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Anthropometric Data from Launch and Entry Suited Test Subjects for the Design of a Recumbent Seating System

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ERRATA

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by

Lara E. Stoycos and Glenn K. Klute

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Acronyms and Abbreviations

ABL	Anthropometric and Biomechanic Laboratory
Ave	average
ECS	Environmental Control System
JSC	Lyndon B. Johnson Space Center, Houston, Texas
LES	Launch and Entry Suit
Max	maximum
Min	minimum
NASA	National Aeronautics and Space Administration
St Dev	standard deviation
STS	Space Transportation System

Executive Summary

In early 1995, an American astronaut will be launched, along with Russian cosmonauts, to the Russian space station, Mir. Three to four months later, the Space Shuttle will dock with Mir and return the American astronaut and two Russian cosmonauts.

This long duration mission aboard Mir has raised concerns over physiological changes caused by the absence of gravity and their effect on the crewmembers' ability to withstand the return flight. Because the long stay aboard Mir will cause some atrophy of crewmembers' muscular systems, it was suggested that the crew return to Earth in a recumbent position to minimize the effects of these physiological changes.

Returning the crewmembers in a recumbent position requires the design of a new seating system. Current anthropometric data are based on measurements taken while the subjects were unsuited and sitting. To be most accurate, it is necessary to design by measurements of subjects in the launch and entry suit (LES) in a recumbent position.

Since the design of the recumbent seating system must meet the requirements of both 5th percentile Japanese female and 95th percentile American male crewmembers, a delta is reported rather than absolute measurements of the test subjects. This delta is the difference in the measurements taken with the subjects unsuited and sitting and those taken with the subjects suited and recumbent. This delta, representative of the change due to the suit, can be added to the existing Man-Systems Integration Standards (MSIS) (NASA-STD-3000) anthropometric data to project the measurements for 5th percentile Japanese female and 95th percentile American male crewmembers. A delta accounting for the spinal elongation caused by prolonged exposure to microgravity is added as well. Both unpressurized and pressurized suit conditions are considered.

This document presents background information, the test protocol and procedure, analysis of the data, and recommendations.

Section 1 Purpose

The purpose of this investigation was to quantify anthropometric dimensions of test subjects wearing launch and entry suits (LESs) in a recumbent position. These anthropometric characteristics will be used to design a recumbent seating system which will be flown on STS-71, the STS/Mir mission, in June of 1995.

Section 2 Background

In early 1995, an American astronaut will be launched, along with Russian cosmonauts, to the Russian space station, Mir. In 3 to 4 months, the Space Shuttle Orbiter will dock with Mir and return the American astronaut and two Russian cosmonauts.

This long duration mission aboard Mir has raised concerns over physiological changes caused by the absence of gravity and the effect of these changes on the crewmembers' ability to withstand the return flight. It is well known that long duration stays in zero gravity result in atrophy of the muscular system. Hence, it has been suggested that the crewmembers return to Earth in a recumbent position to minimize the effects of these physiological changes. The three crewmembers retrieved from Mir will therefore return to Earth lying in the middeck of the Orbiter, perpendicular to and between the middeck lockers and the airlock. A fourth American astronaut will also return in the middeck, sitting beside the port hatch. All crewmembers, including the two cosmonauts, will be wearing the American LES.

This seating system may also be used to return future crewmembers from long duration missions aboard Space Station Freedom. Therefore, it will be designed to accommodate the full anticipated range of crewmember dimensions.

Man-Systems Integration Standards (MSIS), NASA-STD-3000, Volume 1, Section 3.3, gives anthropometric measurements of unsuited individuals. (Extracts from MSIS are given in Appendix A of this paper.) Estimates for suited anthropometric data have previously been made by adding to these unsuited anthropometric measurements deltas that account for the addition in length due to the suit and spinal elongation. Since these data were subjective and never validated, the investigation described herein was performed to obtain more accurate measurements.

Section 3 Method

Measurements were first taken with the subject unsuited and sitting. The same measurements were then taken with the subject suited and recumbent. Both unpressurized and pressurized conditions were considered. Ultimately, the change in dimensions obtained while wearing the suit were added to the existing MSIS anthropometric data to estimate the total lengths. Deltas due to spinal elongation, also reported in MSIS, were added as well.

3.1 Subjects

Since the seat design should meet the extreme requirements of MSIS 5th percentile Japanese female and 95th percentile American male crewmembers, an attempt was made to recruit subjects who are most representative of these percentiles. The stature, weight, sitting height, and buttock-popliteal length of all possible candidates were measured prior to testing, and six subjects best representative of each percentile were asked to participate in the study. Because the subject pool was limited to JSC employees with current Air Force Class III physicals, it was difficult to select subjects to meet either the MSIS 5th percentile female or the 95th percentile male dimensions. The subjects were chosen as close to these requirements as possible without picking those either above a 95th percentile American or below a 5th percentile Japanese female. The stature and percentile data for each subject are shown in table 1. None of the test subjects had been in a pressurized LES prior to this test.

