Man, Space Flight and Medicine

Charles A. Berry

Space flight 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. 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 space flight and unmanned efforts are being advocated in preference. Thus, to obtain objective data to prove that men's body-systems' performance is adequate is vital as we look at longer duration flights. I personally am very optimistic in this regard.

Man is made up of subsystems as is a spacecraft 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 because they can select "hi rel" (high-reliability screened) parts from known vendors, build the system to their specifications, test it to destruction, and determine a mean time to failure. This we cannot do. We cannot select vendors or the parts. We have no input to the specifications and the determination of mean time to failure is complex and quite out of the question. Nevertheless, certain important answers concerning man have been obtained from our flight experience.

Mercury

The Mercury Program exposed the first U.S. crewmen to the space environment. We were able to do a significant number of biomedical investigations, including clinical and laboratory evaluations and 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 showed that man could survive launch and activity and that he could perform admirably in the space environment. As a result of this performance, future programs, and even the later Mercury flights, were modified to take advantage of man's

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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 as measureable on the return to Earth was noted in the latter two Mercury flights when a condition known as orthostatic hypotension was noted. 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 (Figure 1) to expose the crewmen to a 70 degree passive tilt for a period of 15 minutes. This response has come to be known as cardiovascular deconditioning. The heart and blood vessels comprising the cardiovascular system seem to be "deconditioned" in relation to the Earth-gravity environment. Our own research has led us to the belief that these changes are acclimatization changes by which the body systems adjust to be more efficient in a zero *g* environment. The readjustment is puzzling only when the crewman returns to the Earth environment. Here a different acclimatization is required to Earth gravity, which eluded the astronauts during weightless flight.

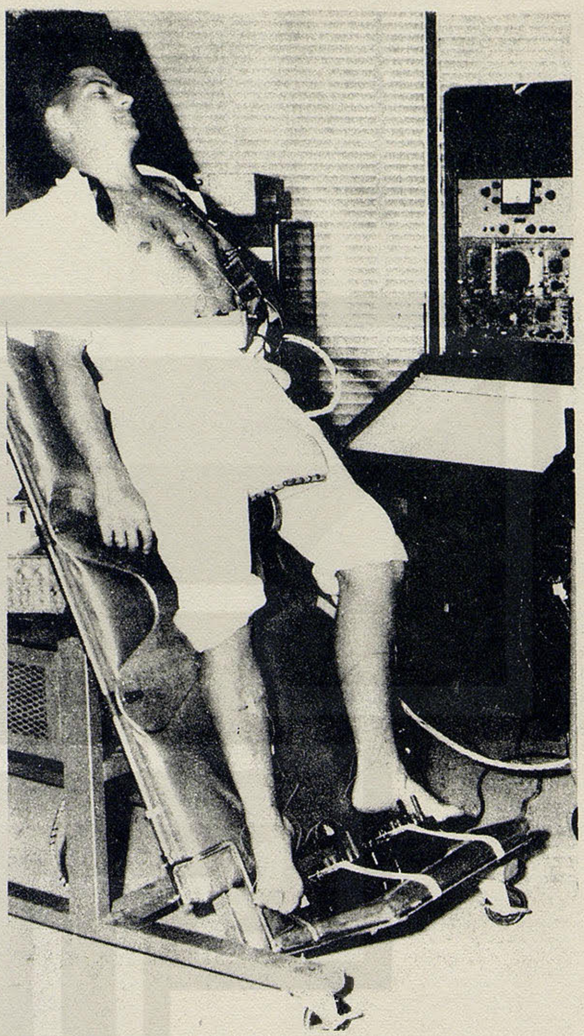


Figure 1 *Tilt table.*

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 of 4, 8, and 14 days. Four of the medical experiments were aimed at determining the magnitude of the cardiovascular decrement. In order to simulate gravity's effect on the column of blood in the legs, blood pressure cuffs on the extremities were to be 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. The heart's response to a given metabolic load using an elastic exercise device was also determined. Biochemical responses in both blood and urine were evaluated and a calcium and nitrogen balance study was conducted to determine whether or not the body indeed had lost any of these substances as a result of exposure to the weightless environment. X-ray densitometry measurements of the heel and small finger were done to determine the loss of bone density. During the first two days of the 14-day mission, an electroencephalogram recorded sleep characteristics. Some early investigations also were carried out relating to responses of the otolith portion of the inner ear.

