Fiscal Year:	FY 2010	**Task Last Updated:**	FY 02/11/2010
PI Name:	Pisacane, Vincent L. Ph.D.		
Project Title:	Lunar EVA Dosimetry: Microdosimeter-Dosimeter Instrument		
Division Name:	Human Research		
Program/Discipline:	NSBRI		
Program/Discipline--Element/Subdiscipline:	NSBRI--Radiation Effects 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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Organization Name:	United States Naval Academy		
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PI Web Page:			
City:	Annapolis	**State:**	MD
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:**	2007 Crew Health NNJ07ZSA002N
Start Date:	01/01/2009	**End Date:**	09/30/2011
No. of Post Docs:	3	**No. of PhD Degrees:**	1
No. of PhD Candidates:	5	**No. of Master' Degrees:**	0
No. of Master's Candidates:	3	**No. of Bachelor's Degrees:**	3
No. of Bachelor's Candidates:	3	**Monitoring Center:**	NSBRI
Contact Monitor:		**Contact Phone:**	
Contact Email:			
Flight Program:			
Flight Assignment:	NOTE: PI retired and end date changed to 9/30/2011 from original end date of 12/31/2012; task transferred to James Ziegler and continues through 3/31/2013, per NSBRI (Ed., 2/29/2012)		
Key Personnel Changes/Previous PI:			
COI Name (Institution):	Cucinotta, Francis (NASA Johnson Space Center) Rozenfeld, Anatoly (University of Wollongong) Nelson, Martin (US Naval Academy) Zaider, Marco (Memorial Sloan-Kettering Cancer Institute) Dicello, John (US Naval Academy) Dolecek, Quentin (US Naval Academy)		
Grant/Contract No.:	NCC 9-58-RE01601		
Performance Goal No.:			
Performance Goal Text:			

Task Description:	AIMS: The objective of this project is to design, develop, and test a prototype solid-stated microdosimeter by Dec. 2012 for use in the new NASA spacesuit and robotic operations on rovers, tool boxes, and spacecraft. This 4 year project was initiated 1 Jan. 2009. It includes development of two instruments, a benchtop and a breadboard flight prototype instrument. The bench-top instrument is used to advance the state-of-the-art of solid-state microdosimetry with the goal of incorporating advancements into the breadboard flight prototype. The benchtop instrument is not limited by power, mass, or component selection. Through the benchtop instrument performance objectives are established for the flight prototype. The flight prototype is constrained by mass, power, and use of components with hardened analogs. As part of the project, an aim is to develop improved microdosimetric sensors. FINDINGS: In the first 10 months we have designed and developed a preliminary working version of the flight prototype and performed initial pulser and radiation tests at the USNA. We also carried out two sets of radiation beam tests at the Brookhaven's NSRL. In June 2009 we measured NSRL proton microdosimetric spectra at 0.1 and 1 GeV/n. In October 2009 we measured NSRL iron microdosimetric spectra at 0.6 and 1 GeV/n. Analysis of these data is in progress, but our preliminary noise cutoff for energy deposition delE/delx in tissue is about 1 keV/um. We have compared our experimental results favorably with simulations of the radiation transport code GEANT4 and two Hawk tissue equivalent proportional counters (TEPCs) placed in the beam with our solid-state instruments. The bench-top instrument uses a sensor identical to that in the flight prototype. It was used this year at both the USNA and NSRL to obtain microdosimetric spectra of protons and iron ions at energies between 0.050 - 1 GeV/n. At NSRL, with about 200 feet of cable between the beam and the experimental rooms this system had a lower limit for delE/delx energy deposition in silicon of about 0.3 keV/um (corresponding to a delE/delx in tissue of approximately 0.2 keV/um) with no upper limit. This is significantly better than that available using the HAWK TEPC system and comparable or better than those being obtained with systems under development using other TEPC detection systems; however, these values are still insufficient to obtain that portion of the microdosimetric spectra below the modal value for high-energy protons of typically 0.2 to 0.3 keV/um in tissue, with protons responsible for the majority of the physical dose and a major contributor to the dose equivalent. High-energy protons and the low lineal-energy portion of the spectra for heavy ions account for 20-30% of the heavy ion dose. We have built and are testing a new type preamplifier. Initial noise measurements of this new design are promising. The recent spectra obtained at NSRL were added to our comprehensive data library used for comparisons with data from the flight unit, theoretical calculations, and spectra from commercial TEPCs. With previous spectra collected by Dr. Dicello over a period of 40 years with walled and wall-less TE and silicon detectors for energetic heavy ions and protons as well as x-rays down to 0.2 keV, gamma rays, pions, and muons, we have one of the most extensive microdosimetric data bases. When collecting NSRL spectra with our two solid-state instruments, we routinely collect spectra with two Far West Hawk TEPCs to compare with the spectra we obtain in silicon. These are used along with spectra from radiation transport codes to interpret and evaluate the performance of the two solid-state instruments. Another objective satisfied, is the development of a rechargeable battery power supply to reduce noise on the power lines, a major problem observed in a previous flight. Since the microdosimeter is to be used to monitor astronaut health and determine future flight eligibility, remote operational calibrations and end-to-end system level tests are critical. We have conceived and developed a means, without using an ionizing radiation source, to remotely carry out recalibrations and end-to-end system level tests to assure the sensor and electronics continue to perform as anticipated. A provisional patent application has been submitted. This technique eliminates the many handling and shipping constraints imposed by regulations on ionized radiation sources. We have obtained from our contractor at the University of Wollongong proprietary second generation silicon microdosimetric sensors of a new design and have carried out preliminary pulser, Am-241 radiation sources, and iron ions beam tests. IMPACT: We are ahead of schedule and have not uncovered any significant limitations. We have established a delE/delx energy deposition of about 0.2 keV/um tissue-equivalent with no upper limit for our bench-top instrument. RESEARCH for 2010: Our plan includes the following objectives: 1. Flight Breadboard a. Finalize the design and development of a non-ionizing radiation source for in-orbit end-to-end system testing and b. Carry out evaluation of new silicon microdosimetric sensors with both the benchtop and flight systems c. Upgrade the MIDN flight prototype to mod2 breadboard d. Carry out radiation beam tests at NSRL in the Summer 2010 and compare results with radiation transport codes and HAWk TEPCs 2. Bench-Top System a. Test the newly designed preamplifier to match impedances to that of the old and new detectors to further reduce noise b. Evaluate new silicon microdosimeter sensors, c. Carry out radiation beam tests at NSRL in the Summer 2010 and compare results with radiation transport codes and HAWK TEPCs d. Use experimental results to develop a protocol for obtaining regulatory risk from measured spectra 3. Built-In Remote Tester a. Finalize design and test of in-orbit calibration and end-to-end system test