Fifth percentile, 50th percentile and 95th percentile data from three sources were used to determine the percentile of the test subjects according to stature. These sources were: (1) MSIS (NASA-STD-3000), Volume 1, Section 3.3; (2) 1988 Anthropometric Survey of U.S. Army Personnel; and (3) a data base containing astronaut candidate anthropometric data compiled by the Anthropometry and Biomechanic Laboratory (ABL), Johnson Space Center (JSC), Houston, Texas. Using the equation for a z-score (see any general statistical methods/data analysis text), the program calculates the number of standard deviations that the stature measurements lie away from the mean. A look-up table, which is defined by a normal population and the 5th, 50th, and 95th percentile measurements from each of the data sets separately, then correlates the calculated z-score with the appropriate percentile.

The female percentiles calculated with the MSIS data were higher than the percentiles calculated with either the military or astronaut candidate data. This discrepancy is due to the fact that the MSIS data are taken from Japanese females while the military and astronaut candidate data are taken from American females. Because all of the female test subjects in this study were American, they fell into a higher percentile when compared to the MSIS data. The male

percentiles calculated with the MSIS data were lower than the percentiles calculated with either the military or astronaut candidate data. This difference was due to the fact that the MSIS data predict measurements for the year 2000, while the military and astronaut candidate data are relatively current. Since stature is expected to increase by the year 2000, the MSIS stature measurements are greater than either the military and astronaut candidate measurements. Thus, the male subjects fell into lower percentiles when compared to the MSIS data.

Table 1. Statures and Approximate Percentiles of the Test Subjects

Subject #	Stature ¹	Approx. % NASA ²	Approx. % Military ³	Approx. % Astronaut ⁴
Males				
1	185.9	84	94	89
2	184.3	76	91	88
3	183.5	72	89	87
4	184.1	75	89	85
5	186.5	86	95	90
6	183.3	71	88	87
Ave	184.6	77.3	91.0	87.7
Females				
7	151.0	12	4	2
8	150.1	8	3	1
9	153.8	26	9	3
10	154.0	27	10	4
11	152.4	17	6	2
12	155.8	40	15	6
Ave	152.9	21.7	7.8	3.0

¹Stature is given in cm

²NASA - MSIS (NASA-STD-3000), Volume 1, Section 3.3

³Military - 1988 Anthropometric Survey of U.S. Army Personnel

⁴Astronaut - Astronaut Candidate Anthropometric Data, ABL, JSC

3.2 Apparatus

A mockup recumbent seat was used to require the subjects to lie in a position similar to that expected in the new seat. This mockup was built to meet the design requirements of the estimated minimum seat back length and the 139.7-cm constraining distance between the base of the airlock and the middeck lockers. These dimensions are shown in figure 1. The handle on the airlock was considered to be above the recumbent crewmember's helmet and therefore was not considered in the measurement of the constraining distance. The minimum seat back length was estimated by adding the unsuited sitting height of the tallest subject and distances allowed for pressurization of the suit, elongation of the spine and head clearance. A mockup of this configuration is shown in figure 2.

Two LESSs, one small and one large, were required for this investigation, along with the equipment necessary to pressurize them. Suit support was provided by the JSC Crew and Thermal Systems Division. The environmental control system (ECS) was provided by the ABL. A standard anthropometer (Siber Hegner and Co., Inc.) was used to take the measurements.

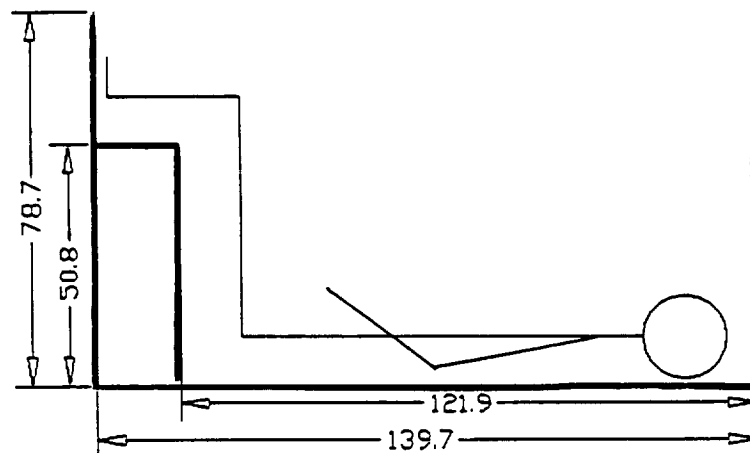


Figure 1. Dimensions (cm) for the recumbent seating system.

