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DEVELOPMENT OF MICROGRAVITY, FULL BODY FUNCTIONAL REACH
ENVELOPE USING 3-D COMPUTER GRAPHIC MODELS AND
VIRTUAL REALITY TECHNOLOGY

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INTRODUCTION

In microgravity conditions mobility is greatly enhanced and body stability is difficult to achieve (Fauquet & Okushi, 1991). Because of these difficulties, optimum placement and accessibility of objects and controls can be critical to required tasks on board shuttle flights or on the proposed space station. Anthropometric measurement of the maximum reach of occupants of a microgravity environment provide knowledge about maximum functional placement for tasking situations.

Calculations for a full body, functional reach envelope for microgravity environments are imperative. To this end, three dimensional computer modeled human figures, providing a method of anthropometric measurement, were used to locate the data points that define the full body, functional reach envelope. Virtual reality technology was utilized to enable a occupant of the microgravity environment to experience movement within the reach envelope while immersed in a simulated microgravity environment.

THE HUMAN BODY IN A MICROGRAVITY ENVIRONMENT

In micro-gravity the human body experiences significant changes in perception, posture, and efficiency of movement (Fauquet & Okushi). Due to liberation from supporting the body's weight, space between each vertebra expands, and the spinal length escalates, therefore increasing the height of the person by approximately three per cent (NASA, 1978). There is, however, a decrease in effective body height resulting from the crouched neutral body posture brought on by life in microgravity (Fauquet & Okushi). The frame, nevertheless, is extended when stretching to reach for an object or control if anchored in body or foot restraints. This study is undertaken to determine the maximum reach, along a variety of planes, under these conditions.

NEED FOR A MICROGRAVITY, FULL BODY FUNCTIONAL REACH ENVELOPE

Distinct problems in the placement and adjacency of controls and equipment are encountered in a micro-gravity environment. It is necessary to the health, comfort, and productivity of participants in such an environment that maximum reach envelope calculations be established and tested to assist in the placement of equipment in relation to body restraint apparatus and adjacency of equipment that must be used simultaneously or in sequence. "In order to choreograph human/machine interface within physically and emotionally supportive body envelopes the characteristics of the interface morphology of human mobility in microgravity must be understood", (Fauquet & Okushi, p. 1).

Review of the literature reveals only partial reach envelope

data for this environmental situation (NASA, 1978 and NASA, 1989). Fully developed reach envelope calculations are needed and should be presented in a way that may be used for training or interactive experience--not for information alone.

Calculation of maximum extension points within a full body reach envelope cannot be achieved by usual means in Earth's gravity. Body positions that can be achieved under micro-gravity conditions must, in Earth's gravity, be simulated in contrived situations such as in a neutral buoyancy diving tank or during a flight that is designed to provide a few seconds of micro-gravity experience. Such flights are conducted by NASA's K-135 (Fauquet & Okushi).

These methods are costly and have limitations due to required life support equipment and/or necessary brevity of the experiment. Limitations of this type restrict researchers' ability to calculate a variety of reach envelope maximum data points.

SETTING REACH ENVELOPE DATA POINTS USING THREE DIMENSIONAL COMPUTER GENERATED HUMAN MODELS

Mannequin uses a library of ergonomic data that allows human to figures be integrated into simulations to make a designed environment or object more functional (Gamble-Risley, 1992). The human model chosen for this study was defined by Mannequin Pro as a large, American, male, adult of average build, corresponding to the a 95th percentile male in stature (Biomechanic Corporation of America 1992 & NASA, 1989).

Human models provided in Mannequin Pro software were used to find data points along a curve that defined the reach envelope (Figure 1 and Figure 2). Data points were dimensioned and coordinates were recorded for additional points including the fingertip, top of head, and suprasternum. The suprasternum data point was chosen as the point from which to calculate the curve along which the figure moves to form each plane of the reach envelope (Figure 3 and Figure 4).

The figure was manipulated to move from zenith to the left side (Figure 1) and forward and backward (Figure 2). Since the figure existed in simulated microgravity, it was not necessary to keep the center of gravity above the feet. Range of motion for the figure was from zero degrees to 180 degrees. The curve was calculated and graphics produced by Mathmatica software (Figure 3 and Figure 4).

