# THE CURRENT STATUS OF MAN'S RESPONSE TO THE SPACE ENVIRONMENT

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The purpose of this position paper is to briefly review and summarize our current knowledge of man's reaction in adapting to the space environment and his readapting to the 1g of earth following space flight. We have now completed almost 38,000 man hours of exposure to the space environment in the U.S. and U.S.S.R. flight programs. In addition, a number of hours of extravehicular experience in 0g and in the 1/6g of the moon have been obtained. We have also had men totally isolated for periods of time as they passed behind the moon during the Apollo Lunar missions. At the time of writing this review, two U.S.S.R. cosmonauts are adding to our flight exposure at the rate of 48 man hours per day.

It would take a great deal of time to totally review our painful experiences as we faced the criticism of scientific colleagues in the development of the flight programs to date. It is well, however, to remember that space flight thus far has been indeed an experimental program. Much of the medical information gained on early flights was obtained in an environment which was heavily engineering oriented in order to get man safely into the environment and back. It required a great deal of faith in man's capability on the part of the space medical community in order to commit him with the collection of only minimal data with which to make predictions. If one compared the time frame of the development in duration of exposure of aviation and of space flight, you can not help but be impressed with the very rapid progress made in the field of space flight in contrast to the much slower progress in aviation. There is much that could be recounted concerning the dire predictions that were made, the validity of only a few and finally the flight proof that many were erroneous. There are many references that are pertinent in summarizing the data and they are appended to the paper.

One might summarize in a few sentences the current status of man's responses as follows: With short or long durations up to 84 days, while there has been some individual variability, man has always been able to perform his inflight task and to suffer no permanent physiological change postflight but only time limited readaptational changes, if we supply an adequate atmosphere, adequate food and hygiene facilities, adequate exercise and adequate workload planning and rest, adequate time to acclimatize or adapt and adequate countermeasures where warranted. It is important to remember these ifs, for the development of future flight programs can easily fall into the trap of taking a cavalier attitude concerning them. Man has shown himself able to adapt over a period of days to weeks inflight to even discomforting physiologic changes, such as vestibular abnormality with motion sickness. He has further shown himself able to readapt through a series of physiologic changes on the return to earth. Time phasing of these adaptations is of considerable interest and as one would expect, varies with individuals. It appears that there is a general adaptation that starts within the first hours of space flight and some of the body's systems have adapted or at least acclimatized within a matter of hours. The vestibular responses have all shown adaptation within a period of one week and if we look at overall body systems it appears the major shifts occur within a week period and that certainly within the 60 days period inflight most of the lability of system response has leveled out. The postflight time to readapt to 1g has in fact seemed to decrease with increasing flight duration - 24 days for a 28 day flight and 5-7 days for 59 and 4-5 days for 84 day flights. It will be a continuing interesting exercise, as man is exposed further, to detail the individual system adaptations by time with careful checking of each of these systems.

For purposes of brevity but in order to provide a point for discussion, I will outline the principle facts observed in the systems most affected by space flight and list those systems having shown little effect or change by the measures used thus far. We will then address the present view concerning the need for various countermeasures for the effects and the predictions concerning very long duration flight. We shall then try to outline some of the gaps in the data and to conjecture as to how they may be filled.

Histories taken from our astronauts and cosmonauts have revealed a general sense of enjoyment and well-being in the weightless state. To be sure there are sensations of fullness in the head and occasional motion sickness symptomatology associated with the freedom of movement and ease of activity in this peculiar environment where up and down is related only to the placement of objects within the spacecraft.

The first system to evidence physiologicl change has continued to do so throughout the duration of any flight to date and that is the cardiovascular system. We early noted orthostatic-hypotension in the immediate postflight state and this has been investigated throughout the 84 day flight duration. This was evidenced further in decreased exercise capacity on the bicycle ergometer postflight coupled with a marked decrease in cardiac output. This is understandable when related to the pooling of blood in the lower extremities which would occur on return to 1g and was shown in postflight studies on the 84 day flight were echo-cardiography coupled with lower body negative pressure demonstrated that we were observing changes due to blood volume and not due to inherent defect of the myocardium. All of the cardiac electrical activity, measured in detail by vectorcardiography, was not significantly altered. There have been minimal episodes of cardiac arrhythmia noted with the slowing of rate in Apollo and a single episode during exercise in Skylab.

In the hematology area we have observed a loss of red cell mass. The mean losses as observed postflight were 9.4%, with individuals as high 15, 8.6% and 5.9% respectively for the 28, 59 and 84 day missions. It appears that there is a suppression of red cell production but that it is governed in some way limiting this suppressive effect so that it does not tend to increase with increasing flight duration. In addition there appears to be a replacement curve developing which tends to return the red cell mass toward the normal level. This is an interesting and fascinating finding deserving further evaluation.