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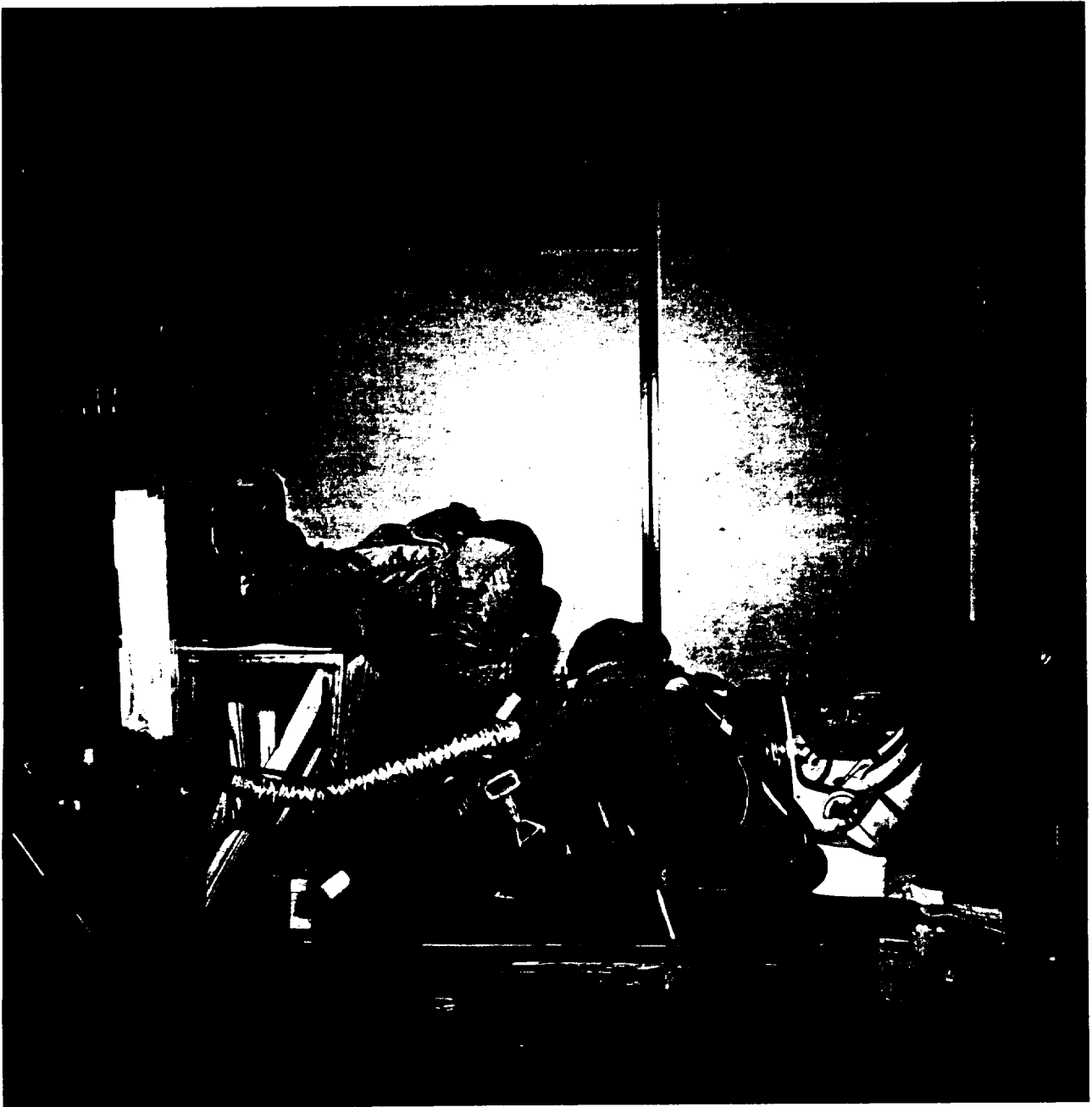


Figure 2. Mockup of the recumbent seating system.

3.3 Procedure

Anthropometric measurements were first taken in the control condition, with the subjects unsuited and sitting. Measurements were then taken under two test conditions, unpressurized and pressurized, each with the subjects suited and lying in a recumbent position. For each condition, the following ten measurements were taken (see Appendix A):

- Sitting height
- Shoulder height
- Elbow rest height
- Buttock-popliteal length
- Shoulder breadth
- Elbow-elbow width
- Hip breadth
- Chest depth
- Hip angle
- Knee angle

All measurements were taken with the seat pan positioned 122 cm from the top of the seat (airlock). This left 18 cm between the seat pan and the foot plate (middeck forward lockers). One male and one female test subject could not be fully pressurized (subjects 1 and 8); therefore only their unpressurized measurements were recorded.

