, USA
Shielding materials for highly penetrating space radiations
Kiefer, Richard L.; Orwoll, Robert A.; Nov 14, 1995; In English
Contract(s)/Grant(s): NCC1-151
Report No.(s): NASA-CR-199720; NAS 1.26:199720; NIPS-95-06073; No Copyright; Avail: CASI

Interplanetary travel involves the transfer from an Earth orbit to a solar orbit. Once outside the Earth's magnetosphere, the major sources of particulate radiation are solar cosmic rays (SCR's) and galactic cosmic rays (GCR's). Intense fluxes of SCR's come from solar flares and consist primarily of protons with energies up to 1 GeV. The GCR consists of a low flux of nuclei with energies up to 10(exp 10) GeV. About 70 percent of the GCR are protons, but a small amount (0.6 percent) are nuclei with atomic numbers greater than 10. High energy charged particles (HZE) interact with matter by transferring energy to atomic electrons in a Coulomb process and by reacting with an atomic nucleus. Energy transferred in the first process increases with the square of the atomic number, so particles with high atomic numbers would be expected to lose large amounts of energy by this process. Nuclear reactions produced by (HZE) particles produce high-energy secondary particles which in turn lose energy to the material. The HZE nuclei are a major concern for radiation protection of humans during interplanetary missions because of the very high specific ionization of both primary and secondary particles. Computer codes have been developed to calculate the deposition of energy by very energetic charged particles in various materials. Calculations show that there is a significant buildup of secondary particles from nuclear fragmentation and Coulomb dissociation processes. A large portion of these particles are neutrons. Since neutrons carry no charge, they only lose energy by collision or reaction with a nucleus. Neutrons with high energies transfer large amounts of energy by inelastic collisions with nuclei. However, as the neutron energy decreases, elastic collisions become much more effective for energy loss. The lighter the nucleus, the greater the fraction of the neutron's kinetic energy that can be lost in an elastic collision. Thus, hydrogen-containing materials such as polymers are most effective in reducing the energy of neutrons. Once neutrons are reduced to very low energies, the probability for undergoing a reaction with a nucleus (the cross section) becomes very high. The product of such a reaction is often radioactive and can involve the release of a significant amount of energy. Thus, it is important to provide protection from low energy neutrons during a long duration space flight. Among the light elements, lithium and boron each have an isotope with a large thermal neutron capture cross section, Li-6 and B-10. However, B-10 is more abundant in the naturally-occurring element than Li-6, has a thermal neutron capture cross section four times that of Li-6, and produces the stable products, He-4 and Li-7 in the interaction while Li-6 produces radioactive tritium (H-3). Thus, boron is the best light-weight material for thermal neutron absorption in spacecraft. The work on this project was focused in two areas: computer design where existing computer codes were used, and in some cases modified, to calculate the propagation and interactions of high energy charged particles through various media, and materials development where boron was incorporated into high performance materials.
Author
Absorption Cross Sections; Boron Reinforced Materials; Boron 10; Computer Programs; Particle Interactions; Polymeric Films; Radiation Protection; Spacecraft Shielding; Thermal Neutrons; Thin Films

19960009794 Foreign Broadcast Information Service, Washington, DC, USA, Foreign Broadcast Information Service, Washington, DC, USA
MIR and other Russian spacecraft orbits examined
Mitrikas, V. G.; Tsetlin, V. V.; FBIS Report: Science and Technology. Central Eurasia: Mir and Other Russian Spacecraft Orbits Examined; Oct 27, 1995; In English; Copyright; Avail: Other Sources

This paper gives the results of a statistical analysis of the radiation situation on the Mir manned orbital station in 1987-1992. Comparison of the dynamics of the absorbed dose rate with astrophysical indices shows that it correlates with the proton fluxes of galactic cosmic rays. The authors discuss effects relating to the way that the dose rate depends on the altitude of the orbital station, including the anomalous behavior of this dependence in 1991. Quasiperiodic variations are observed in the correlation coefficient between the mean diurnal absorbed dose rate and the average altitude of the station orbit.
Author (revised)
Correlation Coefficients; Galactic Cosmic Rays; Ionizing Radiation; Mir Space Station; Radiation Dosage; Radiation Effects; Spacecraft Orbits; Statistical Analysis

19960003438 NASA Langley Research Center, Hampton, VA, USA
NUCFRG2: An evaluation of the semiempirical nuclear fragmentation database
Wilson, J. W.; Tripathi, R. K.; Cucinotta, F. A.; Shinn, J. L.; Badavi, F. F.; Chun, S. Y.; Norbury, J. W.; Zeitlin, C. J.; Heilbronn, L.; Miller, J.; Oct 1, 1995; In English
Contract(s)/Grant(s): RTOP 199-45-16-11
Report No.(s): NASA-TP-3533; NAS 1.60:3533; L-17470; NIPS-95-05718; No Copyright; Avail: CASI

A semiempirical abrasion-ablation model has been successful in generating a large nuclear database for the study of high charge and energy (HZE) ion beams, radiation physics, and galactic cosmic ray shielding. The cross sections that are generated are compared with measured HZE fragmentation data from various experimental groups. A research program for improvement of the database generator is also discussed.
Author
Data Bases; Fragmentation; Galactic Cosmic Rays; Ion Beams; Nuclear Physics; Radiation Shielding; Technology Assessment

19960001020 California Univ., Berkeley. Lawrence Berkeley Lab, CA, USA
Neoplastic transformation of human cells
Goth-Goldstein, Regine; Jul 31, 1995; In English
Contract(s)/Grant(s): NASA ORDER T-9297-R
Report No.(s): NASA-CR-199483; NAS 1.26:199483; No Copyright; Avail: CASI

The goal of this project was to gain a better understanding of the cellular mechanisms of cancer induction by ionizing radiation as a risk assessment for workers subjected to high LET irradiation such as that found in space. The following ions were used for irradiation: Iron, Argon, Neon, and Lanthanum. Two tests were performed: growth in low serum and growth in agar were used as indicators of cell transformation. The specific aims of this project were to: (1) compare the effectiveness of various ions on degree of transformation of a single dose of the same RBE; (2) determine if successive irradiations with the same ion (Ge 600 MeV/u) increases the degree of transformation; (3) test if clones with the greatest degree of transformation produce tumors in nude mice; and (4) construct a cell hybrid of a transformed and control (non-transformed) clone. The cells used for this work are human mammary epithelial cells with an extended lifespan and selected for growth in MEM + 10% serum.
Derived from text
Cancer; Cells (Biology); Cytology; Ion Irradiation

19950020951 NASA Langley Research Center, Hampton, VA, USA
Abrasion-ablation model for neutron production in heavy ion reactions
Cucinotta, Francis A.; Wilson, John W.; Townsend, Lawrence W.; Jun 1, 1995; In English
Contract(s)/Grant(s): RTOP 199-45-16-12
Report No.(s): NASA-TM-4656; L-17455; NAS 1.15:4656; No Copyright; Avail: CASI

In heavy ion reactions, neutron production at forward angles is observed to occur with a Gaussian shape that is centered near the beam energy and extends to energies well above that of the beam. This paper presents an abrasion-ablation model for making quantitative predictions of the neutron spectrum. To describe neutrons produced from the abrasion step of the reaction where the projectile and target overlap, the authors use the Glauber model and include effects of final-state interactions. They then use the prefragment mass distribution from abrasion with a statistical evaporation model to estimate the neutron spectrum resulting from ablation. Measurements of neutron production from Ne and Nb beams are compared with calculations, and good agreement is found.
Author
Ablation; Abrasion; Galactic Cosmic Rays; Heavy Ions; Neutron Spectra; Neutrons; Particle Interactions; Particle Production

19950023916 NASA Langley Research Center, Hampton, VA, USA
Parameterized spectral distributions for meson production in proton-proton collisions
Schneider, John P.; Norbury, John W.; Cucinotta, Francis A.; Jun 1, 1995; In English
Contract(s)/Grant(s): NAG1-1154; RTOP 199-45-16-12
Report No.(s): NASA-TM-4675; L-17464; NAS 1.15:4675; No Copyright; Avail: CASI

Accurate semiempirical parameterizations of the energy-differential cross sections for charged pion and kaon production

from proton-proton collisions are presented at energies relevant to cosmic rays. The parameterizations, which depend on both the outgoing meson parallel momentum and the incident proton kinetic energy, are able to be reduced to very simple analytical formulas suitable for cosmic ray transport through spacecraft walls, interstellar space, the atmosphere, and meteorites.
Author
Atomic Collisions; Atomic Spectra; Cross Sections; Distribution Functions; Galactic Cosmic Rays; Kaon Production; Mesons; Parameterization; Pions; Proton-Proton Reactions; Spectral Methods; Transport Theory

19950022109 NASA Langley Research Center, Hampton, VA, USA
HZETRN: Description of a free-space ion and nucleon transport and shielding computer program
Wilson, John W.; Badavi, Francis F.; Cucinotta, Francis A.; Shinn, Judy L.; Badhwar, Gautam D.; Silberberg, R.; Tsao, C. H.; Townsend, Lawrence W.; Tripathi, Ram K.; May 1, 1995; In English
Contract(s)/Grant(s): RTOP 199-45-16-11
Report No.(s): NASA-TP-3495; L-17417; NAS 1.60:3495; No Copyright; Avail: CASI

The high-charge-and energy (HZE) transport computer program HZETRN is developed to address the problems of free-space radiation transport and shielding. The HZETRN program is intended specifically for the design engineer who is interested in obtaining fast and accurate dosimetric information for the design and construction of space modules and devices. The program is based on a one-dimensional space-marching formulation of the Boltzmann transport equation with a straight-ahead approximation. The effect of the long-range Coulomb force and electron interaction is treated as a continuous slowing-down process. Atomic (electronic) stopping power coefficients with energies above a few A MeV are calculated by using Bethe's theory including Bragg's rule, Ziegler's shell corrections, and effective charge. Nuclear absorption cross sections are obtained from fits to quantum calculations and total cross sections are obtained with a Ramsauer formalism. Nuclear fragmentation cross sections are calculated with a semiempirical abrasion-ablation fragmentation model. The relation of the final computer code to the Boltzmann equation is discussed in the context of simplifying assumptions. A detailed description of the flow of the computer code, input requirements, sample output, and compatibility requirements for non-VAX platforms are provided.
Author
Algorithms; Applications Programs (Computers); Boltzmann Transport Equation; Electron Scattering; Nucleons; Radiation Shielding; Radiation Transport

19950047002 NASA Langley Research Center, Hampton, VA, USA
Parameterization of spectral distributions for pion and kaon production in proton-proton collisions
Schneider, John P.; Norbury, John W.; Cucinotta, Frank A.; Astrophysical Journal Supplement Series; April 1995; ISSN 0067-0049; 97, 2; In English
Contract(s)/Grant(s): NAG1-1154; Copyright; Avail: Other Sources

Accurate semi-empirical parameterizations of the energy-differential cross sections for charged pion and kaon production from proton-proton collisions are presented at energies relevant to cosmic rays. The parameterizations depend on the outgoing meson momentum and also the proton energy, and are able to be reduced to very simple analytical formulas suitable for cosmic-ray transport.
Author (Herner)
Astronomical Models; Atomic Collisions; Collision Parameters; Cosmic Rays; Kaons; Pions; Proton-Proton Reactions; Spectral Energy Distribution

19950019511 San Francisco Univ., CA, USA
Cosmic ray particles with different LET values under various thicknesses of shielding in low altitude orbits: Calculations and Cosmos-2044 measurements
Benton, E. V.; Frank, A. L.; Benton, E. R.; Marenny, A. M.; Nymmik, R. A.; Suslov, A. A.; High LET, Passive Space Radiation Dosimetry and Spectrometry; Mar 1, 1995; In English
Contract(s)/Grant(s): NCC2-521; No Copyright; Avail: CASI

Fluxes of cosmic ray particles with different LET values were measured on board the COSMOS-2044 biosatellite under various thicknesses of shielding by stacks of CR-39 and nitrocellulose plastic nuclear track detectors (mounted outside the satellite). The component composition of the particles detected under shieldings of 0.1-2.5 g cm(exp -2) is verified by

comparing experimental data with the results of model simulations of the fluxes of galactic cosmic ray particles and of radiation belt protons.
Author
Biosatellites; Cosmic Rays; Linear Energy Transfer (LET); Low Altitude; Radiation Shielding

19950019514 NASA Marshall Space Flight Center, Huntsville, AL, USA
Space radiation dosimetry on US and Soviet manned missions
Parnell, T. A.; Benton, E. V.; San Francisco Univ., High LET, Passive Space Radiation Dosimetry and Spectrometry; Mar 1, 1995; In English
Contract(s)/Grant(s): NAS9-17389; NAG8-071; No Copyright; Avail: CASI

Radiation measurements obtained on board U.S. and Soviet spacecraft are presented and discussed. A considerable amount of data has now been collected and analyzed from measurements with a variety of detector types in low-Earth orbit. The objectives of these measurements have been to investigate the dose and Linear Energy Transfer (LET) spectra within the complex shielding of large spacecraft. The shielding modifies the external radiation (trapped protons, electrons, cosmic ray nuclei) which, in turn, is quite dependent on orbital parameters (altitude, inclination). For manned flights, these measurements provide a crew exposure record and a data base for future spacecraft design and flight planning. For the scientific community they provide useful information for planning and analyzing data from experiments with high sensitivity to radiation. In this paper, results of measurements by both passive and active detectors are described. High-LET spectra measurements were obtained by means of plastic nuclear track detectors (PNTD's) while thermoluminescent dosimeters (TLD's) measured the dose.
Author (revised)
Extraterrestrial Radiation; Linear Energy Transfer (LET); Manned Space Flight; Radiation Detectors; Radiation Dosage; Radiation Measurement; Radiation Shielding

19950065292 NASA Langley Research Center, Hampton, VA, USA
Computing Interactions Of Free-Space Radiation With Matter
Wilson, J. W.; Cucinotta, F. A.; Shinn, J. L.; Townsend, L. W.; Badavi, F. F.; Tripathi, R. K.; Silberberg, R.; Tsao, C. H.; Badwar, G. D.; NASA Tech Briefs; Mar 1, 1995; ISSN 0145-319X; 19, 3; In English
Report No.(s): LAR-15225; No Copyright

High Charge and Energy Transport (HZETRN) computer program computationally efficient, user-friendly package of software adressing problem of transport of, and shielding against, radiation in free space. Designed as ″black box″ for design engineers not concerned with physics of underlying atomic and nuclear radiation processes in free-space environment, but rather primarily interested in obtaining fast and accurate dosimetric information for design and construction of modules and devices for use in free space. Computational efficiency achieved by unique algorithm based on deterministic approach to solution of Boltzmann equation rather than computationally intensive statistical Monte Carlo method. Written in FORTRAN.
Computer Programs; Radiation Dosage; Shielding; Spacecraft Shielding

19950002958 Hutchinson (Fred) Cancer Research Center, Seattle, WA, USA
Deep space flight radiation risk assessment/protection
Curtis, Stanley B.; Feb 14, 1995; In English
Contract(s)/Grant(s): NAG9-732
Report No.(s): NASA-CR-197722; NAS 1.26:197722; No Copyright; Avail: CASI

The importance of testing the additivity assumption which is inherent in the present radiation risk assessment methodology has been studied. This assumption states that risks from individual components of a complex radiation field involving many different types of radiation can be added to yield the total risk of the complex radiation field. The study confirms that the length of exposure plays a critical role in determining the probability of tumor-induction at least from the high-LET (linear energy transfer) radiation contributions. As a result, the modifying factor to be applied to the absorbed dose is a function of exposure time, in addition to LET. It is therefore concluded that the additivity assumption would break down, and a simple addition of risks is inappropriate. A reanalysis of the data on lung-tumor induction by radon-inhaling rats in the rat-lung carcinogenesis study is also addressed.
Derived from text
Aerospace Safety; Assessments; Biological Effects; Deep Space; Extraterrestrial Radiation; Flight Safety; Linear Energy Transfer (LET); Radiation Hazards; Radiation Protection; Risk

19950014774 NASA Langley Research Center, Hampton, VA, USA
Heavy ion track-structure calculations for radial dose in arbitrary materials
Cucinotta, Francis A.; Katz, Robert; Wilson, John W.; Dubey, Rajendra R.; Feb 1, 1995; In English
Contract(s)/Grant(s): RTOP 199-45-16-11
Report No.(s): NASA-TP-3497; L-17424; NAS 1.60:3497; No Copyright; Avail: CASI

The delta-ray theory of track structure is compared with experimental data for the radial dose from heavy ion irradiation. The effects of electron transmission and the angular dependence of secondary electron ejection are included in the calculations. Several empirical formulas for electron range and energy are compared in a wide variety of materials in order to extend the application of the track-structure theory. The model of Rudd for the secondary electron-spectrum in proton collisions, which is based on a modified classical kinematics binary encounter model at high energies and a molecular promotion model at low energies, is employed. For heavier projectiles, the secondary electron spectrum is found by scaling the effective charge. Radial dose calculations for carbon, water, silicon, and gold are discussed. The theoretical data agreed well with the experimental data.
Author
Electron Energy; Electron Mobility; Electron Spectroscopy; Energy Spectra; Energy Transfer; Heavy Ions; Ion Irradiation; Particle Collisions; Particle Interactions

19950016512 NASA Langley Research Center, Hampton, VA, USA
Comparison of exact solution with Eikonal approximation for elastic heavy ion scattering
Dubey, Rajendra R.; Khandelwal, Govind S.; Cucinotta, Francis A.; Maung, Khin Maung; Feb 1, 1995; In English
Contract(s)/Grant(s): RTOP 199-45-16-11
Report No.(s): NASA-TP-3498; L-17428; NAS 1.60:3498; No Copyright; Avail: CASI

A first-order optical potential is used to calculate the total and absorption cross sections for nucleus-nucleus scattering. The differential cross section is calculated by using a partial-wave expansion of the Lippmann-Schwinger equation in momentum space. The results are compared with solutions in the Eikonal approximation for the equivalent potential and with experimental data in the energy range from 25A to 1000A MeV.
Author
Absorption Cross Sections; Eikonal Equation; Elastic Scattering; Heavy Ions; Ion Scattering; Nuclear Interactions

19950017380 Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Cologne, Germany
Dosimetric results on EURECA
Reitz, G.; NASA. Langley Research Center, LDEF: 69 Months in Space. Third Post-Retrieval Symposium, Part 1; Feb 1, 1995; In English; No Copyright; Avail: CASI

Detector packages were exposed on the European Retrievable Carrier (EURECA) as part of the Biostack experiment inside the Exobiology and Radiation Assembly (ERA) and at several locations around EURECA. The packages consist of different plastic nuclear track detectors, nuclear emulsions and thermoluminescence dosimeters (TLD's). Evaluation of these detectors yields data on absorbed dose and particle and LET spectra. Preliminary results of absorbed dose measurements in the EURECA dosimeter packages are reported and compared to results of the LDEF experiments. The highest dose rate measured on EURECA is 63.3 plus or minus 0.4 mGy d(exp -1) behind a shielding thickness of 0.09 g cm(exp -2) in front of the detector package.
Author
Dosimeters; Earth Orbital Environments; Eureca (ESA); Ionizing Radiation; Linear Energy Transfer (LET); Nuclear Emulsions; Spaceborne Experiments; Thermoluminescence

19950017381 San Francisco Univ., CA, USA
Preliminary results of radiation measurements on EURECA
Benton, E. V.; Frank, A. L.; NASA. Langley Research Center, LDEF: 69 Months in Space. Third Post-Retrieval Symposium, Part 1; Feb 1, 1995; In English
Contract(s)/Grant(s): NAG9-235; No Copyright; Avail: CASI

The eleven-month duration of the EURECA mission allows long term radiation effects to be studied similarly to those of the Long Duration Exposure Facility (LDEF). Basic data can be generated for projections of crew doses and electronic and computer reliability on spacecraft missions. A radiation experiment has been designed for EURECA which uses passive integrating detectors to measure average radiation levels. The components include a Trackoscope, which employs fourteen

plastic nuclear track detector (PNTD) stacks to measure the angular dependence of LET (greater than or equal to 6 keV/microns) radiation. Also included are TLD's for total absorbed doses, thermal/resonance neutron detectors (TRND's) for low energy neutron fluences and a thick PNTD stack for depth dependence measurements. LET spectra are derived from the PNTD measurements. Preliminary TLD results from seven levels within the detector array show that integrated doses inside the flight canister varied from 18.8 plus or minus 0.6 cGy to 38.9 plus or minus 1.2 cGy. The TLD's oriented toward the least shielded direction averaged 53 percent higher in dose than those oriented away from the least shielded direction (minimum shielding toward the least shielded direction varied from 1.13 to 7.9 g/cm(exp 2), Al equivalent). The maximum dose rate on EURECA (1.16 mGy/day) was 37 percent of the maximum measured on LDEF and dose rates at all depths were less than measured on LDEF. The shielding external to the flight canister covered a greater solid angle about the canister than in the LDEF experiments.
Author
Earth Orbital Environments; Eureca (ESA); Extraterrestrial Radiation; Long Term Effects; Radiation Dosage; Radiation Effects; Radiation Measurement; Radiation Shielding

19950017385 NASA Marshall Space Flight Center, Huntsville, AL, USA
LDEF contributions to cosmic ray and radiation environments research
Parnell, Thomas A.; NASA. Langley Research Center, LDEF: 69 Months in Space. Third Post-Retrieval Symposium, Part 1; Feb 1, 1995; In English; No Copyright; Avail: Other Sources

LDEF-1 carried three experiments which are producing significant advances in our knowledge of ultra heavy and anomalous cosmic rays, solar flare particles, and heavy nuclei in the trapped belts. Nine other experiments made measurements on the radiation environments or performed dosmetric monitoring. Data from those experiments, and from measurements of induced radioactivity in LDEF components have significantly improved our knowledge of LEO radiation environment. Measurements at various locations shielding depths of radiation absorbed dose, linear energy transfer spectra, proton, neutron and heavy ion fluences, and induced radioactivity have been made, and many of these results have been compared to models. This has allowed the assessment of accuracy, and the potential for improvement, of the models. Serendipitous results from the radiation measurements include the discovery of atmospheric Be-7 plated on the front surface of LDEF, which has motivated a series of new investigations. A sample of measurements and modeling results will be presented, as well as the status of archiving the measurements and models.
Author
Cosmic Rays; Earth Orbital Environments; Heavy Nuclei; Long Duration Exposure Facility; Radiation Measurement; Solar Flares; Spaceborne Experiments

19960043015 Los Alamos National Lab., NM USA
Los Alamos Science, No. 23, Radiation protection and the human radiation experiments
Cooper, Necia Grant, Editor; 1995; In English
Contract(s)/Grant(s): W-7405-eng-36
Report No.(s): LA-UR-95-4005; DE96-012061; No Copyright; Avail: CASI

There are a variety of myths and misconceptions about the ionizing radiation that surrounds and penetrates us all. Dispel a few of these by taking a leisurely tour of radiation and its properties, of the natural and man-made sources of ionizing radiation, and of the way doses are calculated. By damaging DNA and inducing genetic mutations, ionizing radiation can potentially initiate a cell on the road to cancer. The authors review what is currently known about regulation of cellular reproduction, DNA damage and repair, cellular defense mechanisms, and the specific cancer-causing genes that are susceptible to ionizing radiation. A rapid survey of the data on radiation effects in humans shows that high radiation doses increase the risk of cancer, whereas the effects of low doses are very difficult to detect. The hypothetical risks at low doses, which are estimated from the atomic-bomb survivors, are compared to the low-dose data so that the reader can assess the present level of uncertainty. As part of the openness initiative, ten individuals who have worked with plutonium during various periods in the Laboratory's history were asked to share their experiences including their accidental intakes. The history and prognosis of people who have had plutonium exposures is discussed by the Laboratory's leading epidemiologist.
DOE
Ionizing Radiation; Radiation Effects; Radiation Protection; Radiation Dosage; Radiation Hazards; Genetics

19960016660 NASA Langley Research Center, Hampton, VA USA

Variations in astronaut radiation exposure due to anisotropic shield distribution

Wilson, John W.; Nealy, John E.; Wood, James S.; Qualls, Garry D.; Qualls, Garry D.; Atwell, William; Shinn, Judy L.; Simonsen, Lisa C.; Jan. 01, 1995; ISSN 0017-9078; In English

Report No.(s): NASA-TM-111337; NAS 1.15:111337; No Copyright; Avail: CASI

The dose incurred in an environment generated by extraterrestrial space radiations within an anisotropic shield distribution depends on the orientation of the astronaut's body relative to the shield geometry. The fluctuations in exposure of specific organ sites due to astronaut re-orientation are found to be a factor of 2 or more in a typical space habitation module and typical space radiations. An approximation function is found that overestimates astronaut exposure in most cases studied and is recommended as a shield design guide for future deep space missions.

Author

Extraterrestrial Radiation; Astronauts; Radiation Dosage; Radiation Shielding; Risk; Aerospace Medicine; Variations; Anisotropy; Spatial Distribution

19970003298 NASA Langley Research Center, Hampton,VA USA

Issues In Space Radiation Protection: Galactic Cosmic Rays

Wilson, J. W.; Kim, M.; Schimmerling, W.; Badavi, F. F.; Thibeault, S. A.; Cucinotta, F. A.; Shinn, J. L.; Kiefer, R.; Health Physics Society; Jan. 1995; ISSN 0017-9078; Volume 68, No. 1; In English

Report No.(s): NASA-TM-111575; NAS 1.15:111575; Copyright; Avail: CASI

When shielding from cosmic heavy ions, one is faced with limited knowledge about the physical properties and biological responses of these radiations. Herein, the current health is discussed in terms of conventional protection practice and a test biological response model. The impact of biological response on optimum materials selection for cosmic ray shielding is presented in terms of the transmission characteristics of the shield material. Although liquid hydrogen is an optimum shield material, evaluation of the effectiveness of polymeric structural materials must await improvement in our knowledge of both the biological response and the nuclear processes.

Author

Spacecraft Shielding; Radiation Protection; Galactic Cosmic Rays; Biological Effects; Radiation Hazards; Space Stations; Spacecrews

19950009997 NASA Langley Research Center, Hampton, VA, USA

Kinetics model for initiation and promotion for describing tumor prevalence from HZE radiation

Cucinotta, Francis A.; Wilson, John W.; Dec 1, 1994; In English

Contract(s)/Grant(s): RTOP 199-45-16-11

Report No.(s): NASA-TP-3479; L-17404; NAS 1.60:3479; No Copyright; Avail: CASI

A kinetics model for cellular repair and misrepair for multiple radiation-induced lesions (mutation-inactivation) is coupled to a two-mutation model of initiation and promotion in tissue to provide a parametric description of tumor prevalence in the Harderian gland in a mouse. Dose-response curves are described for gamma-rays and relativistic ions. The effects of nuclear fragmentation are also considered for high-energy proton and alpha particle exposures The model described provides a parametric description of age-dependent cancer induction for a wide range of radiation fields. We also consider the two hypotheses that radiation acts either solely as an initiator or as both initiator and promoter and make model calculations for fractionation exposures from gamma-rays and relativistic Fe ions. For fractionated Fe exposures, an inverse dose-rate effect is provided by a promotion hypothesis using a mutation rate for promotion typical of single-gene mutations.

Author

Age Factor; Cancer; Cosmic Rays; Exposure; Gamma Rays; Kinetics; Lesions; Mice; Radiation Distribution; Radiation Effects; Tumors

19950039901

Rapid neutrophil accumulation and protein oxidation in irradiated rat lungs

Fliss, Henry; Menard, Michel; Journal of Applied Physiology; December 1994; ISSN 8750-7587; 77, 6; In English; Copyright; Avail: Other Sources

Exposure of lungs to high doses of ionizing radiation can initiate an injurious acute inflammatory response. We show that neutrophil content in the lungs of rats exposed to 10 Gy whole body gamma radiation increased threefold 4.5 h after irradiation and returned to normal by 24 h. Oxidized methionine in the proteins of the lungs, heart, liver, kidney, and jejunum increased

significantly in 2 h. Treatment with the antioxidant dithiothreitol immediately after irradiation prevented methionine oxidation. Methionine oxidation was also observed after intrabronchial instillation of phorbol myristate acetate, a model of neutrophil oxidant-mediated pulmonary injury, as well as in isolated lungs perfused with hypochlorous acid, confirming the ability of neutrophil oxidants to cause protein oxidation in lungs. No change in glutathione or protein sulfhydryl content was detected in irradiated lungs 4.5 h after irradiation, possibly as a result of protection by the observed increases in pulmonary glutathione reductase. We therefore show that the acute pulmonary inflammatory response to radiation involves rapid neutrophil accumulation, oxidant production, and protein oxidation.
Author (Herner)
Antioxidants; Gamma Rays; Leukocytes; Lungs; Oxidation; Radiobiology

19950009192 NASA Langley Research Center, Hampton, VA, USA
Multiple-scattering model for inclusive proton production in heavy ion collisions
Cucinotta, Francis A.; Nov 1, 1994; In English
Contract(s)/Grant(s): RTOP 199-45-16-11
Report No.(s): NASA-TP-3470; L-17387; NAS 1.60:3470; No Copyright; Avail: CASI

A formalism is developed for evaluating the momentum distribution for proton production in nuclear abrasion during heavy ion collisions using the Glauber multiple-scattering series. Several models for the one-body density matrix of nuclei are considered for performing numerical calculations. Calculations for the momentum distribution of protons in abrasion are compared with experimental data for inclusive proton production.
Author
Galactic Cosmic Rays; Glauber Theory; Heavy Ions; Ionic Collisions; Particle Production; Proton Scattering

19950010497 NASA Langley Research Center, Hampton, VA, USA
Performance study of galactic cosmic ray shield materials
Kim, Myung-Hee Y.; Wilson, John W.; Thibeault, Sheila A.; Nealy, John E.; Badavi, Francis F.; Kiefer, Richard L.; Nov 1, 1994; In English
Contract(s)/Grant(s): RTOP 199-45-16-11
Report No.(s): NASA-TP-3473; L-17389; NAS 1.60:3473; No Copyright; Avail: CASI

The space program is faced with two difficult radiation protection issues for future long-term operations. First, retrofit of shield material or conservatism in shield design is prohibitively expensive and often impossible. Second, shielding from the cosmic heavy ions is faced with limited knowledge on the physical properties and biological responses of these radiations. The current status of space shielding technology and its impact on radiation health is discussed herein in terms of conventional protection practice and a test biological response model. The impact of biological response on the selection of optimum materials for cosmic ray shielding is presented in terms of the transmission characteristics of the shield material. Although the systematics of nuclear cross sections are able to demonstrate the relation of exposure risk to shield-material composition, the current uncertainty in-nuclear cross sections will not allow an accurate evaluation of risk reduction. This paper presents a theoretical study of risk-related factors and a pilot experiment to study the effectiveness of choice of shield materials to reduce the risk in space operations.
Author
Biological Effects; Galactic Cosmic Rays; Heavy Ions; Ionizing Radiation; Physiological Responses; Radiation Protection; Risk; Shielding; Thermal Stability

19940039019 NASA, Washington, DC, USA, NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1992
Horneck, G., editor; Buecher, H., editor; Cox, A., editor; Todd, P., editor; Yang, T. C., editor; Worgul, B. V., editor; Donlon, M., editor; Atwell, W., editor; Shea, M. A., editor; Smart, D. F., editor, et al.; Advances in Space Research; October 1994; ISSN 0273-1177; 14, 10; In English; See also A94-62469 through A94-62589; Copyright; Avail: Other Sources

Papers presented on long-term exposure to ionizing radiation, obtained from the Long Duration Exposure Facility, included radiation monitoring, radiation effects, and dosimetry. Mechanisms of biological systems, especially cells, under ionizing radiation and relative biological effectiveness were compared. The role of HZE particles as agents of mutation were reported from plant, animal, and in vitro models. Data on known and predicted effects of cosmic rays and other solar radiation

on biological systems included differences related to Linear Energy Transfer and heavy ion particles.
Herner
Heavy Ions; Ionizing Radiation; Long Duration Exposure Facility; Manned Space Flight; Radiation Hazards; Risk

19940039028 NASA Lyndon B. Johnson Space Center, Houston, TX, USA, NASA Langley Research Center, Hampton, VA, USA
Measurements of trapped protons and cosmic rays from recent shuttle flights
Badhwar, G. D.; Konradi, A.; Braby, L. A.; Atwell, W.; Cucinotta, F. A.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English; Copyright; Avail: Other Sources

We have flown two new charged particle detectors in five recent Shuttle flights. In this paper we report on the dose rate, equivalent dose rate, and radiation quality factor for trapped protons and cosmic radiation separately. A comparison of the integral Linear Energy Transfer (LET) spectra with recent transport code calculations show significant disagreement. Using the calculated dose rate from the omni-directional AP8MAX model with IGRF reference magnetic field epoch 1970, and observed dose rate as a function of (averaged over all geographic latitude) and longitude, we have determined the westward drift of the South Atlantic anomaly. We have also studied the east-west effect, and observed a 'second' radiation belt. A comparison of the galactic cosmic radiation lineal energy transfer spectra with model calculations shows disagreement comparable to those of the trapped protons.
Author (Herner)
Aerospace Environments; Galactic Cosmic Rays; Inner Radiation Belt; Linear Energy Transfer (LET); Radiation Dosage; Space Shuttle Orbiters

19940039030
Radiation factors in space and a system for their monitoring
Kovtunenko, V. M.; Kremnev, R. S.; Pichkhadze, K. M.; Bogomolov, V. B.; Kontor, N. N.; Filippichev, S. A.; Petrov, V. M.; Pissarenko, N. F.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English; Copyright; Avail: Other Sources

The radiation environment is of special concern when the spaceship flies in deep space. The annual fluence of the galactic cosmic rays is approximately 10(exp 8)/sq cm and the absorbed dose of the solar cosmic rays can reach 10 Gy per event behind the shielding thickness of 3-5 g/sq cm Al. For the radiation environment monitoring it is planned to place a measuring complex on the space probes 'Mars' and 'Spectr' flying outside the magnetosphere. This complex is to measure: cosmic rays composition, particle flux, dose equivalent, energy and Linear Energy Transfer (LET) spectra, solar X-rays spectrum. On line data transmission by the space probes permits to obtain the radiation environment data in space.
Author (revised by Herner)
Galactic Cosmic Rays; Radiation Measurement; Radiation Shielding; Solar X-Rays

19940039031 NASA Pasadena Office, CA, USA
Radiation effects in nematodes: Results from IML-1 experiments
Nelson, G. A.; Schubert, W. W.; Kazarians, G. A.; Richards, G. F.; Benton, E. V.; Benton, E. R.; Henke, R.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English; Copyright; Avail: Other Sources

The nematode Caenorhabditis elegans was exposed to natural space radiation using the ESA biorack facility aboard Spacelab on International Microgravity Laboratory 1, STS-42. For the major experimental objective dormant animals were suspended in buffer or on agar or immobilized next to CR-39 plastic nuclear track detectors to correlate fluence of HZE particles with genetic events. This configuration was used to isolate mutations in a set of 350 essential genes as well as in the unc-22 structural gene. From flight samples 13 mutants in the unc-22 gene were isolated along with 53 lethal mutations from autosomal regions balanced by a translocation eT1(III;V). Preliminary analysis suggests that mutants from worms correlated with specific cosmic ray tracks may have a higher proportion of rearrangements than those isolated from tube cultures on a randomly sampled basis. Flight sample mutation rate was approximately 8-fold higher than ground controls which exhibited laboratory spontaneous frequencies.
Author (Herner)
Chromosomes; Cosmic Rays; Earth Orbital Environments; Mutations; Spacelab; Worms

19940039035 NASA, Washington, DC, USA, NASA Lyndon B. Johnson Space Center, Houston, TX, USA

Development of human epithelial cell systems for radiation risk assessment

Yang, C. H.; Craise, L. M.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English

Contract(s)/Grant(s): T9297R; Copyright; Avail: Other Sources

The most important health effect of space radiation for astronauts is cancer induction. For radiation risk assessment, an understanding of carcinogenic effect of heavy ions in human cells is most essential. In our laboratory, we have successfully developed a human mammary epithelial cell system for studying the neoplastic transformation in vitro. Growth variants were obtained from heavy ion irradiated immortal mammary cell line. These cloned growth variants can grow in regular tissue culture media and maintain anchorage dependent growth and density inhibition property. Upon further irradiation with high-Linear Energy Transfer (LET) radiation, transformed foci were found. Experimental results from these studies suggest that multiexposure of radiation is required to induce neoplastic tranformation of human epithelial cells. This multihits requirement may be due to high genomic stability of human cells. These growth variants can be useful model systems for space flight experiments to determine the carcinogenic effect of space radiation in human epithelial cells.

Author (revised by Herner)

Carcinogens; Cells (Biology); Epithelium; Heavy Ions; Human Tolerances; Ionizing Radiation; Radiation Tolerance

19940039044

Double strand breaks in the DNA of Bacillus subtilis cells irradiated by heavy ions

Micke, U.; Horneck, G.; Kozubek, S.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English; Copyright; Avail: Other Sources

Cells of Bacillus subtilis strain TKJ 8431 in stationary phase were irradiated with X-rays (150 kV at DLR) or heavy ions (Ne, Ar, Pb with residual energies between 3 and 15 MeV/u at GSI). The action cross section for the formation of double strand breaks in the DNA of the irradiated cells follows a similar dependence on mass and energy of the ions as has been found for various biological endpoints, e.g. inactivation, mutagenesis and repair efficacy.

Author (Herner)

Bacteria; Deoxyribonucleic Acid; Heavy Ions; Ionizing Radiation; Mutations

19940039050

Mutation induction by heavy ions

Kiefer, J.; Stoll, U.; Schneider, E.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English; Copyright; Avail: Other Sources

Mutation induction by heavy ions is compared in yeast and mammalian cells. Since mutants can only be recovered in survivors the influence of inactivation cross sections has to be taken into account. It is shown that both the size of the sensitive cellular site as well as track structure play an important role. Another parameter which influences the probability of mutation induction is repair: Contrary to naive assumptions primary radiation damage does not directly lead to mutations but requires modification to reconstitute the genetic machinery so that mutants can survive. The molecular structure of mutations was analyzed after exposure to deuterons by amplification with the aid of polymerase chain reaction. The results - although preliminary - demonstrate that even with densely ionizing particles a large fraction does not carry big deletions which suggests that point mutations may also be induced by heavy ions.