Results of these studies confirmed that, in fact, we were observing some moderate cardiovascular deconditioning or, more properly, an adaptation to zero *g* as evidenced by orthostatic hypotension on return to Earth. Regardless of flight duration, the longest period in which these effects were noted was about 50 hours postflight. Also observed were moderate losses of exercise capacity as measured by response to a regulated exercise load on a bicycle ergometer. X-ray densitometry confirmed that there was some loss of bone density. Detailed calcium and nitrogen balance study confirmed these densitrometric measurements. Moderate body weight losses were noted in each of the postflight examinations. The EEG (electroencephalogram) and the crew's and medical monitor's operational reports revealed some interference with adequate sleep.

Two unexpected findings occurred. We observed one during extravehicular activity (EVA); a very high-metobolic expenditure and an elevated heart rate along with body overheating due to the increased physical exercise. The other unexpected finding was the loss of 20 percent of the red blood cell mass. Despite these findings, we felt assured that we could proceed with the proposed lunar missions, especially since none were expected to be as long in duration as the 14-day flight of Gemini 7.

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 to confinement in the very small volume of the spacecraft. Other factors in the Apollo program required all measurements in Apollo to be conducted before and after flight. In spite of the freedom to move about and exercise in a limited way in the Apollo spacecraft, the Gemini results were generally confirmed. We noted again cardiovascular adaptational change to zero *g* and a reduced exercise tolerance of virtually the same degree as noted in the Gemini program. Minimal loss of bone

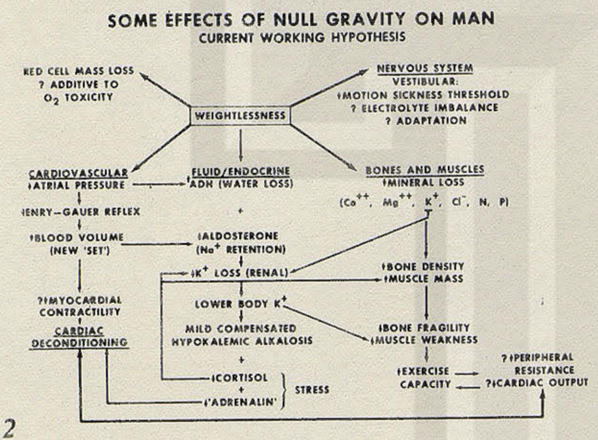


Figure 2

density was confirmed. We showed with flight results and ground-based chamber studies that the loss of red cell mass was apparently due to the 100 percent oxygen environment. This anomaly could be prevented by very minimal amounts of nitrogen in the cabin atmosphere.

As our information increased, and methods became more sophisticated, we were able to look at mineral and hormone values to show that there was some altered fluid balance postflight. We first encountered inflight illness of an infectious nature, a viral upper respiratory infection similar to the common cold. During the Apollo missions, we have noted a number of preflight, inflight, and postflight illnesses generally related to ground or preflight exposure. These experiences required an expanded crew preflight preventive medicine program for the crew and associated personnel. Inflight motion sickness was noted for the first time in our flight program, in contrast to the Russian experience. Motion sickness occurred in a few crewmen; consequently, we have been unable to predict this occurrence on baseline information from preflight tests on the crews. However, in every instance, the crewmen have adapted to the altered responses to weightlessness and the duration of symptoms have not exceeded five days. In most instances, adaptation occurred within a few hours.

