MAN, SPACEFLIGHT, AND MEDICINE

by
Charles A. Berry, M.D.
Director of Medical Research and Operations
NASA Manned Spacecraft Center
Houston, Texas

Spaceflight is one of man's current and few remaining frontiers. This is particularly true of aerospace medicine where the excitement and the challenge of the unknown daily lead us to new observations about man and his ability to perform in and adapt to the peculiar, weightless world of space.

Prior to man's first flight in space his expected response was best represented as a huge question mark. Indeed good scientists projected their ground based knowledge of man's physiology into the space environment and predicted many dire effects. (See table 1). Today some of these may look strange but they were serious concerns at the time, with some scientists even predicting man's demise on lift off. Oddly enough, today man is again being assailed as the weak link in manned spaceflight and unmanned efforts are being advocated in preference. Thus, the obtaining of objective data to prove that men's body-systems' performance is adequate is vital as we look at longer duration flight. I personally am very optimistic in this regard.

Man is made up of subsystems just like a spacecraft is, but instead of an environmental control system, guidance system, or waste management system, etc., we have respiratory, cardiovascular, endocrine, nervous, genitourinary, gastrointestinal systems, etc. Nor are we as fortunate as our engineering counterparts for they can select "hi rel" (high reliability screened) parts from known vendors, build the system to their specifications, test it to destruction and get a mean time to failure.

(In print) American Institute of Aeronautics and Astronautics (AIAA) Student Journal, New York, New York. To be published in February, 1972, issue.

We cannot even select the vendors much less the parts. We had no input to the specifications and the determination of mean time to failure is complex and out of the question. Nevertheless, certain important answers concerning man have been obtained from our flight experience.

MERCURY

In the Mercury Program, where the U. S. first exposed crewmen to the space environment, we were able to do a significant number of biomedical investigations, including clinical and laboratory evaluations with special studies of the catechol and steroid response to stress, some evaluations of the function of the digestive system by the use of a xylose absorption test, a number of preflight and inflight psychomotor tests and some safety monitoring. Even with these minimal studies, we were able to show that man could not only survive launch and activity in the space environment, but he could perform admirably. As a result of this performance, future programs and even the later Mercury flights were modified to take advantage of man's capability. The results also showed that such vital functions as blood pressure, pulse rate, digestion, and excretion responded normally. The effects of space flight stress appeared tolerable as measured by the hormone responses and no psychomotor impairment was observed. The first indication of physiologic adjustment measureable on the return to earth was noted in the latter two Mercury flights when a condition known as orthostatic hypotension was noted following the flights. This condition is characterized by an increase in pulse rate and a decrease in blood pressure when one assumes the upright position. It was quantitated by using a tilt table to expose the crewmen to a 70° passive tilt for a period of 15 minutes. This response has come to be known as cardioyascular deconditioning, due to the fact that the heart and blood vessels comprising the cardiovascular system do indeed seem to be "deconditioned" in relation to the 1g earth environment requirements for their function. Actually, studies and later programs have led us to the belief that these changes are adaptive changes by which the body systems render themselves more efficient in a zero g environment and in that sense they are not an adverse adjustment. The adjustment appears adverse only when the crewman returns to the 1g environment on earth and must readapt.

GEMINI

The one-man Mercury missions were followed by the two-man Gemini series during which some inflight evaluations of the cardiovascular changes first noted in Mercury were carried out on the three long-duration flights, 4, 8, and 14 days in duration. Four of the medical experiments were aimed at determining the magnitude of the cardiovascular decrement. These included the use of blood pressure cuffs on the extremities which were inflated in a rhythmic fashion to interfere with blood return to the heart from the lower extremities. The tilt table evaluations were repeated pre and postflight. Inflight measurements included a phonocardiogram or record of heart sounds in addition to the normal electrocardiogram and the heart's response to a given exercise load using a bungee was determined. The response of the body's biochemical systems to the spaceflight stress was evaluated in both blood and urine and a very detailed calcium and nitrogen balance study was conducted to determine whether the body had indeed lost any of these substances as a result of the exposure to the weightless environment. This study was complimented by x-ray densitometry to determine the loss of bone density in the heel and small finger. An electroencephalogram was used inflight for the first time to record the levels of sleep during the first two days of the 14 day mission. Some early investigations were also carried out relating to the otolith portion of the inner ear. The results of these studies confirmed that we did have some moderate cardiovascular deconditioning, or preferrably cardiovascular adaptation to 0g evidenced by orthostatic hypotension on return to earth. Regardless of flight duration the longest period these effects lasted was some 50 hours postflight. We also observed some moderate loss of exercise capacity measured by response to a given exercise load with a bicycle ergometer. The x-ray densitometry confirmed that there was some minimal loss of bone density and the detailed calcium and nitrogen balance study confirmed some minimal loss of calcium and muscle nitrogen. There were moderate body weight losses noted on each of the postflight examinations and the EEG (electroencephalogram) and the crew's and medical monitor's operational reports revealed some interference with adequate sleep. Two unexpected findings occurred. One resulted from our extravehicular activity where we observed very high metabolic expenditures resulting in elevated heart rates and body overheating due to the workloads imposed. The other unexpected finding was the loss of 20% of the red blood cell mass. A review of these findings left us with the assurance that we would be able to safely send man on the proposed lunar missions for none were expected to be as long as the 14-day Gemini flight.