Author (Herner)

Heavy Ions; Ionizing Radiation; Mutations; Yeast

19940039054

Radiobiology and photobiology on Earth and in space: Points of encounter and protection considerations

Riklis, E.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English; Copyright; Avail: Other Sources

All radiations originate in space, and the spectrum of radiations reaching the troposphere is limited only because of their range and absorption by the ozone layer above the atmosphere. Ultraviolet-C and the very heavy ions are therefore produced

on earth only artificially, by special lamps and in accelerators. The range of biological effects of the different ultraviolet (UV) radiations and low and high Linear Energy Transfer (LET) radiations have been studied extensively, yet only recently new facts such as the production of DNA strand breaks by long wave UV light were established, adding to the various points of encounter existing between ionizing and nonionizing radiations. There are some similarities in radiation products, and the resulting effects of insult by radiation on biological systems very often are similar, if not the same. A common phenomenon that exists in all healthy biological cells is the ability to repair damage to DNA and thus either survive or mutate, and although the specific mechanisms of repair are somewhat different, the end result is the same. Recently a mechanism of improved radioprotection was found to involve an effect of certain radioprotective compounds on DNA repair. It is suggested that improved, and nontoxic, modes of protection may be offered by employing such compounds as biological response modifiers and natural substances. Further research is needed and is under way.
Author (revised by Herner)
Cosmic Rays; Gamma Rays; Heavy Ions; Radiation Effects; Radiation Protection; Ultraviolet Radiation

19940039056
Mutagenic effects of heavy ions in bacteria
Horneck, G.; Krasavin, E. A.; Kozubek, S.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English; Copyright; Avail: Other Sources

Various mutagenic effects by heavy ions were studied in bacteria, irradiated at accelerators in Dubna, Prague, Berkeley or Darmstadt. Endpoints investigated are histidine reversion (B. subtilis, S. typhimurium), azide resistance (B. subtilis), mutation in the lactose operon (E. coli), SOS chromotest (E. coli) and gamma-prophage induction (E. coli). It was found that the cross sections of the different endpoints show a similar dependence on energy. For light ions (Z is less than or equal to 4) the cross section decreases with increasing energy. For ions of Z = 10, it is nearly independent of energy. For heavier ions (Z is greater than or equal to 26) it increases with energy up to a maximum of saturation. The increment becomes steeper with increasing Z. This dependence on energy suggests a 'mutagenic belt' inside the track that is restricted to an area where the density of departed energy is low enough not to kill the cell, but high enough to induce mutations.
Author (revised by Herner)
Bacteria; Heavy Ions; Ionizing Radiation; Mutations; Radiation Tolerance; Sublethal Dosage

19940039058 NASA, Washington, DC, USA
Mutation induction in human lymphoid cells by energetic heavy ions
Kronenberg, A.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English
Contract(s)/Grant(s): T-9309; NIH R29 GM 4317803; Copyright; Avail: Other Sources

One of the concerns for extended space flight outside the magnetosphere is exposure to galactic cosmic radiation. In the series of studies presented herein, the mutagenic effectiveness of high energy heavy ions is examined using human B-lymphoblastoid cells across an Linear Energy Transfer (LET) range from 32keV/micrometer to 190 keV/micrometer. Mutations were scored for an autosomal locus, thymidine kinase (tk), and for an X-linked locus, hypoxanthine phosphoribosyltransferase (hprt). For each of the radiations studied, the autosomal locus is more sensitive to mutation induction than is the X-linked locus. When mutational yields are expressed in terms of particle fluence, the two loci respond quite differently across the range of LET. The action cross section for mutation induction peaks at 61 keV/micrometer for the tk locus and then declines for particles of higher LET, including Fe ions. For the hprt locus, the action cross section for mutation is maximal at 95 keV/micrometer but is relatively constant across the range from 61 keV/micrometer to 190 keV/micrometer. The yields of hprt-deficient mutants obtained after HZE exposure to TK6 lymphoblasts may be compared directly with published data on the induction of hprt-deficient mutants in human neonatal fibroblasts exposed to similar ions. The action cross section for induction of hprt-deficient mutants by energetic Fe ions is more than 10-fold lower for lymphoblastoid cells than for fibroblasts.
Author (revised by Herner)
Heavy Ions; Ion Beams; Mutations; X Ray Irradiation

19940039059 NASA Lyndon B. Johnson Space Center, Houston, TX, USA

Charged-particle mutagenesis 2. Mutagenic effects of high energy charged particles in normal human fibroblasts

Chen, D. J.; Tsuboi, K.; Nguyen, T.; Yang, T. C.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English; Copyright; Avail: Other Sources

The biological effects of high Linear Energy Transfer (LET) charged particles are a subject of great concern with regard to the prediction of radiation risk in space. In this report, mutagenic effects of high LET charged particles are quantitatively measured using primary cultures of human skin fibroblasts, and the spectrum of induced mutations are analyzed. The LET of the charged particles ranged from 25 KeV/micrometer to 975 KeV/micrometer with particle energy (on the cells) between 94-603 MeV/u. The X-chromosome linked hypoxanthine guanine phosphoribosyl transferase (hprt) locus was used as the target gene. Exposure to these high LET charged particles resulted in exponential survival curves; whereas, mutation induction was fitted by a linear model. The Relative Biological Effect (RBE) for cell-killing ranged from 3.73 to 1.25, while that for mutant induction ranged from 5.74 to 0.48. Maximum RBE values were obtained at the LET of 150 keV/micrometer. The inactivation cross-section (alpha i) and the action cross-section for mutant induction (alpha m) ranged from 2.2 to 92.0 sq micrometer and 0.09 to 5.56 x 10(exp -3) sq micrometer respectively. The maximum values were obtained by Fe-56 with an LET of 200 keV/micrometer. The mutagenicity (alpha m/alpha i) ranged from 2.05 to 7.99 x 10(exp -5) with the maximum value at 150 keV/micrometer. Furthermore, molecular analysis of mutants induced by charged particles indicates that higher LET beams are more likely to cause larger deletions in the hprt locus.

Author (revised by Herner)

Charged Particles; Genetics; Guanines; Heavy Ions; Linear Energy Transfer (LET); Mutations; Xanthines

19940039065

Overview on experience to date on human exposure to space radiations

Petrov, V. M.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English; Copyright; Avail: Other Sources

The human exposure in space depends on the three factors: the flight trajectory, its date and duration and the cyclogram of the cosmonaut's activities. In the near-Earth orbits the daily dose varies within the limits of (1.5-5.0) times 10(exp -4) Gy/day and greatly increases if the altitude increases. The mean daily quality factor is 1.6-2.0. Strong solar proton events in the orbits with the inclination of less than 52 deg result in the dose rate increase up to 2-3 cGy/day. On the surface of the orbital spacecrafts the daily dose reaches 2 Gy. The neutron dose depends on the shielding mass distribution varying within the limits of 6%-30% of the charged particles dose. In deep space the dose is mainly formed by the galactic and solar cosmic rays (GCR, SCR). Behind the shielding of 2-3 g/sq cm Al the GCR dose varies in the range of (20-30) times 10(exp -5) Gy/day. The SCR dose can reach hundreds of cSv.

Author (revised by Herner)

Earth Orbital Environments; Galactic Radiation; Manned Space Flight; Solar Radiation

19940039066

Radiation risk of the crew members of the expeditions on the 'Mir' station during the 22nd solar activity cycle

Alekhina, I. G.; Mitrikas, V. G.; Petrov, V. M.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English; Copyright; Avail: Other Sources

The radiation risk at the end of the flight was calculated for the members of the main expeditions on the 'Mir' station. It was based on the absorbed dose dynamics data measured by the board dosimeter. The radiation damage models created for standards of the radiation safety of the space flights were used in the calculations. The analysis of the obtained values of the risk and its dynamics for some cosmonauts are presented in the topic. The risk values delta P are close to the limited levels given by equation of delta P = 0.6 times 10 times T(exp -4), where T- is flight duration in months.

Author (revised by Herner)

Irradiation; Mir Space Station; Radiation Dosage; Radiation Hazards; Risk; Safety

19940039067

Anatomical models for space radiation applications: An overview

Atwell, W.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English; Copyright; Avail: Other Sources

Extremely detailed computerized anatomical male (CAM) and female (CAF) models that have been developed for use in space radiation analyses are discussed and reviewed. Recognizing that the level of detail may currently be inadequate for certain radiological applications, one of the purposes of this paper is to elicit specific model improvements or requirements from the scientific user-community. Methods and rationale are presented which describe the approach used in the Space Shuttle program to extrapolate dosimetry measurements (skin doses) to realistic astronaut body organ doses. Several mission scenarios are presented which demonstrate the utility of the anatomical models for obtaining specific body organ exposure estimates and can be used for establishing cancer morbidity and mortality risk assessments. These exposure estimates are based on the trapped Van Allen belt and galactic cosmic radiation environment models and data from the major historical solar particle events.
Author (Herner)
Biological Models (Mathematics); Bionics; Computerized Simulation; Ionizing Radiation; Radiation Dosage

19940039069
Models of CNS radiation damage during space flight
Hopewell, J. W.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English; Copyright; Avail: Other Sources

The primary structural and functional arrangement of the different cell types within the Central Nervous System (CNS) are reviewed. This was undertaken with a view to providing a better understanding of the complex interrelationships that may contribute to the pathogenesis of lesions in this tissue after exposure to ionizing radiation. The spectrum of possible CNS radiation-induced syndromes are discussed although not all have an immediate relevance to exposure during space flight. The specific characteristics of the lesions observed would appear to be dose related. Very high doses may produce an acute CNS syndrome that can cause death. Of the delayed lesions, selective coagulation necrosis of white matter and a later appearing vascular microangiopathy, have been reported in patients after cancer therapy doses. Lower doses, perhaps very low doses, may produce a delayed generalised CNS atrophy; this effect and the probability of the induction of CNS tumors could potentially have the greatest significance for space flight.
Author (revised by Herner)
Central Nervous System; Manned Space Flight; Radiation Damage; Radiation Dosage; Radiation Tolerance

19940039074 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
The influence of dose, dose-rate and particle fragmentation on cataract induction by energetic iron ions
Medvedovsky, C.; Worgul, B. V.; Huang, Y.; Brenner, D. J.; Tao, F.; Miller, J.; Zeitlin, C.; Ainsworth, E. J.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English
Contract(s)/Grant(s): T5328R; W17,468; DOE-DE-FG02-90ER6009; FG02-88ER60631; EY02648; NAG9-256-52; Copyright; Avail: Other Sources

Because activities in space necessarily involve chronic exposure to a heterogeneous charged particle radiation field it is important to assess the influence of dose-rate and the possible modulating role of heavy particle fragmentation on biological systems. Using the well-studied cataract model, mice were exposed to plateau 600 MeV/amu Fe-56 ions either as acute or fractionated exposures at total doses of 5-504 cGy. Additional groups of mice received 20, 360 and 504 cGy behind 50 mm of polyethylene, which simulates body shielding. The reference radiation consisted of Co-60 gamma radiation. The animals were examined by slit lamp biomicroscopy over their three year life spans. In accordance with our previous observations with heavy particles, the cataractogenic potential of the 600 MeV/amu Fe-56 ions was greater than for low-Linear Energy Transfer (LET) radiation and increased with decreasing dose relative to gamma rays. Fractionation of a given dose of Fe-56 ions did not reduce the cataractogenicity of the radiation compared to the acute regimen. Fragmentation of the beam in the polyethylene did not alter the cataractotoxicity of the ions, either when administered singly or in fractions.
Author (revised by Herner)
Cataracts; Heavy Ions; Mice; Radiation Dosage; Radiation Shielding

19940039079
Heavy ion induced changes in small intestinal parameters
Carr, K. E.; Mccullough, J. S.; Brennan, P.; Hayes, T. L.; Ainsworth, E. J.; Nelson, A. C.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th

Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English; Copyright; Avail: Other Sources

The effects on 17 different structural parameters of mouse small intestine three days after treatment with three types of heavy ion (neon, iron and niobium) are compared, the first two being of particular relevance to space flight. The data for niobium are given in full, showing that changes after niobium ion treatment are not standard and are concentrated in the epithelial compartment, with few of the parameters having a response which is dose dependent. When comparisons are made for the three types of heavy ion, the damage is greatest after neon ion irradiation, implying that the additional non-epithelial damage produced as Linear Energy Transfer (LET) rises from X rays through neutrons to neon ions is not necessarily maintained as LET continues to rise. Further understanding is therefore needed of the balance between changes affecting the vascular and absorptive components of the organ. Variation from group to group is also important, as is variation of strain or gastrointestinal status. All such factors are important in the understanding of changes in multicellular organs after exposure to heavy ion radiation.

Author (revised by Herner)

Epithelium; Heavy Ions; Intestines; Ion Irradiation; Mice; Radiation Damage

19940039081

Haemopoietic cell renewal in radiation fields

Fliedner, T. M.; Nothdurft, W.; Tibken, B.; Hofer, E.; Weiss, M.; Kindler, H.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English; Copyright; Avail: Other Sources

Space flight activities are inevitably associated with a chronic exposure of astronauts to a complex mixture of ionizing radiation. Although no acute radiation consequences are to be expected as a rule, the possibility of Solar Particle Events (SPE) associated with relatively high doses of radiation (1 or more Gray) cannot be excluded. It is the responsibility of physicians in charge of the health of astronauts to evaluate before, during and after space flight activities the functional status of hemopoietic cell renewal. Chronic low level exposure of dogs indicate that daily gamma-exposure doses below about 2 cGy are tolerated for several years as far as blood cell concentrations are concerned. However, the stem cell pool may be severely affected. The maintenance of sufficient blood cell counts is possible only through increased cell production to compensate for the radiation inflicted excess cell loss. This behavior of hemopoietic cell renewal during chronic low level exposure can be simulated by bioengineering models of granulocytopoiesis. It is possible to define a 'turbulence region' for cell loss rates, below which an prolonged adaptation to increased radiation fields can be expected to be tolerated. On the basis of these experimental results, it is recommended to develop new biological indicators to monitor hemopoietic cell renewal at the level of the stem cell pool using blood stem cells in addition to the determination of cytokine concentrations in the serum (and other novel approaches). To prepare for unexpected hemopoietic effects during prolonged space missions, research should be increased to modify the radiation sensitivity of hemopoietic stem cells (for instance by the application of certain regulatory molecules). In addition, a 'blood stem cell bank' might be established for the autologous storage of stem cells and for use in space activities keeping them in a radiation protected container.

Author (revised by Herner)

Hematopoiesis; Ionizing Radiation; Manned Space Flight; Radiation Damage; Solar Radiation

19940039083

Effects of radiation on rat respiratory epithelial cells: Critical target cell populations and the importance of cell-cell interactions

Terzaghi-Howe, M.; Ford, J.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English; Copyright; Avail: Other Sources

The oncongenic effects of radiation on rat respiratory tissues are modulated in vivo within the intact tissue. The degree of modulation as well as the mechanism whereby modulation occurs appears to be different for different types of ionizing radiations. A combined cell culture in vivo model is described. This model has been developed to evaluate the influence of the host and tissue environment on development and expression of the neoplastic phenotype in irradiated rat trachea. Our data indicates that the potentially oncogenic effects of neutrons, X Rays, and alpha particles are different depending on the exposure conditions employed and the conditions under which exposed cells are maintained following exposure.

Author (revised by Herner)

Alpha Particles; Neutron Irradiation; Radiation Tolerance; Rats; Respiratory System; Trachea; X Ray Irradiation

19940039084 NASA, Washington, DC, USA

Fluence-based relative biological effectiveness for charged particle carcinogenesis in mouse Harderian gland

Alpen, E. L.; Power-Risius, P.; Curtis, S. B.; Deguzman, R.; Fry, R. J. M.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English

Contract(s)/Grant(s): T1931M; DE-AC03-76SF00098; DE-AC05-85OR21400; Copyright; Avail: Other Sources

Neoplasia in the rodent Harderian gland has been used to determine the carcinogenic potential of irradiation by HZE particles. Ions from protons to lanthanum at energies up to 670 MeV/a have been used to irradiate mice, and prevalence of Harderian gland tumors has been measured 16 months after irradiation. The Relative Biological Effectiveness (RBE) for tumor induction has been expressed as the RBE(sub max), which is the ratio of the initial slopes of the dose vs prevalence curve. The RBE(sub max) has been found to be approximately 30 for ions with Linear Energy Transfer (LET) values in excess of 100 keV/micrometer. Analysis on the basis of fluence as a substitute for dose has shown that on a per particle basis all of the ions with LET values in excess of 100 keV/micrometer have equal effectiveness. An analysis of the probabilities of ion traversals of the nucleus has shown that for these high stopping powers that a single hit is effective in producing neoplastic transformation.

Author (revised by Herner)

Eye (Anatomy); Ionizing Radiation; Mice; Radiation Damage; Relative Biological Effectiveness (RBE)

19940039087

Angular distributions of energetic charged particles observed with Helios-1 and -2 between 0.3 and 1 AU and their relevance to manned interplanetary space missions

Kunow, H.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English

Contract(s)/Grant(s): GBFT-01 QC 8601; Copyright; Avail: Other Sources

The University of Kiel Cosmic Ray Instrument on board the solar probes HELIOS-1 and -2 measured angular distributions of electrons, protons, and heavier nuclei between 0.3 and 1 AU over one complete solar cycle between 1974 and 1986. Anisotropies are observed mainly during the rising phase of solar particle events or close to the passage of certain interplanetary shocks. The anisotropies are presented as proton data of energies between 27 and 37 MeV. The dependence of the anisotropies on particle energy and distance from the sun is provided based on diffusive propagation in interplanetary space. Strong anisotropies could provide a chance of efficient shielding of the passenger compartment by moving heavier parts of the spacecraft structure into the direction of the highest flux. A reduction of the total radiation dose by less than a factor of 2 might be achievable, however, selection of quiet times for the mission reduces the radiation hazard much more.

Author (Herner)

Charged Particles; Heavy Nuclei; Interplanetary Spacecraft; Radiation Distribution; Radiation Shielding; Solar Electrons; Solar Protons

19940039093

The dose rate observed on 19-21 October 1989 and its modulation by geographic effects

Smart, D. F.; Shea, M. A.; Dachev, Ts. P.; Bankov, N. G.; Petrov, V. M.; Bengin, V. V.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English; Copyright; Avail: Other Sources

The Liulin dosimeter-radiometer on the MIR space station detected the 19 October 1989 high energy solar proton event. These results show that the main particle increase contains protons with energies up to about 9 GeV. After the main particle onset the Liulin dosimeter observed a typical geomagnetic cutoff modulation of the dose rate from the solar particles as the MIR space station traversed magnetic latitudes. When the interplanetary shock and associated solar plasma enveloped the earth on 20 October between 14 and 17 UT the radiation exposure increased significantly due to the lowering of the geomagnetic cutoff. The analysis of this event shows how various geophysical phenomena can significantly modulate the dose rate encountered by earth-orbiting spacecraft.

Author (Herner)

Flux Transfer Events; Geomagnetic Pulsations; Mir Space Station; Solar Protons

19940039095 NASA Langley Research Center, Hampton, VA, USA, NASA Lyndon B. Johnson Space Center, Houston, TX, USA

Analysis of radiation risk from alpha particle component of solar particle events

Cucinotta, F. A.; Townsend, L. W.; Wilson, J. W.; Golightly, M. J.; Weyland, M.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English; Copyright; Avail: Other Sources

The Solar Particle Events (SPE) will contain a primary alpha particle component, representing a possible increase in the potential risk to astronauts during an SPE over the often studied proton component. We discuss the physical interactions of alpha particles important in describing the transport of these particles through spacecraft and body shielding. Models of light ion reactions are presented and their effects on energy and Linear Energy Transfer (LET) spectra in shielding are discussed. We present predictions of particle spectra, dose, and dose equivalent in organs of interest for SPE spectra typical of those occurring in recent solar cycles. The large events of solar cycle 19 are found to have substantial increase in biological risk from alpha particles, including a large increase in secondary neutron production from alpha particle breakup.

Author (revised by Herner)

Alpha Particles; Biological Effects; Flux Transfer Events; Neutron Scattering; Prediction Analysis Techniques; Solar Corpuscular Radiation; Solar Radiation Shielding

19940039096 NASA Langley Research Center, Hampton, VA, USA

Estimates of HZE particle contributions to SPE radiation exposures on interplanetary missions

Townsend, L. W.; Cucinotta, F. A.; Wilson, J. W.; Bagga, R.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English; Copyright; Avail: Other Sources

Estimates of radiation doses resulting from possible HZE (high energy heavy ion) components of Solar Particle Events (SPEs) are presented for crews of manned interplanetary missions. The calculations assume a model spectrum obtained by folding measured solar flare HZE particle abundances with the measured energy spectra of SPE alpha particles. These hypothetical spectra are then transported through aluminum spacecraft shielding. The results, presented as estimates of absorbed dose and dose equivalent, indicate that HZE components by themselves are not a major concern for crew protection but should be included in any overall risk assessment. The predictions are found to be sensitive to the assumed spectral hardness parameters.

Author (Herner)

Heavy Ions; Ionizing Radiation; Radiation Dosage; Solar Flares; Spacecraft Shielding

19940039100

A comparison of two different types of geosynchronous statellite measurements during the 1989 solar proton events

Normand, E.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English; Copyright; Avail: Other Sources

The proton telescope aboard the Geostationary Operational Environmental Satellite (GOES-7) satellite continuously records the proton flux at geosynchronous orbit, and therefore provides a direct measurement of the energetic protons arriving during Solar Energetic Particle (SEP) events. Microelectronic devices are susceptible to Single Event Upset (SEU) caused by both energetic protons and Galactic Cosmic Ray (GCR) ions. Some devices are so sensitive that their upsets can be used as a dosimetric indicator of a high fluence of particles. The 93L422 1K Static Random Access Memory (SRAM) is one such device. Eight of them are on the Tracking and Data Relay Satellite-1 (TDRS-1) satellite in geosynchronous orbit, and collectively they had been experiencing 1-2 upset/day due to the GCR background. During the large SEP events of 1989 the upset rate increased dramatically, up to about 250 for the week of 19 Oct., due to the arrival of the SEP protons. Using the GOES proton spectra, the proton-induced SEU cross section curve for the 93L422 and the shielding distribution around the 93L422, the calculated upsets based on the GOES satellite data compared well against the log of measured upsets on TDRS-1.

Author (revised by Herner)

Galactic Cosmic Rays; Random Access Memory; Single Event Upsets; Solar Protons; Synchronous Satellites

19940039107 NASA Goddard Inst. for Space Studies, New York, NY, USA

Galactic cosmic ray composition and energy spectra

Mewaldt, R. A.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English

Contract(s)/Grant(s): NAS5-722; NAGW-1919; Copyright; Avail: Other Sources

Galactic cosmic ray nuclei represent a significant risk to long-duration spaceflight outside the magnetosphere. We review briefly existing measurements of the composition and energy spectra of heavy cosmic ray nuclei, pointing out which species and energy ranges are most critical to assessing cosmic ray risks for spaceflight. Key data sets are identified and a table of cosmic ray abundances is presented for elements from H to Ni (Z = 1 to 28). Because of the 22-year nature of the solar modulation cycle, data from the approaching 1998 solar minimum is especially important to reducing uncertainties in the cosmic ray radiation hazard. It is recommended that efforts to model this hazard take advantage of approaches that have been developed to model the astrophysical aspects of cosmic rays.

Author (Herner)

Energy Spectra; Galactic Cosmic Rays; Manned Space Flight; Radiation Hazards

19940039108 NASA Lyndon B. Johnson Space Center, Houston, TX, USA

Long-term modulation of galactic cosmic radiation and its model for space exploration

Badhwan, G. D.; O'Neill, P. M.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English; Copyright; Avail: Other Sources

As the human exploration of space has received new attention in the USA, studies find that exposure to space radiation could adversely impact the mission design. Galactic Cosmic Radiation (GCR), with its very wide range of charges and energies, is particularly important for a mission to Mars, because it imposes a stiff mass penalty for spacecraft shielding. Dose equivalent versus shielding thickness calculations, show a rapid initial drop on exposure with thickness, but an asymptotic behavior at a higher shielding thickness. Uncertainties in the radiobiology are largely unknown. For a fixed radiation risk, this leads to large uncertainties in shielding thickness for small uncertainties in estimated dose. In this paper we investigate the application of steady-state, spherically-symmetric diffusion-convection theory of solar modulation to individual measurements of differential energy spectra from 1954 to 1989 in order to estimate the diffusion coefficient, kappa(r,t), as a function of time. We have correlated the diffusion coefficient to the Climax neutron monitor rates and show that, if the diffusion coefficient can be separated into independent functions of space and time: kappa(r,t)=K(t) k(sub 0) beta Pk(sub 1) (r), where beta is the particle velocity and P the rigidity, then (i) The time dependent quantity 1/K(t), which is proportional to the deceleration potential, phi(r,t), is linearly related to the Climax neutron monitor counting rate. (ii) The coefficients obtained from hydrogen or helium intensity measurements are the same. (iii) There are different correlation functions for odd and even solar cycles. (iv) The correlation function for the Climax neutron monitor counting rate for given time, t, can be used to estimate mean deceleration parameter phi(t) to within +/- 15% with 90% confidence. We have shown that k(r,t) determined from hydrogen and/or helium data, can be used to fit the oxygen and iron differential energy spectra with a root mean square error of about +/- 10%, and essentially independent of the particle charge or energy. We have also examined the ion chamber and C-14 measurements which allow the analysis to be extended from the year 1906 to 1990. Using this model we have defined reference GCR spectra at solar minimum and solar maximum. These can be used for space exploration studies and provide a quantitative estimate of the error in dose due to changes in GCR intensities.

Author (revised by Herner)

Galactic Cosmic Rays; Manned Space Flight; Radiation Shielding; Relative Biological Effectiveness (RBE)

19940039117 NASA Lyndon B. Johnson Space Center, Houston, TX, USA

Galactic cosmic ray abundances and spectra behind defined shielding

Heinrich, W.; Benton, E. V.; Wiegel, B.; Zens, R.; Rusch, G.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English

Contract(s)/Grant(s): 50 QV 85643; NAG9-235; Copyright; Avail: Other Sources

Linear Energy Transfer (LET) spectra have been measured for lunar missions and for several near Earth orbits ranging from 28 deg to 83 deg inclination. In some of the experiments the flux of Galactic Cosmic Rays (GCR) was determined separately from contributions caused by interactions in the detector material. Results of these experiments are compared to model calculations. The general agreement justifies the use of the model to calculate GCR fluxes. The magnitude of variations

caused by solar modulation, geomagnetic shielding, and shielding by matter determined from calculated LET spectra is generally in agreement with experimental data. However, more detailed investigations show that there are some weak points in modeling solar modulation and shielding by material. These points are discussed in more detail.
Author (revised by Herner)
Electromagnetic Shielding; Galactic Cosmic Rays; Linear Energy Transfer (LET); Mathematical Models; Radiation Shielding

19940039120 NASA Langley Research Center, Hampton, VA, USA
Galactic cosmic ray transport methods: Past, present and future
Wilson, J. W.; Townsend, L. W.; Shinn, J. L.; Cucinotta, F. A.; Costen, R. C.; Bodavi, F. F.; Lankin, S. L.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English; Copyright; Avail: Other Sources

The developement of the theory of high charge and energy (HZE) ion transport is reviewed. The basic solution behavior and approximation techniques will be described. An overview of the HZE transport codes currently available at the Langley Research Center will be given. The near term goal of the Langely program is to produce a complete set of one-dimensional transport codes. The ultimate goal is to produce a set of complete three-dimensional codes which have been validated in the laboratory and can be applied in the engineering design enviroment. Recent progress toward completing these goals is discussed.
Author (Herner)
Collision Parameters; Fragmentation; Galactic Cosmic Rays; Heavy Ions; Mathematical Models; Radiation Shielding; Radiation Transport

19940039121 NASA Langley Research Center, Hampton, VA, USA, NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Solar modulation and nuclear fragmentation effects in galactic cosmic ray transport through shielding
Townsend, L. W.; Cucinotta, C. F.; Wilson, J. W.; Shinn, J. L.; Badhwar, G.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English; Copyright; Avail: Other Sources

Crews of manned interplanetary missions may accumulate significant radiation exposures from the Galactic Cosmic Ray (GCR) environment in space. Estimates of how these dose levels are affected by the assumed temporal and spatial variations in the composition of the GCR environment, and by the effects of the spacecraft and body self-shielding on the transported fields are presented. In this work, the physical processes through which shielding alters the transported radiation fields are described. We then present estimates of the effects on model calculations of (1) nuclear fragmentation model uncertainties, (2) solar modulation, (3) variations between solar cycles, and (4) proposed changes to the quality factors which relate dose equivalent to absorbed dose.
Author (Herner)
Coulomb Collisions; Fragmentation; Galactic Cosmic Rays; Interplanetary Medium; Manned Space Flight; Mathematical Models; Particle Collisions; Radiation Shielding; Spacecraft Shielding

19940039122 NASA Langley Research Center, Hampton, VA, USA
Galactic cosmic ray radiation levels in spacecraft on interplanetary missions
Shinn, J. L.; Nealy, J. E.; Townsend, L. W.; Wilson, J. W.; Wood, J.S.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English; Copyright; Avail: Other Sources

Using the Langley Research Center Galactic Cosmic Ray (GCR) transport computer code (HZETRN) and the Computerized Anatomical Man (CAM) model, crew radiation levels inside manned spacecraft on interplanetary missions are estimated. These radiation-level estimates include particle fluxes, LET (Linear Energy Transfer) spectra, absorbed dose, and dose equivalent within various organs of interest in GCR protection studies. Changes in these radiation levels resulting from the use of various different types of shield materials are presented.
Author (Herner)
Bone Marrow; Computerized Simulation; Lenses; Radiation Dosage; Radiation Shielding; Solar Radiation; Thyroid Gland

19940039123

Fluxes of galactic iron nuclei and associated HZE secondaries, and resulting radiation doses, in the brain of an astronaut

Craven, P. A.; Rycroft, M. J.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English; Copyright; Avail: Other Sources

Although galactic iron nuclei constitute only a small percentage of the total flux of radiation in space, they are extremely significant from a biological standpoint, and represent a concern for long term manned space missions of the future. Dosages resulting from iron nuclei, and the high-charge secondary nuclei subsequently produced in nuclear fragmentation reactions, have been calculated at the center of a simple model of the human brain, shielded by various thicknesses of aluminum. Three mission scenarios are considered representing different geomagnetic shielding conditions at solar minimum. Without artificial shielding absorbed dose rates outside the magnetosphere, polar orbit and in the proposed Space Station orbit, are approximately 0.3, 0.1 and 0.03 cGy/year respectively, corresponding to dose equivalent rates of 8.0, 2.5 and 0.8 cSv/year, and decreasing by roughly a factor of two behind 10 g/cm sq of aluminum. In line with new approaches to risk estimation based on particle fluence and track structure, calculations of the number of cell nuclei likely to be struck by these HZE particles are also presented. Behind 10 g/cm sq of aluminum, 3.4%, 1.3% and 0.5% of cell nuclei at the center of the brain will be traversed at least once by such a particle within three years, for the three mission scenarios respectively.

Author (revised by Herner)

Cosmic Rays; Heavy Ions; Iron Isotopes; Radiation Dosage

19940039124

Radiation protection issues in galactic cosmic ray assessment

Sinclair, W. K.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English; Copyright; Avail: Other Sources

Radiation protection involves the limitation of exposure to below threshhold doses for direct (or deterministic) effects and a knowledge of the risk of stochastic effects after low doses. The principal stochastic risk associated with low dose rate galactic cosmic rays is the increased risk of cancer. Estimates of this risk depend on two factors (a) estimates of cancer risk for low Linear Energy Transfer (LET) radiation and (b) values of the appropriate radiation weighting factors, W(subR), for the high-LET radiations of galactic cosmic rays. Both factors are subject to considerable uncertainty. The low-LET cancer risk derived from the late effects of the atomic bombs is vulnerable to a number of uncertainties including especially that from projection in time, and from extrapolation from high to low dose rate. Nevertheless, recent low dose studies of workers and others tend to confirm these estimates. W(subR), relies on biological effects studied mainly in non-human systems. Additional laboratory studies could reduce the uncertainties in W(subR) and thus produce a more confident estimate of the overall risk of galactic cosmic rays.

Author (revised by Herner)

Cosmic Rays; Extraterrestrial Radiation; Neoplasms; Radiation Dosage; Radiation Protection; Risk

19940039125 NASA, Washington, DC, USA

Single-track effects and new directions in GCR risk assessment

Curtis, S. B.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English

Contract(s)/Grant(s): T-9310R; Copyright; Avail: Other Sources

Light flashes in the eye as recorded by astronauts on missions outside the geomagnetosphere are presumably caused by single particle traversals of galactic cosmic rays traversing the retina. Although these flashes are not considered to have deleterious short- or long-term effects on vision, they are testimony that the body can detect single particle traversals. The frequencies of the flashes implicate ions in the charge range of 6 to 8 (i.e., carbon and/or oxygen ions). Other particles with higher charge and causing more ionization are present at lower frequencies. The possibility of the importance of such single-track effects in radiation carcinogenesis and other late effects suggest that a risk assessment system based on particle fluence rather than absorbed dose might be useful for assessing risk on long-term space missions. Such a system based on the concept of risk cross section is described. Human cancer risk cross sections obtained from recently compiled A-bomb survival

data are presented, and problems involving the determination of the Linear Energy Transfer (LET)-dependence of such cross sections are discussed.
Author (revised by Herner)
Galactic Cosmic Rays; Linear Circuits; Radiation Damage; Radiation Dosage; Risk

19940039126
An inductive assessment of radiation risks in space
Dicello, J. F.; Zaider, M.; Varma, M. N.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English; Copyright; Avail: Other Sources

Procedures for the assessment of risks or vulnerabilities from radiation in space are evaluated in terms of model-independent inductive approaches. The reliablity of risks calculated for space applications on the basis of accelerator-based physical and biological data is examined from a microdosimetric perspective. Probability distributions for energy deposition in biologically significant sites extend over several decades in lineal energy even for monoenergetic high-energy particles of relatively high atomic number. Because the response depends on a large number of variables and because of the difficulty of incorporating all such factors into calculations, a precise correlation between a physical descriptor of the field and observed effects in space is not feasible. For the same reasons, it is equally difficult to estimate the accuracies of each risk assessments. We use recently published microdosimetric spectra for HZE particles and biological weighting functions, including those derived from biological measurements with maximum entropy techniques, to illustrate some problems associated with the evaluations of risks from radiation fields in space.
Author (Herner)
Biological Models (Mathematics); Cosmic Rays; Heavy Ions; Ionizing Radiation; Radiation Dosage; X Ray Irradiation

19940039128 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Results of time-resolved radiation exposure measurements made during U.S. shuttle missions with a tissue equivalent proportional counter
Golightly, M. J.; Hardy, A. C.; Hardy, K.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English; Copyright; Avail: Other Sources

Time resolved exposure measurements inside the crew compartment have been made during recent shuttle missions with the USAF Radiation Monitoring Equipment-III (RME-III), a portable four-channel tissue equivalent proportional counter. Results from the first six missions are presented and discussed. The missions had orbital inclinations ranging from 28 degrees to 57 degrees, and altitudes from 200-600km. Dose equivalent rates ranged from 40-5300 micro Sv/dy. The RME-III measurements are in good agreement with other dosimetry measurements made aboard the vehicle. Measurements indicate that medium- and high- Linear Energy Transfer (LET) particles contribute less than 2% of the particle fluence for all missions, but up to 50% of the dose equivalent, depending on the spacecraft's altitude and orbital inclination. Isa-dose rate contours have been developed from measurements made during the ST-28 mission. The drift rate of the South Atlantic Anomaly (SAA) is estimated to be 0.49 degrees W/yr and 0.12 degrees N/yr. The calculated trapped proton and Galactic Cosmic Radiation (GCR) dose for the STS-28 mission were significantly lower than the measured values.
Author (revised by Herner)
Biological Effects; Galactic Cosmic Rays; Proton Belts; Radiation Belts; Radiation Measuring Instruments; Space Shuttle Orbiters

19940039129
Near-earth radiation model deficiencies as seen on CRRES
Gussenhoven, M. S.; Mullen, E. G.; Brautigam, D. H.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English; Copyright; Avail: Other Sources

The Space Radiation (SPACERAD) experiments on the Combined and Radiation Effects Satellite (CRRES) gathered 14 months of radiation particle data in an 18 degree inclination orbit between 350 km and 36000 km from July 1990 to October 1991. When compared to the NASA radiation belt models AP8 and AE8, the data show the proton model (AP8) does not take into account a second belt formed after major solar flare/shock injection events, and the electron model (AE8) is misleading, at best, in calculating dose in near-Earth orbits. The second proton belt, although softer in energy than the main proton belt,

can produce upsets in proton sensitive chips and would produce significant dose in satellites orbiting in it. The MeV electrons observed on CRRES show a significant particle population above 5 MeV (not in the AE8 model) which must be included in any meaningful dose predictions for satellites operating between L-shells of 1.7 and 3.0 R(sub E).
Author (revised by Herner)
Crres (Satellite); Microelectronics; Proton Belts; Radiation Belts; Radiation Effects; Radiation Measuring Instruments

19940039130
Contribution of secondaries to the radiation environment on space missions
Haskins, P.; Mckisson, J.; Truscott, P.; Dyer, C.; Flatman, J.; Snead, L.; Rothmann, J.; Ward, T.; Camp, D.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English; Copyright; Avail: Other Sources

Calculations to predict the radiation environment for spacecraft in low earth orbit sometes ignore the contribution from secondary radiation products. However, the contribution of secondaries, particularly neutrons, on heavy spacecraft or in planetary bodies can be of concern for biological systems. The Shuttle Activation Monitor (SAM) and Cosmic Radiation Effects and Activation Monitor (CREAM) experiments provide valuable data on secondary (as well as primary) radiation effects. Comparisons have been made between induced activity from flight-exposed samples, induced activity in a ground-irradiated sample, and Monte Carlo-derived predictions with and without secondaries. These comparisons show that for a flight-exposed sample, predictions which omit the secondary contribution result in a spectrum that is too low by a factor of 2. The addition of the secondaries results in a predicted spectrum that closely matches the measured data.
Author (revised by Herner)
Ionizing Radiation; Mathematical Models; Radiation Belts; Radiation Measuring Instruments; Radiation Shielding; Secondary Emission; Space Shuttle Orbiters

19940039131 NASA Goddard Inst. for Space Studies, New York, NY, USA
Uncertainties in radiation effect predictions for the natural radiation environments of space
Mcnulty, P. J.; Stassinopoulos, E. G.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English; Copyright; Avail: Other Sources

Future manned missions beyond low earth orbit require accurate predictions of the risk to astronauts and to critical systems from exposure to ionizing radiation. For low-level exposures, the hazards are dominated by rare single-event phenomena where individual cosmic-ray particles or spallation reactions result in potentially catastrophic changes in critical components. Examples might be a biological lesion leading to cancer in an astronaut or a memory upset leading to an undesired rocket firing. The risks of such events appears to depend on the amount of energy deposited within critical sensitive volumes of biological cells and microelectronic components. The critical environmental information needed to estimate the risks posed by the natural space environments, including solar flares, is the number of times more than a threshold amount of energy for an event will be deposited in the critical microvolumes. These predictions are complicated by uncertainties in the natural environments, particularly the composition of flares, and by the effects of shielding. Microdosimetric data for large numbers of orbits are needed to improve the environmental models and to test the transport codes used to predict event rates.
Author (Herner)
Ionizing Radiation; Particle Tracks; Radiation Measurement; Solar Activity; Solar Storms

19940039132
Experimental simulation of proton space radiation environments: A dosimetric perspective
Hardy, K. A.; Leavitt, D. D.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English
Contract(s)/Grant(s): F-33615-87-D-0627; F-33615-87-D-0005; F-33615-87-D-0009; Copyright; Avail: Other Sources

Three-dimensional dose calculation techniques developed for radiotherapy treatment planning were used to calculate dose distributions from unidirectional, planar rotational and omnidirectional incident radiation (experimental proton beams and solar flares). The calculations predicted regions for high dose within primate heads exposed to 55-MeV protons, supporting the postulate of radiation-induced brain tumors within this population. Comparisons among predicted doses to the human head from solar flares of three different energies demonstrated differences between unidirectional and omnidirectional irradiation

in the space environment. The results can be used to estimate dose distributions based on: a) limited phantom measurements, or b) nonuniformly incident radiation in orbit; both simulations are difficult to replicate under laboratory exposure conditions. Author (revised by Herner)

Proton Irradiation; Radiation Dosage; Solar Flares; Solar Protons

19940039134

Issues and problems for radiobiological research in space

Kiefer, J.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English; Copyright; Avail: Other Sources

The uniqueness of the space radiation field creates specific problems in the evaluation of hazards to men and materials. Comprehensive measurements of all physical parameters are necessary but not sufficient. Particular attention has to be paid to variables like solar flares by applying fast-responding active dosimetry. The assessment of biological consequences poses even more problems. There are no human data for the kinds of particles seen in space and they will presumably never be available. The only reasonable approach is therefore to use the information obtained for the other radiations and check their applicability for the space situation. This involves both the study of fundamental processes in ground experiments as well as their verification in space missions. Special emphasis has to be laid on the modification of radiation effects by flight-dynamic factors and microgravity. Radiation protection guidelines for space flights cannot simply be transformed from existent regulations designed for radiation workers on earth but have to be tailored to the specific situation in space.

