Valens Institute Functional Body Forms Project

Adaptations For Ground-To-Orbital Operation

Introduction

The **Functional Body Forms Project** is exploring ways to adapt the human body to new environments and new operational roles within those environments. This is building on recent advances in reconstruction and rearrangement of limbs and other human body parts, using nonsurgical tissue-growth and reshaping techniques. In this particular summary Report, we look at experiments in creating a body form suitable for roles such as spacecraft construction and piloting of vehicles between planetary orbit and planetary surfaces. This combines the requirement of spending long periods in zero-gravity conditions with frequent commutes between such conditions and planetary surfaces.

Such a body form can usefully be made more compact than a conventional human body. Long legs, so important for long-distance mobility on a planetary surface, just take up space and become an obstacle to free movement in low or zero gravity (microgravity). But instead of removing the lower limbs completely, it makes sense to *adapt them to the function of an extra pair of arms*. An extra pair of hands can be useful in zero gravity, since their grasping ability does not only serve manipulation purposes, but also works for mobility with the help of suitable handholds within the interiors of microgravity habitations and work spaces.

Extra hands can even be vital for operating construction equipment in zero-gee environments. Unlike on planetary surfaces, the operator needs to be able to work in a fully three dimensional space, both for vehicle movement and for manipulation of building materials. This will require more than one pair of hands.

However, those lower arms must still serve the function of legs when operating in a significant gravitational field on a planetary surface. Hands are not suited to taking as high a pressure load (from body weight, objects being carried etc) as feet.

This leads to an interesting conclusion: that the legs should be replaced with an extra pair of arms, but as a compromise, those arms should carry *feet instead of hands* at their extremities! But then, those feet would have to take on the alternate role of additional hands in microgravity conditions. So then we have to ask the question: how well can a pair of feet work for manipulation purposes? Can their grasping and manipulation capabilities be made sufficient, or nearly so, to be an extra pair of hands?

That is what this study is about.

The Subject Body Form

The body form in question will be worn by Pavla, one of our more experienced volunteers. It can often take an individual about three to six months to get fully acclimated to a new body form, but Pavla was able to begin performing at a functional level after a little more than a month.

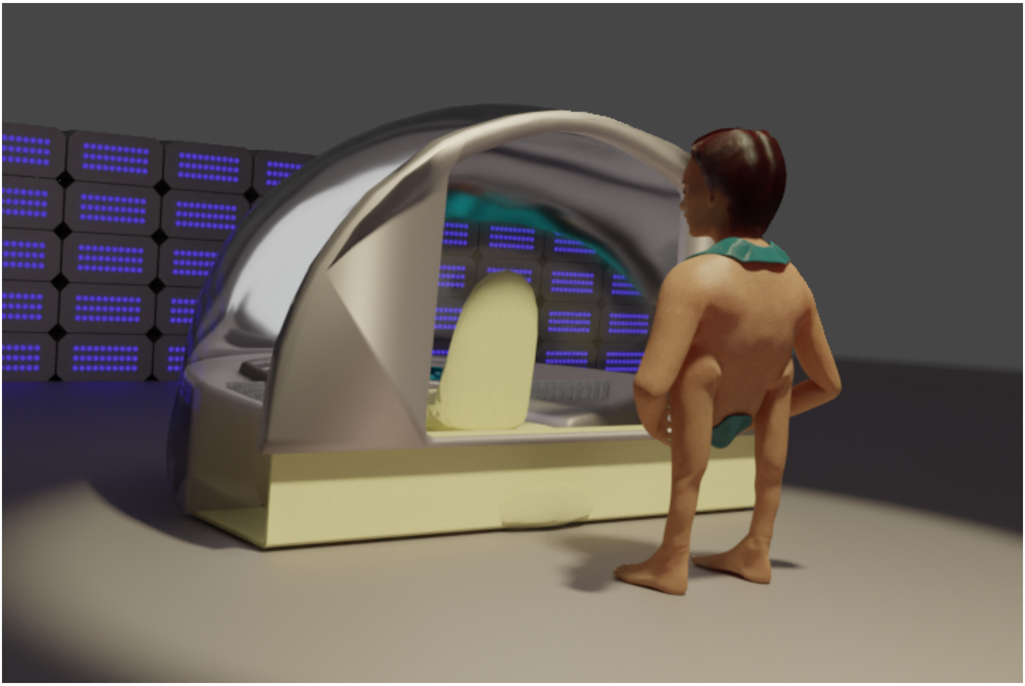
Note the overall body shape, more compact than a conventional human form with regular arms and legs. The internal organs, including the digestive system, were optimized somewhat, particularly in the lower body, to minimize the need for a regular human-sized abdomen below the arms.

Enter Pavla

Simulated Vehicle Operation

In the first part of this study, we explore various ways in which the subject may use her limbs to operate the controls of a space vehicle, and how efficiently she can perform a range of operational tasks.

The vehicle simulator is equipped with a basic array of controls of different types: an aircraft-style steering wheel, a pair of joysticks for operating external manipulator arms, a pair of touchscreens for status displays and function selection, and a pair of button banks for additional controls.



