Fiscal Year:	FY 2009	**Task Last Updated:**	FY 06/05/2009
PI Name:	Pisacane, Vincent L. Ph.D.		
Project Title:	Lunar EVA Dosimetry: MIcroDosimeter iNstrument (MIDN) System Suitable for Space Flight		
Division Name:	Human Research		
Program/Discipline:	NSBRI		
Program/Discipline--Element/Subdiscipline:	NSBRI--Smart Medical Systems and Technology Team		
Joint Agency Name:		**TechPort:**	Yes
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)		
Space Biology Element:	None		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	None		
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Zip Code:	21402-1314	**Congressional District:**	3
Comments:	PI retired October 2011 (Ed., 2/29/2012; information from NSBRI)		
Project Type:	GROUND	**Solicitation / Funding Source:**	2003 Biomedical Research & Countermeasures 03-OBPR-04
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No. of PhD Candidates:	1	**No. of Master' Degrees:**	0
No. of Master's Candidates:	0	**No. of Bachelor's Degrees:**	4
No. of Bachelor's Candidates:	6	**Monitoring Center:**	NSBRI
Contact Monitor:		**Contact Phone:**	
Contact Email:			
Flight Program:			
Flight Assignment:	Note: title changed per NSBRI info (12/08) NOTE: End date changed to 12/31/2008 per NSBRI (5/2008)		
Key Personnel Changes/Previous PI:			
COI Name (Institution):	Cucinotta, Francis (NASA Johnson Space Center) Rozenfeld, Anatoly (University of Wollongong) Ziegler, James (United States Naval Academy) Nelson, Martin (United States Naval Academy) Zaider, Marco (Memorial Sloan-Kettering Cancer Institute) Dicello, John (United States Naval Academy)		
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Task Description:	A microdosimeter is perhaps the only active detector capable of directly determining the mean radiation quality of a mixed or unknown radiation field, and, therefore, the dose equivalent and effective dose from which the radiation risk can be assessed in real time. Objectives of this research project are to develop a rugged, portable, low power, low mass, solid-state microdosimeter suitable for an area sensor, a spacecraft or habitat, and as a personnel monitor, such as a spacesuit, and to verify its performance through radiation source and beam tests and comparison of experimental results with radiation transport codes. The original objectives were expanded to include a student-developed instrument for the MidSTAR-I spacecraft launched in March 2007. The original aims of the project were to 1. Demonstrate that a small, compact, and portable flight qualifiable, solid-state microdosimeter can be developed to measure quantitative information on the dose and dose distribution of energy deposited in silicon cells of tissue size and by inference in tissue. 2. Analyze data from radiation beam experiments and compare with radiation transport codes to provide quantitative information on the radiation environment, potential risk, and the accuracy of the codes to correctly calculate energy deposition spectra. 3. With data from radiation beam experiments correlated with radiation transport codes, determine the effectiveness of selected materials to minimize the total risk from primary and secondary radiation. The specific objectives of the MIcroDosimeter iNstrument (MIDN) instrument are to 1. Make real-time measurements of the radiation environment to assess risk (dose equivalent). 2. Actively warn crew during onset of enhanced radiation events. 3. Allow crew to determine safe locations during enhanced radiation events. 4. Provide observations to validate and improve space radiation environment models. 5. Provide observations to validate and improve radiation transport theories for shield materials and different tissues types. While not part of this proposal, a student design effort developed an early version of a MIDN instrument that was launched on the MidSTAR-I spacecraft in 2007 although only a short time was available for its design and development by the students. We have satisfied most but not all of our aims and instrument development objectives. We have successfully evolved two sets of instrumentation, a bench-top system to evaluate instrument components without regard for power or size and two prototype flight instruments. Each instrument consists essentially of a sensor, sensor electronics, amplifiers, analog-to-digital conversion, and a multichannel analyzer under computer or microprocessor control. We have tested these instruments at the NASA Space Radiation Laboratory (NSRL) at Brookhaven National Laboratory (BNL). Ions examined include: iron, oxygen, silicon, hydrogen, carbon, and titanium. We were able to achieve in our benchtop system with a 10 um thick sensor a dE/dx < 1keV/um in silicon that is equivalent to a lineal energy of approximately 0.4 keV/um in tissue. In our flight prototype instrument with a 10 um thick sensor, we were able to achieve a dE/dx ~ 3 keV/um in silicon that is equivalent to a lineal energy of ~ 1 keV/um in tissue. The anticipated flight system will require a power of approximately one watt and could be packaged into a volume of less than 12 x 8 x 4 cm and should have a dE/dx < 1keV/um in silicon that is equivalent to a lineal energy of approximately 0.4 keV/um in tissue. These are significant accomplishments that satisfy the primary objectives of the research and verify our original hypotheses that verify that silicon microdosimetery appears to be a viable alternative to assess a mixed and unknown time varying radiation field to estimate regulatory risk. This is the final year of this National Space Biomedical Research Institute (NSBRI) grant.