Author (Herner)

Radiation Dosage; Radiation Hazards; Relative Biological Effectiveness (RBE); Risk

19940039135 NASA, Washington, DC, USA

Importance of dose-rate and cell proliferation in the evaluation of biological experimental results

Curtis, S. B.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English

Contract(s)/Grant(s): T-9310R; Copyright; Avail: Other Sources

The nuclei of cells within the bodies of astronauts traveling on extended missions outside the geomagnetosphere will experience single traversals of particles with high Linear Energy Transfer (LET) (e.g., one iron ion per one hundred years, on average) superimposed on a background of tracks with low LET (approximately one proton every two to three days, and one helium ion per month). In addition, some cell populations within the body will be proliferating, thus possibly providing increasing numbers of cells with 'initiated' targets for subsequent radiation hits. These temporal characteristics are not generally reproduced in laboratory experimental protocols. Implications of the differences in the temporal patterns of radiation delivery between conventionally designed radiation biology experiments and the pattern to be experienced in space are examined and the importance of dose-rate and cell proliferation are pointed out in the context of radiation risk assessment on long mission in space.

Author (revised by Herner)

Cell Division; Galactic Cosmic Rays; Manned Space Flight; Radiation Dosage; Risk; Space Environment Simulation

19940039136

On the parametrization of the biological effect in a mixed radiation field

Kraft, G.; Scholz, M.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English; Copyright; Avail: Other Sources

The exposure of astronauts and electronics to the cosmic radiation especially to the particle component poses a major risk to all space flights. Up to now it is not possible to quantify this risk within acceptable limits of accuracy. This uncertainty is not only caused by difficulties in the more or less exact prediction of the incidence of the cosmic radiation but depends also on the problem of the quantification of the radiation field and the correlation of the biological effect. Usually the biological action of a mixed radiation field is estimated as product of the measured dose with an average quality factor, the relative biological efficiency. Because of the large variation in energy and atomic number of the cosmic particles, average values of

the quality factor are not precise for risk estimation. A more appropriate way to treat the biological effects of mixed radiation is the concept of particle fluence and action cross section.
Author (revised by Herner)
Cosmic Rays; Fluence; Radiation Hazards; Relative Biological Effectiveness (RBE); Risk

19940039139
Inactivation of individual Bacillus subtilis spores in dependence on their distance to single cosmic heavy ions
Facius, R.; Reitz, G.; Schafer, M.; Life Sciences and Space Research 25 (2) Radiation Biology: Topical Meeting of the COSPAR Interdisciplinary Scientific Commission F of the COSPAR 29th Plenary Meeting, Washington, DC, Aug. 28-Sep. 5, 1; October 1994; ISSN 0273-1177; 14, 10; In English; Copyright; Avail: Other Sources

For radiobiological experiments in space, designed to investigate biological effects of the heavy ions of the cosmic radiation field, a mandatory requirement is the possibility to spatially correlate the observed biological response of individual test organisms to the passage of single heavy ions. Among several undertaking towards this goal, the BIOSTACK experiments in the Apollo missions achieved the highest precision and therefore the most detailed information on this question. Spores of Bacillus subtilis as a highly radiation resistant and microscopically small test organism yielded these quantitative results. This paper will focus on experimental and procedural details, which must be included for an interpretation and a discussion of these findings in comparison to control experiments with accelerated heavy ions.
Author (Herner)
Bacillus; Heavy Ions; Ionizing Radiation; Radiation Tolerance; Relative Biological Effectiveness (RBE)

19950036666
Design and construction of shielded lunar outpost
Jolly, S. D.; Happel, J.; Sture, S.; Journal of Aerospace Engineering; October 1994; ISSN 0893-1321; 7, 4; In English; Copyright; Avail: Other Sources

The construction of an outpost on the Moon in which humans can live and work for periods exceeding six months will require special countermeasures to adapt to the hostile environment present at the lunar surface. Various inherent dangers such as meteoroids, galactic cosmic radiation, solar proton events, and large thermal extremes will drive the design configuration of the outpost. Other considerations such as lunar soil mechanics, equipment performance, mass delivery, risk, reliability, and tele-operability act strongly as constraints that shape and control the design alternatives. Analysis of these fundamental relationships have resulted in lunar civil engineering guidelines, which are unique to this domain, and these in turn have pointed to research areas needing further attention. A preliminary design is presented for a lunar outpost shelter. Additionally, the design methodology is explored, and early enabling technologies are identified to facilitate an understanding of lunar shelter designs from an integrated system standpoint.
Author (EI)
Lunar Bases; Lunar Environment; Lunar Shelters; Lunar Surface; Moon; Operational Hazards; Radiation Shielding; Reliability Analysis; Structural Design; Structural Engineering

19950011373 Commissariat a l'Energie Atomique, Fontenay-aux-Roses, France
Dose rate and LET spectrum aboard Mir Station since Antares until Altair mission
Bottollier-Depois, J. F.; Nguyen, V. D.; Lebaron-Jacobs, L.; Siegrist, M.; Andre-Deshays, C.; Marsal, O.; Petrov, V. M.; Koslova, S. B.; Tognini, M.; Avdeev, S.; ESA, Proceedings of the Fifth European Symposium on Life Sciences Research in Space; Aug 1, 1994; In English; Copyright; Avail: CASI

The NAUSICAA system is installed aboard the Russian orbital station Mir since the French-Russian joint mission Antares. Data are available until the Altair mission. Interesting results about radiation measurements show the South Atlantic Anomaly (SAA) crossing, the increase of radiation near the poles, and the solar eruptions effects (the most important one occurs at the beginning of Nov. 1992). These data give also a precise idea about the dose and the quality factor of the radiation received by the cosmonauts during different missions.
ESA
Dosimeters; Earth Orbital Environments; Mir Space Station; Radiation Dosage; Radiation Measurement

19950011374
HZE-dosimetry on plastic track detectors
Beaujean, Rudolf; Kopp, J.; ESA, Proceedings of the Fifth European Symposium on Life Sciences Research in Space; Aug 1, 1994; In English
Contract(s)/Grant(s): BMFT-01-QV-192; BMFT-01-QV-8566; DARA-50-QV-8566; Copyright; Avail: CASI

Nuclear track detectors were used to measure the integral linear energy transfer (LET) spectra above 1 GeV per cm water in numerous space flights. The measurements are compared with calculations which take into account the solar and geomagnetic modulation as well as the influence of different shielding by matter on the contribution of the high charge, high energy HZE particles of the galactic cosmic radiation.
ESA
Cosmic Rays; Dosimeters; Earth Orbital Environments; Linear Energy Transfer (LET); Radiation Measurement

19960025273 NASA Langley Research Center, Hampton,VA USA
Alpha-cluster description of excitation energies in C-12(C-12, 3 alpha)X at 2.1A GeV
Cucinotta, Francis A.; Dubey, Rajendra R; Aug. 1994; In English
Report No.(s): NASA-TM-111577; NAS 1.15:111577; No Copyright; Avail: CASI
An alpha-cluster expansion of the Glauber multiple scattering series is used to calculate the energy transfer spectrum to the C-12 projectile in the C-12(C-12,3 alpha)X reaction at 2.1A GeV. Cluster-abrasion response functions are defined in terms of alpha-cluster wave function and the collision dynamics appropriate for heavy-ion reactions. Comparisons are made to recent quasiexclusive experimental data with good agreement found. Calculations indicate that substructures in a C-12 projectile are likely to be true spectators in fragmentation, however, with virtual states of excitation in the projectile ground state making a significant contribution to the fragmentation cross section.
Author
Cluster Analysis; Energy Transfer; Atomic Excitations; Carbon 12; Ionic Collisions; Applications of Mathematics; Mathematical Models

19950019426 Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Cologne, Germany
Effects of sparsely and densely ionizing radiation on cells of Deinococcus radiodurans
Zimmermann, Heike; Jul 26, 1994; ISSN 0939-2963; In German
Report No.(s): DLR-FB-94-14; No Copyright
The biological effects of particle irradiation in comparison to X-rays and gamma rays were measured in a very radiation resistant bacterium, Deinococcus radiodurans, by analyzing inactivation and DNA (Deoxyribonucleic Acid) DSB (Double Strand Break) induction and their repair. The cells of Deinococcus show the same survival after X-ray and gamma irradiation while the DNA DSB induction after gamma irradiation is nearly three times higher as that after X-ray irradiation. The obtained inactivation and DNA-DSB cross sections after ion irradiation increased for higher atomic numbers and for ions Z greater than or equal to 36 with increasing energy. A DNA DSB repair ('rejoining') was measured for Deinococcus after X-ray and ion irradiation. After irradiation with high X-ray doses and very heavy ions, the DNA DSB repair was found to be related.
ESA
Bacteria; Biological Effects; Deoxyribonucleic Acid; Gamma Rays; Ion Irradiation; Radiation Effects; Strands; X Ray Irradiation; X Rays

19940032774 NASA Langley Research Center, Hampton, VA, USA
Estimates of cellular mutagenesis from cosmic rays
Cucinotta, Francis A.; Wilson, John W.; Jul 1, 1994; In English
Contract(s)/Grant(s): RTOP 199-45-16-11
Report No.(s): NASA-TP-3453; L-17377; NAS 1.60:3453; No Copyright; Avail: CASI
A parametric track structure model is used to estimate the cross section as a function of particle velocity and charge for mutations at the hypoxanthine guanine phosphoribosyl transferase (HGPRT) locus in human fibroblast cell cultures. Experiments that report the fraction of mutations per surviving cell for human lung and skin fibroblast cells indicate small differences in the mutation cross section for these two cell lines when differences in inactivation rates between these cell lines are considered. Using models of cosmic ray transport, the mutation rate at the HGPRT locus is estimated for cell cultures in space flight and rates of about 2 to 10 x 10(exp -6) per year are found for typical spacecraft shielding. A discussion of how model assumptions may alter the predictions is also presented.
Author (revised)
Bioastronautics; Fibroblasts; Galactic Cosmic Rays; Genetics; Mutations; Radiation Damage; Radiation Shielding; Spacecraft Shielding

19960023417 NASA Langley Research Center, Hampton,VA USA
Optical model analyses of heavy ion fragmentation in hydrogen targets
Townsend, Lawrence W.; Jun. 1994; ISSN 0556-2813; In English
Report No.(s): NASA-TM-111557; NAS 1.15:111557; Copyright; Avail: CASI

Quantum-mechanical optical-model methods for calculating cross sections for the fragmentation of high-energy heavy ions by hydrogen targets are presented. The cross sections are calculated with a knockout-ablation collision formalism which has no arbitrary fitting parameters. Predictions of elemental production cross sections from the fragmentation of 1.2A GeV(La-139) nuclei and of isotope production cross sections from the fragmentation of 400A MeV(S-32) nuclei are in good agreement with recently reported experimental measurements.
Author
Fragmentation; Heavy Ions; Hydrogen; Galactic Cosmic Rays; Optical Properties; Particle Accelerator Targets; Ionic Collisions

19940029180 NASA Langley Research Center, Hampton, VA, USA
Effects of isotope selection on solution convergence in HZE transport
Kim, Myung-Hee Y.; Wilson, John W.; Kiefer, Richard L.; Thibeault, Sheila A.; May 1, 1994; In English
Contract(s)/Grant(s): RTOP 199-45-16-11
Report No.(s): NASA-TP-3445; L-17357; NAS 1.60:3445; No Copyright; Avail: CASI

A fragmenting iron ion produces hundreds of isotopes during nuclear reactions. These isotopes are represented in the solution of the transport problem. A reduced set of isotopes is selected to minimize the computational burden but introduces error in the final result. A minimum list of 122 isotopes is required for adequate representation of the mass and charge distributions of the secondary radiation fields. A reduced set of 80 isotopes is sufficient to represent the charge distribution alone and represents reasonably well the linear energy transfer properties of the iron beam. Because iron fragmentation produces nearly every isotope lighter than iron, the resulting 122-isotope list should be adequate for ion beams with charges equal to or less than 26.
Author
Charge Distribution; Ion Beams; Iron; Isotopes; Linear Energy Transfer (LET); Metal Ions; Nuclear Reactions; Radiation Distribution

19950037623
Optimization of spacecraft orbit and shielding for radiation dose
Gates, Michele M.; Lewis, Mark J.; Journal of Spacecraft and Rockets; May-June 1994; ISSN 0022-4650; 31, 3; In English; Copyright; Avail: Other Sources

An implementation of the optimization of spacecraft orbit and shielding thickness for the control of exposure from the natural orbital radiation environment is described. Many space missions, such as crewed flights and those carrying sensitive electronics, are constrained by a maximum allowable radiation dose to materials inside the vehicle. Generally, in the event of a radiation dose concern, additional shielding is added for radiation protection, thus adding more mass to the spacecraft. However, a modification to the orbit might also be used to reduce the radiation dose, which, depending on the flexibility of the mission design, may provide a more advantageous solution. It is shown with established optimization techniques that there are many combinations of orbits and shieldings that will yield a specific dose. For a given design space, weighting the importance of the various spacecraft and mission design parameters, including shielding thickness and orbital parameters, allows for mission specific optimization, providing a flexible design tool.
Author (EI)
Radiation Dosage; Radiation Shielding; Spacecraft Design; Spacecraft Orbits; Spacecraft Shielding

19950036669 NASA Langley Research Center, Hampton, VA, USA
Radiation exposure predictions for long-duration-stay Mars missions
Striepe, Scott A.; Simonsen, Lisa C.; Nealy, John E.; Journal of the Astronautical Sciences; April-June 1994; ISSN 0021-9142; 42, 2; In English; Copyright; Avail: Other Sources

In this study, the ionizing radiation environment is estimated, using the Mission Radiation Calculation (MIRACAL) program, for several long-duration-stay Mars missions proposed for early in the 21(sup st) century. Both minimum energy and fast transfer missions are evaluated and their 30-day maximum, annual maximum, and total slab skin and blood-forming organ (BFO) doses are compared. When large flares were included while the astronauts were on the surface, the delivered dose did

not significantly contribute to the total dose (less than 4 cSv BFO dose, or 8 percent of the guideline annual limit, for the most energetic event simulated) due to the substantial protection provided by the Martian atmosphere. However, dose delivered by large flares during transit is dependent on vehicle shielding and distance from the Sun. All of the fast transfer missions studied had lower total and annual maximum doses than the corresponding minimum energy transfer missions (on average, 30% less for missions having no large flares and the shielding thicknesses evaluated in this study). For all the missions studied, having the astronauts spend one-third of their day during transit in a 10 g/sq cm storm shelter resulted in an approximate 10% reduction in the total mission dose.
Author (EI)
Computerized Simulation; Interplanetary Flight; Ionizing Radiation; Long Duration Space Flight; Mars (Planet); Mars Exploration; Physiological Responses; Radiation Dosage; Radiation Protection; Sun

19950026308 Justus Liebig-Univ., Giessen, Germany
Heavy ion action on single cells: Cellular inactivation capability of single accelerated heavy ions
Kost, M.; Pross, H.-D.; Russmann, C.; Schneider, E.; Kiefer, J.; Kraft, G.; Lenz, G.; Becher, W.; NASA. Ames Research Center, Minutes of the 12th Joint NASA(DARA-DLR Life Sciences Program Working Group Meeting; JAN 1, 1994; In English; No Copyright; Avail: CASI

Heavy ions (HZE-particles) constitute an important part of radiation in space. Although their number is small the high amount of energy transferred by individual particles may cause severe biological effects. Their investigation requires special techniques which were tested by experiments performed at the UNILAC at the GSI (Darmstadt). Diploid yeast was used which is a suitable eucaryotic test system because of its resistance to extreme conditions like dryness and vacuum. Cells were placed on nuclear track detector foils and exposed to ions of different atomic number and energy. To assess the action of one single ion on an individual cell, track parameters and the respective colony forming abilities (CFA) were determined with the help of computer aided image analysis. There is mounting evidence that not only the amount of energy deposited along the particle path, commonly given by the LET, is of importance but also the spatial problem of energy deposition at a submicroscopical scale. It is virtually impossible to investigate track structure effects in detail with whole cell populations and (globally applied) high particle fluences. It is, therefore, necessary to detect the action of simple ions in individual cells. The results show that the biological action depends on atomic number and specific energy of the impinging ions, which can be compared with model calculations of recent track structure models.
Derived from text
Biological Effects; Deactivation; Energy Transfer; Eukaryotes; Heavy Ions; Populations; Radiation Damage; Radiation Effects; Yeast

19960029054 Johann-Wolfgang-Goethe-Univ., Frankfurt am Main, Germany
The biological effect of the high energetic cosmic radiation field in a multicellular model object during short and long duration space flights
Kranz, A. R.; [1994]; In German
Contract(s)/Grant(s): BMFT-50QV8565; No Copyright; Avail: Other Sources

Experiences with exemplary results of lasting radiobiological experiments for the duration of 8 to 2150 days in space are summarized. By the state of biophysical knowledge obtained from earlier experiments (BIOSTACK on Apollo-Soyuz, Spacelab-1 and accelerators UNILAC, BEVALAC), which demanded new evaluation of the dose concept, the suitability of detectors and bioobjects for heavy ions effect, new flight units (improved compartments for detectors and bioobjects) were built by inert structure material. They provided more exact differentiated microdosimetric data of particle hits. Thus, the significance of charge (Z) and linear energy transfer (LET) for the relative biological effect (RBE) of single and multiple particle hits of the mixed radiation in orbit inside potential targets of a multicellular model object (Arabidopsis seed empbryo) was indicated. Specifics of radiation damage (lethality, survival, sterility etc.) were interpreted as physiological stress (modification) and genetic risk (mutation). The role of orbit, duration and shielding in the composition of the particle radiation spectrum and, thus, its acute and interactive damage effect is recognized for the improvement of radiation protection during repeated, long lasting space flights.
Author (FIZ)
Cosmic Rays; Space Flight; Radiation Effects; Cells (Biology); Biological Effects; Radiation Damage

19940012782 Christopher Newport Coll., Newport News, VA, USA
Shielding from space radiations
Chang, C. Ken; Badavi, Forooz F.; Tripathi, Ram K.; Dec 1, 1993; In English
Contract(s)/Grant(s): NAG1-1286
Report No.(s): NASA-CR-194664; NAS 1.26:194664; No Copyright; Avail: CASI

This Progress Report covering the period of 1 June 1993 to 1 Dec. 1993 presents the development of an analytical solution to the heavy ion transport equation in terms of a one-layer Green's function formalism. The mathematical developments are recasted into an efficient computer code for space applications. The efficiency of this algorithm is accomplished by a nonperturbative technique of extending the Green's function over the solution domain. The code may also be applied to accelerator boundary conditions to allow code validation in laboratory experiments. Results from the isotopic version of the code with 80 isotopes present for a single layer target material, for the case of an Iron beam projectile at 600 MeV/nucleon in water is presented.
Author (revised)
Extraterrestrial Radiation; Green's Functions; Heavy Ions; Isotopes; Mathematical Models; Radiation Shielding; Transport Theory

19940015590 Christopher Newport Coll., Newport News, VA, USA
Shielding from space radiations
Chang, C. Ken; Badavi, Forooz F.; Tripathi, Ram K.; Dec 1, 1993; In English
Contract(s)/Grant(s): NCC1-178
Report No.(s): NASA-CR-194683; NAS 1.26:194683; No Copyright; Avail: CASI

This Progress Report covering the period of 1 June 1993 to 1 Dec. 1993 presents the development of an analytical solution to the heavy ion transport equation in terms of a one-layer Green's function formalism. The mathematical developments are recasted into an efficient computer code for space applications. The efficiency of this algorithm is accomplished by a nonperturbative technique of extending the Green's function over the solution domain. The code may also be applied to accelerator boundary conditions to allow code validation in laboratory experiments. Results from the isotopic version of the code with 80 isotopes present for a single layer target material, for the case of an iron beam projectile at 600 MeV/nucleon in water is presented.
Author (revised)
Green's Functions; Heavy Ions; Iron Isotopes; Radiation Shielding; Transport Theory

19940012545 NASA Langley Research Center, Hampton, VA, USA
Energy-loss cross sections for inclusive charge-exchange reactions at intermediate energies
Cucinotta, Francis A.; Townsend, Lawrence W.; Dubey, Rajendra R.; Nov 1, 1993; In English
Contract(s)/Grant(s): RTOP 199-45-16-11
Report No.(s): NASA-TM-4522; L-17277; NAS 1.15:4522; No Copyright; Avail: CASI

Charge-exchange reactions for scattering to the continuum are considered in a high-energy multiple scattering model. Calculations for (p,n) and (He-3,H-3) reactions are made and compared with experimental results for C-12, O-16, and Al-27 targets. Coherent effects are shown to lead to an important role for inelastic multiple scattering terms when light projectiles are considered.
Author
Charge Transfer; Energy Dissipation; Neutrons; Nucleon-Nucleon Interactions; Nucleon-Nucleon Scattering; Particle Collisions; Particle Production; Protons

19940013193 NASA Langley Research Center, Hampton, VA, USA
Calculations of cosmic-ray helium transport in shielding materials
Cucinotta, Francis A.; Nov 1, 1993; In English
Contract(s)/Grant(s): RTOP 199-45-16-11
Report No.(s): NASA-TP-3354; L-17225; NAS 1.60:3354; No Copyright; Avail: CASI

The transport of galactic cosmic-ray helium nuclei and their secondaries through bulk shielding is considered using the straight-ahead approximation to the Boltzmann equation. A data base for nuclear interaction cross sections and secondary particle energy spectra for high-energy light-ion breakup is presented. The importance of the light ions H-2, H-3, and He-3 for cosmic-ray risk estimation is discussed, and the estimates of the fractional contribution to the neutron flux from helium

interactions compared with other particle interactions are presented using a 1977 solar minimum cosmic-ray spectrum.
Author (revised)
Boltzmann Transport Equation; Galactic Cosmic Rays; Helium Isotopes; Light Ions; Nuclear Interactions; Radiation Shielding; Spacecraft Shielding

19940012611 NASA Langley Research Center, Hampton, VA, USA
Approximate Green's function methods for HZE transport in multilayered materials
Wilson, John W.; Badavi, Francis F.; Shinn, Judy L.; Costen, Robert C.; Oct 1, 1993; In English
Contract(s)/Grant(s): RTOP 199-45-16-11
Report No.(s): NASA-TM-4519; L-17302; NAS 1.15:4519; No Copyright; Avail: CASI

A nonperturbative analytic solution of the high charge and energy (HZE) Green's function is used to implement a computer code for laboratory ion beam transport in multilayered materials. The code is established to operate on the Langley nuclear fragmentation model used in engineering applications. Computational procedures are established to generate linear energy transfer (LET) distributions for a specified ion beam and target for comparison with experimental measurements. The code was found to be highly efficient and compared well with the perturbation approximation.
Author
Green's Functions; Ion Beams; Linear Energy Transfer (LET); Multilayer Insulation; Radiation Shielding

19940034507
Experience from active dosimetric investigations on Mir-space station - Proposal for a new conception and design of space dosimetry systems for future manned missions
Semkova, J. V.; Dachev, Ts. P.; Matvijchuk, Yu. N.; Tomov, B. T.; Koleva, R. T.; Bajnov, P. T.; Kanchev, N. G.; Petrov, V. M.; Shurshakov, V. A.; Bengin, V. V., et al.; Oct 1, 1993; In English; 44th, Oct. 16-22, 1993, Graz, Austria
Report No.(s): IAF PAPER 93-171; Copyright; Avail: Other Sources

Since 1988, using the Bulgarian-Russian semiconductor dosimetry-radiometry system Liulin and the French tissue-equivalent system CIRCE, active dosimetric investigations have been performed on board the Mir space station. Investigations during quiet solar conditions and during solar proton events are presented. The main results can be summarized as follows: The mean dose behind 5 g/sq cm at an altitude of about 400 km and inclination of 51.6 deg was determined by the semiconductor detector for quiet solar conditions to be about 0.3 mGy/day. High linear energy transfer events produced by ions with q values in the 10-20 range significantly contribute to the total dose outside the South Atlantic anomaly. The mean flux of such events in March-April 1989 is 14/sq cm per day. The variations of flux and dose rate in different compartments of the station are more than 200 percent because of different shielding. For the era of large orbital stations, lunar bases and interplanetary space ships, a new conception and design of on board dosimetry systems is proposed.
AIAA
Long Duration Space Flight; Manned Space Flight; Mir Space Station; Radiation Hazards; Spacecraft Shielding

19940011343 NASA Langley Research Center, Hampton, VA, USA
Exposure fluctuations of astronauts due to orientation
Wilson, John W.; Nealy, John E.; Wood, James S.; Qualls, Gary; Atwell, William; Shinn, Judy L.; Simonsen, Lisa C.; Sep 1, 1993; In English; 5 functional color pages
Contract(s)/Grant(s): RTOP 199-45-16-11
Report No.(s): NASA-TP-3364; L-17254; NAS 1.60:3364; No Copyright; Avail: CASI

The dose incurred in an anisotropic environment depends on the orientation of the astronaut's body relative to the direction of the radiation field. The fluctuations in exposure of specific organs due to astronaut orientation are found to be a factor of 2 or more in a typical space habitation module and typical space radiations. An approximation function is found that overestimates astronaut exposure in most cases studied and is recommended as a shield design guide for future space missions.
Derived from text
Aerospace Medicine; Astronauts; Bioastronautics; Radiation Dosage; Radiation Effects; Radiation Protection; Radiation Shielding; Spacecraft Shielding

19930067959 NASA Langley Research Center, Hampton, VA, USA
Universal characteristics of transverse momentum transfer in intermediate energy heavy ion collisions
Khan, F.; Townsend, L. W.; Tripathi, R. K.; Cucinotta, F. A.; Physical Review C - Nuclear Physics, 3rd Series; Aug. 1993; ISSN 0556-2813; 48, 2; In English; Copyright; Avail: Other Sources

A microscopic optical model formalism for estimating momentum transfer in intermediate energy heavy ion collisions predicts universal behavior of the transverse component. In particular, for symmetric systems heavier than niobium, it appears that values of P(perpendicular)/A are independent of the mass and charge of the colliding nuclei and vary only with impact parameter and incident beam energy. This suggests that momentum transfer per nucleon saturates to some limiting value with increasing mass.
AIAA
Heavy Ions; Ionic Collisions; Momentum Transfer

19940006304 NASA Langley Research Center, Hampton, VA, USA
Nonperturbative methods in HZE ion transport
Wilson, John W.; Badavi, Francis F.; Costen, Robert C.; Shinn, Judy L.; Aug 1, 1993; In English
Contract(s)/Grant(s): RTOP 199-45-16-11
Report No.(s): NASA-TP-3363; L-17241; NAS 1.60:3363; No Copyright; Avail: CASI
A nonperturbative analytic solution of the high charge and energy (HZE) Green's function is used to implement a computer code for laboratory ion beam transport. The code is established to operate on the Langley Research Center nuclear fragmentation model used in engineering applications. Computational procedures are established to generate linear energy transfer (LET) distributions for a specified ion beam and target for comparison with experimental measurements. The code is highly efficient and compares well with the perturbation approximations.
Author
Energetic Particles; Green's Functions; Ion Beams; Ionizing Radiation; Linear Energy Transfer (LET)

19940006806 NASA Langley Research Center, Hampton, VA, USA
A proposed performance index for galactic cosmic ray shielding materials
Wilson, John W.; Wood, J. S.; Shinn, Judy L.; Cucinotta, Francis A.; Nealy, John E.; Aug 1, 1993; In English
Contract(s)/Grant(s): RTOP 592-43-21-01
Report No.(s): NASA-TM-4444; L-17199; NAS 1.15:4444; No Copyright; Avail: CASI
In past studies, the reductions in absorbed dose and dose equivalent due to choice of material composition have been used to indicate shield effectiveness against exposure to galactic cosmic rays. However, these quantities are highly inaccurate in assessing shield effectiveness for protection against the biological effects of long-term exposure to the galactic heavy ions. A new quantity for shield performance is defined that correlates well with cell killing and cell transformation behind various shield thicknesses and materials. In addition, a relative performance index is identified that is inversely related to biological injury for different materials at a fixed shield mass and is directly related to the ratio of the fourth- and the second-order linear energy transfer (LET) moments.
Author (revised)
Biological Effects; Galactic Cosmic Rays; Radiation Dosage; Radiation Protection; Radiation Shielding

19940007963 NASA Langley Research Center, Hampton, VA, USA
Final state interactions and inclusive nuclear collisions
Cucinotta, Francis A.; Dubey, Rajendra R.; Aug 1, 1993; In English
Contract(s)/Grant(s): RTOP 199-45-16-11
Report No.(s): NASA-TP-3353; L-17240; NAS 1.60:3353; No Copyright; Avail: CASI
A scattering formalism is developed in a multiple scattering model to describe inclusive momentum distributions for high-energy projectiles. The effects of final state interactions on response functions and momentum distributions are investigated. Calculations for high-energy protons that include shell model response functions are compared with experiments.
Author
Atomic Collisions; Galactic Cosmic Rays; High Energy Interactions; Nuclear Reactions; Scattering Cross Sections

19940008402 NASA Langley Research Center, Hampton, VA, USA
Effects of radiobiological uncertainty on vehicle and habitat shield design for missions to the moon and Mars
Wilson, John W.; Nealy, John E.; Schimmerling, Walter; Cucinotta, Francis A.; Wood, James S.; Aug 1, 1993; In English
Contract(s)/Grant(s): RTOP 199-04-16-11
Report No.(s): NASA-TP-3312; L-17188; NAS 1.60:3312; No Copyright; Avail: CASI
Some consequences of uncertainties in radiobiological risk due to galactic cosmic ray (GCR) exposure are analyzed for

their effect on engineering designs for the first lunar outpost and a mission to explore Mars. This report presents the plausible effect of biological uncertainties, the design changes necessary to reduce the uncertainties to acceptable levels for a safe mission, and an evaluation of the mission redesign cost. Estimates of the amount of shield mass required to compensate for radiobiological uncertainty are given for a simplified vehicle and habitat. The additional amount of shield mass required to provide a safety factor for uncertainty compensation is calculated from the expected response to GCR exposure. The amount of shield mass greatly increases in the estimated range of biological uncertainty, thus, escalating the estimated cost of the mission. The estimates are used as a quantitative example for the cost-effectiveness of research in radiation biophysics and radiation physics.
Author (revised)
Biophysics; Cost Analysis; Cost Estimates; Galactic Cosmic Rays; Lunar Bases; Radiation Shielding; Radiobiology; Safety Factors; Space Exploration; Space Habitats

19940008790 NASA Langley Research Center, Hampton, VA, USA
Semiempirical fragmentation models on galactic cosmic ray transport calculations with hydrogen target
Shinn, Judy L.; Wilson, John W.; Badavi, Francis F.; Aug 1, 1993; In English
Contract(s)/Grant(s): RTOP 199-45-16-11
Report No.(s): NASA-TP-3350; L-17227; NAS 1.60:3350; No Copyright; Avail: CASI

Nuclear fragmentation cross sections of Silberberg and Tsao that are more accurate for a hydrogen target were implemented in the data base to replace those of Rudstam for a galactic cosmic ray transport code (HZETRN). Sample calculations were made for the transported galactic cosmic ray flux through a liquid hydrogen shield at solar minimum condition to determine the effect of such a change. The transported flux based on the Silberberg-Tsao semiempirical formalism contains fewer high-LET (linear energy transfer) components but more low-LET components than the results based on Rudstam's formalism: and this disparity deepens as the shield thickness increases. A comparison of the results obtained from using both energy-dependent and energy-independent cross sections of Silberberg and Tsao indicates that the energy-independent assumption results in an underestimation of high-LET flux above 100 keV/micron by approximately 40 percent for a 15-g/cm(sup 2) thickness of liquid hydrogen. Similar results were obtained in a previous study when both energy-dependent and energy-independent cross sections of Rudstam were considered. Nonetheless, the present study found that an energy-independent calculation would be best accomplished by using Rudstam's cross sections as done in the past for various engineering applications.
Author (revised)
Fragmentation; Galactic Cosmic Rays; Liquid Hydrogen; Nuclear Reactions; Radiation Shielding; Radiation Transport

19940009241 NASA Langley Research Center, Hampton, VA, USA
Cellular track model for study of heavy ion beams
Shinn, Judy L.; Katz, Robert; Cucinotta, Francis A.; Wilson, John W.; Ngo, Duc M.; Aug 1, 1993; In English
Contract(s)/Grant(s): RTOP 199-45-16-11
Report No.(s): NASA-TP-3351; L-17231; NAS 1.60:3351; No Copyright; Avail: CASI

Track theory is combined with a realistic model of a heavy ion beam to study the effects of nuclear fragmentation on cell survival and biological effectiveness. The effects of secondary reaction products are studied as a function of depth in a water column. Good agreement is found with experimental results for the survival of human T-l cells exposed to monoenergetic carbon, neon, and argon beams under aerobic and hypoxia conditions. The present calculation, which includes the effect of target fragmentation, is a significant improvement over an earlier calculation because of the use of a vastly improved beam model with no change in the track theory or cellular response parameters.
Author
Biological Effects; Heavy Ions; Immune Systems; Ion Beams; Radiation Effects

19940014203 Lockheed Missiles and Space Co., Palo Alto, CA, USA
The LET spectrum and its uncertainty during the CRRES mission
Chenette, D. L.; Guzik, T. G.; Wefel, J. P.; May 7, 1993; In English
Contract(s)/Grant(s): F19628-90-C-0101
Report No.(s): AD-A269977; AD-E201607; PL-TR-93-2111; SR-2; No Copyright; Avail: CASI

We present LET spectra calculated for the 1990-1991 CRRES mission using the galactic cosmic ray (GCR) and solar energetic particle (SEP) models which were developed for the CRRES/SPACERAD program. We discuss the dependence of

the spectra on uncertainties in the galactic cosmic ray and solar energetic particle models and LET calculation methods. Finally, we illustrate the application and significance of these spectra by using them to predict single event upset rates in a sample integrated circuit memory device, a 256 x 4-bit bipolar static RAM device.
DTIC
Conferences; Crres (Satellite); Energetic Particles; Galactic Cosmic Rays; Integrated Circuits; Linear Energy Transfer (LET); Radiation Effects; Single Event Upsets; Spectra

19930052381 NASA Langley Research Center, Hampton, VA, USA
Cross section parameterizations for cosmic ray nuclei. I - Single nucleon removal
Norbury, John W.; Townsend, Lawrence W.; Astrophysical Journal Supplement Series; May 1993; ISSN 0067-0049; 86, 1; In English
Contract(s)/Grant(s): NAG1-1134; NAG1-1457; Copyright; Avail: Other Sources
Parameterizations of single nucleon removal from electromagnetic and strong interactions of cosmic rays with nuclei are presented. These parameterizations are based upon the most accurate theoretical calculations available to date. They should be very suitable for use in cosmic ray propagation through interstellar space, the Earth's atmosphere, lunar samples, meteorites, spacecraft walls and lunar and Martian habitats.
AIAA
Cosmic Rays; Electromagnetic Interactions; Mathematical Models; Nuclear Interactions; Nucleons; Parameterization; Particle Collisions

19930017716 NASA Langley Research Center, Hampton, VA, USA
Description of alpha-nucleus interaction cross sections for cosmic ray shielding studies
Cucinotta, Francis A.; Townsend, Lawrence W.; Wilson, John W.; Apr 1, 1993; In English
Contract(s)/Grant(s): RTOP 593-42-21-01
Report No.(s): NASA-TP-3285; L-17139; NAS 1.60:3285; No Copyright; Avail: CASI
Nuclear interactions of high-energy alpha particles with target nuclei important for cosmic ray studies are discussed. Models for elastic, quasi-elastic, and breakup reactions are presented and compared with experimental data. Energy-dependent interaction cross sections and secondary spectra are presented based on theoretical models and the limited experimental data base.
Author
Absorption Cross Sections; Alpha Particles; Elastic Scattering; Galactic Cosmic Rays; Mathematical Models; Nuclear Interactions

19930065567 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Depth-dose equivalent relationship for cosmic rays at various solar minima
Badhwar, G. D.; Cucinotta, F. A.; O'Neill, P. M.; Radiation Research; April 1993; ISSN 0033-7587; 134, 1; In English; Copyright; Avail: Other Sources
Galactic cosmic rays (GCR) pose a serious radiation hazard for long-duration missions. In designing a lunar habitat or a Mars transfer vehicle, the radiation exposure determines the GCR shielding thickness, and hence the weight of spacecraft. Using the spherically symmetric diffusion theory of the solar modulation of GCR, and data on the differential energy spectra of H, He, O, and Fe, from 1965 to 1989, it has been shown that (1) the flux is determined by the diffusion parameter which is a function of the time in the solar cycle, and (2) the fluxes in the 1954 and 1976-1977 solar minima were similar and higher than those in 1965. In this paper, we have extended the spherical solar modulation theory back to 1954. The 1954-1955 GCR flux was nearly the same as that from 1976 to 1977; the 1965 flux values were nearly the same as those in 1986. Using this theory we have obtained the GCR spectra for all the nuclei, and calculated the depth dose as a function of Al thickness. It is shown that the shielding required to stay below 0.5 Sv is 17.5 -3/+8 g/sq cm of Al, and 9 -1.5/+5 g/sq cm to stay below 0.6 Sv. The calculated dose equivalent using the ICRP 60 values for quality factors is about 15 percent higher than that calculated using the ICRP 26 value.
AIAA
Cosmic Rays; Long Duration Space Flight; Radiation Dosage; Radiation Hazards; Spacecraft Shielding

19930014207 NASA Langley Research Center, Hampton, VA, USA
Polarization correction for ionization loss in a galactic cosmic ray transport code (HZETRN)
Shinn, Judy L.; Farhat, Hamidullah; Badavi, Francis F.; Wilson, John W.; Mar 1, 1993; In English
Contract(s)/Grant(s): RTOP 593-41-21-01
Report No.(s): NASA-TM-4443; L-17192; NAS 1.15:4443; No Copyright; Avail: CASI

An approximate polarization correction for ionization loss suggested by Sternheimer has been implemented in the galactic cosmic ray transport code (HZETRN) developed at the Langley Research Center. Sample calculations made for the aluminum shield and liquid hydrogen shield show no more than a plus or minus 2 percent change in the linear energy transfer (LET) distribution for flux compared with those without polarization correction. This very small change is expected because the effect of polarization correction on the reduction in stopping power of ions with energies above 2 GeV/amu is suppressed by the decrease in galactic cosmic ray ion flux at such high energies.
Author (revised)
Computer Programs; Galactic Cosmic Rays; Heavy Ions; Ionization; Linear Energy Transfer (LET); Polarization Characteristics; Radiation Shielding

19930008825 NASA Langley Research Center, Hampton, VA, USA
Effects of radiobiological uncertainty on shield design for a 60-day lunar mission
Wilson, John W.; Nealy, John E.; Schimmerling, Walter; Feb 1, 1993; In English
Contract(s)/Grant(s): RTOP 199-04-16-11
Report No.(s): NASA-TM-4422; L-17136; NAS 1.15:4422; No Copyright; Avail: CASI

Some consequences of uncertainties in radiobiological risk due to galactic cosmic ray exposure are analyzed to determine their effect on engineering designs for a first lunar outpost - a 60-day mission. Quantitative estimates of shield mass requirements as a function of a radiobiological uncertainty factor are given for a simplified vehicle structure. The additional shield mass required for compensation is calculated as a function of the uncertainty in galactic cosmic ray exposure, and this mass is found to be as large as a factor of 3 for a lunar transfer vehicle. The additional cost resulting from this mass is also calculated. These cost estimates are then used to exemplify the cost-effectiveness of research.
Author
Exposure; Galactic Cosmic Rays; Lunar Shelters; Lunar Spacecraft; Radiation Shielding; Radiobiology; Risk; Spacecraft Shielding

19930009192 NASA Langley Research Center, Hampton, VA, USA
Target fragmentation in radiobiology
Wilson, John W.; Cucinotta, Francis A.; Shinn, Judy L.; Townsend, Lawrence W.; Feb 1, 1993; In English, 22-23 Apr. 1991, Houston, TX, USA
Contract(s)/Grant(s): RTOP 199-04-16-11
Report No.(s): NASA-TM-4408; L-17138; NAS 1.15:4408; No Copyright; Avail: CASI

Nuclear reactions in biological systems produce low-energy fragments of the target nuclei seen as local high events of linear energy transfer (LET). A nuclear-reaction formalism is used to evaluate the nuclear-induced fields within biosystems and their effects within several biological models. On the basis of direct ionization interaction, one anticipates high-energy protons to have a quality factor and relative biological effectiveness (RBE) of unity. Target fragmentation contributions raise the effective quality factor of 10 GeV protons to 3.3 in reasonable agreement with RBE values for induced micronuclei in bean sprouts. Application of the Katz model indicates that the relative increase in RBE with decreasing exposure observed in cell survival experiments with 160 MeV protons is related solely to target fragmentation events. Target fragment contributions to lens opacity given an RBE of 1.4 for 2 GeV protons in agreement with the work of Lett and Cox. Predictions are made for the effective RBE for Harderian gland tumors induced by high-energy protons. An exposure model for lifetime cancer risk is derived from NCRP 98 risk tables, and protraction effects are examined for proton and helium ion exposures. The implications of dose rate enhancement effects on space radiation protection are considered.
Author
Biological Effects; Biological Models (Mathematics); Ionizing Radiation; Linear Energy Transfer (LET); Nuclear Reactions; Prediction Analysis Techniques; Radiation Damage; Radiation Hazards; Radiation Therapy; Radiobiology; Relative Biological Effectiveness (RBE)

19930048786

Longitudinal study of astronaut health - Mortality in the years 1959-1991

Peterson, L. E.; Pepper, L. J.; Hamm, P. B.; Gilbert, S. L.; Radiation Research; Feb. 1993; ISSN 0033-7587; 133, 2; In English; Copyright; Avail: Other Sources

We conducted a historical cohort study of mortality among 195 astronauts who were exposed to space and medical sources of radiation between 1959 and 1991. Cumulative occupational and medical radiation exposures were obtained from the astronaut radiation exposure history data base. Causes of death were obtained from obligatory death certificates and autopsy reports that were on file in the medical records. There was a total of 20 deaths that occurred during the 32-year follow-up period of which 16 were due to accidents. The all-cause standardized mortality ratio (SMR) was 181 (95 percent confidence interval 110, 279). There was 1 cancer death in the buccal cavity and pharyngeal ICD-9 rubric whose occurrence was significantly beyond expectation. Mortality for coronary disease was 53 percent lower than expected (2 deaths; SMR = 47; 95 percent confidence limits 5, 168). The crude death rate for 12 occupationally related accidents was 445 deaths per 100,000 person-years and was an order of magnitude greater than accidental death rates in the mining industries. The SMR of 1346 for fatal accidents was significantly beyond expectation (16 deaths; 95 percent confidence limits 769, 2168) and was similar to SMRs for accidents among aerial pesticide applicators. The 10-year cumulative risk of occupational fatalities based on the exponential, Weibull, Gompertz, and linear-exponential distributions was 10 percent. Overall, it was found that astronauts are at a health disadvantage as a result of catastrophic accidents.

