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SKYLAB EXPERIENCE BULLETIN NO. 17

NEUTRAL BODY POSTURE IN ZERO-G

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National Aeronautics and Space Administration

LYNDON B. JOHNSON SPACE CENTER

Houston, Texas

July 1975

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MAN-MACHINE ENGINEERING DATA APPLICATIONS OF SKYLAB EXPERIMENTS M487/M516

BULLETIN NO. 17

NEUTRAL BODY POSTURE IN ZERO-G

This document is the seventeenth in a series of releases which are intended to make available to NASA and contractor personnel those results from the Skylab Man-Machine Engineering experiments which have design and requirements relevance to current projects and programs.

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JULY 1975

NEUTRAL BODY POSTURE IN ZERO-G

SUMMARY

Man's posture in the weightlessness of space differs from his one-g posture. The importance of this difference received little serious consideration prior to Skylab data analysis and evaluation. Inflight crew comments, postflight debriefings, and inflight photography focused attention on the importance of relaxed body posture as related to crew station and workstation design. For example, one crewman stated, "Relaxed body posture gradually changes from the initial erectness (straightened spine) to a normal forwardly bent erect position. Throughout the three months, it was difficult to lean forward and fatiguing to hold that position, and it was equally difficult to sit in a chair. These observations should be given major consideration in crew station and workstation design." (Ref. 1)

From the Skylab data it became evident that fitting workstations to the crew population could greatly influence their comfort, physical well-being and output efficiency. Workstations properly designed for use in a weightless environment require that consideration be given to man's relaxed or neutral body posture in zero-g. This neutral position is based upon the analysis of a series of 35mm still photos made during the SL-4 mission under controlled conditions of relaxed body posture. The primary conclusion is that there is a definable relaxed body posture in zero-g and

that the eligible flight crew population can be fitted to that posture, within a describable envelope. The accompanying recommendation is that this basic posture be given very serious consideration in future designs in order to take advantage of the body's most comfortable posture as a means of increasing the efficiency of zero-g man-machine interfaces.

PRE-SKYLAB EXPERIENCE

Prior to Skylab, U.S. manned spacecraft were relatively small volume vehicles. Consequently crew intervehicular activities (IVA) were somewhat limited and the IVA cabin area had to accommodate the stress of launch and entry as well as the on-orbit worksites. Consequently, the crew cabins that preceded Skylab were designed about the seat-bound crewman, and short-term zero-g worksites were of small concern. These constraints prevented taking full advantage of man's mobility and flexibility in zero-g. Further, the confines of these spacecraft had somewhat misled designers into a false sense of security regarding the effects of zero-g on posture, and no specific data were taken on how to best design an open-volume worksite for zero-g interfaces. Thus, Skylab's IVA worksite design progressed without the benefit of specific flight data gathered in its behalf.

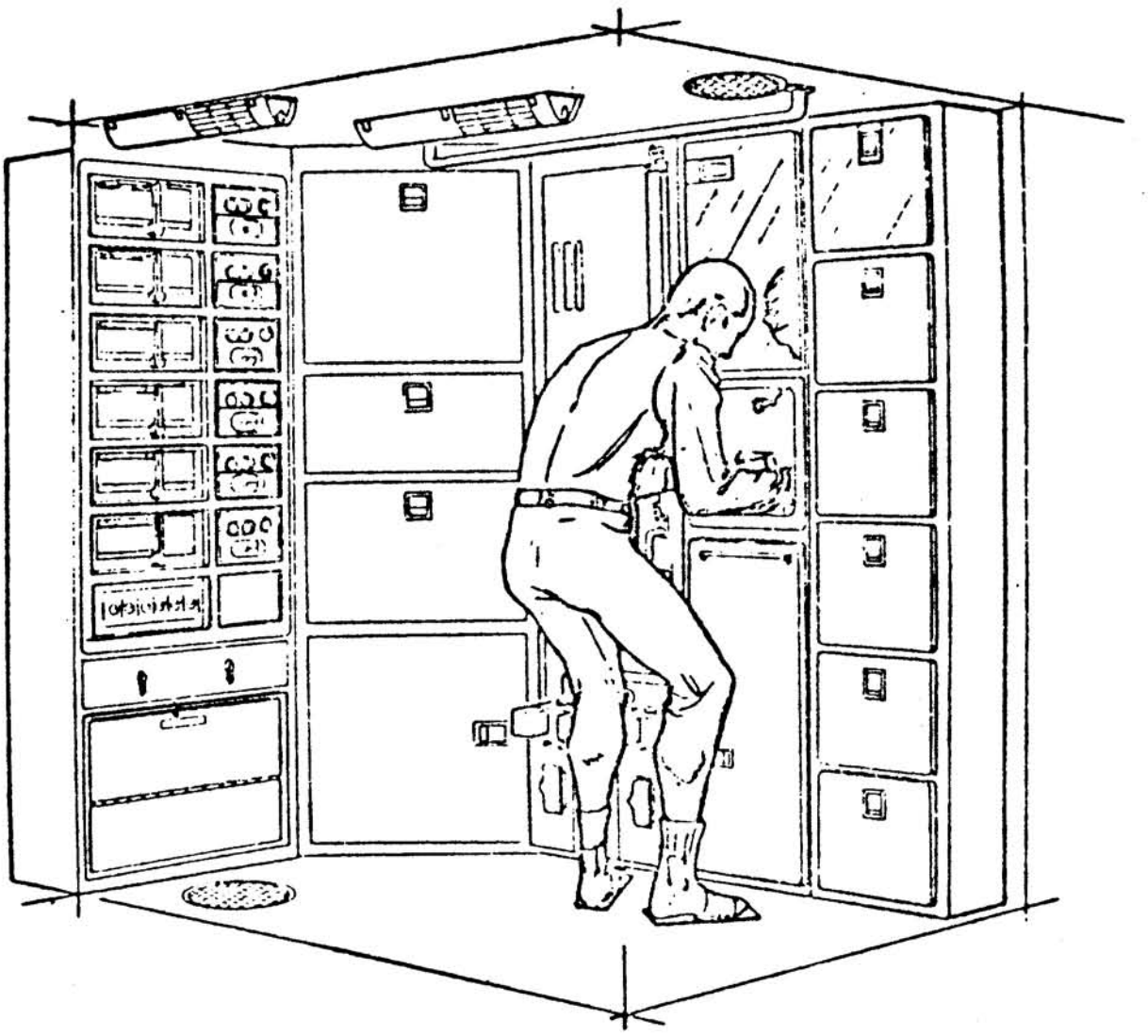
SKYLAB DESIGN

For the first time in U.S. manned spaceflight, Skylab presented the crewmembers with large open volumes through which to traverse and with worksites and functional interfaces designed to accommodate a standing posture. Much of the interior of Skylab was structured to present a standard one-g environment. This design was not so much aimed at creating a home-like appearance for the crew as it was an outgrowth of the convenience associated with one-g configurations on the ground where the manufacturing, testing, checkout, and training had to be conducted. Nevertheless, the design of numerous facilities aboard Skylab was directed toward a standing one-g

posture and the finished product took on a perspective never before seen in a manned spacecraft. Also, contributing to the unique appearance of this vehicle was the fact that for the first time sufficient volume and weight allocations were available to allow separate facilities to be designed for eating, sleeping, hygiene, and working. For example, Figure 1 shows a cutaway view of the waste management compartment depicting the design of the handwasher and indicating the posture required to use it. Figure 2 shows the design of the wardroom table with its combination restraint system capable of being used as a foot restraint alone, a thigh restraint alone, or both concurrently. Again, the use position intended by the design is essentially a standing one-g posture as can be seen from the dimensioned sketch shown in Figure 3 where the distances are noted from the zero datum points.

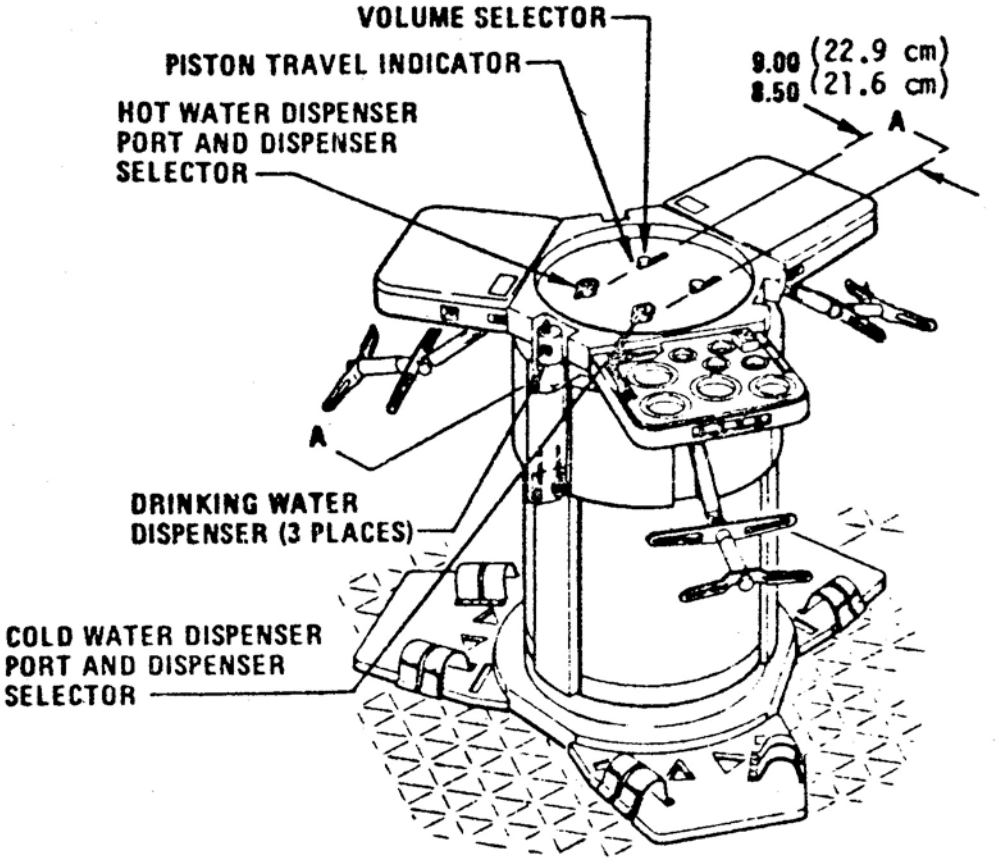
Various worksites were also designed to accommodate a standing crewman as evidenced by the view of the scientific airlock (SAL) shown in Figure 4. The centerline of the window on the SAL was located 43 inches (109 cm) above the grid floor of the forward compartment, necessitating a standing type posture in order to operate any experiments located in the SAL if concurrent foot restraint was to be employed on the grid floor.

Another prominent worksite aboard Skylab which was designed to accommodate either a standing or a seated crewman was the ATM console. Figure 5 illustrates the standing mode of operation while Figure 6 shows the chair restraint being used.



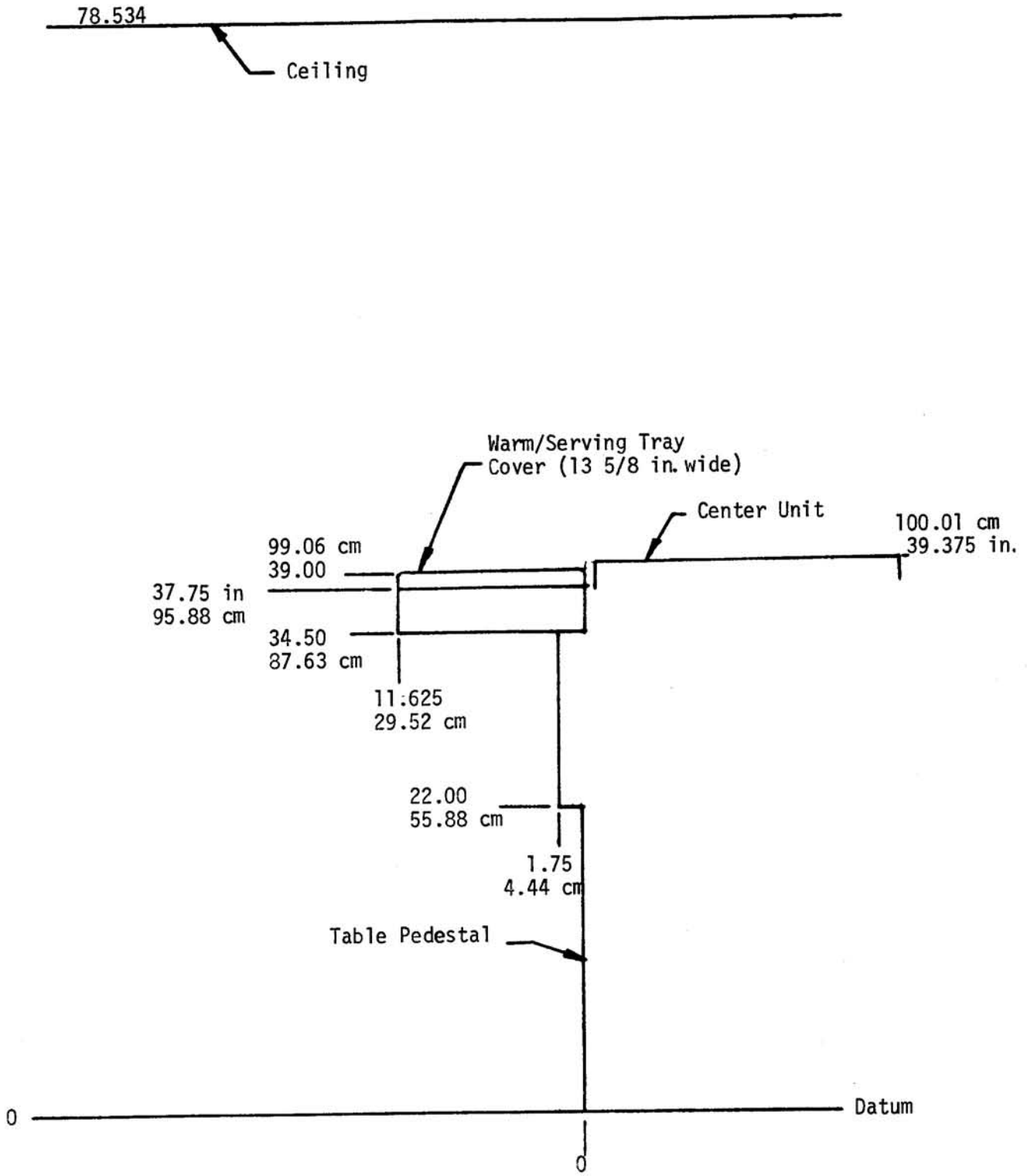
Standing Posture Assumed for Handwasher Design

