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Dr Berry
Lib - Skylab
Sci. Exp.
- A First Report

MARTIN MARIETTA AEROSPACE

DENVER DIVISION
POST OFFICE BOX 179
DENVER, COLORADO 80201
TELEPHONE (303) 794-5211

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March 27, 1975

University of Texas
Medical Center
P. O. Box 20036
Houston, Texas 77025

Attention: Dr. Charles A. Berry, President
University of Texas Health Science Center

Dear Dr. Berry:

Enclosed is a copy of the manuscript we have submitted to Dr. Horace Jacobs for publication in the forthcoming AAS volume entitled, "Skylab Science Experiments - A First Report."

We normally attempt only to prepare an abstract from tapes if a paper is not available for publication. However, we felt that your presentation at the Skylab symposium warranted an effort on our part to provide the complete text of your remarks.

You may want to review the enclosed manuscript to ensure that we have not introduced any errors into the text.

The publication of this volume has been delayed already beyond the originally planned publication date, thus we would appreciate it if you could review it promptly and limit your corrections to those required to correct errors.

If you agree with the text as written or if you would like to request any changes, please advise Dr. Horace Jacobs at the following address:

Dr. Horace Jacobs
P. O. Box 551
Dept. 8440
Unit 35
Lockheed California Company
Burbank, California 91520

Business Phone: 213/847-5646 or 5647
Home Phone: 714/487-7560

Very truly yours,

G E Simonson

G. E. Simonson
Co-Editor
Skylab Volume
Ext. 2848 or 5103
Mail No. 6200

cc: Dr. Horace Jacobs

SKYLAB MEDICAL CONTRIBUTIONS AND SIGNIFICANCE TO MANNED SPACE FLIGHT*

Charles A. Berry**

INTRODUCTION

From the very beginning of man's space flight there have been many kinds of cautions and dire predictions about what man might or might not be able to do in the space environment. I am sure that many of you remember, as I do so well, that at the very beginning of the Mercury Program there were predictions that man would not even survive the first launch. These claims have now been proven erroneous, but it has taken a great deal of activity in the early flight programs to do that. In those early missions the accumulation of data depended principally upon pre- and post-flight medical measurements because of the nature of those early programs and because of the nature of the spacecraft themselves. We certainly did not accumulate the kind of data from the early programs that would allow us to answer questions as decisively as we have been able to do with the data obtained from the Skylab program. In those early flights, we had to have a fairly courageous approach based upon a firm conviction. From Skylab we obtained the accumulation of hard data to replace the "gut" feeling that man was indeed going to do well in space flight.

The earlier incremental increases in space flight time were carried to the extreme in Skylab where we went to the 84-day mission duration.

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* Transcribed from tape by Miss Judy Gerlach Martin Marietta Corporation. Unfortunately Dr. Berry's slides were not available for this book.

**Director, Life Sciences, National Aeronautics and Space Administration, Washington, D. C.

We have accumulated a tremendous amount of time in Skylab compared to the previous flight missions, and we have a considerable amount of flight time in excess of that obtained by our Russian colleagues. As of today, the total in man-hours of space flight, both ours and the USSR's, exceeds 25,000 man-hours. That's a large amount of flight time.

Now one of the difficulties that we have always had, and we're still not completely free of this problem, is the fact that we have been asked many times by our engineering counterparts to predict the mean-time-to-failure of the man just as they have been able to do with spacecraft components. The engineers have been able to do that exceptionally well in the space flight program. They were able to select high reliability parts and test them singly, then at the sub-systems level, and finally, at the system level. They tested them to destruction and thus determined mean-times-to-failure and predicted accordingly. Now this has provided a large safety factor in the equipment for the space program. Man was always looked upon as not having that same safety factor for space flight. Some of this concern is based upon the fact that we cannot do the same sort of things with men that we have done with components.

For one thing, NASA didn't have anything to do with the initial selection process (i.e., the conception of the astronauts). We did, however, put the astronaut candidates through a selection process, but this was after the fact. When we did that, we found that we had some fairly normal human beings who were going to be subjected to a very alien environment.

THE SKYLAB DATA

I'd like to run through the data that we have obtained in the Skylab series. You have seen pictures of the Skylab vehicle that we used for the laboratory in orbit and pictures of the crew not only inside the vehicle, but outside during EVA.

