

Spacesuit Fit and Mobility Assessments by Digital Human Modeling

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Spacesuits are required to accommodate safe operations for astronauts across gender and a wide variety of body shapes and sizes. This goal has been of particular importance given the increasing diversity of NASA crewmembers for upcoming Missions. While testing with design prototypes is a critical step for spacesuit development, iterative mockup design, fabrication, and human subject tests can be extremely costly and time consuming. Moreover, testing with a limited subject pool has often raised questions for validity, as test subjects need to represent the entire astronaut population, not only of the past or current, but also the future.

This study is aimed at demonstrating how digital human modeling (DHM) tools have been built and directly supported NASA spacesuit developments. With DHM, the computer aided design (CAD) model of a spacesuit was integrated with human body models. Two use scenarios are presented in this paper, namely fit and mobility. For fit assessments, the suit-to-body contact and compression patterns were estimated using 3D human body scan models virtually wearing a spacesuit model. A statistical fit classifier was made from the contact patterns and applied against a large database of body scans (N=2,500). With this technique, the NASA reference design spacesuit Exploration EVA Mobility Unit (xEMU) was verified to accommodate 90% of the astronaut-like population, with the critical dimensions covering 1st to 99th percentiles of the target body measurements.

A similar technique assessed xEMU mobility. The maximum reach envelopes were considered, within which the work objects and critical hardware interfaces should be located for safe and ergonomic operations. While the reach envelope geometry varies significantly with the suit wearer's body size and strength, the existing test data did not include the subjects critically required to define suit mobility requirements, such as very small females or large males. Using the xEMU virtual model kinematically simulated and permuted for a hypothetical wearer, however, the existing data were statistically transformed and scaled. This method enabled for a parametric estimation of the reach envelopes from the 1st percentile female or 99th percentile male. The outcome was successfully incorporated for requirement developments.

With the new DHM tools, human integration of the spacesuit was structurally simulated and predictively assessed, which would have been otherwise impossible. Also, the needs for iterative mockup and subject tests were significantly reduced, which resulted in time and cost saving. Additional work is in progress to integrate additional vehicles, tools, and hardware with DHM framework.