Figure 1



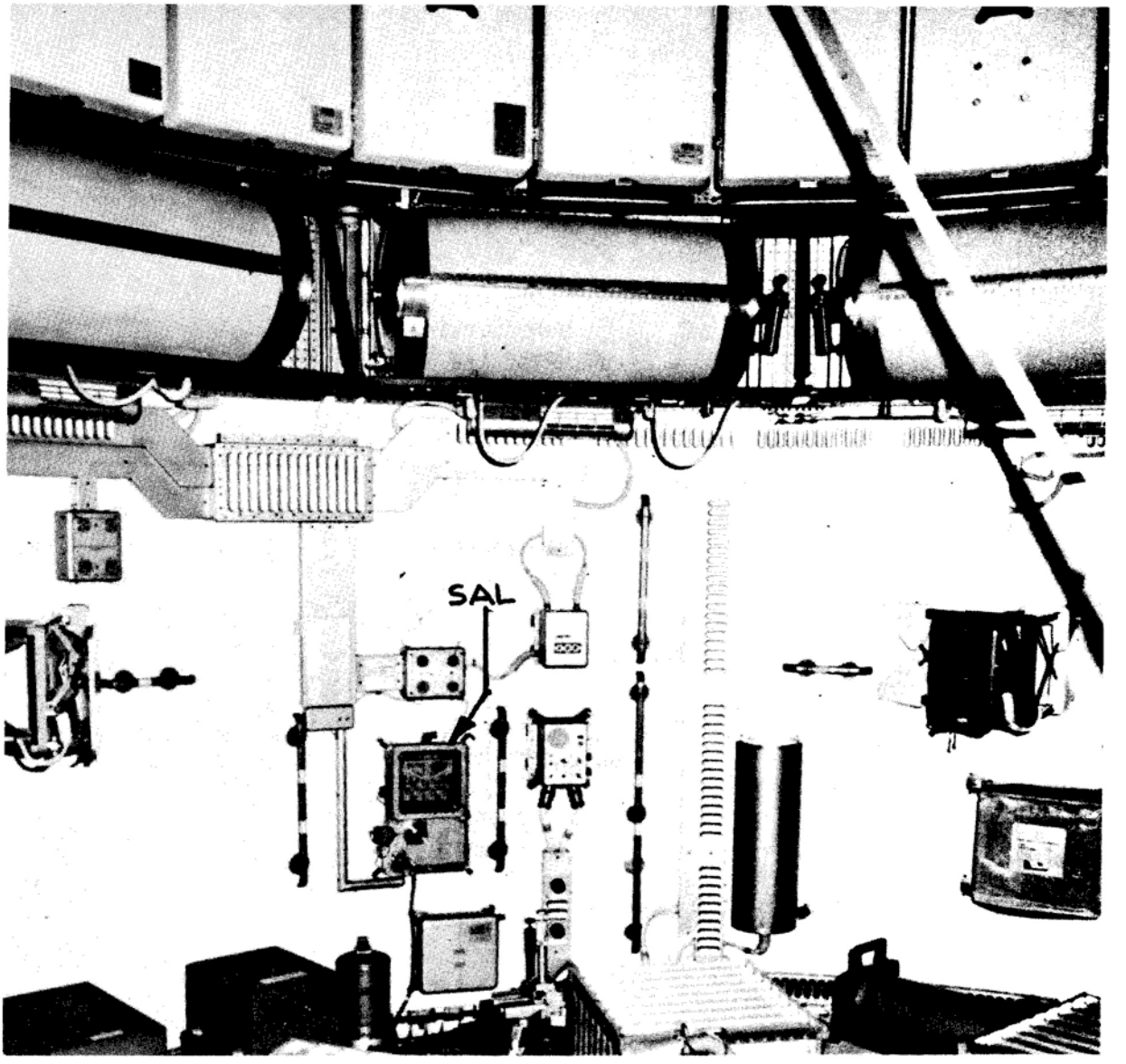
Skylab Wardroom Table

Figure 2



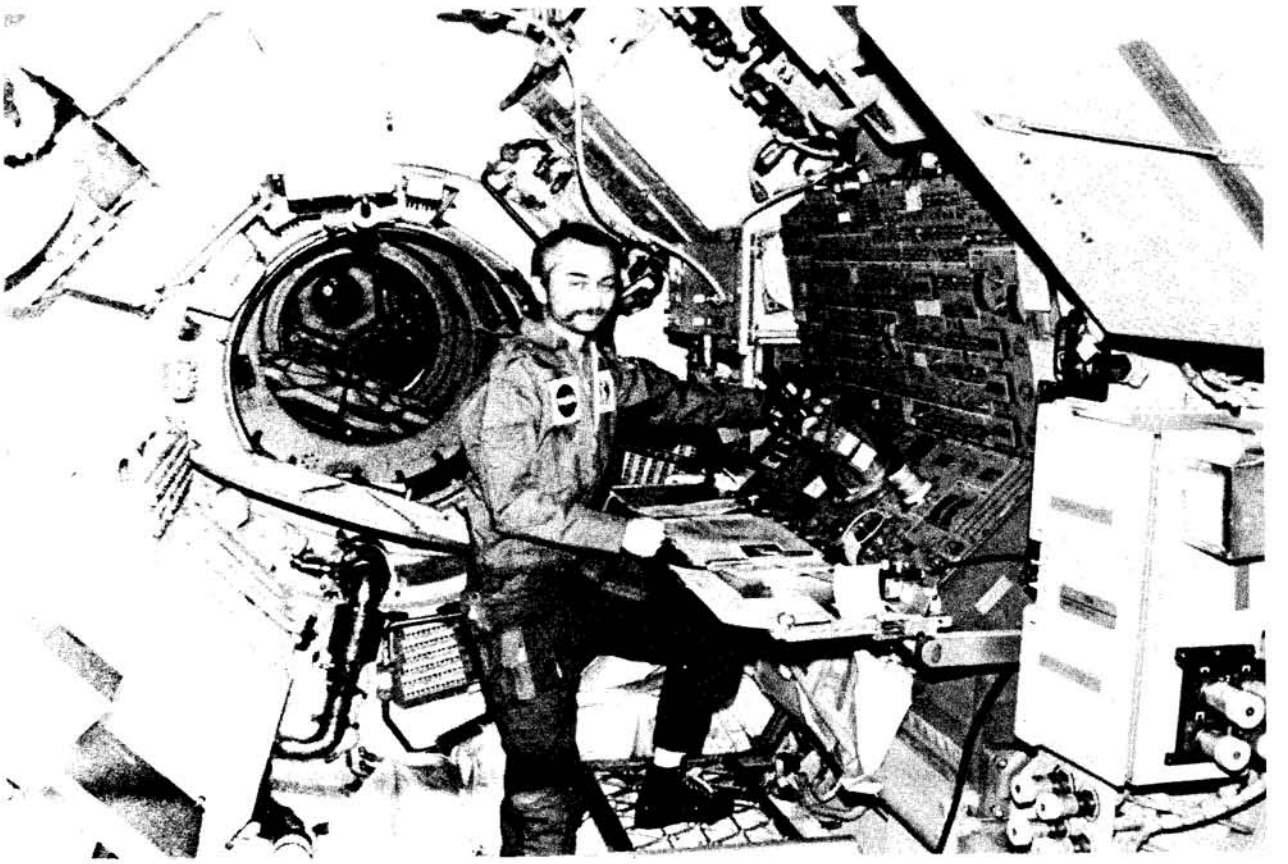
Dimensioned Profile of Skylab Wardroom Table and Attached Food Tray

Figure 3



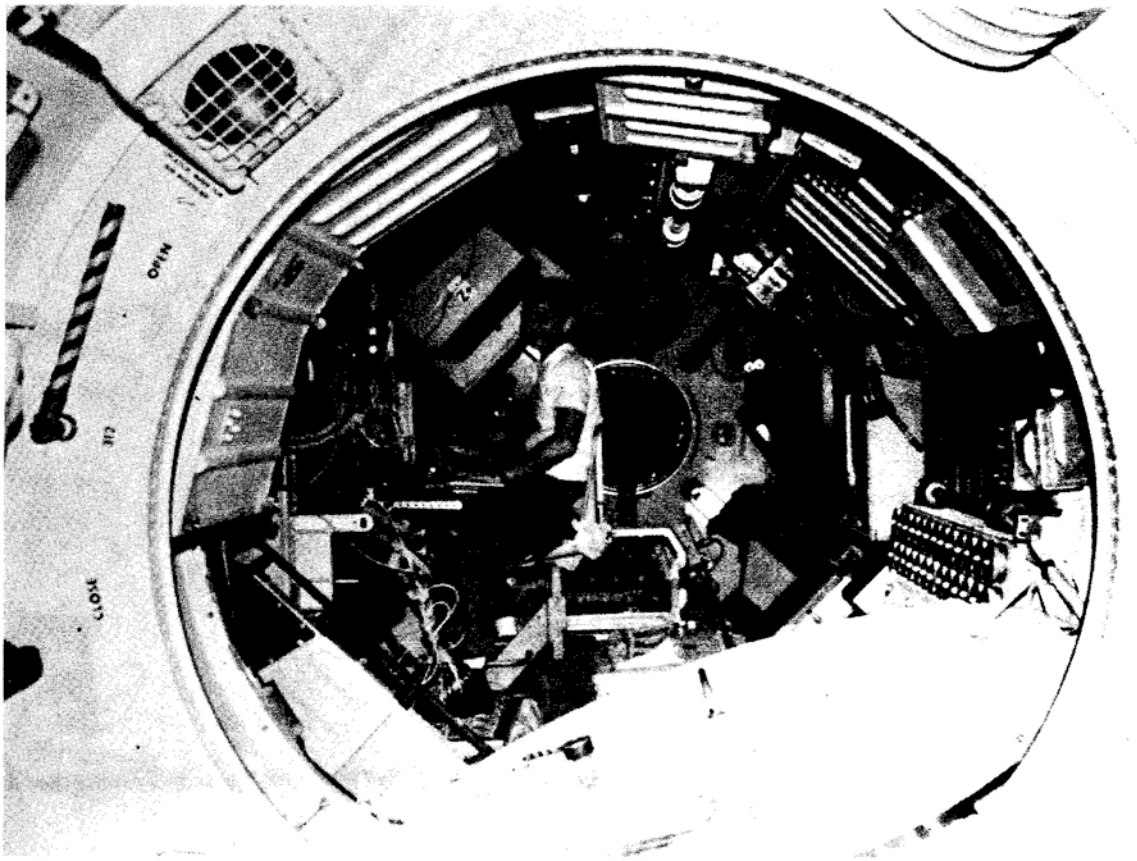
View of Scientific Airlock in Skylab Forward Compartment

Figure 4



Standing Operation at ATM Console

Figure 5

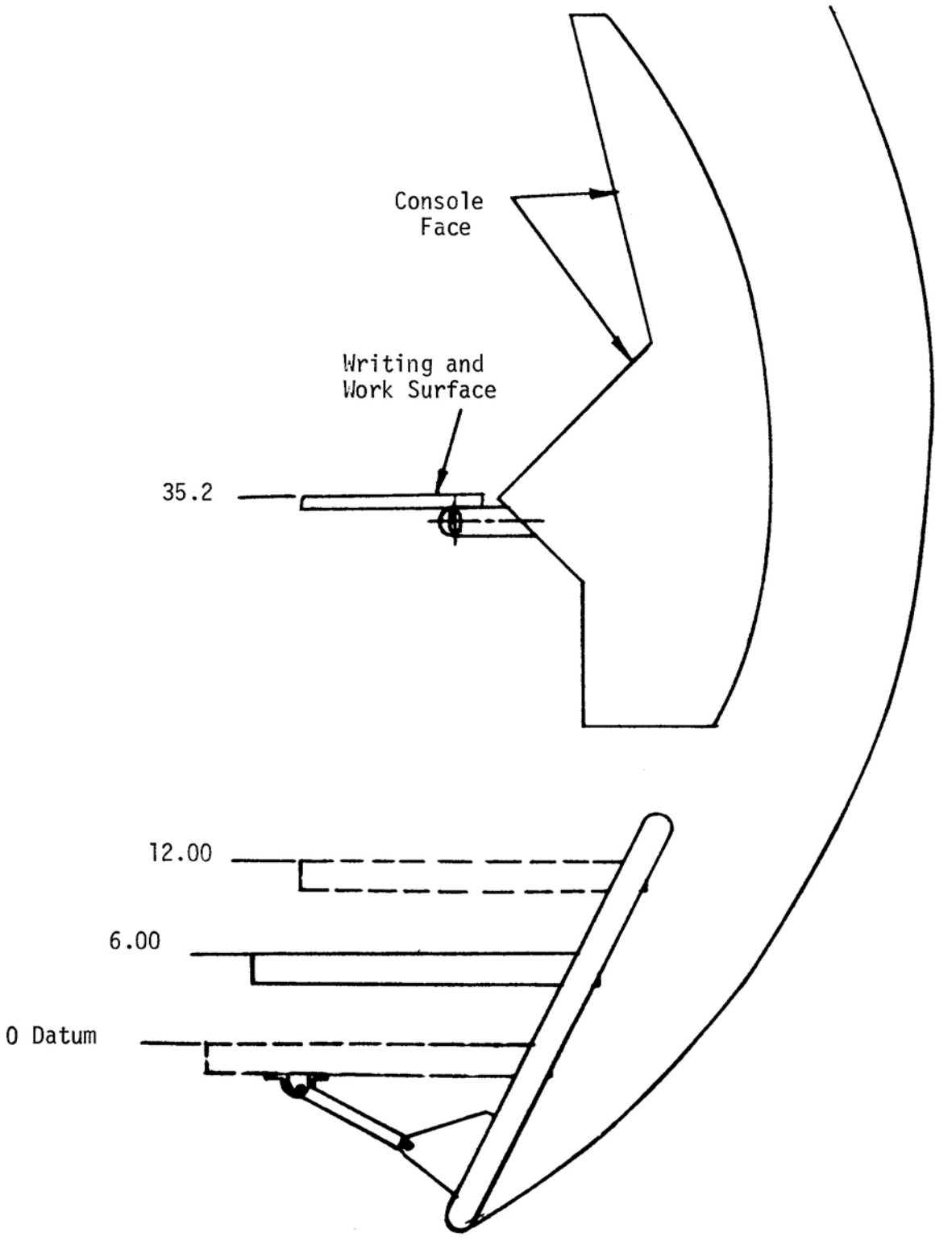


Seated Operation at ATM Console

Figure 6

Figure 7 gives a dimensional profile of this workstation, showing the various restraint levels available to the crewman by adjusting the position of the foot restraint platform. No analysis will be made in this bulletin of the relative merits of the various restraint systems employed at the ATM console or other worksites located throughout Skylab. This subject has been thoroughly treated previously in Skylab Experience Bulletins 7, 9, and 10. (Ref. 2, 3, and 4)

The worksites and functional interfaces presented in this section are only a representative sample of the total spectrum available for discussion. This report is not intended to delve deeply into worksite design, but only to present a sufficient coverage of that topic to illustrate that worksite layout can be a serious influence on posture. In many instances, the worksite or functional interface creates a situation that can only be solved by the crewman adjusting himself inflight to accommodate the task requirements. A thorough treatment of worksite evaluation and future design application of the results will be available in the near future in another publication.



