Phase 2 Project Summary

Firm:	Radiation Monitoring Devices, Inc.
Contract Number:	NNJ08JA55C
Project Title:	Tissue-Equivalent Radiation Dosimeter-On-A-Chip

Identification and Significance of Innovation:

NASA's *Vision for Space Exploration* strategy is primarily focused on establishing a permanent human presence on the Moon and then human flights to Mars and involves replacing the Space Shuttle with the much smaller Crew Exploration Vehicle (CEV). By definition, such missions will be of long duration (months to years) and outside the protection provided by the geomagnetic field in low-Earth orbit (LEO). To fulfill this strategy, NASA will require improved instrumentation for space crew dosimetry. Real-time monitoring is important for low-Earth orbiting spacecraft and interplanetary space flight to alert the crew when Solar Particle Events (SPE) increase the particle flux of the spacecraft environment.

This SBIR Phase-II project designed and fabricated a prototype personal dosimeter comprised of a tissue-equivalent plastic scintillator coupled to a solid-state photomultiplier (SSPM). The dosimeter provides a response to the relevant energies and types of radiation encountered during low-Earth orbit and interplanetary space-flight to the Moon or Mars. The instrument will be sensitive to the dose rates and particle fluxes from ambient Galactic Cosmic Rays (GCR) and to enhanced rates of major SPEs. The dosimeter will complement the existing Crew Passive Dosimeter (CPD) by providing real-time dosimetry and as an alarming monitor for SPE.

Technical Objectives and Work Plan:

The goal of the program was to develop a dosimeter for recording the radiation dose absorbed by astronauts during exposure to space radiation by meeting the following technical obejctives:

A. Optimize detector parameters for space applications.
B. Determine suitable signal and data processing electronics.
C. Meet space certification requirements.

The following work was proposed to meet the above objectives:

1. Calibrate existing advanced prototype for various radiation fields.
2. Develop and conduct Monte Carlo simulations of dosimeter.
3. Specify detector parameters and choose readout electronics.
4. Determine dose conversion algorithms from calibration and simulation data.
5. Design and layout SSPM with integrated readout electronics.
6. Fabricate CMOS SSPM with Integrated Readout (DoseChip).
7. Evaluate DoseChip at RMD and NASA test facilities.
8. Determine data acquisition requirements.
9. Migrate dose-processing algorithms to readout circuitry.
10. Examine temperature effects.
11. Design and layout CMOS micro-data acquisition unit (μDAQ).
12. Integrate DoseChip and μDAQ into a package with small mass and form factor.
13. Evaluate tissue equivalent dosimeter at RMD
14. Evaluate tissue equivalent dosimeter at NASA test facilities.
15. Condense and review project results and prepare for transition to Phase III.

Technical Accomplishments:

The development process began with separate components consisting of signal processing modules used in electronic crates and external power supplies. After a few iterations, a compact prototype was fabricated, which consists of a plastic scintillator coupled to a solid-state photomultiplier and readout using an ADC and a microprocessor. The device

easily rests in the palm of a hand and is powered using a compact lithium-ion battery, or externally through a USB cable. Successive iterations of the solid-state photomultiplier have been made to optimize the response of the device over a broad LET range to allow for the best dose accuracy for protons up to iron ions. The device has been tested using test beams of protons and heavier ions providing an expected response and illustrating a dose accuracy of less than 5% for protons. Though a few technical issues need to be addressed, this work has provided a functional device that inherently collects a spectrum of the incident radiation field, allowing for a comprehensive measure of the dose and dose equivalent.

NASA Applications:

During spaceflight, both the immediate rate and total exposure information can be recorded simultaneously by these high-efficiency digital dosimeters. The lightweight, compact size and inexpensive nature of these sensors also opens the possibility of monitoring many areas for comparison of radiation exposure, including individual monitors for each crewmember with online data for the whole mission. Ground-based research and comparisons will also become easier and less expensive with the SSPM dosimeter. The CMOS environment used to fabricate the SSPM and supporting electronics enables low-cost and lightweight space radiation dosimeters and solar particle monitors for NASA satellites.

Non-NASA Commercial Applications:

Inexpensive radiation dosimeters are in general demand for commercial applications, such as personnel or waste monitoring; other applications include border monitoring for homeland security and protecting satellites and ground-based equipment from solar flares. The ability to inexpensively mass-produce these devices creates an entirely new market for arrays of distributed sensors. As high altitude commercial flights become more prevalent, active dosimeters can provide the redundant safeguards and information required to protect companies from unnecessary litigation and passengers from hazardous radiation conditions. We will also consider application of these instruments for dose monitoring both for air travel and space tourism, such as planned by Virgin Galactic. As space is opening to commercial entities, such as Space X, we will explore the potential for these instruments for their applications.

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