All measurements were taken on the right side of the subject, most using the reference points described in MSIS (NASA-STD-3000), Volume 1, Section 3.3 (see Appendix A of this report). Some reference points were difficult to establish when the suit was pressurized so the following landmarks were used for both test conditions:

- Shoulder width—bottom of NASA patch on right arm to bottom of American flag on left arm
- Hip breadth—harness strap to harness strap
- Chest depth—center of parachute buckle to seat back
- Buttock-popliteal length—to back of knee, even if no space between calf and thigh; right leg lifted to place anthropometer behind knee

Data were obtained for both the pressurized and unpressurized test conditions. In a non-emergency situation, the crew typically returns with the suits unpressurized and the helmet visors up. The unpressurized sitting height was therefore measured to the top of the bailer bar, with the bailer bar held above the helmet and perpendicular to the seat back. This orientation represents the minimum clearance required to rotate the visor (note that in figure 2, the bailer bar is rotated downward). In the case of an emergency, the suit is pressurized and the visor is down. The pressurized sitting height was therefore measured to the top of the helmet. There is a 5.5 cm

distance between the top of the helmet and the bailer bar. If it is decided that the crew will return unpressurized but with the visors down, 5.5 cm should be subtracted from the sitting height of the unpressurized test condition.

Subjective data were taken with regard to the fit and comfort of the suit in the recumbent position. The g-suit and pressure suit were separately inflated and the subjects were asked to assess any discomfort or pain, especially any caused by pressurization of the suit.

Section 4 Results

4.1 Quantitative

The raw data for the control and test conditions are given in Appendix B, tables B-1, B-2, and B-3. From these raw data, deltas were calculated for all measurements, except the hip and knee angles, for each subject. These deltas were defined as the difference in the test condition and the control condition (see appendix B, tables B-4 and B-5). For each measurement the average and standard deviation of the deltas for the male and female groups were calculated separately. The maximum delta for the males and the minimum delta for the females were also calculated. These data are shown in tables 2 and 3.

Table 2. Change in Anthropometric Measurements from the Control Condition to the Unpressurized Test Condition

Subject#	Sitting Height	Shoulder Height	Elbow Rest Height	Buttock-Popliteal Length	Shoulder Width	Elbow-Elbow Width	Hip Breadth	Chest Depth
Males								
Max	17.9	9.8	11.9	8.5	13.4	14.4	9.1	14.1
Ave	15.3	8.3	10.4	6.2	9.3	10.7	6.3	13.0
St Dev	2.60	1.04	1.24	1.87	3.89	3.39	2.06	1.08
Females								
Min	11.2	5.3	7.9	8.7	6.2	7.0	4.1	10.4
Ave	16.0	7.0	12.1	9.9	14.8	12.6	7.8	11.2
St Dev	4.05	1.65	2.99	0.92	4.33	4.04	2.72	0.59

Measurements are given in cm

Table 3. Change in Anthropometric Measurements from the Control Condition to the Pressurized Test Condition

Subject#	Sitting Height	Shoulder Height	Elbow Rest Height	Buttock-Popliteal Length	Shoulder Width	Elbow-Elbow Width	Hip Breadth	Chest Depth
Males								
Max	13.7	10.9	17.0	13.1	13.4	20.6	8.0	19.0
Ave	10.8	9.7	13.7	12.1	9.8	12.1	4.8	17.1
St Dev	4.96	4.04	5.92	5.08	5.15	8.50	3.18	7.15
Females								
Min	8.1	8.1	11.9	10.5	15.3	11.0	3.4	10.1
Ave	11.3	8.6	12.5	13.0	17.3	16.0	5.4	13.6
St Dev	2.40	0.50	0.73	1.54	1.27	3.69	1.58	2.76

Measurements are given in cm

It was assumed that the deltas calculated from the test subject data would be representative of the deltas characteristic of a 5th percentile Japanese female and a 95th percentile American male. The average and standard deviation of the deltas presented in tables 2 and 3 were therefore redefined as the projected deltas for the 5th percentile and 95th percentile populations. Although the average deltas for the males and females were similar for some measurements, the standard deviations were not. Therefore, the same delta could not be used for both males and females. Instead, the average delta was reported for both sexes as well as the average plus one standard deviation for the males and the average minus one standard deviation for the females (see Appendix B, tables B-6 and B-7).

The projected deltas were then added to the 5th percentile Japanese female and 95th percentile American male anthropometric measurements from the MSIS (see Appendix A, table A-1). The deltas for spinal elongation were then added to the sitting height, shoulder height, and elbow-rest height. As reported in MSIS, spinal elongation is expected to be about 3 percent of stature. Using this estimate, the deltas for spinal elongation would be 4.5 cm and 5.7 cm for the 5th percentile Japanese female and 95th percentile American male, respectively.

Tables 4 and 5 show the total lengths important to the design of the recumbent seating system. These compensated measurements equal the MSIS data reported for 5th percentile Japanese female and 95th percentile American male subjects, plus projected deltas due to suit and spinal elongation. These total lengths are given for both the unpressurized/visor-up and the pressurized/visor-down conditions. For those readers who prefer English units, Appendix C reports the same measurements in inches.