Mass and Weight - The next slide shows the body weight measuring mechanism. This is the way we obtain body weight in flight. It's a mass measuring device and this is astronaut Al Bean using that device in flight. You can see it's a spring pendulum and as the astronaut vibrates on this spring pendulum you can determine mass. Mass is recorded in a recorder on the left side of the device. This allows us to analyze the curve recorded to determine actual body weight.

The next slide shows the body weights of the three Skylab crews. We show a different color for each one of the crewmen. You can see that there is an initial body weight loss. Remember that we had a heat load problem at the beginning of Skylab 2 and the motion sickness problem, too. We also had a little bit of motion sickness in one crewman on Skylab 3 flight and some mild sickness in another crewman, who actually vomited. He experienced an initial weight loss associated with his not eating and drinking properly. This has been something that we were particularly interested in seeing, namely the initial weight loss and then as the chart shows a sort of downward trend, although not as sharp with the Skylab 3 crew as on Skylab 2. In Skylab 3 there appeared to be some downward trend, for one individual, while the other two appeared to be vascillating around an in-flight weight. They eventually ended up with some weight loss at the end of the flight, but they appeared to stabilize around an in-flight weight, at least during the latter 30 days of the flight.

On Skylab 4 a different phenomenon happened which has only happened in one other individual in the manned space flight history of either our country or the USSR. We had an individual who actually regained his weight in flight! At the end of the mission, he actually was within one-fourth of a pound of what he had weighed during pre-flight. The other two individuals fluctuated. While they did not get back to their pre-flight weight, they were certainly fairly well stabilized at an in-flight weight and they increased during the latter part of the mission.

The next slide shows the actual weights and the decrement at recovery. The actual decrement in weight is in pounds compared to the other chart which depicted the percentage of their weight loss. This slide shows the actual poundage losses for each crewman, including the one I mentioned that attained a weight within one-fourth of a pound of pre-flight weight. At R plus 5 you can see the recovery that occurs initially, the very fast recovery portion due to replacement of fluid.

Caloric Intake - The crewmen had to eat to maintain weight, obviously, and the next slide is a chart that shows the caloric intake for each of the three manned flights. Again, the pre-flight baselines are shown. It takes a while for them to get an in-flight baseline established and there are individual variations. If you were to plot your own personal caloric intake, you would find variations occurring of this same sort. Caloric intake follows the same sort of curve that was shown on the previous slide depicting weight. An initial drop occurs and then the crewmen began to fluctuate around a rate that was less than their pre-flight intake. The same thing appeared on Skylab 3 although the drop from their pre-flight intake was not nearly the same. Two of the astronauts pretty well attained their pre-flight baselines. For the last crew the intake followed almost exactly the same pattern all the way across, with the exception of this initial drop in the one individual, which we mentioned previously.

Food Provisions - The next slide shows the in-flight food tray and the types of food they ate. They were provided the capability to heat the food. The drink container worked better than what we have used previously. The crewmen could compress it, and it had a valve which allowed them to eat or to drink from this container at will. The crewman didn't have to drink the contents all at once, as they had to do with the containers that were used on previous flight missions. Also, instead of just adding hot water to the food as was done during the Apollo flights, the new system allowed the heating of the food in a container. Whether the menu was the freeze dried foods used on the Apollo flights, the new types of canned food with moisture already in them, or some frozen foods, which was the best line of food for all of the crew, the new system was applicable.

The next slide depicts a picture of one of the crewmen that talked to you this morning, Dr. Garriott. Here Owen is eating in flight. If you look at the pre-flight caloric intakes and the in-flight caloric intakes, you can see that there is a tendency to increase the caloric intake with each of the succeeding flights.

Shift of Body Fluids - Now I want to make a point about shift of body fluid. This is one of the first things that the crew notices when they go into flight, and this was noted in earlier missions as well as in Skylab. There is a tendency to have a feeling of fullness of the head as if you have turned upside down, a feeling that blood has rushed to the head, such as you would experience if you were to stand on your head or hang from a parallel bar. This has been described variously by different crewmen, as they sometimes describe actual redness of the face or a standing out of the veins on the head.

If you know astronaut Pete Conrad, whose particular picture is in the next slide, you can tell that there is a definite fullness in his face compared to his appearance here on Earth. This effect has been fairly much the same for each of the individuals who has flown. For the first time in these Skylab missions we have gotten individual pictures of each of the people. We have also obtained some infrared photography which should help to look at the blood flow pattern. We now think that there is a redistribution of fluid because of the weightless state.