AIAA

Astronauts; Biomedical Data; Health; Manned Space Flight; Mortality; Radiation Dosage

19930048787

Accelerated heavy particles and the lens. VIII - Comparisons between the effects of acute low doses of iron ions (190 keV/microns) and argon ions (88 keV/microns)

Brenner, D. J.; Medvedovsky, C.; Huang, Y.; Worgul, B. V.; Radiation Research; Feb. 1993; ISSN 0033-7587; 133, 2; In English; Copyright; Avail: Other Sources

The nature of the RBE-LET relationship for radiation-induced effects in vivo is not well known in the high-LET range above about 100 keV/microns. Here, we compare the cataractogenic effects of acute doses of 190 keV/microns iron ions on the eyes of rats with those of 88 keV/microns argon ions. The RBEs of the two radiations cannot be distinguished statistically, both being between 50 and 200 at our lowest dose of 0.01 Gy and decreasing to between 2 and 14 at our highest dose of 0.5 Gy; these values are consistent with results obtained in vivo, both for cataractogenesis and for oncogenesis. For this end point, therefore, the RBE-LET relationship probably varies very slowly between 88 and 190 keV/microns. On the basis of these studies with acute doses of 88 and 190 keV/microns particles, the detailed distribution in LET of the very high-LET galactic cosmic-ray dose to which astronauts in deep space are exposed may not be critical for the prediction of biological hazard. Such a conclusion might simplify the task of high-LET radiation risk estimation in space.

AIAA

Argon; Cataracts; Energetic Particles; Etiology; Ferric Ions; Heavy Ions; Linear Energy Transfer (LET); Primary Cosmic Rays; Radiation Dosage; Radiation Hazards

19940007086 NASA Lyndon B. Johnson Space Center, Houston, TX, USA

Potential health effects of space radiation

Yang, Chui-Hsu; Craise, Laurie M.; Sixth Annual Workshop on Space Operations Applications and Research (SOAR 1992), Volume 2; Feb 1, 1993; In English

Contract(s)/Grant(s): NASA Order T-9297-R; No Copyright; Avail: CASI

Crewmembers on missions to the Moon or Mars will be exposed to radiation belts, galactic cosmic rays, and possibly solar particle events. The potential health hazards due to these space radiations must be considered carefully to ensure the success of space exploration. Because there is no human radioepidemiological data for acute and late effects of high-LET (Linear-Energy-Transfer) radiation, the biological risks of energetic charged particles have to be estimated from experimental results on animals and cultured cells. Experimental data obtained to date indicate that charged particle radiation can be much more effective than photons in causing chromosome aberrations, cell killing, mutation, and tumor induction. The relative biological effectiveness (RBE) varies with biological endpoints and depends on the LET of heavy ions. Most lesions induced by low-LET radiation can be repaired in mammalian cells. Energetic heavy ions, however, can produce large complex DNA damages, which may lead to large deletions and are irreparable. For high-LET radiation, therefore, there are less or no dose rate effects. Physical shielding may not be effective in minimizing the biological effects on energetic heavy ions, since fragments of the primary particles can be effective in causing biological effects. At present the uncertainty of biological effects

of heavy particles is still very large. With further understanding of the biological effects of space radiation, the career doses can be kept at acceptable levels so that the space radiation environment need not be a barrier to the exploitation of the promise of space.
Author (revised)
Energetic Particles; Galactic Cosmic Rays; Health Physics; Heavy Ions; Radiation Belts; Radiation Damage; Radiation Dosage; Radiation Effects; Relative Biological Effectiveness (RBE); Spacecrews

19940007087 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Radiation considerations for interplanetary missions
Badwar, Gautam D.; Oneill, Patrick M.; Cucinotta, Francis A.; Sixth Annual Workshop on Space Operations Applications and Research (SOAR 1992), Volume 2; Feb 1, 1993; In English; No Copyright; Avail: Other Sources

Galactic cosmic radiation (GCR) poses a serious radiation hazard for long-duration missions. In designing a lunar habitat or Mars transfer vehicle, the worst-case radiation exposure determines shielding thickness and, hence, the weight of spacecraft. Using the spherically symmetric diffusion theory of the solar modulation of GCR, it was possible to use data on the differential energy spectra of hydrogen, helium, oxygen, and iron from 1954 to 1989 to show that the flux at 1 A.U. is determined by the diffusion parameter, K, which is a function of the time in the solar cycle. This analysis also showed that the solar minimum of 1976 to 1977 was the deepest minimum in the last 37 years. Using this theory, we have obtained the GCR spectra for all the nuclei and calculated the depth-dose as a function of aluminum shield thickness. Using the ICRP-26 definition of the quality factor, it is shown that the shielding required to stay below the LEO recommended annual limit of 50 cSv is 17.5 (+8, -3), g/sq cm of aluminum; if the limit is raised to 60 cSv, the required shielding is 9 (5, -1.5) g/sq cm. We also discuss the issues and shielding needs for protection against solar particle events.
Author (revised)
Energy Spectra; Galactic Cosmic Rays; Lunar Bases; Radiation Dosage; Radiation Hazards; Radiation Shielding; Solar Activity Effects; Solar Cycles; Thickness

19940007088 Kelsey Seybold Clinic, P.A., Houston, TX, USA
Longitudinal study of astronaut health: Mortality in the years 1959-1991
Peterson, Leif E.; NASA. Johnson Space Center, Sixth Annual Workshop on Space Operations Applications and Research (SOAR 1992), Volume 2; Feb 1, 1993; In English; No Copyright; Avail: Other Sources

We conducted a historical cohort study of mortality among 195 astronauts who were exposed to space and medical sources of radiation between 1959 and 1991. Cumulative occupational and medical radiation exposures were obtained from the astronaut radiation exposure history data base. Causes of death were obtained from obligatory death certificates and autopsy reports that were on file in the medical records. A total of 18 deaths occurred during the 32-year follow-up period for which the all-cause standardized mortality ratio (SMR) was 142 (95 percent confidence interval 84 225). There was one cancer death in the buccal cavity and pharynegeal ICD-9 rubric whose occurrence was significantly beyond expectation. Mortality for coronary disease was 59 percent lower than expected (2 deaths; SMR = 41; 95 percent confidence limit 5 147). The crude death rate for 10 occupationally related accidents was 400 deaths per 100,000 person-years, which is an order of magnitude greater than accidental death rates in mining industries. The SMR of 1027 for fatal accidents was significantly beyond expectation (14 deaths; 95 percent confidence limit 561 1723) and was similar to SMRs for accidents among aerial pesticide applications. The 10-year cumulative risk of occupational fatalities based on the exponential, Weibull, Gompertz, and linear-exponential distributions was 10 percent. Mortality from motor vehicle accidents was slightly higher than expected but was not significant (1 death; SMR = 145; 95 percent confidence limit 2 808). Radiation exposures from medical procedures accounted for a majority of cumulative dose when compared with space radiation exposures. The results of the study do not confirm the impression that astronauts are at increased risk of cancer, but this does not obviate the need for further study. Overall, it was found that astronauts are at a health disadvantage as a result of catastrophic accidents.
Author (revised)
Astronauts; Cancer; Confidence Limits; Death; Extraterrestrial Radiation; Histories; Mortality; Radiation Dosage; Standardization

19950049833
Radiation environment during the long space mission (Mars) due to galactic cosmic rays
Pissarenko, N. F.; 1993; In English; Copyright; Avail: Other Sources

Galactic cosmic radiation (GCR) mostly determines dose equivalents inside the spacecraft during long-term manned

missions in space. In this paper some new results are collected concerning different characteristics of GCR's. Together with earlier obtained data they show that during most part of the solar cycle such spaceflights are not possible. Attention is drawn to very great errors in the estimates of dose equivalent and shielding thickness.
Author (Herner)
Galactic Cosmic Rays; Long Duration Space Flight; Radiation Dosage; Radiation Shielding; Solar Activity Effects

19930017917 Oak Ridge National Lab., TN, USA
The radiation protection problems of high altitude and space flight
Fry, R. J. M.; JAN 1, 1993; In English, 11-13 Jan. 1993, Paris, France
Contract(s)/Grant(s): DE-AC05-84OR-21400
Report No.(s): DE93-008573; CONF-930181-1; No Copyright; Avail: CASI

This paper considers the radiation environment in aircraft at high altitudes and spacecraft in low earth orbit and in deep space and the factors that influence the dose equivalents. Altitude, latitude and solar cycle are the major influences for flights below the radiation belts. In deep space, solar cycle and the occurrence of solar particle events are the factors of influence. The major radiation effects of concern are cancer and infertility in males. In high altitude aircraft the radiation consists mainly of protons and neutrons, with neutrons contributing about half the equivalent dose. The average dose rate at altitudes of transcontinental flights that approach the polar regions are greater by a factor of about 2.5 than on routes at low latitudes. Current estimates of doses to air crews suggest they are well within the ICRP (1990) recommended dose limits for radiation workers.
DOE
Aerospace Environments; Aerospace Medicine; Deep Space; Dosage; Earth Orbital Environments; Radiation Effects; Radiation Hazards; Radiation Protection

19950049832 NASA Goddard Space Flight Center, Greenbelt, MD, USA, NASA Langley Research Center, Hampton, VA, USA, NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Biological effects and physics of solar and galactic cosmic radiation, Part B; Proceedings of a NATO Advanced Study Institute on Biological Effects and Physics of Solar and Galactic Cosmic Radiation, Algarve, Portugal, Oct. 13-23, 1991
Swenberg, Charles E., editor; Horneck, Gerda, editor; Stassinopoulos, E. G., editor; 1993; In English; See also A95-81432 through A95-81454; Copyright; Avail: Other Sources

Since there is an increasing interest in establishing lunar bases and exploring Mars by manned missions, it is important to develop appropriate risk estimates and radiation protection guidelines. The biological effects and physics of solar and galactic cosmic radiation are examined with respect to the following: the radiation environment of interplanetary space, the biological responses to radiation in space, and the risk estimates for deep space missions. There is a need for a long-term program where ground-based studies can be augmented by flight experiments and an international standardization with respect to data collection, protocol comparison, and formulation of guidelines for future missions.
Herner
Conferences; Galactic Cosmic Rays; Interplanetary Space; Lunar Exploration; Manned Mars Missions; Radiation Effects; Radiation Protection; Risk; Solar Cosmic Rays; Standardization

19930040735 NASA Marshall Space Flight Center, Huntsville, AL, USA
Implementation of ionizing radiation environment requirements for Space Station
Boeder, Paul A.; Watts, John W.; Jan 1, 1993; In English; 31st, Jan. 11-14, 1993, Reno, NV, USA
Report No.(s): AIAA Paper 93-0612; Copyright; Avail: Other Sources

Proper functioning of Space Station hardware requires that the effects of high-energy ionizing particles from the natural environment and (possibly) from man-made sources be considered during design. At the Space Station orbit of 28.5-deg inclination and 330-440 km altitude, geomagnetically trapped protons and electrons contribute almost all of the dose, while galactic cosmic rays and anomalous cosmic rays may produce Single Event Upsets (SEUs), latchups, and burnouts of microelectronic devices. Implementing ionizing radiation environment requirements for Space Station has been a two part process, including the development of a description of the environment for imposing requirements on the design and the development of a control process for assessing how well the design addresses the effects of the ionizing radiation environment. We will review both the design requirements and the control process for addressing ionizing radiation effects on Space Station.
AIAA
Aerospace Environments; Ionizing Radiation; Radiation Damage; Radiation Protection; Space Stations

19930048788 NASA Langley Research Center, Hampton, VA, USA

Temporal analysis of the October 1989 proton flare using computerized anatomical models

Simonsen, L. C.; Cucinotta, F. A.; Atwell, W.; Nealy, J. E.; Radiation Research; Jan. 1993; ISSN 0033-7587; 133, 1; In English; Copyright; Avail: Other Sources

The GOES-7 time history data of hourly averaged integral proton fluxes at various particle kinetic energies are analyzed for the solar proton event that occurred between October 19 and 29, 1989. By analyzing the time history data, the dose rates which may vary over many orders of magnitude in the early phases of the flare can be estimated as well as the cumulative dose as a function of time. Basic transport calculations are coupled with detailed body organ thickness distributions from computerized anatomical models to estimate dose rates and cumulative doses to 20 critical body organs. For a 5-cm-thick water shield, cumulative skin, eye, and blood-forming-organ dose equivalents of 1.27, 1.23, and 0.41 Sv, respectively, are estimated. These results are approximately 40-50 percent less than the widely used 0- and 5-cm slab dose estimates. The risk of cancer incidence and mortality are also estimated for astronauts protected by various water shield thicknesses.

AIAA

Computerized Simulation; Etiology; Health Physics; Neoplasms; Radiobiology; Solar Flares; Solar Protons

19950002659 Argonne National Lab., IL, USA

Inhibition of topoisomerase 2 activity in CHO K1 cells by 2-((aminopropyl)amino)ethanethiol (WR-1065)

Grdina, David J.; Constantinou, Andreas; Shigematsu, Naoyuki; Jan 1, 1993; In English

Contract(s)/Grant(s): W-31-109-ENG-38

Report No.(s): DE94-016375; ANL/BIM/PP-78769; No Copyright; Avail: CASI

Aminothiol 2-((aminopropyl)amino)ethanethiol (WR-1 065) is an effective radiation protector and an analog of WR-2721. Topoisomerase I and II activities and associated protein contents were measured in the K1 cell line using a DNA relaxation assay and immunoblotting. WR-1065 was ineffective in modifying topo I activity, but it did reduce topo II activity by 50%. Cell-cycle effects were monitored by flow cytometry. Exposure of cells to 4 mM of WR-1065 for a period of up to 3 h resulted in a buildup of cells in the G2 compartment. Of several mechanisms of radiation protection attributed to aminothiol compounds such as WR-1065, one has been their ability to affect endogenous enzymatic reactions involved in DNA synthesis, repair, and cell-cycle progression. Results obtained here are consistent with such a proposed mechanism and demonstrate in particular a modifying effect by 2-(aminopropyl)amino ethanethiol on type II topoisomerase, which is involved in DNA synthesis.

DOE

Biological Effects; Cells (Biology); Enzyme Activity; Inhibitors; Protectors; Proteins; Radiation Effects; Radiation Protection

19950049854

Radiological operational scenario for a permanent lunar base

Mccormack, Percival D.; 1993; In English; Copyright; Avail: Other Sources

An operational scenario for a lunar base is postulated based on 30 lunar base personnel and 2 year tours of duty plus stipulated numbers of EVA's and sorties in the lunar rover vehicles. It is also postulated that the main shielding material for the lunar base units (habitats, laboratories, etc.) will be lunar regolith. Using the solar minimum period as the basis, total accumulated dose equivalents for the galactic cosmic radiation over the two year period are computed at various shielding depths. Depths of regolith of over 20 g/sq cm are sufficient to reduce the total dose equivalents to well under the present limits. The second arm of the radiological health strategy -- continuous and all-encompassing radiation dosimetry -- is also discussed in some detail. It is also emphasized that monitoring of the base personnel for genetic mutations and chromosomal aberrations must be part of the radiological health program in the lunar base.

Author (revised by Herner)

Galactic Cosmic Rays; Lunar Bases; Lunar Radiation; Radiation Dosage; Radiation Protection; Regolith; Space Habitats

19950049852

Radiation protection for human interplanetary spaceflight and planetary surface operations

Clark, Benton C.; 1993; In English; Copyright; Avail: Other Sources

Radiation protection issues are reviewed for five categories of radiation exposure during human missions to the moon and Mars: trapped radiation belts, galactic cosmic rays, solar flare particle events, planetary surface emissions, and on-board radiation sources. Relative hazards are dependent upon spacecraft and vehicle configurations, flight trajectories, human susceptibility, shielding effectiveness, monitoring and warning systems, and other factors. Crew cabins, interplanetary mission

modules, surface habitats, planetary rovers, and extravehicular mobility units (spacesuits) provide various degrees of protection. Countermeasures that may be taken are reviewed relative to added complexity and risks that they could entail, with suggestions for future research and analysis.
Author (Herner)
Countermeasures; Long Duration Space Flight; Prevention; Radiation Effects; Radiation Hazards; Radiation Shielding; Relative Biological Effectiveness (RBE)

19950049851
Radiation: What determines the risk?
Mitchel, R. E. J.; Trivedi, A.; 1993; In English; Copyright; Avail: Other Sources

Radiation, like other DNA damaging agents, can initiate a series of cellular events responsible for cancer development. However, in any individual the risk of cancer arising from a carcinogen exposure is variable, and is not a fixed value dependent only on the dose of carcinogen. This variability in overall risk arises from variability in the probabilities of the intermediate steps of the multistep processes of carcinogenesis. Using cellular and animal model systems, we have shown that deliberate manipulation of these biological processes is possible, and that the risk of cancer from a fixed exposure to a carcinogen can be made to increase or decrease. We have also shown that such changes in risk can result from intervention at times long before or after that carcinogen exposure. These results indicate that the principles of radiation protection can be expanded. We suggest that in addition to offering protection against exposure, radiation protection can include the development of strategies for protection against the ultimate biological consequences of an exposure. Improved understanding of the biology of radiation responses may lead to techniques for deliberate intervention that could be particularly useful in long duration manned space flight.
Author (Herner)
Carcinogens; Pretreatment; Prevention; Radiation Effects; Radiation Protection; Relative Biological Effectiveness (RBE); Risk

19950049850
The relative biological effectiveness of attenuated protons
Robertson, James B.; Glisson, William C.; Archambeau, John O.; Coutrakan, George B.; Miller, Daniel W.; Moyers, Michael F.; Siebers, Jeffrey F.; Slater, James M.; Dicello, John F.; 1993; In English; Copyright; Avail: Other Sources

The 250 MeV Synchrotron at Loma Linda University Medical Center has been in operation since October 1990. In this paper we will report the data collected for survival of V79 cells suspended in gelatin exposed to 100 MeV protons that are attenuated with varying thicknesses of polycarbonate plastic. The measurement relative biological effectiveness (RBE) for single-cell killing ranges from 1.05 to 1.20 as the protons are reduced in energy from 64 MeV. Survival profiles show that this RBE effect will result in a 2.5 fold difference in cell survival between high and low energy protons at a dose of 1000 cGy. Correspondingly, the microdosimetric spectra measured in the same beam offer a quantitative explanation for the observed variation in RBE. Both the biological and the microdosimetric results suggest that the number of intermediate lineal energy events increase as the protons are attenuated. These results suggest that while shielding will reduce the total absorbed dose due to a solar proton event, it might not be equally effective in reducing the radiobiological effect of the exposure.
Author (Herner)
Galactic Cosmic Rays; Proton Beams; Proton Irradiation; Radiation Effects; Relative Biological Effectiveness (RBE); Solar Protons

19960024151 NASA Langley Research Center, Hampton,VA USA
Cell Kinetics And Track Structure
Wilson, John W.; Cucinotta, F. A.; Shinn, J. L.; 1993; In English
Report No.(s): NASA-TM-111541; NAS 1.15:111541; No Copyright; Avail: CASI

A major uncertainty in shield requirements for deep-space missions is establishing biological risk for high charge and energy (HZE) exposure. Estimates of biological risk in space requires an understanding of the relationship of ground-based biological experiments with intense particle beams to the low exposure rates in the space environment. We have examined the relation of a (relatively) general cell kinetic model to the track structure theory of Katz and determined repair coefficients from the experiments of Yang et al. as a means of predicting biological response to low dose-rate exposure in the deep-space environment. The model provides repair dependent relative biological effectiveness (RBE's) which agree well with values found in ion exposure experiments and makes predictions which could be tested in future laboratory studies. The model seems

to provide the necessary requirement of relating laboratory response data to space exposure conditions with the exception of the gravity environment effects.
Author
Biological Effects; Kinetics; Particle Beams; Exposure; Radiation Effects; Dosage; Prediction Analysis Techniques

19950049848 NASA Langley Research Center, Hampton, VA, USA
Solar particle dose rate buildup and distribution in critical body organs
Atwell, William; Weyland, Mark D.; Simonsen, Lisa C.; 1993; In English; Copyright; Avail: Other Sources

Human body organs have varying degrees of radiosensitivity as evidenced by radioepidemiologic tables. The major critical organs for both the male and female that have been identified include the lung, thyroid, stomach, and breast (female). Using computerized anatomical models of the 50th percentile USA Air Force male and female, we present the self-shielding effects of these various body organs and how the shielding effects change as the location (dose point) in the body varies. Several major solar proton events from previous solar cycles and several events from the current 22nd solar cycle have been analyzed. The solar particle event rise time, peak intensity, and decay time vary considerably from event to event. Absorbed dose and dose equivalent rate calculations and organ risk assessment data are presented for each critical body organ. These data are compared with the current NASA astronaut dose limits as recommended by the National Council on Radiation Protection and Measurements.
Author (Herner)
Human Body; Organs; Radiation Dosage; Relative Biological Effectiveness (RBE); Risk; Solar Cosmic Rays; Solar Protons; Solar Storms

19950049847 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Relating space radiation environments to risk estimates
Curtis, Stanley B.; 1993; In English
Contract(s)/Grant(s): NASA ORDER T-9310-R; DE-AC03-76SF-00098; Copyright; Avail: Other Sources

A number of considerations must go into the process of determining the risk of deleterious effects of space radiation to travelers. Among them are (1) determination of the components of the radiation environment (particle species, fluxes and energy spectra) which will encounter, (2) determination of the effects of shielding provided by the spacecraft and the bodies of the travelers which modify the incident particle spectra and mix of particles, and (3) determination of relevant biological effects of the radiation in the organs of interest. The latter can then lead to an estimation of risk from a given space scenario. Clearly, the process spans many scientific disciplines from solar and cosmic ray physics to radiation transport theeory to the multistage problem of the induction by radiation of initial lesions in living material and their evolution via physical, chemical, and biological processes at the molecular, cellular, and tissue levels to produce the end point of importance.
Author (Herner)
Biological Models (Mathematics); Galactic Cosmic Rays; Radiation Dosage; Radiation Hazards; Radiation Shielding; Risk

19950049845 NASA Langley Research Center, Hampton, VA, USA
HZE reactions and data-base development
Townsend, Lawrence W.; Cucinotta, Francis A.; Wilson, John W.; 1993; In English; Copyright; Avail: Other Sources

The primary cosmic rays are dispersed over a large range of linear energy transfer (LET) values and their distribution over LET is a determinant of biological response. This LET distribution is modified by radiation shielding thickness and shield material composition. The current uncertainties in nuclear cross sections will not allow the composition of the shield material to be distinguished in order to minimize biological risk. An overview of the development of quantum mechanical models of heavy ion reactions will be given and computational results compared with experiments. A second approach is the development of phenomenological models from semi-classical considerations. These models provide the current data base in high charge and energy (HZE) shielding studies. They will be compared with available experimental data. The background material for this lecture will be available as a review document of over 30 years of research at Langley but will include new results obtained over the last year.
Author (Herner)
Galactic Cosmic Rays; Heavy Ions; Linear Energy Transfer (LET); Radiation Shielding

19950049844 NASA Langley Research Center, Hampton, VA, USA
Transport methods and interactions for space radiations
Wilson, John W.; Townsend, Lawrence W.; Schimmerling, Walter; Khandelwal, Govind S.; Khan, Ferdous; Nealy, John E.; Cucinotta, Francis A.; Simonsen, Lisa C.; Shinn, Judy L.; Norbury, John W.; 1993; In English; Copyright; Avail: Other Sources

This report presents a brief history leading to the involvement of the Langley Research Center of the National Aeronautics and Space Administration (NASA) in space-radiation physics and protection. Indeed, a relatively complete summary of technical capability as of the summer of 1990 is given. The Boltzmann equations for coupled ionic and neutronic fields are presented and inversion techniques for the Boltzmann operator are discussed. Errors generated by the straight ahead approximation are derived and are shown to be negligible for most problems of space-radiation protection. A decoupling of projectile propagation from the target fields greatly simplifies the Boltzmann equations and allows an analytic solution of the target fragment transport. Analytic and numerical methods of solving the projectile transport equations are discussed. The nuclear physics underlying the coefficients in the Boltzmann equation is discussed. A coupled-channel optical model is found as a consequence of the loose binding of nuclear matter and closure of the nuclear states in high-energy reactions. Transport solutions with the developed data base are used with laboratory experiments to validate both the transport code and the data base. Numerical benchmarks and comparison with Monte Carlo calculations are also used for code validation.
Author (revised by Herner)
Boltzmann Transport Equation; Fragmentation; Galactic Cosmic Rays; NASA Programs; Radiation Transport

19950049843 NASA Langley Research Center, Hampton, VA, USA
Heavy-ion fragmentation studies in thick water absorbers
Shavers, M. R.; Miller, J.; Schimmerling, W.; Wilson, J. W.; Townsend, L. W.; 1993; In English; Copyright; Avail: Other Sources

Proposed long-term space missions could expose crewmembers to significant fluxes of galactic cosmic radiation (GCR) particles and secondary particles created from nuclear collisions. An assessment of radiobiological risks is dependent upon an accurate description of the charged-particle radiation field inside the human body. As shield thickness increases and the incident ions are slowed, the production of secondary particles contributes an increasingly significant fraction of the total dose until eventually secondary particles become more important than the primary particles. The nuclear mean free path of the GCR ions (which usually have nuclear charge between 1 (protons) and 26 (iron), both inclusive) are comparable with thicknesses typical of spacecraft structures and the human body. Collisions in these media will create projectile and target fragments with charge less than that of the primary particle, and each interaction event can have a multiplicity of more than one emerging interaction product. Projectile fragments usually continue on with very nearly the velocity of the primary ion (the so-called straightahead approximation). Having sufficient energy, the fragments may collide with atomic nuclei in thick shields and create a second generation of fragments, and so on. Target fragments are emitted from a struck nucleus, usually with much lower energy than projectile fragments and nearly isotropically in the rest frame of the absorbing medium. The resulting spectrum of particles and their energy loss rates will be very different from that in the unshielded environment, will determine the radiobiological impact on exposed living tissues -- whether in space or in ground-based radiobiology experiments -- and will play an important role in radiation effects on microelectronics.
Author (revised by Herner)
Absorbers (Materials); Fragmentation; Galactic Cosmic Rays; Heavy Ions; Radiation Protection; Water

19930011114 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Radiological assessment for Space Station Freedom
Badhwar, Gautam D.; Hardy, Alva C.; Robbins, Donald E.; Atwell, William; Jan 1, 1993; In English
Report No.(s): NASA-TM-104758; S-703; NAS 1.15:104758; No Copyright; Avail: CASI

Circumstances have made it necessary to reassess the risks to Space Station Freedom crewmembers that arise from exposure to the space radiation environment. An option is being considered to place it in an orbit similar to that of the Russian Mir space station. This means it would be in a 51.6 deg inclination orbit instead of the previously planned 28.5 deg inclination orbit. A broad range of altitudes is still being considered, although the baseline is a 407 km orbit. In addition, recent data from the Japanese A-bomb survivors has made it necessary for NASA to have the exposure limits reviewed. Preliminary findings of the National Council on Radiation Protection and Measurements indicate that the limits must be significantly reduced. Finally, the Space Station will be a laboratory where effects of long-term zero gravity on human physiology will be studied in detail. It is possible that a few crewmembers will be assigned to as many as three 1-year missions. Thus, their accumulated exposure will exceed 1,000 days. Results of this radiation risk assessment for Space Station Freedom crewmembers finds that females less than 35 years old will be confined to mission assignments where the altitude is less than about 400 km. Slight restrictions may also need to be made for male crewmembers less than 35 years old.
Author
Aerospace Environments; Extraterrestrial Radiation; Gravitational Effects; Radiation Protection; Space Station Freedom

19950052966 NASA, Washington, DC, USA

CAD-based stand-alone spacecraft radiation exposure analysis system: An application of the early man-tended Space Station

Appleby, M. H.; Golightly, M. J.; Hardy, A. C.; 1993; In English

Report No.(s): SAE PAPER 932557; Copyright; Avail: Other Sources

Major improvements have been completed in the approach to analyses and simulation of spacecraft radiation shielding and exposure. A computer-aided design (CAD)-based system has been developed for determining the amount of shielding provided by a spacecraft and simulating transmission of an incident radiation environment to any point within or external to the vehicle. Shielding analysis is performed using a customized ray-tracing subroutine contained within a standard engineering modeling software package. This improved shielding analysis technique has been used in several vehicle design programs such as a Mars transfer habitat, pressurized lunar rover, and the redesigned international Space Station. Results of analysis performed for the Space Station astronaut exposure assessment are provided to demonstrate the applicability and versatility of the system.

Author (Herner)

Computer Aided Design; Computerized Simulation; Radiation Shielding; Space Environment Simulation; Space Stations; Spacecraft Design

19930004384 NASA Langley Research Center, Hampton, VA, USA

A study of the generation of linear energy transfer spectra for space radiations

Wilson, John W.; Badavi, Francis F.; Dec 1, 1992; In English

Contract(s)/Grant(s): RTOP 199-04-16-11

Report No.(s): NASA-TM-4410; L-17137; NAS 1.15:4410; No Copyright; Avail: CASI

The conversion of particle-energy spectra into a linear energy transfer (LET) distribution is a guide in assessing biologically significant components. The mapping of LET to energy is triple valued and can be defined only on open subintervals. A well-defined numerical procedure is found to allow generation of LET spectra on the open subintervals that are integrable in spite of their singular nature.

Author

Biological Effects; Energy Spectra; Extraterrestrial Radiation; Linear Energy Transfer (LET); Particle Energy

19930003832 NASA Langley Research Center, Hampton, VA, USA

Fully energy-dependent HZETRN (a galactic cosmic-ray transport code)

Shinn, Judy L.; John, Sarah; Tripathi, Ram K.; Norbury, John W.; Wilson, John W.; Townsend, Lawrence W.; Nov 1, 1992; In English

Contract(s)/Grant(s): RTOP 593-42-21-01

Report No.(s): NASA-TP-3243; L-17103; NAS 1.61:3243; No Copyright; Avail: CASI

For extended manned space missions, the radiation shielding design requires efficient and accurate cosmic-ray transport codes that can handle the physics processes in detail. The Langley Research Center galactic cosmic-ray transport code (HZETRN) is currently under development for such design use. The cross sections for the production of secondary nucleons in the existing HZETRN code are energy dependent only for nucleon collisions. The approximation of energy-independent, heavy-ion fragmentation cross section is now removed by implementing a mathematically simplified energy-dependent stepping formalism for heavy ions. The cross section at each computational grid is obtained by linear interpolation from a few tabulated data to minimize computing time. Test runs were made for galactic cosmic-ray transport through a liquid hydrogen shield and a water shield at solar minimum. The results show no appreciable change in total fluxes or computing time compared with energy-independent calculations. Differences in high LET (linear energy transfer) spectra are noted, however, because of the large variation in cross sections at the low-energy region. The high LET components are significantly higher in the new code and have important implications on biological risk estimates for heavy-ion exposure.

Author

Applications Programs (Computers); Galactic Cosmic Rays; Manned Space Flight; Radiation Shielding

19930003835 NASA Langley Research Center, Hampton, VA, USA

Katz model prediction of Caenorhabditis elegans mutagenesis on STS-42

Cucinotta, Francis A.; Wilson, John W.; Katz, Robert; Badhwar, Gautam D.; Nov 1, 1992; In English

Contract(s)/Grant(s): RTOP 199-04-16-11

Report No.(s): NASA-TM-4383; L-17090; NAS 1.15:4383; No Copyright; Avail: CASI

Response parameters that describe the production of recessive lethal mutations in C. elegans from ionizing radiation are obtained with the Katz track structure model. The authors used models of the space radiation environment and radiation transport to predict and discuss mutation rates for C. elegans on the IML-1 experiment aboard STS-42.
Author
Cosmic Rays; Environment Models; Ionizing Radiation; Mutations; Radiation Effects; Radiobiology

19920024910 NASA Langley Research Center, Hampton, VA, USA
Track structure model of cell damage in space flight
Katz, Robert; Cucinotta, Francis A.; Wilson, John W.; Shinn, Judy L.; Ngo, Duc M.; Oct 1, 1992; In English
Contract(s)/Grant(s): RTOP 199-04-16-11
Report No.(s): NASA-TP-3235; L-17058; NAS 1.60:3235; No Copyright; Avail: CASI
The phenomenological track-structure model of cell damage is discussed. A description of the application of the track-structure model with the NASA Langley transport code for laboratory and space radiation is given. Comparisons to experimental results for cell survival during exposure to monoenergetic, heavy-ion beams are made. The model is also applied to predict cell damage rates and relative biological effectiveness for deep-space exposures.
CASI
Biological Effects; Cells (Biology); Exposure; Extraterrestrial Radiation; Linear Energy Transfer (LET); Radiation Damage; Relative Biological Effectiveness (RBE); Survival

19930033510 NASA Langley Research Center, Hampton, VA, USA
Multiple-scattering effects in quasielastic alpha-He-4 scattering
Cucinotta, Francis A.; Townsend, Lawrence W.; Wilson, John W.; Physical Review C - Nuclear Physics, 3rd Series; Oct. 1992; ISSN 0556-2813; 46, 4; In English; Copyright; Avail: Other Sources
A multiple-scattering series for describing the quasielastic peak in nucleus-nucleus collisions is derived using the high-energy optical model. The effects of multiple knockout of target nucleons and internal excitation of the projectile are studied and found to be important for large energy loss and momentum transfers in inclusive alpha-He-4 scattering at 7 GeV/c. An approximate evaluation of higher-order inelastic collision terms is considered for forward-peaked wave functions and is demonstrated to be accurate.
AIAA
Alpha Particles; Eikonal Equation; Elementary Particle Interactions; Helium Isotopes; Inelastic Collisions; Inelastic Scattering; Nucleon-Nucleon Scattering

19930061625
Investigation of the radiation situation on board the Mir station during the solar proton event of September 29, 1989 using the Liulin dosimeter-radiometer
Bengin, V. V.; Kostereva, T. A.; Makhmutov, V. S.; Panova, N. A.; Petrov, V. M.; Shurshakov, V. A.; Dachev, Ts. P.; Semkova, I. V.; Matvijchuk, Yu. N.; Bankov, N. G.; Kosmicheskie Issledovaniya; Sept.-Oct. 1992; ISSN 0023-4206; 30, 5; In Russian; Copyright; Avail: Other Sources
The Liulin dosimeter-radiometer was used to measure the dose rate and flux on board the Mir space station in September-October 1989. The parameters of the space station's orbit was: apogee - 410 km, perigee 379 km, and inclination - 51.6 deg. Special attention is given to the variation of radiation conditions on the space station during the high-power solar proton event on September 29, 1989. An additional absorbed dose measured during the event was 0.31 cGY, and the daily mean dose rate exceeded the background level by a factor of 10. The results are compared with the solar proton flux data from the GOES-7 geostationary satellite.
AIAA
Dosimeters; Mir Space Station; Radiation Detectors; Solar Cosmic Rays; Solar Protons

19930003688 NASA Langley Research Center, Hampton, VA, USA
Radiation dose to critical body organs for October 1989 proton event
Simonsen, Lisa C.; Atwell, William; Nealy, John E.; Cucinotta, Francis A.; Sep 1, 1992; In English
Contract(s)/Grant(s): RTOP 593-42-31-01
Report No.(s): NASA-TP-3237; L-17078; NAS 1.60:3237; No Copyright; Avail: CASI
The Geostationary Operational Environmental Satellite (GOES-7) provides high-quality environmental data about the

temporal development and energy characteristics of the protons emitted during a solar particle event. The GOES-7 time history of the hourly averaged integral proton flux for various particle kinetic energies are analyzed for the solar proton event occurring October 19-29, 1989. This event is similar to the August 1972 event that has been widely studied to estimate free-space and planetary radiation-protection requirements. By analyzing the time-history data, the dose rates, which can vary over many orders of magnitude in the early phases of the flare, can be estimated as well as the cumulative dose as a function of time. When basic transport results are coupled with detailed body organ thickness distributions calculated with the Computerized Anatomical Man and Computerized Anatomical Female models, the dose rates and cumulative doses to specific organs can be predicted. With these results, the risks of cancer incidence and mortality are estimated for astronauts in free space protected by various water shield thicknesses.
Author
Astronauts; Biological Effects; Computerized Simulation; Radiation Dosage; Radiation Hazards; Solar Corpuscular Radiation; Solar Flares

19930008257 Future Systems Consultants, Los Angeles, CA, USA
Vertical regolith shield wall construction for lunar base applications
Kaplicky, Jan; Nixon, David; Wernick, Jane; NASA. Johnson Space Center, The Second Conference on Lunar Bases and Space Activities of the 21st Century, Volume 1; Sep 1, 1992; In English; No Copyright; Avail: CASI

Lunar bases located on the lunar surface will require permanent protection from radiation and launch ejecta. This paper outlines a method of providing physical protection using lunar regolith that is constructed in situ as a modular vertical wall using specially devised methods of containment and construction. Deployable compartments, reinforced with corner struts, are elevated and filled by a moving gantry. The compartments interlock to form a stable wall. Different wall heights, thicknesses, and plan configurations are achieved by varying the geometry of the individual compartments, which are made from woven carbon fibers. Conventional terrestrial structural engineering techniques can be modified and used to establish the structural integrity and performance of the wall assembly.
Author
Construction; Lunar Bases; Lunar Rocks; Lunar Shelters; Regolith; Walls