To The Simulator

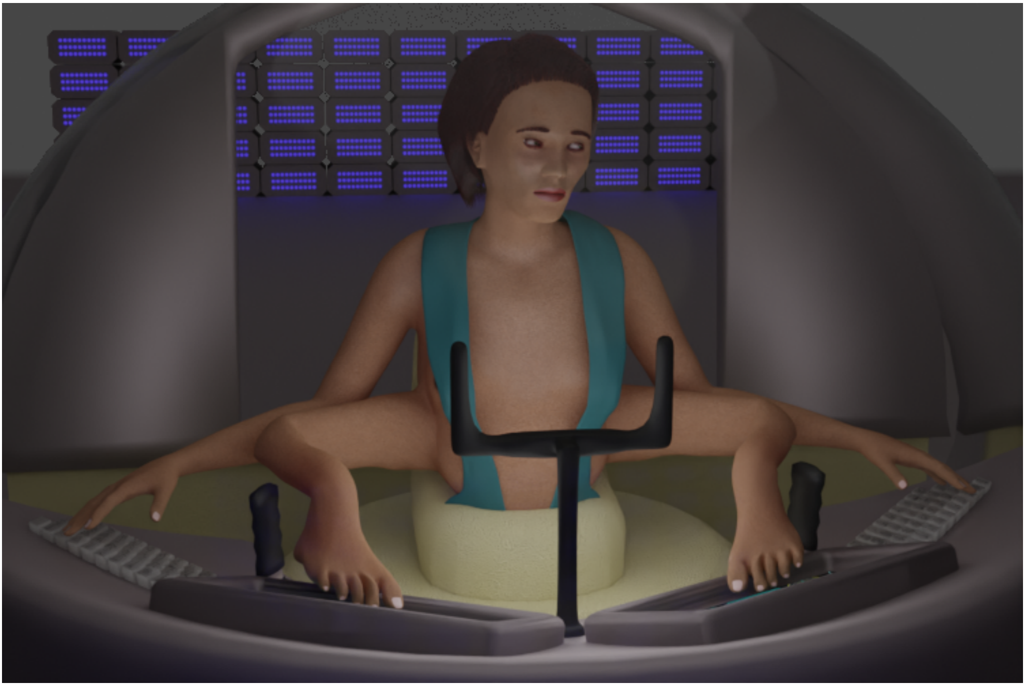
First of all, note the seating position. There is no allowance for “legroom” as such, since the operator has no legs. Most control positions are designed to be reached as easily with the feet as the hands. So the question becomes, can the controls be operated just as nimbly with feet and toes as with hands and fingers.

At The Control Seat

Here is an initial example: simultaneous operation of both touchscreens and both button banks. As an integral part of the new body design, the toes are given the same individual dexterity control as the fingers.

Touchscreens And Buttons

As a demonstration of versatility, here the operations of the hands and feet are interchanged. Then a comparison of facility and efficiency of the two modes of operation is done.



Touchscreens And Buttons, Swapped

The foot is also given additional plasticity, with more wristlike ankle mobility, and also some metatarsal separability to give the big toe something close to the opposability achievable with the thumb. This allows it to be used to grip suitably-shaped controls.

Hand And Foot Grip

As before, each mode is also tested with the hands and feet interchanged.


Hand And Foot Grip, Swapped

Mobility In Microgravity

The second part of the study looked at basic ability to move about in actual microgravity and perform simple manual tasks.

Movement is typically done by pulling on suitable handholds, or pushing against fixed surfaces. With suitably prehensile toes on armfeet, the handholds function as footholds as well.

No Need To Stand In Zero G

Performing operations on equipment can become tricky in the absence of gravity to aid in anchoring the body. An obvious alternative is to use anchoring restraint belts, but these can be inconvenient to fasten and unfasten, if the operator needs to move around a lot during the procedure. This is a situation where having more than two grasping limbs comes in handy, so one or two may be used to provide an anchor point, leaving at least two free for manipulation purposes.

Indeed, in many situations, a single limb anchor point may be sufficient, allowing the use of a third hand (or foot) to assist in some of the more fiddly procedures.

Three Hands Better Than Two

Conclusion

The subject, Pavla, showed a remarkable ability to adapt to the test body shape. The main limitation to using toes like fingers, once the necessary improvements to the musculature have been addressed, are their obvious difference in shape: can shorter toes be as nimble as longer fingers?

Our initial experiments along these lines look promising: the subject was able to achieve all the basic tasks to a high degree of reliability, after a modest amount of training.

Of course, much more experience is required, in order to collect more data. The next step will be to try more demanding, longer-duration tasks. What are the performance limits of this body configuration? We need to know precisely what a subject wearing such a body shape is capable of, as well as what her limits are, before we can commit to wider deployment on actual mission-critical operations.

At some point, testing will have to progress to operation of actual equipment on planetary surfaces, planetary orbit and everything in-between. Only then will we have the confidence to launch long-term missions that will depend so crucially on crews being able to live and work efficiently and safely in such a wide variety of conditions, with such a radically-altered body shape.