APOLLO

We then planned a series of investigations during the Apollo program, involving three men on a crew, to determine whether these results were indeed due to weightlessness or whether confinement in the very small spacecraft was a large factor in their production. Program pressures required some reevaluation of our plans and all of the measurements in Apollo have been pre- and postflight. We found that in spite of the freedom to move about and to exercise in the Apollo spacecraft in contrast to Gemini and Mercury, the Gemini results were generally confirmed. We again noted cardiovascular adaptational changes to 0g and a reduced exercise tolerance of virtually the same degree noted in the Gemini program. The minimal loss of bone density was also confirmed. We were able to show with both flight results and a ground-based chamber study that the loss of red cell mass was apparently due to our 100% oxygen environment and that it could be prevented by very minimal amounts of nitrogen being present in the cabin atmosphere. As our methods became more sophisticated, we were able to look at mineral and hormonal values and to show that there was some altered fluid balance postflight. For the first time in the flight program, we encountered inflight illness of an infectious nature, the first being a viral upper respiratory infection, much like the common cold. In the Apollo series, we have had a number of preflight, inflight, and postflight illnesses, all of which have been related to ground exposure and resulted in an expanded crew preflight preventive medicine program. We also noted inflight motion sickness for the first time in our flight program in contrast to the Russian experience. This has occurred in a few crewmen and we have been unable to predict this occurrence from baseline information available on the crews preflight. In every instance, the crewmen have adapted to the altered vestibular responses in weightlessness and the longest duration of symptoms has been 5 days. In the large majority of instances, it has lasted only a matter of a few hours before adaptation occurred. The necessity to conduct a postflight quarantine caused us to develop an excellent program of preflight and postflight sampling of the crew microflora (bacteria, viruses, etc.). Results of these studies indicate some simplification of the microflora and some overgrowth of particular organisms as a response to living in the isolated environment of the spacecraft. On the Apollo 14 mission, we have seen the first indication that exercise and residence in the 1/6g condition of the lunar surface may have had a beneficial effect on the physiological decrements which we have discussed. The two crewmen who spent time on the lunar surface did not exhibit evidence of cardiovascular adaptational changes to 0g nor loss of their exercise tolerance, whereas the crewman who spent all of his time in 0g did exhibit changes of the magnitude expected from previous flights. This is a single data point and may be complicated by some differences in caloric and fluid intakes and further study will be required on the remaining Apollo missions before we are able to make a positive statement. Our findings to date have allowed us to develop a working hypothesis concerning the effects of zero gravity on man. This hypothesis is illustrated in Figure ________. Weightlessness as a stressor of the flight environment has produced effects on the nervous system, the bones and muscles, the fluid, electrolyte and endocrine system, and the cardiovascular system. One of the first effects noted by the crew on achieving the weightlessness condition is a feeling of fullness in the head which we feel is due to a redistribution of the weightless column of blood allowing a greater amount to be above the heart level than is present in the 1g condition. This increased amount of blood returned to the right heart increases the pressure in the right atrium and initiates a reflex stimulus to the pituitary gland calling for a reduction in the secretion of antidiuretic hormone and thus an increased excretion of urine occurs. This provides a new blood volume level compatible with and more efficient in a zero g environment. As the increased urine flow occurs, the adrenal is stimulated to increase the level of aldosterone, another of the body's hormones, which allows the kidney to retain sodium ion but there is no system that retains potassium. The lack of a gravity vector leads to some decrease in calcium, magnesium, potassium, chloride, nitrogen, and phosphorus in the bones and muscles resulting in a decrease in bone density and muscle mass. These interrelations may be followed more carefully in Figure ____. There are definite changes in body fluids as a part of the adjustment to zero g and the readjustment to function in 1g. Post-flight studies have shown a decrease in total body water and the major portion of this decrease has occurred in the intercellular fluid compartment. The body weight losses noted postflight are mainly due to this fluid decrease. The human has ample ability to aid these readjustments by proper food, fluid and electrolyte intake. Once the magnitude of these changes is determined, some additional countermeasures may be necessary, but certainly to date the physiological adjustments noted have not compromised crew ability to perform demanding flight missions.