Rationale for HRP Directed Research:	

Research Impact/Earth Benefits:	To determine the risk from currently used radiation dosimeters requires knowledge of the species, energies, and frequencies of the radiation types or the frequency distributions as a function of linear energy transfer are required. The more frequently used passive dosimeters in addition are processed after the exposure and are not real-time instruments so the risk is inferred only after exposure. Microdosimeters are unique in that they can be used to directly determine the regulatory risk from radiation in real time when neither the species nor energies of the radiation are known. Thus it is a superior instrument for use in situations when the radiation environment is unknown and perhaps time varying. With sufficient investment in VLSI technology the solid-state microdosimeter can be integrated into a cell-phone sized instrument. Since microdosimetry provides the regulatory risks from radiation exposure in real time, it can be beneficially used by first responders in emergency situations when there is uncertainty in the radiation risk. The microdosimeter can be used in nuclear power plants and other facilities with radioactive materials to provide risk due to exposure. It can also be used to detected contraband radioactive material; because of its compact size and potentially relatively low cost, it can be used in situations where large numbers of sensitive detectors are needed. Development of SOI microdosimeters has a potentially significant impact on applications to monitor the dose equivalent during proton therapy, for instance in treating cancer, to reduce the possibility of secondary cancers generated in normal tissue by the radiation. Development of a calibration technique that does not use an ionizing radiation source will reduce the exposure of handlers of the microdosimeter. It will also eliminate the cost of satisfying the regulations on certification of users and on the handling, shipping, and facilities.
Task Progress:	The overall objective of this research project is to design, develop, and test a prototype solid-stated microdosimeter by December 2012 suitable for use in the new NASA spacesuit and robotic operation on rovers, tool boxes, and spacecraft. Our project consists of the development of two instruments, a benchtop instrument and a breadboard flight instrument. The bench-top instrument is used to advance the state of the art of solid-state microdosimetry for ultimate inclusion in a flight system and consequently is not limited by power and mass and selection of components. The breadboard flight prototype is necessarily constrained by mass, power, and limited to use of components with radiation hardened analogs. The bench-top instrument has used as its primary sensor the same sensor that has been incorporated into the present version of the flight system, although sensor and components are relatively easy to change. It has been used at both the Naval Academy and the NSRL BNL to obtain microdosimetric spectra. We have designed and developed a preliminary version of the breadboard flight prototype and have carried out preliminary pulser and radiation-source tests at the Naval Academy. We have also carried out radiation beam tests of both instruments at the NSRL at BNL) in June and October 2009. We are still processing the data and comparing our experimental results with simulations using the radiation transport code GEANT4 and with additional experimentat results obtained with two Far West HAWK tissue equivalent proportional counters that were in the same beams. The preliminary comparisons are promising. These spectra have been added to our past data sets to update our extensive library of microdosimetric spectra. Another objective satisfied this year was the development a rechargeable battery power supply to reduce noise on the power lines. This subsystem provides a low noise ±5 volts source from a external power supply with any input voltage ±5 volts. The power supply consists of 4 batteries of which each has its own recharging circuits so that while any two are providing power either one or both of the other two batteries can be recharged. This provides flexibility when the external supply power is limited or too noisy. Since the microdosimeter is to be used to monitor astronaut health, periodic remote operational calibration and remote operational end-to-to end system level tests are critical. To this end we have conceived and developed a means that does not use an ionizing radiation source to assure that the entire instrument continues to perform as anticipated. A provisional patent application has been submitted. This eliminates the onerous regulations imposed by international and federal regulations on the use of ionizing radiation sources. We have begun preliminary tests of our custom proprietary Mod-2 sensors at the Naval Academy and NSRL with pulser tests, Am-241 radiation sources, and the NSRL iron ion beam.
Bibliography Type:	Description: (Last Updated: 07/24/2015)
Articles in Peer-reviewed Journals	Lai NS, Lim WH, Ziebell AL, Reinhard MI, Rozenfeld 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
Articles in Peer-reviewed Journals	Pisacane VL, Dolecek QE, Malak H, Dicello JF. "End-to-end system test for solid-state microdosimeters." Radiation Protection Dosimetry. Submitted, 2009. , Sep-2009
Awards	Zeibell A. "PhD student at the University of Wollongong, IEEE Nuclear and Plasma Sciences Society Phelps Educational Award at the IEEE Nuclear Science Conference Medical Imaging Conference, October 2009." Oct-2009
Awards	Janca E, Nusbaum N, Ried N. "Honorable Mention Best Undergraduate Student Paper, AIAA Region I Young Professional, Student and Education Conference, Laurel MD, 6 November 2009." Nov-2009