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Man-Machine Analysis of Translation & Work Tasks of Skylab Films

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Abstract

It was the purpose of this investigation to determine translation characteristics of Skylab astronauts. This was accomplished through a biomechanical analysis of translation. The results of the analysis may be helpful in improving the efficiency of translation and ultimately the productivity of future missions. Additionally, representative segments of Skylab film were identified in order that a film may subsequently be developed. Such a film would contain examples of relatively efficient and inefficient translations within various Skylab compartments. The film could then be utilized in training future astronauts.

To address the issues of the contract, selected film segments were digitized. Determination was also made of the body part utilized for initiating and terminating translations. An efficiency of translation scale was developed and each of 200 segments of film were rated with regard to the astronauts translation characteristics.

Results indicate that in general the astronauts were able to acclimate themselves to the zero g environment quite well. Results indicate that astronauts tend to translate in 1 g orientations when in the experimental compartment and the wardroom which are architecturally 1 g. However, when the astronauts are in the forward compartment, which is zero g oriented, they begin to translate more frequently in a zero g manner. There appear to be improvements in translation across time. These improvements appear more so in the forward compartment than in the wardroom or the experimental compartment. Possible changes in the architecture of the wardroom and the experimental compartment are suggested in order to improve translation within these compartments.

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1.0 Purpose

It was the purpose of this study to determine how the various astronauts did or did not utilize the unique zero-g environment to their advantage. The intent was to lead to generalizations concerning translation and work in zero-g, thus allowing efficient movement (translation) and effective time utilization by future astronauts. This could ultimately lead to greater productivity on the part of the astronauts.

This end will be ultimately accomplished through selected film segments of Skylab referenced to the data gathered from this biomechanical study.

2.0 Scope

The variables considered were translation and work in the zero-g environment of skylab missions. Study design and results should be applicable to subsequent development of a composite film, thus providing a learning experience for future astronauts. This would ultimately lead to more effective use of time and thus greater productivity on the part of the astronauts while they are in the zero-g environment.

3.0 Background

During each of the Skylab missions (missions 2, 3, and 4), films were taken of translation as well as various other tasks accomplished on the mission. The films from the missions are housed at the Space Craft Design division, with the Skylab Man-Machine Data Catalog Index (Contract NAS 9-14210) organized by major and subcategory classifications to aid in reviewing these films. Preliminary study of select Skylab films by these investigators indicated that there are, in fact, unique characteristics of translation and work in zero-g.

The results of biomechanical analyses can form the basis for understanding the complexities of human motion and provide important insight into performance at the practical level. Such analyses are gaining popularity in the analysis of human movement.

The results of biomechanical analyses provide the researcher with a quantitative method of analyzing human motion. Such techniques are being utilized in the analysis of sports activities. In that the translations that occur during zero-g experiences approximate those demonstrated in athletic activities, it was the contractors' intent to use biomechanical techniques to address the work tasks of this contract.

4.0 Objectives

4.1 The work to be accomplished with this contract is listed under the following numerical classifications.

4.1.1 Define translation modified through learning from initial stages of a Skylab mission to later stages of the same mission.

4.1.2 Quantify the forces used to initiate translations; describe the body part(s) for initiating and completing translation; identify vehicle structure and objects used during translation; quantify displacements and trajectories of translation.

4.1.3 Quantify and describe differences and similarities of selected translation and work tasks of various Skylab Astronauts. This objective seeked to cite how certain astronauts did or did not use zero-g to their advantage.

4.1.4 Once the analysis of 4.1.1 through 4.1.3 was completed, to provide a descriptive analysis of selected translation and work tasks for development of a composite film of representative translations and work tasks to be accomplished by future astronauts.

5.0 Methods and Procedures

5.1 Film Sample

The data for this investigation were film records of the three manned skylab missions. These film records were organized by major and subcategory classifications in the Skylab Man-Machine Data Film Catalog Index (Contract NAS 9-14210) and housed at the Space Craft Design Division - J.S.C. From the Catalog Index eight reels of film (#77 through #84 inclusive) constituting 2954 feet from the Catalog subcategories I.1 - Translation/Withincompartment, I.2 - Translation/Intercompartmental, and I.4 - Zero G Adaptability were selected for preliminary review by the contractors and technical monitor. Because these films constitute all those in the Catalog Index major category I. - Locomotion it was assumed by the contractors and technical monitor that they represented translation tasks appropriate for examination and analysis. As Table 1 indicates, the film sample did provide representative translation tasks across the three manned missions, mission days, compartment, and crewman.

5.2 Film Analysis

The above noted film records of translation tasks, as performed in the Skylab manned missions, were reviewed, coded, and analyzed within the framework of the procedures outlined in the following sections.

Table 1

Breakdown of Film Segments Analyzed

Skylab Mission	No. of observations
2	93
3	39
4	68

Mission Day	No. of observations
2	2
3	6
4	18
5	7
6	2
7	2
8	27
9	2
10	17
11	7
12	8
13	3
14	3
15	1
16	2
18	6
19	2
20	13
21	1
22	16
24	1
26	1
27	2
28	2
29	8
32	1
34	2
35	6
36	2
37	7
54	9
56	3
58	6
77	2
79	3

Person	No. of Observations
1	51
2	23
3	17
4	3
5	25
6	11
7	23
8	33
9	12
Unidentifiable	2

Compartment	
Experimental Compartment	65
Ward Room	40
Forward Compartment	89
Other	6

5.2.1 Qualitative review and coding.

All film records noted in section 5.1 were qualitatively reviewed and coded as to the following parameters:

a. A movement of a crewman was categorized as a translation task if the crewman's approximated center of mass (assumed to be in the pelvic region of the body) displaced more than an approximated linear distance of 50 - 70 centimeters. A total of 207 such translation tasks were so identified on film reels #77 to #84 inclusive.

b. The translation task was labelled in terms of its sequential position within a given reel. The scene identification information was obtained from the appropriate entry in the Catalog Index, pages 117 to 136 inclusive. The information obtained from the Catalog Index consisted of the following:

   (1) Reel number
   (2) Scene number
   (3) Skylab mission (II, III, or IV)
   (4) Mission day
   (5) Frame rate of film recording (2, 6, or 24 pictures per second)
   (6) Compartment location - Experimental Compartment, Wardroom, Forward Compartment, MDA. This information was coded on forms A and B. (See Appendix A).

