Adjustable Mock-up for Integrated Vehicle, Seat, and Suit Evaluations

Sudhakar Rajulu, *Johnson Space Center*
Matt Cowley, *Lockheed Martin*
Lynn K. Pickett, *Lockheed Martin*

Vehicle accommodation requirements are difficult to test and verify. Activities such as ingressing the seat in a vehicle require adequately capturing and analyzing the entire ingress motion to ensure that crew members can deal with limited and restrictive ingress volume space without being stopped or bumping into any surrounding hardware interfaces and protrusions. Having an accurate mock-up is critical because the vehicle, seats, hatch, suits, and other surrounding, necessary hardware all affect motions and postures adopted by the crew member to perform tasks. Postures and movement strategies will also change depending on the occupant's size, age, and gender. The culminating effect of all these factors on subject performance is something that is not easily understood and captured with just simulation software such as digital human modeling. Often, the multifactorial aspects of specific vehicle-seat-suit interfaces and how they would affect (collectively and singularly) pressure-suited humans of different shapes and sizes have yet to be captured in such a simulation software. Most importantly, to simulate such realistic conditions is simply not possible. To see the full picture, some human-in-the-loop testing is required.

Human-in-the-loop testing was previously carried out in standard mock-ups to address design performance and verify requirements are being met. However, standard mock-ups have opaque walls that limit the ability to use motion-capture technology, still and video cameras, and visual observations. Ordinarily these mock-ups also rely on hardware permanently fixed in place to a specific design iteration. Extensive changes to the mock-up design (shape and volume) often would result in the need to build an entirely new mock-up. This may prove to be costly and time consuming. Most importantly, engineers do not get an adequate amount of relevant engineering specific data, which they need to mitigate potential crew-hardware interface accommodation issues.

In the automobile and aerospace industry, it is common practice to design and evaluate vehicle cockpits using transparent and adjustable mock-ups along with state-of-the-art motion-capture technologies (figure 1). Collecting motion-capture data during ingress/egress and other types of tasks in an open mock-up greatly increases the ability to understand and quantify the ergonomic issues associated with various-sized humans interacting with tasks to be carried out in confined work areas. However, nothing of this nature existed at NASA for testing designs for space vehicle cockpits.

The Anthropometry and Biomechanics Facility (ABF) at Johnson Space Center (JSC) developed an adjustable, transparent mock-up of the Orion crew module to fill this void in the design verification abilities of NASA and allow designers to use the latest technologies for human-in-the-loop hardware evaluation. The new mock-up is designed to reduce the amount of visual occlusions to the still, video, and motion-capture cameras and test observers; be adjustable to multiple crew module configurations; and maintain a high level of realism for the test subjects. Figure 2 depicts an assembly of the module structure, netting, display panel, seat pallet, and high-fidelity Orion seats.

Nylon mesh is used for the walls and other hardware in the crew module to give the subject the perception of solid objects, while allowing the cameras and observers to see through the structure. The netting was chosen over glass and transparent plastics because it did not refract light, which would render motion-capture cameras useless. The netting is retractable and enables safety personnel quick and easy access to suited test subjects from any location should a problem arise.

The mock-up is designed with an extruded aluminum frame for easy assembly/disassembly and portability, while maintaining the ability to support loads incurred during testing. The structural configuration for the Orion crew module (fig, 2) frame components can support the weight of a suited crew member during evaluations, allowing that crew member to perform tasks in a realistic manner. The structure can support the full weight of the largest suited crew member when catching a fall on one of the several handholds (not shown).