Dimensioned Profile of ATM Console

Figure 7

SKYLAB EXPERIENCE

The purpose of this bulletin is to quantitatively define the relaxed body posture in zero-g. The application of this definition will be left to future publications.

Data Acquisition

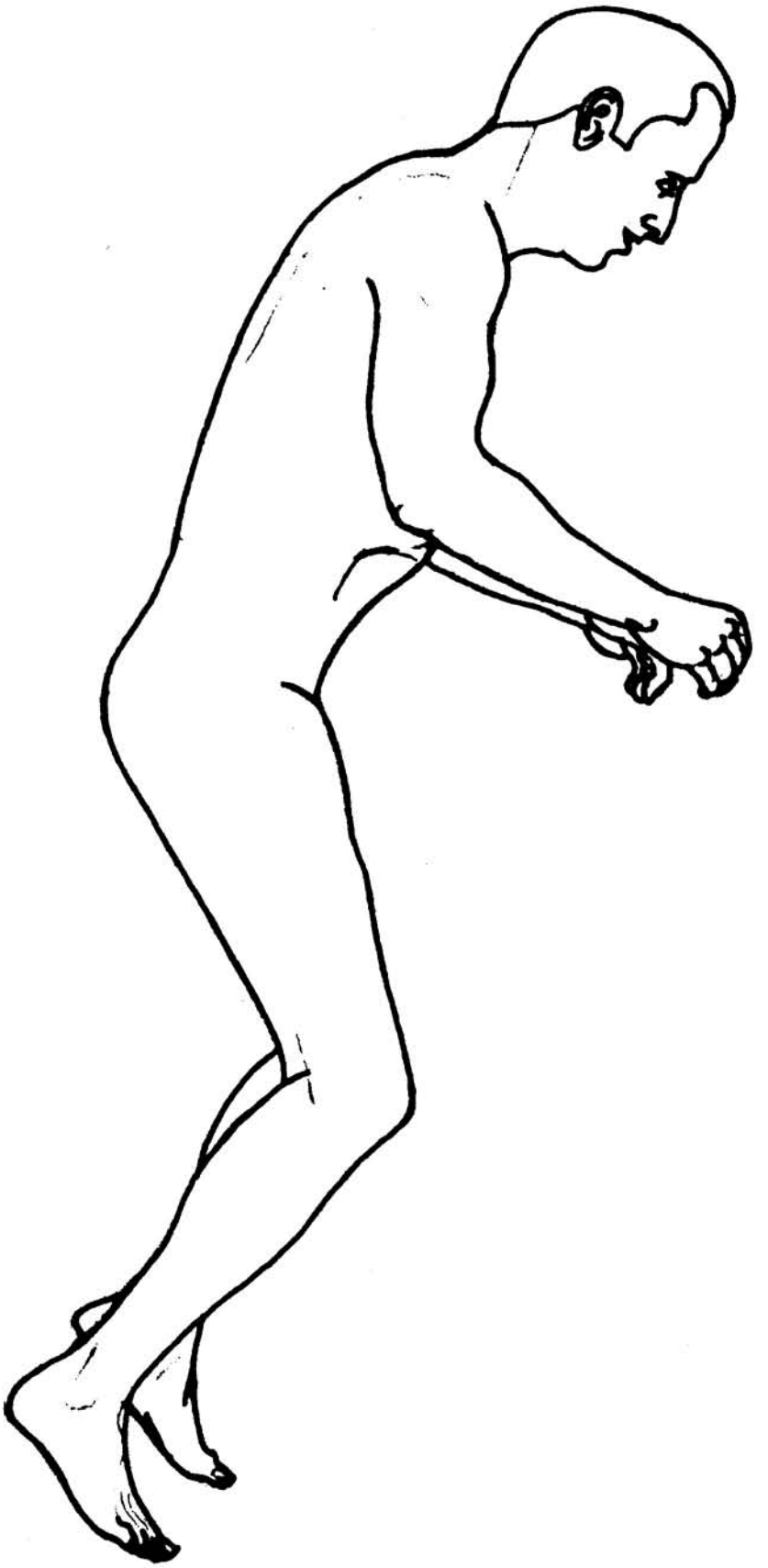
No formal activities were instituted prior to the beginning of the Skylab missions to acquire posture data. Rather, the opportunity presented itself following study of inflight film, TV, still photos, and participation in postflight crew debriefings following the first two missions. Many comments were offered by the crewmen concerning the tendency of the body to want to seek a null or neutral position in zero-g (see Raw Data Appendix), and the discomfort associated with departing from that neutral position as a function of amount of departure and the time required to remain in the posture dictated by the task or the workstation. In order to document this posture, the SL-4 crew was asked to make a series of 35mm still photographs (profile and frontal views) of each other while in a completely relaxed position. These photos were distributed throughout the mission to allow analysis of potential deviations as a function of exposure time to the weightless environment. These full-body semi-clad photographs are on restricted distribution but are identified in the Raw Data Appendix by NASA number for those who wish to view the raw data. Due to the poor quality of some of the photographs, only 12 were used in the analysis leading to the neutral posture definition.

Data Analysis

The 12 photographs used as raw data for this report were given a thorough geometric analysis based on a technique employing anatomical drawings. Figures 8, 9, and 10 illustrate the method used. Figure 8 shows a tracing of one of the photographs (NASA SL4-151-5114). To this profile outline, the underlying major skeletal segments were added, as shown in Figure 9. This addition allowed identification of surface landmarks based upon corresponding underlying major joint axes. Connecting these major joint axes established a body link system as shown in Figure 10. The link system was then measured to determine the angular relationship between the various links. This technique was repeated for each photograph and several analysts measure each photograph several times to smooth out errors in procedure. The average of these measurements and their associated standard deviations led to the final determination of the relaxed zero-g neutral body posture.

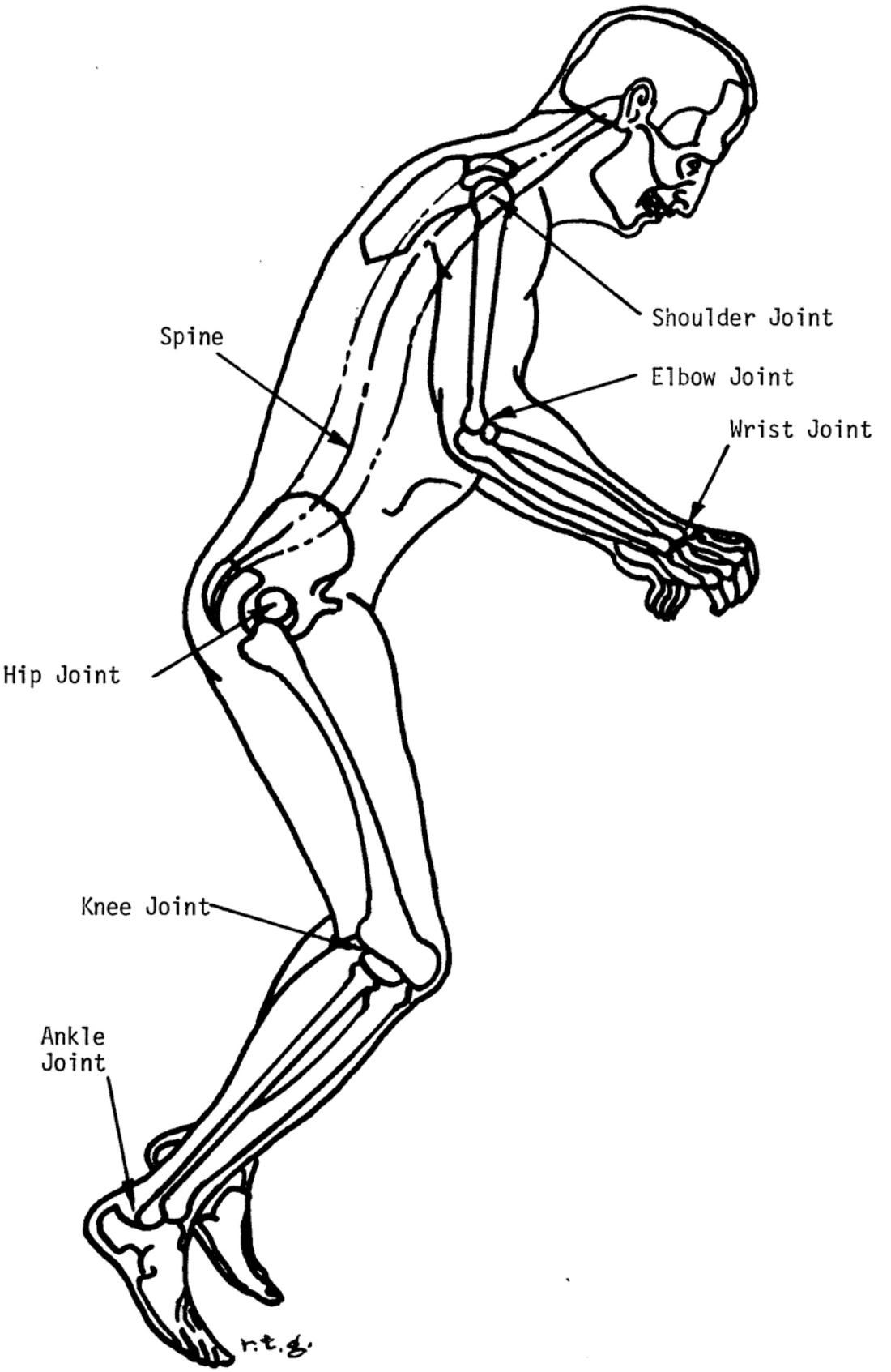
Results

The neutral body posture in zero-g is that position which the body tends to seek when completely relaxed and acted upon by no external forces. The position is quantitatively definable within a reasonable envelope of deviation and varies within that envelope between individuals and for any given individual from time to time.



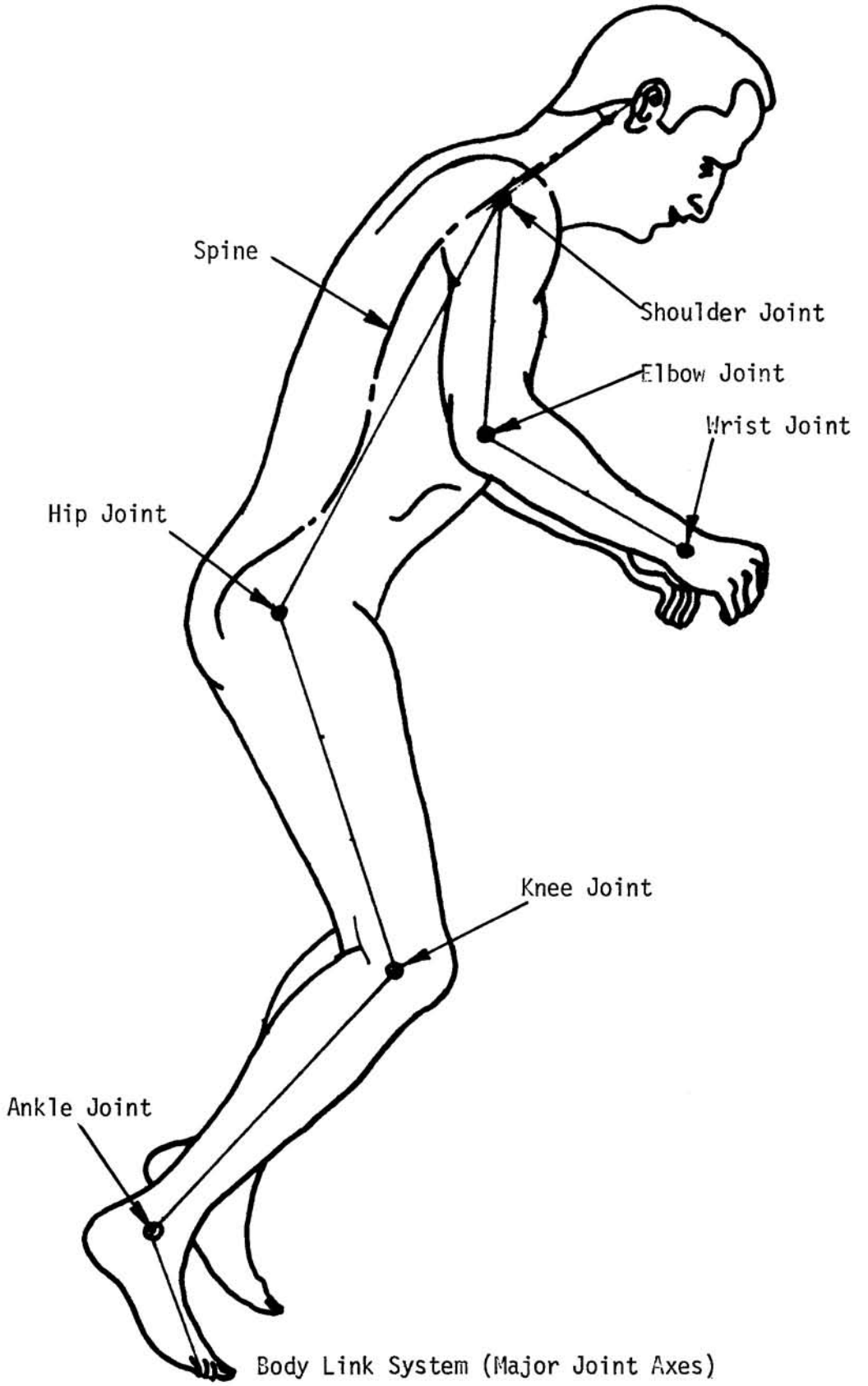
Overlay of Skylab Crewman Photograph

Figure 8



Selected Landmarks for Measurement of Body Posture

Figure 9



Body Link System (Major Joint Axes)

Figure 10

The relaxed neutral body posture for zero-g is shown in Figure 11. The standard deviations have been applied in terms of degrees of latitude about a centrally defined position. The magnitude of some of these deviations, particularly with respect to the arm, is evidence of a good bit of variance between the exact posture assumed by different individuals as well as a lesser degree of variance between any given individual's posture from one data take to the next. Nevertheless, it is strongly felt that Figure 11 represents a well-defined phenomenon that is repeatable, measureable, and valid as a design tool.