Table 4. Compensated Unpressurized Anthropometric Measurements

	Sitting Height	Shoulder Height	Elbow Rest Height	Buttock-Popliteal Length	Shoulder Width	Elbow-elbow Width	Hip Breadth	Chest Depth
Projected Anthropometric Measurements for a 95% American Male								
Ave	120.5	84.0	45.8	61.7	53.6	72.2	48.6	41.2
Ave+ St Dev	123.0	85.0	47.0	63.6	57.4	75.6	50.6	42.2
Projected Anthropometric Measurements for a 5% Japanese Female								
Ave	98.7	N/A	37.2	47.8	47.2	N/A	38.2	28.6
Ave- St Dev	94.7	N/A	34.2	46.9	42.9	N/A	35.4	28.0

Measurements = MSIS + Suit Delta + Spinal Elongation Delta.
Measurements are given in cm.

Table 5. Compensated Pressurized Anthropometric Measurements

	Sitting Height	Shoulder Height	Elbow Rest Height	Buttock-Popliteal Length	Shoulder Width	Elbow-elbow Width	Hip Breadth	Chest Depth
Projected Anthropometric Measurements for a 95% American Male								
Ave	116.0	85.4	49.1	67.6	54.1	73.6	47.1	45.3
Ave+ St Dev	121.0	89.4	55.1	72.7	59.2	82.1	50.3	52.5
Projected Anthropometric Measurements for a 5% Japanese Female								
Ave	94.1	N/A	37.7	50.9	49.7	N/A	35.8	31.0
Ave- St Dev	91.7	N/A	37.0	49.4	48.5	N/A	34.2	28.2

Measurements = MSIS + Suit Delta + Spinal Elongation Delta.
Measurements are given in cm.

4.2 Subjective

4.2.1 Test Subject Comments

Once measurements were made in the unpressurized condition, the g-suit was inflated. Although all subjects felt pressure around the abdomen and thighs, as expected, none felt pain in the joints. Pressure was relieved when the lap belt was loosened.

All male subjects had some type of discomfort while in the recumbent position. Some felt pressure in the knees; others felt a slight loss of circulation in the lower extremities. The major problem was the knees rotating to the outside. All of the male subjects had to work to keep their knees within the width of the chair. When the suit was pressurized, it was difficult to hold the arms and knees together. After approximately 30 minutes, the subjects were asked to estimate how long they could remain in the recumbent position. Most subjects commented that they would become uncomfortable after an hour or so.

The female subjects did not have problems with fit, but some did have difficulty holding their arms in their laps when the suit was pressurized.

The lack of leg room caused the male subjects to exert strong forces on the foot plate, particularly when the suit was inflated. Not only did the foot plate deflect quite a bit, but the lower leg was actually wedged into the given space. It was impossible for both female and male subjects to lift their own legs off the seat. Over the course of the study, the foot plate loosened quite a bit.

Once the suit was pressurized, it was extremely difficult to release the lap belt. The subjects were unable to release the belts on their own; rather they required assistance from the suit technician.

4.2.2 Hip and Knee Angles

The hip and knee angles were used as a subjective measure of how cramped the legs were, particularly when the suit was pressurized. Table 6 gives the hip and knee angles for both the pressurized and unpressurized test conditions. As seen in the data, pressurization of the suit caused the hip angle to increase. Though the hip angles were the same for males and females, the knee angle was smaller for the males than for the females, thus causing the males to feel more uncomfortable and exert more force on the foot plate.

Table 6. Hip and Knee Angles

Subject #	Unpressurized		Pressurized	
	Hip Angle	Knee Angle	Hip Angle	Knee Angle
Males				
1	73	54	N/A	N/A
2	66	49	71	50
3	62	54	75	50
4	72	60	78	53
5	68	55	77	56
6	71	55	73	55
Ave	68.7	54.5	74.8	52.8
Females				
7	83	70	76	67
8	70	64	N/A	N/A
9	74	69	77	55
10	73	64	81	67
11	72	69	77	72
12	68	65	78	68
Ave	73.3	66.8	77.8	65.8

Measurements are given in degrees.

Section 5 Conclusions and Recommendations

This investigation produced anthropometric data for subjects wearing the LES and lying in a recumbent position. Tables 4 and 5 report the overall dimensions which should be taken into consideration for the design of the recumbent seating system. The overall dimensions are defined as the MSIS (NASA-STD-3000) anthropometric measurements for an unsuited, sitting subject plus two deltas which account for the increase in length due to the suit and spinal elongation.