19920073217
Main environmental hazards for Mars missions
Romero, M.; Bourrieau, J.; Mandeville, J. C.; Fernandez-Maillard, A.; Melkonian, G.; Aug 1, 1992; In English
Report No.(s): IAF PAPER 92-0533; Copyright; Avail: Other Sources

The radiation and meteoroid impact hazards associated with manned missions to Mars are examined. Computations are made of equivalent doses received by astronauts inside a spacecraft, a shelter, and during EVA are presented, and possible ways of reducing the radiobiological risk are discussed. Estimates are also made of the level of meteoroid impacts for a spacecraft that draws near to the asteroid belt located between Mars and Jupiter. The importance of the proper design and the mission scenario in providing a balanced protection against radiations and meteoroids is emphasized.
AIAA
Cosmic Rays; Ionizing Radiation; Manned Mars Missions; Meteoroid Hazards; Planetary Environments; Radiation Hazards; Radiation Protection

19920066379
Mars transfer vehicle using regolith as propellant
Tillotson, Brian; Jul 1, 1992; In English
Report No.(s): AIAA PAPER 92-3449; Copyright; Avail: Other Sources

This paper describes a Mars mission architecture which uses planetary regolith from the moon and from Deimos as propellant and as radiation shielding. It presents a point design which uses a mass driver as a rocket engine to eject regolith propellant at high speed, a solar array as a power source for the mass driver, and equipment to acquire and transport regolith to the Mars vehicle. A mission for the 2015 earth-Mars conjunction is analyzed to assess vehicle mass and crew radiation exposure. The required mass from earth, including lunar infrastructure, is shown to be less than the mass of an advanced ion propulsion vehicle which uses earth-launched propellant. The crew radiation dose due to galactic cosmic rays is shown to be less than half the dose for the same mission in a conventional vehicle. Discussion includes the state of mass driver technology, issues of orbital debris, several advantages of regolith propellant systems over other propulsion schemes, and areas for future

refinement of the concept. Appendices describe the mass driver rocket concept and show that high mass driver reliability is easy to achieve.
AIAA
Manned Mars Missions; Mass Drivers; Regolith; Rocket Propellants; Spacecraft Configurations

19930003461 Armed Forces Radiobiology Research Inst., Bethesda, MD, USA
AFRRI reports
Jul 1, 1992; In English
Report No.(s): AD-A254581; AFRRI-SR92-16; AFRRI-SR92-17; No Copyright; Avail: CASI

This report includes the following topics: short and long courses of ofloxacin therapy of Klebsiella pneumoniae sepsis following irradiation; possible 'accelerated striatal aging' induced by 56Fe heavy-particle irradiation--implications for manned space flights; modulation of mortality by tissue trauma and sepsis in mice after radiation injury; cytokine therapy in canine and primate models of radiation-induced marrow aplasia; comparison of behavioral and radioprotective effects of WR-2721 and WR-3689; energy transfer mechanisms in DNA--relationship to energy deposition in sub-microscopic volumes; role of interleukin 6 (IL-6) in protection from lethal irradiation and in endocrine responses to IL-1 and tumor necrosis factor; effects on enhancing hemopoietic reconstitution and increasing survival following exposure to ionizing radiation; and radioprotection of hematopoietic tissues in mice by lipoic acid.
DTIC
Accelerated Life Tests; Aging (Biology); Bone Marrow; Deoxyribonucleic Acid; Endocrinology; Klebsiella; Nuclear Radiation; Pathology; Radiation Injuries; Radiation Protection; Radiobiology; Therapy

19930015182
DosiMir: Radiation measurements inside the Soviet Space Station Mir, first results
Vana, N.; Schoener, W.; Fugger, M.; Akatov, J. A.; ESA, Environment Observation and Climate Modelling Through International Space Projects. Columbus Eight (COSY-8): Utilisation of Earth Orbiting Laboratories; Jul 1, 1992; In English; Copyright; Avail: CASI

Two dosemeter packets containing Thermoluminescence Dosemeters (TLD's) and track etch foils were used to measure the absorbed dose and the average Linear Energy Transfer (LET) of the radiation within the Space Station Mir. One packet was exposed over a period of about 5 months and the other one during the Austria-Soviet manned space program in Oct. 1991. Various types of standard TLD's, Soviet Al2O3 TLD's and Austrian labor made LiF single crystals were used. The change in the peak height ratio, phototransfered TL and glow peak deconvolution were used to measure the absorbed dose and the average LET of the radiation within the space station Mir. The first results taken by TLD's reveal a radiation dose of 1.6 mGy and an average LET of 7 keV/micrometers in tissue caused by the radiation field within the space station Mir during the mission.
ESA
Dosimeters; Ionizing Radiation; Mir Space Station; Radiation Measurement; Spacecraft Environments; Thermoluminescence

19930057532 NASA Langley Research Center, Hampton, VA, USA
Concepts and strategies for lunar base radiation protection - Prefabricated versus in-situ materials
Simonsen, Lisa C.; Nealy, John E.; Townsend, Lawrence W.; Jul 1, 1992; In English; 22nd, July 13-16, 1992, Seattle, WA, USA
Report No.(s): SAE PAPER 921370; Copyright; Avail: Other Sources

The most recently accepted environment data are used as inputs for the Langley nucleon and heavy-ion transport codes, BRYNTRN and HZETRN, to examine the shield effectiveness of lunar regolith in comparison with commercially-used shield materials in nuclear facilities. Several of the fabricated materials categorized as neutron absorbers exhibit favorable characteristics for space radiation protection. In particular, polyethylene with additive boron is analyzed with regard to response to the predicted lunar galactic cosmic ray and solar proton flare environment during the course of a complete solar cycle. Although this effort is not intended to be a definitive trade study for specific shielding recommendations, attention is given to several factors that warrant consideration in such trade studies. For example, the transporting of bulk shield material to the lunar site as opposed to regolith-moving and processing equipment is assessed on the basis of recent scenario studies. The transporting of shield material from Earth may also be a viable alternative to the use of regolith from standpoints of cost-effectiveness, EVA time required, and risk factor.
AIAA
Lunar Bases; Radiation Protection; Radiation Shielding; Space Habitats; Spacecraft Construction Materials

19920022949 NASA Langley Research Center, Hampton, VA, USA

Effects of fragmentation parameter variations on estimates of galactic cosmic ray exposure: Dose sensitivity studies for aluminum shields

Townsend, Lawrence W.; Cucinotta, Francis A.; Shinn, Judy L.; Wilson, John W.; Jul 1, 1992; In English

Contract(s)/Grant(s): RTOP 593-42-21-01

Report No.(s): NASA-TM-4386; L-17082; NAS 1.15:4386; No Copyright; Avail: CASI

Initial studies of the sensitivities of estimates of particle fluence, absorbed dose, and dose equivalent to fragmentation parameter variations are undertaken by using the LaRC galactic cosmic ray transport code (HZETRN). The new results, presented as a function of aluminum shield thickness, include upper and lower bounds on dose/dose equivalent corresponding to the physically realistic extremes of the fragmentation process and the percentage of variation of the dose/dose equivalent as a function of fragmentation parameter variation.

CASI

Applications Programs (Computers); Estimates; Exposure; Fragmentation; Galactic Cosmic Rays; Radiation Dosage; Radiation Effects; Radiation Shielding; Radiation Transport; Variations

19930051239

Methodology for clinical testing of antiradiation means intended for manned space flight conditions

Efimov, V. I.; Aviakosmicheskaia i Ekologicheskaia Meditsina; May-June 1992; ISSN 0233-528X; 26, 3; In Russian; Copyright; Avail: Other Sources

Methods for clinical testing of antiradiation measures to be used in manned space missions are proposed and discussed. The tests should be based on: individual tolerance to a recommended medicinal form of the drug; tolerances to the effects of motion sickness and prolonged transverse and longitudinal accelerations; graded physical exercise; and evaluation of performance (operator activity).

AIAA

Manned Space Flight; Radiation Protection; Tolerances (Physiology)

19920017981 Pacific Northwest Lab., Richland, WA, USA

Sensitivity of LDEF foil analyses using ultra-low background germanium versus large NaI(T1) multidimensional spectrometers

Reeves, James H.; Arthur, Richard J.; Brodzinski, Ronald L.; NASA. Langley Research Center, Second LDEF Post-Retrieval Symposium Abstracts; Jun 1, 1992; In English; No Copyright; Avail: Other Sources

Cobalt samples were analyzed for cosmic ray induced Co-60 with both an ultralow background germanium gamma ray spectrometer and with a large NaI(T1) multidimensional spectrometer using electronic anticoincidence shielding. Aluminum samples were analyzed for Na-22. The results are presented along with the relative sensitivities and precision afforded by the two methods.

CASI

Cobalt; Cobalt 60; Gamma Ray Spectrometers; Germanium; Long Duration Exposure Facility; Sodium Iodides; Sodium 22

19920056956 NASA Ames Research Center, Moffett Field, CA, USA

Space suits and life support systems for the exploration of Mars

Kuznetz, Lawrence H.; Gwynne, Owen; British Interplanetary Society, Journal; May 1, 1992; ISSN 0007-094X; 45, 5, Ma; In English; Copyright; Avail: Other Sources

The requirements and technologies needed for space suits to be used for the manned exploration of Mars are examined. Alternative concepts are proposed for both the space suit and the portable life support system (collectively called the Extravehicular Mobility Unit, or EMU) needed for Mars exploration. EMU system requirements are outlined. It is pointed out that the most fundamental difference between a Mars EMU and those that preceded it is that the design of a Mars EMU must be driven by science and permanent habitability requirements, while all prior EMU designs have been driven by engineering requirements. The EMU weight issues are discussed, and the system mass and mobility concerns are addressed, along with the backpack-to-body-weight ratio. The challenges of thermal and cosmic radiation protection, micrometeorite protection, and EMU system and crew heat rejection are dealt with briefly, as well as the physiological issues of pressure regulation and bacterial or contaminant isolation. A mathematical model is then presented for evaluation of candidate EMU designs and for

concept optimization and selection. Lead technology issues are also discussed.
AIAA
Extravehicular Mobility Units; Manned Mars Missions; Mars Environment; Portable Life Support Systems; Space Suits

19920015857 NASA Langley Research Center, Hampton, VA, USA
MIRACAL: A mission radiation calculation program for analysis of lunar and interplanetary missions
Nealy, John E.; Striepe, Scott A.; Simonsen, Lisa C.; May 1, 1992; In English
Contract(s)/Grant(s): RTOP 593-42-31-01
Report No.(s): NASA-TP-3211; L-17044; NAS 1.60:3211; No Copyright; Avail: CASI

A computational procedure and data base are developed for manned space exploration missions for which estimates are made for the energetic particle fluences encountered and the resulting dose equivalent incurred. The data base includes the following options: statistical or continuum model for ordinary solar proton events, selection of up to six large proton flare spectra, and galactic cosmic ray fluxes for elemental nuclei of charge numbers 1 through 92. The program requires an input trajectory definition information and specifications of optional parameters, which include desired spectral data and nominal shield thickness. The procedure may be implemented as an independent program or as a subroutine in trajectory codes. This code should be most useful in mission optimization and selection studies for which radiation exposure is of special importance.
CASI
Computer Programs; Manned Space Flight; Mathematical Models; Radiation Dosage; Radiation Tolerance; Space Exploration

19920017589 NASA Langley Research Center, Hampton, VA, USA
Quasi-elastic nuclear scattering at high energies
Cucinotta, Francis A.; Townsend, Lawrence W.; Wilson, John W.; May 1, 1992; In English
Contract(s)/Grant(s): RTOP 593-42-21-01
Report No.(s): NASA-TM-4362; L-17036; NAS 1.15:4362; No Copyright; Avail: CASI

The quasi-elastic scattering of two nuclei is considered in the high-energy optical model. Energy loss and momentum transfer spectra for projectile ions are evaluated in terms of an inelastic multiple-scattering series corresponding to multiple knockout of target nucleons. The leading-order correction to the coherent projectile approximation is evaluated. Calculations are compared with experiments.
CASI
Energy Dissipation; Momentum Transfer; Nuclear Scattering; Nucleons; Optical Properties; Scattering Cross Sections

19930051226
Equivalent dose of cosmic rays at representative points of human-body models
Krasil'nikov, G. V.; Perova, L. A.; Sakharov, V. M.; Aviakosmicheskaia i Ekologicheskaia Meditsina; Mar.-Apr. 1992; ISSN 0233-528X; 26, 2; In Russian; Copyright; Avail: Other Sources

Equivalent doses of cosmic-ray protons were investigated in a wide range of spectra (characterizing solar cosmic rays and the earth's radiation belts) for three standardized models of the human body. The shielding functions of representative points of an anthropometric model were calculated, and equivalent dose values in various models were compared. It was shown that representative points of the central nervous and hemopoietic systems in a spherical model of the human body did not yield correlated values of equivalent dose as compared to more rigorous models.
AIAA
Bionics; Proton Irradiation; Radiation Dosage; Radiation Shielding; Solar Cosmic Rays

19940022046 Korean Atomic Energy Research Inst., Daeduk, Republic Of Korea
Molecular biological studies on the human radioresistance and drug resistance
Kim, Chang Min; Hong, Weon Seon; Apr 1, 1992; In Korean
Report No.(s): DE93-632682; KAERI/RR-1114/91; No Copyright; Avail: CASI

We irradiated the MKN45 and PC14 cell lines with 500 rads and also established the adriamycin-resistant and cis-platinum resistant cell line. The genomic DNA and total RNA were extracted and subjected to the Southern and Northern analysis using various probes including heat shock protein 70, MDR1, fos, TGFb, etc. The mRNA transcript was increased 1 hour after the irradiation and sustained during the 48 hours and returned to the level of pre-irradiation. No significant change was observed with the drug resistant cell lines at the level of gene dosage. We suggest that the marked increase of the hsp70

transcript is a very important finding and is believed to be a good candidate for the modulation of the cellular response to irradiation and the radioresistance.
DOE
Deoxyribonucleic Acid; Drugs; Irradiation; Molecular Biology; Mutations; Neoplasms; Proteins; Radiation Effects; Radiation Tolerance; Radiobiology; Ribonucleic Acids

19920012975 NASA Langley Research Center, Hampton, VA, USA
An efficient HZETRN (a galactic cosmic ray transport code)
Shinn, Judy L.; Wilson, John W.; Apr 1, 1992; In English
Contract(s)/Grant(s): RTOP 593-42-21
Report No.(s): NASA-TP-3147; L-16954; NAS 1.60:3147; No Copyright; Avail: CASI

An accurate and efficient engineering code for analyzing the shielding requirements against the high-energy galactic heavy ions is needed. The HZETRN is a deterministic code developed at Langley Research Center that is constantly under improvement both in physics and numerical computation and is targeted for such use. One problem area connected with the space-marching technique used in this code is the propagation of the local truncation error. By improving the numerical algorithms for interpolation, integration, and grid distribution formula, the efficiency of the code is increased by a factor of eight as the number of energy grid points is reduced. The numerical accuracy of better than 2 percent for a shield thickness of 150 g/cm(exp 2) is found when a 45 point energy grid is used. The propagating step size, which is related to the perturbation theory, is also reevaluated.
CASI
Computer Programs; Energetic Particles; Galactic Cosmic Rays; Grid Generation (Mathematics); Interpolation; Mathematical Models; Radiation Shielding; Spatial Marching; Transport Theory

19920012943 NASA Langley Research Center, Hampton, VA, USA
Multiple lesion track structure model
Wilson, John W.; Cucinotta, Francis A.; Shinn, Judy L.; Mar 1, 1992; In English
Contract(s)/Grant(s): RTOP 199-04-16-11
Report No.(s): NASA-TP-3185; L-16988; NAS 1.60:3185; No Copyright; Avail: CASI

A multilesion cell kinetic model is derived, and radiation kinetic coefficients are related to the Katz track structure model. The repair-related coefficients are determined from the delayed plating experiments of Yang et al. for the C3H10T1/2 cell system. The model agrees well with the x ray and heavy ion experiments of Yang et al. for the immediate plating, delaying plating, and fractionated exposure protocols employed by Yang. A study is made of the effects of target fragments in energetic proton exposures and of the repair-deficient target-fragment-induced lesions.
CASI
Cell Division; Cells (Biology); Heavy Ions; Lesions; Mathematical Models; Radiation Damage; Radiation Effects; X Rays

19920014360 Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA, USA
Genetic and molecular dosimetry of HZE radiation (7-IML-1)
Nelson, Gregory A.; NASA. Marshall Space Flight Center, First International Microgravity Laboratory Experiment Descriptions; Feb 1, 1992; In English; No Copyright; Avail: CASI

The objectives of the study are to determine the kinetics of production and to characterize the unique aspects of genetic and developmental lesion induced in animal cells by radiation present in the space environment. Special attention is given to heavy charged particles. The organism Caenorhabditis elegans, a simple nematode, is used as a model system for a coordinated set of ground-based and flight experiments.
CASI
Exobiology; Experiment Design; Genetics; Lesions; Physiological Effects; Radiation Effects; Spaceborne Experiments; Spacelab Payloads; Worms

19920014361 International Center for Genetic Engineering and Biotechnology, Trieste, Italy
Microgravitational effects on chromosome behavior (7-IML-1)
Bruschi, Carlo; NASA. Marshall Space Flight Center, First International Microgravity Laboratory Experiment Descriptions; Feb 1, 1992; In English; No Copyright; Avail: CASI

The effects of the two major space-related conditions, microgravity and radiation, on the maintenance and transmission

of genetic information have been partially documented in many organisms. Specifically, microgravity acts at the chromosomal level, primarily on the structure and segregation of chromosomes, in producing major abberations such as deletions, breaks, nondisjunction, and chromosome loss, and to a lesser degree, cosmic radiation appears to affect the genic level, producing point mutations and DNA damage. To distinguish between the effects from microgravity and from radiation, it is necessary to monitor both mitotic and meiotic genetic damage in the same organism. The yeast Saccharomyces cerevisiae is used to monitor at high resolution the frequency of chromosome loss, nondisjunction, intergenic recombination, and gene mutation in mitotic and meiotic cells, to a degree impossible in other organisms. Because the yeast chromosomes are small, sensitive measurements can be made that can be extrapolated to higher organisms and man. The objectives of the research are: (1) to quantitate the effects of microgravity and its synergism with cosmic radiation on chromosomal integrity and transmission during mitosis and meiosis; (2) to discriminate between chromosomal processes sensitive to microgravity and/or radiation during mitosis and meiosis; and (3) to relate these findings to anomalous mitotic mating type switching and ascosporogenesis following meiosis.
CASI
Cell Division; Chromosomes; Cosmic Rays; Deoxyribonucleic Acid; Experiment Design; Gravitational Physiology; Microgravity; Saccharomyces; Spaceborne Experiments; Weightlessness

19920014386 National Space Development Agency, Tokyo, Japan
Radiation monitoring container device (16-IML-1)
Nagaoka, S.; NASA. Marshall Space Flight Center, First International Microgravity Laboratory Experiment Descriptions; Feb 1, 1992; In English; No Copyright; Avail: CASI

In this experiment, layers of radiation detectors and biological specimens, bacterial spores (Bacillus subtilis), shrimp eggs (Altemia salina), and maize seeds (Zea mays) are sandwiched together in the Radiation Monitoring Container. The detectors, sheets of plastic materials, record the nuclear track of cosmic radiation. The dosimeter package contains conventional detectors made of materials such as lithium fluoride or magnesium-silica-terbium. The thermoluminescent materials (TLD) will, when moderately heated, emit luminescent photons linearly depending upon the dose of radiation received. The experiment, enclosed in a box-like container, is mounted on the aft end cone of the Spacelab, the area where the shielding is somewhat less than other locations.
CASI
Cosmic Rays; Dosimeters; Lithium Fluorides; Radiation Detectors; Radiation Dosage; Radiation Effects; Radiobiology; Thermoluminescence

19920019442 Lawrence Livermore National Lab., Livermore, CA, USA
Somatic gene mutation in the human in relation to radiation risk
Mendelsohn, M. L.; Jan 1, 1992; In English; 27th, 2-3 Apr. 1991, Washington, DC, USA
Contract(s)/Grant(s): W-7405-ENG-48
Report No.(s): DE92-009459; UCRL-JC-109513; CONF-9104298-2; No Copyright; Avail: CASI

This report discusses the measurement of somatic gene-mutation frequencies in the human. Questions were asked concerning their measurement, response to radiation, ability to function as a dosimeter, and what they tell us about the somatic mutation theory of carcinogenesis.
DOE
Carcinogens; Dosimeters; Genes; Genetics; Ionizing Radiation; Mutations; Pathogenesis; Radiation Effects

19920038282
Prostaglandin-induced radioprotection of murine intestinal crypts and villi by a PGE diene analog (SC-44932) and a PGI analog (Iloprost)
Hanson, Wayne R.; Collins, Paul W.; Advances in Space Research; JAN 1, 1992; ISSN 0273-1177; 12, 2-3,; In English; Copyright; Avail: Other Sources

The aminothiols exemplified by WR-2721 are effective radioprotectors; however, their toxicity associated with hypotension, nausea, and emesis has limited their development for applications in medicine or in hazardous radiation environments. A variety of prostaglandins (PGs) have been shown to be radioprotective agents and some appear to have fewer toxic side effects than the aminothiols. Iloprost, a stable PGI analog, protects the clonogenic epithelial cells of intestinal crypts but does not protect epithelial cells of the villi. In contrast, an E-series omega chain diene analog designated SC-44932 protects epithelial cells of both crypts and villi. When the two are combined, protection of the crypts is additive and the villi are

protected to the same degree as when SC-44932 is given alone. The pattern of radioprotection seen with these two analogs depend on the location of the respective receptors or on the ability of differentiated villus cells to respond to PGs.
AIAA
Intestines; Prostaglandins; Radiation Hazards; Radiation Protection

19920038281
Radioprotection by polysaccharides alone and in combination with aminothiols
Patchen, Myra L.; Macvittie, Thomas J.; Solberg, Brian D.; D'Alesandro, Michele M.; Brook, Itzhak; Advances in Space Research; JAN 1, 1992; ISSN 0273-1177; 12, 2-3,; In English; Copyright; Avail: Other Sources

It is demonstrated that glucan, a beta-1,3 polysaccharide immunomodulator, enhances survival of mice when administered before radiation exposure. Glucan's prophylactic survival-enhancing effects are mediated by several mechanisms, including (1) increasing macrophage-mediated resistance to potentially lethal postirradiation opportunistic infections, (2) increasing the D(O) of hematopoietic progenitor cells, and (3) accelerating hematopoietic reconstitution. In addition, even when administered shortly after some otherwise lethal doses of radiation, glucan increases survival. Glucan's therapeutic survival-enhancing effects are also mediated through its ability to enhance macrophage function and to accelerate hematopoietic reconstitution; glucan's therapeutic potential, however, is ultimately dependent on the survival of a critical number of hematopoietic stem cells capable of responding to glucan's stimulatory effects.
AIAA
Amines; Biochemistry; Polysaccharides; Radiation Protection; Radiobiology; Thiols

19930058129
Medical care on the moon
Schaefer, Ron; In: Engineering, construction, and operations in space III: Space '92; Proceedings of the 3rd International Conference, Denver, CO, May 31-June 4, 1992. Vol. 2 (A93-41976 17-12); 1992; In English; Copyright; Avail: Other Sources

The establishment of a health maintenance facility at a lunar base to assure the health and productivity of the crew is discussed. In particular, attention is given to the principal characteristics of the lunar environment, the main goals and the equipment of a lunar health maintenance facility, communications, robotics, and logistics. The discussion also covers surgery on the moon, decompression sickness, effects of reduced gravity, radiation, environmental contamination, life pods, and disaster planning.
AIAA
Aerospace Medicine; Contamination; Decompression Sickness; Lunar Bases; Microgravity; Radiation Dosage

19920038280
Radioprotection by metals - Selenium
Weiss, J. F.; Srinivasan, V.; Kumar, K. S.; Landauer, M. R.; Advances in Space Research; JAN 1, 1992; ISSN 0273-1177; 12, 2-3,; In English; Copyright; Avail: Other Sources

The radioprotective potential of selenium (Se) is examined. Both the inorganic salt, sodium selenite, and the organic Se compound, selenomethionine, enhance the survival of irradiated mice (Co-60, 0.2 Gy/min) when injected IP either before (-24 hr and -1 hr) or shortly after (+15 min) radiation exposure. When administered at equitoxic doses (one-fourth LD(10); selenomethionine = 4.0 mg/kg Se, sodium selenite = 0.8 mg/kg Se), both drugs enhanced the 30-day survival of mice irradiated at 9 Gy. Survival after 10-Gy exposure was significantly increased only after selenomethionine treatment. An advantage of selenomethionine is lower lethal and behavioral toxicity (locomotor activity depression) compared to sodium selenite, when they are administered at equivalent doses of Se.
AIAA
Biochemistry; Radiation Injuries; Radiation Protection; Selenium Compounds

19930060989 NASA Langley Research Center, Hampton, VA, USA
Production of H-3 at large momentum in alpha-(C-12) collisions at 2A GeV
Cucinotta, Francis A.; Townsend, Lawrence W.; Wilson, John W.; Physics Letters B; 1992; ISSN 0370-2693; 282, 1-2; In English; Copyright; Avail: Other Sources

Calculations of the longitudinal and transverse momentum distributions for H-3 production at large momentum in alpha-(C-12) collisions near 2A GeV are compared to experiment. Triton exchange and final-state interactions are shown to represent large corrections to the impulse approximation for proton knockout. A method for calculating interference effects for

inelastic fragmentation is discussed. Good agreement with experiment using a phenomenological overlap function for (H-3)-p is found successful in describing H-3 production in pion-induced reactions. Comparisons to momentum distributions obtained through (p, 2p) and (e, ep) reactions on He-4 are made.
AIAA
Alpha Particles; Carbon 12; Hydrogen 4; Inelastic Collisions; Momentum; Nuclear Scattering; Tritium

19920038279
Some recent data on chemical protection against ionizing radiation
Fatome, M.; Laval, J. D.; Roman, V.; Advances in Space Research; JAN 1, 1992; ISSN 0273-1177; 12, 2-3,; In English; Copyright; Avail: Other Sources

Once introduced into the organism, the radioprotectors decompose rapidly and that increases their toxicity, shortens their duration of action, and renders them inactive after oral delivery. An attempt was made to protect them by incorporating them in vectors. When a cysteamine-liposomal suspension was orally delivered, it showed a radioprotective activity for about 4 hours. By using S-35 cysteamine, it was noted that its plasmatic concentration was increased. Freeze-drying of these preparations was a good means of conservation if the samples were stored at 4 C. A good and sustained activity was also obtained after oral delivery of WR-2721 entrapped in microspheres.
AIAA
Biochemistry; Cysteamine; Ionizing Radiation; Lipids; Radiation Protection; Radiobiology

19920038278
Radioprotection of DNA by biochemical mechanisms
Riklis, Emanuel; Advances in Space Research; JAN 1, 1992; ISSN 0273-1177; 12, 2-3,; In English; Copyright; Avail: Other Sources

Attention is given to the presentation of genetic information and function by protecting the DNA from the deleterious effects of radiation by reducing the degree of damage, as well as to the utilization of biochemical entities whose function is to repair damage which has already been formed in DNA, thus enhancing the protection of living cells. Emphasis is placed on the compound nicotinamide (NA). Experiments showed that contrary to claims made of it being an inhibitor of repair, it exhibited at very low concentrations a definite property of enhancement of repair. The effect of NA is demonstrated not only on DNA repair and cell survival, but also on the manifestation of these properties in biological dosimetry: micronuclei formation as a result of radiation damage in lymphocytes decreases in the presence of NA even if it is added after exposure to gamma radiation.
AIAA
Biochemistry; Deoxyribonucleic Acid; Ionizing Radiation; Radiation Protection; Radiobiology

19920066526 NASA Langley Research Center, Hampton, VA, USA
Risk analyses for the solar particle events of August through December 1989
Townsend, Lawrence W.; Cucinotta, Francis A.; Shinn, Judy L.; Wilson, John W.; Radiation Research; JAN 1, 1992; ISSN 0033-7587; 130; In English; Copyright; Avail: Other Sources

The solar particle events of August through December 1989, among the largest ever recorded, are analyzed to assess the potential hazards to humans on interplanetary missions from events of these types. Using the coupled neutron-proton space radiation transport computer code BRYNTRN, risk estimates for the effects of exposures to the skin, ocular lens, and bone marrow are made for nominal thicknesses of the spacecraft aluminum shielding. Risk assessment in terms of absorbed dose is made for each event. Also presented are estimates of organ absorbed dose and dose equivalent for pairs of events which occurred within 30-day periods, and for the cumulative August through December 1989 period.
AIAA
Radiation Dosage; Radiation Hazards; Solar Corpuscular Radiation; Solar Radiation Shielding; Spacecraft Shielding; Spacecrews

19950057001
Circadian rhythms in the sensitivity to radiation and different drugs in mouse intestinal epithelium
Ijiri, K.; 1992; In English; Copyright; Avail: Other Sources

The circadian rhythms in the cellular responses to different cytotoxic agents were studied for mouse intestinal epithelium. The incidence of cell death (apoptosis) was investigated in the intestinal crypts after radiation (gamma rays), two colon

carcinogens, and six other cytotoxic drugs. A clear circadian rhythm was displayed in the incidence of radiation-induced cell death. The peak time of day for inducing cell death was 06.00-09.00 h, and the trough occurred at 18.00-21.00 h. When mice were transferred to a room with the light-cycle reversed, the transition from the normal-light pattern to the reversed-light pattern of the circadian rhythm in radiation-induced cell death occurred 7 days after the transfer and the rhythm was completely reversed by 14 days. Cell death induced by the carcinogens and other cytotoxic drugs also exhibited similar patterns of rhythm to that by radiation.
Author (Herner)
Circadian Rhythms; Epithelium; Intestines; Radiation Tolerance

19920038246 NASA, Washington, DC, USA
Development of countermeasures for medical problems encountered in space flight
Nicogossian, Arnauld E.; Rummel, John D.; Leveton, Lauren; Teeter, Ron; Advances in Space Research; JAN 1, 1992; ISSN 0273-1177; 12, 1, 19; In English; Copyright; Avail: Other Sources

Past experience with piloted space missions is reviewed to develop potential countermeasures to the medical problems associated with a long-duration space flight. Particular attention is given to the Extended Duration Orbiter Medical Program, which is aimed at ensuring crew health and safety on Space Shuttle missions; Soviet experience with long-duration space flights; and a variety of countermeasures including physiological, psychological, environmental health, radiation protection, and artificial gravity countermeasures.
AIAA
Aerospace Medicine; Earth Orbital Environments; Interplanetary Flight; Long Duration Space Flight; Manned Space Flight

19920038277
Role of endogenous thiols in protection
Vos, O.; Advances in Space Research; JAN 1, 1992; ISSN 0273-1177; 12, 2-3,; In English; Copyright; Avail: Other Sources

The importance of intracellular GSH in determining cellular radiosensitivity has been shown by irradiating cells that had very low GSH levels. Such cells appear to have a high radiosensitivity, especially in hypoxic conditions. On the other hand, it has been demonstrated that induction of a high GSH level (100-200 percent above the normal level) provides only a small protection. In vitro experiments with DNA indicate that thiols with a high positive charge condense in the vicinity of DNA and are effective protectors, whereas thiols with a negative charge are kept away from it and are poor protectors. In comparison with the most effective exogenous aminothiols like cysteamine and WR1065, GSH is not an effective radioprotector. Putative explanations for this relatively poor protective ability of GSH are presented.
AIAA
Glutathione; Ionizing Radiation; Radiation Injuries; Radiation Protection; Radiobiology; Thiols

19920038308
Effects of increased shielding on gamma-radiation levels within spacecraft
Haskins, P. S.; Mckisson, J. E.; Weisenberger, A. G.; Ely, D. W.; Ballard, T. A.; Dyer, C. S.; Truscott, P. R.; Piercey, R. B.; Ramayya, A. V.; Camp, D. C.; Advances in Space Research; JAN 1, 1992; ISSN 0273-1177; 12, 2-3,; In English; Copyright; Avail: Other Sources

The Shuttle Activation Monitor (SAM) experiment was flown on the Space Shuttle Columbia from 8-13 August, 1989 in a 57-deg, 300-km orbit. One objective of the SAM experiment was to determine the relative effect of different amounts of shielding on the gamma-ray backgrounds measured with similarly configured sodium iodide and bismuth germante detectors. To achieve this objective, twenty-four hours of data were taken with each detector in the middeck of the Shuttle on the ceiling of the airlock (a high-shielding location) as well as on the sleep-station wall (a low-shielding location). For the cosmic-ray induced background, the results indicate an increased overall count rate in the 0.2 to 10 MeV energy range at the more highly shielded location, while in regions of trapped radiation the low shielding configuration gives higher rates at the low-energy end of the spectrum.
AIAA
Background Radiation; Galactic Cosmic Rays; Gamma Rays; Radiation Shielding; Spacecraft Shielding

19930036653 NASA Langley Research Center, Hampton, VA, USA
Inclusive inelastic scattering of heavy ions in the independent particle model
Cucinotta, Francis A.; Townsend, Lawrence W.; Wilson, John W.; Journal of Physics G - Nuclear Physics; 1992; ISSN 0305-4616; In English; Copyright; Avail: Other Sources

We consider the inclusive inelastic scattering of heavy ions using the Glauber (1959) model and the independent particle approximation. Inclusive inelastic distributions for projectile excitation of the target and total inelastic scattering, where all projectile and target excited states are summed, are discussed using closure. The total inelastic distribution, when integrated, is shown to be equivalent to the absorption cross section, found from applying the optical theorem to the elastic scattering amplitude in the coherent approximation. Calculations are presented for several heavy-ion pairs, using realistic nuclear densities in a large mass number approximation.
AIAA
Absorption Cross Sections; Center of Mass; Heavy Ions; Inelastic Scattering

19950057000
Possible effects of microgravity and/or cosmic radiation on gene expression of stress proteins
Okaichi, Kumio; Muramatu, Tutomu; Ihara, Makoto; Ohnishi, Takco; 1992; In English; Copyright; Avail: Other Sources

Many environmental elements induce stress repsonses in organisms. It is essential for organisms to synthesize specific proteins, known as heat shock proteins, against these various types of stress. Since the methods of the measurement of the induced gene expression have been established by the use of advanced techniques such as northern blotting and western blotting, it has become easy to detect the induction of heat shock proteins. Our recent experimental results have indicated that not only heat treatment but also ultraviolet light-irradiation induced a heat shock protein (HSP72), one of the most famous stress proteins, in human cultured cells. In addition there is evidence that microgravity inhibits cell differentiation. In order to investigate whether the space condition of mictogravity and/or cosmic radiation play(s) a role in environmental stress on mammalian cells, we propose the simple application in space experiments to detect the induced level in the mammalian cell cultured systems.
Author (Herner)
Cosmic Rays; Genes; Gravitational Physiology; Microgravity; Radiation Injuries; Skin (Anatomy); Stress (Biology)

19920014059 NASA Marshall Space Flight Center, Huntsville, AL, USA
Radiation exposure of LDEF: Initial results
Benton, E. V.; Frank, A. L.; Benton, E. R.; Csige, I.; Parnell, T. A.; Watts, J. W., Jr.; NASA. Langley Research Center, LDEF: 69 Months in Space. First Post-Retrieval Symposium, Part 1; Jan 1, 1992; In English
Contract(s)/Grant(s): NAG8-168; No Copyright; Avail: CASI

Initial results from LDEF include radiation detector measurements from four experiments, P0006, P0004, M0004, and A0015. The detectors were located on both the leading and trailing edges of the orbiter and also on the Earthside end. This allowed the directional dependence of the incoming radiation to be measured. Total absorbed doses from thermoluminescent detectors (TLDs) verified the predicted spatial east-west dose ratio dependence of a factor approx. 2.5, due to trapped proton anisotropy in the South Atlantic Anomaly. On the trailing edge of the orbiter a range of doses from 6.64 to 2.91 Gy were measured under Al equivalent shielding of 0.42 to 1.11 g/sq cm. A second set of detectors near this location yielded doses of 6.48 to 2.66 Gy under Al equivalent shielding of 0.48 to 15.4 g/sq cm. On the leading edge, doses of 2.58 to 2.10 Gy were found under Al equivalent shielding of 1.37 to 2.90 g/sq cm. Initial charged particle LET (linear energy transfer) spectra, fluxes, doses and dose equivalents, for LET in H2O greater than or = 8 keV/micron, were measured with plastic nuclear track detectors (PNTDs) located in two experiments. Also preliminary data on low energy neutrons were obtained from detectors containing (6)LiF foils.
CASI
Leading Edges; Linear Energy Transfer (LET); Long Duration Exposure Facility; Radiation Detectors; Radiation Dosage; Trailing Edges

19920038276 NASA Lyndon B. Johnson Space Center, Houston, TX, USA, California Univ., Berkeley. Lawrence Berkeley Lab, CA, USA
Radiation issues for piloted Mars mission
Badhwar, Gautam D.; Nachtwey, D. S.; Yang, Tracy C.; Advances in Space Research; JAN 1, 1992; ISSN 0273-1177; 12, 2-3,; In English; Copyright; Avail: Other Sources

Current radiation risk for a piloted Mars mission is estimated using the idea of absorbed dose and ICRP-26, LET-dependent quality factors. In a spacecraft with aluminum walls (2 g/sq cm) at solar minimum the calculated dose equivalent is 0.73 Sv for a 406-day mission. Based on the current thinking this leads to an excess cancer mortality in a 35-year male of about 1 percent. About 75 percent of the dose equivalent is contributed by HZE particles and target fragments with

average quality factors of 10.3 and 20, respectively. The entire concept of absorbed dose, quality factor, and dose equivalent as applied to such missions needs to be reexamined, in light of the fact that less than 50 percent of the nuclei in the body of the astronaut would have been traversed by a single GCR nuclei in the 406-day mission.
AIAA
Ionizing Radiation; Manned Mars Missions; Radiation Dosage; Radiation Protection; Radiobiology

19930008829 Texas Univ., Austin, TX, USA
Conceptual design of a fleet of autonomous regolith throwing devices for radiation shielding of lunar habitats
Armstrong, Karem; Mcadams, Daniel A.; Norrell, Jeffery L.; JAN 1, 1992; In English
Report No.(s): NASA-CR-192030; NAS 1.26:192030; No Copyright; Avail: CASI

This report presents refinements in two areas of the initial design presented in the report entitled 'Conceptual Design of a Fleet of Autonomous Regolith Throwing Devices for Radiation Shielding of Lunar Habitats'. The first section presents an evaluation of the critical areas of the design and presents alternative solutions for these areas. The areas for design refinement are the traction required by the device and the stability of the device when throwing regolith. Several alternative methods are presented to solve these problems. First, the issue of required traction is covered. Next, the design is refined to provide a more stable device. The issue of stability is addressed both by presenting solutions for the configuration chosen for the computer simulation and by presenting two more device configurations. The next section presents the selected solutions. To prevent inadequate traction, the depth of dig-per-pass is reduced. A method combining a dynamic counterweight and an outrigger is chosen to provide a stable device.
Author
Automatic Control; Lunar Bases; Lunar Construction Equipment; Lunar Excavation Equipment; Lunar Rocks; Radiation Shielding; Regolith; Space Habitats; University Program

19920020769 Rider Coll., Lawrenceville, NJ, USA
Stopping powers and cross sections due to two-photon processes in relativistic nucleus-nucleus collision
Cheung, Wang K.; Norbury, John W.; Electromagnetic Processes in Nucleus-Nucleus Collisions Relating to Space Radiation Research; JAN 1, 1992; In English; No Copyright; Avail: CASI

The radiation dose received from high energy galactic cosmic rays (GCR) is a limiting factor in the design of long duration space flights and the building of lunar and martian habitats. It is of vital importance to have an accurate understanding of the interactions of GCR in order to assess the radiation environment that the astronauts will be exposed to. Although previous studies have concentrated on the strong interaction process in GCR, there are also very large effects due to electromagnetic (EM) interactions. In this report we describe our first efforts at understanding these EM production processes due to two-photon collisions. More specifically, we shall consider particle production processes in relativistic heavy ion collisions (RHICs) through two-photon exchange.
CASI
Cosmic Rays; Electromagnetic Interactions; Heavy Ions; Mathematical Models; Nuclear Interactions; Particle Collisions; Radiation Protection; Relativistic Particles

19920038275 Tuskegee Inst., AL, USA, NASA Ames Research Center, Moffett Field, CA, USA, Alicante Univ., Moffett Field, CA, Spain
Comparative study of spermatogonial survival after X-ray exposure, high LET (HZE) irradiation or spaceflight
Sapp, W. J.; Williams, C. S.; Williams, J. W.; Philpott, D. E.; Kato, K.; Miquel, J. M.; Serova, L.; Advances in Space Research; JAN 1, 1992; ISSN 0273-1177; 12, 2-3,; In English
Contract(s)/Grant(s): NIH-G12-RR-03059-01A1; NCC2-12; NCC2-455; Copyright; Avail: Other Sources

Spermatogonial cell loss has been observed in rats flown on Space Lab 3, Cosmos 1887, Cosmos 2044 and in mice following irradiation with X-ray or with HZE particle beams. Spermatogonial loss is determined by cell counting in maturation stage-6 seminferous tubules. With the exception of iron, laboratory irradiation experiments (with mice) revealed a similar pattern of spermatogonial loss proportional to the radiation dose at levels less than 0.1 Gy. Helium and argon irradiation resulted in a 5-percent loss of spermatogonia after only 0.01 Gy exposure. Significant spermatogonial loss (45 percent) occurred at this radiation level with iron particle beams. The loss of spermatogonia during each spaceflight was less than 10 percent when compared to control (nonflight) animals.
AIAA
Linear Energy Transfer (LET); Radiation Injuries; Spaceborne Experiments; Spermatogenesis; Spermatozoa; X Ray Irradiation

19920038306

Radiation situation determining the possibility of a manned flight to Mars and back

Pisarenko, N. F.; Advances in Space Research; JAN 1, 1992; ISSN 0273-1177; 12, 2-3,; In English; Copyright; Avail: Other Sources

Possible manned flights toward Mars are discussed from the viewpoint of radiation hazard. A standard situation is considered for crossing the earth's radiation belts. The flight to Mars is shown to be practically impossible without a special system of radiation shelters, because of the effect of penetrating galactic and solar radiations which are responsible for almost maximum permissible doses. But even in cases where there were radiation shelters on board the spacecraft, their flights are undesirable in the periods of maximum and minimum solar activity. It would obviously be worthwhile to schedule Martian flights for intervals in between the minima and maxima of 11-year cycles of solar activity when primary cosmic ray levels are considerably reduced and flare activity is not yet sufficiently high. It would not be easy to select such allowed intervals.

