DEEP SPACE RADIATION EFFECTS ON PHARMACEUTICALS.

S. Hussey[1] (GRC), R.S. Blue[2] (JSC), V. Daniels[2], T. Bayuse[2], J. Zoldak[3], E. Antonsen[2], [1]NASA Glenn Research Center, 21000 Brookpark Rd, Cleveland, OH, 44135; [2]NASA Johnson Space Center, 2101 E NASA Pkwy, Houston, TX, 77058; [3]ZIN Technologies, 6745 Engle Rd #105, Cleveland, OH, 44130

Introduction: Space radiation may induce chemical changes in the active pharmacological ingredient (API) or the inactive excipients in a given drug formulation rendering parts of the spaceflight pharmacy ineffective or potentially toxic. There is a paucity of data, particularly from controlled studies, regarding pharmaceutical stability in the spaceflight environment. Data from limited non-controlled opportunistic research has suggested that some medications exposed to conditions on the International Space Station may degrade faster than ground controls[1], [2]; however, non-controlled study designs have limited analysis of contributing cofactors, including radiation.Terrestrial-based radiation beam exposures fail to effectively emulate the deep space environment[3], [4], limiting efforts to translate ground-based studies for space radiation risk characterization[5].

This proposal seeks to identify detrimental effects on pharmaceutical stability imposed by the deep space radiation environment over time. Because deep space radiation effects cannot be effectively simulated on ground, Deep Space Gateway (DSG) research is necessary to investigate space radiation-induced decrements to a deep space pharmaceutical formulary. Raman Spectroscopy analysis is a validated, mature technology for the assessment of API and first degradants in various drug formulations. We propose to use this technique for the investigation of exploration pharmaceuticals on DSG to provide much-needed data regarding drug stability, appropriate drug choice and packaging, and radiation-induced risk for long-duration exploration spaceflight.

Methods: A suite of pharmaceuticals, identified as likely for inclusion for a human exploration mission, will be flown aboard DSG missions. Raman Spectroscopy analyzers will be used to analyze the chemical structure and related physical or biopharmaceutical properties of each medication. Spectroscopy will occur weekly during DSG flights, for drug on-board exposure times ranging from 0-1100d. A matched ground-based control group of medications will be maintained in a closed environment similar to the DSG mission, but without the microgravity or deep space radiation exposures, and will be subject to similar analyses over the same time period. A subset of these ground controls will undergo proton and heavy ion beam irradiation for correlation of space and terrestrial radiation effects. Raman results will be down-linked in near-real time for rapid comparison to controls and correlation of data, enabling longitudinal analysis and time-sensitive decision-making guidance for future formulary composition. After pre-determined exposure times, flown medications would also be returned to earth for paired analysis using liquid chromatography and mass spectrometry.

Resources Required: This project will require on-orbit standard integration (power, thermal, structural, data) and minimal payload mass consisting of the spectrometer and drug formulary. Soft stowage during launch with subsequent installation will reduce payload development costs and will require only crew time to install in its DSG location.On-orbit DSG operations are considered to be minimal due to payload automation. Commercial-off-the-shelf Raman Spectroscopy, power supplies, servo motors and drivers will be used for maximal automation. The protoflight payload, which will consist of an indexing scheme to position/align each individual drug for in-flight analysis with the Raman spectroscopy sensor, requires full exposure to the radiation environment. Thus, the experimental platform is ideally mounted internal to the vehicle and without additional shielding, simplifying vehicle and payload interfaces and crew installation. Transmitting Raman data to ground can be limited to transmission only when the crew is not present on DSG, removing some burden on the communications subsystem.Results will be provided to the JSC Pharmacy, Space Medicine Operations Division, and Exploration Medical Capabilities Element for consideration in future formulary development.

References:

[1] Du B. et al. (2011) *AAPS J.*, vol. 13, no. 2, pp. 299–308. [2] Wotring V.E. (2016) *AAPS J.*, vol. 18, no. 1, pp. 210–216, Jan. 2016. [3] Norbury J.W. et al. (2016) *Life Sci. Space Res.*, vol. 8, pp. 38–51. [4] Slaba T. et. al. (2015) National Aeronautics and Space Administration, NASA Langley Research Center, TR NASA/TP-2015-218698. [5]V. E. Wotring V.E. (2012) New York: Springer.