Heart Rate and Blood Pressure Response - One of the ways we have tried to look at the response of the total cardiovascular system to this shift of body fluids and to weightlessness is with the use of lower body negative pressure. This is achieved by a device that allows us to draw the blood into the lower part of the body. We decrease the pressure from 8 to 16, and to 30 millimeters of mercury, and then we go to 40 millimeters of mercury, and then finally to 50 millimeters of mercury. Each of these levels is held for a 5 minute period, and then there is a five minute recovery period, as there was a five minute period of baseline data just before. The chart also shows the leg volume measured with a gauge on the leg. It is a leg band that measures the increase in blood flow to the leg as you apply the pressure thereby sucking the blood down to the lower part of the body. Also shown is the heart rate and a computer plot of the actual heart rate response, the diastolic blood pressure response, and the systolic blood pressure response.

This chart is the pre-flight baseline of the science pilot from the last mission. There is not a great deal of response in blood pressure, some slight drop in systolic during the pressure phase, but not much in the way of diastolic response. Some increase in heart rate is shown, but it's very mild, something between 60 and 70.

The next chart shows an in-flight run which is not typical, but we have had a number of these occur in flight. This is an aborted run. That means that the crewman did not finish the entire run, which would have gone to twenty minutes. If he had, the period between 15 and 20 would be at minus 50. He aborted a little better than a minute before the end of that period. The chart shows the decreasing systolic pressure, the diastolic pressure dropping, and then the heart rate increasing, a drop off of the heart rate and then a very marked increase. In fact it topped out in the amount of blood that was actually sequestered in the lower limbs in the cast.

The next chart shows the number of in-flight runs on the 28-day, 59-day, and 84-day missions. In each case, the number of runs went up as the flight durations increased, with a run roughly every 3 to 4 days. Sometimes there were early terminations occurring, as shown on the chart by differences in the 28-day flight. When an individual did not make the 50 millimeters of mercury, we never ran him to that level again during the mission.

On the subsequent missions, Skylab 3 and 4, they were run to the minus 50 if they aborted a previous run. Aborted runs occurred, for instance, on three different days, on mission day 6, 20, and 46 for one crewman and on mission day 5 for another. We think there are some explanations for some of these particular aborts. In some cases fatigue was involved. In other cases, there were some heat loads involved or the run was made at the tail-end or immediately after the motion sickness period. These are some of the reasons you would expect to see some of these aborts. Some of the aborts certainly can be related to what is happening to the cardiovascular system in its adaptation to the weightless state.

In the post-flight recovery period after Skylab 2, the crewmen took some 21 to 24 days to return to their pre-flight normals. In our previous missions of shorter duration, up through 14 days in Apollo and in Gemini, we saw recoveries that usually took somewhere around 5 days, with the exception of the Apollo 15 experience which stands out as a different response than we had seen in any other flights. The post-flight recovery period was recovered 5 to 7 days after the 59-day Skylab 3 mission, and only 4 to 5 days after the 84-day Skylab 4 mission, which says generally that maybe space is good for you.

The next chart shows the resting heart rates for Skylab 2. There was a tendency to have a decreased resting heart rate, i.e., the resting heart rate decreased. That is also what we had seen in previous missions. On this next chart, it does not look as if that was the case in the

Skylab 3 mission, nor was it the case in the Skylab 4 mission.

The next chart shows the responses to the peak heart rate at 50 millimeters of mercury negative pressure for Skylab 2, 3, and 4 missions. There was a great deal of fluctuation in these Skylab 2 crewmen for that first 28-days and a fair amount of difference from pre-flight baselines. It looked as if it was sort of settling out. At least the variations were getting much less during the latter 28-days of this flight and that was certainly true for two of the individuals on this mission. If you look at the last portion of this mission, two crewmen were fairly well settled out, but we never ever did get a real settling out of the third, the science pilot. It appeared at one point we were going to, but then we observed first one peak and then another and he never did really totally settle out.

In-Flight Exercise - The next chart is just reactivity of the cardiovascular system. This is a shot inside the workshop on the first mission of the lower body negative pressure device that we've talked about, the bicycle-ergometer, and another P.W. ergometer. It illustrates the astronaut facial change characteristic mentioned earlier.

On the next chart the astronaut is spinning. This is Al Bean and he has something under his head to hold himself in position here. We have handle bars that we put on because the crewmen had trouble staying on the bike.

