

## HUMAN RESEARCH ON THE LUNAR SURFACE TO ADVANCE MISSIONS TO MARS.

L.J. Abadie<sup>1</sup> and M.C. Waid<sup>1</sup>

<sup>1</sup>NASA Johnson Space Center, 2101 NASA Pkwy, Houston, TX 77058.

**Introduction:** As NASA's Artemis program aims to land the first woman and next man on the Moon by 2024 and establish a sustainable human presence by 2028, one of the most challenging components is the crew itself. NASA's Human Research Program, or HRP, will utilize the unique platform of the lunar vicinity to identify ways to keep astronauts safe there and on future missions to Mars.

The HRP is responsible for enabling human space exploration beyond low Earth orbit, by reducing risks to astronaut health and performance through a focused program of applied research and technology development. As mission durations lengthen and crews travel farther from Earth, HRP objectives intensify and are driven by specific questions on how the human system is dynamically changing and adapting to the space environment. To investigate these questions, HRP conducts research on Earth in ground-based analogs and laboratories, the International Space Station, and soon the Moon.

**Five Hazards:** While a mission to Mars poses multiple, synergistic hazards to astronauts, a mission to the Moon is much different than a mission on the space station. Artemis missions will provide unique environments, operations, risks, and technology requirements that will change the paradigm for human spaceflight.

The HRP employs a risk-based strategy to address the five hazards of human spaceflight: (1) space radiation; (2) isolation and confinement; (3) distance from Earth; (4) altered gravity; and, (5) hostile/closed environments. Each hazard has multiple risks associated with it, and lunar missions offer inherent hazards more representative of a Mars-class mission. The human research conducted on the lunar surface and Gateway will add significant understanding, mitigation and validation of human health and performance risks in a low gravity, operational, integrated environment.

**The Moon as an Analog:** NASA's HRP has adopted a "Mars-forward" approach to assess and mitigate risks to address the five hazards. This approach uses capabilities that enable tests of crew health and performance systems via analogs and simulations. These analog facilities increase in fidelity, beginning with ground-based facilities (lowest), and working up to the space station, the Gateway and lunar surface, and reaching highest fidelity in an actual transit to Mars. Each successive test is planned to build

on knowledge gained from previous tests, as the lower-levels build confidence for more challenging and costly tests at the higher-levels of fidelity.

Future human research conducted in the lunar vicinity fall into eight categories, based on how the mission could be used in a Mars-forward strategy: (1) Phase 1 Science would evaluate crew health and performance and Mars-forward technologies in deep space, such as in-situ analysis to support follow-on Earth-independent research and operations; (2) Mars Landing Simulation would validate how well the deconditioned crew can perform landing-related tasks without the assistance of a ground support team; (3) Post-landing Science would evaluate crew health and performance after landing in a partial gravity environment; (4) Medical Level of Care V would demonstrate Earth-independent medical operations required for Mars; (5) Mars Habitation Analog could validate the crew's behavioral health and performance and countermeasures in the deep space environment; (6) Deep Space Human Health Science would evaluate crew health risks, such as nutrition and immune, and validate countermeasures; (7) Translational Research would evaluate predictive models and countermeasure efficacy by studying animal models over their lifespan and how that translates to human systems; and, (8) Food/Pharmacy Stowage would evaluate and validate food and pharmaceutical stability after stowage and exposure to the deep space environment over long periods of time.

**Collaboration & Partnerships:** The HRP is committed to national and international collaboration with the goal of buying down risk to human health and performance quicker, more efficiently and identifying mutually beneficial aims. Currently, the HRP partners with many different government agencies, both within the U.S. and abroad, academia, and industry to accomplish its goals by leveraging facilities, expertise and data from its various partners. This collaboration will continue as NASA ventures into the next generation of human space exploration to the Moon and onto Mars, and will ensure astronauts' health and performance during their missions and when they return to Earth.

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