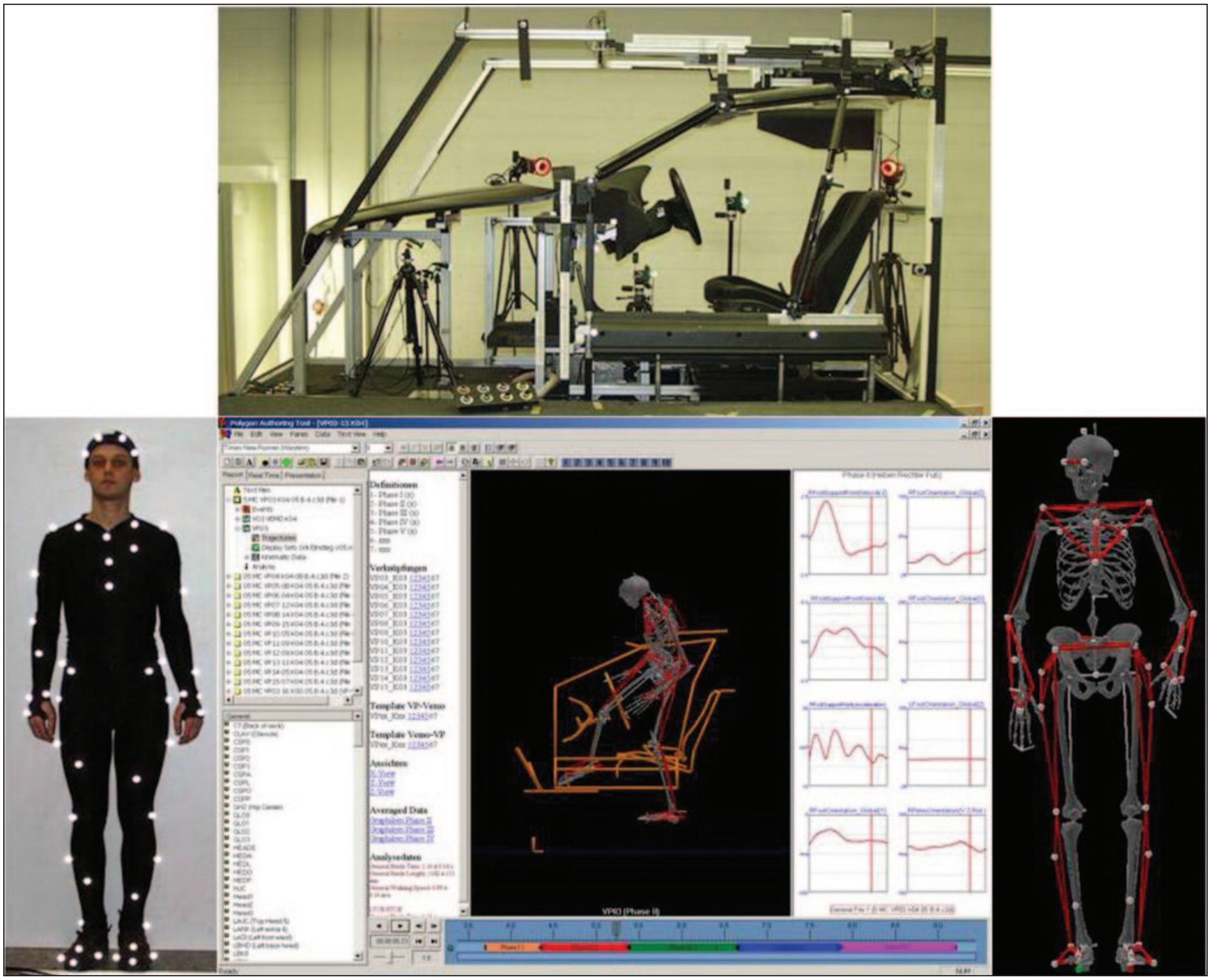

__Fig. 1.__ Human ingress movements for optimization of vehicle accessibility. (Courtesy of Technical University of Munich and BMW)

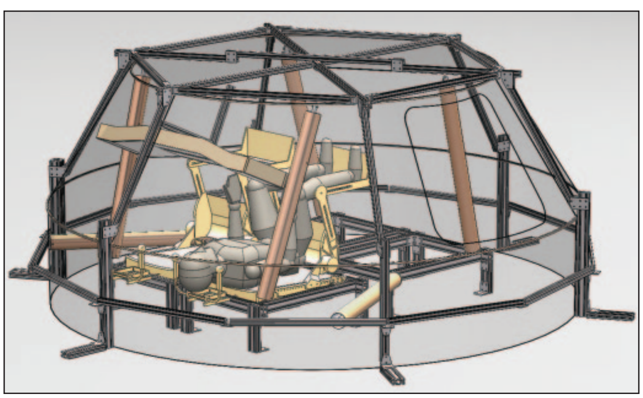

__Fig. 2.__ Computer-aided design depiction of the adjustable mock-up set to Orion crew module dimensions.

The pallet and frame can be easily changed to simulate a variety of crew module designs and volumes. The structural members of the frame can be shortened, lengthened, or changed in angle. Interior hardware—such as seats, pallets, control panels, struts, and other additional hardware—can also be easily changed to fit new dimensions or new crew modules designs. This ability to change the mock-up shape and its hardware content allows for quick turnaround times for verification testing on design changes. For example, the Orion crew module could be swapped out for a commercial design quickly. Dimension verification is simplified with the ability to use the motion-capture equipment. Markers are placed on numerous critical landmarks, and the entire mock-up is