The findings on our flight program to date have also indicated the wisdom in our observing changes in body systems and thus focusing our future flight experiments on those systems where change has been observed. It might seem logical from a scientific point of view to do a detailed survey of each of the body systems, but you can readily realize that this would be both time consuming and expensive with a resulting delay in obtaining the answers necessary for us to carefully evaluate man's capability to perform for long periods in the weightless environment. As a result of our current plan, we have developed a series of inflight experiments to be flown on the Skylab, for missions of 28 and 56-day durations, which allow us for the first time to measure the physiologic response of the involved boyd systems while in the weightless environment and not just pre- and postflight. This focus on the involved systems should allow us to delineate and quantitate the physiologic adoption of the body to the stresses of spaceflight and plan for man's involvement in long duration flight.

These medical findings are interesting and have obvious implications to man's future activity in the space environment. The question raised frequently, however, is what about the mortals who will live their lives on the surface of this planet Earth? Is there any benefit which will accrue to them as a result of man's efforts to explore the space frontier? The space medicine requirements which were necessary for assuring man's safe journey into and return from space have resulted in hardware and techniques of great value to terrestrial medicine. These applications may be viewed in the light of the original requirements.

The initial requirement is the selection of a crew capable of performing the mission required without undue physiologic or psychologic effect. This led to observations on the effect of motivation on performance and adaptation and emphasis on the fact that the human machine is enormously capable of taking punishment and of adapting to new and demanding environments. The selection process also demonstrated the value of dynamic testing by such methods as bicycle ergometry vs. the use of purely static examinations of the individual the examiner wishes to perform at peak level in stressful situations. Another useful technique was a combination of background and psychologic and psychiatric information in order to arrive at the best evaluation position concerning the individual's capabilities. These techniques are obviously applicable to terrestrial medicine wherever there is a need to select people for particularly demanding tasks. They are also of value in predicting performance of these individuals.

Once selected, retention of the crewmen on flying status becomes of great importance because of the large amount of money invested in the training of such an individual. A technique of evaluating the medical deficit of any crewman on an individual basis and making every effort to assure that we keep people flying has had some far-reaching effects on our evaluation of flyers for both civilian and military tasks.

Once selected and retained, there is a need to provide an artificial environment to insure the health of the crewman in hostile space. The resulting hardware has been a series of environmental control systems--space suits, a water-cooled undergarment, water and waste systems, etc. The terrestrial application of these items, ranges from the use of the space suit helmet for pulmonary function testing of children, the water-cooled undergarment for cooling of firemen, race car drivers, etc. to the reclamation of urine and purification of contaminated or potable water supplies for use of our terrestrial environment.

The need to monitor the physiologic function of our crewmen at distances of 240,000 miles while they were working led to the development of miniaturized, non-irritating and highly reliable sensors for such items as electrocardiograms, respiration, phonocardiogram, blood pressure, electroencephalogram and temperature. Once the data is obtained, it is necessary to transmit it to earth. The development of such instrumentation led to a massive effort to create,miniaturize, and make reliable many types of bioinstrumentation which had not previously existed. In fact, this requirement has caused the development of many items which are not yet being flown in space but have excellent medical uses on the ground, such as the endo-radio-sound for gastric PH etc. Spray-on sensors have been developed for use in ambulances to allow the telemetering of electrocardiogram back to an emergency room. The use of our sensors in cardiovascular and intensive care units has become widespread. The ability to monitor individuals at work and to telemeter the data to a central site for immediate viewing or for storage and review or even for recording on tape and later review can place many of our medical decisions on a much firmer scientific basis. Answers to questions concerning the level of hypertension on an individual while he does a particular task and the effect of hypertensive drugs on the elevated blood pressure are possible through use of these techniques. The salient question in a post coronary patient is what level of work he should be allowed to do. This can be determined on a direct physiological basis by monitoring the electrogram while the individual participates in his daily work activity. These techniques also offer the capability for remote telephone or television diagnosis in many areas of our own country and of the world where medicine care is in short supply.