Several items of interest are noted in the posture defined in Figure 11. First, the body has sought a semi-crouched position, neither sitting nor standing. This is probably one of the most significant points to consider, for it will reflect in worksite design to a great extent. Work heights will not be determinable using one-g oriented anthropometric standards. A new standard, taking into account the zero-g aspects of body reaction to the environment, must be established if proper advantage is to be taken of the neutral posture in terms of output efficiency of man-machine interfaces. Secondly, the standard one-g line of sight, which is routinely depressed some 10 to 15 degrees below horizontal is even further depressed in zero-g due to the tendency of the neck and head to droop forward. This artifact can be accommodated in future designs by a combination of restraint location and panel layout, but it is worth considering as a design requirement. Casual conversation with Skylab crew men following their missions indicated that some of them were sufficiently bothered by this droop tendency

to periodically compensate for it by placing the heel of their hand on their foreheads and forcing their head and neck into a more comfortable position.

Arm use frequently requires repositioning to accomplish tasks and the Skylab triangle shoe/grid floor combination forced a flat footed relationship that didn't account for the 15 degree droop of the foot when relaxed. However, to insure the most efficient interface design possible these areas should not be overlooked.

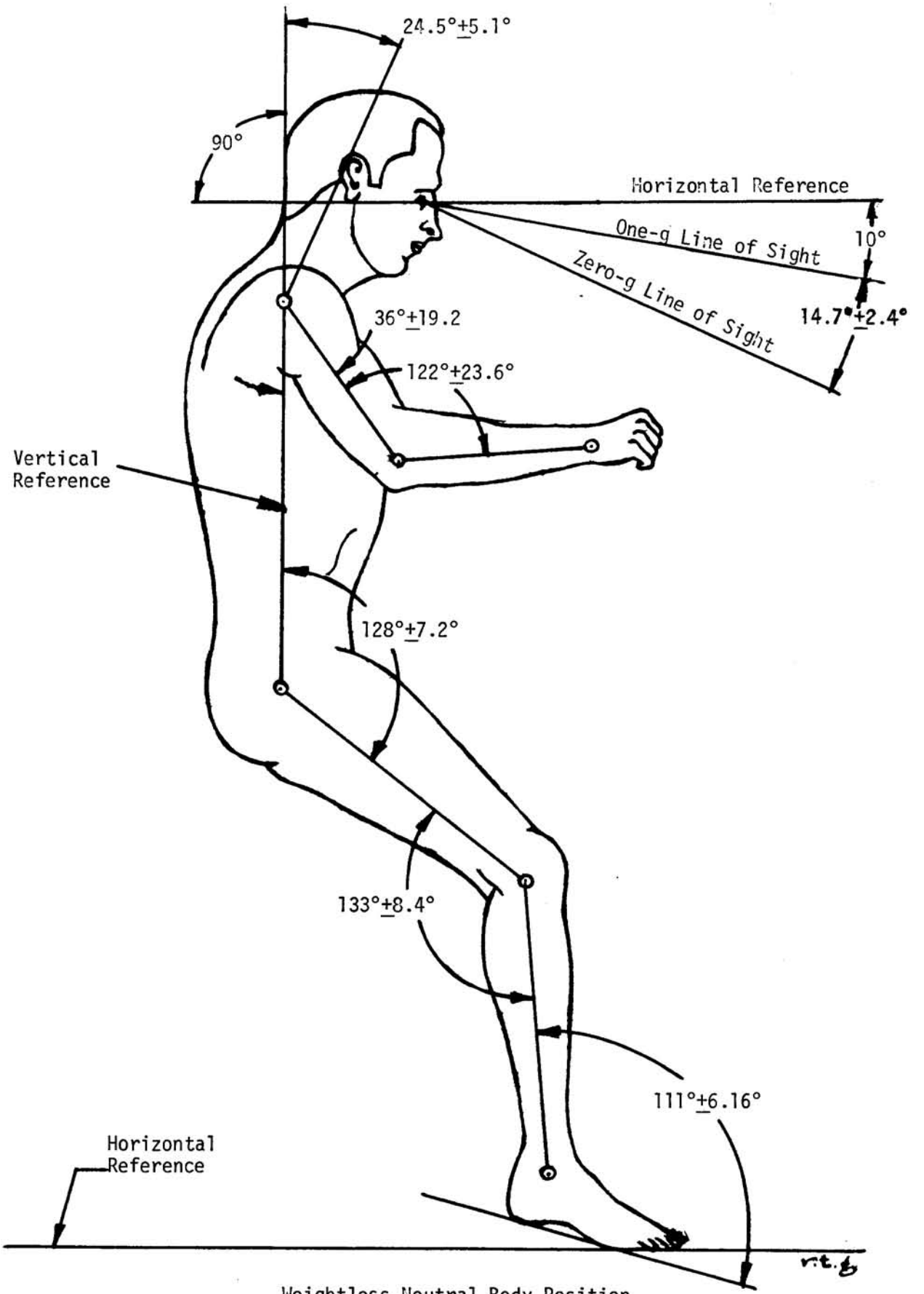
The angle which probably exhibits the most sensitivity to adjustment is that between the body and upper leg. To close this angle, as was required by the posture imposed at the wardroom table and the ATM console, brings into play major body muscle groups and gives the crewman a sensation of being in the position of having partially completed a one-g situp and then having to hold that posture. Fatigue and discomfort associated with that maneuver was the one most prevalent remark regarding posture that Skylab crewmen had to offer.

Validation and Lessons

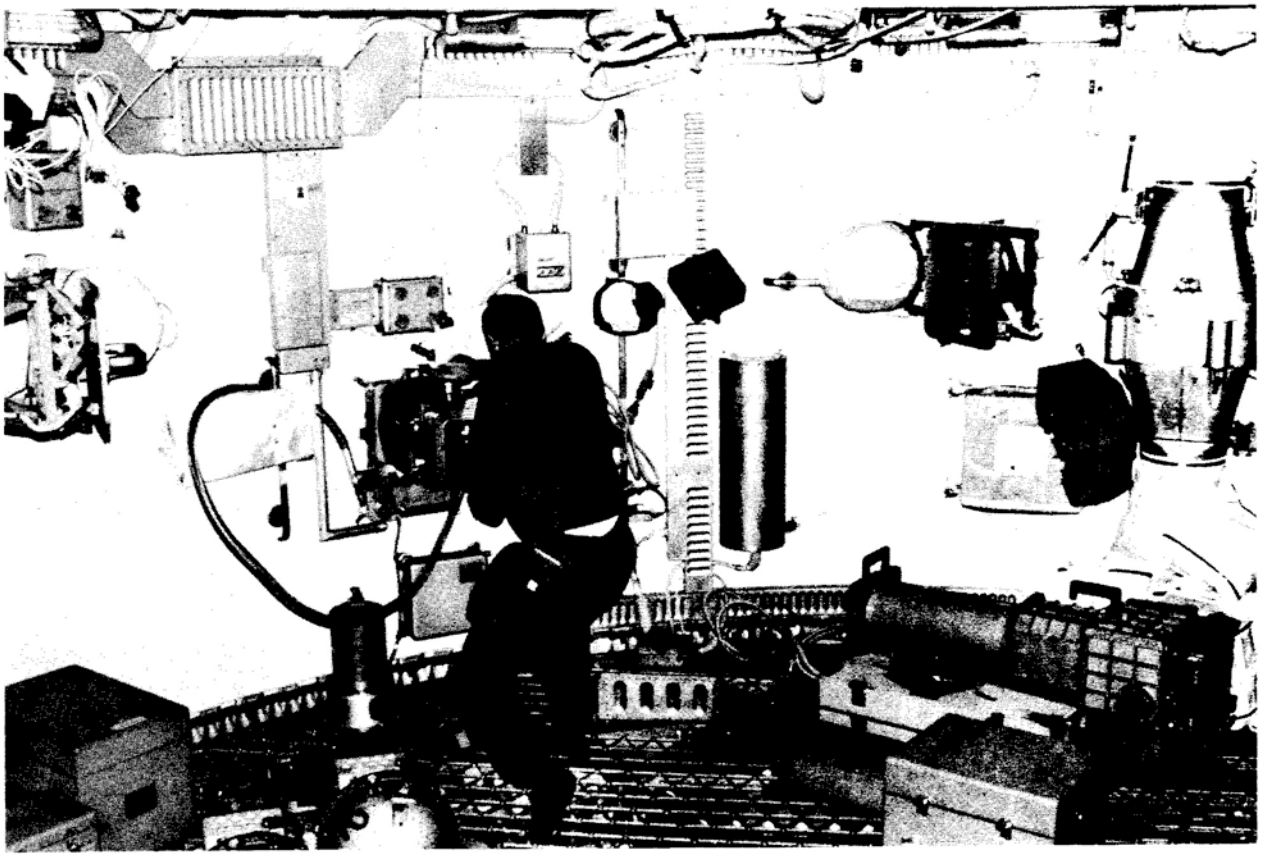
An analysis of numerous scenes from the inflight 16mm motion pictures and TV shot during the missions substantiates the basic hypothesis of a tendency for the body to migrate toward the posture defined in this report. These analyses were somewhat subjective due to the difficulty of making precise geometric measurements without having posed planar views, but the basic

thesis is unquestionably supported by postures seen in the film. Additionally, a retrospective look at some of the still photographs made in the earlier missions also supports the results offered in this bulletin. Figure 12 shows the SL-3 PLT operating an experiment in the SAL, and his posture is no doubt forced by the proximity of the worksite to the restraint system, but the general semi-standing crouch is clearly evident. An even more striking blow is struck for the posture theory when a crewman is shown doing something that does not require a specific posture or position with respect to a manned interface and he nevertheless exhibits the neutral body posture. Figures 13 and 14 fall into this category. Figure 13 shows the SL-3 PLT working in front of the film vault, but not interfacing with the film loading station atop the vault, yet his posture (which had no reason not to be relaxed) is definitely analagous to Figure 11. Figure 14 shows the SL-2 CDR reading, in a completely unrestrained position and the neutral body posture is quite evident. Figures 15 and 16 show the SL-3 SPT and CDR, respectively, in obviously posed (facing the camera) photos at the ATM console, and in this type of momentary relaxed environment the neutral posture is evident.

In terms of lessons about how the design of any given worksite influences posture, and how that influence can be either good or bad, a few examples of poor interfaces should suffice to make the point that posture should become a primary consideration in future designs. Figure 17 shows the SL-3 PLT forced into an almost sitting posture due to the proximity of