USING IMMERSIVE VIRTUAL REALITY TECHNOLOGY TO ILLUSTRATE THE REACH ENVELOPE

Swivel 3-D by VPL Research Incorporated is the modeling software
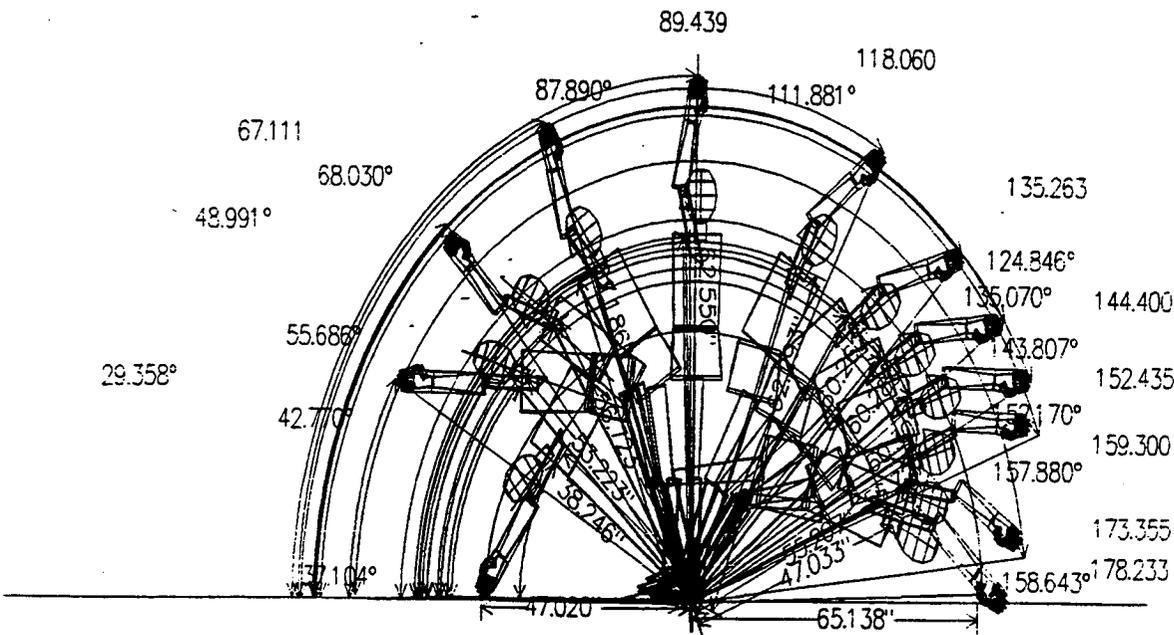
Figure 1.
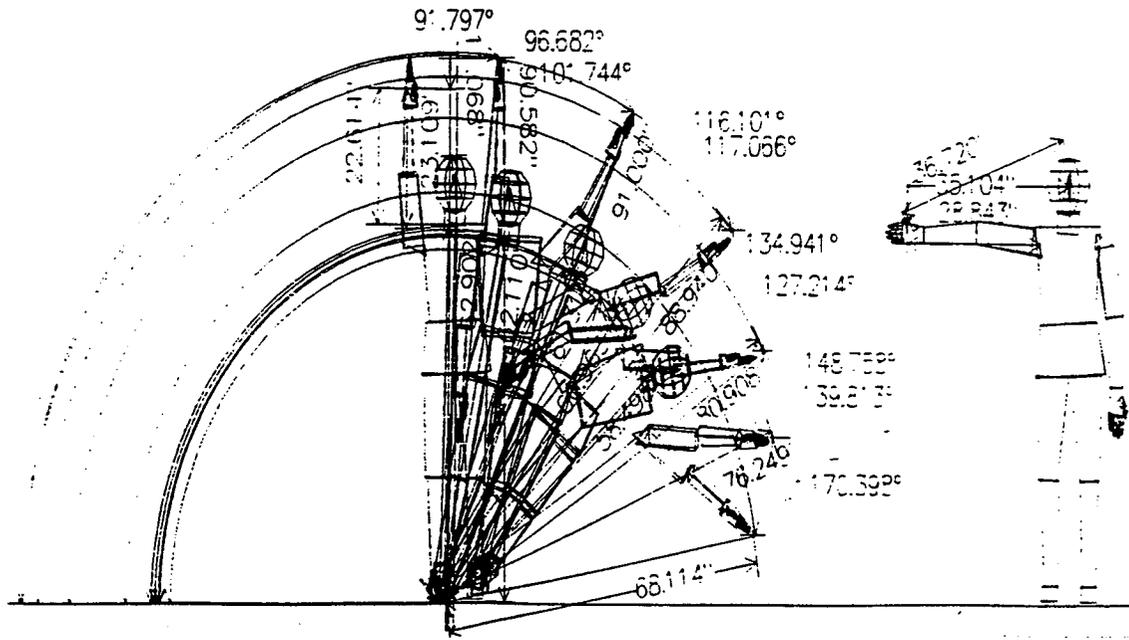
Figure 2.