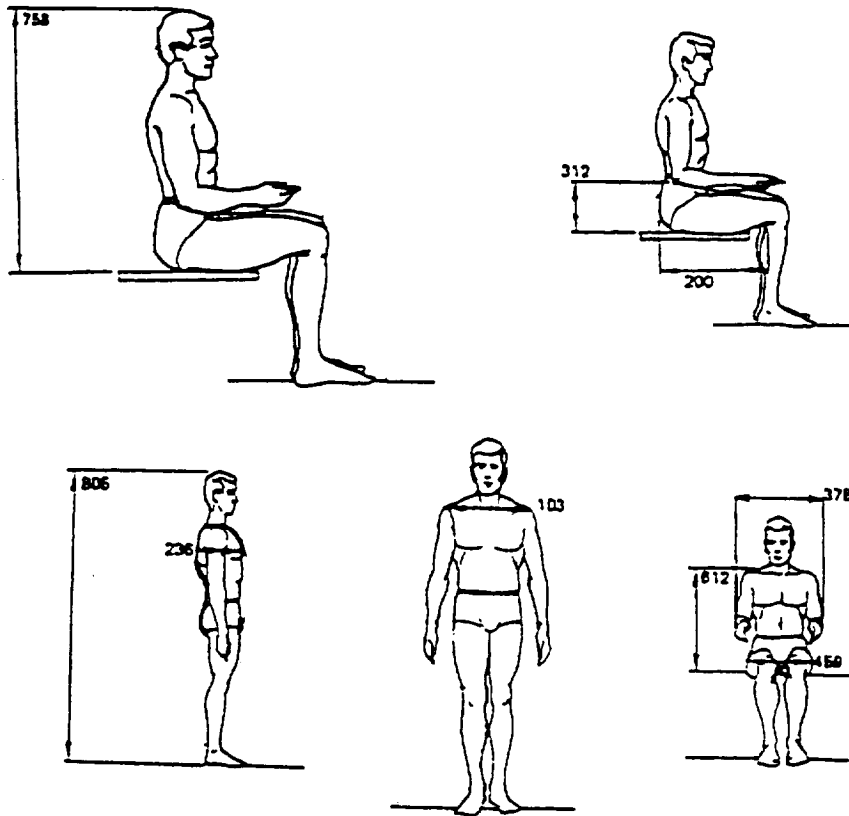
Crew comfort must be taken into consideration when designing the seating system. Most of the male subjects felt that they could not comfortably remain in the required position for an extended period of time. Restraints should be provided to keep the knees close to the body without the crewmembers having to do much of the work themselves.

Because of the strong forces exerted by the legs, a structurally adequate foot or heel plate should be used.

Appendix A

Sitting height, 758	Shoulder breadth, 103
Shoulder height, 612	Elbow rest height, 312
Buttock-popliteal length, 200	Chest depth, 236
Elbow-elbow width, 378	Hip breadth, 459
Stature, 806	

Figure A-1. Measurements taken from NASA-STD-3000, Volume 1, Section 3.3, and Definition of the Hip and Knee Angles.



Sitting height, 758

Shoulder height, 612

Buttock-popliteal length, 200

Elbow-elbow width, 378

Stature, 806

Shoulder breadth, 103

Elbow rest height, 312

Chest depth, 236

Hip breadth, 459

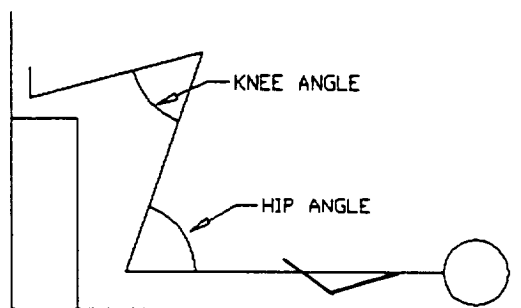


Figure A-1. Measurements taken from NASA-STD-3000, Volume 1, Section 3.3, and Definition of the Hip and Knee Angles.

Table A-1. MSIS Data for 5% Female and 95% Male Subjects

	Sitting Height	Shoulder Height	Elbow Rest Height	Buttock-Popliteal Length	Shoulder Width	Elbow-elbow Width	Hip Breadth	Chest Depth
95% Male	99.5	70.0	29.7	55.5	44.3	61.5	42.3	28.2
5% Female	78.3	N/A	20.7	37.9	32.4	N/A	30.4	17.4

Measurements are given in cm

Appendix B
Recumbent Seat Test Data

Table B-1. Control Condition Raw Data

Subject #	Sitting Height	Shoulder Height	Elbow Rest Height	Buttock-Popliteal Length	Shoulder Width	Elbow-elbow Width	Hip Breadth	Chest Depth
Males								
1	100.0	65.2	26.4	50.0	42.4	54.5	38.0	25.7
2	96.0	61.9	24.6	49.0	44.2	50.5	37.1	23.1
3	91.0	61.1	24.1	51.2	42.2	51.5	38.0	24.5
4	91.1	63.4	24.5	49.4	46.5	53.7	36.6	23.3
5	92.7	63.1	23.3	52.0	43.7	60.0	40.0	26.8
6	95.2	65.6	26.5	49.4	50.6	61.1	42.0	26.7
Females								
7	86.3	52.5	21.1	42.3	34.9	45.1	39.0	24.7
8	77.1	51.5	18.9	43.9	33.0	42.1	30.9	23.1
9	80.3	51.3	19.7	45.3	37.0	45.2	36.7	22.5
10	81.8	54.0	22.5	44.0	37.6	42.5	36.4	23.0
11	84.0	53.7	24.7	41.2	37.5	42.7	36.5	22.3
12	82.8	52.7	19.8	44.7	34.9	41.0	34.5	23.8