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	Microdosimetric techniques are perhaps the only experimental methods for actively determining the radiation quality of mixed or unknown radiation fields and their dose equivalent. Likewise, the compact nature of a solid-state microdosimeter along with its low voltage and low power consumption and remote telemetry makes such a device ideal for in-situ personnel monitors as well as area monitors. The radiation quality and the corresponding dose equivalent and/or effective doses form the basis of regulatory dose limits both in the U.S. and internationally as well as the basis for the evaluation of potential overexposures. Generally, in radiation fields with average quality factors greater than one, those radiation components with the highest quality may represent a component of the dose comparable to the dose uncertainty. For example, as the energy of x-ray therapy machines increases to accommodate intensity modulated radiotherapy and other new techniques, the contributions of secondary neutrons produced in the shielding materials to the whole-body exposure of the clinical personnel as well as the patients themselves increase. With a quality factor as high as 20, a one or two percent neutron component can contribute as much as 20 to 30 percent of the dose equivalent. Likewise, in radiation storage and clean-up, it is the dose equivalent or effective dose, not the physical absorbed dose, that determines the need and level of clean up, yet it is the physical dose that is usually measured because of the difficulty in measuring dose equivalent in the field by personnel who are not experts in microdosimetry. Finally, the detection of radiation emitted by nuclear materials that may be used in terrorist activities requires cheap, reliable, and rugged microdosimeters that can determine small changes in the radiation environment and issue reliable alerts in real time. The use of prior methods is limited in part because of the complexity, sensitivity, and lack of reliability of the most commonly used instruments, gas proportional counters. The compact system that we have developed for space applications would likewise be applicable for these situations and measurements described in the previous paragraph. We have established for the first time in a solid-state microdosimeter a lowered energy cutoff of dE/dx < 1 keV/um in silicon that is equivalent to a lineal energy cutoff of < 0.4 keV/um in tissue. Thus we have an instrument that can be used in space and terrestrially to directly assess regulatory risk.

Task Progress:	MIDN PROTOTYPE FLIGHT INSTRUMENT 1. Based on our experience with the MIDN development, we designed and developed an advanced version of the instrument. 2. A prototype was developed that although did not include all of the specifications was able to achieve with a 10 um thick sensor a dE/dx ~ 3 keV/um in silicon that is equivalent to a lineal energy of ~1 keV/um in tissue. BENCHTOP DEVELOPMENT SYSTEM 1. By designing and constructing a new Faraday cage that houses the sensor and preamplifier circuit, upgrading the signal transmission circuitry between the system and the data acquisition area, and designing a new data acquisition method, we were able to reduce the inherent noise level well below a keV/micron, allowing detection of the peak of the dose distributions for minimum ionizing protons, the most difficult particles to detect microdosimetrically. 2. In collaboration with the M. Sivertz and A. Rusek at BNL, we have developed a system that allows identification of incident particles, categorized them according to their mass-to-charge ratio and energy, and correlated them with individual events in the microdosimeter. Recall that our earlier work in this regard resulted in our identifying lighter ion contaminants in the beam and their contributions to the microdosimetric spectra, a fact that we subsequently learned was known to BNL personnel. 3. We measured the energy deposited in a microdosimeter with radiation beams of Carbon at 290 MeV/n and protons at 1 GeV/n, 600 MeV/n, 250 MeV/n, 100 MeV/n, and 50 MeV/n at the NSRL facility at the BNL and achieved a lower energy cutoff of < 1 keV/um in silicon equivalent to a lineal energy cutoff in tissue of < 0.3 keV/um. ADVANCED SENSOR DEVELOPMENT 1. We now have prototypes of a new design of a solid-state microdosimeter with three dimension micron sized sensitive volumes, addressing some of the shortcomings identified earlier. This sensor was developed at the Centre for Medical Research Physics, and a new grant (Australian Research Council Discovery Project) was recently received by our collaborator to further support this project. 2. We have established collaborations with the EE (electrical engineering) departments at Johns Hopkins University (JHU) to explore the potential of developing alternative silicon sensors. These new sensors will be developed as part of our follow-on grant from the NSBRI. 3. With minimal support, JHU was able to supply us with two dies that have a variety of diodes for preliminary testing. A test fixture was developed to carry out tests, and measurements of alpha particles were successfully conducted. RADIATION TRANSPORT CODES 1. We imported the radiation transport code GEANT4 and two corollary programs MULASSIS (multilayered shielding simulation software tool) and GEMAT. These Monte Carlo codes allow us to simulate the microdosimetry spectra in silicon devices. 2. We also have access to the MCNPX (Monte Carlo N-Particle eXtended) radiation transport code.
Bibliography Type:	Description: (Last Updated: 07/24/2015)
Articles in Peer-reviewed Journals	Lai NS, Lim WH, Ziebell AL, Reinhard MI, Rosenfeld AB, Dzurak AS. "Development and fabrication of cylindrical silicon-on-insulator microdosimeter arrays." IEEE Transactions on Nuclear Science. 2009 Jun;56(3):1637-41. http://dx.doi.org/10.1109/TNS.2009.2015317 , Jun-2009
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