The requirement for a postflight quarantine made it necessary to develop a program of preflight and postflight sampling of the crew microflora (bacteria, viruses, etc.). Results of these studies indicate some reduction of certain microflora and some increases of certain organisms as a response to living in the isolated environment of the spacecraft. For example, on the Apollo 14 mission, we saw the first indication that exercise and exposure to the 1/6*g* condition of the lunar surface may have had a beneficial effect on the expected physiological deconditioning which we have discussed. Those two crewmen spent considerable time on the lunar surface and did not exhibit evidence of cardiovascular deconditioning. The command module pilot, who spent all of his time in zero *g*, did exhibit changes of the magnitude expected from previous flights. Data are inadequate, but seem to indicate that more work is needed to assess the differences in physiological response of lunar EVA pilots as compared with the command/service module pilot in lunar orbit. Certainly, differences in water and caloric intake must be considered.

Our findings to date have allowed us to develop a working hypothesis concerning the effects of zero gravity on man. 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 bead. We feel that this 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 1*g* condition. This increased amount of blood returned to the right side of the heart increases the volume in the right atrium and initiates a reflex stimulus to the pituitary gland. This stimulus calls for a reduction in the secretion of antidiuretic hormone and thus an increased excretion of urine occurs. This provides a new blood volume level commensurate with 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. Aldosterone 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

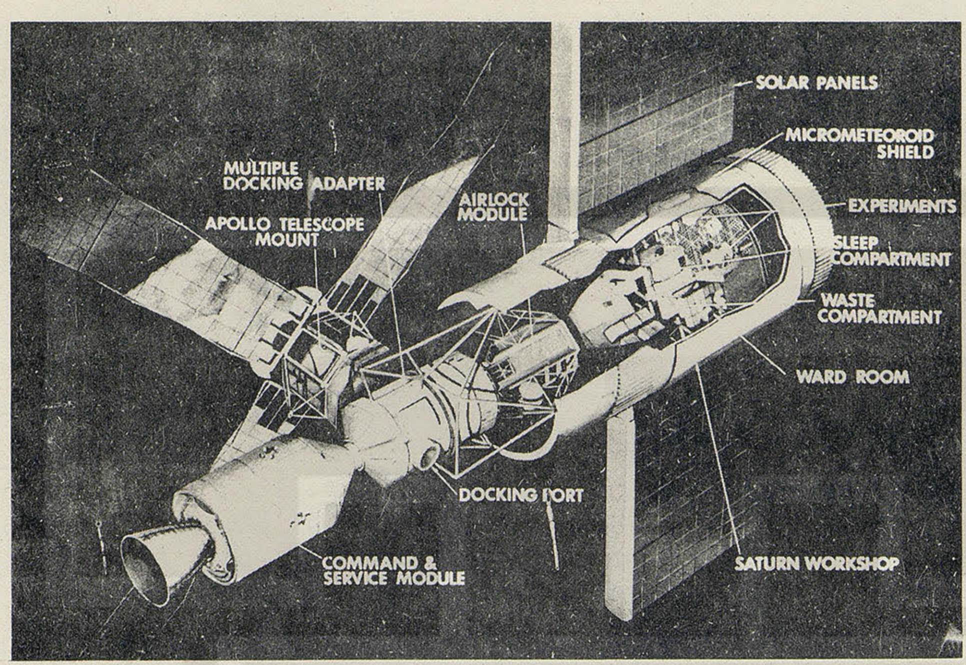


Figure 3
Skylab Configuration.

and muscles, resulting in a decrease in bone density and muscle mass. These interrelations may be followed more carefully in Figure 2.

There are definite changes in body fluids as a part of the adjustment to zero *g* and the readjustment to function in 1*g*. Postflight studies have shown a decrease in total body water. Most 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. 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 this would be both time-consuming and expensive with a resulting delay in obtaining the answers necessary for us carefully to 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 (Figure 3), for missions of 28 and 56-day durations. Skylab allows us for the first time to measure the physiological response of the involved body 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 adaptation of the body to the stresses of space flight 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. This question is raised frequently, however: what about the mortals who 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 of 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 purely static examinations of the individual to perform at peak level in stressful situations. Another useful technique was a combination of background, psychologic, and psychiatric information in order to arrive at the best evaluation position concerning the individual's capabilities. These techniques obviously apply to terrestrial medicine wherever there is a need to select people for particularly demanding tasks.