As soon as we were able to instrument man in such a way that data could be obtained from these great distances, hugh masses of normal data were obtained by constant monitoring on the long-duration flights. This immediately led to the necessity to develop systems which would allow computer interpretation and tabulation of ECG, EEG, and other such data. These techniques are rapidly being put into use in many medical centers about the country and indeed in central repositories where individual practitioners may be connected by telephone. The large amount of data obtained and analyzed has led to a computer stored data base on "normal" individuals which is probably unequalled anywhere. This normal data base may be utilized to better define the ranges of normality and also by its continued manipulation through our automatic handling systems we may be able to find new ways to apply results of several evaluations to terrestrial medical problems. Our entire data system has been based upon the use of minicomputers in the local laboratory area and then connecting these to a larger central computer system for storage and dump of the material for the data base.

As we plan to expose man to longer and longer periods of weightlessness we develop the requirement to predict the body system effects and to evaluate body system function in zero g. This calls for the development of many new laboratory techniques and pieces of laboratory hardware.

As each of our crewmen is used as his own control in determining the effects of spaceflight, it is essential that we know as much as possible about his "normal state". Each crewman has a large battery of clinical laboratory determinations made annually and then depending on his participation in either flight or test activity, he may have this same series repeated at more frequent intervals. This has produced a large volume of laboratory information defining the "normal" for each of these individuals, and in the process providing a great deal of information concerning the definition of normality. The computer is used widely in this operation. There are circadian or time of day variations in most of the body's activities and these are reflected in the values of laboratory determinations made at various times. Whereas, the variation in these values obtained at different times might not be of critical clinical significance in ill patients, it is of great importance to us as we try and determine the effects of space flight on man. In trying to better define these circadian differences and rhythms--their importance to clinical laboratory determinations may be better defined.

It has become very obvious that there can be values which indicate significant alterations of body functions and still these values may be within the usually denoted normal limits. Curves plotting the values for such parameters as blood sugar, white blood cell count, etc., have proven of great value to us indetermining preflight or postflight aberrations of physiological function in our crews. There is an increasing need for rapid answers to the various tests which the physician might request. We have automated our laboratory and tied it to the computer. This has made it possible to do large numbers of blood and urine tests in a very economical manner. It is our intent at all times to use non-invasive techniques if possible for any determination, and we are constantly pushing the state-of-the-art and trying to create technological advances in such techniques which will give us more detailed information concerning body functions. At present, we continue to use less and less blood to get more and more information. At the same time, we are carefully evaluating such bloodless techniques as the use of hair, nails, breath and saliva for obtaining information previously obtainable only through blood samples.

In a further attempt to reduce the number of procedures necessary, we have been developing hemato-logic and immunologic and clinical biochemical screening procedures which emphasize mathematical interractions between laboratory variables thereby minimizing the required analytical procedures without sacrificing any informational content. Some 47 laboratory tests were run on 100 individuals. A computer matrix was created with these 47 variables and it was possible to note that 20 of these gave the bulk of the information obtained and that this list could be further optimized in such a way that 8 tests could provide 85% of the data produced by the 47 laboratory determinations. The tests were selected to obtain information on hydration status, humoral immunity, lipid metabolism, blood cell function, adrenal cortical function, liver status and tissue damages. These techniques are being further refined so that our laboratory may be programmed to automatically run a particular battery of laboratory determinations concerning a certain body area such as the liver, should an indicator test prove to be out of normal limits. In fact, automatic programming of additional laboratory determinations would preclude the necessity for patients to return for further laboratory work and also would reduce or preclude additional time delay in providing the patient with an answer as to his condition.

The need to assess the reactions to spaceflight of the cardiovascular cardiopulmonary and musculoskeletal systems has led to a development of particular laboratory equipment which has been automated to a great extent. Some of this equipment has been further miniaturized and developed to the point that it may be utilized inflight in the Skylab Program.