AIAA

Galactic Cosmic Rays; Manned Mars Missions; Radiation Hazards; Radiation Shielding; Terrestrial Radiation

19930034077 NASA Langley Research Center, Hampton, VA, USA

Galactic cosmic ray transport methods and radiation quality issues

Townsend, L. W.; Wilson, J. W.; Cucinotta, F. A.; Shinn, J. L.; International Journal of Radiation Applications and Instrumentation, Part D: Nuclear Tracks and Radiation Measurements; 1992; ISSN 0735-245X; 20, 1; In English; Copyright; Avail: Other Sources

An overview of galactic cosmic ray (GCR) interaction and transport methods, as implemented in the Langley Research Center GCR transport code, is presented. Representative results for solar minimum, exo-magnetospheric GCR dose equivalents in water are presented on a component by component basis for various thicknesses of aluminum shielding. The impact of proposed changes to the currently used quality factors on exposure estimates and shielding requirements are quantified. Using the cellular track model of Katz, estimates of relative biological effectiveness (RBE) for the mixed GCR radiation fields are also made.

AIAA

Bioastronautics; Galactic Cosmic Rays; Radiation Hazards; Radiation Transport; Solar Protons

19920038305

Chromosomal data relevant for Q values

Edwards, A. A.; Advances in Space Research; JAN 1, 1992; ISSN 0273-1177; 12, 2-3,; In English; Copyright; Avail: Other Sources

Relationships between absorbed dose and biological effect vary with the type of radiation. The application of this knowledge to devise a scheme for specifying the quality factor (Q) in radiological protection is the subject of much debate. There are no tumor data in humans from which the quality factor can be derived. The problems of using animal and cell transformation data which are probably the next best choice are discussed. The extensive data base on chromosomal aberrations in human lymphocytes is described and discussed in terms of relevance to deducing quality factors. Particular emphasis is placed on data obtained at low doses and low dose rates.

AIAA

Chromosomes; Q Factors; Radiation Effects; Radiation Protection; Relative Biological Effectiveness (RBE)

19930033978 NASA Langley Research Center, Hampton, VA, USA

Interplanetary crew exposure estimates for galactic cosmic rays

Townsend, Lawrence W.; Cucinotta, Francis A.; Wilson, John W.; Radiation Research; 1992; ISSN 0033-7587; In English; Copyright; Avail: Other Sources

Using the Langley Research Center galactic cosmic-ray transport computer code and the Computerized Anatomical Man model, initial estimates of interplanetary exposure of astronauts to galactic cosmic rays, during periods of solar minimum activity, are made for a realistic human geometry shielded by various thicknesses of spacecraft aluminum shielding. Conventional dose assessment in terms of total absorbed dose and dose equivalent is made for the skin, ocular lens, and bone marrow. Included in the analyses are separate evaluations of the contributions from the incident primary ions, from subsequent-generation fragmentation products, and from target fragments. In all cases considered, the equivalent sphere

approximation yielded conservative overestimates for the actual organ exposures.
AIAA
Flight Hazards; Galactic Cosmic Rays; Interplanetary Flight; Radiation Dosage; Radiation Hazards

19930034076 NASA Langley Research Center, Hampton, VA, USA
Track structure model for damage to mammalian cell cultures during solar proton events
Cucinotta, F. A.; Wilson, J. W.; Townsend, L. W.; Shinn, J. L.; Katz, R.; International Journal of Radiation Applications and Instrumentation, Part D: Nuclear Tracks and Radiation Measurements; 1992; ISSN 0735-245X; 20, 1; In English; Copyright; Avail: Other Sources

Solar proton events (SPEs) occur infrequently and unpredictably, thus representing a potential hazard to interplanetary space missions. Biological damage from SPEs will be produced principally through secondary electron production in tissue, including important contributions due to delta rays from nuclear reaction products. We review methods for estimating the biological effectiveness of SPEs using a high energy proton model and the parametric cellular track model. Results of the model are presented for several of the historically largest flares using typical levels and body shielding.
AIAA
Bioastronautics; Radiation Hazards; Radiation Transport; Solar Protons

19930008617 Texas Univ., Austin, TX, USA
Conceptual design of a fleet of autonomous regolith throwing devices for radiation shielding of lunar habitats
Armstrong, Karem; Mcadams, Daniel A.; Norrell, Jeffery L.; JAN 1, 1992; In English
Contract(s)/Grant(s): NASW-4435
Report No.(s): NASA-CR-192078; NAS 1.26:192078; No Copyright; Avail: CASI

The National Aeronautics and Space Administration (NASA) in conjunction with Universities Space Research Association (USRA) has requested that the feasibility of a fleet of regolith tossing devices designed to cover a lunar habitat for radiation protection be demonstrated. The regolith, or lunar soil, protects the lunar habitat and its inhabitants from radiation. Ideally, the device will operate autonomously in the lunar environment. To prove the feasibility of throwing regolith on the Moon, throwing solutions were compared to traditional, Earth-based methods for moving soil. Various throwing configurations were investigated. A linear throwing motion combined with a spring and motor energizing system proved a superior solution. Three different overall configurations for the lunar device are presented. A single configuration is chosen and critical parameters such as operating procedure, system volume, mass, and power are developed. The report is divided into seven main sections. First, the Introduction section gives background information, defines the project requirements and the design criteria, and presents the methodology used for the completion of this design. Next, the Preliminary Analysis section presents background information on characteristics of lunar habitats and the lunar environment. Then, the Alternate Designs section presents alternate solutions to each of the critical functions of the device. Fourth, a detailed analysis of throwing the regolith is done to demonstrate its feasibility. Then, the three overall design configurations are presented. Next, a configuration is selected and the conceptual design is expanded to include system performance characteristics, size, and mass. Finally, the Conclusions and Recommendations for Future Work section evaluates the design, outlines the next step to be taken in the design process, and suggests possible goals for future design work.
Author
Autonomy; Habitats; Lunar Environment; Lunar Radiation; Radiation Protection; Radiation Shielding; Regolith; Throwing

19920038272
Combined injury syndrome in space-related radiation environments
Dons, R. F.; Fohlmeister, U.; Advances in Space Research; JAN 1, 1992; ISSN 0273-1177; 12, 2-3,; In English; Copyright; Avail: Other Sources

The risk of combined injury (Cl) to space travelers is a function of exposure to anomalously large surges of a broad spectrum of particulate and photon radiations, conventional trauma (T), and effects of weightlessness including decreased intravascular fluid volume, and myocardial deconditioning. Cl may occur even at relatively low doses of radiation which can synergistically enhance morbidity and mortality from T. Without effective countermeasures, prolonged residence in space is expected to predispose most individuals to bone fractures as a result of calcium loss in the microgravity environment. Immune dysfunction may occur from residence in space independent of radiation exposure. Thus, wound healing would be compromised if infection were to occur. Survival of the space traveler with Cl would be significantly compromised if there

were delays in wound closure or in the application of simple supportive medical or surgical therapies.
AIAA
Aerospace Environments; Ionizing Radiation; Radiation Injuries; Radiation Protection; Radiation Tolerance; Radiobiology

19920038303 California Univ., Berkeley. Lawrence Berkeley Lab, CA, USA, NASA Langley Research Center, Hampton, VA, USA, Oak Ridge National Lab., TN, USA
Fluence-related risk coefficients using the Harderian gland data as an example
Curtis, S. B.; Powers-Risius, P.; Alpen, E. L.; Townsend, L. W.; Wilson, J. W.; Fry, R. J. M.; Advances in Space Research; JAN 1, 1992; ISSN 0273-1177; 12, 2-3,; In English
Contract(s)/Grant(s): DE-AC03-76SF-00098; DE-AC05-84OR-21400; Copyright; Avail: Other Sources

A new concept is introduced for assessing the risk of radiation-induced cancer to space travelers: a fluence-related risk coefficient F (called the risk cross section), which is the risk of a cancer per unit particle fluence for a given particle type. Fs are functions of the LET of the particles in the radiation field and, when integrated over fluence-LET spectra and summed, yield the risk of the endpoint of interest. As an example, tumor prevalence data in mice are used to estimate the probability of the induction of mouse Harderian-gland tumor per year on an extramagnetospheric mission inside an idealized shielding configuration of a spherical 1 g/sq cm thick aluminum shell. Results indicate a yearly tumor prevalence of 0.06 at solar minimum conditions, with 60 percent of this arising from charge components with Z between 10 and 28, and two-thirds of the contribution arising from LET components between 10 and 200 keV/micron.
AIAA
Cancer; Galactic Cosmic Rays; Linear Energy Transfer (LET); Radiation Effects; Space Flight; Spacecrews

19920038302
Radiation quality and risk estimation in relation to space missions
Fry, R. J. M.; Advances in Space Research; JAN 1, 1992; ISSN 0273-1177; 12, 2-3,; In English
Contract(s)/Grant(s): DE-AC05-84OR-21400; Copyright; Avail: Other Sources

While Q is specified as a function of linear energy transfer (LET), in practice the Q for neutrons is selected by a judgment decision based on the relative biological effectiveness (RBE) to induce stochastic effects. There are no RBE values for tumor induction by heavy ions or protons in humans. Thus, selection of Q values is based either on LET (or lineal energy) or RBEs from animal experiments. Estimates of Q for heavy ions in low earth orbit (LEO) range from about 5 to 14. The average Q value of all radiation in LEO is estimated to be about 1.3. There is a lack of experimental data for RBEs for heavy ions but RBE increases as a function of LET. In the case of the Harderian gland the RBE reaches a maximum of 25-30 between about 100-200 keV/microns but does not appear to decrease at higher LETs. The International Commission of Radiological Protection proposes the use of radiation weighting factors in lieu of quality factors. The weighting factors range from 1 to 20.
AIAA
Earth Orbital Environments; Linear Energy Transfer (LET); Q Factors; Radiation Protection; Relative Biological Effectiveness (RBE); Space Missions

19920038270
Induction of chromosome aberrations in mammalian cells after heavy ion exposure
Ritter, S.; Kraft-Weyrather, W.; Scholz, M.; Kraft, G.; Advances in Space Research; JAN 1, 1992; ISSN 0273-1177; 12, 2-3,; In English
Contract(s)/Grant(s): CEC-B16-0197-D; Copyright; Avail: Other Sources

The induction of chromosome aberrations by heavy charged particles was studied in V79 Chinese hamster cells over a wide range of energies (3-100 MeV/u) and LET (20-16,000 keV/micron). For comparison, X-ray experiments were performed. The present data indicate quantitative and qualitative differences in the response of cells to particle and X-ray irradiation. For the same level of cell survival the amount of damaged cells which can be observed is smaller in heavy ion (11.4 MeV/u Ar) irradiated samples. The highest yield of damaged cells is found 8 to 12 hours after particle irradiation and 4 hours after X-irradiation. Differences in the amount of damaged cells are attributed to cell cycle perturbations which interfere with the expression of damage. After heavy ion exposure the amount of cells reaching mitosis (mitotic index) decreases drastically and not all damaged cells reach mitosis within 48 hours after exposure. A portion of cells die in interphase. Cell cycle delays induced by X-ray irradiation are less pronounced and all cells reach the first post-irradiation mitosis within 24 hours after irradiation.
AIAA
Cells (Biology); Chromosomes; Heavy Ions; Ionizing Radiation; Radiation Damage; Radiobiology

19920038301

Multiple cell hits by particle tracks in solid tissues

Todd, P.; Advances in Space Research; JAN 1, 1992; ISSN 0273-1177; 12, 2-3,; In English; Copyright; Avail: Other Sources

Relative biological effectiveness (RBE) and quality factor (Q) at extreme values of linear energy transfer (LET) have been determined on the basis of experiments with single-cell systems and specific tissue responses. In typical single cell systems, each heavy particle (Ar or Fe) passes through a single cell or no cell. In tissue end-point experiments each heavy particle passes through several cells, and the LET can exceed 200 keV/microns in every cell. In most laboratory animal tissue systems, however, only a small portion of the hit cells are capable of expressing the end-point of interest to the investigator, such as cell killing, mutation or carcinogenesis. The following question must therefore be addressed: Do RBE's and Q factors derived from single-cell experiments properly account for the increased probability of multiple-cell damage by HZE tracks? A model is offered in which measured radiation effects and known tissue properties are combined to estimate the value of a multiplier of damage effectiveness on the basis of number of cells at risk, p3n, per track containing a hit cell, where n is the number of cells per track, based on tissue and organ geometry, and p3 is the probability that a cell in the track is capable of expressing the experimental end-point.

AIAA

Linear Energy Transfer (LET); Particle Tracks; Q Factors; Radiation Effects; Relative Biological Effectiveness (RBE); Tissues (Biology)

19920038300

RBE for non-stochastic effects

Barendsen, G. W.; Advances in Space Research; JAN 1, 1992; ISSN 0273-1177; 12, 2-3,; In English; Copyright; Avail: Other Sources

The paper reviews data on the relationship between the nonstochastic effects of ionizing radiation (i.e., the impairment of tissue integrity and function) and the values of the relative biological effectiveness (RBE). It is shown that RBE values can be derived for effects of actual exposures to mixtures of high-LET and low-LET radiations by considering the doses received and the tissue at risk. Application of maximum RBE values (RBE/m/), which can be derived by extrapolating on the basis of a radiobiological model, will yield estimates of maximum values of the equivalent doses. However, these values can only be applied for planning medical interventions if the contribution from high-LET radiation is small.

AIAA

Carcinogens; Linear Energy Transfer (LET); Radiation Dosage; Relative Biological Effectiveness (RBE); Tissues (Biology)

19920020759 Rider Coll., Lawrenceville, NJ, USA

Cross section parameterizations for cosmic ray nuclei. 1: Single nucleon removal

Norbury, John W.; Townsend, Lawrence W.; Electromagnetic Processes in Nucleus-Nucleus Collisions Relating to Space Radiation Research; JAN 1, 1992; In English

Contract(s)/Grant(s): NAG1-1134; No Copyright; Avail: CASI

Parameterizations of single nucleon removal from electromagnetic and strong interactions of cosmic rays with nuclei are presented. These parameterizations are based upon the most accurate theoretical calculations available to date. They should be very suitable for use in cosmic ray propagation through interstellar space, the Earth's atmosphere, lunar samples, meteorites, spacecraft walls and lunar and martian habitats.

CASI

Cosmic Rays; Electromagnetic Interactions; Mathematical Models; Nuclear Interactions; Nucleons; Parameterization; Particle Collisions

19920038296

Quality factor and dose equivalent investigations aboard the Soviet Space Station Mir

Bouisset, P.; Nguyen, V. D.; Parmentier, N.; Akatov, Ia. A.; Arkhangel'skii, V. V.; Vorozhtsov, A. S.; Petrov, V. M.; Kovalev, E. E.; Siegrist, M.; Advances in Space Research; JAN 1, 1992; ISSN 0273-1177; 12, 2-3,; In English; Copyright; Avail: Other Sources

Since Dec 1988, date of the French-Soviet joint space mission 'ARAGATZ', the CIRCE device, had recorded dose equivalent and quality factor values inside the Mir station (380-410 km, 51.5 deg). After the initial gas filling two years ago, the low pressure tissue equivalent proportional counter is still in good working conditions. Some results of three periods are presented. The average dose equivalent rates measured are respectively 0.6, 0.8 and 0.6 mSv/day with a quality factor equal

to 1.9. Some detailed measurements show the increasing of the dose equivalent rates through the SAA and near polar horns. The real time determination of the quality factors allows to point out high linear energy transfer events with quality factors in the range 10-20.
AIAA
Linear Energy Transfer (LET); Mir Space Station; Q Factors; Radiation Dosage; Radiation Protection; Spacecraft Shielding

19920020758 Rider Coll., Lawrenceville, NJ, USA
Electromagnetic processes in nucleus-nucleus collisions relating to space radiation research
Norbury, John W.; JAN 1, 1992; In English; See also N92-30002 through N92-30015
Contract(s)/Grant(s): NAG1-1134
Report No.(s): NASA-CR-190533; NAS 1.26:190533; No Copyright; Avail: CASI

Most of the papers within this report deal with electromagnetic processes in nucleus-nucleus collisions which are of concern in the space radiation program. In particular, the removal of one and two nucleons via both electromagnetic and strong interaction processes has been extensively investigated. The theory of relativistic Coulomb fission has also been developed. Several papers on quark models also appear. Finally, note that the theoretical methods developed in this work have been directly applied to the task of radiation protection of astronauts. This has been done by parameterizing the theoretical formalism in such a fashion that it can be used in cosmic ray transport codes.
Cosmic Rays; Electromagnetic Interactions; Extraterrestrial Radiation; Nuclear Interactions; Nucleons; Quantum Electrodynamics; Quark Models; Radiation Protection

19920038263
Microdosimetric considerations of effects of heavy ions on E. coli K-12 mutants
Takahashi, T.; Yatagai, F.; Izumo, K.; Advances in Space Research; JAN 1, 1992; ISSN 0273-1177; 12, 2-3,; In English; Copyright; Avail: Other Sources

The inactivation cross sections of E. coli K-12 recombination-deficient mutants, JC1553 (recA) and AB2470 (recB), for several MeV/u alpha-particles and N ions have been successfully analyzed by Katz's target theory in which radiosensitivity parameter E(0) is assumed to be LET independent and equal to D37 for gamma-rays. For E. coli K-12 wild type, AB1157 rec(+), uvr(+), however, it is impossible to interpret the inactivation cross-section data by an LET independent E(0)-value. In the latter case, as in the case of B. subtilis spore, it is necessary to assume that the radiosensitivity of the target for the core of a heavy ion is higher than that for delta-electrons.
AIAA
Heavy Ions; Linear Energy Transfer (LET); Microorganisms; Radiation Dosage; Radiation Tolerance

19920017883 Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Cologne, Germany
Long-term exposure of bacterial spores to space
Horneck, G.; Buecker, H.; Reitz, G.; NASA. Langley Research Center, LDEF: 69 Months in Space. First Post-Retrieval Symposium, Part 3; Jan 1, 1992; In English; No Copyright; Avail: CASI

With the NASA mission of the Long Duration Exposure Facility (LDEF), the authors have obtained the opportunity to expose Bacillus subtilis spores for nearly six years to the space environment and to analyze their responses after retrieval. The experiment was mounted onto a side tray of LDEF facing space. Data shows that the chances of microorganisms surviving in free space will be greatly increased by adequate shielding against solar ultraviolet light.
H.A.
Bacillus; Long Duration Exposure Facility; Radiation Dosage; Radiation Effects; Radiation Shielding; Spores

19920038293 Siegen Univ., CA, USA
Measurements of LET spectra and comparison to models
Wiegel, B.; Heinrich, W.; Benton, E. V.; Frank, A.; Advances in Space Research; JAN 1, 1992; ISSN 0273-1177; 12, 2-3,; In English
Contract(s)/Grant(s): BMFT-01-QV-85648; NAG9-235; Copyright; Avail: Other Sources

Measurements of LET spectra for near-earth orbits with various inclinations and altitudes are presented. A comparison with calculated LET spectra shows that the contribution from direct ionizing galactic cosmic rays is well described by the models. An additional contribution to the spectra originates from stopping protons and from nuclear interactions of particles with material. In the case of an interaction, a large amount of energy is deposited in a small volume by target recoils or target

fragments. These events will be called short range (SR) events. For a low-inclination orbit radiation belt protons are the main source of these events while galactic protons become more important when increasing the inclination to near-polar orbits. It is shown that the contribution of SR events for orbits with low altitude (324 km) and 57-deg inclination is comparable to that for an orbit with 28-deg inclination at a high altitude (510 km).
AIAA
Galactic Cosmic Rays; Ionizing Radiation; Linear Energy Transfer (LET); Manned Space Flight; Radiation Belts; Radiation Shielding

19920038261 Colorado State Univ., Fort Collins, CO, USA
Deoxyribonucleoprotein structure and radiation injury - Cellular radiosensitivity is determined by LET-infinity-dependent DNA damage in hydrated deoxyribonucleoproteins and the extent of its repair
Lett, J. T.; Peters, E. L.; Advances in Space Research; JAN 1, 1992; ISSN 0273-1177; 12, 2-3,; In English
Contract(s)/Grant(s): NAG9-10; Copyright; Avail: Other Sources

Until recently, OH radicals formed in bulk nuclear water were believed to be the major causes of DNA damage that results in cell death, especially for sparsely ionizing radiations. That hypothesis has now been challenged, if not refuted. Lethal genomic DNA damage is determined mainly by energy deposition in deoxyribonucleoproteins, and their hydration shells, and charge (energy) transfer processes within those structures.
AIAA
Deoxyribonucleic Acid; Ionizing Radiation; Radiation Damage; Radiation Injuries; Radiobiology

19920038292 NASA Langley Research Center, Hampton, VA, USA, California Univ., Berkeley. Lawrence Berkeley Lab, CA, USA
Human exposure to large solar particle events in space
Townsend, L. W.; Wilson, J. W.; Shinn, J. L.; Curtis, S. B.; Advances in Space Research; JAN 1, 1992; ISSN 0273-1177; 12, 2-3,; In English; Copyright; Avail: Other Sources

Whenever energetic solar protons produced by solar particle events traverse bulk matter, they undergo various nuclear and atomic collision processes which significantly alter the physical characteristics and biologically important properties of their transported radiation fields. These physical interactions and their effect on the resulting radiation field within matter are described within the context of a recently developed deterministic, coupled neutron-proton space radiation transport computer code (BRYNTRN). Using this computer code, estimates of human exposure in interplanetary space, behind nominal (2 g/sq cm) and storm shelter (20 g/sq cm) thicknesses of aluminum shielding, are made for the large solar proton event of August 1972. Included in these calculations are estimates of cumulative exposures to the skin, ocular lens, and bone marrow as a function of time during the event. Risk assessment in terms of absorbed dose and dose equivalent is discussed for these organs. Also presented are estimates of organ exposures for hypothetical, worst-case flare scenarios. The rate of dose equivalent accumulation places this situation in an interesting region of dose rate between the very low values of usual concern in terrestrial radiation environments and the high-dose-rate values prevalent in radiation therapy.
AIAA
Energetic Particles; Manned Space Flight; Radiation Shielding; Radiation Transport; Solar Activity Effects; Solar Protons

19920017880 Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Cologne, Germany
Preliminary total dose measurements on LDEF
Reitz, G.; NASA. Langley Research Center, LDEF: 69 months in Space. First Post-Retrieval Symposium, Part 3 p1643-1649 (SEE N92-27083 17-99); Jan 1, 1992; In English; No Copyright; Avail: CASI

After spending nearly six years in Earth's orbit twenty stacks consisting of radiation detectors and biological objects are now back on Earth. These Free Flyer Biostack experiments are part of the Long Duration Exposure Facility (LDEF). The major objective of the experiments are to investigate the biological effectiveness of single heavy ions of the cosmic radiation in various biological systems and to provide information about the spectral composition of the radiation field and the total dose received in the LDEF orbit. The preliminary analysis of the thermoluminescence dosimeters (TLD) yields maximum absorbed dose rates of 2.24 mGy day(exp -1) behind 0.7 g cm(exp -2) shielding and 1.17 mGy day(exp -1) behind 12 g cm(exp -2) shielding. A thermal neutron fluence of 1.7 n cm(exp -2)s(exp -1) is determined from the differences in absorbed dose for different isotopic mixtures of lithium. The results of this experiment on LDEF are especially valuable since LDEF stayed for almost six years in the prospected orbit of the Space Station Freedom.
CASI
Dosimeters; Fluence; Heavy Ions; Long Duration Exposure Facility; Radiation Dosage; Radiation Measurement; Radiation Shielding; Thermal Neutrons

19930070890 NASA Langley Research Center, Hampton, VA, USA

Human exposure to galactic cosmic rays in space

Townsend, L. W.; Cucinotta, F. A.; Shinn, J. L.; Wilson, J. W.; 1992; In English; Copyright; Avail: Other Sources

The Langley Research Center GCR (galactic cosmic rays) code (HZETRN) and the computerized Anatomical Man (CAM) model are used to estimate astronaut exposures, from GCR particles, for missions beyond earth's magnetosphere. Conventional risk assessments in terms of total absorbed dose and dose equivalent are made for skin, ocular lens, and bone marrow. For each organ, evaluations are made of relative contributions from incident protons, iron nuclei, and their secondary reaction products.

AIAA

Exobiology; Galactic Cosmic Rays; Human Beings; Linear Energy Transfer (LET); Radiation Effects; Radiation Protection

19920038288

'Mir' radiation dosimetry results during the solar proton events in September-October 1989

Dachev, Ts. P.; Matviichuk, Iu. N.; Bankov, N. G.; Semkova, I. V.; Koleva, R. T.; Ivanov, IA.; Tomov, B. T.; Petrov, V. M.; Shurshakov, V. A.; Bengin, V. V., et al.; Advances in Space Research; JAN 1, 1992; ISSN 0273-1177; 12, 2-3,; In English; Copyright; Avail: Other Sources

Using data from dosimetry-radiometry system 'Liulin' onboard the 'Mir' Space Station, the particle flux and dose rate during September-October, 1989 has been studied. The orbit of the station was 379 km perigee, 410 km apogee and 51.6 deg inclination. Special attention has been paid to the flux and dose rate changes inside the station after intensive solar proton events (SPE) on 29 September, 1989. The comparison between the doses before and after the solar flares shows increase of the calculated mean dose per day by factors of 10 to 200. During the SPE on the 29th of September the additional dose was 310 mrad. The results of the experiment are compared with the data for the solar proton fluxes obtained on the GOES-7 satellite.

AIAA

Dosimeters; Mir Space Station; Radiation Dosage; Solar Protons; Solar Terrestrial Interactions

19950051003 NASA Lyndon B. Johnson Space Center, Houston, TX, USA

Radiation health for a Mars mission

Robbins, Donald E.; 1992; In English; Copyright; Avail: Other Sources

Uncertainties in risk assessments for exposure of a Mars mission crew to space radiation place limitations on mission design and operation. Large shielding penalties are imposed in order to obtain acceptable safety margins. Galactic cosmic rays (GCR) and solar particle events (SPE) are the major concern. A warning system and 'safe-haven' are needed to protect the crew from large SPE which produce lethal doses. A model developed at NASA Johnson Space Center (JSC) to describe solar modulation of GCR intensities reduces that uncertainty to less than 10 percent. Radiation transport models used to design spacecraft shielding have large uncertainties in nuclear fragmentation cross sections for GCR which interact with spacecraft materials. Planned space measurements of linear energy transfer (LET) spectra behind various shielding thicknesses will reduce uncertainties in dose-versus-shielding thickness relationships to 5-10 percent. The largest remaining uncertainty is in biological effects of space radiation. Data on effects of energetic ions in human are nonexistent. Experimental research on effects in animals and cell is needed to allow extrapolation to the risk of carcinogenesis in humans.

Author (Herner)

Galactic Cosmic Rays; Health Physics; Manned Mars Missions; Radiation Dosage; Radiation Hazards; Radiation Injuries; Radiation Transport; Solar Radiation

19920038287

Prediction and evaluation of solar particle events based on precursor information

Heckman, G. R.; Kunches, J. M.; Allen, J. H.; Advances in Space Research; JAN 1, 1992; ISSN 0273-1177; 12, 2-3,; In English; Copyright; Avail: Other Sources

Protection from the radiation effects of solar particle events for deep space mission crews requires a warning system to observe solar flares and predict subsequent charged particle fluxes. Such a system relates precursor information observed in each flare to the intensity, delay, and duration of the subsequent Solar Particle Event (SPE) at other locations in the solar system. A warning system of this type is now in operation at the NOAA Space Environment Services Center in Boulder, Colorado for support of space missions. It has been used to predict flare particle fluxes at the earth for flares of Solar Cycle 22. The flare parameters used and the effectiveness of the current warning system, based on Solar Cycle 22 experience, are

presented, with an examination of the shortcomings. Needed improvements to the system include more complete observations of solar activity, especially information on the occurrences of solar mass ejections and consideration of the effects of propagation conditions in the solar corona and interplanetary medium. Requirements for solar observations and forecasting systems on board the spacecraft are discussed.
AIAA
Manned Space Flight; Prediction Analysis Techniques; Radiation Hazards; Radiation Protection; Solar Corpuscular Radiation; Solar Flares

19920038224
Possible mechanism of microgravity impact on Carausius morosus ontogenesis
Ushakov, I. A.; Alpatov, A. M.; Advances in Space Research; JAN 1, 1992; ISSN 0273-1177; 12, 1, 19; In English; Copyright; Avail: Other Sources

Experiments aboard 'Spacelab-Dl' and 'Cosmos-1887' revealed an adverse effect of space flight on Carausius morosus embryos. The main influencing factor for stick insect eggs turned out to be microgravity, while the contribution of HZE particles of cosmic radiation was relatively low. Flight experiments indicated an increased vulnerability of stick insect eggs to microgravity at intermediate stages of development, that could support the 'convection' hypothesis.
AIAA
Bioastronautics; Gravitational Physiology; Microgravity; Ontogeny

19920038255
Life sciences and space research XXIV(2) - Radiation biology; Proceedings of the Topical Meeting of the Interdisciplinary Scientific Commission F (Meetings F3, F4, F5, F6 and F1) of the COSPAR 28th Plenary Meeting, The Hague, Netherlands, June 25-July 6, 1990
Kraft, G., editor; Cox, A. B., editor; Maisin, J. R., editor; Ainsworth, E. J., editor; Reitz, G., editor; Horneck, G., editor; JAN 1, 1992; ISSN 0273-1177; In English; Copyright; Avail: Other Sources

The present topical meeting on life sciences and space research discusses heavy-ion effects in genetically relevant cellular structures, combined effects (radiation, microgravity, trauma, and other factors), physical and chemical protection against ionizing radiation, radiation risk assessment for manned spaceflights, and radiation protection aspects related to manned missions to Mars. Attention is given to delta-electron emission in fast heavy ion atom collisions, structures of heavy ion tracks in AgCl detectors, microdosimetric measurements of heavy ion tracks, and DNA structures and radiation injury. Topics addressed include human reproductive issues in space, a comparative study of spermatogonial survival after X-ray exposure, the treatment of radiation injuries, and alterations in glucose and protein metabolism in animals subjected to simulated microgravity. Also discussed are radiation issues for a piloted Mars mission, the role of endogenous thiols in protection, radioprotection of DNA by biochemical mechanisms, and radioprotection by metals.
AIAA
Conferences; Ionizing Radiation; Manned Space Flight; Radiation Protection

19920038284
Behavioral toxicity of selected radioprotectors
Landauer, M. R.; Davis, H. D.; Kumar, K. S.; Weiss, J. F.; Advances in Space Research; JAN 1, 1992; ISSN 0273-1177; 12, 2-3,; In English; Copyright; Avail: Other Sources

Effective radioprotection with minimal behavioral disruption is essential for the selection of protective agents to be used in manned spaceflight. This overview summarizes the studies on the behavioral toxicity of selected radioprotectors classified as phosphorothioates, bioactive lipids, platelet activating factor (PAF), and immunomodulators (glucan, synthetic trehalose dicorynomycolate, and interleukin-1). Behavioral toxicity was examined in laboratory mice using a locomotor activity test. For all compounds tested, there was a dose-dependent decrease in locomotor behavior that paralleled the dose-dependent increase in radioprotection. While combinations of radioprotective compounds increased radioprotection, they also decreased locomotor activity. The central nervous system stimulant, caffeine, was able to mitigate the locomotor decrement produced by phosphorothioates or PAF.
AIAA
Manned Space Flight; Radiation Dosage; Radiation Protection; Toxic Hazards

19920041450

Dose variation during solar minimum

Gussenhoven, M. S.; Mullen, E. G.; Brautigam, D. H.; Holeman, E.; IEEE Transactions on Nuclear Science; Dec 1, 1991; ISSN 0018-9499; 38; In English; Copyright; Avail: Other Sources

The authors use direct measurement of dose to show the variation in inner and outer radiation belt populations at low altitude from 1984 to 1987. This period includes the recent solar minimum that occurred in September 1986. The dose is measured behind four thicknesses of aluminum shielding and for two thresholds of energy deposition, designated HILET and LOLET. An average dose per day is calculated for each month of satellite operation. It is found that the average proton (HILET) dose per day (obtained primarily in the inner belt) increased systematically from 1984 to 1987, and has a high anticorrelation with sunspot number when offset by 13 months. The average LOLET dose per day behind the thinnest shielding is produced almost entirely by outer zone electrons and varies greatly over the period of interest. If any trend can be discerned over the 4 year period it is a decreasing one. For shielding of 1.5 gm/sq cm (227 mil) Al or more, the LOLET dose is complicated by contributions from greater than 100 MeV protons and bremsstrahlung.

AIAA

Extraterrestrial Radiation; Radiation Belts; Radiation Dosage; Radiation Spectra; Solar Activity; Solar Radiation

19920004563 NASA Langley Research Center, Hampton, VA, USA

Target correlation effects on neutron-nucleus total, absorption, and abrasion cross sections

Cucinotta, Francis A.; Townsend, Lawrence W.; Wilson, John W.; Dec 1, 1991; In English

Contract(s)/Grant(s): RTOP 199-04-16-11

Report No.(s): NASA-TM-4314; L-16955; NAS 1.15:4314; No Copyright; Avail: CASI

Second order optical model solutions to the elastic scattering amplitude were used to evaluate total, absorption, and abrasion cross sections for neutron nucleus scattering. Improved agreement with experimental data for total and absorption cross sections is found when compared with first order (coherent approximation) solutions, especially below several hundred MeV. At higher energies, the first and second order solutions are similar. There are also large differences in abrasion cross section calculations; these differences indicate a crucial role for cluster knockout in the abrasion step.

CASI

Abrasion; Absorption Cross Sections; Correlation; Elastic Scattering; Neutron Scattering; Scattering Amplitude; Targets

19920006738 NASA Langley Research Center, Hampton, VA, USA

Transport methods and interactions for space radiations

Wilson, John W.; Townsend, Lawrence W.; Schimmerling, Walter S.; Khandelwal, Govind S.; Khan, Ferdous S.; Nealy, John E.; Cucinotta, Francis A.; Simonsen, Lisa C.; Shinn, Judy L.; Norbury, John W.; Dec 1, 1991; In English

Contract(s)/Grant(s): RTOP 199-04-16-11

Report No.(s): NASA-RP-1257; L-16882; NAS 1.61:1257; No Copyright; Avail: CASI

A review of the program in space radiation protection at the Langley Research Center is given. The relevant Boltzmann equations are given with a discussion of approximation procedures for space applications. The interaction coefficients are related to solution of the many-body Schroedinger equation with nuclear and electromagnetic forces. Various solution techniques are discussed to obtain relevant interaction cross sections with extensive comparison with experiments. Solution techniques for the Boltzmann equations are discussed in detail. Transport computer code validation is discussed through analytical benchmarking, comparison with other codes, comparison with laboratory experiments and measurements in space. Applications to lunar and Mars missions are discussed.

CASI

Charged Particles; Extraterrestrial Radiation; Radiation Effects; Radiation Protection; Transport Theory

19920006741 NASA Langley Research Center, Hampton, VA, USA

HZETRN: A heavy ion/nucleon transport code for space radiations

Wilson, John W.; Chun, Sang Y.; Badavi, Forooz F.; Townsend, Lawrence W.; Lamkin, Stanley L.; Dec 1, 1991; In English

Contract(s)/Grant(s): RTOP 593-42-11-01

Report No.(s): NASA-TP-3146; L-16952; NAS 1.60:3146; No Copyright; Avail: CASI

The galactic heavy ion transport code (GCRTRN) and the nucleon transport code (BRYNTRN) are integrated into a code package (HZETRN). The code package is computer efficient and capable of operating in an engineering design environment for manned deep space mission studies. The nuclear data set used by the code is discussed including current limitations.

