

Fiscal Year:	FY 2012	Task Last Updated:	FY 06/25/2012
PI Name:	Norbury, John Ph.D.		
Project Title:	Measurements and Transport Phase 2 Physics Project		
Division Name:	Human Research		
Program/Discipline:	HUMAN RESEARCH		
Program/Discipline--Element/Subdiscipline:	HUMAN RESEARCH--Radiation health		
Joint Agency Name:	TechPort:	No	
Human Research Program Elements:	(1) SR :Space Radiation		
Human Research Program Risks:	(1) ARS :Risk of Acute Radiation Syndromes Due to Solar Particle Events (SPEs) (2) Cancer :Risk of Radiation Carcinogenesis (3) CNS :Risk of Acute (In-flight) and Late Central Nervous System Effects from Radiation Exposure (4) Degen :Risk of Cardiovascular Disease and Other Degenerative Tissue Effects From Radiation Exposure and Secondary Spaceflight Stressors		
Space Biology Element:	None		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	None		
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Zip Code:	23681-2199	Congressional District:	1
Comments:			
Project Type:	GROUND	Solicitation / Funding Source:	Directed Research
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No. of Post Docs:	4	No. of PhD Degrees:	0
No. of PhD Candidates:	0	No. of Master' Degrees:	0
No. of Master's Candidates:	0	No. of Bachelor's Degrees:	0
No. of Bachelor's Candidates:	0	Monitoring Center:	NASA LaRC
Contact Monitor:	Contact Phone:		
Contact Email:			
Flight Program:			
Flight Assignment:			
Key Personnel Changes/Previous PI:			
COI Name (Institution):	Blattnig, Steve (NASA Langley Research Center) Cloudsley, Martha (NASA Langley Research Center) Slaba, Tony (NASA Langley Research Center) Simonsen, Lisa (NASA Langley Research Center)		
Grant/Contract No.:	Directed Research		
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<p>Task Description:</p>	<p>Currently, the deterministic space radiation transport code HZETRN (High charge (Z) and Energy TRaNsport), is the major tool used by NASA to evaluate radiation environments inside spacecraft. Deterministic codes have been shown to be superior to Monte Carlo transport for engineering studies. However HZETRN is a one dimensional transport code. The transport of heavy ions ($Z > 2$) has been shown to be valid in the one dimensional approximation because the relativistic heavy ions found in the space radiation spectrum pass through materials relatively un-deflected from their initial trajectories. The cross sections required for one dimensional transport are total absorption and spectral distributions. Meson production and the associated electromagnetic cascade have not yet been incorporated into HZETRN. Phase 1 studies have shown the importance of these processes, which must be included in Phase 2. This project implements the recommendations of several workshops by emphasizing the development of a more accurate description of neutron and light ion transport. Neutrons and light ions scatter at large angles and the one dimensional approximation is no longer valid. Therefore, the one dimensional code HZETRN must begin to include the three dimensional transport of light ions and neutrons to more accurately quantify secondary radiation environments in tissue while maintaining computational speed and efficiency. Such a three dimensional transport code in turn requires fully double differential cross sections as input.</p> <p>Phase II Measurements and Physics Project focuses on light ion production and transport to develop space radiation transport codes capable of predicting primary and secondary spectra of space radiation environment interaction behind typical spacecraft shielding, planetary surfaces, and atmospheres with increased accuracy. Configuration managed V&V'ed source codes are released to the radiation user community including Exploration, RHO, and Operations as well as industry partners or commercial entities. Current exploration vehicle requirements specify that HZETRN shall be utilized by the government for radiation requirement verification. Transport codes directly support verification of NASA STD 3001 Vol. 2 requirements.</p> <p>Phase 2 focus:</p> <ul style="list-style-type: none"> • Current focus is on light ion and neutron transport and production including 3-D effects of neutron backscattered and inclusion of dose received from pion production • Future nuclear physic improvements will focus on improved models needed for definition of Mars Surface Environment <p>Implementation of Phase 2 Physics supports closing the following gaps,</p> <ul style="list-style-type: none"> • Cancer - 11: What are the most effective shielding approaches to mitigate cancer risks? • Cancer - 12: What level of accuracy do NASA's space environment, transport code and cross sections describe radiation environments in space (ISS, Lunar, or Mars)? Pion production models are also being worked on.
<p>Rationale for HRP Directed Research:</p>	
<p>Research Impact/Earth Benefits:</p>	<p>The radiation transport codes developed at NASA Langley Research Center can potentially be used in other applications such as proton and heavy ion therapy treatments for cancer.</p>
<p>Task Progress:</p>	<p>Nuclear data for space radiation has been studied. Human space flight requires protecting astronauts from the harmful effects of space radiation. The availability of measured nuclear cross section data needed for space radiation has been reviewed. The energy range of interest for radiation protection is approximately 100 MeV/n - 10 GeV/n. Most data are for projectile fragmentation partial and total cross sections, including both charge changing and isotopic cross sections. The cross section data are organized into categories which include charge changing, elemental, isotopic for total, single and double differential with respect to momentum, energy and angle. Gaps in the data relevant to space radiation protection were studied and recommendations for future experiments have been made.</p> <p>Deterministic pion and muon transport in Earth's atmosphere has been studied. Secondary particles produced by primary space radiation particle interactions with materials are an important contribution to radiation risk. Many pions are produced in the nuclear interactions typical of space radiations and can be an important contribution to radiation exposure. Charged pions decay to muons, which must also be considered in space radiation exposure studies. The NASA space radiation transport code HZETRN (High charge (Z) and Energy TRaNsport) has been extended to include the transport of charged pions and muons. Muon production in the Earth's upper atmosphere was investigated, and comparisons with recent balloon flight measurements of differential muon flux were presented. Muon production from an updated version of HZETRN is found to agree well with experiment.</p> <p>Light ion improvements to the NUCFRG (NUCclear FRaGmentation) model has been studied. The simple light ion production model has been replaced with a light ion coalescence model and an improved electromagnetic dissociation (EMD) model has been added. Prior versions of the model provide reasonable overall agreement with measured data; however, those versions lacked a physics-based description for coalescence and EMD. The new version, NUCFRG3, has improved the theoretical descriptions of these mechanisms and offers additional benefits, such as the capability to calculate EMD cross sections for single deuteron, triton, helion, and alpha particle emission. NUCFRG3 model evaluation and validation show that the predictive capability has been improved and strengthened by the light ion physics-based changes.</p> <p>Variation in lunar neutron dose estimates has been studied. The transport code, HZETRN2010 was used to calculate the albedo neutron contribution to effective dose as a function of shielding thickness for different space radiation environments and to determine to what extent various factors affect such estimates. Albedo neutron spectra computed with HZETRN2010 were compared to Monte Carlo result. The impact of lunar regolith composition on the albedo neutron spectrum was examined, and the variation on effective dose caused by neutron fluence to effective dose conversion coefficients was studied. The combined variation caused by environmental models, shielding materials, shielding thickness, regolith composition, and conversion coefficients on the albedo neutron contribution to effective dose was determined. It was shown that a single percentage number for characterizing the albedo neutron contribution to effective dose can be misleading. In general, the albedo neutron contribution to effective dose was found to vary between 1 - 32%, with the environmental model, shielding material, and shielding thickness being the most important factors.</p> <p>A low Earth orbit (LEO) dynamic model for proton anisotropy validation has been studied. Previous ionizing radiation measurements on the space transportation system have provided information impacting both the environmental models</p>