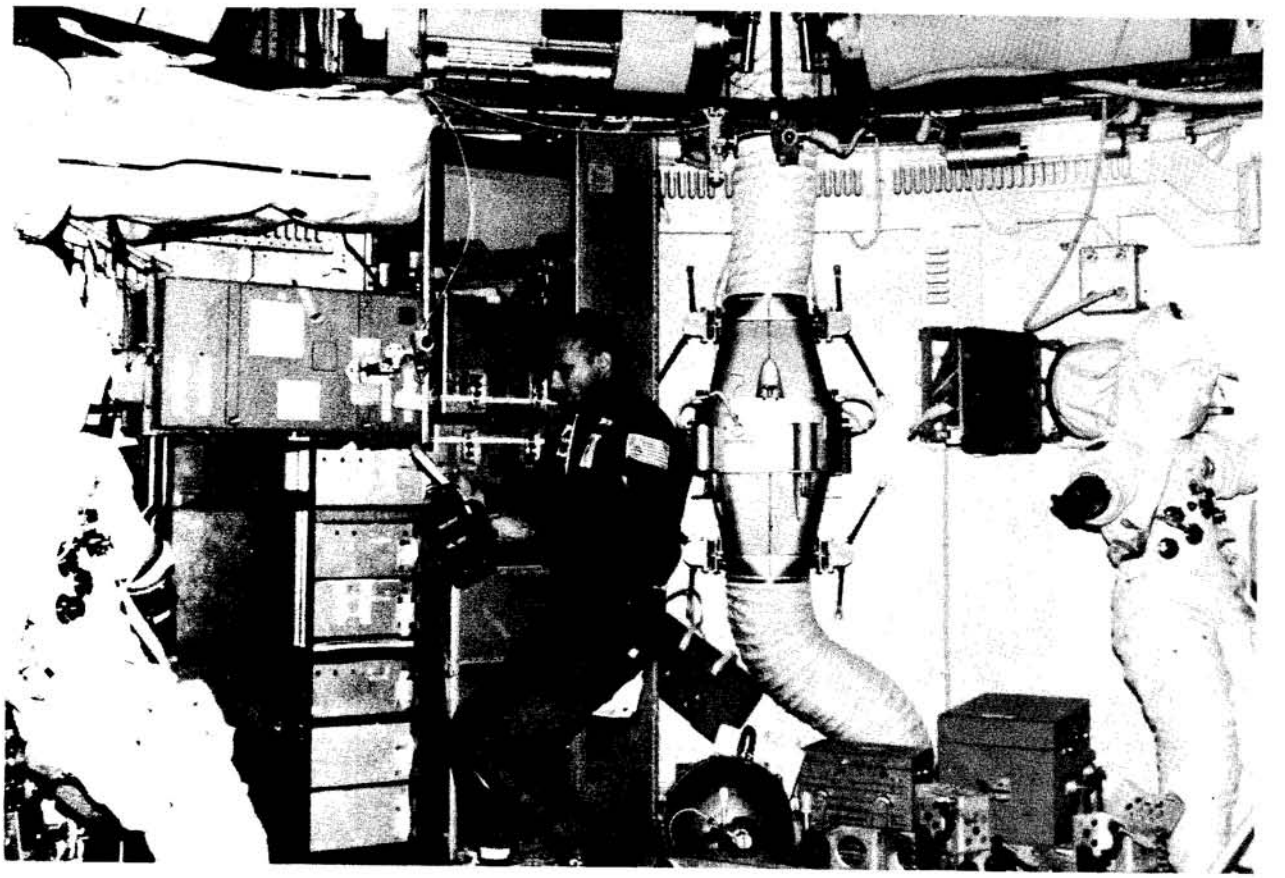


Weightless Neutral Body Position
Figure 11



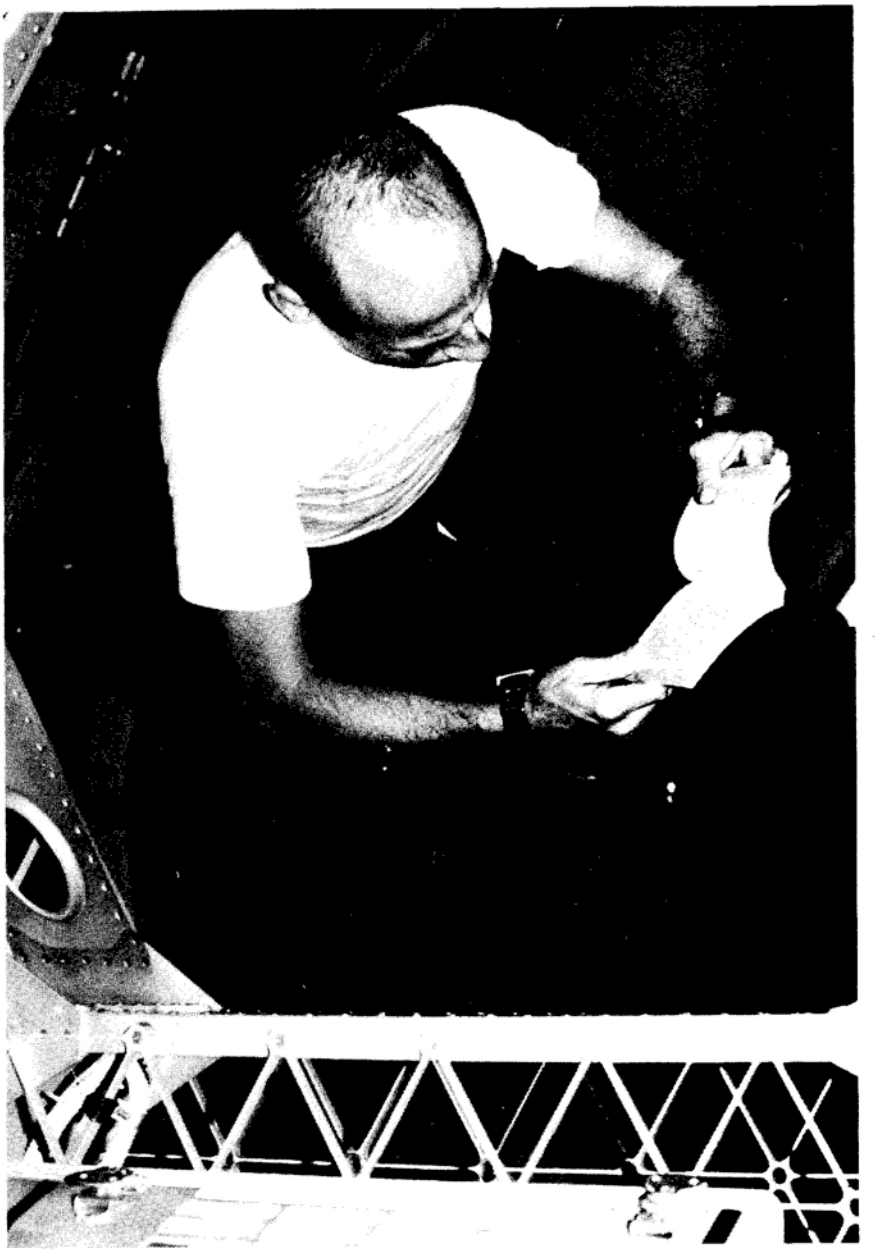
SL-3 PLT at SAL Worksite

Figure 12



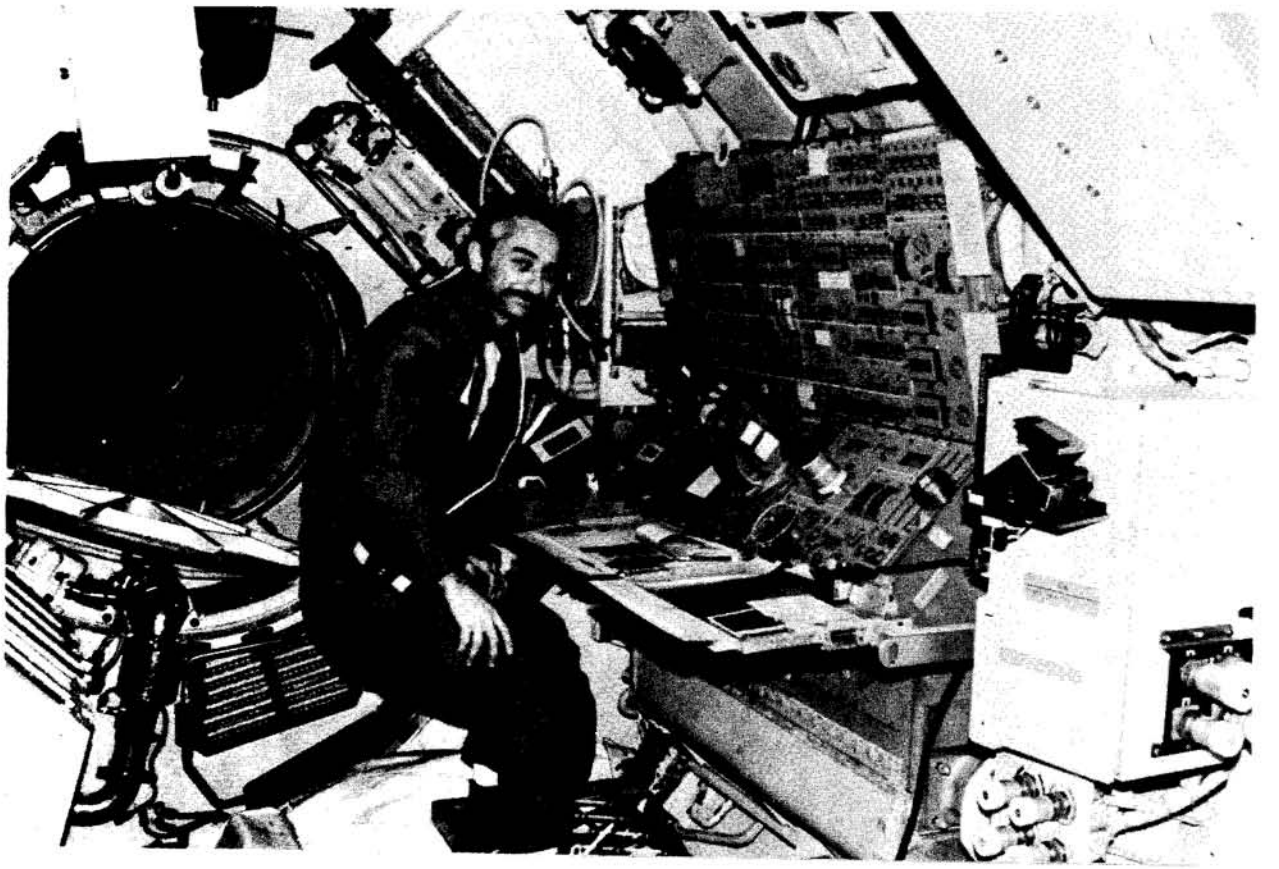
SL-3 PLT Loading Film

Figure 13



SL-2 CDR Reading While Unrestrained

Figure 14

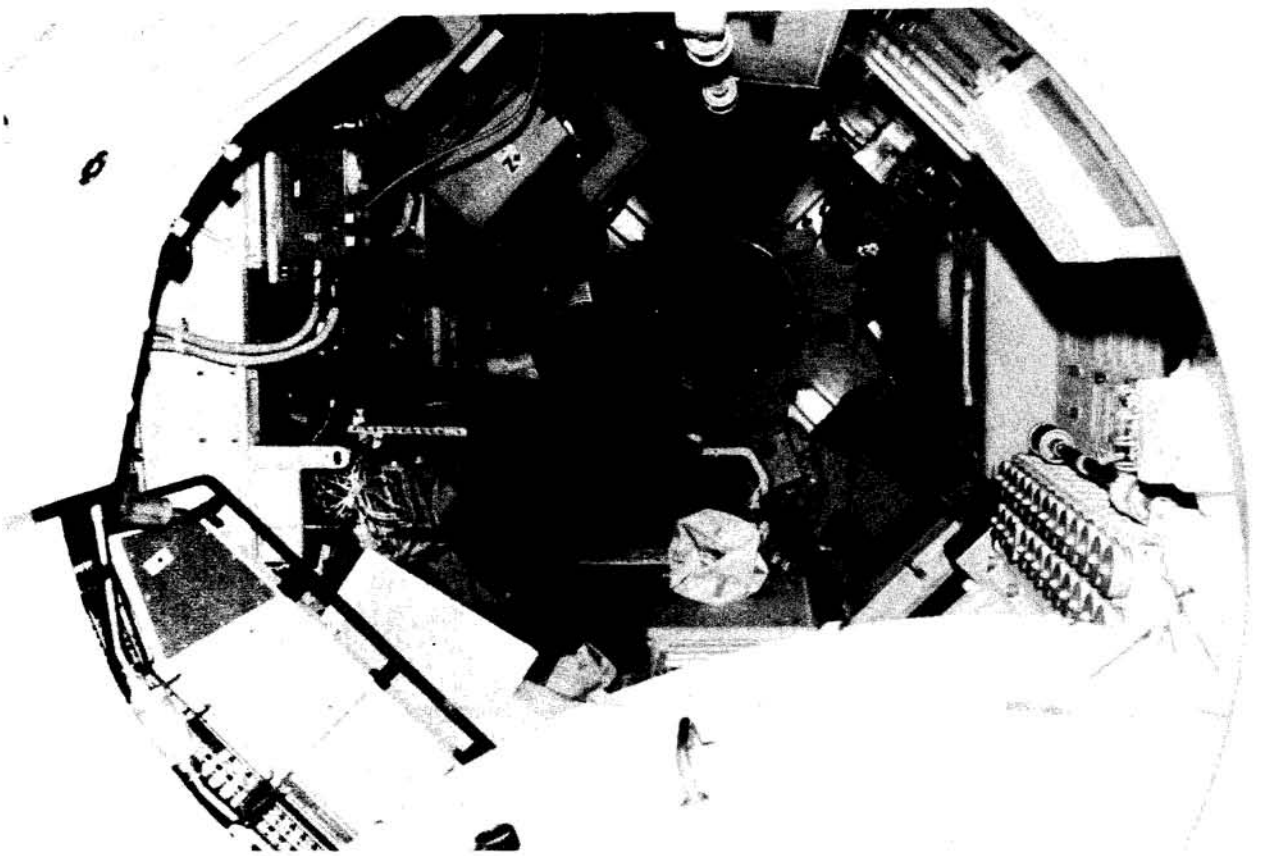


SL-3 SPT at ATM Console

Figure 15

SL-3 CDR at ATM Console

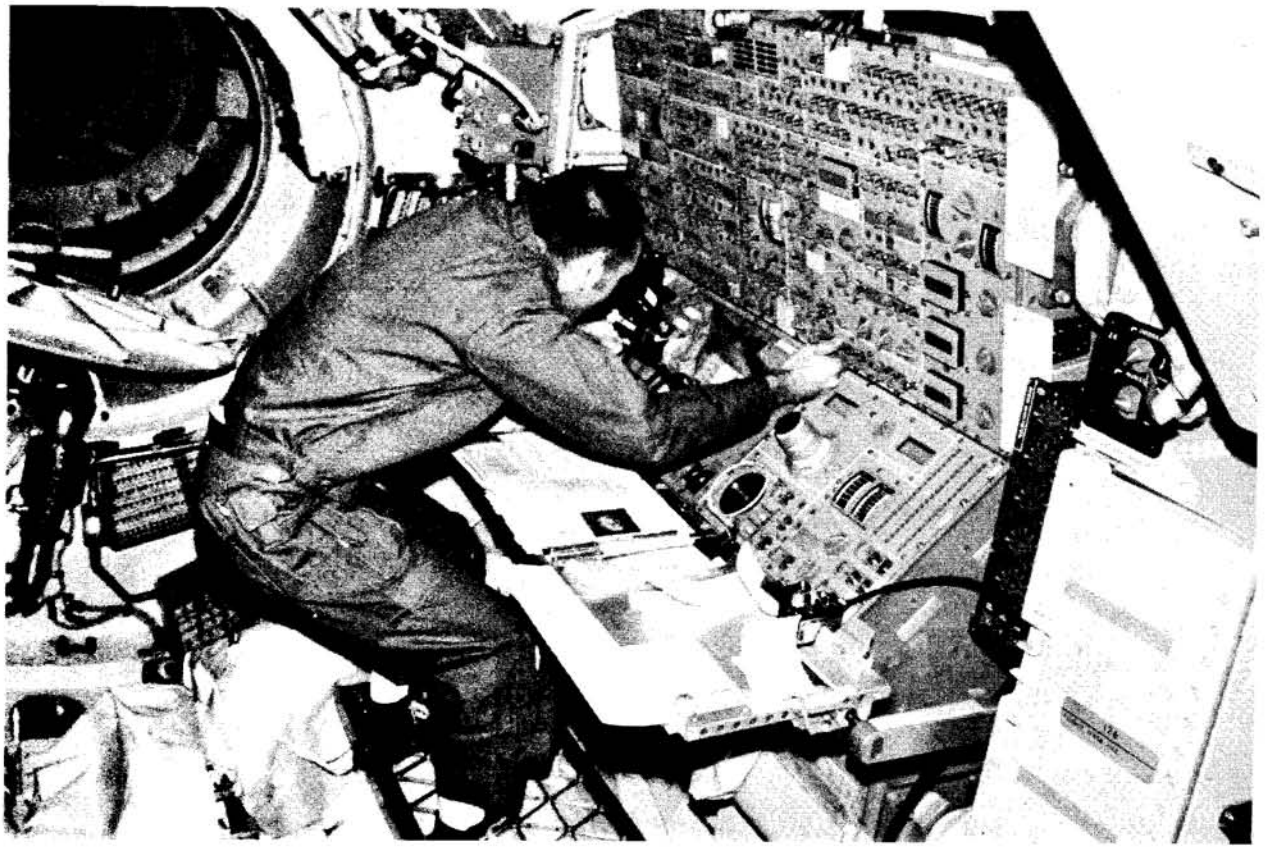
Figure 16



SL-3 PLT at ATM Console

Figure 17

the foot restraint platform (properly positioned for the shorter two members of the crew) to the ATM console work surface. Figure 18 depicts the adverse posture required to operate the polaroid camera on the ATM console. Figure 19 shows a similar posture imposed on the SL-2 SPT to use the IMSS microscope, a generic type task that may appear often in future vehicles carrying life science experiments. These postures should be avoided if the most efficient man-machine interface is to be developed.