5.2.2 A second qualitative analysis of film reels was performed in order to orient the translation task observation as to the following parameters:

a. The individual astronaut performing the translation task was identified by means of still photographs of the crews of the three manned missions. These still photographs were supplied to the contractors by the technical monitor. In a few cases the translation task was performed at a distance away from the camera such that immediate identification of the crewman was not possible. However, in most of those cases, the other two crewmen had been identified within the scene prior or subsequent to the specific translation undergoing the coding process and therefore the crewman could be identified by process of elimination.

b. The direction of the translation task was coded as a progression along or approximately parallel to the Architectural Cardinal reference axes (±X, ±Y, ±Z) as indicated in the Skylab Operations Handbook - OWS/AM/MDA - MSC 04727, Volume 1 pages 2.0-19, 2.0-75, 2.0-79, 2.5-150; and Skylab Experience Bulletin No. 18, page 4.

c. The length or extent of the translation was coded as either a short translation (70cm to 1.8m), medium (1.83m to 3.66m), long (greater than 3.66 or into/from the adjacent compartment).

d. The crewman's orientation relative to the displacement vector of translation was coded in the following manner:

(1) Head first; i.e., during the major portion of the visible translation task the crewman's longitudinal body axis was parallel to or coincident with the displacement vector with his head leading.

(2) Feet first; i.e., during the major portion of the visible translation task the crewman's longitudinal body axis was parallel to or coincident with the displacement vector with his feet leading.

(3) One G orientation; i.e., during the major portion of the visible translation task the crewman's longitudinal body axis was relatively perpendicular to the displacement vector.

e. The crewman's impetus for translation was evaluated and coded in terms of which body segment(s) provided the principle locomotive force for the movement; i.e., which extremity provided the push for the translation. The impetus further was coded as to which combination of hands and feet was used for pushing. If only a portion of the body was visible (due to camera placement/field of view) at the impetus phase of the translation, reactive movements of adjacent body segments were evaluated subjectively to determine if the extremities not visible provided for or contributed to the impetus push. The impetus was not coded in cases where the impetus phase of the translation task was totally not visible.

f. The crewman's recovery, stop or "catch" phase of the translation task was coded in a like manner. If the terminal point of the translation was visible in the film record the combination of hands, feet, or other body segments which provided the reactive "stopping" force was recorded. If only a portion of the crewman's body was visible (due to camera placement/field of view) at the terminal point of translation, reactive movements of adjacent body segments were evaluated subjectively to determine if the extremities not visible provided for or contributed to the recovery, stop or "catch." In cases wherein the recovery phase of the translation task was totally not visible the catch was not coded.

g. The efficiency of the translation task was rated by a panel of three "judges" which included one of the contractors and two advanced degreed physical educators. The efficiency of the translation task was rated independently by each rater on a scale of 1 to 4 based on the criteria as outlined in Table 2. The rating which was coded as datum for inclusion in subsequent data analysis was the mean of the three rater's scores. At this point of film review and analysis seven observations of translation tasks were eliminated because of camera/recording descrepancies. These descrepancies consisted of both impetus and recovery phases of the given translation out of the field of view, or the distance of translation was judged not to be over 50 to

Table 2

Efficiency Scale Criteria

4.0

Proceeds freely without reorientation touches.

Carrys objects easily.

"Acrobatic" movements.

Arrival at destination with little or no adjustment in orientation necessary for commencing subsequent task.

3.0

Intermittent grasps/touches of architecture for slight changes of directions (reorientation).

Arrival at destination oriented for subsequent task with little adjustment/ necessary.

2.0

Maintains control but qualitatively moves with obvious hesitation.

Needs intermittent stops for gross changes of direction.

1.0

Moves with hesitation.

Misses intended destination.

Maintains contact with walls and/or floor.

Looses control..."crashes."

70cm in displacement. This reduced the number of translation observations to a total of 200. The panel of "judges" re-rated the 200 translation task observations in two additional efficiency rating processes, the procedures of which duplicated the procedures as outlined above. The mean of the three ratings for each task observation was used as datum for subsequent analysis.

5.2.3 Quantitative Analysis

Speed of translation data were extracted from the sample of 200 observations of translation tasks by means of the following procedures:

Each of the translation task observation film records was projected on a rear screen projection apparatus which allowed for electronic digitizing of any given series of frames of the film sequence. The digitizing was based on a two-dimensional Cartesian coordinate system which could be manipulated by means of a minicomputer's software. Software was written to extract appropriate segmental endpoint locations, determine the displacements of these segments' projected images, and convert the image unit displacements to real units.