The lower body negative pressure device which sucks the blood into the lower portion of the body requiring the heart and blood vessels to respond to create more normal blood return to the heart is one of these devices. The electrocardiogram, heart rate and blood pressure are taken at very rapid intervals and an automatic blood pressure device has been necessary. This device has been pushing the state-of-the-art development and it now appears that we do have a most accurate piece of hardware which will have great value in the care of surgical patients, in intensive care wards, hypertensive evaluation, etc.

The bicycle ergometer has also been automated to allow a plateauing of workload at a given heart rate--in our case 120, 140, and 160, and we have combined additional pieces of hardware allowing us to determine respiratory flows and cardiac output during such procedures. Both of these devices are dynamic testing gear which allows an evaluation of total body response to a given stress.

The need to determine the metabolic loads of certian activities inflight has led to a development of a metabolic analyzer which will replace the commonly used Douglas bags and such other space consuming equipment in ground based laboratories.

In an effort to evaluate central nervous system function, in particular sleep inflight, a cap with new sponge electrodes has been developed. These will obtain an EEG of excellent quality without any particular preparation of the scalp. This system has also been connected tp a sleep analyzer which will scan the EEG tracing and printout digitally the amount of time spent in level 1, 2, 3, or 4 or REM sleep. This device has great value in drug evaluations and for the use of anesthetists in surgical procedures. It also can be used in treating insominiacs and others experiencing sleep neuroses. Several of the devices have been made available to civilian hospitals such as the Veterans Hospital in Oklahoma City, the Medical Branch of the University of Texas at Galveston, and the University of South Carolina Medical School. The electrode system allows us to obtain electroencencephalogram and an electro-oculogram, to better define the levels and quality of sleep.

Bedrest and water immersion have both been utilized extensively as 1 g analogs of the physiologic effects of weightlessness. They are not true analogs, but they do produce some of the same type, but not magnitude, of physiologic changes observed following exposure to the weightless environment. Bedrest has been utilized by physicians as a time honored method of therapy since the beginning of the practice of medicine. In spite of this long usage, there has not been adequate knowledge concerning the effects of bedrest, both detrimental and beenficial, to the patient's condition. Our need touse this analog to better predict possible effects of the weightless environment has led to much better definition of changes in calcium balance, musculoskeletal integrity, blood colume changes, and the effect of exercise and various other countermeasures in preventing these physiologic decrements. This has great importance to the many patients in whom bedrest will be used as a means of therapy.

While evaluating the effect of spaceflight on the blood, we noted decrease in red blood cells. In studyingthe possible cause of this decrease in red cell mass, particular studies were made of the red blood cell membrane and much has been learned about its function and chemistry which will be of value in the study of various anemias. The electron microprobe which is principally a physical scientist' tool has also been used in determining the location of various elements in the red blood cell. In separating red and white cells, it was noted that neoplastic white cells had high levels of titanium and zinc whereas the normal cells did not. This finding has been noted research and passed on to a number of the large centers conducting research in cancer and other neoplastic diseases. Our flight results have also indicated that nitrogen even in small amounts appears to protect the red blood cell from the lysis occurring in the oxygen environment and this may indicate some basic physiologic effect yet to be elucidated.

In providing food for our crews inflight, we have had to develop a number of methods of preservation and packaging which would allow us to assure both palaitable and safe foods. Such development has lead to specific items such as a rice product which has been freeze dried through two cycles and can thus be made quite edible by the addition of plain tap water; no boiling required. Products such as this will undoubtedly find their way into normal use on the ground. We have found it necessary to conduct a great deal of research in determining basic nutritional needs also such as the levels of protein required and their relationship to such factors as calcium mobilization. All of this information is directly applicable to patients here on earth.

The possibility always exists that our crews will need treatment for some particular condition in flight. Great thought has been given to possible illnesses which might be encountered and we have made attempts to provide medication to care for these difficulties. Motion sickness was one of the early conditions considered in the weightlessness environment and it has been seen on a few occasions in our flights. In preparing for this eventuality, studies were conducted on the effectivity of various medications for the prevention and cure of motion sickness. A very effective dexedrine/scopolamine combination has been developed and this obviously has wide use both in medicine and for such groups as fishermen, aircraft travelers, and boaters. The possible need for a crewman to obtain medication for pain or motion sickness by injection led to the development of an automatic syringe which fires and injects a material merely by a touch of the base of the syringe to the body. This has great application in patients who may have emergency need for medication and not be at a medical center.