Measurements are given in cm

Table B-2. Unpressurized Test Condition Raw Data

Subject #	Sitting Height	Shoulder Height	Elbow Rest Height	Buttock-Popliteal Length	Shoulder Width	Elbow-elbow Width	Hip Breadth	Chest Depth
Males								
1	111.3	72.3	34.8	54.0	N/A	63.3	44.4	37.4
2	109.1	71.7	36.0	53.2	56.1	64.9	46.2	36.9
3	106.2	68.5	34.0	57.2	55.6	65.9	45.2	38.6
4	109.0	71.6	34.6	56.2	54.4	65.6	43.5	36.9
5	109.3	71.1	34.0	59.9	53.4	68.5	44.7	38.4
6	112.6	74.8	38.4	57.9	54.0	67.3	45.2	39.7
Females								
7	97.5	58.6	29.0	51.9	41.1	56.5	43.1	35.8
8	99.3	61.4	35.7	53.3	51.0	49.1	43.3	34.2
9	96.3	57.5	32.0	54.0	53.4	55.9	43.9	34.0
10	100.5	61.8	36.0	55.4	53.1	55.3	43.5	35.1
11	96.4	59.0	35.7	51.0	54.7	57.6	43.6	33.1
12	98.1	59.2	30.6	55.0	50.6	59.9	43.2	34.2

Measurements are given in cm

Table B-3. Pressurized Test Condition Raw Data

Subject #	Sitting Height	Shoulder Height	Elbow Rest Height	Buttock-Popliteal Length	Shoulder Width	Elbow-elbow Width	Hip Breadth	Chest Depth
Males								
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	102.8	72.8	38.0	62.0	55.8	71.1	45.1	42.1
3	102.6	71.4	35.2	63.7	55.6	69.6	44.2	41.8
4	102.7	72.7	37.8	61.5	54.3	62.6	42.5	41.7
5	103.0	72.5	37.2	61.9	55.4	71.7	42.7	41.9
6	108.9	74.1	43.5	62.5	55.0	62.2	43.1	42.6
Females								
7	94.4	60.6	33.0	56.0	52.1	58.5	42.4	34.8
8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9	93.6	59.4	32.0	59	54.9	64.4	41.8	39.2
10	95.7	63.1	35.4	56.8	55.2	53.5	41.8	37.9
11	93.9	62.2	38.3	55.7	56.2	59.6	41.6	37.2
12	94.3	61.8	31.7	55.2	50.2	60.4	42.3	35.1

Measurements are given in cm

Table B-4. Change in Anthropometric Measurements from the Control Condition to the Unpressurized Test Condition

Subject#	Sitting Height	Shoulder Height	Elbow Rest Height	Buttock-Popliteal Length	Shoulder Width	Elbow-elbow Width	Hip Breadth	Chest Depth
Males								
1	11.3	7.1	8.4	4.0	N/A	8.8	6.4	11.7
2	13.1	9.8	11.4	4.2	11.9	14.4	9.1	13.8
3	15.2	7.4	9.9	6.0	13.4	14.4	7.2	14.1
4	17.9	8.2	10.1	6.8	7.9	11.9	6.9	13.6
5	16.6	8.0	10.7	7.9	9.7	8.5	4.7	11.6
6	17.4	9.2	11.9	8.5	3.4	6.2	3.2	13.0
Females								
7	11.2	6.1	7.9	9.6	6.2	11.4	4.1	11.1
8	22.2	9.9	16.8	9.4	18.0	7.0	12.4	11.1
9	16.0	6.2	12.3	8.7	16.4	10.7	7.2	11.5
10	18.7	7.8	13.5	11.4	15.5	12.8	7.1	12.1
11	12.4	5.3	11.0	9.8	17.2	14.9	7.1	10.8
12	15.3	6.5	10.8	10.3	15.7	18.9	8.7	10.4

Measurements are given in cm

Table B-5. Change in Anthropometric Measurements from the Control Condition to the Pressurized Test Condition

Subject#	Sitting Height	Shoulder Height	Elbow Rest Height	Buttock-Popliteal Length	Shoulder Width	Elbow-elbow Width	Hip Breadth	Chest Depth
Males								
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	6.8	10.9	13.4	13.0	11.6	20.6	8.0	19.0
3	11.6	10.3	11.1	12.5	13.4	18.1	6.2	17.3
4	11.6	9.3	13.3	12.1	7.8	8.9	5.9	18.4
5	10.3	9.4	13.9	9.9	11.7	11.7	2.7	15.1
6	13.7	8.5	17.0	13.1	4.4	1.1	1.1	15.9
Females								
7	8.1	8.1	11.9	13.7	17.2	13.4	3.4	10.1
8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9	13.3	8.1	12.3	13.7	17.9	19.2	5.1	16.7
10	13.9	9.1	12.9	12.8	17.6	11.0	5.4	14.9
11	9.9	8.5	13.6	14.5	18.7	16.9	5.1	14.9
12	11.5	9.1	11.9	10.5	15.3	19.4	7.8	11.3