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, an artificial environment is needed to insure the health of the crewman in hostile space. The resulting hardware has been a series of environmental control systems—space suits, water-cooled undergarments, 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 (Figure 4), the water-cooled undergarment for cooling of firemen, race car drivers, etc. (Figure 5), 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, nonirritating and highly reliable sensors. Once the data are 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 additional 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-

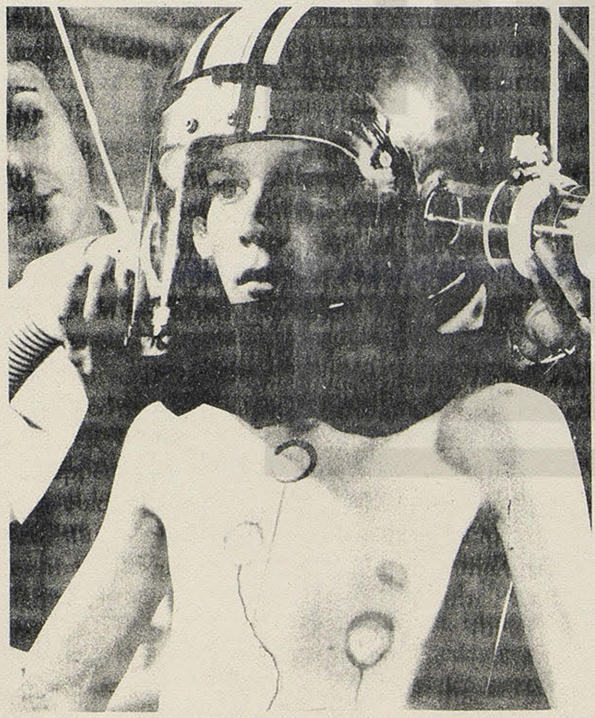


Figure 4 Space helmet for respirometry.

radio-sound for gastric PH, etc. Sprayon sensors have been developed for use in ambulances (Figure 6) to all telemetering of an 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 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 medical care is in short supply.

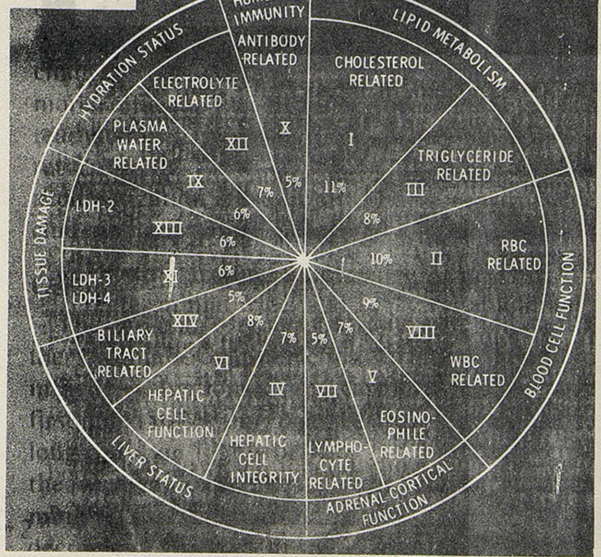
As soon as we were able to instrument man in such a way that data could be obtained from these great distances, huge masses of normal data were obtained by constant monitoring on the long-duration flights. This immediately led to the necessity to develop systems which would allow computer interpretation and tabulation of ECG, EEG, and other such data. These techniques are rapidly being used 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 define better the ranges of normality. 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. These minicomputers are connected 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 space flight, it is essential that we know as much as possible about

Figure 6
Sprayon sensors used to relay electrocardiograms to hospitals.

