Development of Weighout Process and Evaluations for Underwater Partial Gravity EVA Simulations

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For the upcoming Artemis lunar missions, astronauts will need to train in a spacesuit where partial gravity can be simulated such as NASA Neutral Buoyancy Lab (NBL). At the NBL, dive weights and foam can be added around the spacesuit to attain a satisfactory center of buoyancy (CB) and center of gravity (CG) location to simulate the lunar gravity ($1/6^{th}$ G) effects. If CG and CB are not co-located properly, incorrect righting moments can be introduced, and both simulation quality and EVA task performance can be impaired. Based on the findings from the initial testing using xEMU spacesuits, it was observed that the weigh-out method (i.e., determination of the weights and foam quantities and position) needed further development to improve the simulation quality, especially for the subjects who experienced excessive instability. This paper aims to present the on-going effort to improve the weigh-out process for enabling NBL lunar EVA simulations. For this effort, a human-suit model was created to use suit CAD and 3D human body scans to estimate both CB and CG location for each suited subject. NBL weigh-out testing was performed to characterize the effects of CG and CB positioning, in which the 3D human-suit model was used to determine optimal weigh-out combinations of weights and foam. Postural, balance, and subjective feedback were gathered for each weigh-out configuration. The results indicated that, as the CB was shifted higher and the CB and CG located closer to each other, the subject tended to be more stable and their EVA performance improved. A high CB location was then prioritized across 4 additional subjects in both small and large size spacesuits. When compared to the initial xEMU test series, improved performance was observed across all subjects as the CB moved higher and aligned closer to the system CG.