Measurements are given in cm

Table B-6. Projected Change in Anthropometric Measurements from the Control Condition to the Unpressurized Test Condition

	Sitting Height	Shoulder Height	Elbow Rest Height	Buttock-Popliteal Length	Shoulder Width	Elbow-elbow Width	Hip Breadth	Chest Depth
Projected Anthropometric Measurements for a 95% American Male								
Ave	15.3	8.3	10.4	6.2	9.3	10.7	6.3	13.0
Ave+ St Dev	17.8	9.3	11.6	8.1	13.1	14.1	8.3	14.0
Projected Anthropometric Measurements for a 5% Japanese Female								
Ave	16.0	7.0	12.1	9.9	14.8	12.6	7.8	11.2
Ave- St Dev	11.9	5.3	9.1	9.0	10.5	8.6	5.0	10.6

Measurements are given in cm

Table B-7. Projected Change in Anthropometric Measurements from the Control Condition to the Pressurized Test Condition

	Sitting Height	Shoulder Height	Elbow Rest Height	Buttock-Popliteal Length	Shoulder Width	Elbow-elbow Width	Hip Breadth	Chest Depth
Projected Anthropometric Measurements for a 95% American Male								
Ave	10.8	9.7	13.7	12.1	9.8	12.1	4.8	17.1
Ave+ St Dev	15.8	13.7	19.7	17.2	14.9	20.6	8.0	24.3
Projected Anthropometric Measurements for a 5% Japanese Female								
Ave	11.3	8.6	12.5	13.0	17.3	16.0	5.4	13.6
Ave- St Dev	8.9	8.1	11.8	11.5	16.1	12.3	3.8	10.8

Measurements are given in cm

Appendix C
Compensated Data Given In Inches

Table C-1. Compensated Unpressurized Anthropometric Measurements

	Sitting Height	Shoulder Height	Elbow Rest Height	Buttock-Popliteal Length	Shoulder Width	Elbow-elbow Width	Hip Breadth	Chest Depth
Projected Anthropometric Measurements for a 95% American Male								
Ave	47.4	33.1	18.0	24.3	21.1	28.4	19.1	16.2
Ave+ St Dev	48.4	33.5	18.5	25.0	22.6	29.8	19.9	16.6
Projected Anthropometric Measurements for a 5% Japanese Female								
Ave	38.9	N/A	14.7	18.8	18.6	N/A	15.0	11.2
Ave- St Dev	37.3	N/A	13.5	18.4	16.9	N/A	14.0	11.0

Measurements = MSIS + Suit Delta + Spinal Elongation Delta
 Measurements are given in inches

Table C-2. Compensated Pressurized Anthropometric Measurements

	Sitting Height	Shoulder Height	Elbow Rest Height	Buttock-Popliteal Length	Shoulder Width	Elbow-elbow Width	Hip Breadth	Chest Depth
Projected Anthropometric Measurements for a 95% American Male								
Ave	45.7	33.6	19.3	26.6	21.3	29.0	18.5	17.9
Ave+ St Dev	47.6	35.2	21.7	28.6	23.3	32.3	19.8	20.7
Projected Anthropometric Measurements for a 5% Japanese Female								
Ave	37.1	N/A	14.8	20.1	19.6	N/A	14.1	12.2
Ave- St Dev	36.1	N/A	14.6	19.4	19.1	N/A	13.5	11.1

Measurements = MSIS + Suit Delta + Spinal Elongation Delta
 Measurements are given in inches

REPORT DOCUMENTATION PAGE

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13. ABSTRACT (Maximum 200 words) Returning space crews to Earth in a recumbent position requires the design of a new seating system. Current anthropometric data are based on measurements taken while the subjects were unsuited and sitting. To be most accurate, it is necessary to design by measurements of subjects in the launch and entry suit in a recumbent position. Since the design of the recumbent seating system must meet the requirements of both 5th percentile Japanese female and 95th percentile American male crewmembers, a delta is reported rather than absolute measurements of the test subjects. This delta is the difference in the measurements taken with the subjects unsuited and sitting and those taken with the subjects suited and recumbent. This delta, representative of the change due to the suit, can be added to the existing Man-Systems Integration Standards (NASA-STD-3000) anthropometric data to project the measurements for 5th percentile Japanese female and 95th percentile American male crewmembers. A delta accounting for the spinal elongation caused by prolonged exposures to microgravity is added as well. Both unpressurized and pressurized suit conditions are considered. This report presents background information, the test protocol and procedure, analysis of the data, and recommendations.			
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