Deep Space Gateway Science Workshop, February 27–March 1, 2018, Denver, Colorado

MATROSHKA ASTRORAD RADIATION EXPERIMENT (MARE) ON THE DEEP SPACE GATEWAY.
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Risks of human exploration of the solar system include detrimental effects of exposure to the space ionizing radiation environment. While the risk of acute effects to astronauts inhabiting exploration-class spacecraft such as Orion is controlled by design and operational strategies to enhance shielding, risks of long term radiation exposure require additional efforts to fully characterize and mitigate. Some of these risks, including radiation-induced Central Nervous System (CNS) effects, cardiovascular disease, and other tissue degenerative effects, are prioritized as having potential in-mission consequences. The Deep Space Gateway (DSG) provides opportunities for radiation studies previously unfeasible. DSG operates in cis-lunar space, in the harsh radiation environment beyond the protection of Earth's magnetosphere, and representative of that experienced by astronaut crews during a Mars-class mission, including effects of spacecraft shielding. As some biological endpoints are dose rate dependent, radiation biology experiments performed in the actual flight environment may provide more accurate results than those performed in ground facilities (charged particle accelerators) and typically at fluxes significantly higher than the natural space environment. The projected DSG operational lifetime allows for long duration radiation dosimetry studies accounting for the variability of the radiation environment due to Galactic Cosmic Rays (GCR) modulation by the solar cycle and transient increases due to Solar Particle Events (SPE).

This paper focuses on the Matroshka AstroRad Radiation Experiment (MARE) as a candidate radiation measurement platform aboard DSG. MARE is currently planned to fly as a self-contained payload aboard Orion's Exploration Mission 1 (EM-1) flight. In this configuration as shown in Figure 1, MARE consists of two radiotherapy phantoms, i.e., anatomically correct analogs of human torsos manufactured from tissue-equivalent materials of variable realistic density spanning the entire range of bone, soft tissue and lungs. The torsos are fitted with a large number of passive dosimeters and active radiation detectors of various types, including the DLR-developed M-42 Silicon detector. One torso is also fitted with the AstroRad radiation shield. AstroRad is state-of-the art personal protective equipment (PPE) developed in collaboration by Lockheed Martin and StemRad specifically to protect astronauts from space radiation exposure. AstroRad is designed to provide preferential protection to stem cell rich-, and other organs at increased risk from radiation exposure. In addition to heritage Matroshka experiments performed on ISS, MARE not only measures internal body radiation exposure but also the effectivity of the mitigation strategy. A future DSG version of MARE will further advance the scope of the experiment. Instead of a one-time experiment, DSG MARE is envisioned as a science and operational radiation platform that can be leveraged by multiple investigators. MARE would serve a dual purpose. The first is to provide long term operational radiation measurements from baseline DSG detectors. Second, MARE would provide capability for individual tasks such as characterization of novel radiation detectors, or outreach initiatives. For example, academic institutions would leverage MARE to perform radiation dosimetry measurements in the actual flight environment using passive dosimeters in standard packaging. Improvements to the Orion EM-1 MARE needed to achieve the increased scope envisioned for DSG consist of integration with the power and data/telemetry systems of the spacecraft and development of a standard dosimeter interface, and are considered feasible.

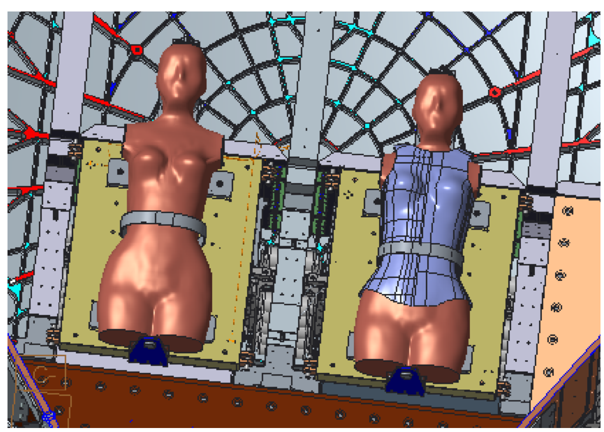

Figure 1. MARE configuration as baselined for Orion consists of two radiotherapy phantoms located at seat positions 3 and 4 in the spacecraft. The phantom at position 4 is fitted with the AstroRad astronaut radiation shield.

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In order to maximize the science potential of DSG, it is critical for the DSG architecture to address science payload integration features from the initial conceptual design phases. DSG power and data systems must allow for autonomous data collection and reporting from various sensors such as radiation detectors while unoccupied. Lockheed Martin invites input from the science community helpful for identifying science critical design features of the DSG, and toward formulation of design goals to implement them.

Estimated experiment properties	Description
Mass of hardware	125 kg (includes two radiation phantoms, AstroRad vest, bracketry and radiation detector complement)
Volume of hardware	0.125 m^3 (TBR)
Accommodation (e.g. internal/external)	Internal
Power required	<30W (TBR)
Data generated	Dose rate @ multiple body internal locations, intravehicular charged particle spectra
Communications needed	Ground, command and status telemetry through the DSG data system
Duration of experiment	Onboard platform for radiation measurements: • Long term for baseline / reference detectors • Short term for novel dosimeters and academia • AstroRad can be leveraged for crew protection while DSG is occupied
Crew tasks (if needed)	Option for crew to wear vest for periods of time Access and servicing (integration of short term dosimeters in MARE via standard interfaces) Radiation biology experiments require crew time
Need for retrieval and return to Earth	Short term detectors only
Specific orbit needs (if any)	None
Operations without crew (if any)	Autonomous data transmission from baseline / reference detectors. Remote command and status