The increasing duration of flight has led to the development of more miniaturized equipment for diagnosis, and therapy as well as for the experimental investigations mentioned previously. We have in development an integrated medical behavorial laboratory system which utilizes a number of advanced techniques making it possible for a single individual to diagnosis, treat, and conduct medical evaluations inflight and these systems may be used through ground direction or with the use of a physician onboard. Many of these laboratory and diagnostic techniques and devices could be utilized by mobile physicians on the ground.

In order to maintain the health of the crew before during and postflight, a number of procedures have been developed which have import to terrestrial medicine. As soon as it was evident that we had the capability to extend man's time in space past one week period we became concerned about the possibility of him developing an illness in flight to which he had been exposed in the preflight period. Our first experience with preflight illness altering the course of a mission occurred in the Apollo program and we very early experienced preflight, inflight,and postflight illness. We immediately developed a very comprehensive preventive medicine program whose aim was to stabilize the health of the crew and to maintain a health screen around them during a 21 day period preflight in order to limit the number of possible disease contacts. This modified isolation program has produced some very interesting epidemiologic information relating to illnesses which might be trivial on the ground. The careful following of primary contacts and their families has given evidence of the risk of the spread of many of the common ground upper respiratory and gastrointestinal viral diseases from one family member to another. This information can be directly applied to ground based epidemiology and disease prevention.

A small percentage of every blood sample drawn is perserved in our serum bank so that we may go back and check historically on either immunity levels or any other parameter involving a particular astronaut. This has proven to be an invaluable aid in such instances as the development of rubella in a backup crewman on Apollo 13. The value of such a serum bank and the epidemiologic investigation of disease is inestimable. Another instance of the value of our baseline data involved the finding of an 8000 white blood cell count on a crewman 5 days before the launch of Apollo 9. In a few hours, it was determined that the distribution of his cells was abnormal, showing a shift to the lymphocytic series and some 8 hours later he had the symptoms and findings of an upper respiratory infection of viral origin. The 8000 white blood cell count is certainly within normal limits but for this individual whose normal was known to us as 4000, this was doubling of his white blood cell count. This has led to the development of a program looking further into the role of the lymphocyte as an early detector of disease. We have initiated studies of mice,inoculating them with various microbiologic agents.

We then studied the urine and the serum for specific antibodies, trace metals and amino acids, examined the tissues, and in particular looked at the lymphocytes with some of the new methods utilized in our laboratory. We have found that it is possible to use the microspectrophotometer and to actually quantitate the RNA and DNA in various portions of the lymphocyte. Indeed by this method one can draw a contour map of the lymphocyte as shown in Figure________. We have also been looking at the uptakes of radioactive thymidine and uridine. These are related to the DNA and RNA levels and these methods demonstrate some changes in ratios and distribution related to evidence of infection. Such methods for the early detection of disease obviously can have great import as we look at individuals doing specific jobs where their presence is required. The ability to detect the disease before symptoms have been exhibited can be a powerful tool in this regard.

The preventive medicine program which is in operation for our crews' alters their risk of disease not just in the pre-flight period but during their entire career. The compilation of such disease information in a control population can prove of value as we adopt more and more preventive medicine programs in the population at large. In space medicine we look upon the development of a disease in one of our crewmen, even though it be infectious as a preventive medicine failure and efforts are expended to try to find the cause of such a failure.

The necessity to study the microbiologic flora of man before and after missions lasting as long as 12 days has shown some interesting changes in samplings of the throat, urine, and feces. We have seen evidence of overgrowth of opportunist organisms and are concerned about the possibility of microbiological shock on exposing crewmen to large doses of organisms after prolonged isolation in the microbially controlled environment of the spacecraft. All of these findings are of value as we consider such common occurrences as infections in patients who have had their immunities altered either through radio- or drug therapy.

In keeping the crews well during a mission we have continued to be concerned about the development of toxic levels of minute amounts of materials contained in water or atmosphere of the spacecraft. Our crewmen are exposed for 24 hrs. a day to any substance in the environment and therefore the standard acceptable levels in industry no longer apply. The consideration of these chronic toxic levels has import to our study of pollution on earth.