At the judgement of the contractors, an appropriate midpoint or "freefloating" phase of the translation task was designated, and film frames which recorded this phase were digitized as follows:

a. Coordinates for the translating crewman's head (at the vertex), shoulders (acromion processes), elbows, wrists, greater trochanters of the femurs (hip joints), knees, and midpoints of feet were recorded if observed. (Figure 1) In all cases the crewman's pelvis was visible. The midpoint on a line connecting the trochanters was used as the approximation of the crewman's total body center of mass.

b. In those translation task observations wherein the displacement vector was perpendicular to or approximating a perpendicular relationship to the optical axis of the recording camera the speed of translation was determined in the following manner:

(1) The magnitude of displacement was measured as the linear distance in image units the crewman's center of mass moved between three successive frame observations. The successive frame observations were taken as three consecutive frames in film recorded at 2 p/p/s and 6 p/p/s, and every fourth frame for three consecutive frame observations in film recorded at 24 p/p/s. The displacement magnitude was converted to real distances by means of a scaling factor.

(2) Scaling factors were individualized for each crewman in that known anthropometric dimensions for each was obtained from the technical monitor. (Appendix B.) The body segments/dimensions

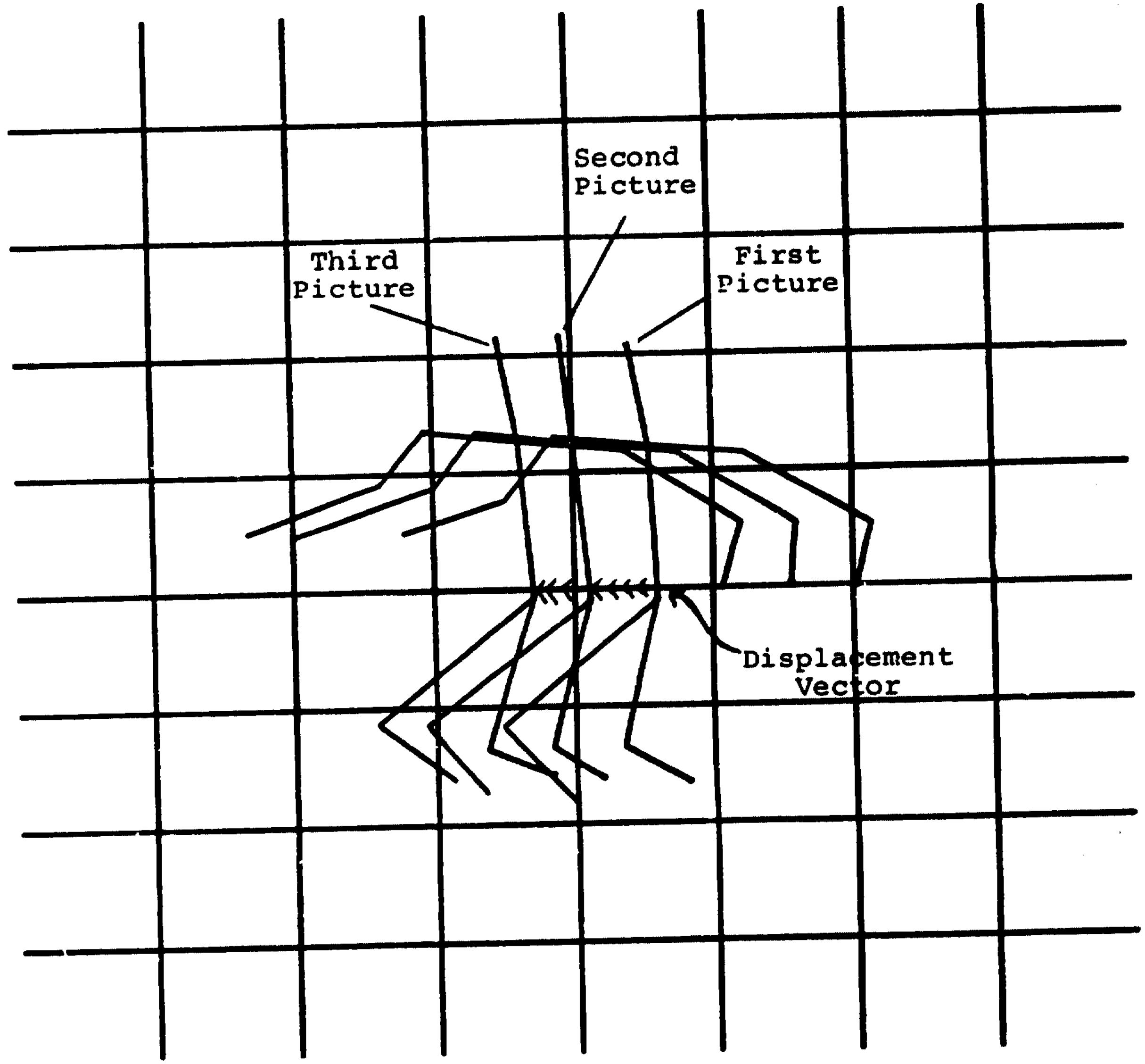


Figure 1. Digital Plot of Body Segments in Midpoint Phase of Translation. Each Stick Figure Represents a Different Picture of the Translation Sequence.

found in a plane approximating a perpendicular to the recording camera's optical axis in this translation midpoint phase were used to convert image units to real units of length. The ratio of image length to real length provided the factor by which the given image displacement magnitude was multiplied.