Although the heavy ion nuclear cross sections are assumed constant, the nucleon-nuclear cross sections of BRYNTRN with full energy dependence are used. The relation of the final code to the Boltzmann equation is discussed in the context of simplifying assumptions. Error generation and propagation is discussed, and comparison is made with simplified analytic solutions to test numerical accuracy of the final results. A brief discussion of biological issues and their impact on fundamental developments in shielding technology is given.
CASI
Computer Programs; Heavy Ions; Nucleons; Particle Interactions; Radiation Shielding; Spacecraft Shielding

19920002467 NASA Langley Research Center, Hampton, VA, USA
Cellular repair/misrepair track model
Wilson, John W.; Cucinotta, Francis A.; Nov 1, 1991; In English
Contract(s)/Grant(s): RTOP 199-04-16-11
Report No.(s): NASA-TP-3124; L-16949; NAS 1.60:3124; No Copyright; Avail: CASI

A repair/misrepair cell kinetics model is superimposed onto the track structure model of Katz to provide for a repair mechanism. The model is tested on the repair-dependent data of Yang et al. and provides an adequate description of that data. The misrepair rate determines the maximum relative biological effectiveness (RBE), but similar results could arise from indirect X-ray lethality not include in the present model.
CASI
Biological Effects; Cells (Biology); Kinetics; Lethality; Radiation Effects; Relative Biological Effectiveness (RBE)

19920031177
Measurement of the radiation dose on the Mir station during solar proton events in September-October 1989
Tverskaia, L. V.; Tel'tsov, M. V.; Shumshurov, V. I.; Geomagnetizm i Aeronomiia; Oct 1, 1991; ISSN 0016-7940; 31; In Russian; Copyright; Avail: Other Sources

An analysis is made of variations of the radiation dose of the Mir orbital station under exposure to solar cosmic rays during September-October 1989. It is shown that increases in the dose which represent a significant radiation hazard are associated with approach of the solar-proton penetration boundary toward the earth during strong magnetic disturbances.
AIAA
Mir Space Station; Proton Flux Density; Radiation Dosage; Radiation Hazards; Solar Cosmic Rays; Solar Protons

19920042652
Protection from effects of radiation at sublethal doses during exposures to hypergravitation
Minkova, M. I.; Pantev, T. P.; Kosmicheskaia Biologiia i Aviakosmicheskaia Meditsina; Oct 1, 1991; ISSN 0321-5044; 25; In Russian; Copyright; Avail: Other Sources

The effects of hypergravitation (G) and of two radiation protective substances, eleutherococcus (E) and adeturon (A), on the development and progress of radiation sickness in rats were investigated in animals exposed to centrifugal acceleration to +5 Gx and/or irradiation (I) by Cs-137 (3 Gy), delivered in the following combinations: E + I, E + G + I, and E + G + A + I. Results indicate that acceleration delivered 1 h before irradiation did not change the sensitivity of animals to radiation sickness development, but canceled the beneficial effect of E, while injections of A in the combination E + G + A + I did not alleviate the early symptoms of radiative sickness, but increased the speed of recovery.
AIAA
Antiradiation Drugs; Gravitational Effects; High Gravity Environments; Physiological Responses; Radiation Tolerance; Radiobiology

19920058160
Dynamics of the radiation conditions along the route of the Mir station during the solar proton event of September 29, 1989
Bengin, V. V.; Makhmutov, V. S.; Shurshakov, V. A.; Petrov, V. M.; Panova, N. A.; Mitrikas, V. G.; Zil', M. V.; Dachev, Ts. P.; Matviichuk, Iu. N.; Bankov, N. G., et al.; Akademiia Nauk SSSR, Izvestiia, Seriia Fizicheskaia; Oct 1, 1991; ISSN 0367-6765; 55, 10, O; In Russian; Copyright; Avail: Other Sources

The dynamics of an absorbed dose of cosmic radiation during the unique solar proton event of September 29, 1989 was measured during a Soviet-Bulgarian experiment with the Liulin dosimeter on board the Mir station. The intensity of the dose in calm conditions was (30 +/-6) x 10 exp -5 Gy/d. An additional absorbed dose conditioned by the above event was 310 x

10 exp -5 Gy. The results are compared with data on solar proton fluxes obtained by the GOES-7 satellite.
AIAA
Mir Space Station; Radiation Counters; Radiation Hazards; Solar Protons

19920004538 NASA Langley Research Center, Hampton, VA, USA
Benchmark solutions for the galactic heavy-ion transport equations with energy and spatial coupling
Ganapol, Barry D.; Townsend, Lawrence W.; Lamkin, Stanley L.; Wilson, John W.; Oct 1, 1991; In English
Contract(s)/Grant(s): RTOP 199-04-16-11
Report No.(s): NASA-TP-3112; L-16909; NAS 1.60:3112; No Copyright; Avail: CASI

Nontrivial benchmark solutions are developed for the galactic heavy ion transport equations in the straightahead approximation with energy and spatial coupling. Analytical representations of the ion fluxes are obtained for a variety of sources with the assumption that the nuclear interaction parameters are energy independent. The method utilizes an analytical LaPlace transform inversion to yield a closed form representation that is computationally efficient. The flux profiles are then used to predict ion dose profiles, which are important for shield design studies.
CASI
Galactic Cosmic Rays; Heavy Ions; Neutrons; Nuclear Interactions; Radiation Dosage; Radiation Shielding; Transport Theory

19920007332 Pacific Northwest Lab., Richland, WA, USA
Improving in vivo calibration phantoms
Lynch, T. P.; Olsen, P. C.; Oct 1, 1991; In English; 37th, 7-11 Oct. 1991, Ottawa, Canada
Contract(s)/Grant(s): DE-AC06-76RL-01830
Report No.(s): DE92-002157; PNL-SA-20013; CONF-911032-4; No Copyright; Avail: CASI

Anthropomorphic phantoms have been the basis for quantification of radioactive material in the body using in vivo measurements. The types of phantoms used and the degree of anthropomorphic detail vary depending on the counting application, the radioactive material to be measured, phantom availability, and cost. Consequently, measurement results for the same types of radioactive material from different facilities are not always comparable. At a February 1990 meeting at the National Institute of Standards and Technology (NIST) the need to develop the 'gold standards' or primary reference standards for in vivo phantoms was discussed in detail. The consensus of the attendees at the meeting was that the state of the art in phantoms was adequate as a starting point and that there was no need to start phantom development from scratch. In particular, the torso phantom developed at the Lawrence Livermore National Laboratory (LLNL) and its commercial progeny, the bottle manikin absorption (BOMAB) phantom and the American National Standards Institute (ANSI) Standard N44.3 thyroid phantom, were identified as the starting points for the development of the primary reference standards. Working groups at the meeting subsequently recommended design improvements for the existing phantom designs. The implementation of these recommendations is the subject of this paper.
DOE
Calibrating; Cells (Biology); Human Body; Quality Control; Radiation Detectors; Radiation Protection; Signatures; Specifications; Standards

19910021747 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Analyses of risks associated with radiation exposure from past major solar particle events
Weyland, Mark D.; Atwell, William; Cucinotta, Francis A.; Wilson, John W.; Hardy, Alva C.; Aug 1, 1991; In English
Report No.(s): NASA-TP-3137; S-639; NAS 1.60:3137; No Copyright; Avail: CASI

Radiation exposures and cancer induction/mortality risks were investigated for several major solar particle events (SPE's). The SPE's included are: February 1956, November 1960, August 1972, October 1989, and the September, August, and October 1989 events combined. The three 1989 events were treated as one since all three could affect a single lunar or Mars mission. A baryon transport code was used to propagate particles through aluminum and tissue shield materials. A free space environment was utilized for all calculations. Results show the 30-day blood forming organs (BFO) limit of 25 rem was surpassed by all five events using 10 g/sq cm of shielding. The BFO limit is based on a depth dose of 5 cm of tissue, while a more detailed shield distribution of the BFO's was utilized. A comparison between the 5 cm depth dose and the dose found using the BFO shield distribution shows that the 5 cm depth value slightly higher than the BFO dose. The annual limit of 50 rem was exceeded by the August 1972, October 1989, and the three combined 1989 events with 5 g/sq cm of shielding. Cancer mortality risks ranged from 1.5 to 17 percent at 1 g/sq cm and 0.5 to 1.1 percent behind 10 g/sq cm of shielding for five events.

These ranges correspond to those for a 45 year old male. It is shown that secondary particles comprise about 1/3 of the total risk at 10 g/sq cm of shielding. Utilizing a computerized Space Shuttle shielding model to represent a typical spacecraft configuration in free space at the August 1972 SPE, average crew doses exceeded the BFO dose limit.
CASI
Aerospace Environments; Computerized Simulation; Hematopoietic System; Radiation Dosage; Radiation Hazards; Radiation Shielding; Solar Corpuscular Radiation

19920039144 Rockwell International Corp., Houston, TX, USA, NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Radiation exposure and risk assessment for critical female body organs
Atwell, William; Weyland, Mark D.; Hardy, Alva C.; Jul 1, 1991; In English
Report No.(s): SAE PAPER 911352; Copyright; Avail: Other Sources

Space radiation exposure limits for astronauts are based on recommendations of the National Council on Radiation Protection and Measurements. These limits now include the age at exposure and sex of the astronaut. A recently-developed computerized anatomical female (CAF) model is discussed in detail. Computer-generated, cross-sectional data are presented to illustrate the completeness of the CAF model. By applying ray-tracing techniques, shield distribution functions have been computed to calculate absorbed dose and dose equivalent values for a variety of critical body organs (e.g., breasts, lungs, thyroid gland, etc.) and mission scenarios. Specific risk assessments, i.e., cancer induction and mortality, are reviewed.
AIAA
Extraterrestrial Radiation; Human Body; Radiation Dosage; Radiation Hazards; Radiation Protection

19920039146 NASA Langley Research Center, Hampton, VA, USA, School of Aerospace Medicine, Brooks AFB, TX, USA, Colorado State Univ., Fort Collins, CO, USA
A study of lens opacification for a Mars mission
Shinn, J. L.; Wilson, J. W.; Cox, A. B.; Lett, J. T.; Jul 1, 1991; In English
Report No.(s): SAE PAPER 911354; Copyright; Avail: Other Sources

A method based on risk-related cross sections is used to estimate risks of 'stationary' cataracts caused by radiation exposures during extended missions in deep space. Estimates of the even more important risk of late degenerative cataractogenesis are made on the basis of the limited data available. Data on lenticular opacification in the New Zealand white rabbit, an animal model from which such results can be extrapolated to humans, are analyzed by the Langley cosmic ray shielding code (HZETRN) to generate estimates of stationary cataract formation resulting from a Mars mission. The effects of the composition of shielding material and the relationship between risk and LET are given, and the effects of target fragmentation on the risk coefficients are evaluated explicitly.
AIAA
Cataracts; Long Duration Space Flight; Manned Mars Missions; Q Factors; Radiation Injuries; Relative Biological Effectiveness (RBE)

19920039147 NASA Langley Research Center, Hampton, VA, USA, Nebraska Univ., Lincoln, NE, USA
LET analyses of biological damage during solar particle events
Cucinotta, Francis A.; Wilson, John W.; Townsend, Lawrence W.; Shinn, Judy L.; Katz, Robert; Jul 1, 1991; In English
Report No.(s): SAE PAPER 911355; Copyright; Avail: Other Sources

The effects of nuclear reactions on integral low-linear-energy-transfer (LET) protons spectra are studied, behind typical levels of spacecraft and body shielding, for the historically largest flares using the high-energy transport code BRYNTRN in conjunction with several biological damage models. The cellular track model of Katz provides an accurate description of cellular damage from heavy ion exposure. The track model is applied with BRYNTRN to provide a LET decomposition of survival and transformation rates for solar proton events. In addition, a fluence-based risk coefficient formalism is used to estimate Harderian gland-tumor induction in rodents and cataractogenesis in rabbits from solar flares, and a LET analysis is used to assess the relative contribution from target fragments on these biological endpoints.
AIAA
Biological Effects; Linear Energy Transfer (LET); Proton Damage; Solar Flares; Solar Protons

19920039160 Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA, USA
The NASA Radiation Health Program
Schimmerling, Walter; Jul 1, 1991; In English
Report No.(s): SAE PAPER 911371; Copyright; Avail: Other Sources

The Space Radiation Health Program (SRHP) is defined in terms of motivation and methodology with specific reference given to the impacts of HZE particles and solar energetic particles. The biological hazards are mentioned that can be associated with the two particle types and ionizing radiation in general. The lack of data on the impact of such radiation and effective shielding countermeasures is identified as the primary motivation for worst-case assumptions. However, the resulting shielding designs can potentially overestimate the thickness by a factor of 10 and add unnecessarily to vehicle take-off mass. A space-based validation system is proposed to complement ground-based investigations of the effects of ionizing radiation in interplanetary space. The Lifesat satellite is proposed as a part of the SRHP effort to determine the requirements for protection and future shielding specifications.
AIAA
Charged Particles; Energetic Particles; NASA Space Programs; Radiation Hazards; Radiation Shielding; Solar Radiation

19920039202
Preliminary analysis of life support resources and wastes as radiation shielding
Doll, Susan C.; Appleby, Matthew H.; Jul 1, 1991; In English
Report No.(s): SAE PAPER 911399; Copyright; Avail: Other Sources

Life support and radiation shielding are two critical technologies for manned exploration missions. For long duration missions, life support resources, such as water and food, must be provided to keep the crew alive and shelter must be provided to protect the crew from radiation. The large amounts of food and water required for long duration missions have been the major reason for developing closed loop life support systems. However, preliminary findings indicate that food and water can be effective as radiation shielding and may result in significant mass savings over dedicated shielding. This dual use of life support resources overall system mass as well as the mass penalty associated with open loop life support.
AIAA
Aerospace Environments; Life Support Systems; Radiation Dosage; Radiation Hazards; Radiation Shielding; Waste Utilization

19920015440 California Univ., Irvine, CA, USA
Genetic variation in resistance to ionizing radiation
Ayala, F. J.; Jun 24, 1991; In English
Contract(s)/Grant(s): DE-FG03-88ER-60713
Report No.(s): DE92-005588; DOE/ER-60713/T1; No Copyright; Avail: CASI

We proposed an investigation of genetically determined individual differences in sensitivity to ionizing radiation. The model organism is Drosophila melanogaster. The gene coding for Cu, Zn superoxide dismutase (SOD) is the target locus, but the effects of variation in other components of the genome that modulate SOD levels are also taken into account. SOD scavenges oxygen radicals generated during exposure to ionizing radiation. It has been shown to protect against ionizing radiation damage to DNA, viruses, bacteria, mammalian cells, whole mice, and Drosophila. Two alleles, S and F, are commonly found in natural populations of D. melanogaster; in addition we have isolated from a natural population 'null' (CA1) mutant that yields only 3.5 pct. of normal SOD activity. The S, F, and CA1 alleles provide an ideal model system to investigate SOD-dependent radioresistance, because each allele yields different levels of SOD, so that S is greater than F is much greater than CA1. The roles of SOD level in radioresistance are being investigated in a series of experiments that measure the somatic and germ-line effects of increasing doses of ionizing radiation. In addition, we have pursued an unexpected genetic event-namely the nearly simultaneous transformation of several lines homozygous for the SOD 'null' allele into predominately S lines. Using specifically designed probes and DNA amplification by means of the Tag polymerase chain reaction (PCR) we have shown that (1) the null allele was still present in the transformed lines, but was being gradually replaced by the S allele as a consequence of natural selection; and (2) that the transformation was due to the spontaneous deletion of a 0.68 Kb truncated P-element, the insertion of which is characteristic of the CA1 null allele.
DOE
Enzymes; Genetics; Ionizing Radiation; Radiation Effects

19920006782 Brookhaven National Lab., Upton, NY, USA
Human round trip to Mars: Six months and radiation-safe
Lazareth, O. W.; Schmidt, E.; Ludewig, H.; Jun 14, 1991; In English; 9th, 13-16 Jan. 1992, Albuquerque, NM, USA
Contract(s)/Grant(s): DE-AC02-76CH-00016
Report No.(s): DE91-014798; BNL-46287; CONF-920104-6; No Copyright; Avail: CASI

We propose an interplanetary transportation system which will provide a round trip for humans traveling from Earth to Mars and back. The journey will be relatively fast and relatively safe from radiation dosage. The basic concept consists of four space vehicles. First, a comparatively heavily shielded, large spacecraft (LC no. 1), which usually is unmanned, is put into a non-stop heliocentric orbit which closely passes Earth and Mars, in that order. Second, but during the same time frame, a second large spacecraft (LC no. 2), which will be used for the return trip, is launched into an orbit which closely passes Mars and Earth in turn. Third, but also during the same time period, an unmanned cargo vessel, containing LH and other supplies, is sent to Mars and lands before any humans depart. Fourth, a comparatively small spacecraft (SC) carrying the crew is launched from the Earth's moon (Moon), travels to a rendezvous point with LC no. 1 and couples to it. The crew transfers to the relative comfort and safety of the LC. When they reach Mars, the SC decouples from LC no. 1 and lands on Mars, while LC no. 1 continues in its orbit. The crew spends about four weeks on Mars, during which time the SC is re-supplied with materials from the cargo ship which was previously sent to Mars. The crew then leaves Mars in the SC and proceeds to a rendezvous pint with LC no. 2 and couples to it. The crew transfers to it and travels back to the vicinity of the Earth. Then the crew transfers back to the SC and returns to the Moon.
DOE
Manned Space Flight; Mars (Planet); Radiation Dosage; Radiation Shielding; Solar Radiation; Spacecraft Shielding

19910016793 NASA Langley Research Center, Hampton, VA, USA
Radiation risk predictions for Space Station Freedom orbits
Cucinotta, Francis A.; Atwell, William; Weyland, Mark; Hardy, Alva C.; Wilson, John W.; Townsend, Lawrence W.; Shinn, Judy L.; Katz, Robert; Jun 1, 1991; In English
Contract(s)/Grant(s): RTOP 199-04-16-11
Report No.(s): NASA-TP-3098; L-16903; NAS 1.60:3098; No Copyright; Avail: CASI
Risk assessment calculations are presented for the preliminary proposed solar minimum and solar maximum orbits for Space Station Freedom (SSF). Integral linear energy transfer (LET) fluence spectra are calculated for the trapped proton and GCR environments. Organ dose calculations are discussed using the computerized anatomical man model. The cellular track model of Katz is applied to calculate cell survival, transformation, and mutation rates for various aluminum shields. Comparisons between relative biological effectiveness (RBE) and quality factor (QF) values for SSF orbits are made.
CASI
Biological Models (Mathematics); Cells (Biology); Irradiation; Physiological Effects; Radiation Effects; Radiation Hazards; Space Station Freedom; Space Stations

19910019277 Pacific Northwest Lab., Richland, WA, USA
Robotic mannequin technology for enhanced product testing
Fecht, B. A.; Bennett, D. W.; Jun 1, 1991; In English; 4th, 18-20 Jun. 1991, Montreal, Quebec, Canada
Contract(s)/Grant(s): DE-AC06-76RL-01830
Report No.(s): DE91-013787; PNL-SA-19455; CONF-9106202-1; No Copyright; Avail: CASI
Engineers at Pacific Northwest Laboratory (PNL) have developed several articulated robotic mannequin systems which closely simulate human anthropometric shape, complex motion and physiological function. These systems provide highly reproducible and realistic tests which aid in the evaluation of high performance clothing, consumer products, and human comfort.
DOE
Anthropometry; Chemical Warfare; Human Factors Engineering; Performance Tests; Robotics

19910013704 NASA Langley Research Center, Hampton, VA, USA
Improvements in computational accuracy of BRYNTRN (a baryon transport code)
Shinn, Judy L.; Wilson, John W.; Weyland, Mark; Cucinotta, Francis A.; May 1, 1991; In English
Contract(s)/Grant(s): RTOP 199-04-16-11
Report No.(s): NASA-TP-3093; L-16898; NAS 1.60:3093; No Copyright; Avail: CASI
Extension of BRYNTRN for use in space radiation dose analyses for very large shield thickness is made possible by improving the numerical algorithms. The efforts were concentrated in obtaining more accurate yet efficient interpolation and integration methods at each local computational step and in optimizing the grid distributions. A brief discussion of the nucleon transport theory and propagating formula is also given in conjunction with the analysis of error propagation which reveals the need for minimizing the local truncation errors. Sample calculations were made to verify the new algorithms. An accuracy of

approximately 5 percent for a shield thickness of 150 g/sq cm was found when a minimal, thirty-point energy grid was used. This is far superior to the results obtained by using the old algorithms where the solutions can be of an order of magnitude different when a reasonable large number of grid points was used. The propagation step size which is restricted by the perturbation theory was re-evaluated to be in line with the improved numerical accuracy.
CASI
Algorithms; Baryons; Computer Programs; Extraterrestrial Radiation; Radiation Counters; Radiation Dosage; Radiation Shielding; Radiation Transport

19910017753 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Engineering knowledge requirements for sand and dust on Mars
Kaplan, D. I.; NASA. Ames Research Center, Sand and Dust on Mars; May 1, 1991; In English; No Copyright; Avail: CASI

The successful landing of human beings on Mars and the establishment of a permanent outpost there will require an understanding of the Martian environment by the engineers. A key feature of the Martian environment is the nearly ubiquitous presence of sand and dust. The process which the engineering community will undertake to determine the sensitivities of their designs to the current level of knowledge about Mars sand and dust is emphasized. The interaction of the engineering community with the space exploration initiative (SEI) mission planners and management is described.
CASI
Dust; Mars Environment; Mars Surface; Sands; Space Bases

19910016279 Oak Ridge National Lab., TN, USA
Radiation shielding requirements for manned deep space missions
Santoro, R. T.; Ingersoll, D. T.; Apr 1, 1991; In English
Contract(s)/Grant(s): DE-AC05-84OR-21400
Report No.(s): DE91-010723; ORNL/TM-11808; No Copyright; Avail: CASI

Galactic cosmic rays (GCR) and, particularly, solar flares (SF) constitute the major radiation hazards in deep space. The dose to astronauts from these radiation sources and the shielding required to mitigate its effect during a 480 day Mars mission is estimated for a simplistic spacecraft geometry. The intent is to ball park the magnitude of the doses for the constant GCR background and for SF's that occur randomly during the mission. The spacecraft shielding and dose data are given only for primary GCR and SF radiation, recognizing that secondary particles produced by primary particle reactions in the spacecraft and High Z-High Energy particles will also contribute to the dose suffered by the astronauts.
DOE
Deep Space; Galactic Cosmic Rays; Manned Space Flight; Radiation Dosage; Radiation Shielding; Solar Flares; Spacecraft Configurations

19910016285 Los Alamos National Lab., NM, USA
Radiation exposure and protection for moon and Mars missions
Macfarlane, R. E.; Prael, R. E.; Strottman, D. D.; Strniste, G. F.; Feldman, W. C.; Apr 1, 1991; In English
Contract(s)/Grant(s): W-7405-ENG-36
Report No.(s): DE91-011346; LA-11904-MS; No Copyright; Avail: CASI

A deep space radiation environment of galactic cosmic rays and energetic particles from solar flares imposes stringent requirements for radiation shielding for both personnel and electronic equipment at a moon base or on a Mars expedition. Current Los Alamos capabilities for calculating the effect of such shielding are described, and extensions and validation needed before actual manned deep space missions are launched are outlined. The biological effects of exposure to cosmic-ray ions and to low doses of radiation at low dose rates are poorly understood. Recent Los Alamos work on mutation effects in cells, DNA repair processes, and the analysis of chromosomal aberrations promises to increase our understanding of the basic processes, to provide methods to screen for radiation sensitivity, and to provide advanced dosimetry equipment for space missions.
DOE
Aerospace Environments; Energetic Particles; Extraterrestrial Radiation; Manned Space Flight; Radiation Dosage; Radiation Protection; Radiation Shielding; Solar Flares

19910051325 NASA Langley Research Center, Hampton, VA, USA, Department of Energy, New York, NY, USA
Analytical relationships of nuclear field and microdosimetric quantities for target fragmentation in tissue systems
Wilson, John W.; Cucinotta, Francis A.; Hajnal, Ferenc; Health Physics; Apr 1, 1991; ISSN 0017-9078; 60; In English; Copyright; Avail: Other Sources

A simple analytic formula for the nuclear fields formed by target fragmentation in tissue systems is derived using the continuous slowing down approximation (CSDA). The energy fluctuations in sensitive localized sites within the tissue system caused by these nuclear events are defined by microdosimetry. In that CSDA is used, the energy fluctuations exclude the role of secondary electrons. The relations also relate to the response of microdosimetric devices to nuclear fragmentation fields.
AIAA
Biological Effects; Linear Energy Transfer (LET); Radiation Distribution; Radiation Dosage

19910042730 Duke Univ., Durham, NC, USA
A deployable high temperature superconducting coil (DHTSC) - A novel concept for producing magnetic shields against both solar flare and Galactic radiation during manned interplanetary missions
Cocks, F. Hadley; British Interplanetary Society, Journal; Mar 1, 1991; ISSN 0007-084X; 44; In English
Contract(s)/Grant(s): NASW-4453; Copyright; Avail: Other Sources

The discovery of materials which are superconducting above 100 K makes possible the use of superconducting coils deployed beyong the hull of an interplanetary spacecraft to produce a magnetic shield capable of giving protection not only against solar flare radiation, but also even against Galactic radiation. Such deployed coils can be of very large size and can thus achieve the great magnetic moments required using only relatively low currents. Deployable high-temperature-superconducting coil magnetic shields appear to offer very substantial reductions in mass and energy compared to other concepts and could readily provide the radiation protection needed for a Mars mission or space colonies.
AIAA
High Temperature Superconductors; Interplanetary Flight; Magnetic Shielding; Manned Space Flight; Radiation Protection

19910007668 NASA Langley Research Center, Hampton, VA, USA
Cellular track model of biological damage to mammalian cell cultures from galactic cosmic rays
Cucinotta, Francis A.; Katz, Robert; Wilson, John W.; Townsend, Lawrence W.; Nealy, John E.; Shinn, Judy L.; Feb 1, 1991; In English
Contract(s)/Grant(s): RTOP 199-04-16-11
Report No.(s): NASA-TP-3055; L-16831; NAS 1.60:3055; No Copyright; Avail: CASI

The assessment of biological damage from the galactic cosmic rays (GCR) is a current interest for exploratory class space missions where the highly ionizing, high-energy, high-charge ions (HZE) particles are the major concern. The relative biological effectiveness (RBE) values determined by ground-based experiments with HZE particles are well described by a parametric track theory of cell inactivation. Using the track model and a deterministic GCR transport code, the biological damage to mammalian cell cultures is considered for 1 year in free space at solar minimum for typical spacecraft shielding. Included are the effects of projectile and target fragmentation. The RBE values for the GCR spectrum which are fluence-dependent in the track model are found to be more severe than the quality factors identified by the International Commission on Radiological Protection publication 26 and seem to obey a simple scaling law with the duration period in free space.
CASI
Biological Models (Mathematics); Cells (Biology); Damage Assessment; Galactic Cosmic Rays; Heavy Ions; Radiation Damage; Radiation Protection; Relative Biological Effectiveness (RBE)

19910008684 NASA Langley Research Center, Hampton, VA, USA
Preliminary calculation of solar cosmic ray dose to the female breast in space mission
Shavers, Mark; Poston, John W.; Atwell, William; Hardy, Alva C.; Wilson, John W.; Feb 1, 1991; In English
Contract(s)/Grant(s): RTOP 199-04-16-11
Report No.(s): NASA-TM-4235; L-16833; NAS 1.15:4235; No Copyright; Avail: CASI

No regulatory dose limits are specifically assigned for the radiation exposure of female breasts during manned space flight. However, the relatively high radiosensitivity of the glandular tissue of the breasts and its potential exposure to solar flare protons on short- and long-term missions mandate a priori estimation of the associated risks. A model for estimating exposure within the breast is developed for use in future NASA missions. The female breast and torso geometry is represented by a simple interim model. A recently developed proton dose-buildup procedure is used for estimating doses. The model considers geomagnetic shielding, magnetic-storm conditions, spacecraft shielding, and body self-shielding. Inputs to the model include

proton energy spectra, spacecraft orbital parameters, STS orbiter-shielding distribution at a given position, and a single parameter allowing for variation in breast size.
CASI
Females; Mammary Glands; Manned Space Flight; Proton Energy; Radiation Dosage; Solar Cosmic Rays; Spacecraft Shielding

19910008685 NASA Langley Research Center, Hampton, VA, USA
Preliminary analysis of a radiobiological experiment for LifeSat
Wilson, John W.; Townsend, Lawrence W.; Nealy, John E.; Hardy, Alva C.; Atwell, William; Schimmerling, Walter; Feb 1, 1991; In English
Contract(s)/Grant(s): RTOP 199-04-16-11
Report No.(s): NASA-TM-4236; L-16844; NAS 1.15:4236; No Copyright; Avail: CASI

With the possibility of performing radiation life science experiments on a dedicated satellite (LifeSat) in space, a combined effort in radiation physics and radiation dosimetry, in addition to radiation biology, is clearly required to ensure that meaningful biological experiments can be performed. To better understand the relationship of these disciplines, some possible LifeSat missions are examined. As a trial biological system, tumorigenesis is considered in the Harderian gland of mice, a system of sufficient radiosensitivity for which relative biological effectiveness (RBE) is well defined by laboratory experiments.
CASI
Biological Effects; Life Sciences; Radiation Dosage; Radiation Tolerance; Radiobiology; Relative Biological Effectiveness (RBE)

19910008686 NASA Langley Research Center, Hampton, VA, USA
Radiation protection for human missions to the Moon and Mars
Simonsen, Lisa C.; Nealy, John E.; Feb 1, 1991; In English
Contract(s)/Grant(s): RTOP 326-83-10-50
Report No.(s): NASA-TP-3079; L-16892; NAS 1.60:3079; No Copyright; Avail: CASI

Radiation protection assessments are performed for advanced Lunar and Mars manned missions. The Langley cosmic ray transport code and the nucleon transport code are used to quantify the transport and attenuation of galactic cosmic rays and solar proton flares through various shielding media. Galactic cosmic radiation at solar maximum and minimum, as well as various flare scenarios are considered. Propagation data for water, aluminum, liquid hydrogen, lithium hydride, lead, and lunar and Martian regolith (soil) are included. Shield thickness and shield mass estimates required to maintain incurred doses below 30 day and annual limits (as set for Space Station Freedom and used as a guide for space exploration) are determined for simple geometry transfer vehicles. On the surface of Mars, dose estimates are presented for crews with their only protection being the carbon dioxide atmosphere and for crews protected by shielding provided by Martian regolith for a candidate habitat.
CASI
Galactic Cosmic Rays; Lunar Surface; Mars Surface; Nucleons; Radiation Protection; Radiation Shielding; Space Stations

19910038835
Radiation protection strategies in Hermes missions
Bourdeaud'hui, J. C.; Feuillais, N.; Contant, J.-M.; Acta Astronautica; JAN 1, 1991; ISSN 0094-5765; 23; In English; Copyright; Avail: Other Sources

The radiation environment in circumterrestial space is discussed, and doses received over several Hermes missions are predicted. Various strategies for avoiding dangerous dose levels are examined. For low inclination orbits and orbits of 28.5-deg inclination (which will be used most frequently by Hermes), the danger from radiation is found to be low. The dose level during EVA can be reduced by correct planning of the time out. During an anomalously large solar event, special precautions may need to be taken, depending on the orbit used, and in polar missions an emergency return should be planned for.
AIAA
Earth Orbital Environments; Hermes Manned Spaceplane; Radiation Hazards; Radiation Protection

19920017575 Brookhaven National Lab., Upton, NY, USA
Human round trip to Mars: Six months and radiation safe
Lazareth, O. W.; Schmidt, E.; Ludewig, H.; Powell, J. R.; JAN 1, 1991; In English; 9th, 13-16 Jan. 1992, Albuquerque, NM, USA
Contract(s)/Grant(s): DE-AC02-76CH-00016
Report No.(s): DE92-010160; BNL-46287-REV; CONF-920104-6-REV; No Copyright; Avail: CASI

We describe a different type of round trip to Mars, using a combination of spacecraft. Compared to typical proposals, this flight is relatively fast and relatively safe from biological radiation dosage. Our study is concerned with the trip from Earth orbit to Mars orbit. Four spacecraft are required for the round trip. The crew spends most of their time on board a comparatively large, well shielded spacecraft (LC) which is in free (non-powered) orbit about the sun. The crew travels from Earth orbit to the LC while on board a comparatively small, powered spacecraft (SC). At Mars, the procedure is reversed and the crew returns on a second LC. In addition, a cargo craft, with no crew, is sent to Mars prior to the crew leaving Earth orbit. The trip time is about six months and the radiation dose equivalent is within guidelines recommended by the National Commission on Radiation Protection and Measurements.
DOE
Aerospace Vehicles; Health Physics; Interplanetary Spacecraft; Manned Mars Missions; Radiation Dosage; Radiation Protection

19920051296 NASA Langley Research Center, Hampton, VA, USA
Biological effectiveness of high-energy protons - Target fragmentation
Cucinotta, Francis A.; Katz, Robert; Wilson, John W.; Townsend, Lawrence W.; Shinn, Judy; Hajnal, Ferenc; Radiation Research; JAN 1, 1991; ISSN 0033-7587; 127; In English; Copyright; Avail: Other Sources

High-energy protons traversing tissue produce local sources of high-linear-energy-transfer ions through nuclear fragmentation. The contribution of these target fragments to the biological effectiveness of high-energy protons using the cellular track model is examined. The effects of secondary ions are treated in terms of the production collision density using energy-dependent parameters from a high-energy fragmentation model. Calculations for mammalian cell cultures show that at high dose, at which intertrack effects become important, protons deliver damage similar to that produced by gamma rays, and with fragmentation the relative biological effectiveness (RBE) of protons increases moderately from unity. At low dose, where sublethal damage is unimportant, the contribution from target fragments dominates, causing the proton effectiveness to be very different from that of gamma rays with a strongly fluence-dependent RBE. At high energies, the nuclear fragmentation cross sections become independent of energy. This leads to a plateau in the proton single-particle-action cross section, below 1 keV/micron, since the target fragments dominate.
AIAA
Biological Effects; Energy Transfer; Nuclear Scattering; Particle Collisions; Proton Energy; Radiation Damage

19910062147 NASA Langley Research Center, Hampton, VA, USA
Interplanetary crew exposure estimates for the August 1972 and October 1989 solar particle events
Townsend, Lawrence W.; Shinn, Judy L.; Wilson, John W.; Radiation Research; JAN 1, 1991; ISSN 0033-7587; 126; In English; Copyright; Avail: Other Sources

Detailed exposure estimates for the bone marrow, ocular lens, and skin of astronauts on manned missions beyond the earth's magnetosphere have been made for the large solar particle events (SPE) of August 1972 and October 1989. The estimates were made using the coupled neutron-proton space radiation transport computer code BRYNTRN and the CAM model for the human body. It is found that at least 10 g/sq cm aluminum shielding is needed to keep estimated dose equivalent values below current space radiation exposure guidelines recommended for LEO missions. Space suits currently being designed will not provide adequate crew protection and may not even ensure crew survival in the event of exposure to a large SPE during extravehicular activity.
AIAA
Radiation Dosage; Radiation Tolerance; Solar Neutrons; Solar Protons; Spacecrews

19910004952 NASA Langley Research Center, Hampton, VA, USA
Space radiation dose analysis for solar flare of August 1989
Nealy, John E.; Simonsen, Lisa C.; Sauer, Herbert H.; Wilson, John W.; Townsend, Lawrence W.; Dec 1, 1990; In English
Contract(s)/Grant(s): RTOP 326-22-20-50
Report No.(s): NASA-TM-4229; L-16812; NAS 1.15:4229; No Copyright; Avail: CASI

Potential dose and dose rate levels to astronauts in deep space are predicted for the solar flare event which occurred during the week of August 13, 1989. The Geostationary Operational Environmental Satellite (GOES-7) monitored the temporal development and energy characteristics of the protons emitted during this event. From these data, differential fluence as a function of energy was obtained in order to analyze the flare using the Langley baryon transport code, BRYNTRN, which describes the interactions of incident protons in matter. Dose equivalent estimates for the skin, ocular lens, and vital organs for 0.5 to 20 g/sq cm of aluminum shielding were predicted. For relatively light shielding (less than 2 g/sq cm), the skin and ocular lens 30-day exposure limits are exceeded within several hours of flare onset. The vital organ (5 cm depth) dose equivalent is exceeded only for the thinnest shield (0.5 g/sq cm). Dose rates (rem/hr) for the skin, ocular lens, and vital organs are also computed.
CASI
Extraterrestrial Radiation; Protons; Radiation Dosage; Radiation Shielding; Solar Flares

19910062149 NASA Lyndon B. Johnson Space Center, Houston, TX, USA, Rockwell International Corp., Houston, TX, USA, Department of Energy, New York, NY, USA, NASA Langley Research Center, Hampton, VA, USA
Energy deposition at the bone-tissue interface from nuclear fragments produced by high-energy nucleons
Cucinotta, Francis A.; Hajnal, Ferenc; Wilson, John W.; Health Physics; Dec 1, 1990; ISSN 0017-9078; 59; In English; Copyright; Avail: Other Sources

The transport of nuclear fragmentation recoils produced by high-energy nucleons in the region of the bone-tissue interface is considered. Results for the different flux and absorbed dose for recoils produced by 1 GeV protons are presented in a bidirectional transport model. The energy deposition in marrow cavities is seen to be enhanced by recoils produced in bone. Approximate analytic formulae for absorbed dose near the interface region are also presented for a simplified range-energy model.
AIAA
Musculoskeletal System; Nuclear Radiation; Radiation Damage; Radiation Dosage

19920006312 Trinity Univ., San Antonio, TX, USA
Late immunobiological effects of space radiation
Stone, William H.; Miller, Michael L.; Dec 1, 1990; In English
Contract(s)/Grant(s): F33615-87-D-0626
Report No.(s): AD-A242590; USAFSAM-TR-90-39; No Copyright; Avail: CASI

The objective of this investigation was to obtain profiles of immune competence in primates more than 25 years following exposures to protons. The availability of irradiated animals provided a unique opportunity to study immune defects which could be relevant to astronauts and high flying pilots. The Delayed Radiation Effects Colony at Brooks Air Force Base provided blood samples. Antibody mediated immune function (associated with B-cell function) was assessed by measuring immunoglobulin levels, hemolytic complement activity and autoantibodies; cell mediated immune function (associated with T-cell function) was evaluated by measuring selected T and B cell activity plus response to mitogens and interleukin production. There were no significant differences between control and irradiated animals for most parameters measured in this preliminary survey, but lymphocyte proliferation tended to decrease as radiation dosage increased. Survivors of low and intermediate doses of proton irradiation apparently show few late immunobiological effects, which is encouraging. Additional monkeys will be measured in future confirmatory studies.
DTIC
Biological Effects; Extraterrestrial Radiation; Globulins; Immunology; Proton Irradiation; Radiation Dosage; Radiation Effects

19910004672 NASA Langley Research Center, Hampton, VA, USA
Inclusive inelastic scattering of heavy ions and nuclear correlations
Cucinotta, Francis A.; Townsend, Lawrence W.; Wilson, John W.; Khandelwal, Govind S.; Nov 1, 1990; In English
Contract(s)/Grant(s): RTOP 199-04-16-11
Report No.(s): NASA-TP-3026; L-16793; NAS 1.60:3026; No Copyright; Avail: CASI

Calculations of inclusive inelastic scattering distributions for heavy ion collisions are considered within the high energy optical model. Using ground state sum rules, the inclusive projectile and complete projectile-target inelastic angular distributions are treated in both independent particle and correlated nuclear models. Comparisons between the models introduced are made for alpha particles colliding with He-4, C-12, and O-16 targets and protons colliding with O-16. Results

indicate that correlations contribute significantly, at small momentum transfers, to the inelastic sum. Correlation effects are hidden, however, when total scattering distributions are considered because of the dominance of elastic scattering at small momentum transfers.
CASI
Angular Distribution; Heavy Ions; Inelastic Scattering; Ion Scattering; Ionic Collisions; Momentum Transfer; Relativistic Particles

19910010366 Commissariat a l'Energie Atomique, Fontenay-aux-Roses, France
New experimental approach in quality factor and dose equivalent determination during a long term manned space mission
Nguyen, Van Dat; Bouisset, P.; Parmentier, N.; Siegrist, M.; Akatov, Y. A.; Archangelsky, V. V.; Vorojtsov, S.; Koslova, S. B.; Mitrikas, V. G.; Petrov, V. M., et al.; ESA, Fourth European Symposium on Life Sciences Research in Space; Nov 1, 1990; In English; Copyright; Avail: CASI

Due to high LET (Linear Energy Transfer) particles existing in space environment, the knowledge of the quality factor is one of priority in radiation protection efforts. During the French Soviet space mission Aragatz, the experiment CIRCE (complex beam in space counter integrator) had recorded dose equivalent and quality factor values inside the MIR station. Results obtained with a new experimental approach by using an active dose equivalent meter based on microdosimetric techniques and a low pressure tissue equivalent proportional counter are presented. In terms of lineal energy, the CIRCE device works in the 0.3 to 1200 keV micron range in tissue. The average dose equivalent is equal to 0.6 mSv. per day and the mean value of quality factor is equal to 1.9. Through the SAA the dose equivalent rate rapidly increases until 1.20 mSv./h and the corresponding quality factor decreases to 1.4.
ESA
Aerospace Environments; Dosimeters; Long Duration Space Flight; Manned Space Flight; Q Factors; Radiation Dosage

19910010367 Johann-Wolfgang-Goethe-Univ., Frankfurt am Main, Germany
Genetic risk and physiological stress induced by heavy ions
Kranz, A. R.; ESA, Fourth European Symposium on Life Sciences Research in Space; Nov 1, 1990; In English
Contract(s)/Grant(s): BMFT-01-QV-85650; Copyright; Avail: CASI