and the nuclear transport code development by requiring dynamic models of the LEO environment. Previous studies using computer aided design models of the International Space Station (ISS) have demonstrated that the dosimetric prediction for a spacecraft at LEO requires the description of an environmental model with accurate anisotropic as well as dynamic behavior. The developed model is a component of a suite of codes collectively named GEORAD (GEOMagnetic RADiation) which computes cutoff rigidity, trapped proton and trapped electron environments. Within SAA (South Atlantic Anomaly), the EW anisotropy results in different levels of exposure to different sections of a spacecraft such as ISS. The study draws quantitative conclusions on the combined effect of proton pitch angle and the EW anomaly.

Low Earth orbit validation of a dynamic and anisotropic trapped radiation model through ISS measurements has been studied, and applies to trapped electrons at various Earth orbits. The trapped electron capabilities of GEORAD are accessible through OLTARIS web interface. GEORAD and OLTARIS interests are in the study of long term effects (i.e. a meaningful portion of solar cycle). Therefore, GEORAD does not incorporate any short term external field contribution due to solar activity. These environmental models were applied to selected target points within ISS 6A (circa early 2001), 7A (circa late 2001), and 11A during its passage through the SAA to assess the validity of the environmental models at ISS altitudes.

A dynamic model for the validation of cosmic ray anisotropy at low Earth orbit has been studied. Within the framework of GEORAD, we described the dynamic and anisotropic capabilities of GEORAD as applied to the interaction of GCR with the geomagnetic field at low Earth orbit (LEO). While the magnitude of the GCR anisotropy at LEO depends on a multitude of factors such as the ions rigidity, transmission, attitude and orientation of the spacecraft along the velocity vector, the study draws quantitative conclusions on the effect of GCR anisotropy at LEO.

Estimates of Carrington - class solar particle event radiation exposures on Mars has been studied. Radiation exposure estimates for astronauts on the surface of Mars were made for solar particle event proton radiation environments comparable to the Carrington event of 1859. It was assumed that the proton energy distributions for these Carrington - type events were similar to those measured for other, more recent large events. The fluence levels of these hypothetical events were normalized to the value for the Carrington event, as reported from measurements in ice core data. Comparisons of the predicted organ exposures with current NASA permissible exposure limits were made.

Bibliography Type:	Description: (Last Updated: 01/11/2021)
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