(3) Translation speed was determined by dividing the scaled displacement magnitudes between successive frame observations by appropriate real time intervals; i.e., .50 second for film recorded at 2 p/p/s and .166 seconds for film recorded at 6 and 24 p/p/s. Because three frame observations constituted two measured displacement determinations, two speed values were derived. The mean of these two values was used for subsequent data analysis. The entire procedure was repeated in 30 cases, and the test/retest reliability coefficient was .98.

c. In those translation task observations wherein the displacement vector was oblique or coincident to the optical axis of the recording camera the speed of the translation at midpoint or "float" phase was determined as follows:

(1) Known architectural landmarks within the given compartment were identified in the recording camera's field of view, and linear distance between

two such landmarks in closest proximity to the midpoint phase of the translation task was measured from Skylab floor plans provided by the technical monitor. The floor plans afforded a linear reference scale. The number of film frames it took the crewman to translate from one landmark to another was counted on three trials. The mean of the trial counts constituted the time for the displacement. From these data an average translation speed was determined by dividing the architectually defined distance of displacement in the midpoint of translation task by the time - the ratio of number of frames for the displacement to the appropriate recording camera frame rate. In these cases the entire procedure was repeated on 30 of the translation tasks so measured, and test/retest comparison manifested a reliability coefficient of .91.

6.0 Results and Discussion

The results of the contract are presented by work task. Each work task is identified by number which can be referenced in the objectives of this report. In addition, a summary of the objective will be listed at the beginning of each section. In some cases, the question for each work task is addressed by compartment.

6.1 Work task 4.1.1:

What changes occurred from the first observation to the last observation?

6.1.1 Experimental Compartment - 1 g orientation

Table 3 presents the efficiency scores for each of the astronauts within the experimental compartment.

In general, the astronauts tended to perform well in all phases within the experimental compartment. The early phases of the missions showed one efficiency score of 2.5 and all scores obtained later than the twentieth day were greater than or equal to 3. See Table 4 for efficiency ratings from first eight mission days.

6.1.2 Wardroom - 1 g orientation

Efficiency ratings are found in Table 5. The scores tended to be lower than those obtained in the experimental compartment, thus indicating somewhat of a difficulty in overall translation. The confined space and architecture (especially the table) of the wardroom seemed to cause the astronauts to move about in a 1 g orientation. With the limiting space around the working area, this made for difficult translation. Movement around the work table appeared to be somewhat of a problem for the astronauts. This fact was also indicated by the astronauts who discussed this problem. (Skylab Experience Bulletin No. 18, pages 18, 26 and 27.) It seems appropriate that further research be conducted regarding mid-deck arrangement of the shuttle with regard to freedom of movement for the astronauts. The possible consideration of an increase in the volume of space for the area would be helpful.

Table 3

Ratings Obtained by Various Astronauts

	Experimental Compartment						
	Efficiency Ratings						
Astronaut	1.0	1.5	2.0	2.5	3.0	3.5	4.0
1.				1[a]	4	2	9
2.				1	4	2	
3.	1		1		1		
4.					1		1
5.					3	2	6
6.							
7.				1	4	2	2
8.					2	1	7
9.						1	5

[a]Number of observations

Table 4

Number of
Ratings by Early Mission Days

Experimental Compartment

	Efficiency Ratings						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0
Mission days							
1-2							
3-4				1[a]	4	1	4
5-6					2		2
7-8					1		5

[a]number of observations

Table 5

Ratings Obtained by Various Astronauts

Wardroom

	Efficiency Ratings						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0
Astronaut							
1			2[a]		7	1	1
2			1		2		2
3			2				
4							1
5					2		1
6						2	2
7		1			1	1	
8			1	1	4	1	2
9						1	1

[a]number of observations

6.1.3 Forward Compartment - Zero g orientation

Table 6 contains the efficiency scores for the forward compartment. In general, the scores tend to increase with time. After day ten scores are greater than or equal to three on all but one observation. However, caution must be used when interpreting these results because of the relatively low number of scores for some periods.

Relative to the experimental compartment and the wardroom, the efficiency scores tend to be somewhat lower in the early phases of the mission but about the same near the later phases of the missions. The scores from the three compartments are very close after the twentieth mission day. See Table 7 for ratings from early mission days.

It appears that if the astronauts are in the zero g orientation, they will have somewhat more difficulty adjusting to the environment during the early phases of the mission. However, because of the more efficient utilization of the space within the forward compartment, perhaps the zero g orientation is best. The general impressions obtained from the data tend to support the impression gathered from the astronauts during debriefing. (cf. Skylab Experience Bulletin No. 18, p. 16)

6.2 Work task 4.1.2:

What are the forces used to initiate translation?

The "crashes" (efficiency rating of 1.0) that occurred with the viewed segments appeared to be the result of applying too much

Table 6

Ratings Obtained by Various Astronauts

Forward Compartment

Efficiency Ratings

Astronauts	1.0	1.5	2.0	2.5	3.0	3.5	4.0
1.				1[a]	3	5	15
2.			1	1	2	3	3
3.	1	1	4	2	4		
4.							
5.					2	1	7
6.					1	2	4
7.			2		3	1	4
8.					3	1	7
9.						2	2

[a]number of observations

Table 7

Number of Ratings by Early Mission Days

Forward Compartment

	Ratings						
	1	1.5	2.0	2.5	3.0	3.5	4.0
Mission Days							
1-2			1[a]	1			
3-4					1	1	
5-6							
7-8	1	1	4	2	3	3	6

[a]number of observations

force for the task that was to be accomplished. Examples of the application of too much force can be seen in the following film segments:

a. Reel 77 Scene 16 Sequence 6

b. Reel 80 Scene 5 Sequence 1

c. Reel 83 Scene 4 Sequence 8

d. Reel 84 Scene 5 Sequence 3

An attempt was made to determine if certain impetuses were being used when "crashes" occurred. This was not found to be the case as various "crashes" were the result of different combinations of hands and feet push-offs.