SL-3 CDR Operating Polaroid Camera on ATM Console

Figure 18

SL-2 SPT Using Microscope

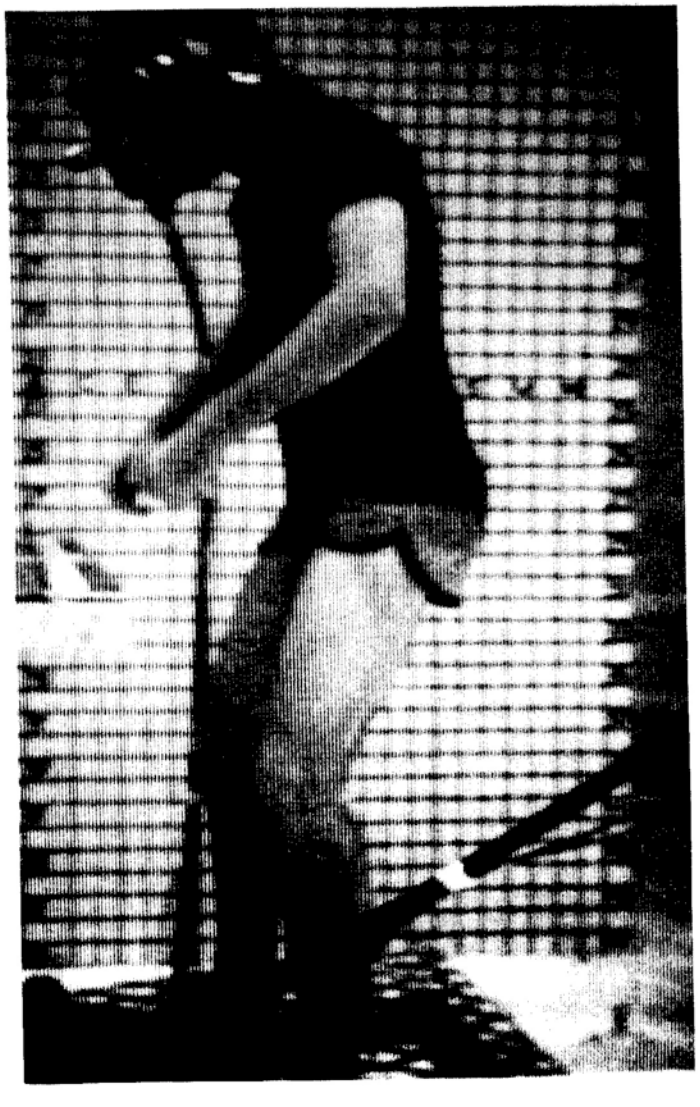
Figure 19

POSTFLIGHT VALIDATIONS

A series of postflight evaluations were conducted in the KC-135 zero-g aircraft and in the JSC Water Immersion Facility (WIF) to test the validity of the results obtained from the analysis of the inflight data. The film of the test subject's responses in the KC-135 tend to indicate a slightly more erect posture than that found in the pure zero-g environment, but part of the difference is probably attributable to a combination of less than perfect zero-g in the aircraft and an unavoidable anticipation on the part of aircraft-wise test subjects of the impending 2.5g pullout at the end of each parabola. The WIF postures tended to coincide quite closely with the inflight data, but an interesting artifact was noticed concerning WIF-wise test subjects. There seemed to be a tendency to unconsciously force the posture into some anticipated "correct" position, and the cues seemed to be visual in nature. This same phenomenon may have been at work in the aircraft also, but it was not found soon enough to eliminate it as was the case in the WIF tests. When the subject in the WIF was "blinded" by masking off his face plate, his posture changed from "too erect" with respect to the inflight data to "more like" the posture depicted in Figure 11. Figures 20 and 21 show this difference very clearly.

WIF Subject With Mask Blinded

Figure 20



WIF Subject With Mask Not Blinded

Figure 21

CONCLUSIONS AND RECOMMENDATIONS

1. The human body tends to seek a neutral posture when relaxed in zero-g.

2. The zero-g neutral posture is definable and quantifiable within a predictably repeatable envelope.

3. The neutral body posture should be taken into account in future designs of worksites and other manned interfaces to allow for the most efficient man-machine relationship possible.

4. Worksite designs that ignore the postural implications may present interfaces that are "workable" but the crewman's efficiency and stay time at that station may be adversely affected.

5. Excursions outside the neutral posture envelope are acceptable for short periods of time, but prolonged deviations combined with strenuous tasks should be avoided.

6. The type of task being performed will definitely influence the tendency for the body to migrate toward the neutral posture; i.e., long-term monitoring tasks (like ATM operations) will tend to encourage the posture while more active tasks requiring frequent and multiple head and arm movements outside the neutral envelope will not result in an as readily definable approximation of the neutral posture.

REFERENCES

No.	Source	Page
1	Colonel William R. Pogue, "Three Months in Space," a paper presented at the annual meeting of the Society of Experimental Test Pilots, Los Angeles, September 27, 1974.	1
2	Maynard Dalton, "An Overview of IVA Personnel Restraint Systems," Skylab Experience Bulletin No. 7, October 1974.	11
3	Maynard Dalton, "Foot Restraint Systems," Skylab Bulletin No. 9, December 1974.	11
4	Maynard Dalton, "Body Restraint Systems," Skylab Experiment Bulletin No. 10, December 1974.	11

RAW DATA APPENDIX

JSC Photo Number	Day of Mission	Subject
SL4-145-4788*	31	SPT
4789	31	SPT
4790*	31	PLT
4791	31	PLT
4792	31	SPT
4793	31	SPT
4794	31	CDR
4795	31	CDR
4796	31	PLT
4797	31	PLT
4798*	31	CDR
4799	31	CDR
SL4-147-4947	55	PLT
4948*	55	PLT
4949	55	SPT
4950*	55	SPT
4951	55	CDR
4952*	55	CDR
SL4-148-4982*	74	SPT
4983	74	SPT
4989	74	PLT
4990*	74	PLT
4991	74	CDR
4992*	74	CDR
4995	74	SPT
4996	74	SPT
4997	74	PLT
4998	74	PLT
4999	74	PLT
5000	74	CDR
5001	74	CDR
SL4-151-5106	3	CDR
5107	3	CDR
5108	3	CDR
5109	3	CDR
5110	3	CDR
5111	3	SPT
5112	3	SPT
5113	3	SPT
5114	3	SPT

*Photographs used in analysis.

JSC Photo Number	Day of Mission	Subject
SL4-151-5115	3	SPT
5121	3	CDR
5122	3	CDR
5123	3	CDR
5124	3	CDR
5125	3	CDR
5126	3	SPT
5128	3	SPT
5129	3	SPT
5130*	3	SPT
5131	3	SPT
5132	3	PLT
5133	3	PLT
5134	3	PLT
5135	3	PLT
5136	3	PLT
5146	8	CDR
5147	8	CDR
5148	8	CDR
5149	8	CDR
5150*	8	CDR
SL4-152-5164	11	CDR
5166	11	CDR
SL4-154-5227	55	CDR
5228	55	CDR
5229	55	CDR
5230	55	SPT
5231*	55	SPT
5232	55	SPT
5233	55	PLT
5234	55	PLT
5236	55	PLT
5249	55	PLT
SL4-155-5250	74	PLT
5251	74	PLT
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5253	74	CDR
5254	74	CDR
5275	74	SPT
5276	74	SPT
5278	74	SPT

*Photographs used in analysis.

JSC Photo Number	Day of Mission	Subject
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5344	31	SPT
5345	31	PLT
5346	31	PLT
5347	31	PLT
5348	31	CDR
5349	31	CDR
5350	31	CDR

CARR It might have been better because it requires that you get the finger in the - in between the wickets to throw a switch; whereas, if you bump it with a foot or something, it will protect it. But you've got an engineering tradeoff there because a whole bunch of wickets are such much heavier and space - use up a lot more space than just a bar across the top.

QUERY True. You commented in the debriefings on the ATM foot restraint position and the fact that it generally was too high for all of you by about 8 or 10 inches. Did you move the ATM foot restraint from its position and what position did you use?

CARR It was all the way down, as far down as it could get.

QUERY It was all the way down?

CARR Yes. See the thing is your natural posture is essentially - standing is just very slightly bowed, with your back hunched just a little bit, your legs flexed just a little bit. And what we ended up with was the eye level right at the top of the panel instead of where we had had all of our training where you're sitting in a chair and you're looking at the panel like this. You had to look at it like that. And the same thing in the food area too. You're not sitting

CARR (CONT'D) down, and so we shouldn't have put the food tables at the sitting down, chest level sort of thing. We should have recognized that people are eating standing up. And so the upshot was that at the food table and at the ATM panel, you had to hunch down in order to get a decent level and - -

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POGUE Tense your abdomen.

CARR Yes, but your abdomen and your muscles tensed up and you just got tired of it. What we need to do is remember postural situation up there and the fact that it is quite natural to be standing up, so you might as well get all of your work surfaces and everything, your eating surfaces up here.

POGUE And the thigh restraint didn't help that any?

CARR Yes.

QUERY That's one thing, which crewman's restraint methods worked best and worst? Did you have any?

POGUE Triangle shoes.

CARR Oh, they were by far the best, yes. It took a little while to get that eye that you need so that you could come right down and put your foot in a triangle and snap it. You know, the first few weeks it was put your foot

POGUE (CONT'D) none for the VTS operator. The one for the material processing facility I didn't use on the M518 sequence.

CARR For 487 I used the one triangle in the upper left-hand corner, because that was the closest one. It was poorly placed for the furnace work.

GIBSON I always wished that the ATM foot restraint were lower. We all found that we were hunched over when we started operating the ATM. We got a little better as we got used to having a higher head position relative to the panel but we always seemed too high on the panel. I would much rather have that thing gone down about 6 to 10 inches.

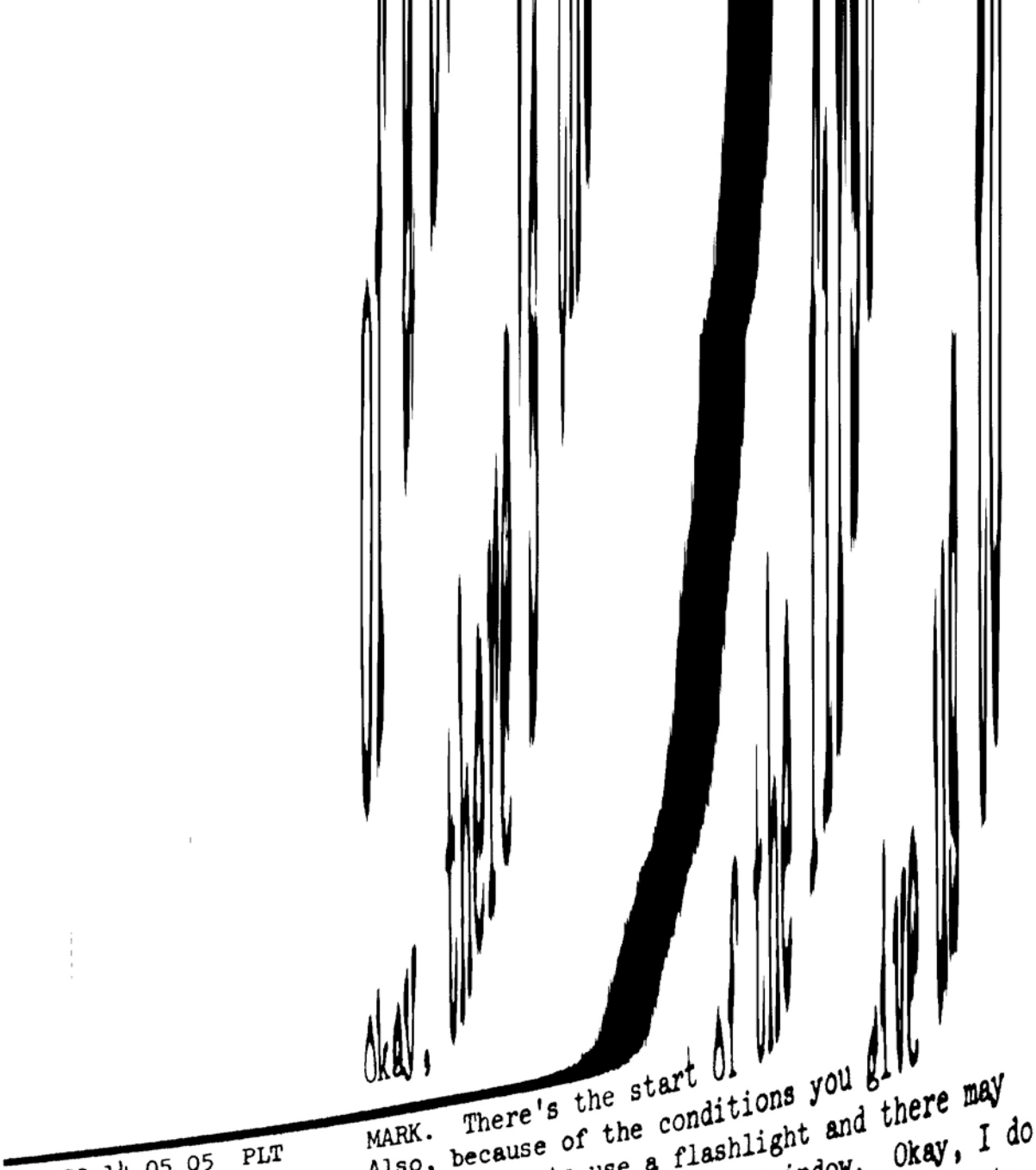
POGUE You tend to get a cramp in your abdomen from tensing, because all the work stations were set up for normal one-g work. Your body tends to hold itself erect, and even slightly arching the back, so you are always held away from your workstation. I thought the aids around the MDA and STS were very poor. It was very difficult to do some of the tasks which were required. In fact I put up long straps, and ended up tying my ankles to single handholds, in order to have a good stable body position for doing some of the early work in the Coolanol servicing loop in particular and for some of the EREP instruments' calibrations.