In the neurological area the most important positive finding involved the development of motion sickness early in flight by four of nine Skylab crewmen. This had been observed earlier in our Program in a number of Apollo astronauts, probably more than have been reported and in a number of U.S.S.R. cosmonauts. In spite of predictions about who would develop this condition, which appeared to work just the reverse of the prediction, and of the determinations of threshold tolerance to head movements which was evaluated in the preflight condition, several Skylab astronauts did develop stomach awareness and in some cases frank vomiting in the early inflight period. This did respond to oral medication and adaptation did occur as shown by the capability of the crewmen within seven to ten days inflight to develop a marked increase in their tolerance to head movements and rotation compared to their preflight baseline. It became virtually impossible to create any symptoms in these individuals at the maximum number of rotations and head movements during the adaptive period inflight. On return to 1g the crewmen had some obvious vestibular disturbance evidenced by abnormal gait and a sensation of vertigo which lasted for several days postflight. The threshold tolerance to motion sickness on head movements with rotation also gradually decreased to the preflight baseline.

An immediate postflight hyper-reflexia was noted in the Skylab crewman, and this was quantitated in the postflight study.

In the musculo-skeletal area, we have seen moderate losses of calcium, phosphorous and nitrogen throughout the flight duration. The data of these detailed balanced studies indicate that the losses are comparable to those observed in bedrest studies and that the trend is continuing with the increased duration noted to date. There has been a relatively low but measurable mineral loss also from the os calcis. The rate of loss would appear to be some 6 grams of calcium per month for roughly 0.5 percent of total body calcium per month. The loss in bone density of the os calcis appears to be predictable based upon initial bone mineral content and hydroxyproline levels.

In the area of fluid and electrolytes determined through the numerous biochemical observations taken before, during and following flight, it is clear from the Skylab data that there are changes showing an increase in Aldosterone secretion, increased sodium and potassium excretion, increases in osmolality and an increase in circulating cortisol levels. These changes are consistent in many ways with the hypothesis which we advanced prior to the Skylab series relating to an increase in thoracic blood volume in the weightless state acting upon stress receptors in the walls of the great vessels and in the atria. This apparent expansion in blood volume produces a loss of water and electrolytes, particularly of sodium. A reduction in blood volume follows, and there is increased secretion of renin and aldosterone leading to establishment of a new fluid and electroltye balance proper to the 0g situation. There are some conflicting data points in that there has been some reduction in antidiuretic hormones and in some instances increase in antidiuretic hormones. At the same time, potassium excretion levels have been elevated, as have sodium, in spite of the markedly elevated aldosterone levels. The evidence of stress on the crewmen is the increased cortisol levels. These changes in biochemical fluid and electrolyte balance have been shown to be well tolerated for the durations of flight thus far undertaken.

While much has been stated concerning the physiologic changes little has been stated concerning any psychological findings with space crews. This is a repeated question from the public and one we must address in view of the public utterances of some of our astronauts. The data are quite clear that there were no dire effects upon performance, that is, problems of isolation, "break off", boredom, etc. The crews were originally selected with strong psyches, good self images and both great achievement needs and accomplishments. There was some evidence of the development of body consciousness during portions of the Skylab flight but certainly never to any abnormal degree.

Most of the questions center around the Apollo astronauts who visited the moon and then did varying activities which appeared out of context with the public's perception of these individuals prior to flight. In one instance there was a reactive depression that was related to demands by the public for public appearances and the individual's perception that the public had reacted only in a minor way to an accomplishment felt to be of great magnitude. In two other well known instances, one individual has concentrated his life on religious pursuits and others have followed in his footsteps. Another has devoted himself to the study of psychic phenomena and para-psychology and it is important in both of these instances to know that these individuals had these interests preflight. I am sure that everyone can appreciate the fact that no individual who was able to leave earth orbit and go to the moon, thus seeing our planet in an entirely different context could possibly remain unaffected by the experience. Those of us who were closely associated with the activity also were affected. All of us developed a much deeper concern about the planet Earth, about mankind, the space crew on it, and what could best be done to assure its future. I think many of the activities in which the crew have engaged have been in this context.

We have tried to summarize the positive findings and still the most remarkable thing about our long duration spaceflight data is the amount of negative data or information which would show that there has been no adverse change in the remaining body systems. In view of the great deal of concern about man's capability to perform in this environment, these data are probably the most valuable ever gleaned concerning man's future. We have seen that man who has been well trained for the mission has been able to enter the space environment, undergo an adaptational period, which is certainly acute for at least a week, shows marked stabilization within a 30-day period and then shows a recovery to the preflight baseline on readaptation to 1g. The recovery has taken a progressively shorter time period with increasing flight durations, the 28-day flight taking some 24 days and the longer 59 and 84 day flight taking less than seven to return to these preflight baselines. This could lead one to the conclusion that indeed long term space flight is good for you. Obviously, however, the above findings must be considered and particularly those involving loss of calcium and nitrogen where we have not seen a stabilization as yet.

In attempting to plot the onset and duration of symptoms and findings in each of the body systems, their treatment and their prevention we must consider countermeasures which might be used.