6.2.1 What are the body parts used for initiating and completing translation?

Experimental Compartment - 1 g orientation

79% of the observations used one or two hands for impetus

17% of the translations used two feet for the impetus

72% of the translations used one or two hands to catch

19% used one or two feet for completing the translation

54% of the translations were 1 g oriented

33% were head first movements

14% were feet first movements

Thus, most translation tasks were initiated and completed with the hands. Over 50% of the movements were 1 g oriented.

6.2.2 Wardroom - 1 g orientation

73% of the movements in the wardroom use hands for impetus

45% used both hands

28% used one hand

25% used one or two feet

75% completed the translation with one or two hands

25% completed using one or two feet

63% of the movements are 1 g oriented

35% were feet first movements

27% were head first movements

Again, movements primarily involved the hands.

6.2.3 Forward Compartment - Zero g orientation

86% of the translations were greater than two meters in length

53% of the translations were greater than four meters in length

16% of all of the movements scores less than or equal to 2.5 on the efficiency scale.

44% of the movements used both hands for the impetus

19% used one hand for the impetus

30% of the translations used one or two feet as impetus

78.5% of the translations were completed with one or two hands

11% of the translations were terminated with the feet

62% of the movements were head first

25% of the translations were 1 g oriented

14% of the translations were feet first

6.2.4 Discussion

In general, it appears that if the compartment is oriented 1 g, the astronauts tend to respond in a 1 g orientation more so than is found in the compartment which is zero g oriented. Once they begin working in the zero g oriented compartment, they appear to quickly adjust and begin to move about more freely without the "mental set" of 1 g.

The vast majority of the movements are initiated with the hands. The astronauts do not make a point of utilizing any particular device which has been specifically designed for translation. They simply use "whatever is close" as a base of support for the pushing off of a translation. Further, the few segments of the film where a person used the "fireman's pole" for movement appeared to be relatively inefficient movements.

The majority of the translations are completed with the hands and not the feet.

The table in the wardroom deserves discussion. Due to the architectural construction of the room, it was situated in a 1 g orientation. Thus, the film reviewed disclosed that the astronauts were continually moving around the table in a 1 g manner. Further, the film review noted the use of the hands on the food trays when translating. (Specifically, an example of the utilization of the tray for a base of support is provided in Skylab Experience Bulletin No. 18, p. 9) Thus, the astronauts continually using the food trays and table to push-off or catch themselves most likely was the cause of the point of attachment for these structures becoming loose. Factors such as these deserve consideration for future spacecraft design.

6.3 Work task 4.1.2

What are the displacements and average speeds by compartment?

6.3.1 Experimental Compartment: (65 observations)

72% of the translations involved movements of greater than two meters while the remaining involved movements of less than two meters. The average speed within the experimental compartment was .5 meter per second with a standard deviation of .26 meters per second (Range was 1.27 to .1 meters per second)

6.3.2 Wardroom (40 observations)

58% of the translations involved movements of less than two meters. The average speed of translation was .56 meters per second with a standard deviation of .36 meters per second. (Range was 2.09 to .15 meters per second)

6.3.3 Forward Compartment (89 observations)

53% of the translations involved movements of greater than four meters in length. 33% involved movements of two to four meters in length. The average speed of translation was .95 meters per second with a standard deviation of .5 meters per second. (Range was 2.43 to .24 meters per second)

6.3.4 Discussion

Generally, greater distances and faster speeds of translation were seen in the forward compartment. Undoubtedly, this is a function of 1) the greater volume of the compartment, 2) the tasks that were to be accomplished required movements over greater linear distances, and 3) the intent of the astronaut while performing the translation.

The speed of movement in the experimental compartment and the ward rooms are generally the same, while those in the forward compartment were approximately 90% greater than those from the experimental compartment and the wardroom. Since the volume of space is larger and the experimental compartment is generally less confining than the wardroom, one might expect that the speed of movement would be faster in the experimental compartment than that obtained within the wardroom. However, even though the experimental compartment does contain a larger volume it appears that the inclusion of miscellaneous equipment within the compartment is causing the astronauts to move about with somewhat more concern for striking the objectives. Objects which appear to be noticeable hinderance to movement are the trash air lock and the bicycle ergometer. To a lesser extent, perhaps the lower body negative pressure chamber may also be affecting the movements within the experimental compartment. Perhaps it would be advisable to move the apparatus to a more zero g oriented position. This is also confirmed by the astronauts wherein they talk about the fear of hitting someone who is riding the ergometer.

6.4 Work task 4.1.3

Generally, what are the differences and similiarities of selected translations of various astronauts?

As indicated in 6.2, the majority of the movements were initiated and completed .th the hands. Generally, when the astronauts were within a 1 g oriented compartment they attempted to move about with a 1 g orientation. Investigation of the translation characteristics of the various astronauts by compartment indicates that, in general, each uses the same modes of translation in moving about the compartments. Certainly, there are small changes in the characteristics of translation from astronaut to astronaut but the changes are not significantly different from one astronaut to another. Few of the translations in any of the compartments are feet first oriented (11% of the translations are feet first, 42% are 1 g oriented, and 48% are head first movements). In general there are few feet first orientations in the wardroom because of the volume of the room. It does not appear that the astronauts translate with differential orientations across mission days.