The next chart shows the heart rate responses to the exercise on that bicycle-ergometer, which goes 25%, 50% and 75% of the maximum oxygen uptakes. It depicts the pre-flight, the in-flight, and the post-flight baselines and basically these individuals never got outside of their pre-flight baseline responses in any of the missions. In fact, on this particular mission it looked as if they had a decreasing heart rate in spite of the fact that they were in a very good state as far as training was concerned. They were very well trained and had reached a better baseline really than the crewmen on the first mission in the pre-flight situation. Still they appeared to have a decreasing heart rate trend. That did not occur on the last mission. We didn't see the same thing. This is a look at the number of runs that were done and again you see pretty much the same sort of thing: the return to pre-flight baseline and no changes in-flight. Note they did have changes immediately in the post-flight period. They had a higher heart rate for the same work load and it took them some 21 to 24 days to return from the first flight, 5 to 7 from the second, and 4 to 5 from the third.

Cardiac Output - I just want to say a quick word to you about cardiac output. We determine this by a very indirect method, looking at the carbon dioxide measurement during the exercise period. There are a lot of calculations involved in that and a lot of assumptions that have to be made, but we did see a reduction in cardiac output immediately in the post-flight period after the first two missions and this was of some magnitude. For instance, in some cases it was a 40 or 50 percent reduction. That output returns to baseline as you can see here and in the post-flight state. But in the last mission, the reduction is much less. Its in the area and one of the individuals had very little cardiac output decrement at all. The maximum that we saw was somewhere between the 20 and 30 percent level on the last mission.

We have some comparative data from the use of an echocardiogram and that is going to be of great help to us. We have also, in looking at the cardiovascular system, been quite concerned about whether we have intrinsic myocardio defect, a defect in the muscle itself, or whether this is just a filling problem in the post-flight state. Is the lower body pooling the blood and thus having a decrease in output when it can't get it back up to the heart. It appears from the initial looks at the echocardiographic data that it is indeed a filling problem and that we have had very little decrement. Even though we get some decrease in size, the muscle mass itself does not appear to be significantly reduced. Next slide please. There was a marked increase in the amount of exercising the crewmen did with each of the missions. Actually the average amounts of exercise performed by all crewmen turned out to be not quite as high as indicated for the one individual, the pilot of the Skylab 3 mission. However, the science pilot on the third mission did have many periods where he had a higher output than this. He got up to the 8,000 to 9,000 watt minutes in a given day, but he missed some days and that pulled his average down. However, there was a marked increase in exercise in this mission compared to the other two. Whether that accounts for much of the improvement is still a moot question, but certainly we have to assume that it had a great deal to do with it. We have a lot of work to do to really pin that down yet. Next slide please. One of the things that we have measured is capped Earth, and the decrease in capped Earth from pre-flight. It went down in the first mission, still farther down in the second mission, and it looks as if it didn't go down as much in the third mission. That is similar to the other things that we mentioned previously. This is a slide that we obtained by the use of E.E.G's. With this particular cap in the sleep station in the workshop we saw some changes increasing in Stage 3 and 4 in the first mission that did not hold up in the second mission. In the third mission, it looks very much like the very first mission.

SUMMARY

Skylab has dealt us a tremendous amount of information. It's the most extensive medical program we've ever conducted in space and it's probably the most comprehensive evaluation of adapter physiology on man that has ever been conducted anywhere. The individual differences were still seen. Man has demonstrated his capability, I think, to adapt and perform very efficiently in space through these durations. It leads us to some very happy conclusions about the fact that if we can see no significant changes for this duration, we probably can predict that we won't see any real show stoppers on very long duration flights. There are changes that we certainly need to look at and there is some pertinence in these to Earth based medicine. I think the role and the function of the kidney and its response to fluid balance control is a very important thing and could have a great impact here on Earth. Our calibration of bed rest physical changes and physiologic changes is very important because many people are finding themselves placed at bed rest. We've learned a great deal in the cardiovascular area. The use of techniques with lower body negative pressure and with echocardiography are things that are going to be used in looking very hard at the fluid volume and pressure changes that go along with cardiac failure and such things as hypertension here on the surface of the Earth. We've learned a great deal about the balance organ, as Dr. Graybiel has already told you, and we've learned that we have some problems with that. We've been able to study it in a unique environment with a stresser that you can't do any other way. Like the cardiovascular system, it appears that we have some sort of governor of our red blood cell mass. All of these things have been done remotely and given us some input to remote medicine. All of our findings are going to provide the research base for many years to come, but today they leave us with an excellent prognosis for man in space flight. Thank you very much!