Figure 7



Independent factors extracted from 47 variables. They account for 86% of the total variance. Remaining 14% variance is unique variability for some variables and error variance for each variable.

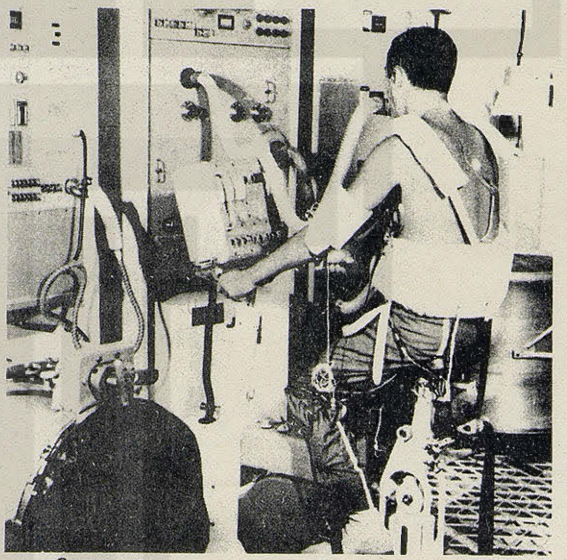


Figure 9 *Bicycle ergometer.*

Figure 8 *Lower body negative pressure device.*

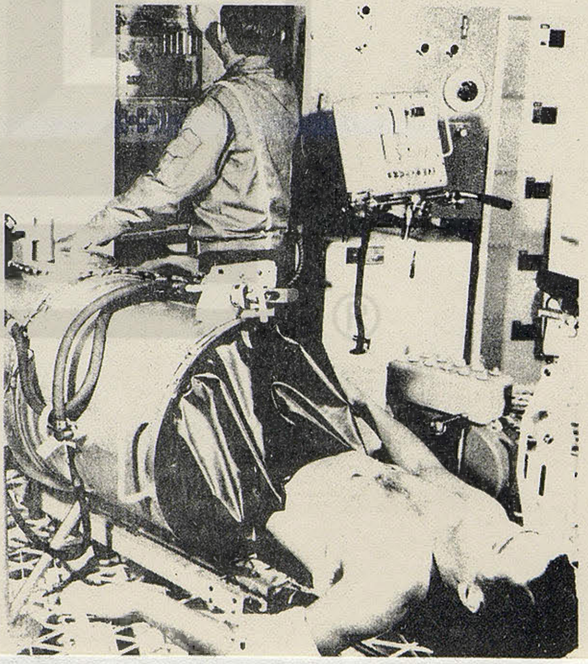
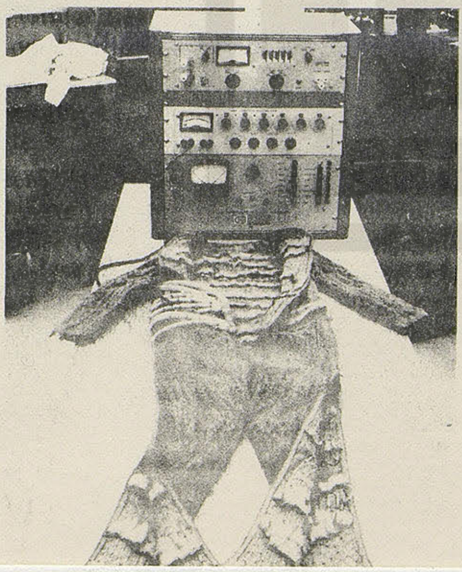


Figure 5
Watercooled undergarment.