When consideration is given regarding previous zero g experience, those individuals with previous experience tended to perform better than those without the experience. This is also confirmed in that scores generally improve with mission day. Thus, the longer that one has been on the mission, "the more previous" experience one has had during the mission. There are qualitative observable differences in the ways that individuals cope with barriers in the various compartments. It appears that some astronauts are freer to move about without having movement orientation dictated by the 1 g "mind set." That is, they move over objects rather than around them because such movements are easier for them or such movements are best able to produce the desired results. An example would be that if two members of the crew were at the table in the wardroom and the third crew member needed to take a position between them and to the back of the room, it would be much simpler for the crewman to go over the table than to attempt to move around the table or have another crewman move out of the way in order to arrive at his desired position. In another segment of the film, it is obvious that a crewman "crashed" into the trash air lock. However, in a subsequent segment the same crewman is seen to have used the trash air lock as a pushing off point in the middle of a translation in order to change the direction of the movement. It appears that while this crewman has, in fact, found the trash air lock to be quite usable for some translations, others stay as far from the trash air lock as possible in order for it not to be a hinderance to their movements.

6.5 Work Task 4.1.4

What film segments typify translation within the segments viewed by the investigators?

To answer this question, the following film segments were listed by compartment. These segments are representative of relatively efficient and inefficient movements within the various compartments. Codes refer to reel and scene numbers taken from the Skylab Man-Machine Data Film Catalog Index. Sequence refers to the movement within the scene.

The film segments presented in Tables 8 through 10 are representative of the movements within each compartment which are efficient and inefficient. As indicated by the number of efficient segments relative to the number of inefficient segments, the

Table 8

Representative Translations from Experimental Compartment

Efficient Translations

Reel	Scene	Sequence
77	3	1
77	8	2
77	9	1
77	12	1
77	13	1
77	16	3
77	16	4
77	16	5
77	16	7
78	3	1
79	9	1
79	10	2
79	10	3
79	10	4
81	1	1
81	1	3
81	1	4
81	7	2
81	7	3
82	4	1
82	4	2
82	4	3
82	4	4
84	1	3
84	1	4
84	1	5
84	1	6
84	1	7
84	1	8
84	1	9
84	2	3
84	2	4
84	2	5
84	2	6
84	2	7
84	2	9
84	2	11
84	2	12
84	2	13
84	9	1
84	9	2
84	9	3

Inefficient Translations

Reel	Scene	Sequence
77	16	1
77	16	5
77	16	6
79	10	1
79	15	7
84	2	1

Table 9

Representative Translations from Wardroom

Efficient Translations			Inefficient Translations		
Reel	Scene	Sequence	Reel	Scene	Sequence
77	4	4	77	4	1
79	7	1	77	4	2
80	2	1	77	5	1
80	2	2	79	5	1
81	2	1	79	6	1
81	3	1	83	2	5
82	1	3	83	2	6
82	5	1	84	5	3
82	7	1			
82	8	1			
83	2	1			
83	5	3			
84	5	2			

Table 10

Representative Translations from Forward Compartment

Efficient Translations

Reel	Scene	Sequence
77	15	2
77	17	1
77	17	2
77	17	3
77	17	4
77	17	5
77	17	6
78	2	1
79	3	1
79	11	1
79	12	1
79	12	2
79	13	1
79	17	1
79	17	2
79	18	1
79	20	1
80	1	1
80	1	2
80	1	7
80	3	1
80	3	2
80	3	3
80	4	2
80	4	5
80	4	6
81	4	1
81	4	2
81	4	3
81	4	4
81	5	2
82	2	1
82	3	1
82	3	2
82	3	3
82	3	4
82	3	5
82	3	6
82	3	7
82	3	8
82	9	1
83	4	1
83	4	2
83	4	4
83	4	6

Inefficient Translations

Reel	Scene	Sequence
77	14	1
78	5	2
79	1	1
79	2	1
79	12	3
80	1	3
80	1	4
80	1	8
80	4	3
80	4	4
80	4	7
80	5	1
83	4	8
84	11	4

Table 10 - (continued)

Reel	Scene	Sequence
84	3	1
84	3	2
84	3	3
84	3	4
84	3	5
84	3	6
84	3	7
84	3	8
84	6	1
84	7	1
84	11	1
84	11	5
84	11	6
84	11	7

Reel	Scene	Sequence

movements within each compartment were generally quite good throughout the missions.

6.6 General impressions

The intent of this investigation was to determine and describe translation characteristics of skylab astronauts. From this description, the investigators were to select appropriate film segments which are representative of the translations completed during various phases of the missions. These selected segments might then later be developed into a training film which would be used to familiarize trainees with the types of movements that are typically performed during future Shuttle missions. The film segments identified in Tables 8, 9, and 10 serve to satisfy this objective of the contract.

Generally, it appeared that, as a group, the astronauts adapted well to the zero g environment. However, if the architectural design dictated a 1 g environment, the astronauts typically responded by translating in a fashion that could be described as 1 g oriented. That is, the line of the body typically was perpendicular to the direction of translation. When the characterization of the compartment was zero g oriented, the astronauts tended to move about more so in a zero g orientation. That is, typically head first and occassionally in a feet first manner.

In general, the efficiency ratings were quite good. However, as expected, the astronauts translated somewhat more efficiently as the mission progressed. If one were to assume that as the efficiency of the translation increased, the productivity and work accomplished by the astronauts would also increase, concern might be given regarding the efficiency of movement in the very earliest phases of the missions. As one of the astronauts commented in Skylab Experience Bulletin #18 (Reference 39, p. 15-9), he "found it was more convenient after being up there for about 4 or 5 days." Further data are needed from the earliest phases of the mission in order to make specific comments or recommendations regarding his statement.