Cardiovascular

The cardiovascular responses do return to normal at a faster rate or in a shorter time period with increasing durations of flight. This more rapid return to baseline may have been aided also by the amount of exercise done inflight. Still, as we look at long duration space flight we must consider the possibility of changing from the crutch which we and our Russian colleagues have both used, a positive pressure garment on the lower extremities, and develop a true countermeasure. Lower body negative pressure inflight, at least for several days prior to return to 1g, offers the possibility of a true countermeasure. Further research is needed.

Blood

The red blood cell mass, as we have stated, did not continue to increase in amount but appeared to be self-governed. It thus appears that there is no need for a countermeasure in this area; however, we certainly need to understand the mechanisms involved.

Vestibular

The vestibular system or motion sickness countermeasures are really unknown at the moment. Here too, we have utilized a crutch in the form of medication, a combination of scopolamine and dexedrine. It appears that selection, which has thus far been notoriously poor in this area, and perhaps training procedures, offer the only true countermeasures. Certainly, detailed investigation into the mechanism of production of these symptoms would be most beneficial as we look at prevention. One area which bears further research is the effect of shifts in blood volume which we know occur.

Musculoskeletal

Many methods of trying to produce pressure upon the skeleton and varying exercise loads have been used to attempt to alleviate progressive calcium loss. None of these have been effective to date. The countermeasure which has the greatest potential from bedrest studies thus far appears to be oral intake of a combination of calcium and phosphorous. It needs to be further studied on long-term bedrest subjects.

Biochemical

There are no biochemcial effects noted wich do not seem to be adaptive changes of some degree. It is important to remember as we look at any countermeasure or attempt to develop one that we must not do anything which would interfere with the body's capability to adapt and, thus, do harm rather than good. This is particularly apt admonition as we consider the biochemical area, and therefore, there are no counter-measures recommended here.

<u>Psychological</u>

Certainly it appears at the moment, that private contact with those on the ground is of import to every individual inflight. Careful attention to work-rest cycles, the physical amenities of habitability and the careful following of the air-to-ground communciations should be of immeasurable help as countermeasures in this area.

The big question then, in the light of the data obtained to date, is <u>can</u> man successfully accomplish a two-year flight of the duration envisioned for a Mars mission? I would like to answer that in the affirmative, based upon data that we have seen to date. If the body continues to peform as the bulk of its systems have, perhaps there is even some regulation that will control the calcium loss. If not, then we certainly must have the countermeasures available to provide the needed protection. I think we are capable of developing these and that we can support man in such an endeavor.

All of the above brave statements do not mean that there are not gaps in our data as we look at man in very long duration flight, and certainly, further research is needed. I still feel as I have expressed on several occasions previously, that we need to procure data on man inflight for a six-month period prior to committing him to a two-year Mars mission. I also feel that research should be directed toward the elucidation of mechanisms of the changes, particularly during the first week of space flight when so many of the changes resulting in acclimatization and adaptation are occuring. Short flights could be used for this purpose if the individuals were properly instrumented and monitored. As we look for mechanisms and detailed information on changes, we are in need of data obtained only by invasive procedures that will require the use of animals. Animals used in conjunction with man in the same conditions would be extremely valuable in answering some of these open questions. I would call your attention to an October 1973, article in Aerospace Medicine, entitled "View of Human Problems to be Addressed for Long Duration Spaceflight", wherein habitability and psychological fitness were addressed as problems of import for the future, as well as the particular system effects previously discussed.

In the cardiovascular area we need to do indepth, noninvasive cardiovascular dynamic monitoring and we need more data to support our observation that there is no direct myocardial effect at the cellular level. Again, we should do invasive studies related to pressure, volume and flow, particularly in the first week of flight with animals. We still have to demonstrate the role or lack of a role for the Gauer-Henry reflex in the onset of the fluid shifts which occur on exposure to 0g. We need to develop a total exercise regimen to maintain all muscle groups. We also need to determine the role of the capacitance of veins in the deconditioning process.

In the musculoskeletal area, we need to further evaluate exact changes in loss of bone mass and muscle mass in animals. As has been noted, further efforts to develop proper countermeasures must be undertaken and we should give consideration to the use of Vogel's prediction formula related to bone density and hydroxyproline levels in the selection for crewmen for long duration flights.

In summary, man has shown himself capable of adapting in specific time frames to space flight and maintaining effective performance levels for 84 days. He has also shown himself capable to readapting himself to the 1g environment with the physiologic variables returning to the preflight baseline in four to five days following an 84 day flight with high exercise levels while it took 21 to 24 days to return to these same preflight levels following a 28-day flight, and five to seven days following a 59 day flight. Certainly we must control development of motion sickness in order to maintain productive crewmen during the initial five to seven days of adaptation and this should be done by a true countermeasure rather than a crutch such as medication. We also must find a true countermeasure for the calicum loss which appears to be progressive at the present time through 84 days of space flight and if it follows bedrest curves as it is currently doing, would continue to be progressive. I think man is capable of conducting a very long duration space flight if we give him the proper support as mentioned above and provide countermeasures where needed. We should diligently plan to obtain the data to allow us to make an early committment of man to continue his greatest adventure and to open and further develop the new frontiers provided by space.