

## Required Space Weather Reconnaissance in the Artemis Era

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Planning is underway at NASA for returning humans to the Moon, followed by human missions to Mars. For the first time since the Apollo era, humans will again venture outside the protective radiation shield of the Earth's magnetosphere, this time for durations of months to several years where they will be vulnerable to long-term exposure from galactic cosmic rays (GCR) and particles associated with solar storms. As the distance from Earth increases, astronauts must increasingly operate independently from Earth due to communication delays and lack of near-term resupply opportunities. Therefore, in order to ensure the safety of astronauts, we must fill critical knowledge gaps in understanding the space environment before attempting long duration human expeditions. As we enter the Artemis era, space weather situational awareness to support human exploration and strategies to mitigate risks to crew health are of paramount importance. Radiation risk is expected to increase due to increased time of exposure and loss of protective Earth's magnetosphere on these mission. This primarily affects the risk of radiation carcinogenesis in the long term health domain with suspected contributions to cardiovascular disease and central nervous system decrements.

This paper summarizes findings from a recently completed study by the NASA Engineering & Safety Center (NESC) on space weather and space environments that impact human exploration in general and requirements for radiation monitoring and radiation shielding in particular [1]. After reviewing our current knowledge of radiation environments including the Earth's radiation belts, solar particle events, and galactic cosmic rays (GCR), we show Artemis missions GCR radiation exposures for various crewed design reference missions to the Moon and Mars. We show the aggregated radiation exposure during these design reference missions and how they compare with NASA's approved exposure limits during crew lifetime. Not surprisingly, total radiation exposures for some of Mars design reference missions can exceed NASA's lifetime exposure of the crew unless protective shielding techniques are factored in the design of spacecrafts, suits, and mission concept of operations. We then discuss some of the potential space weather reconnaissance concepts that can fill the knowledge gap for space weather situational awareness, and shielding requirements to ensure the safety of the crew on long-

term human expeditions to the Moon, Mars, and beyond.

### References:

- [1] Valinia, A., Allen, J., Francisco, D. Minow, J., Pellish, J, and Vera, A. Safe Human Expeditions Beyond Low Earth Orbit (LEO), NASA/TM-202200002905, URL: <https://ntrs.nasa.gov/citations/20220002905>