In addition to many items of value coming from the medical requirements created to support flight activity, there are a number of non-medical space items with ground applications which would have to be called serendipitous. The use of the space helmet for the conduct of pulmonary function testing in children has proven of great value as has an electronic switch which may be operated by the movement of an eye. The switch may be used to power almost anything and it has been coupled with a motorized walker chair that was originally planned for use in unmanned exploration on the lunar surface. These devices have been utilized with neurologically disabled patients of various sorts. A device used to simulate both zero G and 1/6 G movement has found use in the rehabilition of stroke victims. Tiny motors which have been developed in the space program are rapidly finding varied uses within the medical community.

Our flight trainers or simulators have had to be special due to the fact that our crewmen never get to fly in the real vehicle in any practice runs. Each flight could be a first time and therefore the simulators provide great realism and accuracy. The same techniques which were utilized to simulate docking and landing and in procedures trainers are now being utilized by the airlines. They can thus reduce the transition time in some of the major aircraft, such as the 747 to an hour and a half to two hours rendering a great saving in dollars to the airline indusrty.

An area of great current interest is the multispectral scanning and sensing of earth from air and spacecraft. While this has great importance to the study of pollution, water supplies, air, the finding of fish and many other such items it also has great medical promise.

We are able to recognize certain vegetation from air or space by these scanning techniques and such vegetation may be connected with particular disease vectors. A recent example was the concern for Saint Louis encephalitis carried by the Culex mosquito in the Houston area. It was determined that this mosquito breeds in ditches which are fed by drainage from septic tanks and this in streams whiere large amounts of urea were concentrated. Urea will fluoresce and thus can be picked up by scanners and their streams identified from the air and the area sprayed. Some 28 diseases are currently under study as to their vectors and reservoirs in the hopes that direct attack may be made through the use of earth scanning methods.

In an effort to prove that the lunar material returned from the early lunar landing missions did not constitute a hazard to any form of life on the earth, its effects was studied extensively on various life systems in the lunar receiving laboratory. The only biologic effects noted related to plants and to bacteria and perhaps viruses. Some of the core lunar material obtained on Apollo 11 was found to kill cultures of bacteria with which it was placed. It has also been shown to alter the metabolism of viruses. We have had consistent effects with the lunar materials obtained on Apollos 11,12 and 14 on both plant tissue cultures and plant seedlings. There has been an increase in growth over the growth rate shown in standard nutrient media. This effect has been further studied through the use of audioradiography with lettuce. The lettuce seedlings were seen to take up significant amounts of manganese, iron, and a number of other elements such as cobalt, but the uptake of manganese was approximately 100 times greater than that of other elements observed. It appears that lunar material does indeed act as a source of nutrients and specifically manganese is being singled out as a particular nutrient. The import of these biological findings is certainly unknown at the present, but they are of great scientific interest and certainly will develop practical implications.

The necessity to support manned spaceflight medically created a team effort allying the medical community with the engineering community in a most intimate manner. This relationship has at times been stormy, but both have learned a great deal and it has been fruitful in the production not only of mission results but of medical hardware as well as spacecraft hardware to conduct these missions. Such a team concept and such an understanding is absolutely necessary if we are to progress in medicine at the pace that is desired. This experience can and must be transferred directly to the private medicine sector.

Another further strange experience which can prove of benefit to medicine here on the earth is the practice of medicine which has been conducted in a public forum. We have found ourselves in a position of trying to treat patients over a public loud speaking system where the listeners were quick to listen to intone dire consequences for the entire program should there be nay evidence of medical impairment, no matter how slight. The conduct of this activity and the relationships with the press and other agencies has great experience value to the future conduct of medicine as the scene is altered in our terrestrial experience.

Thus it can be seen that there are many items of hardware, techniques and ideas which have evolved through the necessity to support man in the spaceflight environment. This new technology and these new techniques must be applied to the practice of medicine here on earth for this practice must change. The ever-increasing demand for medical care without the adequate increase in medical and paramedical personnel render it mandatory that we utilize technology to help the physician in his task. It is certainly possible to do this and allow the physician time to spend with the patient and keep the all important human factor in medicine. At the same time it is important to remember that the space program developments were not done solely to produce such fallouts.

All of these developments were part of a technologic and scientific base which had to evolve if we were to achieve our goal in manned spaceflight. Such a driving force constantly pushing the country's science and technology ahead is vital if we are to survive as a nation and maintain our position as a prime world power.

Man's destiny I feel is indeed the stars and the technology and scientific base the thrust to achieve that destiny. We placed the ladder. We now ask that you who follow, climb it.