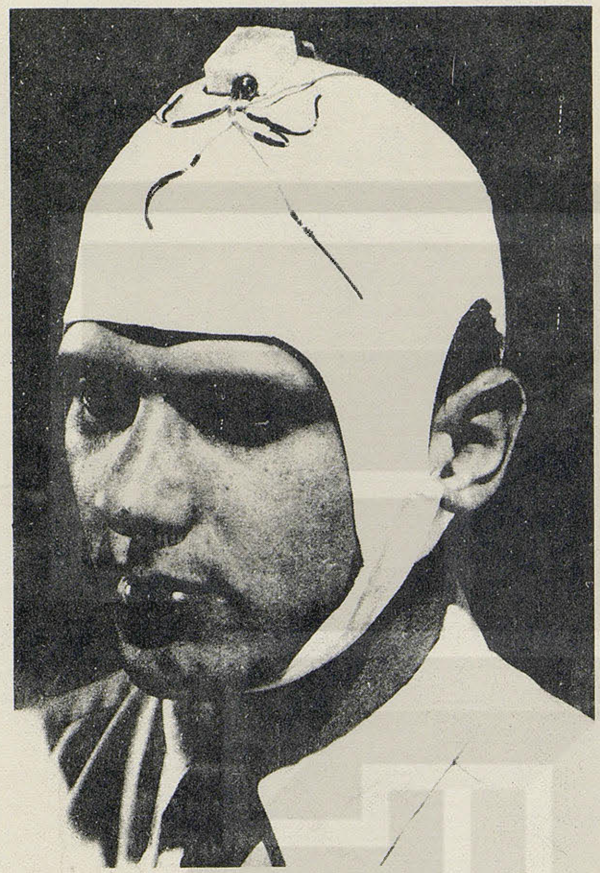


Figure 10 Inflight cap for obtaining EEG.

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, has provided 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 which 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 to determine the effects of space flight on man. In trying to define better 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 in determining 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. We intend, at all times, to use noninvasive techniques, if possible, for any determination. We are constantly pushing the state of the art, trying to create technological advances in such techniques that will give us more detailed information concerning body functions (Table 1). 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, immunologic, and clinical biochemical screening procedures which emphasize mathematical interactions 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. This list could be further optimized in such a way that 8 tests could provide 85 percent of the data produced by the 47 laboratory determinations. The tests (Figure 7) 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 programed to run automatically a particular battery of laboratory determinations concerning a certain body area, such as the liver, should an

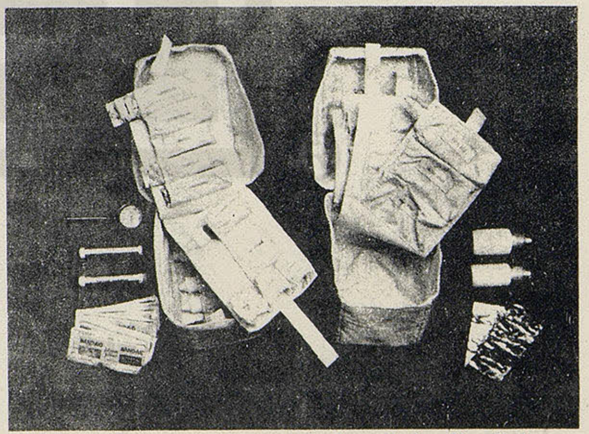


Figure 11 Medical kit used aboard Apollo flights.

indicator test prove to be out of normal limits. In fact, automatic programing 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 space flight of the cardiovascular, cardiopulmonary, and musculoskeletal systems has led to 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 (Figure 8) which sucks 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. An automatic blood pressure device has been necessary, which has been pushing the state-of-the-art development. 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 (Figure 9) also has 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 these devices are dynamic testing gear which evaluate total body response to a given stress.

The need to determine the metabolic loads of certain activities inflight has led to 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, particularly sleep inflight, a cap with new sponge electrodes (Figure 10) has been developed. These electrodes will obtain an EEG of excellent quality without any special preparation of the scalp. This system also has been connected to a sleep analyzer which will scan the EEG tracing and print out digitally the amount of time spent in level 1, 2, 3, or 4 or rapid eye movement (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 insomniacs 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.

Figure 12 Wheel chair controlled by eye movement.

Bed rest 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. Bed rest 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 bed rest, both detrimental and beneficial, to the patient's condition. Our need to use this analog better to predict possible effects of the weightless environment has led to much better definition of changes in calcium balance, musculoskeletal integrity, blood volume 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 bed rest will be used as a means of therapy.