Adjustable Mock-up for Integrated Vehicle, Seat, and Suit Evaluations

continued

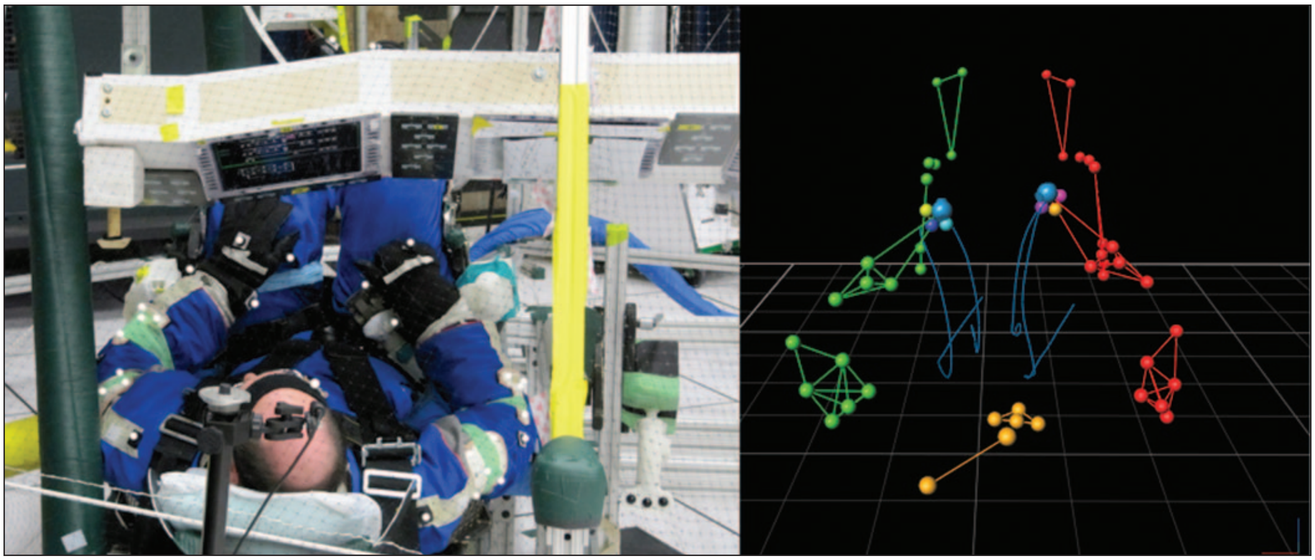

Fig. 3. *A subject in a prototype suit performing Orion launch-and-entry tasks (left) with traces of hand movements in the motion-capture software (right).*

measured in just a few seconds down to the millimeter. The use of Faro Arm (a 6-degrees-of-freedom, 3-dimensional measurement device; not shown) during mock-up testing also enhances the ability to compare and contrast human dimensions to hardware dimensions and clearances.

With the mock-up completed, the JSC ABF team is performing a series of evaluations to test several extravehicular activity prototype suits in the Orion crew module vehicle/seat environment (figure 3). Suited subjects perform planned ingress, egress, and flight tasks while motion-capture data, video data, subjective comment data, dimensional clearances, and observational data are collected. Data that the ABF team will be able to gather using this approach will include, but are not limited to: functional range of motion, motion paths, identification of keep-out zones, collision detection, seated comfort, joint stress, task time to completion, and general observer functionality comments. Performance of the suits, updates to requirements based on actual required task motions, and identification of what is causing certain issues (vehicle, seat and/or suit) are determined.

The mock-up is being used to evaluate the performance of new prototype extravehicular activity suits. An additional benefit of this type of testing is the ability to capture much of the task performance data and then project the individual person's data to a range of subjects to study the impact of vehicle accessibility for a wide range of the population. NASA engineers often have to contend with making important decisions based on only a few subjects' data or comments due to a limited number of suits and suit sizes, or to limited subject availability. While it is true that individual subjects may exhibit different mobility and postural patterns, it is now possible to make a calculated prediction and assessment of a specific vehicle-seat-suit interface for a wide range of population. One additional advantage of this method of using transparent mock-ups with advanced motion-capture technology is that NASA engineers will be able to graphically view and analyze the 3-dimensional human and hardware interference data in a computer-generated replica of the conceptual crew vehicle design and make moderate changes—e.g., to the display control panel—to arrive at a better design without needing to redo the expensive evaluations.