CARR (CONT'D) felt that the experiment was time consuming and that it was not producing any new data.

POGUE I have one comment on M131. When you are adapting things to conform to the human body in zero gravity, you've got to be careful. We found that the body normally wants to assume a more or less erect, slightly arched attitude, and holding yourself in a chair was difficult. The seatbelt helped; although it was hard to adjust. The biteboard could have been better if it had one more degree of freedom. I was never completely comfortable. One problem was that the postural change made it very difficult to adjust the height of the biteboard properly.

GIBSON Regardless of the individual's shortness, we could never get the biteboard high enough in order to make it fit comfortably. We were on the ragged edge of it coming out of the strut which held it up.

CARR When I was stuck into the biteboard, I felt like a horse with a bit that's being reined in tightly with his chin being pulled down towards his neck and the back of the neck being somewhat arched. I always felt like my chin was being pulled down and in, and my neck was being arched. It was rather uncomfortable, and it was difficult to get away from that position.



350 14 05 05 PLT

MARK. There's the start of the
Also, because of the conditions you
work, I have to use a flashlight and there may
be spurious light off of the window. Okay, I do
not have a reticle, so it's difficult for me to
track the horizon. Okay, completion of that one,
except - Okay, I'm sorry. That was on 64 - 32,
and you got a 32-second exposure. Okay, starting
up at - second exposure at 14:07. They have to
leave that off. This is their problem. You have
to leave the timer off so you don't run the battery
down. I had to select this in semidarkness, so I
went to 32 instead of 64. I have 64 set now and
it'll give you a good one next time. Okay, I will
do that at 14:07 right on the money. And that's
1 - 40 seconds from now. Let's see if I can do

CARR (CONT'D) felt that the experiment was time consuming and that it was not producing any new data.

POGUE I have one comment on M131. When you are adapting things to conform to the human body in zero gravity, you've got to be careful. We found that the body normally wants to assume a more or less erect, slightly arched attitude, and holding yourself in a chair was difficult. The seatbelt helped; although it was hard to adjust. The biteboard could have been better if it had one more degree of freedom. I was never completely comfortable. One problem was that the postural change made it very difficult to adjust the height of the biteboard properly.

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Let's see. I wasted one frame of IR checking it - that is, mistakenly installed the film first. I figured I'd better go ahead and make sure the thing was working. And I hope it works today. Okay, I'm looking - I do have somewhat of a horizon. By the the way, a note for future design: This - Operation of this equipment is difficult because of the hardware - I guess just the design of it. It's all a bunch of little bits and pieces put together and it doesn't fit too well and the track drive is rough and jittery and a lot of other things that I won't go into right now.

350 14 03 37	PLT	But one of the things that really bothers you is that you have to remain in a crouch position in order to take these observations. This requires continual muscle tension in the abdomen. So what we've got here is a problem that not only is the hardware not - not optimally designed or - Actually, it's sort of poorly designed. I don't mean to be critical; I'm just saying it doesn't work right. It doesn't work smoothly, it's not easy to see what's going on, this ring track is lousy - But that's beside the point. It does require an awful lot of muscle tension to hold yourself in position. We're coming up on time. Okay, you got 1 minute to go. Let me make sure I've got everything working here. Here's the ring. Tighten that just a little bit. There, that's good. All of a sudden I've lost everything. Okay, 15 seconds. Okay, there's the horizon. Stand by. Okay, 64.
350 14 05 05	PLT	MARK. There's the start of the first exposure. Also, because of the conditions you give us to work, I have to use a flashlight and there may be spurious light off of the window. Okay, I do not have a reticle, so it's difficult for me to track the horizon. Okay, completion of that one, except - Okay, I'm sorry. That was on 64 - 32, and you got a 32-second exposure. Okay, starting up at - second exposure at 14:07. They have to leave that off. This is their problem. You have to leave the timer off so you don't run the battery down. I had to select this in semidarkness, so I went to 32 instead of 64. I have 64 set now and it'll give you a good one next time. Okay, I will do that at 14:07 right on the money. And that's 1 - 40 seconds from now. Let's see if I can do

007 02 22 46 PLT — Okay, that's real good. Now let me record the diopters here. I can - I can record this. I got real good focus now. I start screwing around with this - minus 1.5. Now that's about what I normally get. Okay, now, I'm going to take a zero - zero bias on Sirius. And then if I start setting up for Procyon and Rigel, I twist the eye cup, I destroy my focus. That's my point.

007 02 23 32 PLT — Okay, 00027.

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007 02 23 55 PLT — 00034. I still say - I don't care about twisting this eyepiece or anything else. I still say body posture is one of your big problems. I need to have something to lean against. It'd have to be a prepared station in order to use this thing to the maximum advantage. Just putting your feet in the floor is not good. You ought to be able to lean against something and prep - and in addition to that, you ought to be able to put the instrument against something to steady it. I think you'd get highly repeatable results.

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007 02 24 44 PLT — 00021.

007 02 25 03 PLT — 00022.

007 02 25 18 PLT — 00020. The focus seems to have shifted or my eye has.

PLT — Okay, now I'll change that to minus 1.1.

PLT — Minus - okay, that's - well, let's change the focus back. Minus 2; let's see how that works. Try minus 2.5. No good at all. Minus 1.8. No good. Minus 1.5, see how that looks again. Well, that could do it; I'm going to have to live with that, I guess.

007 02 26 57 PLT — 00022.

007 02 27 12 PLT — That's good, 00021. See how far's that thing's shifted?

007 02 27 29 PLT — 00094. Let's see, 000 - yes; no, I must have hit the knob. It's way off. Disregard that one. I'll be careful there.

	PLT	Okay, now let's see if we can do it. Okay, got to go over to my left just a little and undo my belt one notch. Gee, I can't overemphasize the importance of body restraint. We're using this - getting good results out of this instrument, at least, in de - decreasing the fatigue. It really kills you. Yes, a couple or 3 inches difference in foot position also makes a difference. You ought to be able to move your feet around. So the important thing is to have your body position correct and your head in the right position to look out the Astrodome window or whatever it is you're using. Okay, going to put in both filters. Make sure they're in and - in other words - Okay, that's 2.6. We call that the neutral density.
	PLT	Okay, stand by -
010 18 49 35	PLT	MARK. 55395.
	PLT	I'm not helping your lunch. Sorry about this, Ed. I can fill all these squares today, if I get through here.
	PLT	Stand by -
010 18 50 20	PLT	MARK. 55395. Hmm! Same one.
	CDR	Find it, Ed?
	SPT	No, I'm sorry. No - I'll look for it later.
	CDR	Huh?
	SPT	No, I didn't, Jerry.
	CDR	... - -
	PLT	I've got the wrong star.
	CDR	Pouches.
	SPT	Pouches? Oh, I was looking for the other kind.
	PLT	Let's see. Yes, there's Aldebaran. It should be further away than Rigel. It's at 59 degrees.
	SPT	Okay, I got it.

		up for running and focused. I'm going to use the neutral density filter. I don't see what purpose the reticle might serve. Let's see here. Ooh, this is awfully uncertain.
012 15 09 40	PLT	Gad. The old body posture getting me again. Let me get my belt out. Otherwise, I'm going to get all tensed up here and not be able to do anything.
012 15 09 55	CC	Skylab, Houston through Texas and MILA for 14-1/2 minutes.
	SPT	Hello, Hank.
	PLT	... over Central America.
	CC	We didn't get a report on that last teleprinter test message. How'd it look?
	PLT	Yes.
	SPT	Looks good, Hank.
	CC	Okay, thank you.
012 15 10 12	PLT	The Yucatán.
012 15 22 15	PLT	Okay. PLT resuming T002; had a little interruption there. Well, let's see if we can get any horizon trackings here. Man, this is really hard. Well, I'll tell you, body posture is extremely important; not just important, every - almost everything, being able to stabilize your body. And it's just part of - that should be a major part of this experiment. Stand by. Well, I don't have much faith in the stability - you have three - you get a - the high contrast in the types of images you can -
012 15 23 36	CC	Skylab, Houston. We're 1 minute from LOS. We'll see you again at Madrid at 28 - -
	PLT	Stand by.
	CC	- - dump the recorder there.
	SPT	So long, Hank.
012 15 23 46	PLT	MARK. 03984. Stand by.

SKYLAB MAN-MACHINE DATA FROM MISSION SL-II
FOR: M. MANUAL DEXTERITY
2. Muscle Group Use

MISSION DAY: 5 DAY OF YEAR: 149 (CONTINUED)
MISSION TIME: 17:41:24 GMT

CDR: I was really running out of gas, in fact I was using muscles that I don't normally use down on the ground, so I don't know whether I am going to get more efficient or less efficient or what is going to happen. So that is for what it is worth. End of MO M171 message.

*****

MISSION DAY: 18 DAY OF YEAR: 162
MISSION TIME: 19:01:51 GMT

CDR: One of the other things that I've noticed is that in holding ourselves while we're out here and doing our tasks we really use our stomach muscles. It's really interesting - I - the first three or four days that we were up here we kept finding ourselves just - really holding our stomachs to hold the right position - that you use your stomach muscles more than anything else I think in holding wherever you are. In working on it, whatever it is that you're working on.

CC: Yeah, there's some pretty good physiological reasons for that because normally all of the vertebral muscles are on the back side to take care of center gravity on Earth. And you really don't have much required on Earth.

*****

MISSION DAY: 20 DAY OF YEAR: 164
MISSION TIME: 21:01:51 GMT

CC: Hey, Pete, would - be interested in any further comments on the relative amount of work you might be doing up there and what parts of the body are getting it?

SKYLAB MAN-MACHINE DATA FROM MISSION SL-IV
FOR: M. MANUAL DEXTERITY
2. Muscle Group Use

MISSION DAY: 4 DAY OF YEAR: 323
MISSION TIME: (324)00:05:06 GMT

SPT: One thing I'm trying to do is to keep calves in shape and two things there, just move the triangles to the very tips of the shoes, so that I have to use my calves more and whenever I'm anchoring my feet in and also I'm not tying the top 2 laces on the shoe so that I don't get the extra ankle support from them.

*****

MISSION DAY: 25 DAY OF YEAR: 344
MISSION TIME: 21:39:23 GMT

NOTE: M487-3A

PLT: By the way, a crouching action is very difficult in zero-g, so if you design a foot restraint where there's a posture requires a crouching action then you're not helping us at all. In fact, it is a great hindrance to have to go into a crouch because you have to hold your abdomen very stiff and your legs - muscles very stiff and you're at a constraint strain even putting your on your shoes. When you bend down to put on your shoes - if you bend down it's difficult, if you pull one leg up at a time it's not too bad to lace shoes.

MISSION TIME: (345)01:42:22 GMT

SPT: Hello. Welcome to Skylab 3. Since we got here we've done an awful lot of medical experiments. And especially in the past week or two, they've started to indicate that we're all in pretty good shape. As a matter of fact, a couple of us are probably in better shape than when we came. What we've attributed this to is Bill Thornton's revenge, we call it. It's a device for keeping the calves of the legs with a fair amount of muscle bulk left in them. And this has enabled us to, we think, maintain roughly the same muscle tone in the legs as we have on the ground.

*****

SKYLAB MAN-MACHINE DATA FROM MISSION SL-IV
FOR: M. MANUAL DEXTERITY
2. Muscle Group Use

MISSION DAY: 68 DAY OF YEAR: 022 (CONTINUED)
MISSION TIME: 18:08:46 GMT

NOTE: M487-2D

CDR: Okay, the muscle groups that you use the most in postural positioning is your stomach muscles, I think. For the most part, any pushing, shoving, hauling, anything like that that you do, you use the normal sets of muscles. But I think for most little work jobs we do, where you want to be anchored, you - you're always in sort of a crouch. Sort of a knees flexed, butt down a little bit, shoulders rounded a little bit - just, you know, kind of down a little bit toward being in a crouch. And of course in one-g, in something like that, you'd be standing up straight with your knees locked or something like that. Based on the considerations, I would suggest that things like tool benches, work benches, be chest high. That is, where you don't have to go into a crouch to work since you can anchor your feet and work with your muscles relaxed, relaxed instead of pulled up a little bit. Cause it'll certainly make you a feel a whole lot more rested when you've finished your job. That's essentially it.

MISSION TIME: 18:54:32 GMT

NOTE: M487-2D

SPT: What major muscle groups - anywhere else, anywhere else. About the only places I'm really working most of the time - well, also when I'm doing some of these TV 10X series, I got the television camera mounted on the floor and the lights and everything else, and if I'm bending down there all the time; it's a little bit harder than one-g because you don't have the gravity holding you down. So I find myself with my legs and my back getting tired. What major muscle groups do you employ in zero-g as opposed to one-g? Most of the time you don't employ many muscle groups in zero-g except for the times you're trying to bend over and get something and stay - and stay bent over.

(CONTINUED ON NEXT PAGE)

SKYLAB MAN-MACHINE DATA FROM MISSION SL-III
FOR: M. MANUAL DEXTERITY
3. Postural Adjustments

COROLLARY EXPERIMENTS DEBRIEFING
PAGE 26-28

QUERY: Do you find that there is a neutral position that the body seeks in zero-g when you're not restrained? Does that tend to change as the mission progresses?

GARRIOTT: It seeks one, but it doesn't change.

BEAN: Your legs tend to come up a little bit so that they're partially bent. I estimate 30° from being in a straight line with your spine, both at the hip joint and the knee joint. Your shoulders tend to shrug a little bit because you don't have gravity holding them down. Your muscles will tend to pull them up a little bit. That's the only postural difference that your body would normally assume.

GARRIOTT: Like a relaxed position in a swimming pool.

QUERY: Owen, at the ATM station you used the triangle shoes standing, which made you crouch a little bit to get your design eye?

GARRIOTT: Yes.

QUERY: I assume Jack did the same thing.

GARRIOTT: We all did approximately the same.

QUERY: From a design standpoint, is there any difference between the designing for the standup type console as opposed to the chair type that concerns the eye point?

