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MARE International Payload aboard Orion EM-1: Status Update for 23rd WRMISS

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The natural ionizing radiation environment present in space poses risks to human exploration that require mitigation.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. Orion is NASA's nextgeneration crewed spacecraft, developed specifically for Exploration missions. Orion's first test flight Exploration Flight Test 1 (EFT-1) was successfully completed in December 2014. The upcoming Orion mission Exploration Mission 1 (EM-1) is 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 experienced by the International Space Station (ISS) during South Atlantic Anomaly (SAA) passes. 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. This presentation will include background on the Orion vehicle, 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.

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