

HUMAN VOLUNTEER LUNAR LANDINGS WHILE IN A STANDING POSTURE

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INTRODUCTION

Injury prediction and prevention while landing on the lunar surface in a standing configuration is an event with few analogs. Research on injury due to loading while standing unsupported has focused on pedestrians struck by automobiles. Vertical axis loading research has been conducted in the context of underbody blast injury (e.g., landmines), but this work is much higher rate and much more severe than a lunar landing. Additionally, lunar landings will involve restraints of some form to keep the crewmembers at their stations, potentially provide some offloading, and prevent the crewmember from impacting vehicle structures during the dynamic phases of flight. Terrestrial underbody loading involves a “preload” of gravity pushing the body into contact with the ground. In a lunar landing, the preload could range from a maximum of 1/6th Earth gravity as the vehicle’s thrusters act to slowly match the acceleration of the lunar surface to a minimum of no preload if the thrusters are turned off prior to landing, resulting in momentary free-fall prior to touchdown. Lunar landing while standing results in the ground accelerating towards the human. While the inverse case (human accelerating towards the ground) is similar, muscle activation strategies are likely different, resulting in different biomechanics. Human Landing System (HLS) providers are required to keep the dynamic response of a crewmember’s center of mass below injurious thresholds; however, there is currently no transfer function to predict the dynamic response of a standing occupant given the predicted vehicle accelerations. This work seeks to replicate lunar landing loads by dropping human volunteers on a human-rated test device while standing. The data collected will seek to overcome many of the limitations of the current NASA requirements governing crew landings while standing and address gaps relating to crew in dynamic environments.

METHODS

Human subjects will complete a series of tests utilizing the Vertical Deceleration Tower (VDT) at Wright-Patterson Air Force Base (WPAFB). The VDT consists of a carriage that is attached to a 60-foot guide rail system that allows for unpowered vertical drops. These tests will vary in peak acceleration, pulse length, landing angle, and by restraint and/or suit. The characterization of these variables have been determined by current NASA human standards and by characterization of realistic lunar landing conditions. Subjects will be outfitted with a full IMU (inertial measurement unit) suite and accelerometers to capture kinematic reactions to the drop tests. High speed video will capture additional kinematic data and load cells will capture the forces and moments at the feet and at the restraints. From the collected data, a post-test analysis of the subjects’ human performance will be performed. From this, a mathematical association between the probability of an unstable reaction and the input conditions will be created. This data will help inform appropriate levels of risk for lunar landings. The data collected from this study will also be delivered to other research efforts involving various computer-based modeling efforts, such as finite-element and musculoskeletal modeling. The proposed testing will generate data that can be used for standing landing model validation. This will include proper data filtering and necessary transformations of all applicable data collected. The study will also deliver a mass-spring-damper model similar to the Brinkley Dynamic Response Criterion (BDRC), a model currently used in part to certify space vehicles for transient accelerations experienced by seated crewmembers. The first part will include the natural frequency and damping coefficients in which the model is built on. The second part will include mapping the human performance analysis to the model to implement appropriate limits. Lastly, this study will provide a comparison analysis of unrestrained and restrained cases. This will include any statistical analyses of the effectiveness of restraints, recommendations for future efforts on the study of restraint effectiveness, and recommendations on how to implement deliverables into NASA in context of restraint use.