While evaluating the effect of space flight on the blood, we noted decrease in red blood cells. In studying the 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 an engineer's or physical scientist's tool, also has 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 and passed on to a number of the large centers conducting research in cancer and other neoplastic diseases. Our flight results also have indicated that nitrogen, even in small amounts, appears to protect the red blood cell from the lysis occurring in the oxygen environment, which may indicate some basic physiologic effect yet to be determined.

In providing food for our crews inflight, we developed a number of methods of preservation and packaging which would allow us to assure both palatable and safe foods. Such development has led to items which will find their way into everyday use. Also, we have found it necessary to conduct a great deal of research in determining basic nutritional needs such as the levels of protein required and their relationship to such factors as calcium mobilization. All of this information directly applies 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; we have attempted to provide medication to care for these difficulties. Motion sickness was one of the early conditions considered in the weightless environment and 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, which 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 (Figure 11) by injection led to the development of an automatic syringe which 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 away from 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 behavioral laboratory system which uses a number of advanced technological techniques making it possible for a single individual to diagnose, treat, and conduct medical evaluations inflight. 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 after flight, 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 the one-week period, we became concerned about the possibility of his 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. We, very early, had 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

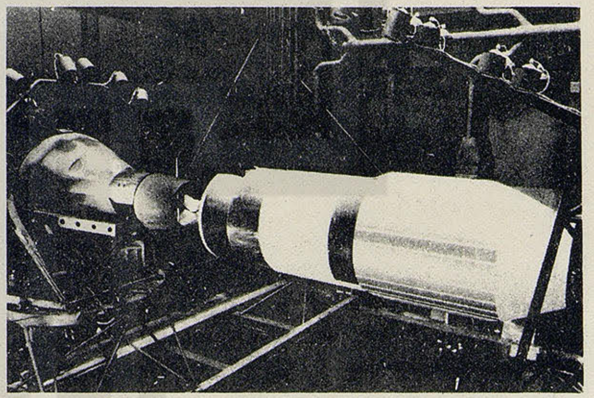


Figure 13 Apollo docking simulator.

health screen around them during a 21-day period preflight 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 gastrointestinal viral and upper respiratory 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 preserved 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 five 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 eight 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 count was known to us as 4000, this doubled his white blood cell count. This development has led to 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 particularly looked at the lymphocytes with some 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. We also have 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 preventative medicine program in operation for our crews alters their risk of disease, not just in the preflight 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 try to find the cause of such a failure.

The necessity to study the microbiologic flora of man before and after missions 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 microbiologically-controlled environment of the spacecraft. All 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 hours a day to any substance in the environment, and therefore the standard acceptable levels has import to our study of pollution on Earth.

In addition to many valuable items coming from medical requirements created to support flight activity, a number of nonmedical space items with ground applications would have to be called serendipitous. The space helmet for conduct of pulmonary function testing in children has proven of great value, as has an electronic switch (Figure 12) which may be operated by eye movement. The switch may be used to power almost anything and it has been coupled with a motorized walker chair 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 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 must be special because 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 (Figure 13) and in procedures trainers now are being utilized by the airlines. They can thus reduce transition time in some major aircraft, such as the Boeing 747, to an hour and a half to two hours, saving many dollars for the airline industry.