6.7 Recommendations for Future Studies of This Type

6.7.1 Interpretation of the results indicates that changes occurred during the first two weeks of the missions. Thereafter, a general leveling of translation performance occurred. If one would be desireous of better addressing the question of what changes occur during the earliest phases of the missions (less than two weeks into the mission) it would require generating new film on the shuttle or skylab missions with the following format:

a. For the first fourteen days of the mission, have repeated trials of similar translation tasks.

b. Have each astronaut on the mission perform the tasks identified in part a above.

c. Data gathered after fourteen days need only be done weekly in order to verify the leveling of translation performance.

The film that was selected from the Skylab Man-Machine Data Film Catalog Index included various translation sequences from throughout the various skylab missions. As a result of reviewing the film, it appears that few of the segments actually contained sequences from the very early phases of the mission. This permitted the investigators to look at the overall changes throughout the missions, however, it was somewhat dfficult to make determinations of the changes that occurred in the first day or two of the mission. With missions of short duration (less than a week), if changes occur in the translation abilities of the astronauts, this could grossly affect the efficiency and ultimately the productivity of the mission.

6.7.2 Standardization of the following biomechanical analyses is recommended with regard to filming:

a. camera location,

b. frame rate,

c. a given path of translation should be recorded by the same camera each time,

d. use appropriate leaders for film splices to facilitate film analysis, (The film readers encountered somewhat of a problem while attempting to digitize the translation sequences. The film that was used for the missions was of a polyester base. As such, the film was somewhat thinner than usual film. However, when the film segments were cataloged and spliced, the leader stock that was used for the film was thicker than the film. Thus, each time the projector came to a splice, the film would jump from the sprocket and the spockets would then tear holes in the film. The problems encountered with the splices made digitizing a much slower task than would have been normally the case.)

e. establish standard known references for each individual on the mission rather than attempting to use anthropometric dimensions. A suggestion would be to have a piece of material or markings of known length be attached to the clothing of each individual, thus permitting the known reference to be utilized in all translations.

6.7.3 It appears that the devices developed as aids to translation within the compartments were generally not used for such. Since the astronauts used "whatever was available" for initiating and completing translation, consideration should be given to the design (i.e., protection of critical yet easily damaged) of control switches or display panels.

6.7.4 It was apparent that due to the confining nature of the wardroom, the food trays and table were extensively used to either initiate, control, or complete translation. Also, it was noted in the debriefing that these structures became increasingly unserviceable as the mission progressed. Therefore, fixtures which might be used in this manner should be more securely attached.

6.7.5 The trash air lock in the experimental compartment appeared to serve repeatedly as a barrier to the movement to a number of astronauts. Therefore, structures designed similar to this should be flush mounted if possible. Generally, although there was adequate volume in the experimental compartment, the usefulness of the volume was hindered by items such as the trash air lock and the bicycle ergometer. Problems such as this could be eliminated by placing the equipment in a more zero g orientation rather than the 1 g position that it maintained in the experimental compartment.

6.7.6 For future missions, perhaps it would be appropriate to inform the astronauts that even though they are in a 1 g orientation in some of the compartments, translations may be facilitated if they can perform tasks in a zero g manner. That is, attempt to have the astronauts "think zero g" rather than thinking 1 g because of the orientation of the compartment.

6.7.7 Consideration should be given to the translation orientation in the three primary architectural axes.

6.7.8 Consideration should be given to the "dynamic neutral" posture assumed in a zero g environment. Such consideration may have significance with regard to the architectural design of the various compartments.

Appendix A

Coding Sheets for Experimental Compartment,
Wardroom and Forward Compartment.

Mission #______ MD _____

Location: ______________________________

Crewmen: ______________________________

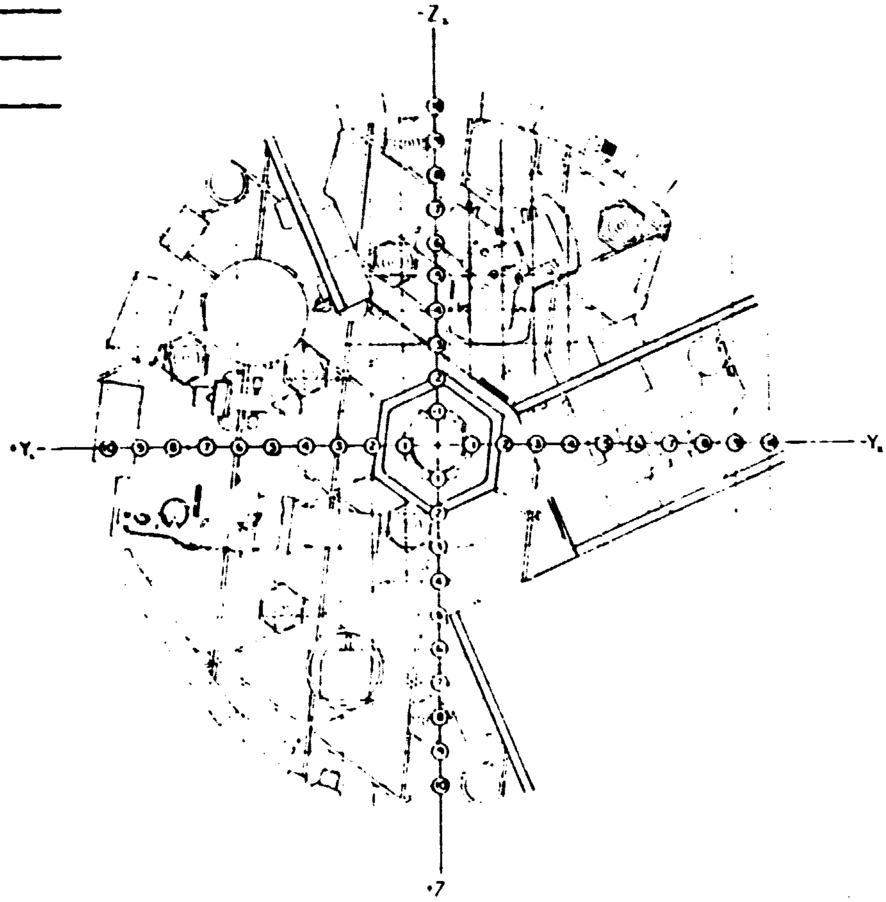
Description:

