Life Sciences as Related to Space (F)
Space Radiation - Dosimetric Measurements and Related Models, Radiation Detector Developments and Ground-based Characterisation (F2.3)

INTERNATIONAL SCIENCE ABOARD ORION EM-1: THE MATROSHKA ASTRORAD RADIATION EXPERIMENT (MARE) PAYLOAD

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Matroshka AstroRad Radiation Experiment (MARE)
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The natural ionizing radiation environment present in space poses risks to human exploration that require mitigation. Space ionizing radiation consists primarily of highly energetic charged particles including protons and heavy ions. Solar energetic particles (SEP) originate from the Sun and are emitted during transient events referred to as Solar Particle Events (SPEs). Galactic Cosmic Rays (GCR) originate outside the solar system and form a slowly varying background modulated by the solar cycle. Spacecraft designed for Exploration beyond Earth orbit (BEO) do not benefit from the Earth's magnetosphere protection and are subject to stricter radiation design requirements than their low Earth orbit (LEO) counterparts. Spacecraft flying beyond Earth orbit may also be exposed to the Van Allen (trapped radiation) belts environment depending upon their trajectories. Orion is NASA's next generation crewed spacecraft, developed specifically for Exploration missions. Orion's first test flight Exploration Flight Test 1 (EFT-1) was successfully completed in December 2014, along a trajectory traversing the peak flux region of the Van Allen proton belt. The upcoming Orion mission referred to as Exploration Mission 1 (EM-1) is a test flight scheduled for 2019. The EM-1 trajectory will reach cis-lunar space for a total mission duration of 21-42 days. The Van Allen proton exposure during EM-1 is expected to be lower than EFT-1 primarily due to faster transit through the belts, but significantly higher than that experienced by the International Space Station (ISS) during South Atlantic Anomaly (SAA) passes. Characterization of the space radiation environment and development of mitigation strategies are complex problems. The environmental components (GCR, SPE, Van Allen radiation) differ in elemental compositions, energy spectra, and intensities. The intra-vehicular environment is modified as a result of interaction of the extra-vehicular environment with the spacecraft materials. This occurs due to both the primary particles being slowed down by electronic interactions with the shielding material,

and secondary particles being generated by nuclear interactions. Knowledge of exposure specific to organ points of interest is important for biological effects quantification. Human body self-shielding differs among organs and tissues. The measuring efficiency of detectors varies across the wide range of particle species and energies of interest. Tissue equivalent phantoms have been used to perform space radiation measurements relevant to biomedical effects. The MATROSHKA series of international collaboration experiments using the anthropomorphic Alderson Rando phantom as measurement platform has been conducted starting from 2004, both intra- and extravehicular on ISS. Lockheed Martin is the NASA prime contractor responsible for the Orion vehicle. Radiation protection has been incorporated in the Orion spacecraft as a design driving requirement and consistent with the ALARA principle. Feedback invited by Lockheed Martin as part of ongoing efforts to optimize radiation protection of the Orion crew attracted interest in an incremental improvement of previous MATROSHKA experiments. In coordination with Lockheed Martin Advanced Programs, an ionizing radiation science payload referred to as MARE (Matroshka AstroRad Radiation Experiment) was proposed by the German Aerospace Center DLR and the Israel Space Agency ISA. In May 2017, MARE was approved by NASA and manifested aboard the Orion EM-1 flight. MARE consists of two CIRS ATOM® 702 Adult Female radiotherapy phantoms flown inside the Orion cabin at seat positions 3 and 4. The phantoms are fitted with ionizing radiation detectors placed both internal for organ point-, and external for skin exposure measurements. In an improvement over the ISS MATROSHKA, the science objectives are expanded to include characterization of a novel personal protection equipment item deployed on one of the phantoms, the AstroRad individual radiation protection shield. AstroRad is the product of an international collaboration between StemRad Ltd., Israel and Lockheed Martin. AstroRad provides customizable radiation protection for astronauts, focused on radiation-sensitive stem-cell rich organs and tissues. The MARE suite of radiation detectors includes over 5,000 passive detectors for dose depth profile and organ point measurements, consisting of Thermoluminescence- and Optically Stimulated Luminescence dosimeters, and Plastic Nuclear Track Detectors. For purposes of dosimetry intercomparison and detector cross-characterization, assemblies of dosimeters provided by the international research community will be included in MARE, with heritage participation in the DOSIS-3D experiment. MARE also features active detectors - the DLR M-42, the NASA CPAD (Crew Personal Active Dosimeter) and the ESA Active Dosimeter Monitor Unit - Orion (EAD MU-O). Time-resolved measurements provided by the active detectors will allow separate characterization of mission-phase-specific environments. Preliminary environment assessments were performed for the EM-1 mission, including on a family of expected trajectories through the Van Allen belts to confirm sensitivity requirements for the MARE detectors. This presentation will include background on the Orion vehicle, BEO vs. LEO radiation environments, heritage space dosimetry efforts relevant to MARE, and focus on the current MARE status including active radiation detector development, testing and characterization. In conjunction with other radiation detectors aboard the vehicle, the Matroshka AstroRad Radiation Experiment is designed to provide a comprehensive picture of the radiation environment beyond Earth orbit specific to the Orion vehicle and internal to human body analogs. This data set will inform about expected exposures, enable better planning by validating the operational toolsets used to predict crew radiation exposure risk on future Orion missions, and evaluate a potential countermeasure. MARE epitomizes the spirit of international collaboration toward human space exploration. The experiment is co-managed by DLR and ISA, with NASA participation as a co-PI. StemRad and Lockheed Martin contribute to the development of AstroRad science objectives. Numerous research groups on three continents participate as co-Is, including ESA. Lockheed Martin personnel facilitate payload integration in the spacecraft. As one of the first science payloads to fly aboard Orion, MARE demonstrates the research opportunities aboard NASA's next generation space exploration vehicle.