An area of great current interest is the

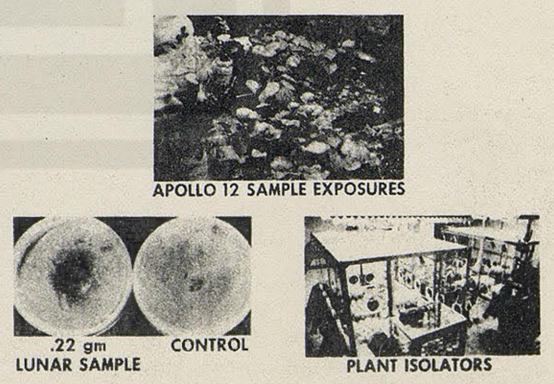


Figure 14 *Germ free plant program.*

multispectral scanning and sensing of earth from aircraft 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. This vegetation may be connected with particular disease vectors. A recent example was the concern for St. Louis encephalitis carried by the Culex mosquito in the Houston, Texas, area. It was determined that this mosquito breeds in ditches fed by drainage from septic tanks and in streams where large amounts of urea were concentrated. Urea will fluoresce and thus can be picked up by scanners. Streams with urea can be identified from the air and the area sprayed. Some 28 diseases are currently under study as to their vectors and reservoirs; we hope that direct attack may be made through the use of Earth-scanning methods.

In an effort to prove that the lunar materials returned from the early lunar landing missions did not constitute a hazard to any form of life on Earth,

CLINICAL LABORATORY ANALYTICAL TRENDS

PROCEDURE	SAMPLE	PAST	PRESENT		FUTURE	ALTERNATE APPROACH NON-INVASIVE
			CLINICAL	RESEARCH		
CHEMISTRY	S					
• ELECTROLYTES		2-5 ml	0.5 ml	1.0 ml	λ	HAIR
• ENZYMES		10-15 ml	0.5 ml	1.0 ml	λ	URINE
• METABOLITES		10-15 ml	0.5 ml	1.0 ml	λ	BREATH
• PROTEIN		10 ml	0.1 ml	0.1 ml	λ	-
COMPARTMENTAL VOLUME	P					
• RED CELL MASS		35 ml	7 ml	10 ml	1-2 ml	BREATH
• PLASMA		15 ml	5 ml	7 ml	1-2 ml	-
• TOTAL BODY WATER		30 ml	5 ml	7 ml	1-2 ml	PAROTID FLUID
BLOOD GASES	WB					
• OXYGEN		10-20 ml	1.0 ml	1.0 ml	λ	BREATH
• CARBON DIOXIDE		10-20 ml	1.0 ml	1.0 ml	λ	BREATH
HORMONES	S,P					
• ACTH		45-50 ml	2.0 ml	5.0 ml	1 ml	URINE
• INSULIN		35-40 ml	2.0 ml	5.0 ml	1 ml	BREATH
• STEROIDS		20-25 ml	2.0 ml	5.0 ml	1 ml	URINE
IMMUNOLOGY	S					
• GLOBULINS		10-15 ml	λ	λ	λ	-
• ACUTE PHASE PROTEIN		10-15 ml	λ	λ	λ	URINE
HEMATOLOGY	WB					
• BLOOD COUNTING			λ	λ 1-2 ml	λ	-
• CYTOGENETICS		10 ml	1.0 ml	1.0 ml	<1.0 ml	SMEARS
• TYPE AND CROSSMATCH		30-40 ml	10 ml	-	1-2 ml	SMEARS

Table 1

its effects were studied extensively on various life systems in the lunar receiving laboratory. The only biologic effects noted related to plants, 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 also has been shown to alter the metabolism of viruses. We have had consistent effects with the lunar materials obtained on Apollos 11, 12 and 14 (Figure 14) on both plant tissue cultures and plant seedlings. We saw 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 shown 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. Lunar material does indeed appear to 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 space flight medically created a team effort allying the medical community with the engineering community in a most intimate manner. This relationship has at times been emotional, but both sides have learned a great deal. Production has been fruitful not only in mission results but in 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 desired pace. This experience can and must be transferred directly to the private medicine sectors.

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

Many items of hardware, techniques, and ideas have evolved through the necessity to support man in the space flight 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 adequate increase in medical and paramedical personnel makes 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 these developments were part of a technologic and scientific base which had to evolve if we were to achieve our goal in manned space flight. 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: the technology and scientific base is the thrust to achieve that destiny. Apollo 15 provided the latest evidence. We placed the ladder. We now ask that you who follow should climb it.