MISSION NO.	REEL NO.	SCENE INDEX/DESCRIPTION						
		NO.	FOOTAGE		FRAME COUNT		FILM REF.
			FEET	FR	START	END	
SL-II Part 1	77 (contd)	6	7	—	06238	06517	MAG MT-02
			MD 4 DOY 148 SPEED: 6 fps CDR shown moving across the Experiment Compartment and back to WDRM.				

Reel#______

Scene#_____

P/F/S _____



Mission #_____ MD _____

Location: ______________________________

Crewmen: ______________________________

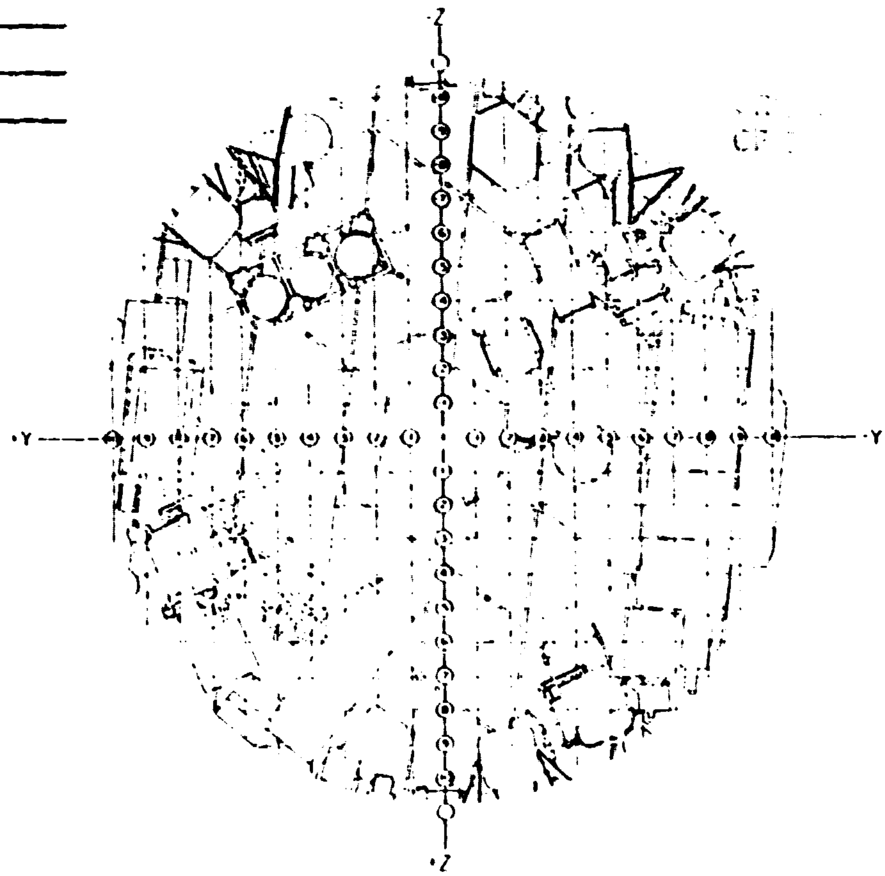
Description:

MISSION NO.	REEL NO.	SCENE INDEX/DESCRIPTION					
		NO.	FOOTAGE		FRAME COUNT		FILM REF.
			FEET	FR	START	END	
SL-II Part 2	78 (contd)	8	13	27	08313	08859	MAG MT-03
			MD 21 DOY 165 SPEED: 6 fps Crewman shown moving through FWD Compartment.				

Reel#_____

Scene#_____

P/F/S _____



Appendix B

Anthropometric Data Used for Scaling Factors

SCALING FACTORS

	Head L.	Shoulder B	Chest Br.	Waist Br.	Hip Br.	Farm L	Farm L
Astronaut							
1.	25.1	48.2	29.2	29.2	35.6	31.8	25.7
2.	24.1	47.0	36.8		35.9		27.9
3.	25.7	48.3	34.3	33.0	36.8	35.6	27.9
4.	22.7	46.4	29.4	30.5	34.8	33.3	27.9
5.	24.4	52.7	35.2	31.4	36.8	35.6	26.3
6.	24.6	42.1	28.3	28.6	31.1	36.1	27.2
7.	22.6	49.7	32.9	30.1	33.1	36.3	28.3
8.	23.3	45.6	31.1	31.1	34.3	36.8	28.5
9.	24.3	48.3	33.6	31.2	31.4	36.2	29.2

Head L. Shoulder B Chest Br. Waist Br. Hip Br. Farm L Farm L

Appendix C

Data Coding Sheet

Film/Scene ____ ____ ____

Film Reference ____

Mission ____

Mission Day ____

Compartment ____

Person ____

Direction ____ ____ ____
X Y Z

Distance ____ S - M - L

Rating ____ 1 - 2 - 3 - 4

Impetus ____ ____
H F

Catch ____ ____
H F

Average Velocity ____

Orientation ____ ____ ____
H F F F 1 g

Comment