First suited physiology tests within the LUNA analog facility: 1 g Baseline Validation and Outlook to 0.16 g Offloading Studies

Jan Breuer[1,2], Dominik Pesta [1, 3, 4] & Wolfgang Potthast[2] & Timo Frett[1]

[1] Institute of Aerospace Medicine, German Aerospace Center, Cologne, Germany

[2] Institute of Biomechanics and Orthopaedics, German Sports University, Cologne, Germany

3 Cologne Excellence Cluster on Cellular Stress Responses in Aging-Associated Diseases (CECAD), University of Cologne, Cologne, Germany

4 Medical Faculty, University of Cologne, Cologne, Germany

Introduction As human exploration returns to the Moon, astronauts must execute time-critical locomotor and operational tasks under reduced gravity, challenging visual conditions (e.g., low sun angles, strong shadows) and mechanical constraints (e.g., uneven regolith, reduced traction), where early-exposure errors may elevate safety risk. ESA/DLR's LUNA facility provides a uniquely real-life environment to rehearse EVA-relevant tasks in regolith and, in future campaigns, under partial-gravity offloading (~0.16 g). Here we report a 1g suited baseline campaign asking whether a modular EVA obstacle-course layout can be executed safely and reproducibly while capturing usable physiological and workload measures. This baseline is a prerequisite for upcoming offloading studies, and it anchors an experimental pathway toward quantifying early-exposure risk and testing mitigation through brief pre-adaptive familiarization.

Method Over three days, a joint ESA–DLR LUNA :envihab team executed a structured test series to verify feasibility, safety procedures, and spatial layout of a modular obstacle course in the LUNA regolith hall at 1 g. The full-suit EVA course included six modules: straight walk with low step-over and turn, S-line walking under low-sun glare, bright-to-dark transition with object collection, carried slalom, kneel/stand recovery maneuver, and a tooling task; subjective workload assessed with the NASA Task Load Index (NASA-TLX; a multidimensional measure of perceived task workload) and Rating of Perceived Exertion (RPE), and heart rate.

Results Physiological monitoring during the suited EVA obstacle course showed moderate cardiovascular strain (mean heart rate 89 bpm) with low signal artifacts and preserved autonomic variability. RPE ratings indicated high physical demand, with frustration rated in the lower range of the NASA-TLX scale and mental/temporal demand rated moderate. and perceived performance rated as good to moderate-good. Task completion times generally improved in most tasks from EVA Day 1 to Day 2, indicating a rapid familiarization, while visually challenging modules were completed more slowly (e.g., low-sun glare, bright-to-dark transition), and performance scaled predictably with external load changes.

Discussion The 1 g suited campaign demonstrated the feasibility of a modular EVA-relevant obstacle course in LUNA. Physiological and subjective responses indicated moderate cardiovascular strain despite high perceived physical demand, while frustration and mental/temporal demand remained relatively low-to-moderate, and task times improved from Day 1 to Day 2, indicating rapid familiarization. Visually challenging modules, (low-sun glare

and bright-to-dark transitions), elicited increased caution, identifying these conditions as key candidates for probing early-exposure risk in future protocols. Collectively, these findings underscore the need for a standardized, transferable task-and-metrics framework, ideally established via expert consensus, to enable comparability across future offloading campaigns.