For the evaluation of heavy ion radiation to human beings on Earth and in space, complete estimation of the total damage (gene mutation, chromosome aberration, cell lethality) of an individual (high-ionizing high energy particles) ion hit is needed. For this the resting embryo of the Arabidopsis seed was a successful test subject in accelerator and space flight experiments. The high-ionizing high energy particles' effect on the genetic lethality, tumorization and the physiological germination and flowering were investigated. The observed endpoints of the heavy ion effect correlated with energy and charge of the high-ionizing high energy particles and the target size of cell nucleus. Particular high-ionizing high energy particles cross sections and specific damage endpoints were obtained resembling both the physiological stress and genetic risk.
ESA
Fruits; Genetics; Germination; Heavy Ions; Lethality; Radiation Dosage; Space Flight; Tumors

19910010386 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Predictions of cell damage rates for Lifesat missions
Cucinotta, Francis A.; Atwell, William; Hardy, Alva C.; Golightly, Michael J.; Wilson, John W.; Townsend, Lawrence W.; Shinn, Judy; Nealy, John E.; Katz, Robert; Nov 1, 1990; In English
Report No.(s): NASA-TM-102170; S-616; NAS 1.15:102170; No Copyright; Avail: CASI

The track model of Katz is used to make predictions of cell damage rates for possible Lifesat experiments. Contributions from trapped protons and electrons and galactic cosmic rays are considered for several orbits. Damage rates for survival and transformation of C3HT10-1/2 cells are predicted for various spacecraft shields.
CASI
Cells (Biology); Exobiology; Extraterrestrial Radiation; Gravitational Effects; Life Sciences; Radiation Damage; Scientific Satellites

19910019406 California Univ., Berkeley. Lawrence Berkeley Lab, CA, USA
Chromosomal changes in cultured human epithelial cells transformed by low- and high-LET radiation
Yang, Tracy Chui-Hsu; Craise, L. M; Prioleau, J. C.; Stampfer, M. R.; Rhim, J. S.; Nov 1, 1990; In English, 25 Jun. - 6 Jul. 1990, The Hague, Netherlands
Contract(s)/Grant(s): DE-AC03-76SF-00098
Report No.(s): DE91-013772; LBL-30024; CONF-9006220-9; No Copyright; Avail: CASI

For a better assessment of radiation risk in space, an understanding of the responses of human cells, especially the epithelial cells, to low- and high-LET radiation is essential. In our laboratory, we have successfully developed techniques to study the neoplastic transformation of two human epithelial cell systems by ionizing radiation. These cell systems are human mammary epithelial cells (H184B5) and human epidermal keratinocytes (HEK). Both cell lines are immortal, anchorage dependent for growth, and nontumorigenic in athymic nude nice. Neoplastic transformation was achieved by irradiation cells successively. Our results showed that radiogenic cell transformation is a multistep process and that a single exposure of ionizing radiation can cause only one step of transformation. It requires, therefore, multihits to make human epithelial cells fully tumorigenic. Using a simple karyotyping method, we did chromosome analysis with cells cloned at various stages of transformation. We found no consistent large terminal deletion of chromosomes in radiation-induced transformants. Some changes of total number of chromosomes, however, were observed in the transformed cells. These transformants provide an unique opportunity for further genetic studies at a molecular level.
DOE
Animals; Cells (Biology); Chromosomes; Ionizing Radiation; Mammary Glands; Pathogenesis; Radiation Effects

19910019819 California Univ., Berkeley. Lawrence Berkeley Lab, CA, USA
Ground-based measurements of galactic cosmic ray fragmentation in shielding
Schimmerling, W.; Nov 1, 1990; In English, 25 Jun. - 6 Jul. 1990, The Hague, Netherlands
Contract(s)/Grant(s): DE-AC03-76SF-00098
Report No.(s): DE91-012336; LBL-30022; CONF-9006220-8; No Copyright; Avail: CASI

The mean free path for nuclear interactions of galactic cosmic rays is comparable to shielding and tissue thicknesses present in human interplanetary exploration, resulting in a significant fraction of nuclear reaction products at depth. In order to characterize the radiation field, the energy spectrum, the angular distribution, and the multiplicity of each type of secondary particles must also be known as a function of depth. Reactions can take place anywhere in a thick absorber; therefore, it is necessary to know these quantities as a function of particle energy for all particles produced. HZE transport methods are used to predict the radiation field; they are dependent on models of the interaction of man-made systems with the space environment to an even greater extent than methods used for other types of radiation. Hence, there is a major need to validate these transport codes by comparison with experimental data. The most cost-effective method of validation is a comparison with ground-based experimental measurements. A research program to provide such validation measurements using neon, iron and other accelerated heavy ion beams will be discussed and illustrated using results from ongoing experiments and their comparison with current transport codes. The extent to which physical measurements yield radiobiological predictions will be discussed.
DOE
Energy Spectra; Fragmentation; Galactic Cosmic Rays; Mean Free Path; Nuclear Reactions; Radiation Shielding; Reaction Products

19920007333 Slovak Technical Univ., Bratislava, Czechoslovakia, Univerzita Pavla Jozefa Safarika, Koscice, Czechoslovakia, Ceskoslovenska Vedeckotechnicka Spolecnost, Prague., USA
Programme and abstracts of contributions presented at the National Radiobiology Conference
Nov 1, 1990; In Czech, Tatranska Lomnica, Czechoslovakia
Report No.(s): DE91-641203; INIS-MF-12891; CONF-9011228; No Copyright; Avail: CASI

The publication contains 63 abstracts of contributions and posters, all of which fall within the INIS scope; they deal with radiation damage at the level of animal cells, pathology of radiation injuries and biochemical changes following irradiation, radiation protection, radiation-induced changes of blood formation, and clinical radiobiology and oncology. Attention is paid to somatic and genetic damage and to metabolic changes.
DOE
Conferences; Pathology; Radiation Damage; Radiation Injuries; Radiation Protection; Radiobiology

19910006721 Bundesministerium fuer Forschung und Technologie, Bonn, Germany
The space flights: Second German Spacelab mission D-2 and Mir 1992
Oct 8, 1990; In German
Report No.(s): REPT-25/90; No Copyright; Avail: CASI

The German research programs of the Spacelab missions are presented. The following topics were studied: fluid physics (capillarity, Marangoni convection), crystallography, biology, human physiology (heart function, respiration), robotics, microgravity, Earth observation (cartography), astronomy. The institutes which cooperated in these programs are reviewed. Some experiments are more precisely described, such as diffusion in metallic fusion, crystalization of biologic macromolecules or doximetry of spatial radiation. The experiments of Mir mission are also depicted, which are based on physiology and radiation protection.
ESA
Exobiology; Germany; Microgravity; Microgravity Applications; Mir Space Station; Spaceborne Experiments; Spacelab; Weightlessness

19900019974 NASA Langley Research Center, Hampton, VA, USA
Comparison of dose estimates using the buildup-factor method and a Baryon transport code (BRYNTRN) with Monte Carlo results
Shinn, Judy L.; Wilson, John W.; Nealy, John E.; Cucinotta, Francis A.; Oct 1, 1990; In English
Contract(s)/Grant(s): RTOP 199-04-16-11
Report No.(s): NASA-TP-3021; L-16806; NAS 1.60:3021; No Copyright; Avail: CASI

Continuing efforts toward validating the buildup factor method and the BRYNTRN code, which use the deterministic approach in solving radiation transport problems and are the candidate engineering tools in space radiation shielding analyses, are presented. A simplified theory of proton buildup factors assuming no neutron coupling is derived to verify a previously chosen form for parameterizing the dose conversion factor that includes the secondary particle buildup effect. Estimates of dose in tissue made by the two deterministic approaches and the Monte Carlo method are intercompared for cases with various thicknesses of shields and various types of proton spectra. The results are found to be in reasonable agreement but with some overestimation by the buildup factor method when the effect of neutron production in the shield is significant. Future improvement to include neutron coupling in the buildup factor theory is suggested to alleviate this shortcoming. Impressive agreement for individual components of doses, such as those from the secondaries and heavy particle recoils, are obtained between BRYNTRN and Monte Carlo results.
CASI
Computer Programs; Extraterrestrial Radiation; Monte Carlo Method; Radiation Dosage; Radiation Shielding; Radiation Transport

19910029448
Radiation shielding estimation for manned space flight to the Mars
Dudkin, V. E.; Kovalev, E. E.; Kolomenskii, A. V.; Sakovich, V. A.; Semenov, V. F., et al.; Oct 1, 1990; In English
Report No.(s): IAF PAPER 90-544; Copyright; Avail: Other Sources

The problem of shielding the crew from radiation during Mars missions is studied. Radiation hazards caused by Galactic cosmic rays (GCR) and solar cosmic rays (SCR) are considered, and it is noted that a radiation-proof shelter can reduce the hazards associated with SCR, while the shielding from multicharged GCR ions may be required for a habitation section of the spacecraft. The pulse operation of a nuclear rocket engine may also require some additional shielding of the crew and liquid-hydrogen tanks against reactor radiation. It is pointed out that any long-term residence within the earth radiation belt can be avoided by using certain combinations of space flight conditions, while Martian mission conditions may be attained by solving the problem of optimal distribution of the mass components for shadow shielding of the reactor and for shielding of the radiation-proof shelter and habitation section. The lowest estimate of the spacecraft mass including the radiation-shielding mass is found to be 500-550 tons.
AIAA
Earth-Mars Trajectories; Flight Crews; Manned Mars Missions; Radiation Shielding

19910029449 Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA, USA
Radiation biology of HZE particles
Nelson, Gregory A.; Oct 1, 1990; In English
Report No.(s): IAF PAPER 90-548; Copyright; Avail: Other Sources

The biological effects of heavy charged particle (HZE) radiation are of particular interest to travellers and planners for long duration space flights where exposure levels represent a potential health hazard. The unique feature of HZE radiation is the structured pattern of its energy deposition in targets which may be related to charge, velocity, or rate of energy loss. There are many consequences of this feature to biological endpoints when compared to effects of ionizing photons. Dose vs response and dose rate kinetics are modified, DNA and cellular repair systems are altered in their abilities to cope with damage and, the qualitative features of damage are unique for different ions. These features must be incorporated into any risk assessment system for radiation health management. HZE induced mutation, cell inactivation and altered organogenesis will be discussed emphasizing studies with the nematode Caenorhabditis elegans and cultured cells. Observations from radiobiology experiments in space will also be reviewed along with plans for future space-based studies.
AIAA
Biological Effects; Charged Particles; Long Duration Space Flight; Radiation Hazards; Radiobiology

19910029451 Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA, USA
The HZE radiation problem
Schimmerling, Walter; Oct 1, 1990; In English
Contract(s)/Grant(s): NIH-CA-23247; DE-AC03-76SF-00098
Report No.(s): IAF PAPER 90-553; Copyright; Avail: Other Sources

Radiation-exposure limits have yet to be established for missions envisioned in the framework of the Space Exploration Initiative. The radiation threat outside the earth's magnetosphere encompasses protons from solar particle events and the highly charged energetic particles constituting galactic cosmic rays; radiation biology entails careful consideration of the extremely nonuniform patterns of such particles' energy deposition. The ability to project such biological consequences of exposure to energetic particles as carcinogenicity currently involves great uncertainties from: (1) different regions of space; (2) the effects of spacecraft structures; and (3) the dose-effect relationships of single traversals of energetic particles.
AIAA
Extraterrestrial Radiation; Galactic Cosmic Rays; Ionizing Radiation; Radiation Effects; Radiation Hazards

19910029503
Cost considerations of solar events on manned space missions
Melkonian, G.; Bourrieau, J.; Romero, M.; Oct 1, 1990; In English
Report No.(s): IAF PAPER 90-598; Copyright; Avail: Other Sources

Solar events risk is discussed for solar low earth orbits, GEO servicing, and moon and Mars missions. The radiation dangers to which a spacecraft is typically exposed are discussed and the resulting biological effects are outlined. These can be classified into the categories of nonstochastic and stochastic effects. Benefits of solar forecasting in order to lessen the deleterious effects of a solar flare are noted including launch postponement, EVA interruption, and space plane reconfiguration for evasion maneuvers or for an early return. The radiation risks resulting from solar flares are compared for a low earth polar orbit, a high altitude mission, a lunar mission, and a Mars mission.
AIAA
Aerospace Safety; Cost Analysis; Manned Space Flight; Radiation Protection; Solar Flares

19910029553
Dosimetric complex for long-time manned space flights
Akatov, IU.; Kovalev, E. E.; Sakovich, V. A.; Deme, S.; Feher, I., et al.; Oct 1, 1990; In English
Report No.(s): IAF PAPER 90-546; Copyright; Avail: Other Sources

The design of a spacecraft radiation safety system for long-term manned space flights is discussed. Consideration is given to the methods for calculating the radiation risk when taking into account the prescribed space flight programs and strict schedules, as well as the probability of deviations. The onboard radiation monitoring systems are described with special attention given to sensors used for continuous monitoring of the absorbed dose.
AIAA
Dosimeters; Long Duration Space Flight; Manned Space Flight; Radiation Protection

19930074955 Lawrence Livermore National Lab., Livermore, CA, USA
Bibliographical database of radiation biological dosimetry and risk assessment, part 2
Straume, T.; Ricker, Y.; Thut, M.; Sep 1, 1990; In English
Contract(s)/Grant(s): W-7405-ENG-48
Report No.(s): DE93-009505; UCRL-21107-PT-2; No Copyright; Avail: CASI

This is part 2 of a database constructed to support research in radiation biological dosimetry and risk assessment. Relevant publications were identified through detailed searches of national and international electronic databases and through our personal knowledge of the subject. Publications were numbered and key worded, and referenced in an electronic data-retrieval system that permits quick access through computerized searches on authors, key words, title, year, journal name, or publication number. Photocopies of the publications contained in the database are maintained in a file that is numerically arranged by our publication acquisition numbers. This volume contains 1048 additional entries, which are listed in alphabetical order by author. The computer software used for the database is a simple but sophisticated relational database program that permits quick information access, high flexibility, and the creation of customized reports. This program is inexpensive and is commercially available for the Macintosh and the IBM PC. Although the database entries were made using a Macintosh computer, we have the capability to convert the files into the IBM PC version. As of this date, the database cites 2260 publications. Citations in the database are from 200 different scientific journals. There are also references to 80 books and published symposia, and 158 reports. Information relevant to radiation biological dosimetry and risk assessment is widely distributed within the scientific literature, although a few journals clearly predominate. The journals publishing the largest number of relevant papers are Health Physics, with a total of 242 citations in the database, and Mutation Research, with 185 citations. Other journals with over 100 citations in the database are Radiation Research, with 136, and International Journal of Radiation Biology, with 132.
DOE
Computer Programs; Data Bases; Data Retrieval; Dosimeters; Health Physics; Indexes (Documentation); Radiation Dosage

19900057580
Medicinal protection with Chinese herb-compound against radiation damage
Zhang, Ruijun; Qian, Jinkang; Yang, Guanghua; Wang, Baozhen; Wen, Xiulan; Aviation, Space, and Environmental Medicine; Aug 1, 1990; ISSN 0095-6562; 61; In English; Copyright; Avail: Other Sources

Experiments were carried out on mice and on subjects irradiated for cancer therapy to evaluate the protective efficacy of a Chinese medicinal-herb-compound (CMHC). The lethality and the degree of leucopenia caused by radiation in mice medicated with CMHC were significantly less in comparison with control mice (p less than 0.01 and p less than 0.001, respectively). CMHC significantly improved the WBC and the thrombocytes in irradiated workers (p less than 0.01 and p less than 0.001, respectively). The WBC count of 40 patients under radiotherapy while treated with CMHC recovered from 3450 + or - 77/c mm to 5425 + or - 264/c mm (p less than 0.001); whereas, in the control group, without any medication, the WBC count dropped significantly (p less than 0.001).
AIAA
China; Plants (Botany); Radiation Damage; Radiation Protection; Radiation Therapy

19900060046 NASA Langley Research Center, Hampton, VA, USA
Space radiation dose estimates on the surface of Mars
Simonsen, Lisa C.; Nealy, John E.; Townsend, Lawrence W.; Wilson, John W.; Journal of Spacecraft and Rockets; Aug 1, 1990; ISSN 0022-4650; 27; In English; Copyright; Avail: Other Sources

The Langley cosmic ray transport code and the Langley nucleon transport code (BRYNTRN) are used to quantify the transport and attenuation of galactic cosmic rays (GCR) and solar proton flares through the Martian atmosphere. Surface doses are estimated using both a low density and a high density carbon dioxide model of the atmosphere which, in the vertical direction, provides a total of 16 g/sq cm and 22 g/sq cm of protection, respectively. At the Mars surface during the solar minimum cycle, a blood-forming organ (BFO) dose equivalent of 10.5 to 12 rem/yr due to galactic cosmic ray transport and attenuation is calculated. Estimates of the BFO dose equivalents which would have been incurred from the three large solar flare events of August 1972, November 1960, and February 1956 are also calculated at the surface. Results indicate surface BFO dose equivalents of approximately 2 to 5, 5 to 7, and 8 to 10 rem per event, respectively. Doses are also estimated at altitudes up to 12 km above the Martian surface where the atmosphere will provide less total protection.
AIAA
Galactic Cosmic Rays; Manned Mars Missions; Mars Atmosphere; Mars Surface; Radiation Dosage; Solar Flares

19910002043 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Radiological health risks to astronauts from space activities and medical procedures
Peterson, Leif E.; Nachtwey, D. Stuart; Aug 1, 1990; In English
Report No.(s): NASA-TM-102164; S-610; NAS 1.15:102164; No Copyright; Avail: CASI

Radiation protection standards for space activities differ substantially from those applied to terrestrial working situations. The levels of radiation and subsequent hazards to which space workers are exposed are quite unlike anything found on Earth. The new more highly refined system of risk management involves assessing the risk to each space worker from all sources of radiation (occupational and non-occupational) at the organ level. The risk coefficients were applied to previous space and medical exposures (diagnostic x ray and nuclear medicine procedures) in order to estimate the radiation-induced lifetime cancer incidence and mortality risk. At present, the risk from medical procedures when compared to space activities is 14 times higher for cancer incidence and 13 times higher for cancer mortality; however, this will change as the per capita dose during Space Station Freedom and interplanetary missions increases and more is known about the risks from exposure to high-LET radiation.
CASI
Extraterrestrial Radiation; Health; Radiation Dosage; Radiation Hazards; Radiation Protection; Space Stations; Spacecrews

19900062011 NASA Langley Research Center, Hampton, VA, USA, Hampton Univ., VA, USA
Risk assessment methodologies for target fragments produced in high-energy nucleon reactions
Shinn, J. L.; Wilson, J. W.; Ngo, D. M.; Health Physics; Jul 1, 1990; ISSN 0017-9078; 59; In English; Copyright; Avail: Other Sources

Collisions of energetic protons with target nuclei yield nuclear products of large linear energy transfer, and it is usually assumed that the energy of the heavy products is absorbed locally with a quality factor of 20. Past methods of risk assessment have relied on the Bertini (1969) model to evaluate the nuclear reaction products. If the Q(F) of 20 is correct, then a significant underestimate of biological risk from the nuclear products could result from the use of Bertini's model. On the other hand, a Q(F) of 20 is probably too large for some of the lighter fragments, leaving prior risk estimates as possibly correct or even conservative. This issue is discussed here in the context of the recently proposed nuclear data set of Wilson et al. (1989).
AIAA
Biological Effects; Energetic Particles; Nuclear Reactions; Nucleons; Particle Collisions; Radiation Hazards

19900062245 Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA, USA
LifeSat - Radiation research
Nelson, Gregory A.; Jul 1, 1990; In English
Report No.(s): SAE PAPER 901228; Copyright; Avail: Other Sources

Spaceflight crews will be exposed to levels of radiation which exceed those experienced on the ground. In order to reduce the uncertainty in the evaluation of risks it is necessary to validate the responses of biological systems in space under conditions which simulate exposure levels expected during exploration class missions. The LifeSat system provides the experimental capabilities to satisfy these goals. Specifically, LifeSat is capable of long duration flights of up to 60 days, is able to fly directly into trapped radiation belts and in circular or eccentric polar orbits, has the ability to provide artificial gravity and imposes fewer restrictions than the STS on the use of hazardous materials such as chemical fixatives. These features along with reference missions and experiments are discussed with respect to radiation research goals.
AIAA
Earth Orbital Environments; Extraterrestrial Radiation; Long Duration Space Flight; Radiation Measurement; Radiobiology

19900062322
Astronaut exposure to space radiation - Space Shuttle experience
Atwell, William; Jul 1, 1990; In English
Report No.(s): SAE PAPER 901342; Copyright; Avail: Other Sources

Space Shuttle astronauts are exposed to both the 'trapped' radiation and the galactic cosmic radiation environments. In addition, the sun periodically emits high-energy particles which could pose a serious threat to flight crews. NASA adheres to federal regulations and recommended exposure limits for radiation protection and has established a radiological health and risk assessment program. Using models of the space radiation environment, a Shuttle shielding model, and an anatomical human model, crew exposure estimates are made for each Shuttle flight. The various models are reviewed. Dosimeters are worn by each astronaut and are flown at several fixed locations to obtain inflight measurements. The dosimetry complement is discussed in detail. A comparison between the premission calculations and measurements is presented. Extrapolation of Shuttle experience to long-duration exposure is explored.
AIAA
Astronaut Performance; Cosmic Rays; Radiation Dosage; Radiation Protection; Spacecraft Shielding

19900062323 NASA Langley Research Center, Hampton, VA, USA
Radiation protection effectiveness of a proposed magnetic shielding concept for manned Mars missions
Townsend, Lawrence W.; Wilson, John W.; Shinn, J. L.; Nealy, John E.; Simonsen, Lisa C.; Jul 1, 1990; In English
Report No.(s): SAE PAPER 901343; Copyright; Avail: Other Sources

The effectiveness of a proposed concept for shielding a manned Mars vehicle using a confined magnetic field configuration is evaluated by computing estimated crew radiation exposures resulting from galactic cosmic rays and a large solar flare event. In the study the incident radiation spectra are transported through the spacecraft structure/magnetic shield using the deterministic space radiation transport computer codes developed at Langley Research Center. The calculated exposures unequivocally demonstrate that magnetic shielding could provide an effective barrier against solar flare protons but is virtually transparent to the more energetic galactic cosmic rays. It is then demonstrated that through proper selection of materials and shield configuration, adequate and reliable bulk material shielding can be provided for the same total mass as needed to generate and support the more risky magnetic field configuration.
AIAA
Magnetic Field Configurations; Magnetic Shielding; Manned Mars Missions; Radiation Protection; Spacecraft Shielding; Spacecrews

19900062326 NASA Langley Research Center, Hampton, VA, USA
Deep-space radiation exposure analysis for solar cycle XXI (1975-1986)
Nealy, John E.; Simonsen, Lisa C.; Townsend, Lawrence W.; Wilson, John W.; Jul 1, 1990; In English
Report No.(s): SAE PAPER 901347; Copyright; Avail: Other Sources

Ionizing radiation exposures and associated dosimetric quantities are evaluated for the 11-year solar cycle ending in 1986. Solar flare fluences for the 55 largest flares occurring during the cycle are superimposed on the Galactic cosmic ray flux. Published summaries of flare data from the Interplanetary Monitoring Platform (IMP)-7 and IMP-8 satellites are used that include flares whose integrated fluences are greater than 10 to the 7th protons/sq cm for energies in excess of 10 MeV. A standard cosmic ray environment model for ion flux values at solar minimum and maximum is invoked with an assumed sinusoidal variation between the lower and upper limits. The radiation shielding analysis is carried out for equivalent water-shield thicknesses between 2 and 15 g/sq cm. Results are expressed in terms of cumulative incurred dose equivalents for deep-space missions lasting between 3 months and 3 years. It was found that medium-to-large flare contributions are of greatest importance for the shorter term missions, while the Galactic component dominates for the longer duration missions.
AIAA
Extraterrestrial Radiation; Long Duration Space Flight; Radiation Measurement; Radiation Shielding; Solar Flares

19900062328
Superhelicity and DNA radiation sensitivity
Swenberg, Charles E.; Holwitt, Eric A.; Speicher, James M.; Jul 1, 1990; In English
Report No.(s): SAE PAPER 901349; Copyright; Avail: Other Sources

Several underwound families of topoisomers of the plasmid pIB130 were irradiated with fission neutrons at 28 c in TE buffer. Form I DNA followed the expected exponential dependence on dose, and was greater for those DNA molecules characterized by larger linking numbers. The radiation sensitivity was found to be linearly related to average linking difference. This enhanced radiation sensitivity is tentatively attributed to the increased number of transient open states that closed DNA experiences with increasing superhelicity. Radioprotectants enhance decrease in the DNA linking number in the presence of topoisomerase I suggests that some of the protection conferred may be due to decreases in DNA superhelicity.
AIAA
Deoxyribonucleic Acid; Isomers; Links (Mathematics); Radiation Damage; Radiation Tolerance

19900015715 NASA Langley Research Center, Hampton, VA, USA
Improved model for solar cosmic ray exposure in manned Earth orbital flights
Wilson, John W.; Nealy, John E.; Atwell, William; Cucinotta, Francis A.; Shinn, Judy L.; Townsend, Lawrence W.; Jun 1, 1990; In English
Contract(s)/Grant(s): RTOP 199-22-76-01
Report No.(s): NASA-TP-2987; L-16759; NAS 1.60:2987; No Copyright; Avail: CASI

A calculational model is derived for use in estimating Solar cosmic ray exposure to critical body organs in low-Earth orbit at the center of a large spherical shield of fixed thickness. The effects of the Earth's geomagnetic field and the astronauts'

self-shielding are evaluated explicitly. The geomagnetic field model is an approximate tilted eccentric dipole with geomagnetic storms represented as a uniform-impressed field. The storm field is related to the planetary geomagnetic index K(sub p). The code is applied to the Shuttle geometry using the Shuttle mass distribution surrounding two locations on the flight deck. The Shuttle is treated as pure aluminum and the astronaut as soft tissue. Short-term, average fluence over a single orbit is calculated as a function of the location of the lines of nodes or long-term averages over all lines of nodes for a fixed inclination.
CASI
Astronauts; Exposure; Fluence; Mathematical Models; Organs; Radiation Dosage; Radiation Shielding; Solar Cosmic Rays

19900016182 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Hazards protection for space suits and spacecraft
Kosmo, Joseph J., inventor; Dawn, Frederic S., inventor; May 8, 1990; In English; See also N89-12206
Patent Info.: Filed 30 Jun. 1988; US-PATENT-4,923,741; US-PATENT-APPL-SN-213880; NASA-CASE-MSC-21366-1; No Copyright; Avail: US Patent and Trademark Office

A flexible multi-layered covering article for protection against the hazards of exposure to the environment of outer space is disclosed. The covering includes an outer layer section comprising an outermost lamina of woven expanded tetrafluoroethylene yarns (Gore Tex) for protecting against abrasion and tearing, an underlying weave of meta-aramid yarns (Nomex) and para-aramid yarns (Kevlar) for particle impart protection, and electrostatic charge dissipation and control system incorporated therein, and a chemical contaminants control barrier applied as a coating. A middle section includes a succession of thermal insulating layers of polymeric thermoplastic or thermoforming material, each of which is coated with a metal deposit of high infra-red emissivity and low solar radiation absorption characteristics and separated from adjacent insulating layers by a low thermal conductance material. The covering further includes a radiation attenuating layer of a tungsten-loaded polymeric elastomer binder for protecting against bremsstrahlung radiation and an inner layer of rip-stop polyester material for abrasion protection. A chloroprene coating may be supplied the polyester-material for added micrometeroid protection. Securing means of low heat conductance material secures the multi-layers together as a laminar composite.
Official Gazette of the U.S. Patent and Trademark Office
Electrostatic Charge; Fabrics; Hazards; Protective Coatings; Radiation Protection; Space Suits

19900012399 NASA Langley Research Center, Hampton, VA, USA
Simplified model for solar cosmic ray exposure in manned Earth orbital flights
Wilson, John W.; Khandelwal, Govind S.; Shinn, Judy L.; Nealy, John E.; Townsend, Lawrence W.; Cucinotta, Francis A.; May 1, 1990; In English
Contract(s)/Grant(s): RTOP 199-22-76-01
Report No.(s): NASA-TM-4182; L-16738; NAS 1.15:4182; No Copyright; Avail: CASI

A simple calculational model is derived for use in estimating solar cosmic ray exposure to critical body organs in low-Earth orbit at the center of a large spherical shield of fixed thickness. The effects of the Earth's geomagnetic field, including storm conditions and the astronauts' self-shielding, are evaluated explicitly. The magnetic storm model is keyed to the planetary index K(sub p).
CASI
Earth Orbital Environments; Exposure; Mathematical Models; Organs; Radiation Dosage; Radiation Shielding; Solar Cosmic Rays

19900009041 NASA Langley Research Center, Hampton, VA, USA
Radiation exposure for manned Mars surface missions
Simonsen, Lisa C.; Nealy, John E.; Townsend, Lawrence W.; Wilson, John W.; Mar 1, 1990; In English
Contract(s)/Grant(s): RTOP 326-22-20-50
Report No.(s): NASA-TP-2979; L-16708; NAS 1.60:2979; No Copyright; Avail: CASI

The Langley cosmic ray transport code and the Langley nucleon transport code (BRYNTRN) are used to quantify the transport and attenuation of galactic cosmic rays (GCR) and solar proton flares through the Martian atmosphere. Surface doses are estimated using both a low density and a high density carbon dioxide model of the atmosphere which, in the vertical direction, provides a total of 16 g/sq cm and 22 g/sq cm of protection, respectively. At the Mars surface during the solar minimum cycle, a blood-forming organ (BFO) dose equivalent of 10.5 to 12 rem/yr due to galactic cosmic ray transport and attenuation is calculated. Estimates of the BFO dose equivalents which would have been incurred from the three large solar flare events of August 1972, November 1960, and February 1956 are also calculated at the surface. Results indicate surface

BFO dose equivalents of approximately 2 to 5, 5 to 7, and 8 to 10 rem per event, respectively. Doses are also estimated at altitudes up to 12 km above the Martian surface where the atmosphere will provide less total protection.
CASI
Galactic Cosmic Rays; Manned Mars Missions; Mars Atmosphere; Mars Surface; Radiation Dosage; Solar Flares

19900016138 Southwest Foundation for Biomedical Research, San Antonio, TX, USA
Program review: The lifetime effects of space radiation in rhesus monkeys
Butler, Thomas M.; Mar 1, 1990; In English
Contract(s)/Grant(s): F33615-87-D-0627; AF PROJ. 7757
Report No.(s): AD-A221127; USAFSAM-TR-90-3; No Copyright; Avail: CASI

Findings are summarized from a select panel of scientists charged with reviewing the quality and productivity of the USAFSAM 24-year in-house study of the lifetime effects of space radiation in the rhesus monkey. The panel also had the responsibility of assessing the value of the study in both military and civilian scientific applications and making recommendations for maximizing the yield of relevant data as the animals near the end of their life span. The panelists reviewed results presented by project scientists during a 2-day conference. They were unanimous in their endorsement of the study as a uniquely important resource of information on the late effects of space radiation and the interaction of late effects with the normal aging process. In asserting that the study should be continued for at least another 5 years, the panel made specific recommendations for additional work to be carried out in collaboration with scientists at other laboratories who could provide the breadth of technical expertise required to fully exploit the potential of this project. The scientific proceedings of the conference will be published as separate journal articles.
DTIC
Aging (Biology); Extraterrestrial Radiation; Monkeys; Radiation Effects; Radiation Protection; Radiation Tolerance; Radiobiology

19900008219 NASA Langley Research Center, Hampton, VA, USA
Estimates of galactic cosmic ray shielding requirements during solar minimum
Townsend, Lawrence W.; Nealy, John E.; Wilson, John W.; Simonsen, Lisa C.; Feb 1, 1990; In English
Contract(s)/Grant(s): RTOP 199-04-16-11
Report No.(s): NASA-TM-4167; L-16715; NAS 1.15:4167; No Copyright; Avail: CASI

Estimates of radiation risk from galactic cosmic rays are presented for manned interplanetary missions. The calculations use the Naval Research Laboratory cosmic ray spectrum model as input into the Langley Research Center galactic cosmic ray transport code. This transport code, which transports both heavy ions and nucleons, can be used with any number of layers of target material, consisting of up to five different arbitrary constituents per layer. Calculated galactic cosmic ray fluxes, dose and dose equivalents behind various thicknesses of aluminum, water and liquid hydrogen shielding are presented for the solar minimum period. Estimates of risk to the skin and the blood-forming organs (BFO) are made using 0-cm and 5-cm depth dose/dose equivalent values, respectively, for water. These results indicate that at least 3.5 g/sq cm (3.5 cm) of water, or 6.5 g/sq cm (2.4 cm) of aluminum, or 1.0 g/sq cm (14 cm) of liquid hydrogen shielding is required to reduce the annual exposure below the currently recommended BFO limit of 0.5 Sv. Because of large uncertainties in fragmentation parameters and the input cosmic ray spectrum, these exposure estimates may be uncertain by as much as a factor of 2 or more. The effects of these potential exposure uncertainties or shield thickness requirements are analyzed.
CASI
Estimates; Galactic Cosmic Rays; Manned Space Flight; Radiation Dosage; Radiation Shielding; Solar Activity Effects

19900017161 San Francisco Univ., CA, USA
Experiment K-6-24, K-6-25, K-6-26. Radiation dosimetry and spectrometry
Benton, E. V.; Frank, A.; Benton, E. R.; Dudkin, V.; Marennyi, A.; NASA, Ames Research Center, The US Experiments Flown on the Soviet Biosatellite Cosmos 1887; Feb 1, 1990; In English
Contract(s)/Grant(s): NCC2-521; NAG9-235; No Copyright; Avail: CASI

Radiation experiments flown by the University of San Francisco on the Cosmos 1887 spacecraft were designed to measure the depth dependence of both total dose and heavy particle flux, dose and dose equivalent, down to very thin shielding. Three experiments were flown and were located both inside and outside the Cosmos 1887 spacecraft. Tissue absorbed dose rates of 264 to 0.028 rad d(-1) under shielding of 0.013 to 3.4 g/sq cm of (7)LiF were found outside the spacecraft and 0.025 rad d(-1) inside. Heavy particle fluxes of 3.43 to 1.03 x 10 to the minus 3rd power cm -2 sub s -1 sub sr -1 under shielding of 0.195

to 1.33 g/sq cm plastic were found outside the spacecraft and 4.25 times 10 to the minus 4th power cm -2 sub s -1 sub sr -1 inside (LET infinity H2O greater than or equal to 4 keV/micron m). The corresponding heavy particle dose equivalent rates outside the spacecraft were 30.8 to 19.8 mrem d(-1) and 11.4 mrem d(-1) inside. The large dose and particle fluxes found at small shielding thicknesses emphasize the importance of these and future measurements at low shielding, for predicting radiation effects on space materials and experiments where shielding is minimal and on astronauts during EVA. The Cosmos 1887 mission contained a variety of international radiobiological investigations to which the measurements apply. The high inclination orbit (62 degrees) of this mission provided a radiation environment which is seldom available to U.S. investigators. The radiation measurements will be compared with those of other research groups and also with those performed on the Shuttle, and will be used to refine computer models employed to calculate radiation exposures on other spacecraft, including the Space Station.
CASI
Dosimeters; Radiation Dosage; Radiation Effects; Radiation Shielding; Radiobiology; Spaceborne Experiments; Spacecraft Construction Materials; Spectrometers

19930005770 Thomson and Nielsen Electronics, Ottawa Ontario, Canada
Radiation monitoring for long duration space flights
Thomson, I.; Mackay, G.; Canadian Space Agency, Proceedings of the Sixth CASI Conference on Astronautics; JAN 1, 1990; In English; No Copyright; Avail: Other Sources

Future space missions will require more detailed knowledge of radiation effects both on inherent electronics and on humans. Single event upsets due to cosmic rays have devastating effects on the former and all types of radiation will potentially damage the latter. The longer the flight duration, the greater the potential hazard. An astronaut, for example, can expect a dose of 9 rems for a 90 day mission in low earth orbit and 100 rems in a 1,000 day Mars mission. The recommended dose limits for radiation workers on earth are 5 rems/year and for the general public, 0.5 rem/year. This paper gives an overview of the space radiation environment and of the physical effects of radiation on electronic equipment and biological specimens. This is followed by a description of new, direct-reading electronic radiation monitoring techniques and their applications to problems in space. It is shown that the miniature silicon sensors can be used for the separate measurement of (1) trapped high energy protons and electrons and (2) cosmic rays. Two experimental applications of these technologies are described. One is a flight on a Soviet spacecraft and the other is the maiden flight of ESA's Ariane Technology Experiment Platform (ARTEP). ARTEP 1 is intended for real-time radiation monitoring in a wide range of space radiation environments. Future experiments and applications are discussed in terms of radiation monitoring and protection.
Author (CISTI)
Biological Effects; Electronic Equipment; Long Duration Space Flight; Radiation Effects; Radiation Measurement

19930029545
Experimental research on the anti-irradiation effects of KW-1 - Protective effect on the 5-HT content of tissues in irradiated mice
Zhang, Yongfa, et al.; Space Medicine & Medical Engineering; 1990; ISSN 1002-0837; 3, 2; In Chinese; Copyright; Avail: Other Sources

The kinetic changes of 5-HT content in the tissues and WBC count of the Co-60-irradiated mice were observed. The results indicate that 5-HT contents decreased significantly in some of the tissues (blood, spleen, and cerebrum) but increased in the intestine after the irradiation, and that the WBC count decreased in a great quantity after the irradiation. The recovery of the WBC count was accelerated by KW-1 which could stimulate proliferation of the hematopoietic stem cells. Administration of KW-1 increased the 5-HT contents significantly in the blood, intestine, spleen, and cerebrum after the irradiation, thus improving innate natural resistance against irradiation damage.
AIAA
Lymphocytes; Radiation Dosage; Radiopathology; Tissues (Biology)

19910043084 McDonnell-Douglas Space Systems Co., Houston, TX, USA, NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Implications of the new radiation exposure limits on Space Station Freedom crews
Stanford, M.; Nachtwey, D. S.; JAN 1, 1990; In English, Apr. 22-26, 1990, Albuquerque, NM, USA; Copyright; Avail: Other Sources

Levels of acceptable risk of radiation exposure for SSF crews have been studied. Since the cancer risk per dose equivalent

has increased over the last decade, new dose-equivalent limits have been recommended. An astronaut may not receive more than a depth-dose equivalent of 50 rem/year. It is found that a 180-day stay aboard Freedom could result in a worst case depth-dose of 30 rem, and a 180-day mission in a nominally shielded spacecraft in a constant atmospheric density orbit with a varying altitude could result in a depth-dose equivalent of 10 rem. This is twice the annual allowable dose-equivalent for terrestrial radiation workers. It is noted that the present understanding of the biological effectiveness of high-LET radiation is not adequate for accurate health risk assessments and that further research is necessary.
AIAA
Ionizing Radiation; Radiation Dosage; Radiation Tolerance; Space Flight; Space Station Freedom; Spacecrews

19910050342
Radiation monitoring for long duration space flights
Thomson, I.; Mackay, G.; JAN 1, 1990; In English; 6th, Nov. 19-21, 1990, Ottawa, Canada; Copyright; Avail: Other Sources
A review of space radiation issues is presented along with a description of new, direct-reading electronic radiation monitoring techniques and their applications to problems in space. It is shown that miniature silicon sensors may be utilized for the separate measurement of trapped high energy protons and electrons, and cosmic rays. These sensors have also been studied at very high energy low atomic number particles, e.g., He at 1200 MeV and the results are practically the same as for lower energy protons. Therefore, this sensor can be utilized as a dosimeter for total dose measurements for trapped particles and low Z cosmic rays, all of which have essentially the same biological effects.
AIAA
Extraterrestrial Radiation; Long Duration Space Flight; Radiation Detectors; Radiation Hazards; Radiation Protection

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