XXIII-3

Angle From Horizontal vs. Foot Restraint - Supersternum Distance in Side-to-Side Plane - Manniquin Data
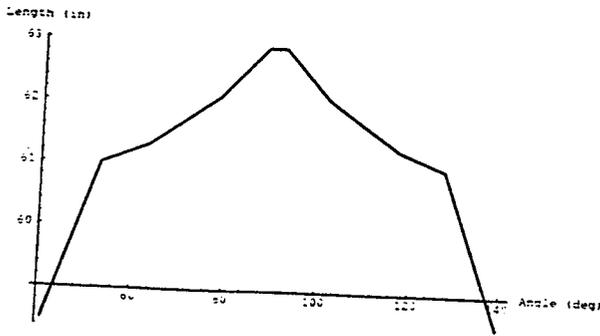
Angle From Horizontal vs. Foot Restraint - Supersternum Distance in Side-to-Side Plane - Curve Fitted to Manniquin Data
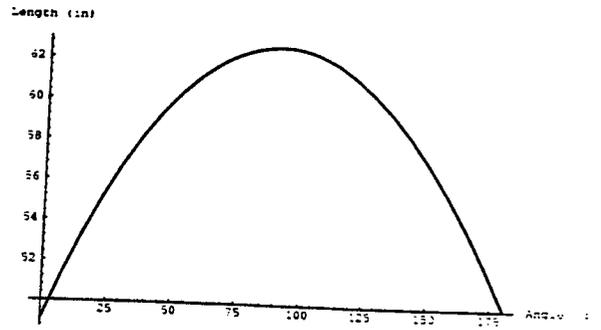
These are the raw datapoints obtained from Manniquin for subject motion in the side-to-side plane. The angle is measured from the horizontal on the subject's left-hand side to the foot restraint-supersternum line.

```
SSdatapoints = {{41.2,58.5},{52.8,61.0},{62.9,61.3},{78.3,62.1},{88.2,62.9},{91.8,6:
{101.7,62.1},{117.1,61.3},
{127.2,61.0},{139.8,58.5}};
ListPlot[SSdatapoints,PlotJoined->True,AxesLabel->{"Angle (deg)","Length (in)"}]
```

Figure 3.

Angle From Horizontal vs. Foot Restraint - Supersternum Distance in Forward-Backward Plane- Manniquin Data
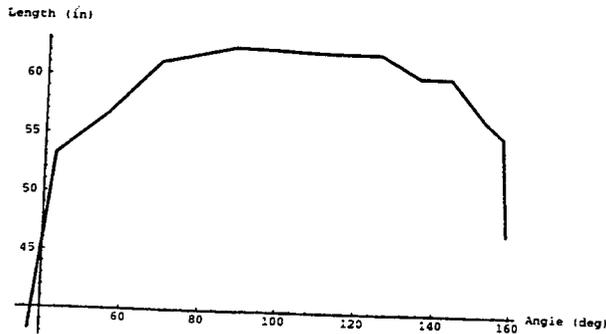
Angle From Horizontal vs. Foot Restraint - Supersternum Distance in Forward-Backward Plane- Curve Fitted to Manniquin Data
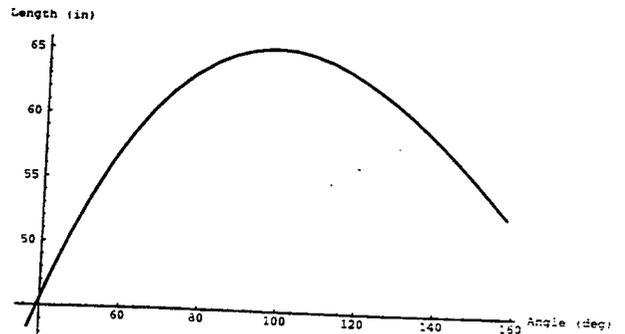
These are the raw data points obtained from the Manniquin software.
The first number of each pair is the angle from the floor directly in front of the subject to the foot restraint-supersternum line. The second point is the length of the foot restraint-supersternum line.

```
FBdatapoints={{37.1,38.2},{42.8,53.2},{55.7,56.7},{68.8,61.2},{87.9,62.6},
{111.9,62.3},{124.8,62.3},{135.1,60.3},{143.0,60.3},{152.2,56.7},
{157.1,55.3},{158.6,47.0}};
```

Figure 4.

used for this study. Body Electric Visual Programming Language connects input by the operator to drive the simulator. As the user makes head or body movements, Body Electric registers the changes to the virtual environment Information sent by Body Electric to drive the simulator is translated by Isaac software.

Data points found using Mannequin figures were placed in a virtual reality simulation of the IML-2. The user is immersed in the simulated reach envelope within the IML-2 and may pivot from side to side or front to back within the confines of the reach envelope by using a joy stick for manipulation. The user may also move along the curve of the reach envelope moving from one set point to another as assigned in Body Electric.

RECOMMENDATIONS FOR FURTHER STUDY

It is recommended that reach enveloped data be collected along additional planes, expanding the data base for a full body, functional reach envelope.

It is recommended that real human subjects be used to collect data in a simulated microgravity situation such as a neutral buoyancy tank or K-135 flight or under actual microgravity conditions.

It is recommended that data be compared to the data set by Mannequin and placed in the virtual reality environment and refinements made where variances exist.

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