GARRIOTT: Working at the ATM panel is considerably better than it is working in a chair in the simulator. The most neutral position did tend to have my eye approximately 6 inches higher than it would be if I were sitting in the chair in the simulator. You also have great flexibility by
(CONTINUED ON NEXT PAGE)

SKYLAB MAN-MACHINE DATA FROM MISSION SL-III
FOR: M. MANUAL DEXTERITY
3. Postural Adjustments

COROLLARY EXPERIMENTS DEBRIEFING (CONTINUED)
PAGE 26-28

GARRIOTT: extending your legs or crouching a little bit and lateral variation enables you to cover the whole panel more easily than you could cover it sitting in a chair at the simulator.

QUERY: So the design eye is a little higher?

GARRIOTT: The design eye is a little bit higher. It is a question of where we had the foot mounted. It turned out to be approximately 6 inches higher than we would normally work here.

QUERY: With no fatigue?

GARRIOTT: It didn't produce any problems. If we wanted to get closer to the scope it was easy to do by bending out legs more. We had a little better visibility at the top of the panel because our head was a little bit higher. You can cover a larger area conveniently with no fatigue than you can in a chair.

*****

SKYLAB MAN-MACHINE DATA FROM MISSION SL-IV
FOR: M. MANUAL DEXTERITY
3. Postural Adjustments

MISSION DAY: 13 DAY OF YEAR: 332
MISSION TIME: 19:39:05 GMT

PLT: The posture I assumed was with one of my triangle shots in the blue restraint panel that is under - below the water tanks. And what I did - I put my left foot in one of the triangles and my right foot I stepped back between the water tanks, and maneuvered it around to hold my position. I'm fairly confident that what happened was that I moved with my foot. And I guess this just points out once more the lack of wisdom in doing things in flight that you never trained before - we had never trained for that all we did was - we read the procedures first time, we got ready to take those IR photographs and we're going through a learning ... probably wasted a lot of film. And it was improper procedure simply because it was completely strained to try to stabilize ourselves. But the main point I'm trying to make is that I am reasonably certain that I kicked the pressurization valve off on water tank 3 while I was maneuvering there taking those IR, shots.

*****

MISSION DAY: 31 DAY OF YEAR: 350
MISSION TIME: 14:03:37 GMT

NOTE: S063 Operations

PLT But one of the things that really bothers you is that you have to remain in a crouched position in order to take these observations. This requires continual muscle tension in the abdomen. So what we've got here is a problem that not only is the hardware not optionally designed, actually it's sort of poorly designed. - - It does require an awful muscle tension to reach up in position.

*****

SKYLAB MAN-MACHINE DATA FROM MISSION SL-IV
FOR: M. MANUAL DEXTERITY
3. Postural Adjustments

MISSION DAY: 46 DAY OF YEAR: 365
MISSION TIME: 19:20:34 GMT

NOTE: T002

PLT: ... awkward angle I have here. The concern's with all wrong problems. The lighting - there's no problem. The concern is getting your body in the right posture. You have to work for the sextant; the sextant does not work for you, you've got to turn sextant around at the right angle. That seems to be the biggest stumbling block to the operation so far.

Let me see. Focus, focus, focus. Oh, knocking everything off the walls here. Sure don't like the instruments in zero-g. Body position is the biggest irritation right now, getting the right body position. You have to work yourself around so that you get your body in the right position and line up.

Oh, my god. Overshot again. 38.551, and I think that's a bad reading. Muscle cramp. I'm getting muscle cramps in arms and in my legs from trying to hold my body in the right position to angle between the two stars. ... that all this over concern about lighting and everything is just a ... red herring. That's not the problem at all. The problem is getting to a body position so that you can hold the sextant properly oriented between the two stars. Okay, I'll change my body position; let's see if I do any better. Making sure I've got - put ... in there. Oooh ... Nope, I sure don't. Have to go back to the floor. Not complaining; I'm just saying that that affects the results.

MISSION TIME: 21:59:41 GMT

NOTE: M487-2C

PLT: Discuss both the beneficial and the detrimental effects of zero-g on the following types of activities. Individual work activities while restrained at a specific work location. Okay, if you're restrained

(CONTINUED ON NEXT PAGE)

SKYLAB MAN-MACHINE DATA FROM MISSION SL-IV
FOR: M. MANUAL DEXTERITY
3. Postural Adjustments

MISSION DAY: 46 DAY OF YEAR: 365 (CONTINUED)
MISSION TIME: 21:59:41 GMT

NOTE: M487-2C

PLT: in zero-g, the only disadvantage of zero-g is the upright preference of the body posture. If you are hunching over an object, like we do at the SAL a lot, that's an awkward posture. Zero-g can work against you as well as for you. It tends to straighten you up, so if your work posture is a crouched over or bent over position at the waist, then you're expending extra energy and zero-g is hurting you.

*****

MISSION DAY: 52 DAY OF YEAR: 006
MISSION TIME: (007)02:23:55 GMT

NOTE: T002

PLT: I don't care about twisting this eyepiece, or anything else. I still say body posture is one of your big problems. I need to have something to lean against. It has to be a prepared station in order to use this thing to the maximum advantage. Just putting your feet on the floor is not good. You ought to be able to lean against something and in addition to that, you ought to be able to put the instrument against something to steady it. I think you'd get highly repeatable results.

*****

MISSION DAY: 55 DAY OF YEAR: 009
MISSION TIME: 12:02:38 GMT

NOTE: T002

PLT: One of the things is getting my fingers off the knob without moving it; that's a problem. Particularly when you hold this in the awkward position, sideways, like I am between these two stars. They're left to

(CONTINUED ON NEXT PAGE)

SKYLAB MAN-MACHINE DATA FROM MISSION SL-IV
FOR: M. MANUAL DEXTERITY
3. Postural Adjustments

MISSION DAY: 59 DAY OF YEAR: 013
MISSION TIME: (014)02:47:51 GMT

NOTE: T002 Use at Wardroom Window

PLT: The main problem is the one I mentioned earlier, and that is you have to strain against the 1-g tension muscles to get the instrument in a favorable position. Now sighting angle requirement is another thing. Now that can also lead to your leaning over to one side or to the other, or trying to get high or low around the window. In any event, all of these things work together to fight the operator. The operator is fighting himself continually; in other words, it's very easy to find an optimal eye instrument position. It's very difficult a lot of times to hold that orientation. Now I've also noticed when I hold the instrument - when I clock the instrument around in order to get the proper mirror angle, that is, to bring the plane of rotation of the mirror along the line of sight between the two stars or whatever it is, that I find it much more difficult to make the observations when I'm holding that thing at 90 degrees. Now I think that since that is more difficult for me personally to do, I think the posture problem aggravates that. However, that's another problem all by itself.

MISSION TIME: (014)02:51:40 GMT

NOTE: T002 Use at Wardroom Window

PLT: I can't overemphasize the influence I think body posture and postural stability has on the accuracy that you're able to get with a - with the handheld instrument like this. And I think that - I wasn't meaning to carp. I was trying to point out what I thought was a very valuable point in that it's got to have help in holding your body in the right position in stabilizing the eye and the instrument at the right position in that window. And if you can accomplish that, and you don't have to worry and concentrate on that, then you can do much, much better job of making the sighting.

*****

SKYLAB MAN-MACHINE DATA FROM MISSION SL-IV
FOR: M. MANUAL DEXTERITY
3. Postural Adjustments

MISSION DAY: 68 DAY OF YEAR: 022
MISSION TIME: 12:15:54 GMT

NOTE: M487-2D

PLT: Number 2, what postural adjustments you have to make in order to accommodate task performance in zero-g? Numerous. Taking stuff out of the dome lockers, you might think, well that wouldn't be too bad, because you've got that blue ring. Well, it's not true, because most - a lot of time in order to get to the equipment that's located in some of the lids you have to come out of the - the blue ring foot restraint and work op - in the open. And there, in the airlock is hard to work, because there are no foot restraints. The STS and the MDA are very difficult locations in which to work with tools, because of the great lack of foot restraints and body restraints. And this means that you end up use - using your body against whatever things - whatever pieces of hardware are available. And I have experienced numerous cuts and bruises and so forth in trying to stabilize myself while I'm working with tools or just with installations.

MISSION TIME: 18:07:24 GMT

NOTE: M487-2D

CDR: What postural adjustments have you had to make in order to accommodate task performance in zero-g? What major muscle groups do you enjoy in zero-g? What would you offer as design recommendation for future vehicles based on these considerations? Postural adjustments. I guess - we find ourselves kind of working everywhere we go - -

MISSION TIME: 18:53:50 GMT

NOTE: M487-2D

SPT: Postural adjustment is question number two. What postural adjustment have you had to make in order to

(CONTINUED ON NEXT PAGE)

SKYLAB MAN-MACHINE DATA FROM MISSION SL-IV
FOR: M. MANUAL DEXTERITY
3. Postural Adjustments

MISSION DAY: 68 DAY OF YEAR: 022 (CONTINUED)
MISSION TIME: 18:53:50 GMT

NOTE: M487-2D

SPT: accommodate task performance in zero-g? First one is at the ATM panel, I wish that the flooring was a little bit lower there. I found myself having to painfully bend over, was much worse at the beginning of the mission when I was used to the simulator. Now, I'm used to working a little higher eye level on the ATM panel, but I still find myself bending over and that is somewhat of a problem.

*****

SKYLAB MAN-MACHINE DATA FROM MISSION SL-IV
FOR: M. MANUAL DEXTERITY
3. Postural Adjustments

COROLLARY EXPERIMENTS DEBRIEFING
PAGE 47

NOTE: T002

POGUE: .... What I consider a constraint on manual operations is that the body tension is built up while holding a preferential posture for the operation at hand. If you don't have something to hold you in a good posture for making the observations, then your abdomen and related muscles get fatigued and you make big mechanical errors. This tiedown was to obviate that problem.

*****

EREP DEBRIEFING
PAGE 75

QUERY: It appeared that a chair, as we know a chair, is not a very useful device.

GIBSON: What a chair does for you down here is take the weight off your legs, but you don't need that up there.

QUERY: You said that it would actually be an effort to hold yourself in a chair, is that right?

CARR: Yes, the 131 chair is a case in point. We just actually had to strap ourselves into that thing because our body didn't naturally bend 90 degrees.

GIBSON: I think your previous observation is more important. You have a much wider range of reach. And we've found this true in working everything. For ATM we had checklists and cards all over the place which I could reach by bending one knee or the other. You could work around a whole sphere, essentially; the chair was very limited.

SKYLAB MAN-MACHINE DATA FROM MISSION SL-IV
FOR: M. MANUAL DEXTERITY
3. Postural Adjustments

EREP DEBRIEFING (CONTINUED)
PAGE 106-107

POGUE: I had the feeling it was a little harder, but I attributed it to the fact that our seated postures gave us a distorted dimensional matchup with whatever we were working, either the 131 chair or the 509. I'm not making that as a positive statement, but it's a feeling that I had. When I was at Denver with the simulator and I made the adjustments on the arms, I was happy with them. It seemed like all of a sudden my arms were 3 inches longer than they used to be. I didn't have enough adjustment.

WHITSETT: Do you have any idea why you felt you couldn't get your hands in close enough to reach the controllers?

POGUE: They were in too close. I wanted to be able to extend them out further and operate them like this, and I felt like I was operating them like this.

CARR: I didn't feel that, of course.

QUERY: I noticed you had them on E position, which still had about 2 inches of displacement.

CARR: What position did I use in training? Do you have it written anywhere? Is the E position I had in flight a little farther out than what I had at Denver?

QUERY: I don't have that available.

CARR: I'm guessing, but I'll bet it's a little farther out. It might just be a postural thing.

*****

SKYLAB MAN-MACHINE DATA FROM MISSION SL-IV
FOR: M. MANUAL DEXTERITY
3. Postural Adjustments

ATM EXPERIMENTS DEBRIEFING
PAGE 38-39

POGUE: One of the things that is very important is body posture; that is, where your head ends up when you have your feet nailed down some place. We've addressed this in the technical debriefing.

GIBSON: We all found that the grid underneath which you put your feet into could never go down far enough. When you stand up, your head comes to the top of the panel. Therefore, to get into the nominal operating position you're always leaning over and straining to lean over. That got tiring after a period of time, so after a while, you learn to operate looking down on the panel.

CARR: You get the impression, looking at that panel, that it was designed for a person to sit down at in one-g.

GIBSON: There's no way anyone could sit in a chair and operate it. We were always having to go over to the STS panel; we had to lean back to look at all the S055 information we had pinned up on lockers in the back. We had to lean over to the right to pick up Polaroid cameras or to reach the VTR. Furthermore, we wanted to move around when we were there for a long period of time, and a chair wouldn't permit that.

CARR: I guess you get the picture; we didn't use the chair.

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EXPERIMENTS M487 & M516 CREW DEBRIEFING
PAGE 6-7

QUERY: We noticed that, when given proper foot restraints like the triangles, when you worked in front of a work station or console that did not require much mental effort, you would adopt a semi-stand or

(CONTINUED ON NEXT PAGE)

SKYLAB MAN-MACHINE DATA FROM MISSION SL-IV
FOR: M. MANUAL DEXTERITY
3. Postural Adjustments

EXPERIMENTS M487 & M516 CREW DEBRIEFING (CONTINUED)
PAGE 6-7

QUERY: crouch position. It seemed to be the most comfortable and you had more reach and more range than if you had been seated in the chair in a normal manner and that the designed eye position in this situation was a little higher and had a very fair amount of flexibility. Now this suggests to us that at work stations, we'll have to revise our handbook engineering data for heights of the counter top.

CARR: The crouch position that you come to is the natural one. We found that in the ATM, you had to pull your stomach in and use your muscles to pull yourself down where you should have been and that was uncomfortable. It was the same thing with eating. We finally all agreed that the tables were too low because you had to pull yourself down to be in a good eating position and if they'd have been chest high tables, it would have been more comfortable.

GIBSON: If we could have had about another 6 inches on the ATM foot restraint for adjustment downward, that would have done it, too.

POGUE: Eye level was just about the top of the panel when you were in a comfortable posture.

CARR: That observation is true and the important thing is to understand what the normal posture is and then work to that.

POGUE: You've got all those pictures, haven't you?

CARR: Yes. You have a lot of medical pictures, too.

PAGE 16

GIBSON: When we would move around in the workshop, we assumed a curled-up position and pulled our legs

(CONTINUED ON NEXT PAGE)

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